PROCEEDING BOOK

KARADENİZ 17. ULUSLARARASI UYGULAMALI BİLİMLER KONGRESİ

RİZE
8 - 10 KASIM 2024

KARADENİZ
17. ULUSLARARASI
UYGULAMALI
BİLİMLER
KONGRESİ

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17th INTERNATIONAL CONFERENCE ON APPLIED SCIENCES

November 8 - 10, 2024
Rize

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RİZE

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Oral presentation

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91 papers presented by participating from Turkey and 111 papers from other Countreies
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Prof.Dr. Yavuz Selim SAĞLAM
Dekan

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9 Kasım / Nov 9, 2024 / 11:00 – 13:00 Time zone in Turkey (GMT+3)				
Salon	Moderator		Bildiri No ve Başlığı / Paper ID and Title	Authors
HALL / SALON 1	**Assist. Prof. Dr., IŞINSU ERSAN ÖZTÜRK**	1	A STUDY ON THE EFFECT OF PUPPETS ON IN OPERA NARRATION: MONDONVILLE'S OPERA TITON ET L'AURORE	Assist. Prof. Dr., IŞINSU ERSAN ÖZTÜRK
		2	THE SOCIOCULTURAL EFFECTS OF GLOBAL TRENDS IN POPULAR MUSIC	Asst. Prof. Dr. Cihan TABAK Zerrin ÇİMEN
		3	PİYANO EĞİTİMİNDE NÜANS TERİMLERİNİN KART OYUNU İLE ÖĞRETİLMESİ VE BAŞARIYA ETKİSİ	Eda Asya AKSU Prof. Dr. M. Kayhan KURTULDU
		4	PİYANO EĞİTİMİNDE GRUBETTO İŞARETİNİN ÖĞRETİLMESİNDE ANLAMLANDIRMAYA DAYALI HİKÂYELERİN ETKİSİ	Şehribanu ZAMAN Prof. Dr. M. Kayhan KURTULDU
		5	DEMİR KÜLTÜ İLE İLGİLİ İNANIŞLAR: ARDAHAN ÖRNEĞİ	Dr. ELVAN SALTAŞ KORKMAZ
		6	KUZEYDOĞU ANADOLU BÖLGESİ HALK İNANIŞLARINDA SÜPÜRGE	Dr. ELVAN SALTAŞ KORKMAZ

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HALL / SALON 2	Doç. Dr. Erkan UZUN	1	EVALUATION OF THE BASIC ELEMENTS OF GREEN BANKING WITH A FUZZY MULTI-CRITERIA DECISION MAKING APPROACH	Doç. Dr., Gülay DEMİR Doç. Dr., Yüksel AYDIN
		2	PRIORITIZATION OF PROJECT CRITERIA WITH FUZZY MULTI-CRITERIA DECISION MAKING METHOD IN BLOCKCHAIN TECHNOLOGY	Doç. Dr., Gülay DEMİR Doç. Dr., Rahim ARSLAN
		3	HALKLA İLİŞKİLER UYGULAMALARINDA YAPAY ZEKA KAYNAKLI BİR TEHDİT: ALGORİTMİK ÖN YARGI	Öğr. Gör. MURAT CAN BAŞARAN Prof. Dr. BURCU ÖKSÜZ
		4	İLETİŞİM ALANINDA YAPAY ZEKA KONULU YAYINLARIN BİBLİYOMETRİK ANALİZİ	Prof. Dr. BURCU ÖKSÜZ Öğr. Gör. MURAT CAN BAŞARAN
		5	BIST SÜRDÜRÜLEBİLİRLİK ENDEKSİNDE İŞLEM GÖREN ŞİRKETLERİN ÇEVRESEL İLKELERE UYUM DURUMUNUN DEĞERLENDİRİLMESİ	Dr. Öğr. Üyesi İpek YAYLALI
		6	KONAKLAMA İŞLETMELERİNDE MALİYET ARTIRAN ETKENLERİN TESPİTİ VE MALİYET DÜŞÜRME ÖNERİLERİ	Doç. Dr. Erkan UZUN
		7	SEYAHAT İŞLETMELERİNDE MALİYET ARTIRAN ETKENLERİN TESPİTİ VE MALİYET DÜŞÜRME ÖNERİLERİ	Doç. Dr. Erkan UZUN
		8	YEŞİL YETENEK ÜZERİNE BİBLİYOMETRİK ANALİZ	Dr. Öğrencisi Merve ŞENER Doç. Dr. Canan YILDIRAN

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HALL / SALON 3	**Prof. Dr. Nilgün GÜNEROĞLU**	1	THE EFFECT OF LANDSCAPE ON MUSEUM DESIGN: THE CASE OF LOUVRE MUSEUM ABU DHABI	Asist. Prof.Dr.MakbulenurONUR Research Assistant Dr. Demet Ülkü GÜLPINAR SEKBAN
		2	PLANT SELECTION IN LANDSCAPE DESIGN IN DESERT CLIMATE CONDITIONS CASE OF DUBAI	Asist. Prof.Dr.MakbulenurONUR Research Assistant Dr. Demet Ülkü GÜLPINAR SEKBAN
		3	THE IMPORTANCE OF MULCHING IN RIDER LANDSCAPE, RIZE CITY EXAMPLE	Assoc. Prof. Dr.,Ömer Lütfü ÇORBACI Res. Asst. Dr.,Türker OĞUZTÜRK
		4	EVALUATION OF GERMINATION SUCCESS OF Liatris spicata (L.) 'ALBA' SEEDS AT DIFFERENT STRATIFICATION TIMES IN STRATIFICATION MEDIA STERILIZED WITH DIFFERENT METHODS	Res. Asst. Dr.,Türker OĞUZTÜRK Assoc. Prof. Dr.,Ömer Lütfü ÇORBACI Ayça MAVİ
		5	Socio-Ecological Approaches in Urban Planning and Design	Assoc. Prof. Dr. Aysel YAVUZ
		6	ON PURPOSE DESIGN SUGGESTIONS FOR ROOF GARDENS	Prof. Dr. Nilgün GÜNEROĞLU
		7	CLIMBING PLANTS IN LANDSCAPE ARCHITECTURE	Prof. Dr. Nilgün GÜNEROĞLU

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HALL / SALON 4	**Prof. Dr., SAVAŞ YILMAZ**	1	DISCRIMINATION OF ALBURNUS DERJUGINI AND VIMBA VIMBA (LEUCISCIDAE) SAMPLED FROM HARŞİT STREAM (TÜRKİYE) WITH OTOLITH MORPHOMETRY AND SHAPE ANALYSIS	Assoc. Prof. Dr., MELEK ÖZPİÇAK Asst. Prof., SEMRA SAYGIN Prof. Dr., SAVAŞ YILMAZ
		2	DETERMINATION OF THE PHYLOGENETIC CHARACTERISTICS OF THE SPECIES *Luciobarbus kersin* (Heckel, 1843)	Arif PARMAKSIZ
		3	DETERMINATION OF THE PHYLOGENETIC CHARACTERISTICS OF THE SPECIES *Luciobarbus xanthopterus* Heckel, 1843	Arif PARMAKSIZ Necmettin DOĞAN Elif KORKMAZ
		4	DYE REMOVAL BY BACTERIA ISOLATED FROM SUGAR INDUSTRY WASTEWATER	PhD Student, Suleyman BERBERLER PhD Student, Kubra OZTAT Prof Dr, Cansu FILIK ISCEN
		5	ISOLATION AND OPTIMIZATION OF A BROWN PIGMENT PRODUCED BY *Bacillus atrophaeus* JCM 9070 FROM PAPER INDUSTRY WASTEWATER	PhD Student, Kubra OZTAT PhD Student, Suleyman BERBERLER Prof Dr, Cansu FILIK ISCEN
		6	DONDURMA YAPIMINDA SÜT YAĞINA VE SÜT PROTEİNİNE ALTERNATİF BİTKİSEL KAYNAKLARIN KULLANIMI	Salih Özdemir Sümeyye Kaçalin Cihat Özdemir

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HALL / SALON 5	**Prof. Dr. Sevim Polat**	1	ISOLATION AND CHARACTERIZATION OF BIOSURFACTANT-PRODUCING BACTERIA FROM OLIVE MILL WASTES	Assoc. Prof. Dr. Ebru UYAR Sümeya ORTAKAYA
		2	POLLUTION CAUSED BY RECREATIONAL FISHING	Muhammet BULUT Doç.Dr. Tuncay ATEŞŞAHİN
		3	EVALUATİON OF THE INVASİVE CARASSİUS GİBELİO SPECİES IN TERMS OF RECREATİONAL FİSHİNG (KARAKAYA DAM LAKE - ELAZIĞ)	Muhammet BULUT Doç.Dr. Tuncay ATEŞŞAHİN
		4	Numerical Analysis of Flow Characteristics of a Water-Particle Mixture in a Manifold Using Ansys CFX Program	Dr. SeyhmusTUMUR
		5	A STUDY ON THE UTILIZATION POSSIBILITIES OF BEACH-CAST MACROALGAE	Prof. Dr. Sevim Polat Prof. Dr. Abdurahman Polat
		6	DETERMINATION OF BIOCHEMICAL CONTENTS OF TWO RED MACROALGAE SPECIES (LAURENCIA OBTUSA AND GANONEMA FARINOSUM) DISTRIBUTED IN MERSİN COAST (NORTHEAST MEDITERRANEAN)	Berna Nur Kodaz Prof. Dr. Sevim Polat

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HALL / SALON 6	**Assoc. Prof. Dr. ZEYNEP ERGÜN**	1	EFFECTS OF ABIOTIC STRESS FACTORS ON BLACKBERRY *(Rubus sp.)* PLANT GROWTH UNDER IN *VITRO* CONDITIONS	Öğr. Gör. SELCAN ÖZYALIN Doç. Dr. HAKAN KELES Doç. Dr. MURAT GÜNEY
		2	IMPORTANCE OF EXPLANT SELECTION IN IN *VITRO* PROPAGATION OF RASPBERRY *(Rubus sp.)*	Öğr. Gör. SELCAN ÖZYALIN Doç. Dr. ZEYNEP ERGÜN Doç. Dr. MÜJGAN GÜNEY
		3	GENE EXPRESSION AND METABOLIC PATHWAYS IN FRUIT QUALITY: FLAVOR, COLOR, AND NUTRITIONAL VALUE	Assoc. Prof. Dr. MÜJGAN GÜNEY Lect. SELCAN OZYALIN Assoc. Prof. Dr. HAKAN KELES
		4	ENHANCING FRUIT QUALITY THROUGH GOOD AGRICULTURAL PRACTICES (GAP): A SUSTAINABLE AND TECHNOLOGICAL PERSPECTIVE	Assoc. Prof. Dr. MÜJGAN GÜNEY Assoc. Prof. Dr. ZEYNEP ERGÜN Assoc. Prof. Dr. MURAT GÜNEY
		5	THE GREEN WALNUT HUSK IN AGRICULTURAL WASTE MANAGEMENT	Doç. Dr. HAKAN KELES Doç. Dr. Müjgan GÜNEY Dr. Öğr. Üyesi. Zeynep ERGÜN
		6	MICROPROPOGATION OF WALNUT (*Juglans regia L.*)	Doç. Dr. HAKAN KELES Öğr. Gör. Selcan ÖZYALIN Doç. Dr. Murat GÜNEY
		7	USAGE AREAS OF SAFFRON (*Crocus sativus L.*) PLANT	Assoc. Prof. Dr. ZEYNEP ERGÜN Assoc. Prof. Dr. MÜJGAN GÜNEY Assoc. Prof. Dr. MURAT GÜNEY
		8	THE IMPORTANCE OF WHİTE LILY *(Lilium candidum L.)* PLANT	Assoc. Prof. Dr. ZEYNEP ERGÜN Lect. SELCAN OZYALIN Assoc. Prof. Dr. HAKAN KELES
		9	TRANSCRIPTOME AND GENOMIC ANALYSIS OF ALMOND (*Prunus dulcis*)	Assoc. Prof. Dr. Murat GÜNEY Assoc. Prof. Dr. Zeynep ERGÜN Assoc. Prof. Dr. Müjgan GÜNEY
		10	ANALYSIS OF PLANT STRESS RESPONSE MECHANISMS USING RNA SEQUENCING	Assoc. Prof. Dr. Murat GÜNEY Lect. Selcan ÖZYALIN Assoc. Prof. Dr. Hakan KELES

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HALL / SALON 7	**Doç. Dr. Ali İMAMOĞLU**	1	MONITORING AND EVALUATING LULC CHANGES IN MARMARA LAKE REGION USING AI-SUPPORTED SENTINEL-2 LAND COVER DATA (2017–2023)	Asst. Prof., Münevver Gizem Gümüş Asst. Prof., Ceren Yağcı Prof. Dr., Kutalmış Gümüş
		2	BOĞAZLIYAN DERESİ HAVZASI'NDA YAŞANAN EROZYON PROBLEMİ (YOZGAT)	Doç. Dr. Ali İMAMOĞLU
		3	VOLKANİK MAĞARA KULLANIMINA KIRSAL BİR ÖRNEK, ANINKAYA MAĞARA KOMPLEKSİ (NEVŞEHİR)	Doç. Dr. Ali İMAMOĞLU
		4	SPATIAL ANALYSIS OF TRAFFIC ACCIDENTS BASED ON SEVERITY INDEX	Assist. Prof. Dr., TUĞBA MEMİŞOĞLU BAYKAL
		5	YENİLENEBİLİR ENERJİ KAYNAĞI OLARAK ODUN PELETİ ÜRETİMİ: TÜRKİYE'NİN KÜRESEL SEKTÖRDEKİ ROLÜ VE POTANSİYELİ	Esma Nur KORKUSUZ Dr. Öğr. Üyesi, Hakan AYDOĞAN

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HALL / SALON 8	**Prof. Dr. Selahattin BARDAK**	1	ECONOMETRIC ANALYSIS OF EDUCATIONAL EXPENDITURES IN TURKEY	Arş. Gör. Dr. Tuba KARABACAK Prof. Dr. Murat KÜLEKÇİ
		2	EVALUATION OF THE MOST COMMON PROBLEMS IN TRADITIONAL SHOPPING WITH THE DECISION TREE MODEL	Prof. Dr. Selahattin BARDAK
		3	EVALUATION OF CONSUMERS' TRADITIONAL AND/OR ONLINE SHOPPING PREFERENCE REASONS WITH COLLABORATION ANALYSIS	Prof. Dr. Selahattin BARDAK
		4	DEĞİŞTİRİLMİŞ Pİ-SİGMA YAPAY SİNcİR AĞI İLE BORSA ÖNGÖRÜSÜ	Prof. Dr. Eren BAŞ Prof. Dr. Erol EĞRİOĞLU
		5	DAYANIKLI RESİM BULANIK REGRESYON FONKSİYONLARI YAKLAŞIMI İLE BORSA ÖNGÖRÜSÜ	Prof. Dr. Eren BAŞ Prof. Dr. Erol EĞRİOĞLU

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HALL / SALON 1	**Natalia Ivanova,**	1	THE HONG KONG LOW-FERTILITY DILEMMA: CAN MAINLANDERS' BIRTHS CONTRIBUTE TO REVITALIZING THE LOW-FERTILITY ISSUE?	Nancy Iri Dr. Ling Sze Leung
		2	A MULTI-AGENT SYSTEM FOR ENHANCING KNOWLEDGE MANAGEMENT AND E-LEARNING	Natalia Ivanova, Viktor Petrov
		3	PHYSICIAN BRAIN DRAIN: DRIVERS AND IMPACTS IN BANGLADESH	Amina Hossain, Farid Mahmud, Saifur Rahman
		4	TRANSITION FROM REGIONALISM TO COALITION: SHIFTS IN LANGUAGE POLITICS AND LEADERSHIP IN THE TAMIL MOVEMENT	Dr. Arun Natarajan
		5	A FRAMEWORK FOR EFFECTIVE KNOWLEDGE SHARING IN INTERCONNECTED ENTERPRISES	Sahar Makhmalbaf
		6	USER ENGAGEMENT AND SATISFACTION IN INFORMATION SYSTEMS	Hasan Kermani, Laila Abdelrahman
		7	ENVIRONMENTAL IMPACTS OF URBANIZATION ON RIVER HEALTH IN THE KERMAN REGION	Mohammad Rezaei, Zahra Tavakoli, Ali Amini, Reza Ghanbari
			A BAYESIAN FRAMEWORK FOR PREDICTING POLITICAL RISKS THROUGH IMPLICIT KNOWLEDGE	Dr. Kaveh Shafiei
		8	ORGANIZATIONAL INNOVATION IN PUBLIC-LISTED REAL ESTATE DEVELOPMENTS	Dr. Maria Sanchez, Ahmed Khalil

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HALL / SALON 2	**Dr. Fahad M. Al-Saleh**	1	RELATIONSHIP BETWEEN GENDER AND PERFORMANCE WITH RESPECT TO A BASIC MATH SKILLS QUIZ IN STATISTICS COURSES IN LEBANON	Hiba Naccache
		2	INSIGHTS AND VISUALS FROM VIRTUAL AND IN-PERSON LEARNING ENVIRONMENTS	Ranya Al-Fahad, Omar K. Salah
		3	STUDENT VIEWS ON CODE SWITCHING BY UNIVERSITY INSTRUCTORS: A PERSPECTIVE FROM THAILAND	Anong Srisai
		4	ADOPTING A STUDENT-CENTERED PEDAGOGY IN TERTIARY EDUCATION	Leila M. Farhat
		5	COMBINING HIGHER ORDER THINKING SKILLS WITH GEOGEBRA IN PRE-SERVICE TEACHER TRAINING	Samira J. Qassem, Fadi K. Marwan
		6	A FLIPPED CLASSROOM MODEL FOR STUDENTS IN THE HUMANITIES	Anjali Patel
		7	THE TECH-PEDAGOGICAL SHIFT: CREATING AND UTILIZING AN ONLINE WRITING PLATFORM	Sarah L. Hughes, Michael J. Tan, Emily R. Martin
		8	EVALUATING THE EFFECTIVENESS OF ONLINE ASSESSMENTS IN PROMOTING CRITICAL THINKING SKILLS	Ahmad Z. Mufeed, Hanan R. El-Khateeb, Laila A. Barakat

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HALL / SALON 3	**Prof. Dr. Jessica Albright**	1	OPEN EDUCATIONAL RESOURCE IN ONLINE MATHEMATICS LEARNING	Haohao Wang
		2	REDEFINING EDUCATIONAL REFORM: ALIGNING CURRICULUM WITH INSTITUTIONAL PRINCIPLES	Emma L. Thompson
		3	EXPLOITING BIG DATA TO ENHANCE EDUCATIONAL OUTCOMES	Ravi Nair
		4	LEVERAGING SOCIAL MEDIA AS AN INNOVATIVE LEARNING PLATFORM IN INDONESIAN TERTIARY EDUCATION: A STRUCTURAL EQUATION MODELING STUDY	Lina Hapsari, Rudi Santoso, Amir Rahman
		5	EMBRACING INFORMATION AND COMMUNICATION TECHNOLOGY TO MAXIMIZE CHILDREN'S SCIENTIFIC POTENTIAL: SUSTAINABLE DEVELOPMENT CHALLENGES IN KENYA	Samuel Karanja
		6	GLOBAL PERSPECTIVES ON HIGHER EDUCATION: CRAFTING A UNIVERSAL SUCCESS FRAMEWORK FOR PRE-CLINICAL MEDICAL STUDENTS – AN ACTION RESEARCH INITIATIVE	Prof. Dr. Jessica Albright
		7	TEAM COLLABORATION IN HIGHER EDUCATION: A DETAILED CASE STUDY	Ananya Verma
		8	EXAMINING TEACHER INTERACTIONS IN A "LEARNER-CENTERED" PEDAGOGICAL FRAMEWORK	Liu Chen

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HALL / SALON 4	**Sukanya Pattharaporn**	1	ACCESS TO HIGHER EDUCATION IN NIGERIA: THE UNIVERSITY OF CALABAR PRE-DEGREE PROGRAM EXPERIENCE	Eni I. Eni, James Okon, Ashang J. Ashang
		2	MANAGING COOPERATIVE LEARNING IN GRADUATE MATHEMATICS COURSES	Dr. Aria Lee
		3	THE INTERCONNECTION BETWEEN ARM ACUPRESSURE POINTS AND TRADITIONAL MASSAGE THERAPY	Sukanya Pattharaporn
		4	ASSESSMENT RUBRICS IN TECHNICAL EDUCATION	Norafida Mohamad, Zainul Azhar, Shahrul Nizam
		5	KNOWLEDGE ABOUT DRUG USE AND BEHAVIOR TOWARD ANTIMICROBIAL MEDICATIONS	Nirun Phanwong
		6	INTEGRATING PROJECT-BASED LEARNING TO ADVANCE NATIONAL QUALIFICATIONS FRAMEWORK OBJECTIVES	Assis. Prof. Dr. Sithiporn Prasert
		7	DEVELOPING ONLINE MODULES TO ENHANCE THE LEARNING EXPERIENCE OF MASTER'S STUDENTS IN CURRICULUM DESIGN AT SRIPatum University	Dr. Pattama Khaopong
		8	FOSTERING COLLABORATIVE ONLINE LEARNING ENVIRONMENTS FOR FACULTY MEMBERS	Maya Chen, Sara Thompson, Alexei Ivanov

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HALL / SALON 5	**Dr. Emilia Rodriguez**	1	VOICE IN PRE-SERVICE TEACHER DEVELOPMENT	Pintipa Seubsang, Suttipong Boonphadung
		2	NURTURING FUTURE EDUCATORS INTO COMPETENT PROFESSIONALS	Dr. Emilia Rodriguez
		3	DEVELOPING A CURRICULUM TO ENHANCE LEARNING ENGAGEMENT OF SECOND-YEAR STUDENTS IN THE COLLEGE OF EDUCATION THROUGH MULTIPLE INTELLIGENCES	Sofia Chen, Liam O'Sullivan
		4	EXPLORING UNIVERSITY STUDENTS' LEARNING STYLES IN BANGKOK: CHARACTERISTICS AND EFFECTIVE TEACHING CONTEXTS	Rajesh Kumar
		5	EXAMINING THE CONNECTION BETWEEN DISTRIBUTED LEADERSHIP AND STUDENT ACHIEVEMENT: A RESEARCH SYNTHESIS	Dr. Anja Müller
		6	EFFECTIVENESS OF THE NEUROLOGICAL IMPRESS METHOD AND RECURRENT READING ON THE READING FLUENCY OF CHILDREN WITH LEARNING DISABILITIES IN OYO STATE, NIGERIA	Samuel Okafor
		7	VIRTUAL CAMPUS AS A PEDAGOGICAL FRAMEWORK FOR ONLINE EDUCATIONAL SUPPORT	Dr. Naomi Patel
			VALIDATING PERSONAL IDENTITY THROUGH REMOTE ASSESSMENT IN E-LEARNING ENVIRONMENTS	Evelyn Johnson, Thomas Chen
		8	THE IMPACT OF INTRINSIC MOTIVATION ON STUDENTS' WILLINGNESS TO ENGAGE WITH SOFTWARE APPLICATIONS	Dr. Rachel Adams, Mark Thompson

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HALL / SALON 6	**Dr. Jamilah Aziz**	1	THE TENDENCIES OF DEVELOPMENT OF THE MANAGEMENT IN THE EDUCATION SYSTEM OF THE REPUBLIC OF KAZAKHSTAN	Altynai Zhaitapova, Aizhan Satyvaldiyeva
		2	REAL-TIME CONTROL LEARNING GAME - VELOCITY CHALLENGE THROUGH WHEEL EDUCATION - DATA COLLECTION SYSTEM DEVELOPMENT	Elena Petrovna, Marko Novic
		3	E-LEARNING ACTIVITIES: ANALYSIS AND CLASSIFICATION BASED ON SIGNIFICANT LEARNING ATTRIBUTES	Sofia Reyes, Ahmed Khan, Laura Martinez, James Kim
		4	INVESTIGATING THE LINK BETWEEN LEARNING MOTIVATION AND ACADEMIC PERFORMANCE	Dr. Aiko Tanaka
		5	INTEGRATING TECHNOLOGY IN EDUCATION: FOSTERING PERSONALITY AND SOCIAL GROWTH IN YOUTH	Dr. Jamilah Aziz, Prof. Fahad Al-Hakim
		6	IMPACT OF ARTIFICIAL SUCCESS IN MATHEMATICAL TASKS ON JUNIOR HIGH STUDENTS' SELF-EFFICACY	Hiroshi Nakamura, Kenji Saito
		7	ENHANCING TEACHER PROFESSIONALISM THROUGH CERTIFICATION PROGRAMS: A CASE STUDY FROM INDONESIA	Assoc. Prof. Rina Prabowo
			DOCTORAL STUDENTS' RESEARCH SKILLS WITHIN A SUSTAINABILITY FRAMEWORK	L. Hristova, D. Stefanov
		8	CONTRIBUTIONS TO SUSTAINABLE DEVELOPMENT AMONG STUDENTS AT THE UNIVERSITY OF MADEIRA (PORTUGAL)	Dr. Filipe Carvalho

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HALL / SALON 7	**Prof. Marco Giordano**	1	OMMUNITIES OF INTEREST: THREE UNIQUE CASE STUDIES IN WIDER UNIVERSITY AND SCHOOL PARTNERSHIPS IN AUSTRALIA	M. Zeegers, D. Barron
		2	TRANSFORMING EDUCATIONAL ENGAGEMENT IN OUTCOME-BASED HIGHER EDUCATION: A MOVE TOWARDS STUDENT-CENTERED APPROACHES	Dr. Elena Petrova
		3	ESSENTIAL ELEMENTS OF CURRICULUM INNOVATION IN LANGUAGE EDUCATOR PREPARATION	Prof. Marco Giordano
		4	ENHANCING E-LEARNING COURSE QUALITY IN HIGHER EDUCATION THROUGH STUDENT FEEDBACK	Maria Johnson, Liam Chen
		5	CREATING A SELF-EFFICACY ASSESSMENT TOOL FOR HIGH SCHOOL PHYSICAL EDUCATION INSTRUCTORS	Dr. Jenna Smith
		6	INNOVATION IN EDUCATION: FOSTERING CREATIVITY FOR ENGAGEMENT AND UNDERSTANDING IN SCIENCE LEARNING	Dr. Amira Zayed
		7	DESIGNING AND ASSESSING A VIRTUAL LEARNING PLATFORM FOR HEARING-IMPAIRED CHILDREN	Aldo Ruiz
		8	DIGITAL STORYTELLING AS A STRATEGY FOR TEACHING READING TO MEDIA-SAVVY STUDENTS	Sarah N. Martinez

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HALL / SALON 1	Prof. Dr. NİZAMİ MUSTAFA	1	Coefficient Bound Estimates for the Pseudo-Convex Function Class of Complex Order	Prof. Dr. NİZAMİ MUSTAFA Doç. Dr. VEYSEL NEZİR Grad. Stud. Davut MİNGSAR
		2	Coefficient Bound Estimates for the Pseudo-Starlike Function Class of Complex Order	Prof. Dr. NİZAMİ MUSTAFA Doç. Dr. VEYSEL NEZİR Grad. Stud. Davut MİNGSAR
		3	COEFFICIENT BOUND ESTIMATES FOR THE PSEUDO-STARLIKE BI-UNIVALENT FUNCTION CLASS	Prof. Dr. NİZAMİ MUSTAFA Doç. Dr. VEYSEL NEZİR Grad. Stud. KENAN YALÇIN
		4	COEFFICIENT PROBLEM FOR THE PSEUDO-CONVEX BI-UNIVALENT FUNCTION CLASS	Prof. Dr. NİZAMİ MUSTAFA Doç. Dr. VEYSEL NEZİR Grad. Stud. KENAN YALÇIN
		5	COEFFICIENT BOUND ESTIMATES AND FEKETE-SZEGÖ PROBLEM FOR THE PSEUDO-CONVEX FUNCTION CLASS	Prof. Dr. NİZAMİ MUSTAFA Doç. Dr. VEYSEL NEZİR Grad. Stud. NAHİDA GÖKÇEK
		6	COEFFICIENT ESTIMATES AND FEKETE-SZEGÖ PROBLEM FOR THE PSEUDO-STARLIKE UNIVALENT FUNCTION CLASS	Prof. Dr. NİZAMİ MUSTAFA Doç. Dr. VEYSEL NEZİR Grad. Stud. NAHİDA GÖKÇEK
		7	FIXED POINT PROPERTY FOR NONEXPANSIVE MAPPINGS ON LARGE CLASSES IN AN -DUAL OF A DIFFERENCE SEQUENCE SPACE	Assoc. Prof. Dr. VEYSEL NEZIR Prof. Dr. NIZAMI MUSTAFA
		8	LARGE CLASSES IN A BANACH SPACES IN CLOSE RELATION TO AN -DUAL OF A DIFFERENCE SEQUENCE SPACE AND THEIR FIXED POINT PROPERTIES FOR NONEXPANSIVE MAPPINGS	Assoc. Prof. Dr. VEYSEL NEZIR Prof. Dr. NIZAMI MUSTAFA
		9	LARGE CLASSES IN -DUAL OF A DIFFERENCE SEQUENCE SPACE AND THEIR FIXED POINT PROPERTIES FOR NONEXPANSIVE MAPPINGS	Assoc. Prof. Dr. VEYSEL NEZIR Prof. Dr. NIZAMI MUSTAFA
		10	LARGE CLASSES IN A KÖTHE-TOEPLITZ DUAL OF A DIFFERENCE SEQUENCE SPACE AND THEIR FIXED POINT PROPERTY FOR NONEXPANSIVE MAPPINGS	PhD Student, AYSUN GÜVEN Assoc. Prof. Dr. VEYSEL NEZIR Prof. Dr. NIZAMI MUSTAFA
		11	FIXED POINT PROPERTY FOR NONEXPANSIVE MAPPINGS ON LARGE CLASSES IN A KÖTHE-TOEPLITZ DUAL OF A DIFFERENCE SEQUENCE SPACE	PhD Student, AYSUN GÜVEN Assoc. Prof. Dr. VEYSEL NEZIR Prof. Dr. NIZAMI MUSTAFA

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HALL / SALON 2	**Doç. Dr. Sema yılmaz RAKICI**	1	FREE FETAL DNA AND RNA IN MATERNAL BLOOD: THEIR PLACE AMONG PRENATAL TESTS	Assis. Prof., Demet ÇAKIR Lecturer, Arslan SAY Assic. Prof., Vasviye EROĞLU
		2	FETAL MONITORING TYPES AND MIDWIFERY APPROACHES	Ass. Prof., Demet ÇAKIR Ass. Prof., Vasviye EROĞLU Lecturer, Arslan SAY
		3	Preparing a Unified Code for Nuclear Data Tables	Dr. Fahrettin KOYUNCU
		4	Touch Therapy and Baby Massage in Neonates:The Evidence	Prof. Dr.Özgür ALPARSLAN Dr. Öğr. Üyesi Gizem ÇITAK
		5	ANTI-VACCINATON PROVISIONS IN PERSONAL AND SCIENTIFIC CASES	Prof. Dr.Özgür ALPARSLAN Dr. Öğr. Üyesi Gizem ÇITAK
		6	GÖZLER KALBİN AYNASIDIR: ONKOLOJİ HASTALARINDA BEDEN DİLİ	Doç. Dr. Sema yılmaz RAKICI
		7	PROSTAT KANSERİNDE PSMA-PET FÜZYON İLE HİPOFRAKSİYONE İNTRAPROSTATİK BOOST RADYOTERAPİ UYGULANMASI	Doç. Dr. Sema yılmaz RAKICI

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HALL / SALON 3	**Assist. Prof. Dr. Necmi YARBAŞI**	1	EXPERİMENTAL INVESTIGATION OF MECHANICAL PERFORMANCE OF SİLİCA FUME-BASED GEOPOLYMER CONCRETE CONTAINING MİCRO SYNTHETİC FİBER EXPOSED TO HİGH TEMPERATURE	Dr. BARIŞ BAYRAK MSc Student, YASEMİN ÖZBEN Prof. Dr. ABDULKADİR CÜNEYT AYDIN
		2	DEVELOPMENT OF DRYING CRACKS IN CLAYEY SOILS ADDED WITH RESIDUAL LIGNITE DUST UNDER WETTING-DRYING CYCLES	Assist. Prof. Dr. Necmi YARBAŞI
		3	EFFECT OF DISTANCE METRICS ON DIABETES PREDICTION USING K-NEAREST NEIGHBOR ALGORITHM	Şahin YILDIRIM Mehmet Safa BİNGÖL

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HALL / SALON 4	**Assoc. Prof. Dr. Ali Rıza DENİZ**	1	DIODE PERFORMANCE OF MgO MATERIAL	Assoc. Prof. Dr. Ali Rıza DENİZ
		2	EFFECTS OF TEMPERATURE AND RADIATION ON ELECTRICAL PARAMETERS OF Au/MgO/p-Si/Al DIODE	Assoc. Prof. Dr. Ali Rıza DENİZ
		3	INVESTIGATION OF THE EFFECTS OF STATCOM IN STEADY STATE OPERATION IN GRID-CONNECTED DFIG-BASED WIND TURBINES	Prof. Dr. M. Kenan DÖŞOĞLU Doç. Dr. Mustafa DURSUN Dr. Öğr. Üyesi Enes KAYMAZ
		4	2D MoSe 2 BASED SELF-POWERED SCHOTTKY PHOTODIODE DESIGN FOR VISIBLE AND NEAR INFRARED DETECTION	Doç. Dr. Musa ÇADIRCI Doç. Dr. Emin YILDIRIZ
		5	ÜÇ FAZLI ÇİFT AKTİF KÖPRÜLÜ DA-DA DÖNÜŞTÜRÜCÜNÜN METASEZGİSEL ALGORİTMA TABANLI PI DENETLEYİCİ İLE KONTROLÜ	TURGUT ABDİOĞLU Dr. Öğr. Üyesi YAHYA DANAYİYEN
		6	PARÇACIK SÜRÜ OPTİMİZASYONU YÖNTEMİ İLE DENKLEŞTİRİCİ KAT SAYILARININ BULUNMASI	Handan DERİN Arş. Gör. Emirhan YETER Dr. Öğr. Üyesi Yahya DANAYİYEN

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HALL / SALON 5	Assoc. Prof. Dr., SELMAN KULAÇ	1	MODELING OF STRAIN AGING EFFECTS IN AISI 304 AUSTENITIC STAINLESS STEEL WITH ARTIFICIAL NEURAL NETWORKS	Asst.Prof. Muhammet Anıl KAYA Asst.Prof. Cengiz Görkem DENGİZ Fırat DOĞAN
		2	A SIMULATIONAL COMPARISON OF EQUAL AND OPTIMUM POWER ALLOCATION CASES IN AN SDF COOPERATIVE TRANSMISSION SCENARIO FOR SMART VEHICLES	Assoc. Prof. Dr., SELMAN KULAÇ
		3	EV TİPİ TAMBURLU ÇAMAŞIR KURUTMA MAKİNELERİNDE MİKROPLASTİK FİLTRELEME SİSTEMİ	E&P Test Uzmanı, Onur TURHAN R&D Müdürü, Mustafa BANİ
		4	IMPROVEMENT OF ANTIBACTERIAL PROPERTIES IN Ti BASED ALLOYS: THE ROLE OF Ag ADDITION	Rumeysa DURAK Prof. Dr. Rıdvan YAMANOĞLU
		5	THE EFFECT OF STRESS SHIELDING IN Ti ALLOYS: A COMPARISON OF β -TYPE ALLOYS AND PRODUCTION METHODS	Rumeysa DURAK Prof. Dr. Rıdvan YAMANOĞLU

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HALL / SALON 6	**Prof. Dr. NİLGÜN ÖZDİL Dr. Öğretim Üyesi Z. EVRİM KANAT**	1	ARK ERGİTME YÖNTEMİ İLE İMALATIN AL-17Sİ VE AL-12Sİ-0,2Tİ ALAŞIMLARININ İÇYAPI VE MEKANİK ÖZELLİKLERİNE ETKİLERİNİN İNCELENMESİ	Doç. Dr. ALİ PAŞA HEKİMOĞLU Arş. Gör. MURAT HACIOSMANOĞLU
		2	EFFECT OF CREEP STRESS ON THE CREEP RATE OF INJECTION MOULDED POLYPROPYLENE BLOCK COPOLYMER MATERIAL	Dr. Öğr. Üyesi, Şenol ŞAHİN, Ferhat AKPINAR,
		3	ORTOPEDİK İMPLANT UYGULAMALARI İÇİN AZ31 Mg ALAŞIMININ Ti MİKRO ALAŞIMLANDIRMA İLE SİTOTOKSİSİTE ÖZELLİKLERİNİN İNCELENMESİ	Arş. Gör. Gamze YILDIRIM Sümeyye KOZAN Prof. Dr. Şennur CANDAN Prof. Dr. Meltem DEMİREL KARS Prof. Dr. Ercan CANDAN
		4	FANTAZİ İPLİK TÜRÜNÜN ÖRME KUMAŞ MUKAVEMETİNE ETKİSİ	Prof. Dr. NİLGÜN ÖZDİL Dr. Öğretim Üyesi Z. EVRİM KANAT
		5	SEPARATION EFFICIENCY OF C 18 STATIONARY PHASE FOR THE CO–ELUTED PEAKS OF TOCOPHEROLS: OPTIMIZATION AND MODELLING WITH CHEMOMETRICS	Fatma Nur Arslan

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HALL / SALON 7	**Dr. Öğr. Üyesi Alper Tunga ŞEN**	1	EVALUATION OF THE DIGITAL TRANSFORMATION PROCESS: A STUDY ON PUBLIC SECTOR AND PRIVATE SECTOR EMPLOYEES	Dr. Öğr. Üyesi Alper Tunga ŞEN
		2	IRON MAN WANG JINXI IN CHINESE PROPAGANDA	Doç. Dr. Abdülhakim Bahadır DARI Dr. Öğr. Üyesi Caner ÇAKI
		3	USA AND ENGLAND IN SOVIET PROPAGANDA IN SECOND WORLD WAR	Doç. Dr. Abdülhakim Bahadır DARI Dr. Öğr. Üyesi Caner ÇAKI
		4	A STUDY ON BENEDETTO CROCE'S UNDERSTANDING OF ART: THE EXAMPLE OF THE MOVIE "ANAYURT OTELİ"	Arş. Gör. Dr. SENA IŞIKGİL
		5	14 MAYIS TÜRKİYE SEÇİMLERİNİN KÖRFEZ ARAP MEDYASINDAKİ GÖRÜNÜMÜ	HASAN ALRAHMOUN Doç. Dr. MEHMET SENA KÖSEDAĞ

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HALL / SALON 8	Doç. Dr.,SAYIM AKTAY	1	IMPLEMENTING TRANSFORMATIONAL LEARNING THROUGH CLASSROOM ACTION RESEARCH TO ENHANCE STUDENT ACHIEVEMENT	Sriyanto Muchlas Ishafit Dwi SULISWORO
		2	GÖRME YETERSİZLİĞİNDEN ETKİLENEN ÖĞRENCİLERİN ÜNİVERSİTE YAŞAMINA UYUMLARI	Dr. Asil DERİN KILIÇ
		3	AN OVERVIEW OF RESEARCH ON READING SKILLS: A REVIEW BASED ON BIOMETRIC AND CONTENT ANALYSIS	Doktora Öğrencisi, Elif AKAN Prof. Dr., A. Halim ULAŞ
		4	SAYI HİSSİ VE PROBLEM ÇÖZME BECERİSİNE YÖNELİK TEMATİK İÇERİK ANALİZİ	Zeliha KILIÇ Prof. Dr. Gönül GÜNEŞ
		5	SINIF ÖĞRETMENLERİNİN SAYI HİSSİNE YÖNELİK GÖRÜŞLERİNİN İNCELENMESİ	Zeliha KILIÇ
		6	ORTAOKUL ÖĞRENCİLERİNİN ZORBALIK VE SİBER ZORBALIK DAVRANIŞLARINA YÖNELİK TEPKİLERİNİN BELİRLENMESİ	Dr. Derya ALTINIŞIK
		7	WHAT IS THE ACTION MODEL? WHAT IS IT NOT?	Doç. Dr. Melike SOMUNCU
		8	OKULLARDA GÜVENLİK VE ÇEVRE DÜZENLENMESİNİN ÖNEMİ	Beril Dindar Doç. Dr. Rukiye ARSLAN
		9	TÜRKİYE YÜZYILI MAARİF MODELİ 2024 HAYAT BİLGİSİ DERSİ ÖĞRETİM PROGRAMI VE ASKI SÜRECİ ETKİSİ	Doç. Dr.,SAYIM AKTAY
		10	TÜRKİYE YÜZYILI MAARİF MODELİ 2024 İLKOKUL SOSYAL BİLGİLER DERSİ ÖĞRETİM PROGRAMI VE ASKI SÜRECİ ETKİSİ	Doç. Dr.,SAYIM AKTAY

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HALL / SALON 1	**Dr. Priya Mehta**	1	THE PROJECT EVALUATION TO DEVELOP THE COMPETENCIES, CAPABILITIES, AND SKILLS IN REPAIRING COMPUTERS OF PEOPLE IN JOMPLUAK LOCAL MUNICIPALITY, BANG KHONTHI DISTRICT, SAMUT SONGKRAM PROVINCE	Wilailuk Meepracha
		2	EXPLORING ERRORS IN PREPOSITION USAGE AMONG FIRST-YEAR ENGLISH STUDENTS AT ALGERIA UNIVERSITY	Dr. Layla Benali
		3	INNOVATIVE EDUCATION SYSTEM FOR ENTREPRENEURSHIP: FUTURE PERSPECTIVES	Ahmed Mansour, Fatima Zohra
		4	FRAMEWORK FOR DEVELOPING, MONITORING, AND EVALUATING CAPSTONE DESIGN PROJECTS IN BACHELOR'S IN MECHANICAL ENGINEERING	Rafiq Ahmed Khan
		5	ANALYSIS OF NATIONAL UNIVERSITY ADMISSION EXAM IN INDIA: ORIGIN, POLICIES, AND STRATEGIES	Dr. Priya Mehta
		6	DIGITAL LANGUAGE LEARNING PLATFORM FOR ARABIC AS A SECOND LANGUAGE	Ziad Khoury
		7	IMPACT OF COGNITIVE ABILITIES AND LEARNING STYLES ON ENGINEERING STUDENTS' ACADEMIC SUCCESS	Dr. Neha Verma
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HALL / SALON 2	**Assoc. Prof. Sarah Thompson**	1	DETERMINATION OF SKILLS GAP BETWEEN SCHOOL-BASED LEARNING AND LABORATORY-BASED LEARNING IN OMAR AL-MUKHTAR UNIVERSITY	Aisha Othman, Crinela Pislaru, Ahmed Impes
		2	AN INNOVATIVE MODEL FOR ENHANCING CREATIVE STRUCTURAL THINKING AND ITS APPLICATIONS ACROSS VARIOUS SYSTEMS	Dr. Elena Petrovna
		3	COMPARATIVE ANALYSIS OF TEACHING METHODS AND THEIR IMPACT ON STUDENT SELF-CONFIDENCE: A STUDY BETWEEN MALAYSIA AND THAILAND	Dr. Amirul Rahman, Prof. Siti Hajar
		4	ASSESSING THE IMPACT OF ICT TRAINING WORKSHOPS ON TUTORS AT OPEN DISTANCE LEARNING UNIVERSITIES IN PAKISTAN	Dr. Amina Khan, Prof. Bilal Zafar
		5	DEVELOPMENT OF A COMPREHENSIVE MEASUREMENT TOOL FOR MULTIPLE INTELLIGENCES IN PRIMARY SCHOOL STUDENTS	Assoc. Prof. Sarah Thompson
		6	DESIGNING A FORMATIVE ASSESSMENT TOOL TO IMPROVE FEEDBACK IN CLASSROOM SETTINGS	Michael Johnson, Dr. Rachel Green
		7	EFFECTS OF ACTIVE LEARNING TECHNIQUES ON ACADEMIC PERFORMANCE AMONG UNDERGRADUATE STUDENTS IN TRINIDAD AND TOBAGO	Dr. Lisa Marie Jones
		8	TECHNOLOGY, RESOURCES, AND ENVIRONMENT: THE INFLUENCE ON TASK COMPLETION IN ESL CLASSROOMS	Dr. Akira Yamamoto
		9	INTEGRATING ETHICAL EDUCATION INTO THE NATIONAL CURRICULUM: A CASE STUDY FROM HUNGARY	Dr. János Szabó, Maria Kovács

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HALL / SALON 3	**Dr. Sarah J. Al-Sayed**	1	COMPUTER GRAPHICS AND UNDERSTANDING SEMIOTICS IN DESIGN	Manoj Majhi, Debkumar Chakrabaty
		2	ANALYZING STUDENT SATISFACTION AMONG WORK-BASED LEARNERS	Julia L. Harris, Ahmed T. Fawzi
		3	ASSESSING THE USABILITY OF AN EDUCATIONAL PORTAL FOR IT FACULTY AT THE UNIVERSITY OF LIBYA	Khaled R. Badr, Laila S. Hamed
		4	DEVELOPING PROBLEM-SOLVING SKILLS IN ENGINEERING STUDENTS THROUGH ENGLISH LANGUAGE INSTRUCTION	Dr. Sarah J. Al-Sayed
		5	**TEXTURES FOR THE VISUALLY IMPAIRED: A STUDY OF HIMMAPAN CREATURES**	Dr. Alex Thompson, Emily Carter
		6	ENGLISH LANGUAGE TEACHING IN THE CONTEXT OF LMD REFORMS: A STUDY FROM ALGERIA	Dr. Leila M. Bouali
		7	DEVELOPING INFORMATIONAL CULTURE AMONG STUDENTS: STRATEGIES AND METHODS	Aigerim K. Nurpeissova
		8	VIRTUAL COLLABORATIVE LEARNING: ENHANCING STUDENT PERFORMANCE IN BAHRAIN	Dr. Omar S. Al-Nasr

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HALL / SALON 4	**Dr. Emily Roberts,**	1	TOWARD A MODEL FOR KNOWLEDGE DEVELOPMENT IN VIRTUAL ENVIRONMENTS: STRATEGIES FOR STUDENT OWNERSHIP	N.B. Adams
		2	THE FUTURE OF OPEN EDUCATION AND DISTANCE LEARNING IN ZAMBIA	*Jane Mwansa*
		3	NAVIGATING BETWEEN POLICY FRAMEWORKS AND TECHNOLOGICAL INNOVATIONS: EVALUATING THE SUSTAINABILITY OF DISTANCE EDUCATION	*Ravi Desai*
		4	FACULTY PERCEPTIONS ON THE IMPORTANCE OF COMPONENTS IN A VIRTUAL LEARNING ENVIRONMENT	Dr. Emily Roberts, Michael Chen
		5	APPLYING THE STUDENT-CENTRIC APPROACH IN TECHNOLOGY EDUCATION: STUDENT INSIGHTS	Amina Shah
		6	LEVERAGING BLOGGING TO FOSTER CRITICAL THINKING: A PILOT STUDY	Lena Kim, Daniel Zhang
		7	THE EXPERIENCES OF NIGERIAN SECONDARY SCHOOL GIRLS IN A DIGITAL MAKERSPACE	Dr. Chika Afolabi, Sadiq Adediran
		8	INVESTIGATING SELF-DIRECTED LEARNING IN YOUNG LEARNERS	Sara A. Kahn, Hassan Faridi

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HALL / SALON 5	**Dr. Ana Petrovic,**	1	THE ECONOMIC AND POLITICAL DIMENSIONS OF POLICE CORRUPTION IN NIGERIA	Amina Bello, Dr. Lukas Müller
		2	THE INFLUENCE OF DİSİNFORMATİON ON PUBLİC POLİCY DYNAMİCS: A COMPREHENSİVE DOCUMENTARY STUDY	Isabella Torres Rodrigues, Lucas Schmidt,
		3	THE NECESSITY OF A COMPREHENSIVE INDUSTRIAL EFFLUENT REGULATION: ADDRESSING RISKS TO EUROPEAN WATER BODIES	Sophie Ellee Thomas Richter
		4	ANALYZING ECONOMIC RELATIONS BETWEEN SOUTH KOREA AND JAPAN THROUGH WTO DISPUTES	Henrik L. Sorensen, Maria K. Johansson
		5	COMPARATIVE APPROACHES TO COUNTERING RADICALIZATION: INSIGHTS FROM EUROPE AND SOUTH EAST ASIA	Ryo Tanaka,
		6	LEGAL IMPLICATIONS OF CLIMATE CHANGE REGULATION: A COMPARATIVE ANALYSIS OF EARTHLIFE AFRICA JOHANNESBURG V MINISTER OF ENERGY AND OTHERS	Dr. Elena Müller Dr. Rajesh Patel
		7	THE INFLUENCE OF SOCİAL MEDİA ON EUROPEAN GOVERNANCE: A COMPARATİVE ANALYSİS	Maria Thompson Luca Bianchi
		8	ETHİCAL CHALLENGES İN LOCAL PUBLİC ADMİNİSTRATİON: A CASE STUDY FROM SOUTHERN EUROPE	Dr. Ana Petrovic,

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HALL / SALON 6	**Dr. Ana Šimunović,**	1	ENHANCING DETECTION OF SUBJECTIVE BIAS USING BIDIRECTIONAL TRANSFORMER REPRESENTATIONS AND LSTM NETWORKS	Sofia Mendes, Luka Pavlović, Elisabeth Keller
		2	ANALYZING DUBBING TECHNIQUES IN THE PORTUGUESE DUBBED VERSION OF MULAN (1998)	Ana Vicente Helena Sousa Ricardo Martins
		3	IMAGE PRIORITIZATION TECHNIQUES FOR ENHANCING OBJECT LABELING IN TRAINING DETECTION MODELS	Dr. Elisabeta Novak, Dr. László Horváth, Dr. Márton Szabó
		4	JUXTAPOSITION OF TIME AND IDENTITY: A STYLISTIC ANALYSIS OF THE SHORT STORY “TOO MUCH JOY” BY EVELYN BERG	Dr. Ana Šimunović,
		5	THE INFLUENCE OF INDUCED POSITIVE EMOTIONS ON CREATIVITY: EXPLORING PERSONAL DEVELOPMENT AND SOCIAL ADAPTATION THROUGH EMOTIONAL NARRATIVES	Sofia Hartmann, Anna Petrova
		6	END-TO-END METAPHOR DETECTION IN GREEK USING ADVANCED NEURAL NETWORK ARCHITECTURES	Andreas Krüger, and Thomas Fischer
		7	ANALYZING MICROBLOGS: EXPLORING THE PSYCHOLOGY OF POLITICAL LEANINGS	Meaghan Bowman
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HALL / SALON 7	**Assoc.Prof. Dr. Helena Borge**	1	ENHANCING ARABIC LANGUAGE PROCESSING WITH AN ADVANCED LIGHT STEMMER	Amina Karim Rustam Kamilov, Gulnara Davletshina
		2	ENHANCING KAZAKH LANGUAGE PROFICIENCY: A CASE STUDY FROM AL-FARABI KAZAKH NATIONAL UNIVERSITY	Aisulu Amanzholova, Marat Tulegenov
		3	THE INFLUENCE OF HYBRID SLANG IN DYSTOPIAN NARRATIVES: AN ANALYSIS OF A CLOCKWORK ORANGE	Alina Nurkhan, Talgat Bekbolat
		4	THE IMPACT OF PLANNING AND MEMORY ON NAVIGATIONAL SKILLS	Anisa Khamidova, Timur Akhmedov, Jamilbek Tursunov, Mukhammadali Nazarov
		5	EXPLORING COMPUTATIONAL CONSCIOUSNESS: THE DYNAMIC ABSTRACTION FRAMEWORK	Aisha Nurmatova, Faridbek Tursunov
		6	EXPLORING MORPHOLOGICAL INNOVATIONS IN TEXT MESSAGING AMONG URBAN BILINGUALS IN GREECE	Maria Papadopoulos Niroshan Silva
		7	INNOVATION IN BILINGUAL ADVERTISING: A STUDY OF SINHALA AND ENGLISH IN SRI LANKA	Assoc.Prof. Dr. Helena Borge
		8	ENHANCING ARABIC SYNTAX CORRECTION WITH MACHINE LEARNING: A EUROPEAN PERSPECTIVE	Lila K. Ritter, Thomas W. Müller, Emilie D. Weber, Hassan A. Bouazizi, Leila M. Johnson

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HALL / SALON 1	**Prof.Dr.Arslan Topakkaya**	1	WHY ARE WE DOING PHILOSOPHY?	Doç. Dr., Serdar SAYGILI
		2	WHY CAN'T WE THINK CRITICALLY?	Doç. Dr., Serdar SAYGILI
		3	METAFİZİK-ONTOLOJİ FARKI	Prof.Dr.Arslan Topakkaya
		4	AUGUSTİNUS'TA METAFİZİK	Prof.Dr. Arslan Topakkaya
		5	MENTAL CONFLICT AND THE PROBLEM OF UNITY IN DESCARTES' PHILOSOPHY	Dr. Eda HAYRİOĞULLARI

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HALL / SALON 2	**Doç. Dr. Yasemin BAKİ**	1	ÇOCUK YAZININDA KARAKTER TÜRLERİ VE KARAKTER GELİŞTİRME YOLLARI: ZAMAN ZAMAN İÇİNDE ANADOLU MASALLARI ÖRNEĞİ	Doç. Dr. Yasemin BAKİ Öğretmen, Nesibe Yıldırım
		2	MEVLANA İDRİS ZENGİN'İN ''KORKU DÜKKANI'' ADLI ESERİNİN DUYARLIK EĞİTİMİ AÇISINDAN İNCELENMESİ	Öğretmen, Nesibe Yıldırım Doç. Dr. Yasemin BAKİ
		3	BİLİM VE SANAT MERKEZİNDE (BİLSEM) GÖREV YAPAN ÖĞRETMENLERİN ÜSTÜN YETENEKLİ ÇOCUKLARA VERİLEN DESTEK EĞİTİM HAKKINDAKİ DÜŞÜNCELERİ	Doç. Dr. Nazan KAYTEZ Öğr. Gör. Dr. Ayşe ÇİFTCİ Dr. Öğr. Üyesi Güzin Yasemin TUNÇAY
		4	COMPARISON OF THE EVALUATION DIMENSIONS OF PRESCHOOL EDUCATION PROGRAMS	Dr. EMİNE ELA ŞİMŞEK
		5	ÖĞRETMEN ADAYLARININ MEDYA OKURYAZARLIĞI DÜZEYLERİ İLE SOSYAL BECERİLERİ ARASINDAKİ İLİŞKİNİN İNCELENMESİ	Yüksek Lisans Öğrencisi, Kudret YILDIRIM
		6	VİSUAL MATHEMATİCS LİTERACY SELF-EFFİCACY PERCEPTİON LEVELS OF SECONDARY SCHOOL STUDENTS STUDYİNG İN URBAN RURAL AREAS	Yüksek Lisans Öğrencisi, AHMET MUAMMER ÖZKAN Prof. Dr. KÜRŞAT YENİLMEZ
		7	OKUL MÜDÜRLERİNİN İLETİŞİM BECERİLERİ	Uzm. Öğretmen Mehtap PÜSKÜRT Prof. Dr. Semiha ŞAHİN
		8	OKUL MÜDÜRLERİNİN KRİZ YÖNETİMİ İLE İLETİŞİM BECERİLERİ ARASINDAKİ İLİŞKİ	Uzm. Öğretmen Mehtap PÜSKÜRT Prof. Dr. Semiha ŞAHİN

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		2	GÖÇLER, REFAKATSİZ ÇOCUKLAR ve SOSYAL HİZMET	Doç. Dr., BEYZA ERKOÇ
		3	SOSYAL MEDYA KULLANIMININ ADOLESANLARDA YARATTIĞI ETKİLER	Doç. Dr., BEYZA ERKOÇ
		4	COMPARISON OF COUNTRY PRACTICES WITHIN THE SCOPE OF DISASTER LOGISTICS MANAGEMENT: JAPAN, USA, TÜRKİYE	ÖZLEM BÖLÜKBAŞ
		5	A MODEL PROPOSAL FOR INCREASING THE EFFECTIVENESS OF PUBLIC SERVANTS' UNIONS IN NATIONAL SOCIAL DIALOGUE PROCESSES	Assist. Prof.Dr. Neşe YILDIZ
		6	RİSK ANALİZİ VE TEHLİKE AVCILIĞI YÖNTEMİ:ÇANAKKALE' DE BİR UYGULAMA	YÜKSEK LİSANS ÖĞRENCİSİ RAHİME AKAT DR.ÖĞRETİM ÜYESİ,FEHMİ VOLKAN AKYÖN,

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HALL / SALON 4	**Prof. Dr. Serkan DİLEK**	1	ANALYSIS OF TURKEY'S FOREIGN TRADE WITH COUNTRIES ON THE CENTRAL CORRIDOR WITHIN THE SCOPE OF THE MODERN SILK ROAD PROJECT	Doç. Dr. Ali KONAK Prof. Dr. Serkan DİLEK
		2	MEASURING SOURCE COUNTRY DIVERSIFICATION OF IMPORTS OF SELECTED ASIAN COUNTRIES WİTH HERFİNDAHL-HİRSCHMAN ENDEKSİ	Prof. Dr. Serkan DİLEK Doç. Dr. Ali KONAK
		3	TÜRKİYE'NİN AVRUPA BİRLİĞİ KARŞISINDAKİ ULUSLARARASI TİCARET VE TAŞIMACILIK PERFORMANSININ ÖLÇÜLMESİ: İSTATİSTİKSEL BİR ANALİZ	Dr. Öğr. Üyesi, SEYYİD ALİ ERTAŞ
		4	AVRUPA BİRLİĞİ ÜLKELERİNDE YAŞAM KALİTESİ GÖSTERGELERİNİN PERFORMANS ANALİZİ: İSTATİSTİKSEL BİR DEĞERLENDİRME	Dr. Öğr. Üyesi, SEYYİD ALİ ERTAŞ
		5	EĞİTİM DURUMLARINA GÖRE FERTLERİN ESAS İŞ GELİRLERİNİN ENFLASYON KARŞISINDAKİ DURUMU	Prof. Dr. SAVAŞ ERDOĞAN Öğr. Gör. Dr. ABDULBAKİ PINAR
		6	D8 ÜLKELERİNİN MAKROEKONOMİK PERFORMANSLARININ CRITIC VE TOPSIS YÖNTEMLERİ İLE ÖLÇÜMÜ	Öğr. Gör. Dr. ABDULBAKİ PINAR Prof. Dr. SAVAŞ ERDOĞAN
		7	ÇAY İŞLETMELERİNİN 2023 YILI PERFORMANSININ VERİ ZARFLAMA ANALİZİ METODUYLA DEĞERLENDİRİLMESİ	Yüksek Lisans Öğrencisi, GAMZE ÇAKMAK Prof. Dr. MEHMET KARAHAN
		8	HOLLANDA SENDROMU: AZERBAYCAN ÜZERİNE LİTERATÜR TARAMASI	Tarlan Azizov

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HALL / SALON 5	MİNE HAM	1	SERBEST DÜZGÜN TAM VEKTÖR ÖRGÜLERİ	Cemile Yüsra Nur GENERAL Prof. Dr. Ömer GÖK
		2	SIRALI YARI-FREDHOLM OPERATÖRLERİ	Zelal AVCI Prof. Dr. Ömer GÖK
		3	A STUDY OF THE GENERALIZED ABSOLUTE VALUE DISTANCE FUNCTION AND ITS GEOMETRIC PROPERTIES	DOĞUKAN AYLIKCI Prof. Dr. SÜHEYLA EKMEKÇİ
		4	Riesz Spaces Of Disjointness Preserving Operators	Ayşe Zeynep ÇETİN Prof. Dr. Ömer GÖK
		5	ON THE 3-NETS IN THE PROJECİVE PLANE OF ORDER 25	EMİN MENGİ Prof. Dr. ZİYA AKÇA
		6	ON THE ROLE OF CARTESIAN GROUP IN THE STRUCTURE AND EXISTENCE OF SUBPLANES OF PROJECTIVE PLANE OF ORDER 25	EMİN MENGİ Prof. Dr. ZİYA AKÇA
		7	A NOTE ON THE CHINESE CHECKERS HYPERSPHERES	MİNE HAM Prof. Dr. ZİYA AKÇA

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HALL / SALON 6	**Dr. Öğr. Üyesi HİLAL TUĞÇE LAPÇIN**	1	THE RELATIONSHIP BETWEEN TRANSFORMATIONAL LEADERSHIP AND INNOVATION IN NURSES: A REVIEW STUDY	Yüksek Lisans Öğrencisi Mustafa DOĞAN Doç.Dr. Esma Ülkü KAYA
		2	PERSPECTIVES OF DISADVANTAGED GROUPS ON ENTREPRENEURSHIP: A PRACTICE FOR VOCATIONAL AND TECHNICAL HIGH SCHOOL STUDENTS	Dr. Öğr. Üyesi HİLAL TUĞÇE LAPÇIN
		3	WHY BE A CREATIVE ORGANIZATINON?	Dr., OYA ÖNALAN
		4	The Effect of Person-Job Fit on Organizational Citizenship Behavior	Asst. Prof. Dr. NERİMAN ÇELİK

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HALL / SALON 7	**Assoc. Prof. Dr. Yakup ASLAN**	1	İŞLETMENİN SÜREKLİLİĞİ KAVRAMININ BAĞIMSIZ DENETİM STANDARDI 570 KAPSAMINDA DEĞERLENDİRİLMESİ	Dr. Öğr. Üyesi Mehtap BULUT DENİZ
		2	MÜŞAKERE FİNANSMANIN FAİZSİZ FİNANS MUHASEBE STANDARDI 4 (FFMS 4) KAPSAMINDA MUHASEBELEŞTİRİLMESİ	Dr. Öğr. Üyesi Mehtap BULUT DENİZ
		3	WHAT IS CLIMATE CHANGE ACCOUNTING?	Assoc. Prof. Dr. Yakup ASLAN
		4	DISPLAYING LEASING TRANSACTIONS IN FINANCIAL STATEMENTS WITHIN THE SCOPE OF TFRS 16	Assoc. Prof. Dr. Yakup ASLAN
		5	ESTIMATION OF DARDANELLES STRAIT SHIP CROSSINGS BY WEKA	Research Assistant, Şeyma ÖZEKİNCİ Assistant Professor, Hikmet ERBIYIK
		6	TÜRKİYE'DE ENFLASYON MUHASEBESİ SÜRECİ	Merve ŞENOCAK Doç. Dr. Bilal AKKAYNAK
		7	MUHASEBEDE E-DÖNÜŞÜM SÜRECİ	Merve ŞENOCAK Doç. Dr. Bilal AKKAYNAK

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HALL / SALON 8	**Dr. Arş. Gör. Elif ARSLAN DİNÇ**	1	SOSYAL MEDYA KULLANIM EĞİLİMLERİNİN REKLAM AJANSLARINA ETKİSİ: WE ARE SOCIAL DIGITAL 2023 VERİLERİ IŞIĞINDA BİR DEĞERLENDİRME	Yüksek Lisans Öğrencisi, BENGİSU TAŞDELEN
		2	YOUTUBE İÇERİKLERİNDEKİ MARKA YERLEŞTİRME STRATEJİLERİNİN İNCELENMESİ	Dr. Arş. Gör. Elif ARSLAN DİNÇ
		3	THE EFFECT OF PERSON-ORGANIZATION FIT ON QUIET QUITTING: AN EMPIRICAL STUDY	Doç. Dr. Gökhan KERSE Öğr. Gör. Dr. Vural DENİZ
		4	THE EFFECT OF SELF-ESTEEM ON BURNOUT: A RESEARCH ON TOURISM ACADEMICIANS	Yüksek Lisans Öğrencisi Sümeyra KESİCİ Doç. Dr. Erkan TAŞKIRAN
		5	ULUSLARARASI PAZARLAMA STRATEJİLERİ, ULUSLARARASI PAZARLAMADA KARŞILAŞILAN SORUNLAR, KAYSERİ ORGANİZE SANAYİ BÖLGESİNDEKİ İHRACATÇILARA DAİR BİR UYGULAMA	Dr. Öğr. Üyesi, SELMA BÜYÜKKANTARCI TOLGAY Öğrenci, SUDENUR BÜYÜKÖZTÜRK

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HALL / SALON 1	**Dr. Yumi Kim,**	1	EVALUATION OF ENERGY OUTPUT AND IRRADIANCE ANALYSIS TECHNIQUES İN PHOTOVOLTAIC SYSTEMS	Minh Chau Tran, Nguyen Hoang Anh, Ha Thi Mai
		2	INTEGRATION OF SOLAR POWER GENERATORS AND ENERGY STORAGE SYSTEMS İN POWER DISTRIBUTION NETWORKS	L. Tran, H. Nguyen, V. Pham, N. Hoang
		3	THE PROMISE OF HYBRID MICROGRIDS FOR ALLEVIATING POWER SHORTAGES İN LEBANON	T. Nguyen, H. Tran
		4	ANALYSIS OF VIBRATION SIGNALS İN SMALL VERTICAL AXIS WIND TURBINES	Mei Lin Zhang, Zhao Wei Chen, Haruto Nakamura
		5	INVESTIGATION OF LEAK EFFECTS ON THE DURABILITY OF SOLID OXIDE ELECTROLYSIS CELLS UNDER CO-ELECTROLYSIS CONDITIONS	Dr. Yumi Kim, Dr. Wei Zhang, Dr. Haruto Nakamura, Dr. Elena Costa
		6	A NOVEL THERMOCHEMICAL ENERGY STORAGE SOLUTION FOR TRANSPORTATION: DESIGN AND EVALUATION	Lin Cheng, Yulia Petrov
		7	ADVANCED CONSUMER LOAD PROFILING USING AN ENTROPY-ENHANCED K-MEANS APPROACH	Aisha Z. Jafari, Mei Ling Zhao
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HALL / SALON 2	Prof. Dr. Anne-Margré	1	REVIEWING THREE YEARS OF MEDICAL RECORDS: POISONING ADMISSIONS AT A CHILDREN'S HOSPITAL IN BENGHAZI, LIBYA	S Bengleil Mudafara
		2	A RESEARCH ON THE IMPACT OF PROLACTIN AND ITS ABERRATIONS ON SEMEN PARAMETERS IN MALE WHITE RATS	Assis. Prof. Hasan Rizvi
		3	DEXAMETHASONE: EFFECTS ON TESTICULAR FUNCTION	H. Guettaf, Bekkouche Hadj
		4	EXPLORING VMAT ALGORITHMS AND DOSIMETRY: AN INVESTIGATIVE APPROACH	Amone. Taqaddas
		5	ADDRESSING AUTISM SPECTRUM DISORDER: A KEY CHALLENGE IN THE KINGDOM OF SAUDI ARABIA	Rana Zeina, Laila Ayadhi, Bashir Shahid
		6	SEROLOGICAL IGG TESTING FOR DIAGNOSIS OF DIET-INDUCED CONDITIONS AND EFFICACY MONITORING IN CANINES	Prof. Dr. Anne-Margré Dr. Lec. C. Vink
		7	GENETIC VARIABILITY AND HAPLOTYPE ANALYSIS OF THE ORGANIC CATION TRANSPORTER 1 GENE IN THE ZULU POPULATION OF SOUTH AFRICA	N. Hoosain, Modela Du Plessis, Minao. Benjeddou
		8	EFFECTS OF LOWER BODY POSITIVE PRESSURE TRAINING ON BODY COMPOSITION IN OBESE CHILDREN	Basant Refay, Nabeel T. Faiad

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HALL / SALON 3	**Assoc. Prof. Dr. Sofia Torres,**	1	DEVELOPMENT AND VALIDATION OF AN AERODYNAMIC MODEL FOR THE HORIZONTAL STABILIZER OF THE CESSNA CITATION X USING OPENVSP AND DIGITAL DATCOM TECHNIQUES	Dr. Emilia Tanaka, Dr. Hiroshi Nakano, Dr. Samuel Okafor
		2	ENHANCING ADS-B SECURITY THROUGH HYBRID PAM-PSK MODULATION TECHNIQUES	S. Chen, R. Takahashi, L. Zhang, H. Nguyen, M. Kim, J. Zhang
		3	AN ANALYTICAL EXAMINATION OF AIR COOLING SYSTEMS UTILIZING THERMAL EJECTORS WITH VARIABLE GENERATOR PRESSURES	Assoc. Prof. Dr. Sofia Torres, Akio Nakamura
		4	IMPACT OF PRIMARY STREAM PRESSURE VARIATIONS ON EJECTOR REFRIGERATION SYSTEM EFFICIENCY: A NUMERICAL APPROACH	Maria Silva, Hiroshi Tanaka, Carlos Martinez, Dr. Anil Kumar
		5	TIME-DOMAIN ANALYSIS OF SURFACE-MOUNTED WAVE ENERGY CONVERTER DYNAMICS	Akira Tanaka, Hanae Yamamoto, Li Wei
		6	NUMERICAL ANALYSIS OF A SURFACE-GLIDING WAVE ENERGY CONVERTER'S PERFORMANCE AND DYNAMICS	Li Wei, Zhang Qiang, Wu Ming,
		7	ENHANCED SINGLE SWITCH HIGH STEP-UP DC/DC CONVERTER WITH ZERO CURRENT SWITCHING	Li Wei, Chen Ming, Aria Elmi, and Jorge Silva

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HALL / SALON 4	**Dr. Elena Rossi,**	1	DEVELOPMENT AND EVALUATİON OF AN ELECTRO-THERMAL SYMMETRİCAL MİCROGRİPPER FOR PRECİSİON MANİPULATİON	Dr. Emil Weber, Prof. Dr. Carla Rodriguez
		2	OPTİMAL PID CONTROL DESİGN FOR A 3-DOF HELİCOPTER USİNG LQR METHOD	Dr. Elena Rossi,
		3	ADAPTİVE FUZZY PID CONTROL FOR SHUNT ACTİVE POWER FİLTERS USİNG THE D-Q-O REFERENCE FRAME TECHNİQUE	Isabelle Dupont, Michael Sommer
		4	EYE-CONTROLLED WHEELCHAİR SYSTEM USİNG MİCROCONTROLLER TECHNOLOGY	Maria Gonzalez, Luca Bianchi, Sophie Dubois, Andreas Müller, Elena Schmidt
		5	AFFORDABLE SURFACE ELECTROMYOGRAPHİC SİGNAL AMPLİFİER USİNG ARDUİNO MİCROCONTROLLER	Anya Petrov, Viktor Ivanov, Elena Smirnova
		6	ADVANCED CONTROL OF SİNGLE-PHASE PWM INVERTERS WİTH M68HC11E MİCROCONTROLLER INTEGRATİON	Maria L. Santos,
		7	OPTİMAL PID CONTROLLER DESİGN FOR LOAD FREQUENCY CONTROL USİNG GENETİC ALGORİTHMS	A. Ribeiro, L. Silva
		1	DEVELOPMENT AND EVALUATİON OF AN ELECTRO-THERMAL SYMMETRİCAL MİCROGRİPPER FOR PRECİSİON MANİPULATİON	Dr. Emil Weber, Prof. Dr. Carla Rodriguez

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HALL / SALON 5	**Dr. Lena Huber**	1	ADVANCED TECHNIQUES IN MECHANICAL AND MECHATRONICS ENGINEERING: INNOVATIONS AND APPLICATIONS	Dr. Laura Klein Prof. Dr. Marco Rossi,
		2	ADVANCED SIMULATION AND DYNAMIC ANALYSIS OF INTELLIGENT SKID-STEERING VEHICLES USING TRUCKSIM AND SIMULINK	Arnaud Dubois, Isabella Rossi, Liam O'Connor, Markus Schneider
		3	INVESTIGATING THE ONSET OF IRONING IN MONO-DIAMETER WELL CASING EXPANSION	J. Müller, A. Smith, L. García, M. Bellamy
		4	ADVANCING INDOOR DRONE TECHNOLOGY FOR CREATIVE SECTOR APPLICATIONS	Dr. Lena Huber, Dr. Adam Turner
		5	EMOTION-AWARE ROBOTICS: ASSESSING AUTOMATIC EMOTION RECOGNITION TECHNIQUES ON A HUMANOID ROBOT FOR ENHANCED EMOTIONAL INTELLIGENCE	Elena Schmidt, Marco Russo
		6	ENHANCING EMOTIONAL INTELLIGENCE IN HUMANOID ROBOTS: A COMPARATIVE ANALYSIS OF AUTOMATIC EMOTION RECOGNITION TECHNIQUES	Matthias Weber, Clara Fischer, Lena Braun
		7	Automated Landmark Selection via Feature Clustering for Visual Navigation in Unmanned Aerial Vehicles	Ahmed Al-Mansoori, Elena Rodriguez
		8	EVALUATING LEAN MANUFACTURING IMPACTS: CREATION OF A STRUCTURAL MEASUREMENT MODEL	Maria Schmidt, Thomas Isabelle

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HALL / SALON 6	**Dr. Anjali Reddy,**	1	MODELING RADIAL HEAT AND MASS TRANSFER IN A FIXED BED CATALYTIC REACTOR THROUGH SIMULATION STUDY	K. Vakhshouri, M.M. Y. Motamed Hashemi
		2	BEHAVIOR OF CO2 AND CH4 HYDRATES IN POROUS MEDIA	Alexandra Petrov, Elena Ivanova, Dmitry Smirnov
		3	NOVEL MULTI-SOLID THERMODYNAMIC MODEL FOR WAX FORMATION PREDICTION	Mohammad Tabrizi, Leila Hosseini, Amir Zare
		4	APPLICATION OF NEURAL NETWORKS IN ESTIMATING KINETIC PARAMETERS	Dr. Maria Novak, Igor Petrenko
		5	PHASE EQUILIBRIUM STUDY IN AQUEOUS TWO-PHASE SYSTEMS USING POLY (ETHYLENE GLYCOL) AND POTASSIUM CITRATE AT VARIED pH LEVELS	Zeynab Rahmani, Reza Tavakkoli
		6	UTILIZATION OF MIXED AMINE SOLUTIONS FOR GAS SWEETENING PROCESSES	Dr. Fatima Al-Shahrani, Assoc. Prof. Khaled Mansour, Sara El-Gharbi
		7	INFLUENCE OF ANIONIC AND NON-IONIC SURFACTANTS ON OXYGEN UPTAKE RATES AND NITRIFICATION IN ACTIVATED SLUDGE	Nabila A. Abdalla, Ling Zhang, Bo Zhang
		8	PHYSICO-CHEMICAL TREATMENT OF TAR-LADEN WASTEWATER FROM BIOMASS GASIFICATION FACILITIES	Dr. Anjali Reddy, Dr. Sunil Kumar
		9	CONTINUOUS FERMENTATION OF CHEESE WHEY USING CANDIDA PSEUDOTROPICALIS	Elena Dmitrievna, Prof. Dr. Sami Al-Mansoori

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		2	REAL-TIME MONITORING OF PATHOGEN CONCENTRATION USING GRAPHENE-BASED BIOSENSOR	James K. Monroe, Helena C. Davies, Victor L. Ramirez
		3	DESIGNING AN ULTRA-WIDEBAND ANTENNA FOR CANCER DETECTION IN MICROWAVE IMAGING	Dr. Samuel D. Greene, Dr. Lin Wei-Hong
		4	DEVELOPMENT OF A SHAPE MEMORY ALLOY CLAMPING SYSTEM FOR MINIMALLY INVASIVE SURGERY	Amir Farshad, Jonathan P. Harris, Sima Mohammadi
		5	INVESTIGATING DIURNAL VARIATIONS IN HUMAN HEIGHT: A BIOMECHANICAL STUDY	Asst. Prof. Dr. Jonathan Lee Kim
		6	MICROORGANISM-BASED SENSOR FOR DETECTING ANTIOXIDANT ACTIVITY	Dr. Maria Fernandez, Isaac O. Delgado, Ethan L. Roberts, Sophia N. Clarke
		7	ANALYZING THE FRICTIONAL PROPERTIES OF MUCIN COATINGS ON MEDICAL DEVICES	Dr. Aisha M. Khan
		8	**IMPACT OF MICROSTRUCTURE ON THE TRIBOLOGICAL BEHAVIOR OF TITANIUM IMPLANTS**	Faizan M. Rehman, Dr. Sarah Q. Ahmed, Iqbal S. Rashid

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HALL / SALON 1	**Prof. Dr. Erol EĞRİOĞLU**	1	SEPSİS RİSKİNİN METABOLOMİK ANALİZ İLE ERKEN TESPİTİ	Burak Yagin Öğr. Gör. Abdulvahap Pinar Doç. Dr. Ahmet Selim Özkan Arş. Gör. Fatma Hilal Yagin Prof. Dr. Cemil Colak
		2	CONSTRUCTION OF MACHINE LEARNING-BASED PREDICTION MODEL FOR PREDICTING VOICE CHANGES ASSOCIATED WITH PARKINSON'S DISEASE	Öğr. Gör. Abdulvahap Pinar Burak Yagin Arş. Gör. Fatma Hilal Yagin, Prof. Dr. Cemil Colak
		3	DEEPDENT OTOMATİK ÖNGÖRÜ YÖNTEMİNİN AYLIK TUFE ÖNGÖRÜSÜ İÇİN PERFORMANSININ ARAŞTIRILMASI	Prof. Dr. Erol EĞRİOĞLU Prof. Dr. Eren Baş
		4	KLASİK VE BOOTSTRAP HİPOTEZ TESTLERİNİN PERFORMANSLARININ AUTODEEPDENT İÇİN KARŞILAŞTIRILMASI	Prof. Dr. Erol EĞRİOĞLU Prof. Dr. Eren Baş
		5	BULANIK REGRESYON FONKSİYONLARI YAKLAŞIMLARININ BORSA ÖNGÖRÜSÜ ÜZERİNDEN KARŞILAŞTIRILMASI	Öğr. Gör. Şeyda DEMİREL TATLI Prof. Dr. Erol EĞRİOĞLU Prof. Dr. Eren BAŞ
		6	OECD ÜLKELERİNDE MULTİDİSİPLİNER BİLİMSEL YAYINLARIN İNCELENMESİ	Doç. Dr. RAHİM ARSLAN Doç. Dr. GÜLAY DEMİR
		7	OECD ÜLKELERİNDE YENİLENEBİLİR ENERJİ ALANINDA YAPILAN BİLİMSEL YAYINLARIN İNCELENMESİ	Doç. Dr. RAHİM ARSLAN Doç. Dr. GÜLAY DEMİR

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HALL / SALON 2	**Prof. Dr. Hatice Karakuş Öztürk**	1	THE ETERNAL CHILD ARCHETYPE IN GÜZİDE SABRİ AYGÜN'S NOVEL CALLED HÜSRAN	Dr. Öğr. Üyesi, Ece SERRİCAN KABALCI
		2	THE NOVELS TRANSLATED FROM TURKISH TO GERMAN ACCORDING TO TEDA DATA	Dr. Öğr. Üyesi, Ece SERRİCAN KABALCI
		3	DIFFERENCES AND SIMILARITIES BETWEEN MAGICAL REALISM AND FANTASY	Gül Miray ÇELİK
		4	İSMAİL HAKKI BALTACIOĞLU ÇOCUKLARIN TERBİYESİ KİTAP ANALİZİ	Prof. Dr. Hatice Karakuş Öztürk
		5	KADINLAR ARASI REKABET WOMAN'S INHUMANİTY TO WOMAN KİTABI ÜZERİNE BİR ANALİZ	Prof. Dr. Hatice Karakuş Öztürk
		6	DIALECT ELEMENTS IN THE WORK TITLED HÜYÜKTEKİ NAR AĞACI	Doç. Dr. Serdal KARA
		7	PRESENCE OF CIMMERIAN - SCYTHIAN IN THE CENTRAL AND EASTERN BLACK SEA REGION	Arş. Gör. Dr. Burak BİNGÖL

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		2	THE CRIME OF DEFALATION IN THE CONTEXT OF AN-NUR SURAH VERSE 11 IN TERMS OF ISLAMIC LAW	Dr. Öğr. Üyesi, TAHA YILMAZ
		3	THE VALUE OF THE SUNNAH AS A SOURCE OF ISLAMIC LAW ACCORDING TO IBN HAZM	Dr. Öğr. Üyesi, TAHA YILMAZ
		4	AİLEDE TEMEL MANEVİ İHTİYAÇLAR	Prof. Dr. Muammer CENGİL
		5	el-FIKHU'L-EKBER RİSÂLESİ ÜZERİNE YAZILAN ŞERHLERİN YAZIM AMAÇLARI	Hasan Fidan

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HALL / SALON 4	**HUKUK Dr. Gürkan KANAT**	1	JUDICIAL PROTECTION OF LABOUR RIGHTS IN THE BULGARIAN LAW	Assoc. prof. Ivaylo Staykov, DSc
		2	KAMULAŞTIRMADA BEDEL TESPİTİ VE TESCİLİ	Av. FATMANUR KUŞCU
		3	LIMITED ŞIRKETLERDE KAMU ALACAKLARINDAN SORUMLULUK	Avukat,Hatice Kübra NİTELİK ALÇİÇEK
		4	DEVLET MEMURUNUN ÖDEV VE YÜKÜMLÜLÜKLERİ	CEREN TUZCU
		5	KİRA İLİŞKİSİNDEN KAYNAKLI UYUŞMAZLIKLARIN ÇÖZÜMÜNDE DAVA ŞARTI OLARAK ARABULUCULUK	Dr. OĞUZ USTA
		6	TIBBİ MÜDAHALENİN HUKUKA UYGUNLUĞU	Av. SENA MUTLU
		7	STATE IDENTITY AND THE COUNTER TERRORISM: SOCIAL REFLECTIONS OF NATIONALIST DISCOURSE IN TURKEY	Dr. Gürkan KANAT

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PLANT SELECTION IN LANDSCAPE DESIGN IN DESERT CLIMATE CONDITIONS CASE OF DUBAI

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ABSTRACT

Global warming leads to an increase in temperatures worldwide, radically changing climatic conditions. With this, there is an increase in temperature every day. This change has significant impacts on both natural ecosystems and man-made environments. Cities and rural areas have to develop various strategies to adapt to increasing temperature and drought conditions. In this context, in line with sustainability goals, designers and urban planners are looking for solutions that are more environmentally friendly and resilient to climate change. This now affects every decision taken in every design. Designers, urban planners, landscape architects, etc. many professional disciplines take measures for this. There is a gap in the literature on what plant choices should be. Within the scope of this study, it will be determined which plants are selected in landscape studies in Dubai, which has a desert climate. In line with these determinations, why these plants were chosen and the relationship between the general characteristics of the plants will be interpreted. Therefore, this study will make an important contribution in terms of determining the plants used in landscape works in regions with desert climate such as Dubai and examining the reasons for the selection of these plants.

Keywords : Landscape design, desert landscape, arid plants

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ÇÖL İKLİMİ KOŞULLARINDA PEYZAJ TASARIMINDA BİTKİ SEÇİMİ: DUBAİ ÖRNEĞİ

ÖZET

Küresel ısınma, dünya genelinde sıcaklıkların artmasına yol açarak iklim koşullarını köklü bir şekilde değiştirmektedir. Bununla birlikte her geçen gün sıcaklık artışı görülmektedir. Bu değişim, hem doğal ekosistemler hem de insan yapımı çevreler üzerinde önemli etkiler oluşturmaktadır. Şehirler ve kırsal alanlar, artan sıcaklık ve kuraklık koşullarına uyum sağlamak için çeşitli stratejiler geliştirmek zorundadır. Bu bağlamda, sürdürülebilirlik hedefleri doğrultusunda, tasarımcılar ve şehir plancıları daha çevre dostu ve iklim değişikliğine karşı dayanıklı çözümler aramaktadır. Bu artık yapılan her tasarımda alınan her kararı etkilemektedir. Tasarımcılar, şehir plancıları, peyzaj mimarları vb. birçok meslek disiplini bunu için önlem almaktadır. Bitki seçimlerinin ne olması gerektiğine dair ise literatürde bir boşluk bulunmaktadır. Yapılan bu çalışma kapsamında çöl iklimine sahip olan Dubai'de yapılan peyzaj çalışmalarında hangi bitkilerin seçildiği tespit edilecektir. Bu tespitler doğrultusunda neden bu bitkiler seçilmiş ve bitkilerin genel özellikleri arasındaki ilişki yorumlanacaktır. Bu nedenle, yapılan bu çalışma, Dubai gibi çöl iklimine sahip bölgelerde peyzaj çalışmalarında kullanılan bitkilerin tespit edilmesi ve bu bitkilerin seçilme nedenlerinin incelenmesi açısından önemli bir katkı sağlayacaktır.

Anahtar Kelimeler: Peyzaj tasarımı, çöl peyzajı, kurakçıl bitkiler

1.INTRODUCTION

Today, landscape architecture is planned to support and protect resources (Çetin, Mansuroğlu 2018). Countries are developing new alternative solutions to protect water resources by developing water policies. Landscape architects are among the active professional disciplines in this regard. Landscape architects have important responsibilities and the green areas they create can affect water processes (Pouya et., al. 2020). Each geography has its own specific planting design criteria and plant selection criteria. Landscape design in desert and rule climate conditions is a part of this. Factors such as temperature, low precipitation rates and limited water resources bring many difficulties.

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Drought, one of the most obvious and visible effects of climate change, is an insidious threat and one of the greatest disasters of nature. Drought creates various impacts on social life due to the dependence of people and their activities on water resources. Prolonged lack of moisture causes the air to dry out, leading to a reduction in vegetation, forests and water reserves. This situation eventually leads to serious economic, environmental and social problems (Öztürk 2002). The increase in the need for agricultural irrigation due to drought results in excessive water withdrawal from uncontrolled underground wells. This situation leads to a decrease in groundwater levels and drying out of plants by making it difficult for plant roots to access water. In addition, a possible rise in sea level may cause salinisation of groundwater resources in coastal areas, which may cause serious problems on freshwater resources (Dabanlı, 2017).

As one of the 21st century's most critical environmental issues, many professions are trying to develop solutions with their own methods to combat global climate change. With the increase in droughts, green areas have started to dry up and have a neglected appearance. This situation has brought arid landscape designs that use water more efficiently and are environmentally friendly to the forefront in landscape architecture (Çetin, 2024).

Increasing temperatures and irregular rainfall with changing climatic conditions around the world make water scarcity an increasingly serious problem. This situation can negatively affect not only human life but also the life of plants and animals. Necessary measures should be taken as soon as possible to leave reliable and clean water resources to future generations and to prevent losses caused by water scarcity. In landscape areas, which are one of the areas that will be most affected by water scarcity, measures to address this problem should be implemented rapidly. In order to create sustainable landscapes, landscape planning and design approaches that use water efficiently should be adopted, thus unnecessary water losses should be minimised (Ayanoğlu, 2023).

As a result, global environmental problems such as climate change and drought are putting great pressure on natural resources and habitats. The rapid decrease in water resources and damage to green areas have made sustainable landscape understanding a necessity. It should be aimed to use water efficiently and economically with plant species and design approaches suitable for the unique climatic and environmental conditions of each region. In order to leave a more livable world for future generations, water-sensitive and environmentally compatible approaches should be preferred in landscape planning and design; thus, economic,

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environmental and social losses should be minimised. Such steps will support both the creation of more balanced living spaces with nature and the mitigation of the negative effects of climate change.

2. MATERIAL AND METHOD

The summer months are extremely hot and humid, with daytime temperatures rising to an average of 41.8 °C and nighttime temperatures dropping to around 29.7 °C. There are usually sunny days throughout the year. The winter season is mild and short, with an average daytime temperature of 23 °C and a nighttime temperature of 14 °C. The amount of precipitation has increased in recent years and the total annual precipitation has reached 87.3 mm. Precipitation is mainly concentrated in the winter months (15 mm in January, 31 mm in February and 18.9 mm in March). Due to the shallow waters of the Arabian Gulf, the humidity in Dubai is quite high, averaging 59 per cent per year. This rate reaches its highest level of 65% in January and February (URL-1).

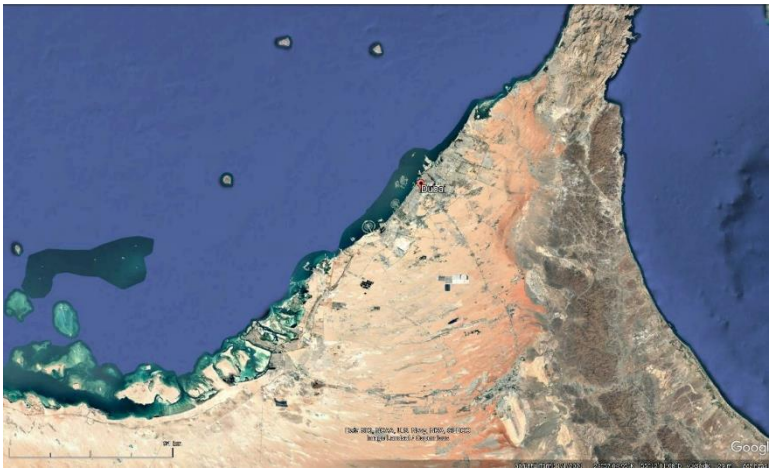

Figure 1. Study area (Google Earth Pro)

Dubai's hot and humid summers and mild winters emphasise xeriscape and sustainable plant selection strategies in landscaping. The high temperatures and limited rainfall regime require water to be used sparingly, while the high humidity necessitates the durability of plant species and the careful selection of maintenance methods. In this climate, plants that can adapt to environmental conditions, have low water requirements, are salt-resistant and tolerate intense sunlight should be prioritised. Plants native to the desert ecosystem, succulent species, palm varieties, arid trees such as acacia and hardy groundcovers can find an ideal place in the Dubai landscape. In addition, grouping plants in different areas according to their water needs

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contributes to the effective management of water. Sustainable practices such as rainwater harvesting systems and permeable surface designs should be integrated into landscaping to utilise winter rainfall more efficiently. Such arrangements both support the conservation of water resources and allow the creation of landscape areas that are compatible with the environment in terms of aesthetics and functionality.

2.1.RESEARCH AIM

Within the scope of this study, the most commonly used plant species taxa in Dubai were identified. The reasons for these choices were analysed and the plant selection criteria of the city were revealed.

3. PLANT SELECTION IN HOT CLIMATE CONDITIONS

Dubai has a distinct systematisation of plant species used in the urban landscape, which has been developed based on the city's climatic conditions, environmental requirements and sustainability objectives. The selection of plant species in the city has adopted an approach specifically designed for arid climatic conditions and limited water resources. This approach offers significant advantages in terms of both aesthetic and ecological sustainability.

One of the most striking elements of Dubai's landscape is the high importance given to the adaptability of plant species. In the selection of plants in the city, plants that can best adapt to environmental conditions stand out. In this selection, only species that meet the requirements of the climate are preferred, taking into account factors such as water needs, temperature tolerance and growth rates of plants. In this context, water-saving species such as arid plants and succulents are frequently used in the city landscape. However, the plants used should not only fulfil climatic requirements, but also have aesthetic value, increase environmental sustainability and be compatible with local ecosystems.

Plant species in the city often take the approach of reusing the same species over large areas, thus avoiding plant wastage. This allows both efficient use of resources and visual integrity. At the same time, many of these plant species work in harmony with other landscape elements in the city, contributing to the creation of sustainable green spaces. Such a combination of various plant taxa and winding plants allows the landscape to be efficient not only in terms of aesthetics, but also in terms of ecological functionality.This strategy, followed in the landscape design of Dubai, prevents the waste of plant species in the city, while at the

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same time developing a system that promotes environmental sustainability and supports the urban ecosystem. By adopting this approach, the city not only copes with climatic challenges, but also implements a landscape approach that considers ecological balance.

Table 1. Some plant taxa used in Dubai

Acacia tortilis	*Delonix regia var. Golden*
Adenium obesum	*Delonix regia var. flavida*
Asystasia gangetica	*Ficus benjamina*
Aloe vera	*Hibiscus tiliaceus*
Bougainvillea spp.	*Hymenocallis littoralis*
Bougainvillea spectabilis	*Jacaranda mimosifolia*
Buxus microphylla	*Ligustrum ovalifolium*
Delonix regia	*Lantana camara*
Nigella sativa	*Phoenix dactylifera L.*
Nerium oleander	*Pistacia chinensis*
Pennisetum setaceum	*Plumeria rubra*
Philadelphus coronarius	*Pseuderanthemum maculatum*
Phoenix dactylifera	*Ruellia simplex*
Sesuvium portulacastrum	*Tecoma stans*
Tabebuia pallida	*Terminalia catappa*
Volkameria inermis	

4. CONCLUSION AND RECOMMENDATIONS

Arid plants are of great importance to support the sustainability of ecosystems in regions where water resources are limited. These plants stand out with their ability to survive even in harsh desert climates such as water scarcity and extreme heat. In addition to their contribution to nature, arid plants have many environmental benefits such as improving urban air, preventing erosion, storing carbon and reducing temperatures in cities. With these features, dryland plants have become an important component in sustainable landscape designs and green infrastructure works.

Dubai is a city that deeply feels the importance of arid plants due to its geographical location and climatic conditions. In this region, where limited water resources and high temperatures

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prevail, the use of arid plants is encouraged for the continuity of natural ecosystems and the environmental sustainability of the city. In line with Dubai's sustainable urbanism goals, dryland plants are preferred in green infrastructure projects by utilising desert vegetation, thus both strengthening ecosystem services and reducing the city's environmental footprint. In addition, in order to maximise water saving in landscape areas, plant species compatible with the region are selected and it is aimed to disseminate these plants.

Drought plants are of great importance in terms of efficient use of natural resources and contributing to environmental sustainability. Especially in desert cities such as Dubai, the use of these plants in landscaping and green infrastructure projects offers economic advantages as well as environmental benefits. Dubai's efforts to expand the use of arid plants are a source of inspiration for other cities in arid and semi-arid climates and set an example in the field of sustainable urbanism. In this context, the use of dryland plants contributes not only to the conservation of existing resources, but also to the ecological and social balance, leaving a more livable environment for future generations. As a result of the examinations and on-site observations, the urban contributions of Dubai's strategic species selection are as follows;

- Plant selection compatible with urban ecology: Not preferring species that cannot adapt to the urban ecosystem in a specific geography prevents waste of resources and offers a sustainable approach in vegetative landscape arrangements.
- Aesthetic and ecological integrity: The selection of plants with high adaptability to urban conditions allows urban green areas to provide optimal results in terms of both visual quality and ecological functionality.
- Design guidance: The use of plants that have been extensively tested and found to be suitable for urban conditions is considered as a reliable guide for landscape designers and urban planners.
- Reduced maintenance costs: The use of highly urban-adapted species increases the long-term survival rate of plants, reducing maintenance, irrigation and replanting costs.
- Supporting biodiversity: Favouring plants that are compatible with the local ecosystem encourages the conservation of biodiversity in cities, creating healthier habitats for both fauna and flora.

For Dubai, which is located in a hot climate zone, such successful plant selection and identification helps to create a successful urban appearance. This is an example for all cities. Because it is among the important examples that can address both ecological and aesthetic concerns without wasting plants. The importance of rules, practices and controls in this regard is undeniably great.

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THE EFFECT OF LANDSCAPE ON MUSEUM DESIGN: THE CASE OF LOUVRE MUSEUM ABU DHABI

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ABSTRACT

Louvre Abu Dhabi is an art and history museum in Abu Dhabi, United Arab Emirates. Opened on 11 November 2017, the museum was designed by the famous French architect Jean Nouvel. The museum is positioned quite differently in terms of landscape design. Water, one of the most important elements of the landscape, is the most effectively used tool in the museum. The museum has a remarkable dome weighing 7,500 tonnes. This dome creates a fascinating atmosphere in the space by combining light plays with landscape design. The museum is located between islets and waterways on the water's edge. Within the scope of this study, the Louvre Museum of Art and History was chosen as the study area. The main reason for this selection is that the combination of the museum with landscape elements is quite different and unique. The landscape design is not seen very effectively until you enter the study area from the entrance gate and even exit. Until the exit, the target is focussed inside the museum. A meeting point was designed at the exit point of the museum and this meeting point was organised with the effect of water. Within the scope of the study, the effect of water on this design was analysed and supported with visuals. As a result of the study, the effect of the elements of landscape design on the museum design was discussed.

Anahtar Kelimeler : landscape design, art museum landscape, museum landscape, water effect

PEYZAJIN MÜZE TASARIMINA OLAN ETKİSİ:

LOUVRE MÜZESİ ABU DHABİ ÖRNEĞİ

ÖZET

Louvre Abu Dhabi, Birleşik Arap Emirlikleri'nin Abu Dhabi şehrinde yer alan sanat ve tarih müzesidir. 11 Kasım 2017 tarihinde açılan müze, ünlü Fransız mimar Jean Nouvel tarafından tasarlanmıştır. Müze peyzaj tasarımı açısından oldukça farklı konumlandırılmıştır. Peyzajon en önemli elamanlarından olan su ile müzede en etkin kullanılan araçtır. Müzenin dikkat çekici 7.500 ton ağırlığında kubbesi bulunmaktadır. Bu kubbe, ışık oyunlarıyla peyzaj tasarımını birleştirip mekânda büyüleyici bir atmosfer yaratmaktadır. Müze, su kenarındaki adacıklar ve suyolları arasında konumlanmıştır. Yapılan bu çalışma kapsamında çalışma alanı olaral Louvre sanat ve tarih müzesi seçilmiştir. Bu seçimin temel sebebi müzenin peyzaj öğeleri ile birleşiminin oldukça farklı ve özgün olmasıdır. Çalışma alanına giriş kapısından girilip hatta çıkana kadar peyzaj tasarımı çok etkin bir şekilde görülmemektedir. Çıkışa kadar hedef müze içerisine odaklıdır. Müzenin çıkış noktasında bir buluşma noktası tasarlanmış ve bu buluşma noktası su etkisi ile düzenlenmiştir. Çalışma kapsamında suyun bu tasarıma etkisi incelenmiş ve görseller ile desteklenmiştir. Çalışmanın sonucunda peyzaj tasarımının elemanlarının müze tasarımına etkisi tartışılmıştır.

Anahtar Kelimeler : peyzaj tasarımı, sanat müzesi peyzajı, müze peyzajı, su etkisi

1.INRODUCTION

Museums have an important place for landscape design (Onur, Gulpinar Sekban 2020). In the changing and transforming order, efforts to progress in science and art have gained momentum, especially since the mid-19th century. In addition to scientific developments, the support of institutions that serve these developments has created significant effects that spread to the society in general and contributed to the shaping of the future. In this period, museums also entered an important transformation process. In Turkey, after the proclamation of the Republic, artistic and cultural developments gained momentum rapidly and continued to grow stronger in the following years. By the mid-20th century, developments in these fields had reached much higher levels and contributed to the development of Turkey's cultural heritage in line with the modernisation process (Çalış, 2023). Sometimes museums are designed as memory gardens. The monuments in these gardens give educational messages about the past, emphasise unity and integrity, condemn terrorism and do not directly point to events or people

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by indirectly conveying sad aspects. Therefore, emotional concerns are conveyed through symbols and icons, creating a peaceful environment away from the outside world in limited spaces (Demir, Pouya 2016).With this changing order, many museums in Turkey still serve as a focal point for tourists by providing landscape and artistic services.

Museums have an important place in the creation of the unique identities of cities and in bringing cultural heritage together with social life. These areas, which bring different cultures together, also provide economic and social benefits to their environment (Atik, Yılmaz, 2024; Alkan, 2024). The effect of landscape design on museum design is very important both aesthetically and ecologically. The tourism trip or recreational effects of each tourist, even each individual, are very different. For example, while an engineer looks at technical aspects while examining the museum, landscape architects or designers pay attention to many different features such as aesthetic ecological, architectural, etc. Although the Louvre Museum, which is examined within the scope of the study, is a work of art that has served many different civilisations, the fact that it is located in the middle of the sea and the successful construction of the surrounding landscape connections have made the design more attractive.

Louvre Abu Dhabi is an art and history museum located in Abu Dhabi, United Arab Emirates. Opened on 11 November 2017, the museum bears the signature of the famous French architect Jean Nouvel. The landscaping of the museum has an unusual layout. Water, one of the most important components of the landscape, is used as one of the most effective elements in the museum design. One of the remarkable features of the museum is its dome weighing 7,500 tonnes. This dome creates an impressive atmosphere by integrating the landscape design with light and shadow plays. The museum is located between water canals and islets, and this unique layout is an important feature that distinguishes it from other museums (URL-1).

Pritzker Prize-winning architect Jean Nouvel was inspired by traditional Arab architecture when designing the Louvre Abu Dhabi concept. Adopting an approach sensitive to the context of the space, Nouvel conceived the museum as a ‘museum city’ located in the sea. The row of white coloured buildings is inspired by the traditional city of Medina and low Arab settlements (Figure 1) (URL-2).

Within the scope of this study, the Louvre Museum of Art and History was chosen as the study area. The main reason for this choice is the different and unique structure of the landscape elements of the museum in harmony with the architectural design. From the entrance gate of

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the museum to the inside, the landscaping arrangements are not clearly felt, and the attention of the visitors is directed to the museum building. However, at the exit point, a meeting area was designed and this area was supported by a water element. This study analyses the role of water in this design and examines it by supporting it with visuals. At the end of the study, the effects of the elements of landscape design on the museum architecture are discussed in detail.

Figure 1. Louvre Museum (URL-3).

This ‘museum city’ consists of 55 independent buildings, 23 of which are exhibition galleries. A total of 3,900 ultra-high performance fibre concrete (UHPC) panels were used on the facades of the buildings to provide durability and aesthetic harmony. This design blends traditional architectural elements with modern engineering techniques to create an innovative structure (Figure 2) (URL-2).

The complex pattern of the dome is the product of a detailed geometric design process. It was realised through close collaboration between the architectural team at Ateliers Jean Nouvel and structural engineers at BuroHappold Engineering. The pattern consists of eight different layers, each layer containing repeated shapes of various sizes and angles. Each ray of light travels through these eight layers before gaining visibility and disappearing. This design creates a dynamic ‘play of light and shadow’ during the day, depending on the movement of the sun, and this cinematic effect offers visitors a unique experience. At night, the dome presents a visual feast of a total of 7,850 stars, visible from both inside and outside. This impressive

phenomenon is called the ‘rain of light’ and is one of the key elements defining the concept of the museum. This idea has been matured through years of detailed modelling and model studies and has contributed to the iconic identity of the museum (URL-2).

Figure 2. Louvre Museum Plan (URL-4)

The Louvre Museum, which is the subject of the study, attracts attention both as a museum and as landscape areas with its adjacent park area and recreation services (URL-5). Walking paths, sitting resting places, places to watch the sea are just a few of them. The fact that the museum is located on the sea has also created important vista places for people in the landscape area. This potential has been utilised in a good way and seating, resting, walking and viewing places have been created for people. In this design, the mystical effect of the museum has been designed in a supportive manner (Figure 3-4).

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Figure 3. Louvre Museum landscape design (URL-5)

The open spaces in the museum were designed by French landscape architect Michel Desvigne. These spaces include various semi-open spaces, including a garden. The garden is inspired by traditional Arabian oasis gardens and is designed with terraces and pools to create a calm and peaceful atmosphere. Tidal pools are integrated into the semi-open spaces at different surface levels. Strengthening the connection between the sun, sky (dome), earth (mosaic floor), air (cool winds and humid fog) and water (sea), this design approach aims to increase structural efficiency and climate sensitivity compared to traditional methods, and also aims to build more sustainable buildings and structures using algorithms and data-driven design processes. (Figure 4-5) (URL-6).

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Figure 4. Louvre Museum, effective use of the water element accessing from the interior to the open space

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Figure 5. Louvre museum landscape design (URL-5).

3. CONCLUSION and RECOMMENDATIONS

In landscape architecture, water is not only a visual element, but also plays an important environmental, functional and psychological role. Water not only provides aesthetic appeal in landscape designs, but also regulates the microclimate, lowering temperatures, increasing humidity and improving environmental comfort. For this reason, this area examined within the scope of the study is very important both aesthetically and ecologically. Water surfaces absorb heat. For this reason, it is highly preferred in hot climatic conditions, either artificially or

naturally. For this reason, it is emphasised in the study that the most effective landscape design element of the study area is water. At the same time, thanks to the reflective properties of water, it creates a cooling microclimate especially in hot and arid regions and improves the quality of life. It creates psychologically relaxing effects; the sound and movement of water provides mental relaxation, reduces stress and strengthens the feeling of connecting with nature. In fact, the mystical, serene effect desired to be created is blended with landscape elements in a very successful and effective way in this example. The fact that the museum seems to float in the water is combined with the serene effect of the water and the result is a blended design example that uses the effects of the landscape at the maximum level.

In this context, the structure of the Louvre Museum in Abu Dhabi, designed as if floating on water, is a striking example of both aesthetic and scientific use of water in landscape architecture. In the museum design, water is not only used as an aesthetic element but also its ecological properties. As a result, while the museum aims to explain its own purpose, namely art, civilisations and many other things, its architecture enriched with water sets an inspiring example for contemporary landscape architecture in terms of environmental sustainability and aesthetics by exhibiting the effects of water in the landscape even in arid climates. In this study, it reveals how landscape elements are used effectively in museum design and the effect that emerges when used.

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FARKLI YÖNTEMLERLE STERİL EDİLEN KATLAMA ORTAMLARINDA *Liatris spicata* (L.) 'ALBA' TOHUMLARININ FARKLI KATLAMA SÜRELERİNDE ÇİMLENME BAŞARISININ DEĞERLENDİRİLMESİ

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ÖZET

Tohumla üretimde bazı bitkiler neslini devam ettirmek için farklı ekoloik şartlara uyum sağlayarak tohumlarının çimlenmesinde farklı uyarı sistemleri geliştirmiştir. Bu uyarı sistemlerinin bulunduğu bitkilere çimlenme engeli olan bitkiler denilmektedir. Bitki üretiminin yüksek başarı getirmesi için çimlenme engelleri ortadan kaldırılması oldukça önemlidir. Bu sayede düşük maliyetle yüksek oranda bitki bireyi elde edilebilir. Çimlenme engeline örnek olarak; soğuk kış şartlarında çimlenerek tohumunun canlılığını yitirmesini engellemek için bazı bitki tohumları soğuk bir dönemde uykuda bekledikten sonra toprak sıcaklığı belirli bir sıcaklığa ulaşılınca tohum çimlenmesini başlatmaktadır. Bu tip bitkilerin tohumlarının çimlendirilebilmesi için, tohumların buzdolabı gibi belirli sıcaklıkta belirli bir süre bekletilmesi ile uyku döneminin atlatılmasına soğuk katlama yöntemi denilmektedir. Bu yöntemlerin uygulanmasında katlama sırasında kullanılan katlama ortamı materyalinin sterilizasyonuda çok önemlidir. *Liatris spicata* bitkisinin tohumla üretimi üzerine yürütülen bu çalışmada sterilizasyon açısından birbirinden farklı 3 katlama ortamında tohumlar 5 farklı zaman diliminde bekletilerek çalışma gerçekleşmiştir. Çalışmada katlama ortamları %50 Torf ve %50 Perlit karışımı olarak seçilmiştir. Tüm denemelerde katlama ortamı için aynı karışım kullanılmıştır. Katlama ortamı sterilizasyonunun tohum çimlenmesi üzerine etkisinin tespit edilebilmesi için kontrol, buhar uygulaması ve fırınlama ile steril edilen katlama ortamlarıyla 3 farklı deneme kurulmuştur. Bu çalışmanın sonuçları, katlama ortamlarına uygulanan farklı sterilizasyon işlemlerinin çimlenme sayıları üzerinde çeşitli etkilere sahip olduğunu göstermiştir.

Anahtar Kelimeler: Çimlenme, *Liatris spicata*, tohum üretimi.

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1. GİRİŞ

Bitkiler, hayvanlar ve insanlar arasında karşılıklı bir denge bulunmaktadır ve mitolojik anlatılara göre bitkiler, tanrının insanlığa sunduğu en kıymetli armağanlardır. Bu, bitkilerin insan hayatına sunduğu hizmetlerden kaynaklanmaktadır; zira bitkiler hem gıda hem de tedavi olarak insanlara hizmet etmekte ve bu rolünü yaşamın her aşamasında sürdürmektedir. Bilimsel araştırmalar, insanların yeme-içme ve sağlık tedavilerinde bitkilerden nasıl faydalandıklarını ortaya koymaktadır (Koçer, 2021).

Bitkilerin insan ve hayvan beslenmesindeki kritik rolü nedeniyle, bitkisel üretimin artışının dünya nüfusunun büyümesine katkı sağladığı genel kabul görmektedir (Tuğay, 2012). Türkiye'nin de dahil olduğu Nesli Tehlike Altındaki Türlerin Uluslararası Ticaretine İlişkin Sözleşme (CITES) çerçevesinde, canlıların sürdürülebilir bir şekilde gelecek nesillere aktarılabilmesi için bitkiler gibi canlı varlıkların korunmalarının zorunlu olduğunu vurgulamışlardır (Kiehn ve Benítez-Díaz, 2013; Mirenda vd., 2015).

Bitkisel üretim yöntemleri, generatif (eşeyli) ve vejetatif (eşeysiz) olmak üzere iki ana kategoriye ayrılır. Generatif üreme, tohum ve spor aracılığıyla gerçekleşirken, vejetatif üreme çelik, daldırma, soğan, yumru, stolon ve rizom gibi değişik yapılarla meydana gelir (Kamenetsky, 1993; Yadav ve Singh, 2018). Tohum, bitkilerdeki generatif ve vejetatif evrelerin nihai ürünüdür ve meyvede bulunan en olgun hücredir. Tarımsal üretimde arzu edilen bitki yoğunluğu ve yüksek verim, öncelikle tohumların hızlı, uniform ve eksiksiz çimlenmesine bağlıdır. Çimlenme süreci, sıcaklık, nem ve toprak tuzluluğu gibi çevresel faktörlerin yanı sıra, tohumların genetik yapıları, olgunluk durumları ve boyutları gibi değişkenlerden de etkilenebilir, bu da çimlenmeyi zorlaştırabilir. Özellikle laboratuvar ortamında yapılan çalışmalarda sıkça karşılaşılan sorunlardan biri tohum dormansisidir. Dormansi, tohumların çimlenmesi için gerekli koşullar mevcutken bile, tohum kabuğunun su ve gaz geçirmezliği veya içindeki kimyasal maddeler gibi içsel ve dışsal faktörler nedeniyle çimlenmenin gerçekleşmemesidir (Ateş ve Üremiş, 2021; Bozdoğan, 2019). Dormansiyle mücadele etmek için geliştirilen yöntemler arasında katlama, ekim öncesi ıslatma, tohumları boyutlarına göre sınıflandırma, osmotik çözeltilerle muamele ve asitlerle aşındırma bulunur (Kanmaz, 2013; Bozdoğan, 2019).

Bitki malzemesi olarak seçilen Liatris spicata, Asteraceae ailesine ait çok yıllık ve otsu bir türdür (Yadav vd., 2022). Bu bitki, hem peyzaj bahçelerinde süs bitkisi olarak hem de ticari amaçla kesme çiçek (taze veya kurutulmuş) ve saksı bitkisi olarak yetiştirilmektedir. Bu bitki, gösterişli çiçekleriyle estetik açıdan dikkat çeker ve peyzaj düzenlemelerinde kullanılabilir. Liatris spicata, çok yıllık bir bitki olup, aynı zamanda kesme çiçekçilikte de ticari değeri yüksek bir tür olarak yetiştirilmektedir (Han, 1992). Tohumla üretim en yaygın yöntemdir (Espinosa and Healy, 1991). Liatris spicata tohumlarının çimlenme şartlarına dair kısıtlı bilgi bulunmaktadır, ancak çimlenmeyi engelleyen faktörler saptanmıştır (Parks ve Boyle, 2002). Araştırmada, peyzaj değeri yüksek olan bu bitkinin tohumlarına soğuk stratifikasyon (katlama) işlemi uygulanmış ve uygulanmadan önce tohumların 100 tane ağırlıkları ölçülmüştür. Bu araştırmada soğuk katlama işlemi yapılmadan önce tohumların katlamaya koyulacağı toprak ortamına üç farklı sterilizasyon işlemi uygulanmıştır. Bu çalışma ile Liatris spicata (L.) ‘Alba’ bitkisinin tohumlarının farklı sterilizasyon yöntemlerine tabi tutulan katlama ortamlarında farklı zaman süreçlerine göre çimlenme başarılarının nasıl değiştiğinin tespit edilmesi amaçlanmıştır.

2. DENEYSEL ÇALIŞMALAR

2.1. Materyal ve Yöntem

Çalışma materyali olarak Asteraceae familyasına ait çok yıllık ve otsu bir takson olan Liatris spicata (L.) 'Alba' bitkisinin tohumları seçilmiştir. Gerekli tohumlar Karadeniz Teknik Üniversitesi serasında bulunan Orman Fakültesi Serasında 75 m rakım, 40°59'37.09" kuzey enlemi ve 39°46'40.36" doğu boylamında bulunan perennial bahçeden temin edilmiştir.

Katlama ortamı olarak satın alınarak temin edilen torf ve perlit kullanılmıştır. Tohum keselerinin muhafazası için 3 adet kapaklı plastik kap ve zamanı gelen tohumların ekimi için üst çapı 5 cm, alt çapı 3,8 cm, yükseklik 5 cm olan viyoller kullanılmıştır.

Çalışma Recep Tayyip Erdoğan Üniversitesi Zihni Derin Yerleşkesi Mühendislik ve Mimarlık Fakültesi Peyzaj Mimarlığı Bölümü Bitki laboratuvarında gerçekleştirilmiştir.

Bitki çeşitliliğinin sağlanması, orman ekosisteminin doğal yapısının bozulmaması ve biyoçeşitliliğin devamı için tüm bitki gruplarının nesilden nesile korunması ve sürdürülmesi gerekmektedir. Bu nedenle Liatris spicata bitkisinin bazı tohum özellikleri, uygun ekim zamanı ve ön uygulama önlemleri belirlenmeye çalışılmıştır. Bu nedenle kaliteli tohum üretimi ve uygun yetiştirme ortamlarında ekim çalışmaları hakkında ön bilgiler elde edilmeye çalışılmıştır.

Liatris spicata bitkisinin tohumla üretimi üzerine yürütülen bu çalışmada 3 farklı sterilizasyon işlemi uygulanan katlama ortamlarında tohumlar 5 farklı zaman diliminde +4 °C'de bekletilerek çalışma gerçekleşmiştir.

Liatris spicata (L.) 'Alba' bitkisinin tohumlarının farklı steril yöntemlere tabi tutulan katlama ortamlarının farklı zaman süreçlerine göre çimlenme başarılarının tespiti için 6 aşamada bu çalışma yürütülmüştür.

Soğuk katlama işleminden önce besi ortamlarına ön işlem uygulanmıştır. çalışmada katlama ortamları hacimsel olarak %50 torf ve %50 perlit karışımı olarak seçilmiştir. Tüm denemelerde katlama ortamı için aynı karışım kullanılmıştır. Katlama ortamı sterilizasyonunun tohum çimlenmesi üzerine etkisinin tespit edilebilmesi için kontrol, buhar uygulaması ve fırınlama ile steril edilen katlama ortamlarıyla 3 farklı deneme kurulmuştur. Tohumlar 5 farklı katlama süresinde bu ortamlarda bekletilmiştir. Çalışma 6 aşamadan oluşmuştur. Aşamalar Çizelge 1'de verilmiştir.

Çizelge 1. Yürütülen çalışma aşamaları.

1. Aşama	*Liatris spicata* tohumları toplanmıştır.
2. Aşama	Tohumların 100 tane ağırlıkları ölçülmüştür.
3. Aşama	100 tane ağırlıkları ölçülen tohumlar tül keselere yerleştirilmiştir.
4. Aşama	Soğuk katlama işleminden önce besi ortamlarına ön işlem uygulanmıştır.
5. Aşama	Tohumlar 5 farklı zamanda katlamaya alınıp dolapta bekletilmiştir.
6. Aşama	Katlama süresi dolan tohumların laboratuvar ortamında ekimleri yapılmıştır.

Amacımız doğrultusunda katlama ortamlarının gün ve ortama göre deneme deseni Çizelge 2'de verilmiştir.

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Çizelge 2. Katlama ortamlarının gün ve katlama ortamına göre deneme deseni

	Kontrol	15 gün	30 gün	60 gün	90 gün	120gün
A	A1	A 2	A3	A4	A5	A6
B	B1	B2	B3	B4	B5	B6
C	C1	C2	C3	C4	C5	C6

Çalışmada kontrol grubu hariç laboratuvar çimlendirilmesi için katlamaya alınan 1500 tohumdan rastgele yöntemle seçilen 450 adet tohum ekim için kullanılmıştır. Kontrol grubuyla toplamda 540 adet tohum ekilmiştir.

İlk olarak Karadeniz Teknik Üniversitesi serasında bulunan perennial bahçesi gezilerek tohum toplamak için gelişimi en iyi bitki bireyleri belirlendikten sonra bu bireylerden çalışmamız için gerekli olan miktarda tohum toplanmıştır. Daha sonra toplanan tohumların 100 tane ağırlığı ölçülmüştür.

100 tane ağırlıkları ölçülen tohumlar 5x10 cm boyutlarında dikdörtgenler şeklinde dikilen tül keseler içerisine yerleştirilmiştir (Görsel 1).

Görsel 1. Tohumların 100 tane ağırlıkları ölçülmesi ve keselenmesi.

Birinci ortam (A ortamı) hiçbir işlem uygulanmayan kontrol ortamını ifade etmektedir. İkinci ortama (B ortamı) katlama ortamını sterilleştirmek amacı ile 15 dakika süreyle 55 C° sıcaklıkta buhar uygulanan katlama ortamını ifade etmektedir (Görsel 2a). Üçüncü ortam (C ortamı) ise 125 C° sıcaklıkta 3 saat fırınlama yapılarak steril hale getirilen katlama ortamını ifade etmektedir (Görsel 2b). Kempf (2008)'e göre bakteriyel sporların 120 C°'nin üzerinde yok olmaktadır. Bu doğrultuda C ortamında kullanılan sıcaklık derecesi 125 C° olarak belirlenmiştir.

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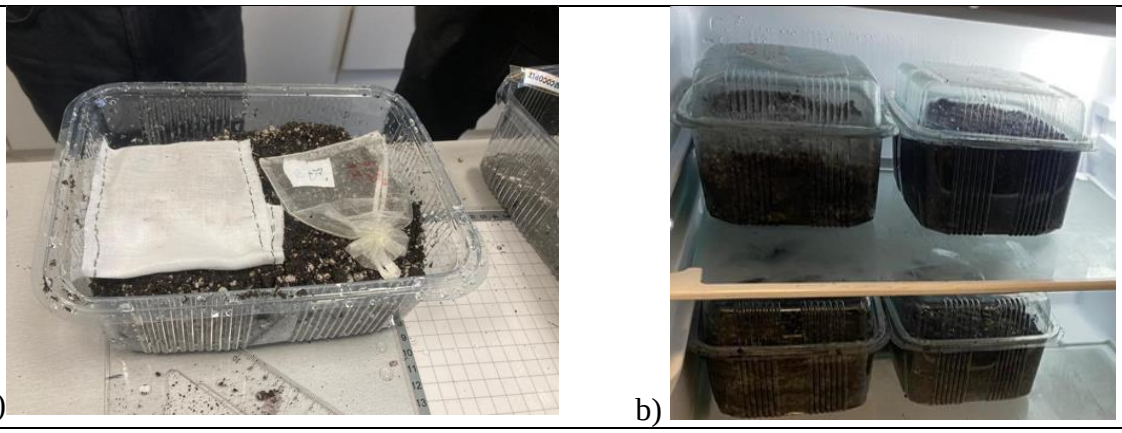
a) b)

Görsel 2. a)B katlama ortamına buhar uygulaması, b)Fırınlanmış C ortamı uygulaması

100'er adet tohum koyulan 15 adet kese 3 farklı plastik kutu içerisinde bulunan A, B ve C katlama ortamlarına farklı sürede çıkartılıp viyollere ekilmek üzere her bir ortama 5'er adet kese gelecek şekilde koyulmuştur (Görsel 3a). Tohumlar en iyi sonucu verecek katlama süresinin belirlenmesi amacıyla; kontrol, 15, 30, 60, 90 ve 120 gün olmak üzere 5 farklı sürede katlamaya alınmıştır. Plastik kapta gerekli hava alma delikleri açıldıktan sonra kapakları kapatılan kaplar +4 °C 'de çalışan buzdolabında katlamaya alınmıştır (Görsel 3b). Bu işlemlerin paralelinde bir viyole 10 adet tohum gelecek şekilde 3 tekrarlı toplamda 30 tohum kontrol grubu olarak viyollere ekilmiştir.

a) b)



Görsel 3. A)Soğuk katlamaya alma, b) +4°C'deki dolapta tohumların işleme alınması.

Katlama süresini tamamlayan tohum keseleri ortamlardan çıkarıldıktan sonra kontrol tohumları gibi her bir viyole 5 adet tohum gelecek şekilde 6 tekrarlı olarak toplamda 100 tohum arasından rast gele yöntemle seçilen 30 tohum viyollere ekilmiştir (Görsel 4). Deneme desenine göre tohumların ekim tarihleri Çizelge 3'de verilmiştir.

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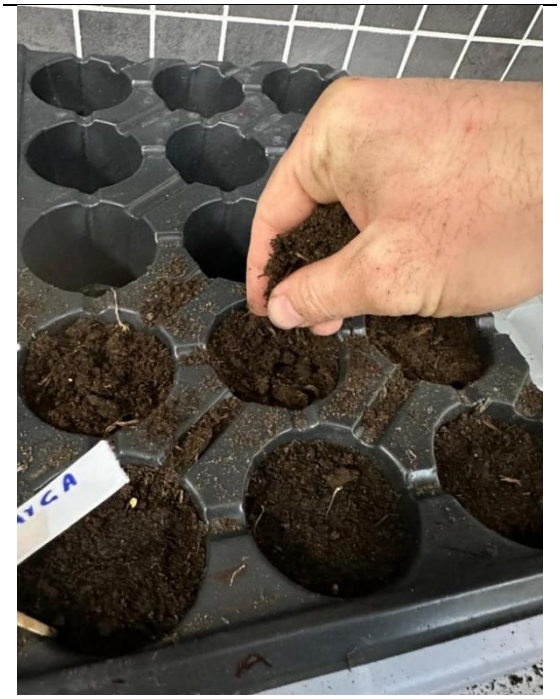
Çizelge 3. Tohum ekim tarihleri.

Ortam Kodu	AK-BK-CK	A1-B1-C1	A2-B2-C2	A3-B3-C3	A4-B4-C4	A5-B5-C5
Ekim Tarihi	28.01.2022	11.01.2023	26.01.2023	25.02.2023	27.03.2023	27.04.2023



Görsel 4. Viyollere tohum ekimleri.

2.2. Bulgular

Üç farklı katlama ortamı (A, B, C) altında altı farklı süre boyunca katlamaya alınan tohumların çimlenen adetleri tespit edilmiştir. Bu veriler analiz edilerek her bir ortamın çimlenme başarısı belirlenmiştir. Kullanılan tohum materyalinin 100 tane ağırlıkları Çizelge 4'de verilmiştir.

Çizelge 4. Tohum materyaline ait 100 tane ağırlıkları.

	Kontrol	15 gün	30 gün	60 gün	90 gün	120 gün
A	0,25gr	0,25gr	0,24gr	0,26gr	0,24gr	0,24gr
B	0,25gr	0,25gr	0,20gr	0,26gr	0,26gr	0,25gr
C	0,24gr	0,24gr	0,28gr	0,26gr	0,27gr	0,26gr

Kontrol grubunda çimlenme gözlenmezken, 15. gün itibarıyla çimlenme başlamış ve 90. günde en yüksek çimlenme oranına (%37,78) ulaşmıştır. 90. günden sonra ise çimlenme oranı düşüşe geçmiştir. İstatistiksel analiz sonuçlarına göre, farklı zaman noktaları arasında anlamlı farklar bulunmaktadır ($F = 15,26$, $P < 0,001$). Gruplar arasında (a, b, c) harfleri ile anlamlı istatistiksel farklılıklar vardır; en yüksek çimlenme oranı "a" harfiyle belirtilen 90. günde görülmüştür. Çizilen ikinci dereceden polinom eğrisi ($y = -1,9202x^2 + 17,762x - 15,794$) ve R^2 değeri (0,6166), zamana göre, çimlenme yüzdelerinin değişimini orta düzeyde açıklamaktadır (Görsel 5).

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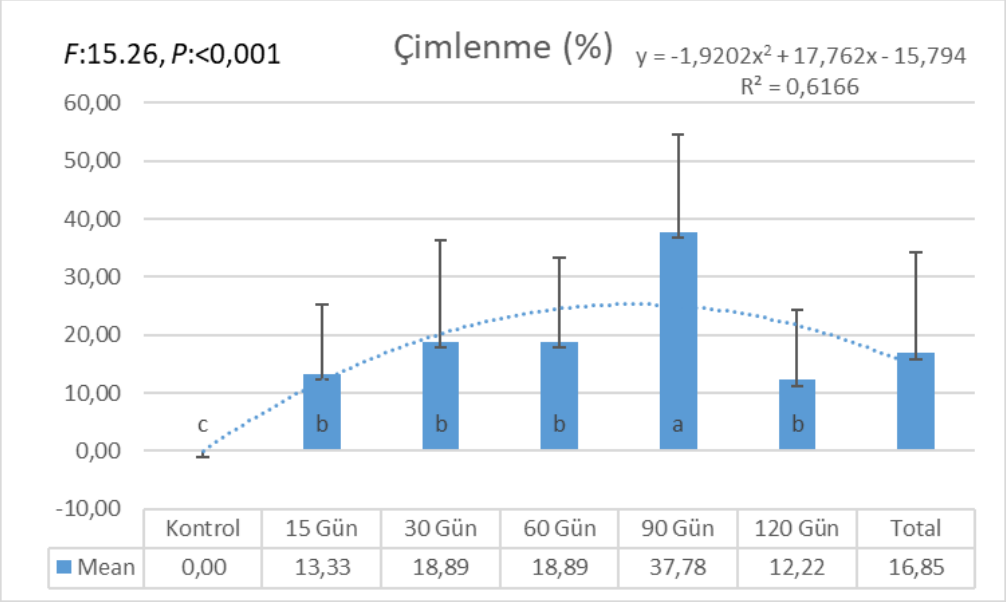
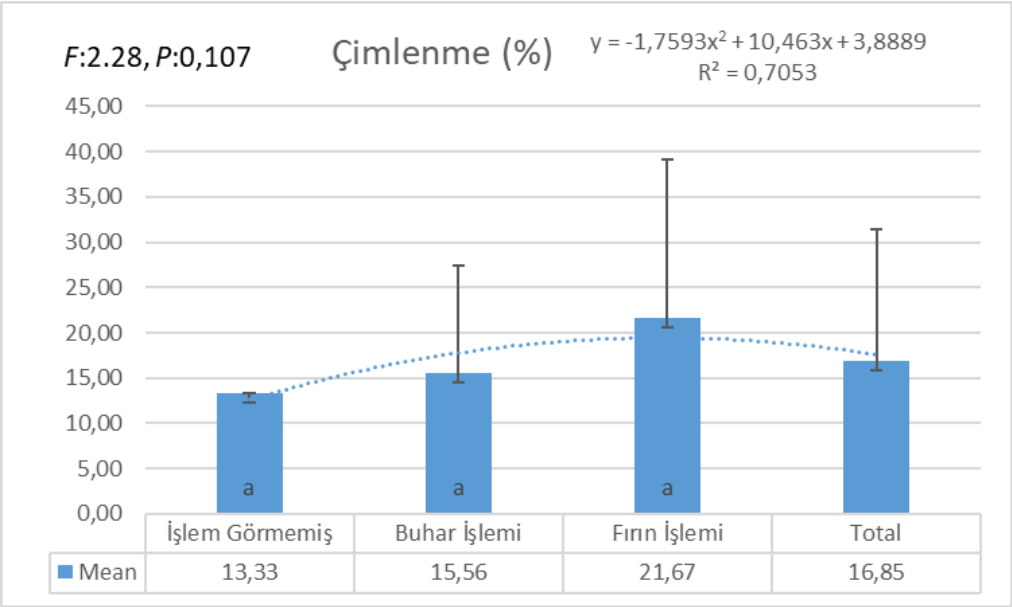


Görsel 5. Katlama süresine göre çimlenme yüzdesi.

En yüksek çimlenme oranı %21,67 ile "Fırın İşlemi" grubunda, en düşük oran ise %13,33 ile "İşlem Görmemiş" grupta gözlenmiştir. Ancak "İşlem görmemiş, buhar işlemi ve fırın işlemi" ön işlemlerinin çimlenme oranlarına istatistiksel açıdan anlamlı bir etkisi olmadığı tespit edilmiştir (*F = 2,28, P = 0,107)* (Görsel 6).



Görsel 6. Sterilizasyon işlemine göre çimlenme yüzdesi.

Tüm çimlenme sterilizasyon ortamlarının katlama süresine göre eğilimlerinin aynı doğrultuda olduğu görülmüştür. 90 gün sonunda çimlenme oranı zirveye ulaştıktan sonra, 120. günde tüm sterilizasyon yöntemleri için çimlenme oranlarında bir düşüş gözlemlenmektedir (Görsel 7).

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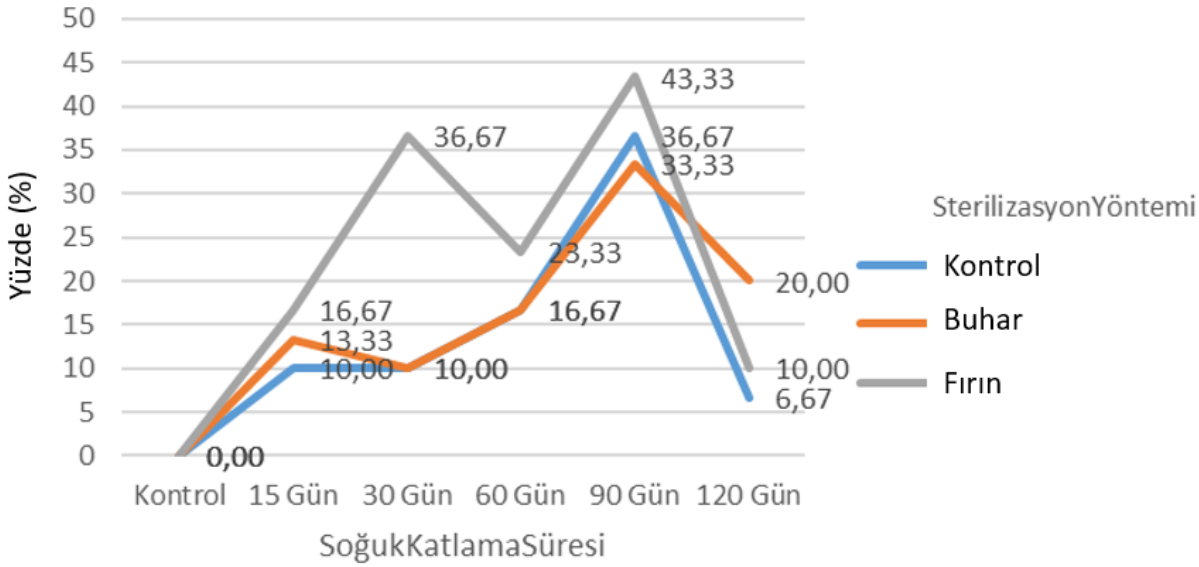
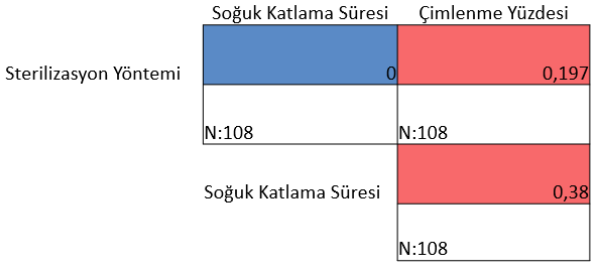


Görsel 7. Ön işlemlere göre çimlenme yüzdesi.

Çimlenme yüzdeleri incelenen 108'er tohum içinde soğuk katlama süresi ile çimlenme yüzdesi arasında orta seviyede doğru orantılı bir ilişki olduğu tespit edilmiştir (Görsel 8).



Görsel 8. Correlations analizi.

3. SONUÇLAR

Bu çalışmada, *Liatris spicata* (L.) 'Alba' tohumlarının farklı sterilizasyon yöntemleriyle hazırlanan katlama ortamlarında ve çeşitli soğuk katlama sürelerinde çimlenme başarıları incelenmiştir. Elde edilen bulgular, soğuk katlama süresinin ve kullanılan sterilizasyon yönteminin çimlenme oranları üzerinde önemli etkileri olduğunu göstermiştir.

Grafik analizlerine göre, en yüksek çimlenme yüzdesi 90 gün süreyle +4°C'de bekletilen tohumlarda gözlemlenmiştir. Özellikle bu süre zarfında, kontrol grubu ve sterilizasyon uygulanmış gruplar arasında belirgin farklılıklar gözlenmemiştir. Çimlenme oranları, sterilizasyon yöntemi olarak fırın işleminin diğer yöntemlerden daha iyi performans sergilediğini göstermektedir. İstatistiksel analizler, soğuk katlama süresi ile çimlenme yüzdesi arasında anlamlı bir ilişki olduğunu ($r = 0,380$, $p < 0,001$) ve sterilizasyon yöntemi ile çimlenme yüzdesi arasında da zayıf fakat istatistiksel olarak anlamlı bir ilişki bulunduğunu ($r = 0,197$, $p < 0,05$) ortaya koymuştur.

Bu sonuçlar, Liatris spicata tohumlarının üretiminde soğuk katlama süresinin ve sterilizasyon yönteminin dikkatlice seçilmesinin çimlenme başarısını artırabileceğini göstermektedir. Fırınlama işleminin ve 90 günlük soğuk katlama süresinin kombinasyonu, optimal çimlenme oranını sağlamak açısından en etkili yöntem olarak belirlenmiştir. Bu veriler, orman ekosistemlerinin biyoçeşitliliğinin korunması ve bitki türlerinin nesiller boyu sürdürülebilirliğinin sağlanması açısından önemli bilgiler sunmaktadır.

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MALÇLAMANIN KURAKÇIL PEYZAJDAKİ ÖNEMİ, RİZE KENTİ ÖRNEĞİ

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ÖZET

Var olduğumuz zaman diliminde gün geçtikçe betonlaşan kentlerde su gereksinimi artmaktadır. Tüketim odaklı günümüz şartlarında her şeyde olduğu gibi suyun tüketiminin de düzensiz ve verimsiz kullanılması çevresel sorunların yanı sıra ekonomik açıdan da sorunlar oluşturmaktadır. Bilinçli su tüketimi mevcut temiz su kullanımının sürdürülebilirliği açısından büyük öneme sahiptir. Günümüzde su tüketimini en aza indirmek ve en ideal seviyelerde su tasarrufu sağlayabilmek adına birçok yöntem uygulanmaktadır. Açık yeşil alanlarda kullanılan bu yöntemlerden birisi de kurakçıl peyzaj çalışmalarıdır. Kurakçıl peyzaj çalışmalarının 7 temel ilkesi bulunmaktadır. Bu 7 temel ilkeden bir tanesi de malçlamadır. Kurakçıl peyzaj çalışmalarında malçlama önemli bir role sahiptir. Zemin üzerine serilen malzeme toprağın buharlaşmayı azaltarak zeminin nemli ve ideal sıcaklık dengesinde kalmasına olanak sağlamaktadır. Bu sayede su tasarrufu ile suyun etkin kullanımı sağlanırken sulama gereksinimi de azaltılarak iş gücünden tasarruf edilmiş olur. Malçlamanın katma değerleri bunlarla sınırlı değildir. Kullanılan malç malzemesinin yapısı ve özelliklerine göre sağladığı avantajlar artmaktadır. Bu çalışmada Rize ilinde kullanılan malçlama yöntemleri ve sağladıkları avantajlar ve dezavantajlar değerlendirilmiştir.

Anahtar Kelimeler: Malç, su tasarrufu, kurakçıl peyzaj, Rize, peyzaj tasarımı.

1. GİRİŞ

Günümüzde suyun ve sulamanın önemi hala büyük bir etkiye sahiptir. Dünya nüfusu sürekli olarak artmakta ve bu artan nüfus, su kaynaklarının taleplerini karşılayamaz hale gelmesiyle suyun stratejik bir değer kazanmasına yol açmaktadır (Sılay ve Tomar, 2009).

TÜİK (Türkiye İstatistik Kurumu), Türkiye nüfusunun 2030 yılında 100 milyon civarında olacağını öngörmektedir. Mevcut veriler doğrultusunda 2030 yılında kişi başına düşen temiz su miktarının yaklaşık olarak 1.120 m3/yıl civarında olacağı tahmin edilmektedir Gelişen kentlerin ve bağlı alışkanlıkların su tüketim hızını ve su kaynakları üzerindeki baskıyı artırabileceği öngörülmektedir. Bu tahminlerin gerçekleşebilmesi için ise mevcut kaynakların 20 yıl sonra da herhangi bir tahribata uğramadan aktarılması gerekmektedir. Dolayısıyla, Türkiye'nin gelecek nesillere sağlıklı ve yeterli su temin edebilmesi için kaynakların titizlikle korunması, akılcı ve tasarruflu kullanılması gerekmektedir (Caf, 2019).

İnsanoğlu her zaman bitki materyallerini kendi amaçları için (hastalık tedavisi, ekipmanlar, alet ve gıda vb.) kullanmıştır. Bitki materyallerinin kullanım yöntemleri nesilden nesile aktarılarak günümüze kadar gelişerek gelmiştir (Url 1).

Günümüzde bitki materyallerinin kullanımında ekolojik istekleri yüksek olan bitki taksonlarının kullanılmasından dolayı peyzaj uygulamalarında, maliyet ve bakım gereksinimleri artmaktadır. Aynı zamanda küresel ısınma, proje alanıyla uyumlu olmayan egzotik taksonların baskın hale gelmesi, yetersiz yeşil alan, biyoçeşitlilik kaybı, kirlilik vb. sorunların yanı sıra bitkisel tasarımlarda son zamanlarda su israfı önemi artan en büyük problemlerin başında gelmektedir.

Bitkisel üretim sektörleri, dünya genelinde su tüketimi açısından toplam su kullanımının yaklaşık %70'ini kullanarak dünyada en fazla su tüketen sektörlerdir (Prem vd., 2020).

Su kaynaklarının etkin kullanımı için farklı meslek disiplinleri birbirinden farklı çalışmalar yürütmektedir.

Peyzaj mimarları, diğer tasarım disiplinlerinden farklı olarak, tasarımlarında canlı varlık olan bitkilere odaklanırlar. Bitkiler, peyzaj tasarımının temel unsurlarından biridir ve suya olan ihtiyaçları yaşamsal önem taşır. Ancak, günümüzde küresel iklim değişikliği, artan nüfus ve bilinçsiz su kullanımı gibi faktörler, doğal su kaynaklarının azalmasına neden olmaktadır.

Bu durum, peyzaj mimarlarını su verimliliği ve sürdürülebilir su yönetimi konularında önemli bir rol üstlenmeye teşvik etmektedir. Peyzaj mimarları, tasarımlarında su kaynaklarını koruma, kuraklıkla mücadele etme ve toplumu su kaynakları konusunda bilinçlendirme gibi konuları ele alarak çözümler sunarlar. Bu çabalar, doğal su kaynaklarının sürdürülebilir bir şekilde kullanılmasına ve gelecek kuşaklara aktarılmasına katkı sağlar.

Son yıllarda, Türkiye'de iklim değişikliğinin etkileri daha belirgin hale gelmiştir. Bu bağlamda, su kaynaklarının korunması ve suyun tasarruflu kullanımı, peyzaj mimarlığı uygulamalarında öncelikli bir konu haline gelmiştir. İklim değişikliğinin etkilerinin artmasıyla birlikte, bu bölgelerde suyun etkin ve sürdürülebilir bir şekilde yönetilmesi, çevresel sürdürülebilirlik ve su kaynaklarının uzun vadeli korunması açısından hayati öneme sahiptir. Bu nedenle, peyzaj mimarlığı alanında yapılan çalışmalar, suyun verimli kullanımını teşvik eden, yerel ekosistemlere uyumlu ve suya duyarlı tasarım ve uygulamaları öne çıkarmaktadır (Atik ve Karagüzel 2007).

Bu doğrultuda peyzaj mimarlığında suyun verimli kullanımı için yeni kavramlar geliştirilmiştir, bunlar "Su-Etkin Peyzaj Düzenlemesi" (Water-Efficient Landscaping) başlığı altında toplanmaktadır. Bu

yaklaşımlar, geleneksel peyzaj düzenleme anlayışlarından farklılık gösterir ve "Suyun Akılcı Kullanımı" (Water-Wise, Water-Smart), "Az Su Kullanımı" (Low-Water) ve "Doğal Peyzaj Düzenleme" (Natural Landscaping) gibi kavramları içermektedir. Bu kavramların sentezlenmesi sonucunda Kurakçıl Peyzaj (Xeriscape) kavramı ortaya çıkmıştır. Bu yeni peyzaj düzenleme kavramı, bitkilendirme çalışmalarında daha az su tüketen doğal taksonların tercih edilmesini, geniş çim yüzeylerin yerine yer örtücü taksonların tercih edilmesini ve su tüketiminin azaltılmasını vurgulayan bir yaklaşımdır (Güvenç ve Demiroğlu, 2016; Çorbacı vd., 2017).

Kurakçıl peyzaj özellikle su tüketimini en aza indirerek su kaynaklarının ve çevrenin korunmasını amaçlayan özel bir peyzaj tasarımıdır. Bu yaklaşım, suyu en az girdi ile en verimli şekilde kullanarak bitki yetiştirme ve peyzaj düzenlemesi yapmayı amaçlamaktadır. Bu sayede, suyun israfının önlenmesi, kurak bölgelerde veya su kaynaklarının kısıtlı olduğu alanlarda yaşayan bitki ve ekosistemlerin sürdürülebilirliğinin sağlanacaktır (Çorbacı vd., 2017).

Kurakçıl peyzaj bölgelerin doğal ekolojisini dikkate alarak yeraltı ve yerüstü su kaynaklarını akıllıca kullanmayı amaçlamaktadır. Bitki seçimi, sulama yöntemleri ve toprak yönetimi gibi unsurları içeren bu kavram, suyun verimli kullanımını teşvik ederek sürdürülebilir peyzaj uygulamaları sunmaktadır. Bu çabalar, su kaynaklarının korunması ve kurak bölgelerde su sıkıntısının azaltılmasına yönelik önemli adımları içermektedir (Çetin ve Mansuroğlu, 2018).
Kurakçıl peyzaj uygulamaları peyzaj uygulamalarında kullanılan tüm aşamaları içerirken temel prensip olarak suyu önemli bir girdi olarak ele almaktadır. Suyun tasarruflu kullanımıyla en az su tüketimi ile en yüksek bitkisel verimi almayı amaçlar. Kurakçıl peyzaj kavramı içerisinde suyun verimli ve düşük miktarlarda kullanılmasını hedefleyen yedi temel ilke bulunmaktadır (Çorbacı vd., 2017; Çorbacı ve Ekren, 2022).

1) Planlama ve tasarım
2) Toprak hazırlığı
3) Uygun bitki seçimi
4) Çim alanların oluşturulması
5) Etkin sulama
6) Malç kullanımı
7) Bakım ve Budama

Etkin bir kurakçıl peyzaj çalışması ile yaklaşık %40-60 oranında su tasarrufu sağlanabilmektedir (Çorbacı vd., 2017). Kurakçıl peyzaj çalışmasından istenilen sonucun elde edilebilmesi için bu 7 temel ilkenin eksiksiz bir şekilde yerine getirilmesi gerekmektedir. Bu 7 temel ilke bir biri ile sıkı bir etkileşim halindedir. Bu çalışmada bu 7 temel ilkeden birisi olan malç kullanımı hakkında detaylı açıklamalara yer verilecektir. Rize ilinde yapılan malçlama çalışmaları hakkında bilgiler aktarılacak ve kurakçıl peyzaj çalışmalarındaki öneminden bahsedilecektir.

Malç kullanımı: Malçlama, bitki köklerinin etrafında gerekli sıcaklık ve nem düzeylerini sağlamak ve toprak nemini optimize etmek amacıyla, toprak yüzeyinin uygun özelliklere sahip malzemelerle (örneğin kuru yapraklar, ağaç kabuğu, saman vb.) kaplanması işlemidir. Bu yöntem, bitkilerin sağlıklı bir şekilde gelişmesini ve toprak verimliliğinin artmasını desteklerken, sulama ihtiyacını azaltarak su tasarrufu sağlamaktadır (Ertop, 2009). Malçlamanın temel hedefi, buharlaşmayı en aza indirerek toprakta daha fazla suyun muhafaza edilmesini sağlamak, toprak sıcaklığını düzenlemek ve erozyonu

önlemektir. Yabancı otların önüne geçilmesi için kullanılan herbisit gibi kimyasalların önüne geçilebilmesi sağlamaktadır.

Malçlama; Organik malç, İnorganik malç ve Biyolojik Malç (Yaşayan malç) olarak 3' e ayrılmaktadır (Leary, J. ve Defrank, J. 2000)

Organik malçlama: Organik malç, yapraklar, ağaç kabukları, yongalanmış bitkisel materyaller ve bitki artıklarından oluşan bir malç türüdür. Bu malç türünün kullanımı, toprak yüzeyinden suyun buharlaşmasını azaltırken, yağmur ve karın nemi tutmasına yardımcı olur. Ayrıca, yabancı ot oluşumunu engeller, erozyonu azaltır ve toprak sıcaklığının dalgalanmasını önler (Ranian, 2017). Organik malçlar toprak sıcaklığını genellikle azaltırken, inorganik malç materyalleri de genellikle artırmaktadır. Toprak sıcaklığını artıran malç materyalleri arasında siyah ve şeffaf plastik malçlar en çok bilinenleridir (Zengin, 2019).

İnorganik malç: Sentetik malç olarakta adlandırılan bu sistem kâğıt, alüminyum, plastik (farklı renklerdeki plastik malzemeler), petrol eriyikleri gibi malzemeler ve bunların farklı birleşimleri kullanılarak elde edilen doğal olmayan malzemelerin kullanılmasıyla yapılan malçlamadır (Zengin, 2019). Buharlaşmayı ve paralelinde topraktaki tuz konsantrasyonunu azaltma yetenekleri nedeniyle toprak tuzluluğunu azaltıcı etkileri vardır (Aragüés, Medina ve Clavería, 2014).

Biyolojik Malç (Yaşayan malç): Biyolojik Malçlar (Canlı malçlar), ana bitkilerin aralarına dikilen ve canlı zemin örtüsü olarak muhafaza edilen yer örtücü bitkilerin örtü materyali olarak kullanılması ile yapılan malçlamadır. Her ne kadar canlı malçlar bazen örtü bitkileri olarak anılsa da, ana bitkilerle eş zamanlı olarak büyürler (Muhammedi, 2012)

2. DENEYSEL ÇALIŞMALAR

2.1. Materyal ve Yöntem

Çalışma alanı olarak Rize İli merkezinde bulunan malç uygulaması yapıldığı tespit edilen Ziraat Botanik Parkı, Çiftekavak sera alanı, Recep Tayyip Erdoğan Üniversitesi Zihni Derin yerleşkesi Peyzaj Mimarlığı Bölümü sera alanı ve Rize Merkez ilçedeki kavşakta bulunan yeşil alanlar seçilmiştir. Çalışma alanı Görsel 1'de verilmiştir.

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Görsel 1. Çalışma alanlarının Google Earth görüntüsü.

Çalışmanın materyalleri olarak;

1. Araştırmanın kapsamı, Rize'deki malç uygulaması yapılan yeşil alanları ve çevresini içermektedir.
2. Malç uygulamaları ile ilgili mevcut literatür özetleri incelenmiştir.
3. Çalışma alanlarına yapılan saha ziyaretleri sırasında yapılan gözlemler ve çekilen fotoğraflar.
4. Google Earth Pro'dan elde edilen uydu fotoğraflarından yararlanılmıştır

Bu çalışma, Rize ilinde kullanılan mevcut malçlama yöntemlerini tespit etmek, bu yöntemlerin yeterliliğini incelemek ve gerekli önerileri geliştirmek amacıyla yapılmıştır. Çalışma iki ana aşamadan oluşmaktadır. İlk aşamada, malçlama uygulamalarına ilişkin literatür bilgileri araştırılmıştır. İkinci aşamada ise, Rize ilinde uygulanan mevcut malçlama uygulamalarının neler olduğu tespit edilmiş daha sonra uygulanan bu yöntemlerinin avantajları ve dezavantajları bulundukları alanlarda gözlemler ile belirlenmiştir. Her iki aşamada da alan gezileri yapılarak fotoğrafları çekilmiştir.

2.2. Bulgular

Rize ilinde malç uygulaması olarak organik olarak Ziraat Botanik Parkı'nda ağaç kabuğu ve Merkez ilçe kavşağında çay çöpü uygulaması, inorganik olarak ise Çifte Kavak sera alanında kil bilyesi ve Merkez ilçe kavşağında dolomit taşı uygulaması olmak üzere dört farklı malç uygulamasının yapıldığı tespit edilmiştir. Bunlar aşağıda açıklanmıştır.

Çay çöpü uygulaması: Rize Belediyesi çay atıklarının mangal kömürü ve elektrik üretiminde değerlendirilmesi amacıyla Rize ili Kalkandere ilçesi Rize Organize Sanayi Bölgesi'nde Çay Çöpünden Mangal Kömürü Üretim Tesisi kurmuştur. Tesisten geriye kalan çay atıkları üç aşamada değerlendirilmektedir. Çay çöpü malç uygulaması şekil 2'de verilmiştir.

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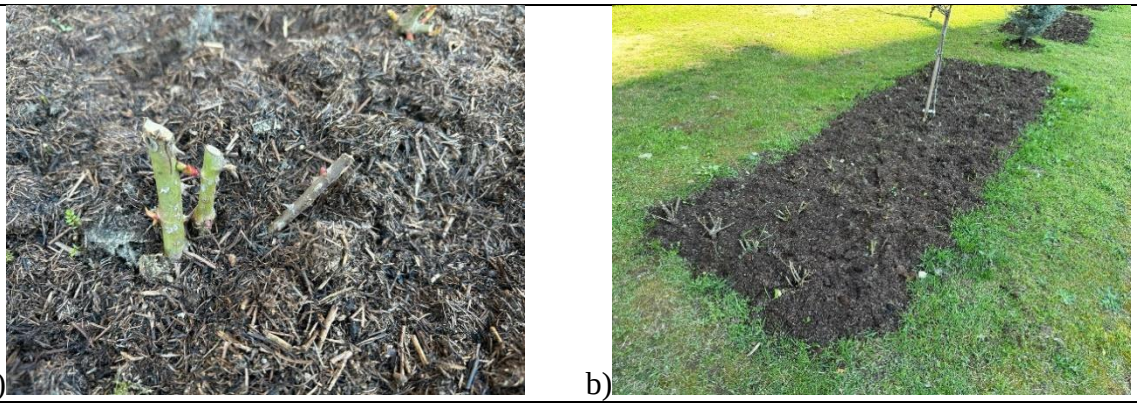

Görsel 2. Merkez kavşakta A) Çay atığı malç uygulaması, B) Çay atığı malç uygulaması genel görünümü.

Kil Bilyesi Uygulaması: Çifte Kavak sera alanındaki farklı tipteki Limon (Citrus spp.) taksonlarından oluşan koleksiyon bahçesindeki alanın zeminine uygulanmıştır. Alan önce çapalatılmış daha sonra jüt serilerek yaklaşık 3 cm kalınlığında kil bilyesi uygulaması yapılmıştır. Fabrikasyon üretimle killerin özel işlemler sonrası farklı boyutlarda toplar haline getirilmesi ile oluşan kil bilyeleri'nin avantajları açısından nem tutma, istilacı otların bastırılması, sıcaklık dengeleme, damla erozyon kontrolü gibi özelliklerinin yanı sıra, organik malçlara göre zararlı çekme etkisinin daha az olduğu görülmüştür. Yeniden kullanılabilir bir malzeme olduğu görülmektedir. Kil Bilyesi malç uygulaması Görsel'3 de verilmiştir.

Görsel 3. Çiftekavak serasında A) Kil Bilyesi malç uygulaması, B) Kil Bilyesi malç uygulaması genel görünümü

Dolomit Taş serim uygulamaları: Rize Belediyesi Park ve Bahçeler Müdürlüğü ekipleri tarafından Merkez ilçedeki Kavşak alanında uygulanmıştır. Peyzaj projesindeki malç serilecek hatlar plastik sınır elamanı ile oluşturulmuş, içleri çapalanmış daha sonra jüt serilerek üzerlerine yaklaşık 5-10 cm kalınlığında beyaz renkteki dolomit taşı uygulaması yapılmıştır. Malç olarakta kullanılabilecek dolomit taş uygulamaları gibi parça taş serim işlemleri ilk amaç olarak görsel ve estetik formlar oluşturmak amacıyla kullanıldığı anlaşılmıştır. Bu uygulamaların aynı zamanda malç özelliği gösterdiği belirlenmiştir Taş serimi malç uygulaması Görsel 4'de verilmiştir.

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a)  b) 

Görsel 4. Rize ili merkez kavşakta A) Taş serimi malç uygulaması, B) Taş serimi malç uygulaması genel görünümü

Taban Örtüsü (Jüt): Recep Tayyip Erdoğan Üniversitesi Zihni Derin yerleşkesi Peyzaj Mimarlığı Bölümü sera alanı dışındaki bitki yastıklarının üzerinde uygulanmıştır. Alan önce çapalanmış daha sonra üzerine jüt serilmiştir. Avantajları açısından nem tutma, istilacı otların bastırılması, damla ve rüzgar erozyon kontrolü gibi özelliklerinin yanı sıra, en önemli özelliklerinden birinin hafif olması olduğu öngörülmüştür. Aynı zamanda dayanıklı ve çürümeye karşı dirençli olduğu gözlemlenmiştir. Taban Örtüsü malç uygulaması Görsel 5'de verilmiştir.

a) 

Görsel 5. RTEÜ Serasında a) Taban Örtüsü malç uygulaması.

Ağaç Yongası: Recep Tayyip Erdoğan Üniversitesi Zihni Derin yerleşkesi Peyzaj Mimarlığı Bölümü sera alanı dışındaki bitki yastıklarının üzerinde uygulanmıştır. Alan önce çapalanmış daha sonra üzeri jüt ile kapatılarak 5 cm kalınlığında ağaç kabuğu serilmiştir.

Avantajları açısından buharlaşmayı azaltarak nem tutma, istilacı otların alana gelmesini engelleme, toprak sıcaklığının dengelenmesi, damla ve rüzgar erozyon kontrolü gibi özelliklerinin yanı sıra, peyzaj açısından kabuk ve yonganın malç olarak kullanılması görsel

açıdan estetik çekicilik sunmak için de kullanılabileceği anlaşılmıştır. Ağaç yongası malç uygulaması Görsel 6'de verilmiştir.

a)  b) 

Görsel 6. RTEÜ Serasında a) Ağaç yongası malç uygulaması, b) Ağaç yongası malç uygulaması genel görünümü.

Kum: Avantajları açısından diğer materyallerden ayrışmaktadır. Kum malç malzemesi olarak kullanıldığı gibi bitkiler için besi ortamı olarak da işlevi bulunmaktadır. Bu doğrultuda yabancı ot mücadelesi için kısmen etkili olduğu tespit edilmiştir. İnce bir tabaka olarak serildiğinde ot mücadelesinde etkisinin sınırlı olduğu gözlemlenmiştir. Kayda değer sonuçlar almak için kalın bir tabaka olarak serilmesi gerektiği anlaşılmıştır. Kumun yabancı ot mücadelesindeki en büyük rolü yabancı ot temizliği yapılırken bitkilerin kökleriyle kolay sökülmesine olanak sağladığı tespit edilmiştir. Kum malç uygulaması Görsel 7'de verilmiştir.

Görsel 7. Kum malç uygulaması.

3. SONUÇLAR VE DEĞERLENDİRME

Küresel iklim değişikliği başta olmak üzere su israfını ve bakım maliyetlerini azaltmak birçok uygulama çalışmasının hedeflerinden biridir. Bu sorunlaraa bir çözüm yolu olarak da malçlama uygulamalarının kullanımını kentlerde yaygınlaştırmak olduğunu söylenebilir. Özellikle kurak

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ve yarı kurak şartların ön planda olduğu karasal iklim koşulları altında malçlama uygulaması bitki varlığının sürekliliğinin sağlanmasında su yönetimi açısından kesinlikle yapılmalıdır.

Sonuç olarak, tüm malç malzemeleri önemli avantajlar sağladığı gibi farklı dezavantajları da bulunmaktadır. Herhangi bir bahçe, yeşil alan veya peyzaj projesinde, belirlenen hedeflere uygun olarak bitki ve toprak gereksinimlerine göre malç seçimi yapılmalıdır. Malç malzemesinin avantajları ve dezavantajları göz önünde bulundurularak en uygun malç türüne karar verilmelidir. Bu, hem bitkilerin sağlıklı büyümesini destekler hem de peyzajın estetik görünümünü artırır.

Çay çöpü malçlama toprak sağlığı ve bitki büyümesi için çeşitli faydalar sunarken, potansiyel dezavantajlarını dikkate almak ve kullanırken toprak koşullarını izlemek önemlidir. Çay çöpünü malç olarak kullanırken toprağın pH'ını ve besin seviyelerini izlemek ve yetiştirilen bitkilerin özel ihtiyaçlarını dikkate almanın gerektiği düşünülmektedir.

Islak toprak yüzeyinin kalmasını istemediğimiz çatı bahçesi, restoran gibi iç mekânlarda veya herhangi bir peyzaj tasarım alanında kil bilyesi kullanımıyla nemli yüzeylerin, sineklenme ve böceklenme sorununun önüne geçilebilir.

Dolomit taşı gibi taş parçalarının şekil değişiklikleri veya ilerleyen süreçte kaldırılmak istenmesi durumlarında kolaylık arz etmesi için altına jüt, hasır veya benzeri naylon örtü malzemeler serilmesi kullanımına kolaylık sağlayacaktır. Ayrıca taşların arasından çıkabilecek olan yabancı otların önüne geçilecektir.

Malç malzemesi olarak alanda taban örtüsü (jüt) serim işleminde dikkat edilmesi gereken önemli bir nokta taban örtüsünün bitki dikilmeden önce alana serilmesi gerektiğidir. Bitki dikiminden sonra alana tek parça halinde jüt serim işleminde zorluklar yaşanmaktadır.

Malç olarak kumun kullanımında serilen kumun kalın olması daha iyi sonuçlar elde edilmesine olanak sağlayacaktır.

Kırsal ve kentsel bölgelerde gerçekleştirilen kurakçıl peyzaj düzenlemesi çalışmalarında, bitkilerin ve çevrenin ekolojik ilişkilerinin detaylı bir şekilde anlaşılması ve bu doğal ortamın iklim koşullarına uygun bitki türlerinin seçilmesi gerekmektedir. Özellikle kent ve çevresinde yeşil alanların oluşturulması sürecinde, bu nokta daha da kritik bir öneme sahiptir. Bu sebeple, bitkisel tasarım çalışmalarında peyzaj mimarlarının, ekoloji ve meteoroloji alanlarında uzmanlarla işbirliği yaparak bütüncül bir plan ve tasarım geliştirmesi, projenin başarısı için hayati önem taşımaktadır (Çorbacı, 2011).

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SOCIO-ECOLOGICAL APPROACHES IN URBAN PLANNING AND DESIGN

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Abstract

The vulnerabilities and degradation observed in ecosystems under the pressure of urbanization and dense construction are topics of ongoing discussion. Within the framework of sustainable living, it is increasingly essential to enhance quality of life while supporting ecological approaches. In this context, the socio-ecological urban approach has been developed, a model that examines cities through the reciprocal interactions of ecosystems and social structures. This approach considers cities not only as physical structures and infrastructure but also as holistic systems involving humans, social relations, cultural dynamics, and the natural environment. The socio-ecological urban approach aims to build sustainable and resilient cities, prioritizing ecological balance, fulfillment of social needs, climate adaptation, and biodiversity preservation within urban life. This article aims to develop planning and design strategies to ensure urban development and resilience, examining existing research and diverse methodologies in this field. The article specifically details the methods by which landscape architects intervene in urban systems.It provides unique insights into understanding the evolving dynamics of cities and developing solution-oriented strategies.

Key words: Ecosystem, Social–Ecological Systems, Urban Design, Urban Resilience, Urban Landscape

KENTSEL PLANLAMA VE TASARIMDA SOSYO- EKOLOJİK YAKLAŞIMLAR

Özet

Şehirleşme ve yoğun yapılaşma baskısı altında ekosistemde görülen kırılganlıklar ve bozulmalar gündemde tartışılan konular arasındadır. Sürdürülebilir yaşam çerçevesi içerisinde hem yaşam kalitesini artırmak hem de ekolojik yaklaşımları desteklemek önem kazanmaktadır. Bu çerçevede Sosyo-ekolojik kent yaklaşımı ile, şehirleri ekosistemlerin ve sosyal yapıların karşılıklı etkileşimi içinde ele alan bir şehircilik yaklaşımı geliştirilmiştir. Bu model, kentlerin yalnızca fiziksel yapıları ve altyapıları değil, aynı zamanda temelde insan ve toplumu, sosyal ilişkiler, kültürel dinamikler ve doğal çevre ile bir bütün olarak ele almaktadır. Sosyo-ekolojik kent yaklaşımı, sürdürülebilir ve dayanıklı şehirler oluşturmayı hedefler ve kent yaşamında ekolojik dengenin korunmasını, toplumsal ihtiyaçların karşılanmasını, iklim değişikliğine uyum ve biyolojik çeşitliliğin korunmasını ön planda tutar. Kentsel gelişme ve kentsel dayanıklılığı sağlayacak planlama ve tasarım stratejileri geliştirmeyi amaçlayan bu makale, bu konuda yapılan araştırmaları ve farklılaşan yöntemleri ele almaktadır. Makale özellikle, peyzaj mimarlarının kentsel sistemlere müdahale yöntemlerini detaylandırmaktadır. Kentlerin değişen dinamiklerini anlamak ve çözüm stratejilerinin geliştirilmesi konusunda özgün değerler taşımaktadır.

Anahtar kelimeler: Ekosistem, Sosyal-Ekolojik Sistemler, Kentsel Tasarım, Kentsel Dayanıklılık, Kentsel Peyzaj

Introduction

The vulnerabilities and degradations observed in ecosystems under the pressures of urbanization and dense construction are key topics of contemporary debate. Within the framework of sustainable living, enhancing quality of life while supporting ecological approaches is gaining increasing importance. As a result of globalization, cities are becoming increasingly significant for many people, and as they grow, their impacts on surrounding regions continue to expand (Flynn et al., 2016). Urbanization and the transformation of existing urban areas are seen as both causes of environmental and social degradation and as potential solutions to the problems they create (Randrup, 2020). In this context, the socio-ecological urban approach has emerged, which addresses cities within the mutual interaction of ecosystems and social structures. This model considers not only the physical structures and infrastructure of cities, but also, fundamentally, humans and society as an integrated whole, including social relations, cultural dynamics, and the natural environment. Socio-ecological

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urbanism is increasingly being adopted by researchers to enhance resilience in urban areas. The foundation of this approach lies at the intersection of urban ecology and urban design. Its focus is on how urban form shapes and influences the social and ecological services in the built environment (Colding et al., 2022).

In particular, cities in developing countries are at the intersection of the potential and tensions between economic growth, sustainability, and development (Flynn et al., 2016). The depletion of natural resources affects social development, and errors in land use are generating environmental risks (Qi et al., 2024). This vision goes beyond a technical approach to the environment, calling for a new way of thinking that recognizes nature as an integral aspect of civilization (Zhang, Wu & Lin, 2022). Thus, building the resilience of urban socio-ecological systems requires policy discourse that is sensitive to climate change, the ongoing global loss of biodiversity, and the social potential that urban form can provide when properly planned and designed (Colding et al., 2022). These considerations highlight the critical role of an ecological approach in the pursuit of human-centered, nature-friendly urban development. In this regard, urban socio-ecological resilience is not only a response to environmental and social challenges but also an opportunity to design cities that harmonize with both human needs and the natural world.

Cities are complex social and ecological systems where humans interact with ecosystems, playing a critical role in their support and maintenance. In this context, cities are socio-ecological landscapes that must be designed and managed appropriately (Marcus et al., 2019). The fundamental functions of cities are intertwined with social, environmental, and economic dimensions. The social function refers to "improving health, education, security, social cohesion, diversity, and quality of life," while the environmental function focuses on "reducing environmental impact and resource use to sustainable levels, and enhancing environmental quality and safety." The economic function is concerned with "increasing long-term resilience, competitiveness, employment, and the equitable distribution of resources" (Flynn et al., 2016). The discourse on the environmental damage caused by economic growth and industrialization first emerged at the 1970 Stockholm Conference, where the limited nature of the natural environment and resources was acknowledged. This led to the introduction of the concept of 'sustainable development' in the 1987 Brundtland Report. Subsequently, the Rio Summit and Agenda 21, the 1996 UN Habitat II Conference, the 2010 UN Millennium Summit, and the 2012 Rio+20 Summit all contributed to the shift from growth-centric development to a

sustainability approach focused on the preservation of the natural environment and the promotion of social development (Kaya & Susan, 2020).

Urban planners have increasingly focused on enhancing the resilience of cities to the harmful effects of climate change. They have confronted the reality that ecosystems require designs that not only conserve biodiversity but also foster human-nature connections (Colding et al., 2022). In this context, the "Green Pathways of Heaven" (Tianfu Lüdao) project was implemented in Chengdu, China, through a 'socio-ecological correction' (fix) perspective. The Chinese government emphasized the importance of nature in achieving a 'harmonious relationship' between humans and the environment. The project, which developed green infrastructure and environmental opportunities, is seen as the largest urban greenway system in China (Zhang, Wu & Lin, 2022). The fundamental approaches of these solutions involve the efficient use of natural resources, the preservation and enhancement of green spaces, and the integration of ecological systems into urban planning. The aim is to redesign infrastructure to adapt to climate change. By offering holistic solutions to environmental and social challenges, the project encourages collaboration across various disciplines. These efforts will help reshape cities in a way that aligns with nature while being responsive to human needs. In this process, landscape architects are expected to play a crucial role.

Planning Approaches and implementation solutions

The improvement of social and ecological sustainability in cities is closely linked to enhancing the interaction between people and nature through natural public spaces, such as green areas. Urban green spaces have become one of the most important components of urban systems, as they help mitigate social and environmental challenges and improve urban quality of life, thus making them a crucial element of urban planning (Teimouri et al., 2023). The sustainable growth of cities and their alignment with the natural environment are shaped by socio-ecological approaches in urban planning and design. The first pillar of this approach is ecological strategies that focus on environmental protection and the efficient use of resources in urban areas, while the second pillar emphasizes improving the quality of life for urban residents. The central aim of these approaches is to make cities greener, more sustainable, and in harmony with nature. As sensitivity to the environmental impacts of modern urbanization

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has increased, ecological and sustainable approaches have gained even greater significance. A review of the literature reveals a variety of solution tools that stand out within ecological approaches to urban planning.

One of the most widely regarded and effective approaches in socio-ecological urbanism is resilience. This approach seeks to address the social and ecological systems of cities together, aiming to build resistance against challenges such as natural disasters and social crises. Key characteristics of this approach include nature-aligned infrastructure, the sustainable use of local resources, and the protection of urban ecosystems. Additionally, it incorporates sustainable practices such as increasing urban green spaces, water management, waste reduction, and lowering carbon emissions. This approach also encourages the strengthening of neighborhood relationships, community solidarity, and the inclusion of local populations in decision-making processes. As a result, the balance between nature and humans can be maintained, enabling the creation of livable cities that do not harm the environment in the long term. Resilience-based approaches are being implemented in many cities and are considered fundamental for sustainable urban development.

1. Nature-Based Solutions

Biodiversity, ecosystem services, and the United Nations' 17 Sustainable Development Goals, along with the increasingly prominent nature-based solutions, can be seen as efforts to restore and improve not only urban areas but also human life more broadly, addressing humanity's dependence on nature. All of these approaches exemplify the growing interest in the importance of nature and ecosystems in an urbanizing world (Randrup, 2020). Urban agricultural spaces are being developed as multifaceted solutions to ensure food security, reduce carbon footprints, and enhance environmental quality (Zhang et al., 2024).

Nature-based solutions aim to address significant urban challenges, such as climate change, air pollution, and water management, by leveraging nature and ecosystems. Among these solutions, those that support biodiversity, such as green roofs, rain gardens, and vertical forests, stand out from the perspective of landscape architecture. The Bosco Verticale (Vertical Forest) project in Milan, which integrates green spaces with buildings, is an exemplary case, offering both environmental and aesthetic benefits (Figure 1).

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Figure 1. The Bosco Verticale (Vertical Forest) project in Milan (Polat, 2024).

Nature-based solutions, with their potential to provide numerous societal benefits, have been incorporated into EU policies and strategies as an effective approach to addressing social, economic, and environmental challenges simultaneously. Key policies and strategies that incorporate nature-based solutions include the European Green Deal, the Climate Adaptation Strategy and Action Plan (2024-2030), the New Urban Agenda, the Flood Directive, and the Nature Restoration Regulation. By integrating nature-based solutions into these strategic frameworks, the European Union underscores their value in creating resilient and sustainable urban environments while promoting economic growth and social welfare (Panduro et al., 2024). An impressive example within this context is a concept design competition in Haikou, featuring a protected area with terraced landscapes and multi-level interconnected iconic structures that link urban squares. It provides a vibrant, multi-layered urban environment with large open spaces for social gatherings and commercial activities for the city (Figure 2).

Figure 2. Concept design of the shopping avenue on Guoxing Boulevard, Haikou, China (Parametric, 2023).

Melbourne continues to lead the way in urban landscape projects by integrating plant cultivation on buildings and façades, combining grey infrastructure with green infrastructure. The roofs of buildings are designed with nature-based solutions to enhance energy efficiency, reduce the urban heat island effect, and increase the amount of green space in the city. In the newly added building to the Victoria Parliament, 300 native plant species, characterized by wildflowers,

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herbs, and shrubs, have been used. An exceptional landscaped environment has been created with the newly developed rooftop garden (Figure 3).

Figure 3. Australia, which hosts some of the world's most innovative and sustainable architectural designs (a)Constructive, 2023; b)Unacity, 2021).

2. Human and Nature Centered Solutions

It is argued that ideas focused on reconnecting people with nature and acknowledging the relationships among humans, nature, and technology can suggest new, more integrated pathways to urban sustainability. To achieve this, it is essential to embrace the principle of being inspired by nature, recognizing the interconnectedness of humanity, nature, and technology. Moreover, harnessing natural processes across all areas of urban development presents an effective starting point for establishing more holistic approaches to sustainable cities (Randrup, 2020). Cities have begun to adopt a design approach that creates space not only for people but also for nature. This approach aims to enhance the well-being of urban residents while contributing to the city's ecosystem as part of nature.

The increasingly crowded and concrete-dominated structure of cities distances people from connecting with nature. Urban forests play a vital role in restoring this balance. The presence of natural green spaces in cities filled with concrete structures makes urban areas more livable, sustainable, and attractive. Urban forests are regarded as a multifaceted solution that not only promotes ecological balance but also enhances human life, supports environmental sustainability, and serves as a critical tool in combating climate change. With growing interest, landscape architects view urban forests as providing numerous benefits. Establishing urban forests is central to future urbanization policies aimed at making cities greener, healthier, and more resilient.

Singapore is Asia's best-performing city in terms of sustainability criteria. Living on a small island with limited resources, its people recognized that turning to green practices and living

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sustainably was the only path to long-term survival. These efforts have made Singapore a leader in sustainability (Ekoyapıdergisi, 2022). Singapore continues its urban development under the vision of a "City in a Garden," aiming to both conserve nature and provide a high quality of life for its residents (Figure 4).

Figure 4. Singapore with the "City in a Garden" vision (Ekoyapı Journal, 2022).

3. Ecology-Based Solutions

To date, numerous eco-city initiatives have been undertaken, and globally, there has been a noticeable increase in the number of eco-city projects driven by growing interest. Looking at the global scale, notable projects such as Masdar in Abu Dhabi, Tianjin Eco-city in China, and Songdo Eco-city in South Korea are currently being constructed (Caprotti, 2014). Denmark, particularly Copenhagen, stands out as one of the most successful examples of the ecological city (sustainable city) concept. Copenhagen is considered one of the leading cities in the world in terms of ecological urbanism, sustainability, green living, and environmentally friendly practices. Copenhagen aims to become the world's first carbon-neutral capital by 2025, aligning this goal with efforts to reduce carbon emissions to zero, use renewable energy sources, improve energy-efficient buildings, and enhance public transportation systems. The Middelgrunden Wind Farm is regarded as a global model, providing a significant portion of the city's energy from renewable sources such as wind energy and biomass. Carbon emissions are reduced through electric buses and low-emission public transport vehicles. The city is working to minimize dependence on motor vehicles by increasing walkable areas. Over 40% of urban transportation is done by bike, earning it recognition as a bike-friendly city (Kaya & Susan, 2020). Bicycle highways have been developed connecting the city to surrounding areas. In addition, green and blue infrastructure solutions are used to reduce the risks of flooding and

stormwater caused by climate change. The city employs solutions such as green roofs, rain gardens, and permeable surfaces to address heavy rainfall. Particularly, the St. Kjelds District is seen as a successful project where such nature-based solutions have been implemented. The harbor and waterways, which are now used by the public for swimming, water sports, and recreational activities, have been cleaned and transformed into clean water areas.

Copenhagen undertakes awareness-raising activities to encourage the public to adopt a sustainable lifestyle. Particular attention is given to issues such as recycling, energy conservation, and the preservation of green spaces. Educational programs are organized to foster environmental awareness and promote eco-friendly lifestyles. A system is in place to minimize waste and reuse resources. One of the most notable projects in waste management is Amager Bakke, which serves both as a waste incineration plant and an artificial hill where people can ski. This facility not only converts a significant portion of the city's waste into energy but also significantly reduces carbon emissions.

4. Climate Change Resilient Solutions

Cities are experiencing the effects of climate change through droughts, floods, and other extreme weather events, as well as flooding due to rising sea levels and increasing temperatures. Our cities, which are socio-economic and ecologically integrated systems, are characterized by the fragility of system integration, their susceptibility to changes in external factors, and their weak self-regulation capacity. In this context, addressing human activities becomes essential to mitigate the impacts of urban climate and environmental changes and make cities more resilient (Cai et al., 2021). Flood prevention systems, energy-efficient buildings, resilient infrastructures, and sustainable land uses have become increasingly important in urban design to develop effective strategies against climate change risks. For example, New York City has focused on developing resilient infrastructures and green spaces to withstand rising sea levels and climate disasters such as hurricanes.

5. Waste Management and Zero Waste Policy-Focused Solutions

Cities are developing zero waste policies to minimize waste production and increase recycling rates. Promoting the proper management and reuse of waste ensures more efficient use of resources. In this regard, Ljubljana, Slovenia, is known as a leader in managing urban waste and developing a local circular economy. Ljubljana has developed a three-phase waste management policy aimed at becoming Europe's first zero waste capital. These phases are:

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Phase 1: Waste separation and collection implementation,

Phase 2: Overhaul of waste collection services,

Phase 3: Promotion of zero waste (Greencities, 2020).

Socio-ecological systems develop interaction scenarios between people and the biophysical environment through institutional arrangements. They aim to bridge the gap between social and natural sciences and support the convergence of sustainability frameworks in observing cultural landscapes (Barau et al., 2013). Circular economy, on the other hand, is an economic model in which resources are used more efficiently, waste is minimized, and recycling is encouraged. When applied to urban areas, this model leads to the development of projects that reduce resource consumption, promote waste management, and improve energy efficiency. In this regard, Amsterdam is one of the cities that stands out for its circular economy policies focused on the reuse and recycling of waste. Waste management systems aim to maintain ecological balance by increasing recycling rates.

6. Urban Green-Blue Infrastructure Focused Solutions

Rapid urbanization, urban sprawl, and the climate change crisis have led to an increased interest in urban green spaces and the development of new approaches to integrate these areas into city planning. One of the tools for improving the built environment and conserving nature is green infrastructure. Green Infrastructure can be defined as a strategic planning network consisting of interconnected patches of natural, semi-natural, and human-made green spaces. Green infrastructure planning is considered a socio-ecological phenomenon where human needs, ecosystem functions, and green spaces overlap. The concept of urban green infrastructure contributes to better integration of the services provided by green spaces into spatial planning and design policies and guidelines (Fahimeh and Ignatieva, 2023). In this regard, through geographic information and communication technologies (Geo-ICT), some cities, defined as climate-resilient, have made progress in developing timely responses to climate disasters, infrastructure risk assessments, and coordinating urban planning and management (Cai et al., 2021).

Green and blue infrastructure involves the strategic integration of green spaces (parks, gardens, green corridors) and waterways (streams, rivers, canals) in cities. This infrastructure helps reduce flooding, improve air quality, and enhance biodiversity by preserving the natural water

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cycle. In this regard, Copenhagen has focused on innovative solutions in water management by integrating green and blue infrastructure to address flood risks caused by climate change.

7. Sustainable Transportation and Walkability Focused Solutions

One of the key objectives of the socio-ecological paradigm is to investigate the relationships between environmental conditions and human well-being. This approach can reflect the close relationship between the natural and social dimensions of ecosystems and help understand how planning elements can create developed built and social environments in urban areas (Teimouri et al., 2023). From this perspective, sustainable solutions are being developed in transportation infrastructure to reduce carbon emissions and provide more livable spaces for people. Bicycle lanes, electric public transportation systems, walkable neighborhoods, and smart transportation solutions are part of this trend. In this context, Copenhagen is one of the most bicycle-friendly cities in the world, with its extensive bicycle lane network and sustainable public transportation systems. Freiburg is considered a global example of sustainable urban planning and design. The city has created an ecological urban design by incorporating energy-efficient buildings, public transportation systems, and wide bicycle lanes. Additionally, in the Vauban district, ecological structures such as zero-energy homes and green roofs can be found.

8. Carbon Neutral and Energy Efficiency Focused Solutions

Cities have developed various projects with the goal of becoming carbon neutral in order to combat climate change. These projects emphasize the use of renewable energy sources and energy-efficient building designs. Cities aiming to reduce their carbon footprint have sought to reduce energy consumption through innovative solutions. One of this is Copenhagen, which has implemented a large-scale plan aiming to become carbon neutral by 2025.

Another example is the Masdar City project in the United Arab Emirates, designed as a city model with a completely zero-carbon target. In this project, energy needs are met through the use of solar and renewable energy sources. Additionally, electric vehicles and pedestrian pathways are prioritized in the transportation system.

Increasing green spaces in cities is crucial for maintaining ecological balance and improving the quality of life for residents. One of the solutions that will shape the future in this regard is urban forests. Urban forests are seen as an effective tool in combating climate change. By supporting biodiversity in cities, they contribute to the preservation of natural ecosystems. Trees

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help clean the air by capturing carbon, prevent excessive temperature rise, and reduce the risk of flooding by absorbing rainwater. Furthermore, urban forests provide habitats for birds, insects, and other wildlife, thus preserving ecosystem balance.

9. Smart City Solutions

The concept of Smart Cities emerged in the early 1990s, driven by technological changes. Over time, non-technological factors also influenced the evolution of smart city applications, which continue to develop today. It represents a holistic approach to the planning and management of all activities based on the integration of technological, social, economic, environmental, and institutional aspects, aiming to improve people's quality of life. The foundation of smart city initiatives is sustainability and innovation (Barbieri et al., 2025). In other words, it is an innovative vision for the cities of the future, where technology is seen as the key to improving quality of life, enhancing smart city security, and increasing energy efficiency. This vision encompasses the efficient management of systems related to security, city monitoring, sensors, energy consumption, water usage, waste management, and smart transportation. In this context, Singapore uses innovative applications to optimize traffic, energy, and water consumption through smart city technologies. Smart city applications around the world indicate a growing trend with significant potential in this area.

Conclusions

The aim of this article is to outline a framework for improving the structure of cities through socio-ecological systems by summarizing current approaches to cities and the practices involved in urban development. Ecological approaches in urban planning and design assist cities in achieving their environmental sustainability goals. Ecological projects reduce cities' carbon footprints while creating environmentally conscious spaces that enhance quality of life. The efficient use of natural resources, energy conservation, and the improvement of social well-being demonstrate that such projects are indispensable for cities in the long term. In this context, landscape architecture stands out as a professional discipline actively involved in the process of mitigating the ecological, economic, and socio-cultural impacts of global climate change.

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On the other hand, improving the energy efficiency of buildings and public spaces is one of the fundamental elements of sustainable urban planning. Solar panels, wind turbines, and energy-efficient building designs are commonly used in this regard. The ecological approach emphasizes urban designs that encourage people to use public transportation, bicycles, and pedestrian paths rather than individual cars. This can reduce both traffic congestion and air pollution in the city. These urban ecology trends demonstrate that cities can grow with an environmentally sensitive, sustainable, and human-centered approach. Planners, local governments, and administrators will continue their efforts to make future cities more resilient and livable, both ecologically and socially, by establishing a balance between nature and technology. Therefore, by integrating natural ecosystems into cities, they will create both green spaces and protected natural habitats. This will support biodiversity while also generating social and recreational spaces for the people living in the city. Urban water management, rainwater collection, energy efficiency, and carbon footprint reduction are some of the goals for developing green infrastructure. In this context, the sustainability of the water cycle will also be ensured through rain gardens, permeable surfaces, or green roof systems.

A design approach that considers landscape as a starting point highlights nature-based planning and design practices, supporting the implementation of resilient and ecological solutions. When landscape is prioritized, the planning and development of cities begins from a different perspective, using nature-based approaches as strategic spatial guiding principles (Roggema et al., 2021).

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ON PURPOSE DESIGN SUGGESTIONS FOR ROOF GARDENS

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SUMMARY

Today's cities are developing day by day due to intense population growth. This development increases the amount of buildings and causes a decrease in green areas. Especially in cities that have lost their natural features, the quality of life of urban dwellers deteriorates. The search for creating green areas within the dense and losing quality urban texture leads urban planners to new searches. Roof gardens, one of the most important green infrastructure elements, have brought the use of building roofs to the forefront. Roof gardens are planting works with different features than the designs created in the earth's crust. The designs of these gardens are applied by considering elements such as intended use, planted surface area, soil amount, maintenance management. Considering these elements, roof gardens are applied in two different types: extensive and intensive. Intensive roof gardens are usually created with plants of different sizes and allow for uses such as sitting, resting and eating. Designing these gardens in accordance with the uses of the buildings in which they are located can meet the green space needs of the building users. However, roof garden studies have not developed sufficiently in our country where the construction has increased considerably. For this reason, in this study, roof garden designs suitable for 3 different uses were created in a building example. As a result of the study, it is emphasized that roof garden proposals offered in accordance with space diversity and different design styles can offer nature-friendly healthy environments to building users.

Keywords : Green Space, Roof Garden, Landscape Design

1. INTRODUCTION

The rapid increase in urbanization has led to a gradual loss of green spaces as natural areas are replaced by buildings, roads and other urban elements. This loss means not only the loss of natural beauty, but also the loss of vital services provided by the urban ecosystem, such as clean air, water cycle, climate regulation and biodiversity (Onur & Altuntaş, 2021). Therefore,

protecting existing green areas and creating new green areas are of great importance for the sustainability of cities and improving the quality of human life (Güneroğlu et al., 2013).

However, increasing green spaces should not be achieved randomly, but within a system, by adopting a green infrastructure approach. Green infrastructure is based on the principle that natural and man-made elements are harmoniously connected in a network, providing environmental, economic and social benefits. This system not only makes cities look greener, but also more environmentally compatible and resilient (Dihkan, et al., 2015). At the same time, these areas contribute to social welfare by providing spaces where people can spend time in touch with nature, relieve stress and improve social relations. After parks, the most important green infrastructure elements that can be implemented in urban areas are rain gardens, bioswales, vertical gardens, road plantings, edible landscape areas, hobby gardens, biological ponds and roof gardens (Güneroğlu, et al., 2018).

Roof gardens are green infrastructures created by adding soil, plants and sometimes water elements to the roof of buildings. Roof gardens are becoming increasingly popular in order to increase the green areas of cities, improve the environment and offer an aesthetic appearance. The first examples of these gardens were encountered in ancient Mesopotamian civilizations and date back to 4000-600 BC. The Sumerians, Assyrians and Babylonian civilizations built Ziggurats in the form of an artificial hill in the form of a pyramid with 5-7 storey steps to reach God. Trees and shrubs were planted on each floor of this structure to protect from hot weather and to rest (Tokaç, 2009). In 800-1000 A.D., it was determined that the roofs and walls of the buildings belonging to the Viking period in Scotland, Scandinavia and Iceland were covered with grass (Aytin & Ovalı, 2016). In the early 20th century, Le Corbusier brought the term green roof to the agenda and used roof gardens as an indicator of modern architecture. Le Corbusier's roof garden design concept is to create a space that meets the needs of modern life and brings nature and architecture together. By proposing roof gardens to alleviate the coldness and hardness of the large concrete surfaces used in buildings, he aimed to add a green touch to living spaces. They also wanted to solve the lack of open green space in cities with dense high-rise buildings. In the second half of the 20th century, ecological awareness increased and lightweight, shallow green roof systems were developed. In recent years, green roofs have gained importance as sustainable practices and have become popular worldwide (Shafique & Rafiq, 2018). In Turkey, however, roof gardens are not sufficiently developed due to economic reasons (Düzenli et al., 2018). Since the design of roof garden systems applied in our country

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according to the conditions of other countries causes different problems, the widespread use of the system is prevented (Tokaç, 2009).

The use of roofs for various purposes by different civilizations according to their climate, geographical location and beliefs has inspired the development of roof garden applications today. Traditional roof uses have been adapted to modern urban life and laid the foundations of both aesthetic and functional green roof applications. Considering today's applications, the functions of roof gardens can be listed as follows (Ekşi & Uzun, 2016; Yalçınalp et al., 2018; Cengiz & Savaşır, 2024).

Reducing Heat Islands: Reduces the urban heat island effect caused by dense construction and balances the climate of cities by lowering air temperature.

Improving Air Quality: Thanks to plants, carbon dioxide and other pollutants in the air are reduced and the amount of oxygen increases, which contributes to cleaning the city air.

Rainwater Management: Roof gardens absorb rainwater, reducing the risk of flooding and easing the burden on infrastructure. This water is also naturally filtered, helping to protect water resources.

Reducing Noise Pollution: Roof gardens absorb noise from dense urban areas through vegetation, making urban areas quieter.

Supporting Biodiversity: They offer new habitats for plants and animals in the city, providing a habitat for birds, insects and other creatures, thus preserving biodiversity.

Agricultural Roof Gardens: Supporting ecosystems, these gardens can be equipped with local plants. They offer residents the opportunity to grow their own vegetables and fruits. They can be designed as community gardens or small-scale agricultural areas.

Thermal insulation and Energy Saving: Natural insulation contributes to energy savings by reducing the cooling and heating needs of buildings. This reduces the overall energy consumption of cities.

Providing Aesthetic and Recreation Area: Roof gardens add visual richness to cities and at the same time increase the value of the building by creating aesthetically attractive areas. They offer city dwellers the opportunity to rest, socialize and spend time with nature.

Psychological and Physical Health: Providing residents with the opportunity to be close to nature has a positive impact on mental health and encourages physical activity.

Roof gardens offer versatile solutions that serve a variety of needs and purposes. Roof spaces are made more functional with designs for different goals such as aesthetics, sustainability, social interaction and ecological balance. When evaluated from this perspective, roof gardens

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can generally be categorized into two main groups as extensive and intensive green roofs, considering soil depth, plant species, planted surface area, design, maintenance, management and vertical loads (Bianchini & Hewage, 2012).

1.1. Extensive Roof Gardens

This type of garden has little soil depth and low maintenance requirements. Since the soil depth is small, most roofs do not require additional structural support in practice. This feature makes green roofs more applicable in buildings. Drought-resistant, easy-care plants are generally preferred on such roofs. Hardy plants such as moss, sedum, cactus and some shrub species are commonly used in extensive green roofs. This way, the roof can remain healthy with minimal watering and maintenance. These roofs are not accessible, so they are not used for recreational purposes (Figure 1). The design concept of extensive green roofs aims to create green spaces that can be easily implemented in cities while offering ecological benefits by emphasizing sustainability (Getter & Rowe, 2006).

Figure 1. California Academy of Sciences, San Francisco, USA **(URL-1)**

1.2. Intensive Green Roofs

Intensive roof gardens are types of green roofs that function almost like a traditional garden, with a deeper soil layer, a variety of plant species, and extensive landscape design. Unlike extensive green roofs, intensive roofs usually have a large landscape component such as grass, shrubs, small trees, even water features and walkways (Figure 2). Therefore, they require more maintenance, irrigation and structural support. Intensive roof gardens provide a nature-infused space for building occupants, enabling multifaceted activities such as socialization, recreation, and environmental awareness (Tamang, et al., 2022). Table 1 compares the characteristics of intensive and sparse roofs.

Figure 2. Burnley Livings Roof, Melbourne, Australia (URL-2)

Table 1. Comparison of characteristics of extensive and intensive roofs

Criteria	Extensive Green Roof	Intensive Green Roof
Plant communities	Moss-Sedum-Herbs and Grasses	Grass or Perennials, Shrubs and Trees
Use	Ecological protection layer	Park like garden
Costs	Low	High
Irrigation	No	Regularly
Maintenance	Low	High
System height	60-200 mm	150-400 mm

They are important in urban life as versatile spaces that offer ample opportunities to get closer to nature and support a sustainable lifestyle. The activities that can be carried out in such roof gardens can range widely depending on the design of the space, plant diversity and roof capacity. Here are the activities that can be done in intensive roof gardens (Güneroğlu, 2016):

- **Meeting and Event Spaces:** It provides a perfect environment for events such as meetings, birthdays and weddings.
- **Café and Restaurant Areas:** It can host cafes and restaurants, offering visitors an environment in touch with nature.
- **Art Exhibitions and Performances:** For art events, outdoor concerts and exhibitions, roof gardens offer an impressive atmosphere and a different way of bringing art to the community.
- **Yoga and Meditation Spaces:** The environment of the roof gardens in harmony with nature creates a peaceful space for relaxing activities such as yoga and meditation.
- **Fitness and Sports Activities:** Large roof gardens can be made suitable for sports areas such as walking paths, outdoor fitness equipment, table tennis or a small jogging track.
- **Play and Children's Areas:** Playgrounds added to roof gardens provide children with a safe playground and a connection to nature.

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- **Community Gardening and Urban Agriculture:** Roof gardens are used as community gardening spaces, especially in urban areas. They support sustainable food production by providing space for growing vegetables, fruits and herbs.
- **Botanical Garden and Herb Gardening:** Large roof gardens can be designed as botanical areas where local or exotic plants can be grown. These areas can also be used to introduce plant species and raise environmental awareness.
- **Nature Education and Environmental Workshops:** Especially in schools and universities, roof gardens can be used as educational spaces to introduce nature and raise environmental awareness. Students can be taught about plant care, recycling and sustainability.
- **Ecological Workshops**: Workshops on ecological topics such as beekeeping, composting or organic gardening can be organized.
- **Therapy Gardens**: Intensive roof gardens can be used as therapy gardens for patients in hospitals or rehabilitation centers. Resting in a natural environment can positively affect the healing process.
- **Peace and Rest Areas**: Especially for those who want to get away from stressful city life, relaxation areas equipped with comfortable seating areas and small water features can be provided.
- **Film Screenings and Open Air Theaters**: Space can be created for small film screenings or theater performances.
- **Meteorological and Environmental Measurements**: Roof gardens can be used as research points for collecting climate data such as precipitation, temperature and wind.

The aim of the study is to design these gardens, which have an important potential in urban areas with both ecological and functional features and application types, for 3 different uses in a building example. If the selected building is a hotel, a youth center and a hospital, the roof gardens on its roofs were created by considering the design pattern and activity diversity. Autocad, Lumion and Sketchup programs were used to create the visuals.

2. DESIGN SUGGESTIONS

2.1. Roof Garden Project as a Hotel

The first design proposal is based on the fact that the building is a hotel. Hotel roof gardens should generally be oriented towards aesthetics, relaxation and views. They should include

relaxing elements such as areas where guests can relax and socialize, sun loungers and small seating areas. As plant elements, evergreen species that offer an aesthetic appearance and are colored with seasonal flowers can be preferred. Considering these elements, the ratio of green areas and hard surfaces is similar in the proposed roof garden project created with free organic lines. Plant spots belonging to trees, shrubs and grasses are designed in forms similar to the hard ground design character. Sitting corners have been created at different points for the hotel users to watch the view, sit and rest activities by using both movable and fixed equipment. In the central areas, large surfaces are left to serve different purposes such as music, dance, cocktails and exhibitions. In the roof garden where cover elements are also used, formable evergreen shrubs and ground cover plants with color and scent characteristics are used. In addition, tropical areas were tried to be evoked with dwarf palms. Plan, section and three-dimensional images of the study are given in Figure 3.

Figure 3. Roof garden project as a Hotel

2.2. Roof Garden Project as a Youth Center

The second design proposal is based on the fact that the building is a youth center. Roof gardens for youth centers should include social areas, open spaces for group activities and workshops.

Colorful plants, seating areas and sports or play areas can be designed to create a lively and energetic atmosphere. Considering these elements, the proportion of hard floors is higher than green areas because different spaces are designed for young people in the roof garden created with geometric forms such as square and rectangular. Plant spots belonging to trees, shrubs and grasses are designed in forms similar to the hard ground design character. Sitting corners were created for sitting, resting and eating activities for young people by using fixed fixtures at different points. In the central areas, large surfaces are left to serve different purposes such as music, dance, cocktails, exhibitions and shows. In addition, it is aimed to direct young people to sportive activities with a sports park and table tennis corners. In the roof garden, where the water element is also used, formable evergreen shrubs and ground cover plants with color and scent characteristics are used. Plants that provide shade are used next to the fixed reinforcements to prevent the effect of the sun. Plan, section and three-dimensional images of the study are given in the Figure 4.

Figure 4. Roof garden project as a Youth Center

2.3. Roof Garden Proposal as a Hospital

The third design proposal is based on the fact that the building is a hospital. Hospital roof gardens should offer rest and relaxation areas for people undergoing treatment. These areas should emphasize stress-reducing plant species, walking paths, quiet seating areas and elements that will provide a connection with nature. Plants with a peaceful and natural aesthetic, fragrant and known for their healing properties can be used. Since different spaces are designed for patients, companions and staff in the roof garden created with square and linear forms, the ratio of hard floors is higher than green areas. Plant spots belonging to trees, shrubs and grasses are arranged in linear character and built in forms similar to the hard ground. Both moving and still water surfaces are used in three different areas. Seating corners were created at the water's edge using fixed fixtures for sitting, resting and chatting. In the central area of the garden, where dry pools for children are also considered, a walking activity on a straight axis is envisioned. In addition, a giant screen viewing area has been created for mass screenings and promotions during open-air events. Evergreen shrubs and ground cover plants with color and scent characteristics are used in the roof garden where contact with water is also used in the pools. Plants that provide shade are used next to the fixed reinforcements to prevent the effect of the sun. Plan, section and three dimensional images of the study are given in Figure 5.

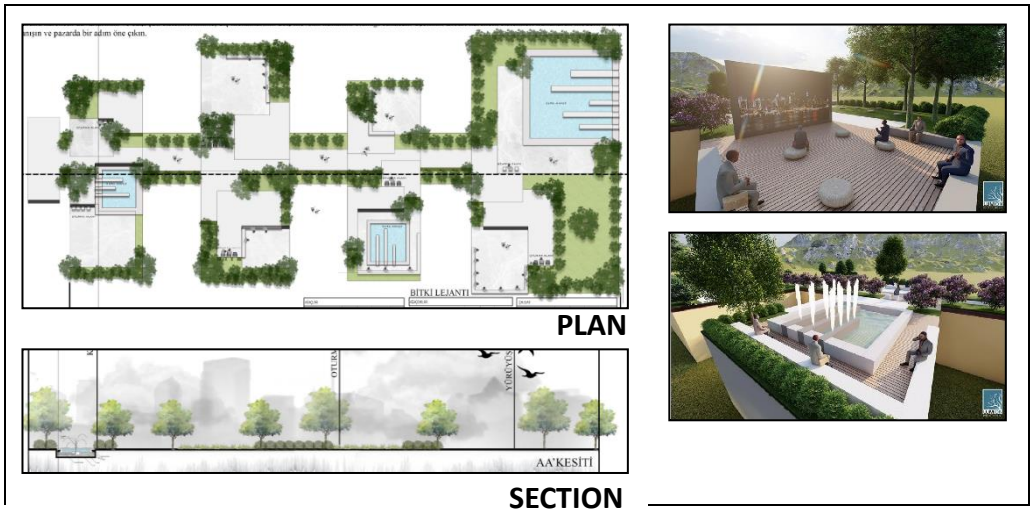

Figure 5. Roof garden project as a Hospital

3. CONCLUSION

In addition to creating an impressive aesthetic, it is very important to offer spaces that meet the various needs of users in roof garden designs. A variety of design patterns and activities enriches the user experience by increasing the functional and visual value of roof gardens. This diversity allows users to actively use the roof garden and makes the space attractive. The harmonious planning of activity areas and design patterns helps to transform the roof garden into a living space that contributes both functionally and aesthetically to the city. The design proposals presented in the study show that roof gardens play an important role in the process of building a sustainable and livable city. Although they are located in buildings with different functions, roof gardens add ecological and functional value while giving their buildings a unique character. For these reasons, roof gardens should be brought into cities. Local governments can incentivize the installation of green roofs on rooftops or vertical gardens on the walls of buildings. Incentives can include tax reductions, permit facilities or financial support.

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CLIMBING PLANTS IN LANDSCAPE ARCHITECTURE

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SUMMARY

Plants, which serve as one of the most important links of the food chain in the natural life cycle, are the most important living materials of landscape designs. Plants are used in landscape designs with different aesthetic, functional and ecological functions. In today's densely built-up cities, in addition to the parks that form large green areas, green areas are small, fragmented and far from each other. It is impossible to use a wide variety of plant species in the planting of small green areas. From this point of view, climbing plants can be used on the walls and ceilings of spaces as well as in small areas. Climbing plants are one of the important plant groups that combine functionality and aesthetics in landscape designs. They offer many advantages such as providing privacy, microclimate regulation and increasing biodiversity. The correct selection of these plants and their appropriate positioning in space add sustainability and aesthetic value to landscape projects. In this study, aesthetic, functional and ecological features of climbing plants in landscape designs were investigated. In addition, the design potentials of the 30 most preferred climbing plant taxa in landscape designs were examined. It was determined that these plants attract attention with their leaf, flower, fruit and calligraphic features. It was also determined that they have the potential to be utilized for agricultural applications in today's cities, especially with their edible properties. As a result, it was emphasized that sustainable and aesthetically rich areas in harmony with nature can be created by using climbing plants in landscape projects.

Keywords : Climbers, Planting Design, Landscape Potential

1. INTRODUCTION

Landscape architecture is a professional discipline that aims to organise natural and built environments in an aesthetic and functional way. This professional discipline has important objectives such as protecting the environment, creating aesthetic spaces and improving the quality of life of the society (Gül, 2000). Plants are the living design element in landscape architecture. Plants are not only an aesthetic element in designs, but also a functional and

ecologically important component. Attention should be paid to the selection and use of plants in landscape projects. Plant selection should be suitable for the climate, soil and intended use of the area. The correct selection and placement of plants improves the spatial experience while protecting ecosystems (Sarı & Karaşah, 2018). In the harmonious design of natural and built environments, plants determine the character of space, transform living spaces and support environmental sustainability. Plants have a wide variety from simple grasses to complex trees. There are millions of plant species on earth and these species determine the structure and functioning of the ecosystem in which they are found. The correct classification of plants in landscape architecture is critical in the design and implementation processes. Plants are divided into categories according to their morphological characteristics.

• Trees, which are the plants with the largest volume in landscape projects, play important roles such as providing shade, cutting wind and defining spatial boundaries. They also help protect the soil with their strong root systems.

• Shrubs, which are medium-sized plants, provide depth and texture by forming the lower layers of the landscape. They are often used to define boundaries, divide and provide privacy.

• Groundcovers, which are low plants, prevent erosion by covering the soil and make the landscape look more holistic. They also save water when used as an alternative to lawns.

• Climbers can grow using vertical surfaces without the need for horizontal spaces. These characteristics make the use of plants more efficient in small gardens, terraces and narrow urban spaces. It also allows buildings to be transformed into green walls, providing a natural solution in urban areas.

1.1.History of Climbing Plants

Climbing plants have been included in the architectural and aesthetic understanding of various cultures from the oldest civilisations of history to the present day. The first use of these plants is seen in the Hanging gardens of Babylon in Assyrian culture (Çerçi & Yüksel, 2019). The Hanging Gardens of Babylon were constructed in the 6th century BC by the Babylonian King Nebuchadnezzar II after his wife Queen Amytis longed for the green valleys of her native Medes. These gardens were located on high platforms and decorated with climbing plants that seemed to be suspended in the air (Figure 1). Climbing plants were also important in ancient Rome. Roman villas and palaces were decorated with climbing plants on the walls. These plants, which were used both to provide an aesthetic visual and to create shade and coolness in

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the hot days of summer, became a characteristic feature of Roman landscaping. The best example of this was found in Pompeii (Kalay & Özen, 2021).

Figure 1. Images of the Hanging Gardens of Babylon (URL-1)

In the Middle Ages, monasteries and palaces hosted spaces surrounded by natural plants. Especially in palace gardens in Europe, walls were decorated with climbing plants such as vines and roses. In this period, climbing plants were mostly used around enclosed courtyards and gardens, providing a green framework. At the same time, the cultivation of medicinal plants was also common in monastery gardens, and these plants were preserved in areas vertically surrounded by ivy plants (Çelmeli, 2024). As the Renaissance period was a period in which new horizons were opened in art and architecture, it also witnessed important developments in terms of garden art. In Italy and France, palace gardens were decorated with large vertical structures enriched with various plants (Gülgün, et al., 2007). Climbing plants were added to the stone walls used in the large gardens of the palaces, thus providing a natural transition between the palace and the gardens. Today, climbing plants have gained importance in urban areas in order to reduce environmental problems and create aesthetic areas. Climbing plants, which are used both in interior spaces and exterior facades, play important roles in cities both aesthetically, functionally and ecologically. For this reason, they are also widely preferred in vertical wall applications (Bekar & Güneroğlu, 2016).

1.2. Usage Characteristics of Climbing Plants

1.2.1. Aesthetic Use Features

The use of climbing plants in landscape designs is very effective with their leaf, flower, fruit and stem features (Erdoğan & Aliasghari Khabbazi, 2013). They offer effective visuals on the facades of buildings, walls and pergolas with their flowers blooming in spring, reddening leaves

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in autumn and calligraphic features (Figure 2). They add variety to compositions with their variegated coloured leaves. With their dense green leaf textures, they soften the structural elements and integrate the landscape with nature. They create a warm and inviting atmosphere by creating contrasting views especially with hard surfaces such as concrete or stone.

Figure 2. Images of aesthetic features of climbing plants (URL-2, URL-3, URL-4)

1.2.2. Ecological Use Features

Climbing plants, like all plants, reduce the carbon level in the atmosphere by absorbing carbon dioxide and produce oxygen. They also regulate the microclimate in the places where they are used. This ability to regulate the microclimate provides an important advantage, especially in urban landscaping projects. Thanks to their shading effect, they reduce the heating of walls and surfaces, reducing the cooling need of buildings in summer and saving energy (Figure 3). They can also filter dust and dirt, which helps to improve air quality, especially in dense urban centres (Ayaşlıgil, 1988). Climbing plants provide shelter and food sources for various bird species, insects, butterflies and other wildlife. These plants increase the ecological value of the landscape by supporting biodiversity in the environment. In addition, they can provide ecological environments even in narrow spaces as they take up less space than other plants.

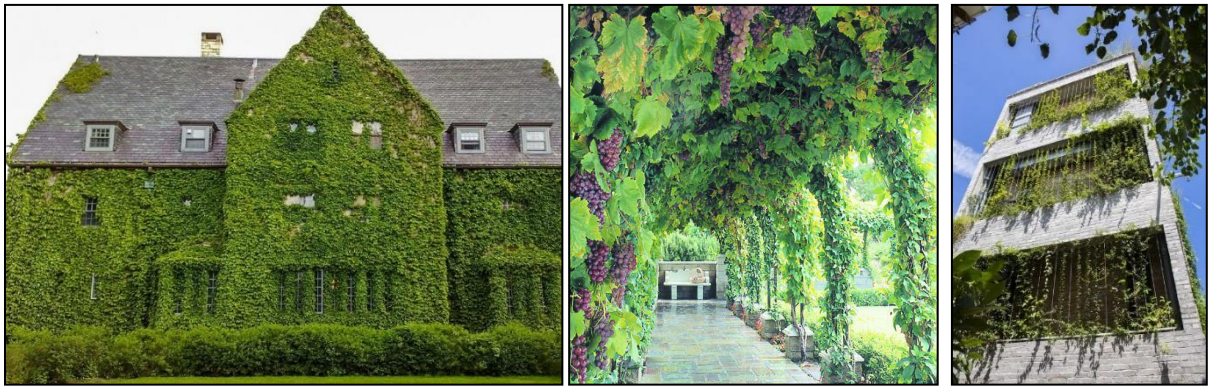

Figure 3. Images of ecological characteristics of climbing plants (URL-5, URL-6,URL-7)

1.2.3. Functional Use Features

These plants are used to provide shade in sunny areas by utilising their intense covering feature (Figure 4). Climbing plants are wrapped around iron, wood and concrete fences and used as border elements. They also act as a natural screen by providing visual privacy. They camouflage vertical building surfaces (Akarsu, 2009). They provide protection from unwanted glances, especially in dense residential areas. In addition, dense leafy species help the landscape to create a calmer atmosphere by reducing noise and wind. They are also used to prevent erosion and provide slope stabilisation. With their different forms and foliage characteristics, they are utilised as accent elements at the entrances of spaces. Since the fruits and leaves of some climbing plants have nutritional value, they are also used for utilitarian purposes. They are also used to provide custic comfort in interior spaces.

Figure 4. Images of functional characteristics of climbing plants (URL-8, URL-9)

Climbing plants have a wide range of uses thanks to their various attachment properties as well as different usage possibilities. These plants, which can easily adapt to different surfaces with their stems, leaves, leeches or clinging roots (Anşin & Terzioğlu, 2011; Tokatlı, 2021), can be easily applied on walls, pergolas, balconies, fences and vertical surfaces. These features contribute to the creation of a natural green texture even in narrow or restricted areas. In order to overcome the limited space problem caused by dense construction in the urban environment, climbing plants offer versatile solutions in landscape design thanks to their adaptability to all kinds of surfaces. For this reason, the families, life forms, leaf conditions, aesthetic characteristics and edibility of the 30 climbing plant taxa investigated in this study are given in Table 1.

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Table 1. Some climbing plant taxa and their characteristics (Anşin & Terzioğlu, 2011; Çelik vd., 2015; Avşar & Ok, 2018; Sarı vd., 2020; Çorbacı vd., 2020; Çorbacı vd., 2022)

Family	Latin Name	Turkish Name	Fruit	Leaf	Flower	Calligraphy	Smell	Autumn Colouring	Evergreen	Deciduous	Natural	Exotic	Edible
Actinidiaceae	*Actinidia sinensis* Planch	Kivi	X		X	X				X		X	X
Apocynaceae	*Vinca major* L.	Büyük Yap. Cezayir Menekşesi			X				X		X		
	Vinca major L. 'Aurea Variegata'	Alacalı Büyük Çiçekli Cezayir Menekşesi		X	X				X		X		
	Vinca minor	Küçük Cezayir menekşesi			X				X		X		
Araliaceae	*Hedera helix* L.	Orman Sarmaşığı		X					X		X		
	Hedera colchica K. Koch	Kara Sarmaşık		X					X		X		
	Hedera helix L. 'Aureo-Variegata'	Dışı Sarı AlacalıYap. Kaya Sarmaşığı		X					X		X		
Bignonaceae	*Campsis radicans* L. Seem.	Acem Borusu			X					X		X	
Caprifoliaceae	*Lonicera caprifolium* L.	Kokulu Hanımeli			X		X		X		X		
	Lonicera japonica Thunb.	Japon Hanımelisi			X		X		X			X	
Celastraceae	*Celastrus orbiculatus* Thunb.	Yaban Yasemini	X					X		X		X	
Fabaceae	*Wisteria floribunda*	Çin mor salkımı			X	X	X			X		X	
	Wisteria sinensis Sims Sweet	Mor Salkım			X	X	X			X		X	
Hydrangeaceae	*Hydrangea petiolaris* Zuuc.	Sarmaşık Ortanca			X					X		X	
Lardizabalaceae	*Akebia quinata* Houtt. Decne.	Çikolata Sarmaşığı	X		X		X			X		X	X
Liliaceae	*Smilax excelsa L.*	Saparna	X						X		X		X
Nyctaginaceae	*Bougainvillea spectabilis* Willd.	Gelin Duvağı			X			X				X	
Oleaceae	*Jasminum nudiflorum* Lindl.	Kış Yasemini ve Sarı Yasemin			X					X		X	
	Trachelospermum jasminoides Lindl. Lem.	Yıldız Çiçekli Yasemin			X		X		X			X	
Passifloraceae	*Passiflora coerulea* L.	Çarkıfelek	X		X					X		X	X
	Passiflora edulis Sims	Maruçya	X		X					X		X	X
Ranunculaceae	*Clematis vitalba* L.	Akasma			X					X	X		
Rosaceae	*Rosa* spp.	Sarmaşık Gülü			X		X			X		X	
	Rosa canina L.	Kuşburnu	X		X					X	X		X
	Rubus fruticosus L.	Böğürtlen	X							X	X		X
	Rubus idaeus L.	Ahududu	X							X	X		X
Vitaceae	*Parthenocissus tricuspidata* Sieb. & Zucc.	3 Loplu Amerikan Sarmaşığı	X	X		X				X		X	
	Parthenocissus quinquefolia L. Planch.	5 Loplu Amerikan Sarmaşığı	X	X		X		X		X		X	
	Vitis vinifera L.	Asma	X	X		X	X			X	X		X

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	Vitis sylvestris Gmelin	Yaban Asması	X			X				X	X		

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Within the scope of the study, a total of 30 taxa belonging to 16 families were evaluated. When the plants were evaluated according to their origin, the number of taxa of exotic origin was 16, while 14 taxa were native to Turkey. According to the family distribution, Rosaceae (4 taxa), Vitaceae (3 taxa) and Apocynaceae (3 taxa) families stand out. Although there are 19 deciduous taxa, there are 4 taxa with autumn colouration. When the taxa were evaluated aesthetically, it was determined that they can attract attention with their fruit characteristics as well as their flower beauty (Figure 5). In addition, it is seen that plants can be evaluated aesthetically in plant designs with their leaf aesthetics, calligraphy and odour features. The fact that they have edible properties shows that they have the potential to be utilised for providing food in urban areas.

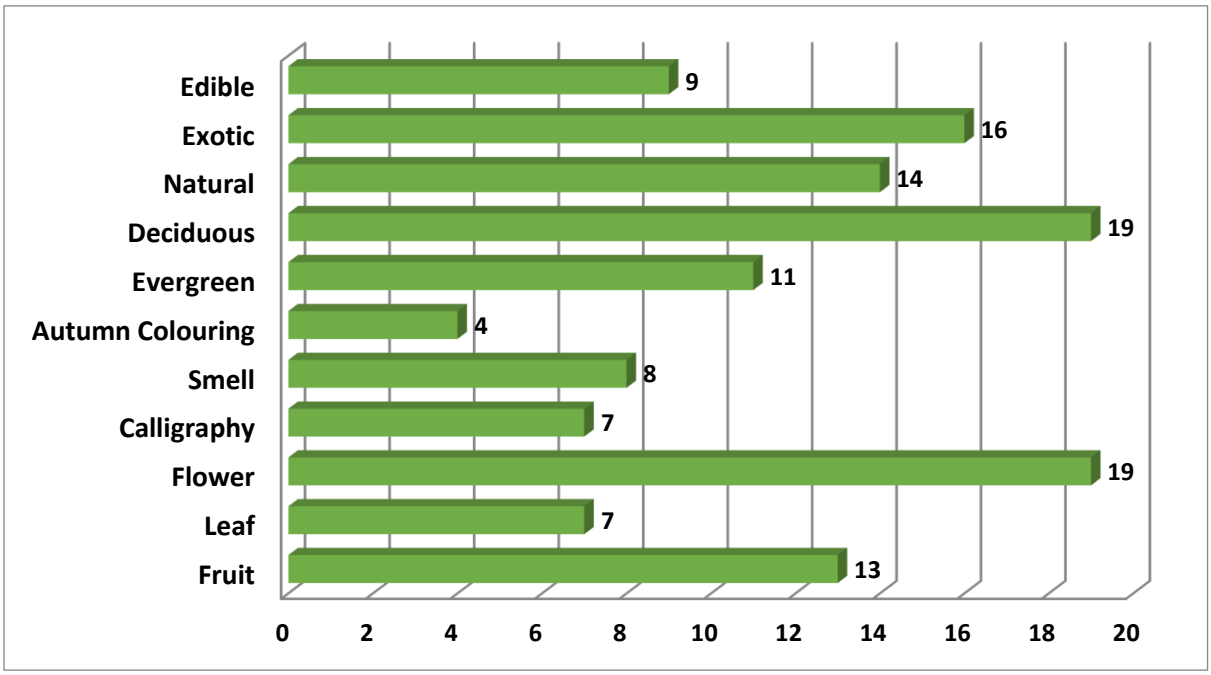

Figure 5. Quantity graph of the characteristics of plant taxa

2. CONCLUSIONS AND RECOMMENDATIONS

As a result of the study, it was determined that climbing plants can be applied to various surfaces and have high usage characteristics and design potentials. For this reason, the use of climbing plants should be increased in order to balance the aesthetic and environmental effects of construction in today's cities. Increasing the use of these plants in urban landscapes will be an important step for healthier and livable cities. Strategies recommended for the increased use of climbing plants in landscape designs are listed below.

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• In public spaces such as parks and walkways, special structures (pergolas, gazebos, arches, columns, etc.) can be created for climbing plants and their usage areas can be expanded.

•Climbing plants can be integrated with urban furniture such as seating areas, rubbish bins, bus stops and street lamps to increase their use.

•Climbing plants can be used in areas that cause bad appearance and noise pollution such as viaduct legs and retaining walls in the city.

•Their use can be encouraged to prevent air pollution in industrial areas with a shortage of green space.

•Awareness activities can be organised in social media in cooperation with municipalities and landscape architects about the benefits and use of climbing plants. The environmental and economic benefits of these plants can be explained especially to building owners and site managers.

•The use of natural climbing plants should be encouraged. These plants provide a more durable and sustainable greening by adapting to local climatic conditions and soil structure. For this purpose, both plant supply and financial support can be provided by municipalities.

These recommendations provide sustainable and aesthetic solutions in the urban landscape and contribute to the provision of a healthier environment for city dwellers.

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HARŞİT ÇAYI (TÜRKİYE)' DAN ÖRNEKLENEN *ALBURNUS DERJUGINI* VE *VIMBA VIMBA* (LEUCISCIDAE)'NIN OTOLİT MORFOMETRİSİ VE ŞEKIL ANALİZLERİ İLE AYRIMI

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ÖZET

Balık otolitleri kullanılarak tür tanımlaması, taksonomik amaçlar için değerli ve uygulanabilir bir araçtır; otolit morfoloji ve otolit şekil analizleri, türler arası ve tür içi varyasyonları tanımlamak için uygun maliyetli olan tekniklerdir. Bu bağlamda, Leuciscidae, Sazangiller içinde en fazla tür çeşitliliğine sahip ve sistematik konumları halen tartışmalı olan familyalardan biridir. Bu çalışmada, iki Leuciscid türü olan *Alburnus derjugini* ve *Vimba vimba*' nın otolit şekil indeksleri (form faktör, boy-yükseklik oranı, yuvarlaklık, dairesellik, dikdörtgensellik ve eliptiklik) ve şekil analiz yöntemleri (eliptik Fourier katsayıları ve dalgacık dönüşümü analizi) kullanılarak türler arası varyasyonlarının incelenmesi amaçlanmıştır. *Alburnus derjugini* (N=41) ve *Vimba vimba* (N=43) bireyleri Harşit Çayı (Türkiye)'ndan örneklenmiştir. Analizlerde sağ asteriskus ve sağ lapillus otolitler kullanılmıştır. Ayrım Analizi (CDA), asteriskus ve lapillus otolitleri için sırasıyla %70,2 ve %75 (şekil indeksleri), %85,7 ve %86,9 (eliptik Fourier katsayıları), %92,9 ve %86,9 (dalgacık analizi) genel sınıflandırma başarı oranlarını ortaya çıkarmıştır. Ayrıca, PERMANOVA analizi üç yöntemin de iki Leuciscid türünün ayrımları için önemli olduğunu saptamıştır (P=0,0001). Sonuç olarak tür ayrımında kullanılan morfometri tabanlı bu yöntemlerin, oldukça maliyetli bir yöntem olan moleküler yöntemlere ek olarak, türler arası ve tür içi farklılıkların belirlenmesinde güvenilir bir şekilde kullanılabileceği önerilmektedir.

Anahtar Kelimeler: Leuciscidae, şekil indeksleri, eliptik Fourier katsayıları, dalgacık analizi, Harşit Çayı

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DISCRIMINATION OF *ALBURNUS DERJUGINI* AND *VIMBA VIMBA* (LEUCISCIDAE) SAMPLED FROM HARŞİT STREAM (TÜRKİYE) WITH OTOLITH MORPHOMETRY AND SHAPE ANALYSIS

ABSTRACT

Species identification using fish otoliths is a valuable and applicable tool for taxonomic purposes; otolith morphology and shape analyses are cost-effective techniques for identifying inter- and intraspecific variations. In this context, Leuciscidae is one of the families with the highest species diversity within the Cyprinidae, and its systematic position is still controversial. This study aims to investigate the interspecific variations of two Leuciscid species, *Alburnus derjugini* and *Vimba vimba*, using otolith shape indices (form factor, aspect ratio, roundness, circularity, rectangularity, and ellipticity) and shape analysis methods (elliptic Fourier coefficients and wavelet analysis). Specimens of *Alburnus derjugini* (N=41) and *Vimba vimba* (N=43) were collected from the Harşit Stream (Türkiye). Right asteriskus and right lapillus otoliths were used in the analyses. Canonical Discriminant Analysis (CDA) revealed overall classification success rates of 70.2% and 75% based on shape indices; 85.7% and 86.9% based on elliptic Fourier coefficients; and 92.9% and 86.9% based on wavelet analysis for asteriscus and lapillus otoliths, respectively, Additionally, PERMANOVA analysis indicated that all three methods were significant for the discrimination of the two Leuciscid species (P=0.0001). As a result, it is quite clear that these morphometry-based methods used in species discrimination can be used reliably in determining both inter-species and intra-species differences in addition to molecular methods that are quite expensive.

Keywords: Leuciscidae, shape indices, elliptic Fourier coefficients, wavelet analysis, Harşit Stream

INTRODUCTION

Otoliths, which are bioinorganic minerals found in teleost fishes' inner ears, are crucial for bony fish's physiological function because they help fishes sense sound and gravity by detecting changes in ambient water pressure (Thomas & Swearer, 2019). These calcified structures which are termed as saccular (sagittae, the largest otoliths in most teleost), utricular (lapilli) and lagenar (asterisci) otoliths are overlies the sensory epithelia in the inner ears of fishes (Casselman, 1987). They are an essential tool because of their morphological patterns. A fish's otolith shape is determined by its genotype, developmental stage (possibly characterized by a number of individual state variables like body size, age, sex, and sexual maturity), as well as the biotic and abiotic environments it has. In addition, knowledge of teleost systematics and biodiversity has greatly benefit been exposed to during its lifespan (Brophy et al., 2016; Arroyo-Zuniga et al., 2022). In addition, knowledge of teleost systematics and biodiversity has greatly benefited from analysis of otolith morphology and shape (Tuset et al., 2016; Zarei et al., 2023), as well as historic diversity, phylogeny, zoogeography (Pavlov & Osinov, 2023), ancient and modern fisheries (Van Neer et al., 2002), life history and habitat, and population structure (Neves et al., 2023). It is unclear and may differ between species how much genetics or

environment have a role in otolith shape variances. In recent decades, a practical and useful method for identifying species or populations has been the morphological, structural, and chemical characteristics of hard components, particularly otoliths (Zhao et al., 2018; Song et al., 2019; Arroyo-Zuniga et al., 2022).

Cypriniformes the largest clade of freshwater fishes, distributed worldwide except for Australia and South America, is the major component of Eurasian freshwater fish fauna (Yang et al., 2015). Recent studies of Cypriniformes have recommended elevation of some of these subfamilies/tribes to family status (Chen & Mayden, 2009; Mayden & Chen, 2010). In Cypriniforms, Leuciscidae and Cyprinidae families have the highest species diversity. The classification of the subfamily Leuciscinae of Leuciscidae family is still under discussion as various numbers of formal or informal groups have been recognized within it in this context. Therefore, different methods are needed to support and evaluate the systematic position of the genera and species included in this family and subfamily.

Species identification by fish otoliths is a valuable and applicable tool as a taxonomical purposes, morphology and otolith shape analyses are cost-effective techniques for identifying inter- and intraspecific variations. Several methods have been developed recently to describe the external contour or shape of otoliths; univariate descriptors such as shape indices (Tuset et al., 2003), geometric morphometrics (Ponton, 2006), wavelet functions (Parisi-Baradad et al., 2005; Sadighzadeh et al., 2014; Yedier et al., 2023), elliptic Fourier coefficients (Bose et al., 2020; Col & Yilmaz, 2022) growth markers (Benzinou et al., 2013), and geodesic methods (Benzinou et al., 2013). The effectiveness of these methods in identifying fish groups is frequently case-specific (Ponton 2006), and it is still unknown whether including additional sources of data would improve their effectiveness in identifying fish groups. The present study focuses on the (i) otolith morphometrics and shape analysis of two Leuciscid species, *Alburnus derjugini* and *Vimba vimba*, as an alternative method for detection of interspecific variation, and (ii) to evaluate the usefulness in the separation of species with more available method based on otolith shape.

1. MATERIAL AND METHODS

1.1.Study area and sampling

Alburnus derjugini (N=41) and *Vimba vimba* (N=43) individuals were collected from Harşit Stream-Gümüshane (Türkiye) in May 2021.

Immediately after sampling, the fish samples were labeled and frozen for subsequent biological analysis. Biological examinations were made on defrosted samples. First of all, total length (TL±0.1 cm) of each sample were recorded in the laboratory. Lagenar and urticular otolith pairs were removed for otolith shape analysis. In this study, the right otolith of samples was chosen to minimize recurrence for further investigations (Chen & Zhu, 2023).

1.2.Otolith morphometrics and shape analyis

Before the analysis, each right otoliths were systematically positioned. To analyze otolith shape, the lapilli and asterisci were photographed in transmitted light at the same magnification and resolution with Leica DFC295. The asteriscus length (AL), asteriscus height (AH), asteriscus perimeter (AP), asteriscus area (AA), lapillus length (LL) and lapillus width

(LW), lapillus perimeter (LP) and lapillus area (LA) were measured to the nearest 0.001 mm using Image J software (Figure1).

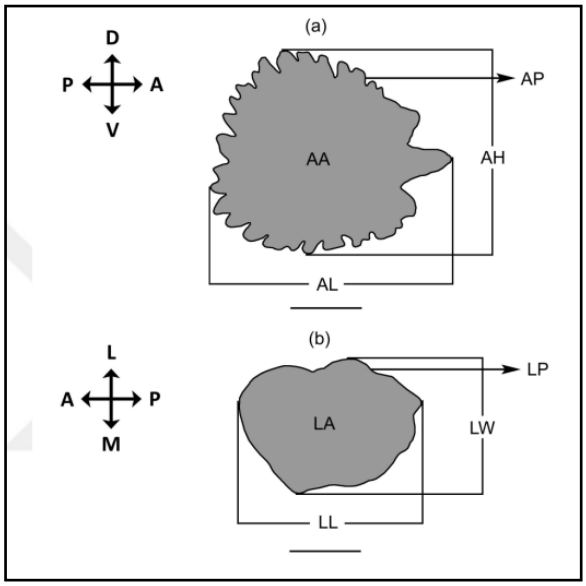

Figure 1. Right (a) Lagenar and (b)utricular ototlith pairs

Due to allometric correlations, the otolith shape indices, which are utilized as dimensionless markers of otolith form, can still be influenced by fish size. To remove he effects of fish size on otolith parameters, all otolith measurements were standardized according to the following formula:

$$Yi^* = Y_i \times (X_0 / Xi)^b,$$

where, Yi* is the standardized parameter; Yi is the original parameter; X0 is the mean total length for all specimen (13.4 cm); Xi is the total length of each specimen; b is the slope of the regression between log Yi and log Xi (Elliott et al., 1995; Lleonart et al., 2000). Then, shape indices (SIs) (form factor (FF), aspect ratio (AR), roundness (RO), rectangularity (REC), circularity (C) and ellipticity (E)) were derived from the morphometric measurements (Ponton, 2006; Tuset et al., 2003).

Afterwards, shapes of each utricular and lagenar otoliths were evaluated by both the elliptic Fourier coefficients (EFCs) and wavelet transform (WT). Shape 1.3 software (Iwata & Ukai, 2002) was utilized to calculate EFCs. The first four harmonics described >99.99 % of otolith shape indicating that shape could be sufficiently summarized by 13 Fourier coefficients for asteriscus and, five harmonics for lapillus, otolith shape was summarized 17 Fourier coefficients for lapillus otoliths. Finally, WT was implemented to asteriscus and lapillus otoliths of *A. derjugini* and *V. vimba*, separately. The wavelet 5 were selected as an intermediate function for two otolith types (Sadighzadeh et al., 2014). The WT was performed as described by (Parisi-Baradad et al., 2010) in site AFORO (http://isis.cmima.csic.es/aforo/index.jsp).

1.3.Data analysis

SIs, EFCs and WT were subjected to the same analytical procedures. Analysis were performed after the Shapiro-Wilk and Levene's tests. First, for SIs, independent samples t-test was used to compare the otolith shape of *A. derjugini* and *V. vimba*. Since the multicollinearity

problem was detected between SIs both asteriscus and lapillus otoliths, a principal component analysis (PCA) was performed to reduce the dimensionality of the data (Col & Yilmaz, 2022; Sadighzadeh et al., 2014). Principal component scores (PCs) were used in a canonical discriminant analysis (CDA, Box's M test, p=0.026 for asteriscus and p=0.000 for lapillus) to distinguish species (Song et al., 2019).

Then, for EFCs, an analysis of covariance (ANCOVA) was used to determine the effect of fish length on the EFCs for asteriscus and lapillus, separately. Because two EFCs (d3 and a4) were significantly different between species for asteriscus (ANCOVA, $p<0.05$), these coefficients were not included in the further analysis. In addition, there were no differences in terms of EFCs between species for lapillus (ANCOVA, $p>0.05$). Also, coefficient d1 for asteriscus and lapillus exhibited significant linear correlation with fish size and standardized according to Cardinale et al. (2004) and Song et al. (2018).

Since multicollinearity problem was not detected among the EFCs, a PCA based on the variance–covariance matrix was performed to reduce dimensionality of data and determine the effective EFCs (Sadighzadeh et al., 2014). The CDA (Box's M test, p=0.000 for asteriscus and p=0.396 for lapillus) was performed to test the accuracy of otolith shape variations between species using the effective coefficients. Finally, in WT analyis, were performed for wavelet 5 function for each otolith without loss of information. Since it was determined that the linear correlations between the effective PCs and the total length of the fish were not significant, no standardization was applied for WT. The CDA (Box's M test, p=0.030 for asteriscus and p=0.237 for lapillus) was performed with the building new PCA matrix and the accuracy of species identification was determined.

A permutational multivariate analysis of variance (one-way PERMANOVA) (Anderson, 2001) based on Euclidean distance and 9999 permutations was used for SIs, EFCs and WT comparisons between two Leuciscid species. All statistical analyses were performed in SPSS 21.0, Minitab 17.0, PAST 3.0 (Hammer et al., 2001) and the Microsoft Excel package.

2. RESULTS

2.1.Otolith morphometry

For lapillus otoliths, the general shape ranges from elongate−ovate to wide−ovate and may also be somewhat angular. The antero−and posteromedial edges are small and rounded. In most lapilli, the antero− and posterolateral edges are distinctly pro−nounced; in general, the posterolateral edge is forming the pointed posterior end of the lapillus. In addition, the general shape ranges from discoidal to oval, mesial and lateral surfaces are convex, and has an acoustic pit (fossa acustica) for asteriscus. The fossa acustica is surrounded by a larger lobe (lobus major), there is an indentation relatively deep between the antirostrum and pseudoantirostrum. Dorsal marjin ranges from rounded to serrate.

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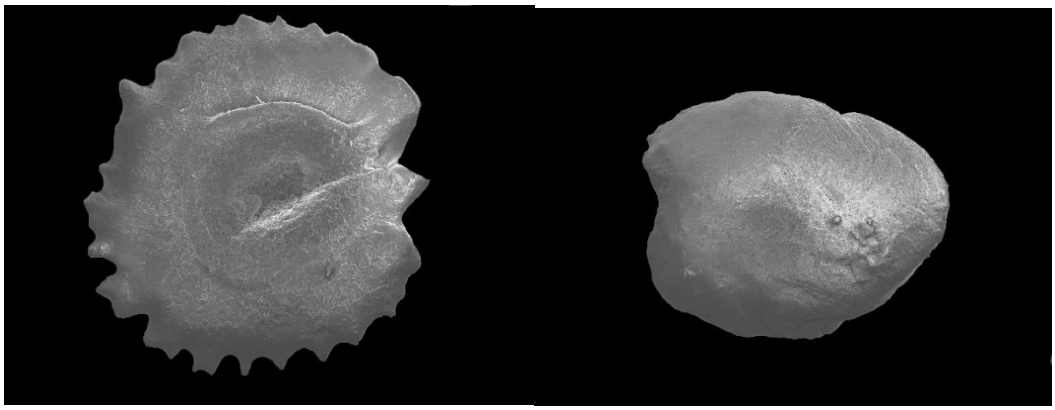

Figure 2. General otolith shape of asteriscus (proksimal surface) and lapillus (dorsal surface)

SIs of otoliths for *A. derjugini* and *V. vimba* were shown in Table 1. When all shape indices were significantly different for asteriscus, C, RO and REC were found statistically important for lapillus otoliths between two species (Independent samples t test, $p<0.05$, Table 1).

In the PCA, only one PC was obtained for both otoliths. This PC differentiated the species based on C and FF for asteriscus and only C for lapillus. Only one canonical discriminant function was used in the CDA analysis both asteriscus ($\lambda=0.754$, $p=0.000$) and lapillus ($\lambda=0.739$, $p=0.000$). The function 1 explained 100% of the total variance (Asteriscus, Eigenvalue=0.327; Lapillus, Eigenvalue=0.353). The CDA generated 70.2% and 75% overall classification success rate for asteriscus and lapillus otoliths, respectively. The percentages of classified individuals obtained with the CDA were 78% for A. *derjugini* and 62.8% for *V. vimba* for asteriscus, and 61% for *A. derjugini* and 88.4% for *V. vimba* for lapillus (Table 2). The PERMANOVA show significant difference between the species for both otolith pairs according to SIs (asteriscus, $F=22.4$, $p=0.0001$; lapillus, $F=19.5$, $p=0.0001$).

Table 1. Shape indices and the assessment of differences between otolith shape indices in *A.derjugini* and *V. Vimba*

Indices	Species	Asteriscus			Lapillus		
		Mean	SD	*p* (Ad-Vv)	Mean	SD	*p* (Ad-Vv)
FF	Ad	4.361	0.315		2.290	0.110	>0.05
	Vv	3.833	0.214	< 0.0001	2.295	0.086	
AR	Ad	0.965	0.054		1.195	0.065	>0.05
	Vv	1.064	0.057	< 0.0001	1.218	0.069	
C	Ad	17.098	1.104		14.889	0.247	
	Vv	18.423	1.570	< 0.0001	14.665	0.132	< 0.0001
RO	Ad	1.000	0.079		0.798	0.037	
	Vv	0.845	0.066	< 0.0001	0.770	0.033	< 0.0001
REC	Ad	0.754	0.024		0.747	0.021	
	Vv	-0.704	0.024	< 0.0001	0.735	0.022	< 0.0001

E	Ad	-0.018	0.027		0.088	0.027	
	Vv	0,031	0.026	< 0.0001	0.097	0.028	>0.05

FF, Form factor; AR, Aspect ratio; C, Circularity; RO, Roundness; REC, Rectangularity; E, Ellipticity; Ad, *Alburnus derjugini;* Vv, *Vimba vimba; SD,* Standard deviation*; p* (Ad–Vv), significance of differences between otolith shape indices in *A.derjugini* and *V. vimba* based on Independent samples t test

2.2.Otolith shape analysis

In the PCA using EFCs, only one PC was obtained both asteriscus and lapillus. For asteriscus otolith, the PC differentiated two species based on the coefficients d1 (R=0.91), and b2 (R=0.29). And also, only one canonical discriminant function was used in the CDA (λ=0.481 p=0.000). This function explained 100% of the total variance (Eigenvalue=1.079). A 88.1% overall classification success rate were obtained in CDA for A.derjugini and V.vimba. PERMANOVA test indicated significant differences between two species (F=35.05; p=0.0001). For lapillus otolith, coefficients (d1, R=0.82; a2, R=-0.52) were used to differentiate species in PCA. In CDA, one canonical discriminant function was used (λ=0.402 p=0.000). This function explained 100% of the total variance (Eigenvalue=1.488). A 86.9% overall classification success rate were obtained in CDA for A.derjugini and V.vimba in lapillus. However, the percentages of classified individuals obtained with the CDA were 85.4% for *A.derjugini* and 88.4% for *V. vimba* (Table 2). And also, PERMANOVA test indicate significant differences between two species (F=35.55; p=0.0001).

Table 2. Classification matrix results of the CDA based on different methods in *A. derjugini* and *V.vimba*

Otolith Type	Shape descriptor	Species	*A. derjugini*	*V. vimba*	Classification success
Asteriscus	SIs	*A. derjugini*	78.0	22.0	**70.2**
		V. vimba	37.2	62.8	
	EFCs	*A. derjugini*	87.8	12.2	**88.1**
		V. vimba	11.6	88.4	
	WLT 5	*A. derjugini*	95.1	4.9	**92.9**
		V. vimba	9.3	90.7	
Lapillus	SIs	*A. derjugini*	61.0	39.0	**75.0**
		V. vimba	11.6	88.4	
	EFCs	*A. derjugini*	85.4	14.6	**86.9**
		V. vimba	11.6	88.4	
	WLT 5	*A. derjugini*	82.9	17.1	**86.9**
		V. vimba	9.3	90.7	

In wavelet analysis, wavelet 5 coefficients used both asteriscus and lapillus in PCA, and only one PC was obtained. Only one canonical discriminant function was used in the CDA

(Asteriscus, λ=0.273, p=0.000; Lapillus, λ=0.370, p=0.000). The function 1 described 100% of the total variance (Asteriscus, Eigenvalue=2.269; Lapillus, Eigenvalue=1.704). The CDA produced an overall classification success rate of 92.9% and 86.9% for asteriscus and lapillus, respectively. The percentages of classified individuals obtained with the CDA were 95.1% for *A. derjugini* and 90.7% for *V.vimba* for asteriscus, and 82.9% for *A. derjugini* and 90.7% for *V.vimba* (Table 2). Average decomposition of otolith contour of two salmonid species using wavelet 5 is shown in Figure 3. In addition, the PERMANOVA analysis yielded significant difference between two Leuciscid species (Asteriscus, F=218.6; p=0.0001; Lapillus, F=139.7; p=0.0001).

3. DISCUSSION AND CONCLUSIONS

In this study, the authors evaluated the discrimination capacity of utricular and lagenar otolith pairs of two leuciscid species in term of otolith morphometry and shape analysis, and provided strong quantitative evidence that WT is a very powerful taxonomic specification method for *A. derjugini* and *V. vimba*. The results are particularly important as the taxonomy of species of the family Leuciscidae has been regarded as most diverse groups among Cypriniformes (Eschmeyer et al., 2023). In this context, otolith morphometry and shape can be used as an alternative method for species discrimination (Zischke et al., 2016; Bose et al., 2020; Arroyo-Zuniga et al., 2022; Yedier et al., 2023).

In addition, classification performance of several classifiers such as shape indices, elliptic Fourier coefficients and wavelet transform were tested in this study. According to literature, there are several studies which used different methods together mentioned in present study (Col & Yilmaz, 2022; D'Iglio et al., 2022; Pavlov, 2022; Chen & Zhu, 2023). The shape of the otoliths is affected by many factors. Therefore, in studies on otolith shape, shape indices may sometimes be insufficient to explain the true shape of the otolith. The shape indices are also too arbitrary and lead to confusion with some specific otolith patterns (Tuset et al., 2021). The the use of shape analysis methods in addition to shape indices to define the otolith shape will help the studies to get rid of subjectivity. In addition, discrimination of two species using asteriscus (70.2%) otoliths was found to be lower than lapillus (75%). According to Assis (2003), the main challenges in using asterisci to identify species are related to: (1) the shape differences in their parts are typically very subtle, not quantifiable, and difficult to describe by words; (2) frequently the same structures are present, despite being different in the degree of expression, giving them a relative value; and (3) the number of usable descriptors is rather small. However, when all shape indices were statistically different between *A.derjugini* and *V.vimba* for asteriscus, only C, RO and REC were found as different for lapillus between species. When the literature is examined, although there is no study investigating the shape indices of *A. derjugini* and *V.vimba*, there are several studies of other leuciscid species (Özpiçak et al., 2018; Abbasi et al., 2020). In addition, Bostanci et al. (2015) investigated otolith shape and morphometry of asteriscus otoliths in four *Alburnus* species for identifying this species and found 93.8% classification success. Ozpicak et al. (2021) analyzed phenotypic variability of asteriscus and lapillus otolith of Alburnus escherichii with shape indices. According to DCA included otolith shape, 79.9% of *A. escherichii* samples were correctly classified (mature and immature samples).

For both of the otolith pairs, WT is found as the best discrimination method in *A. derjugini* and *V. vimba* (Table 2). Tuset et al. (2021) were stated that WT is a better method than shape indices for shape analysis, independent of the type of classifiers. The findings of present study support this idea, too. There are several studies which support WT is a better discrimination method according to others in literature (Sadighzadeh et al., 2012; Sadighzadeh et al., 2014; Song et al., 2018). In addition to allowing the detection of otolith contour singularities, WT also identifies the location of these singularities (Parisi-Baradad et al., 2005). As a result, the contours of the otoliths may be examined point by point to determine where differences occur. This advantage allows us to restrict the analysis to a particular area of interest (Parisi-Baradad et al., 2005; Parisi-Baradad et al., 2010; Wiff et al., 2020). When the literature is examined, there are many studies in which wavelet analysis has been used to determine the variabilities in otolith characteristics both inta- and inter species (Tuset et al., 2020; Chen & Zhu, 2023 Yedier et al., 2023). On the contrary, Pavlov (2022) stated that elliptic Fourier analysis had higher discrimination success than the wavelet analysis in lagenar and utricular otoliths of two *Carassius* species, *Carassius gibelio* and *C. Carassius*. Despite its popularity, the Fourier transform method is unable to capture minor irregularities in otoliths because suitable modeling resolution requires the inclusion of a significant number of high-order harmonics that describe morphological traits (Parisi-Baradad et al., 2005). The EFCs only predicts a global approximation to the original shape and outline variability and could not identify specific zones of the otolith (Song et al., 2018). On the contrary, WT being a multiscale analysis, with spatial and frequency localization properties (Libungan & Palsson, 2015), allows the identification of specific morphological points (landmarks) along the contour (Parisi-Baradad et al., 2005). However, in the literature there are many studies in which EFCs were used to detect otolith shape differences within and between species (Merigot et al., 2007; Cerna et al., 2019; D'Iglio et al., 2021; Ibanez et al., 2022). Also, in the present study, for asteriscus otolith, EFCs give a 88.1% classification success rate but the classification success rate of WT is found as 92.9%. However, for lapillus otolith, the classification success rate is same both of the EFCs and WT (86.9%) (Table 2). This showed that the shape analysis method used may vary depending on the type of otolith studied.

Leuciscidae is one of the largest freshwater clades of Cypriniformes. Consequently, there are many molecular and morphometry-based studies carried out regarding the differentiation of this species belonging to Leuciscidae (Chen & Mayden, 2009; Perea et al., 2010; Bektas et al., 2020; Kalayci, 2022; Kucuk et al., 2023). To date, there were no study about otolith shape of A. derjugini and V. vimba, and also discriminating this leuciscid species using shape analysis methods, together. In the present study, both otolith morphology and shape analysis methods were useful for discriminating these two species. All otolith methods used in the differentiation of the two species have achieved a success rate of over 70%. Our study is the first investigation that compares actual data with related mathematical protocols by several methods together and provides results of a high degree of reliability for species identification in Leuciscidae. Assis (2005) mentioned that lapilli have a most regular intra and inter-specific morphology if compared to asteriscus and sagittae. In this study, although there was high discrimination success in both asteriscus and lapillus otoliths, the fact that shape analysis methods (EFCs and WT) gave the same value in lapillus otolith supports Assis (2005).

As a result, it is quite clear that these morphometry-based methods used in species discrimination can be used reliably in determining both inter-species and intra-species differences in addition to molecular methods that are quite expensive.

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DETERMİNATİON OF THE PHYLOGENETİC CHARACTERİSTİCS OF THE SPECİES *LUCİOBARBUS KERSİN* (HECKEL, 1843)

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Abstract

Luciobarbus kersin (Heckel, 1843), commonly known as the Kersin barbell, is a cyprinid fish found in freshwater habitats in Iran, Syria and southeastern Turkey. The main factors affecting the survival of this species are overfishing, habitat degradation, water pollution and human activities. For these reasons, this species has recently faced threats. Since the number of individuals is decreasing, conservation efforts should be initiated. For a good conservation program, genetic information should be determined. The aim of this study is to perform phylogenetic analyses based on sequences in the mtDNA cyt b gene region of this species. Muscle tissue was taken from fish samples purchased from local fishermen in Atatürk Dam Lake and DNA was isolated using a commercial kit. After DNA was obtained, mtDNA cyt b gene region was amplified by PCR. Sequence analysis was performed on the obtained PCR products with the 3500 XL Genetic Analyzer device. In order to perform the necessary analyses for the obtained sequences, a phylogenetic tree was created by comparing them with similar sequences in the NCBI gene bank.

Keywords: Cyprinidae, Kersin barbell, Conservation, Phylogeny, mtDNA cyt b,

Introduction

Luciobarbus kersin (Heckel, 1843), commonly known as the Kersin barbel, is a fish species first described by Heckel in 1843. It is primarily found in freshwater habitats across Iran, Syria, and southeastern Turkey. Some of the key characteristics of this species include a long, slender body, typically cylindrical in shape. Its body color ranges from silvery white to golden yellow, with the back often being darker. They are commonly found in streams, rivers, and ponds, and thrive in clean, oxygen-rich waters. Their diet mainly consists of small fish, insects, and plant material. The breeding season typically occurs in the spring, with females preferring to lay their eggs on aquatic plants. The species plays an important role in the ecosystem both as prey and predator. Its systematics are as follows.

Scientific classification:

Domain: Eukaryota

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Kingdom: Animalia
Phylum: Chordata
Class: Actinopterygii
Order: Cypriniformes
Family: Cyprinidae
Subfamily: Barbinae
Genus: Luciobarbus
Species*: L. kersin*

Some studies conducted in the region regarding the genus Luciobarbus are as follows; The sex distribution, age, weight and length relationships, as well as egg production, of the *Luciobarbus mystaceus* species in the Atatürk Dam reservoir have been studied (Dörtbudak, 2010). Some biological characteristics, as well as growth and reproductive features, of the Arabibarbus grypus species living in the Atatürk Dam reservoir have been studied (Doğan, 2007). Genetic diversity in the Barbus grypus (Heckel, 1843) populations living in the Euphrates and Tigris rivers has been analyzed based on sequence analysis of the mitochondrial DNA cytochrome c oxidase subunit I (mtDNA COI) gene region (Parmaksız et al., 2017). The levels of heavy metals in *Luciobarbus xanthopterus* and *Luciobarbus esocinus* species found in the Keban and Karakaya Dam reservoirs have been compared (Düşükcan et al., 2014, 2017). Similar studies have been conducted in reservoir lakes. In his 2022 study, Korkmaz analyzed the COI and cyt b sequences of this species and compared them among themselves. In this study, however, a comparison was made with species in the gene bank.

In recent years, it has been observed that the population of this species (*L. kersin*) has been declining due to habitat degradation, overfishing, and the introduction of invasive fish species into the Atatürk Dam reservoir. The aim of this study is to evaluate the phylogenetic relationship of *L. kersin* sequences from the Atatürk Dam reservoir by comparing them with Luciobarbus species in the gene bank.

Material and Methods

In this study, 3 randomly selected specimens of *L. kersin* sold by local fishermen at their stalls in the Atatürk Dam reservoir were used as sample material. The Atatürk Dam serves a multifaceted purpose aimed at strengthening the country's economy through electricity generation, aquaculture, and intensive agricultural activities (Parmaksız, 2022). The samples were brought to the Zoology Laboratory of the Department of Biology, Faculty of Science and Letters at Harran University, maintaining cold chain conditions. After species identification, muscle tissue was extracted from the specimens and placed in microcentrifuge tubes containing 96% ethanol, and stored at -20ºC until DNA extraction. Total DNA extraction from muscle tissue was performed according to the protocol instructions using the GenJET Genomic DNA Purification Kit (Thermo Scientific). Following the protocol, DNA presence was confirmed by loading DNA samples from all individuals into 0.8% agarose gel with SYBR Green, subjecting them to electrophoresis, and visualizing the results using a UV light source (Smart View Pro

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Imager System, Major Science). In this study, PCR was carried out using a Thermal Cycler (BIO-RAD T100™).

In our study, the sequences of the primers used to amplify the mtDNA cyt-b region from muscle samples were obtained from Briolay's study published in 1998, and are provided below:

L15267 F: 5'-GTT TGA TCC CGT TTC GTG TA-3'

H15891 R: 5'-AAT GAC TTG AAG AAC CAC CGT-3'

PCR amplification in this study was carried out using the BIO-RAD T100™ Thermal Cycler. The concentrations of DNA and chemicals used in PCR amplification reactions and the binding temperatures of primers were optimized in a gradient PCR device. The PCR mixture used in the replication of the target region is; 15.9 µl of dH2O, 2.5 µl of 1x PCR buffer, 2 µl of MgCl2, 0.5 µl of dNTPs, 1 µl of primer (F+R), 0.1 µl of Taq polymerase and 3 µl of template DNA. 2% agarose gel was used to control the amplified products after PCR. The agarose gel added to SYBR Green was placed in the tank containing 0.5x TBE (Tris/Boric acid/EDTA Buffer) solution and 2 µl of PCR products were loaded into the wells, and then run for 30 minutes at 100 V electric current and visualized on a UV light-emitting imaging device. Then, the obtained PCR products were sent to a commercial firm and sequence analysis was performed on the 3500 XL Genetic Analyzer (Thermo Fisher Scientific). The raw data of the mtDNA sequences sent to us from the commercial company were evaluated using the FinchTV program and converted into FASTA format. Sequences in FASTA format obtained were aligned using the BioEdit software version 7.2.5 program of all individuals. Then, the sequences were Blasted in the NCBI gene bank and phylogenetic analyzes between similar species were performed using the K2 parameter according to the Neighbor joining tree model in the MEGA X program and a phylogenetic tree was created . The Bootstrap test (1000 replicates) was used to test the reliability of nodes (tree branches).

Conclusion and Discussion

The raw data of the mtDNA cyt b sequences were analyzed using FinchTV 1.4 software, and the sequences of all individuals were aligned using BioEdit 7.2.5 software. Sequences of the target species' mtDNA cyt b region from the gene bank were included in the study, and similarity rates were determined.

Figure 1. The visualization of sequences from this study and the gene bank in the MEGA X program

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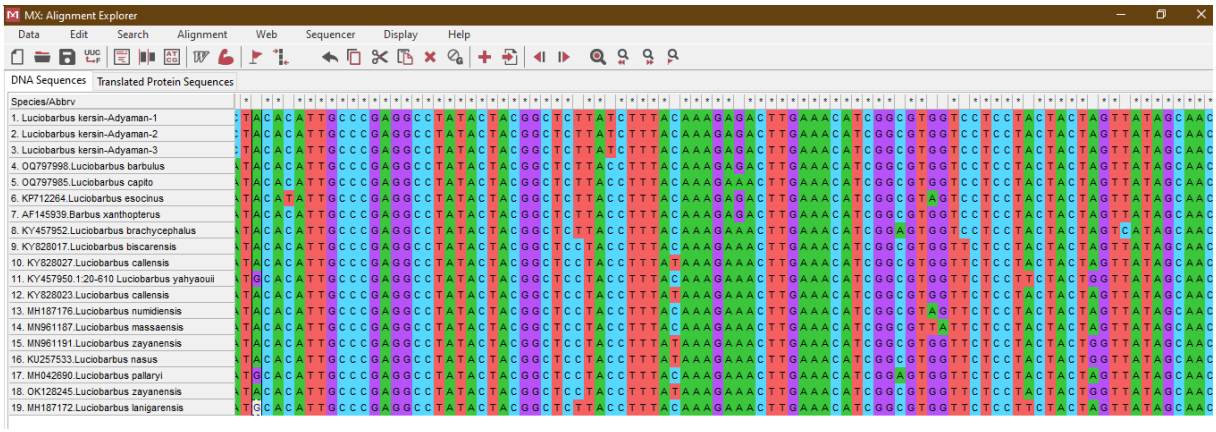

In Figure 1, the base similarities and differences between the species, as well as with other species, are shown. It was observed that there were few differences within the species, but these differences increased between species.

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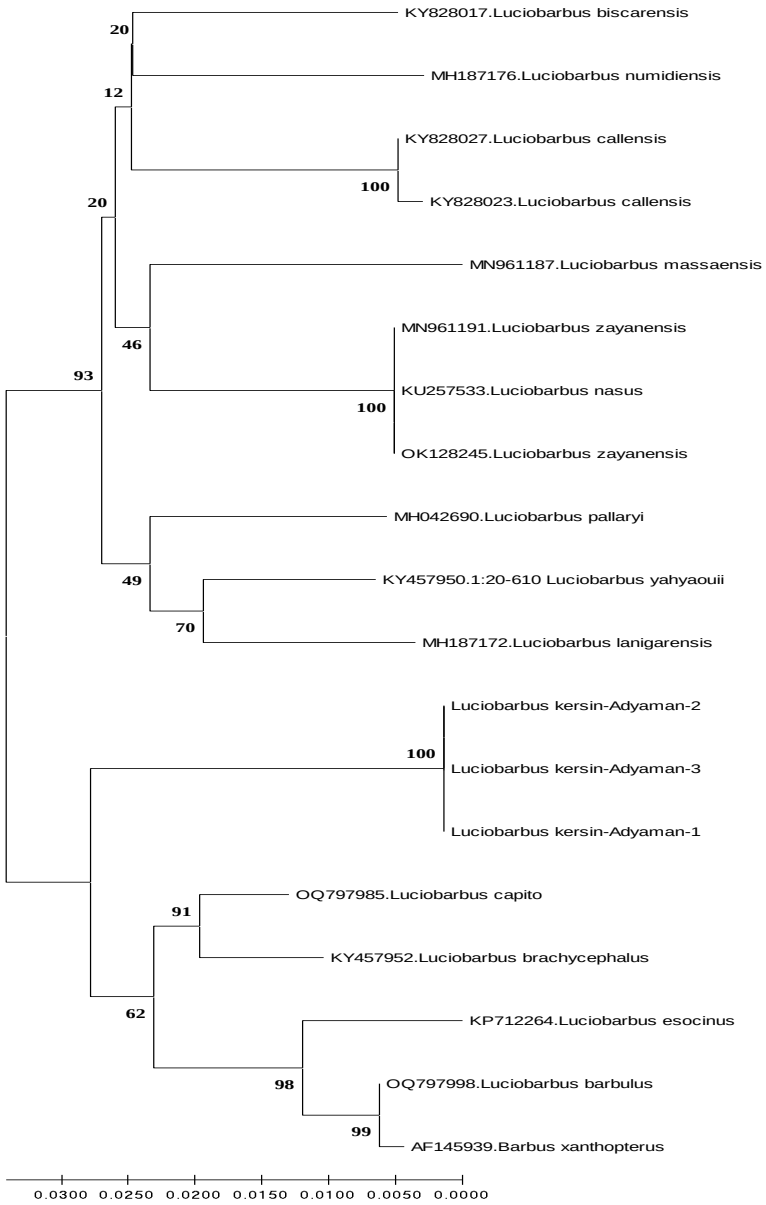
Figure 2. Phylogenetic Tree Based on mtDNA cyt b Region Sequences



The phylogenetic tree in Figure 2 is examined, it is seen that the *Luciobarbus* species first split into two main branches and formed a cluster. The *L. kersin* species showed a closer clustering with *L. capito*, *Luciobarbus brachycephalus*, *L. esocinus*, *L. barbulus*, and *Barbus xanthopterus* species compared to the other species.

Phylogenetic studies are conducted to understand the evolutionary relationships of organisms and to determine the ancestral connections between species. These studies use genetic, morphological, and other biological data to reveal how different organisms have evolved from common ancestors and how they have changed over time. Phylogenetic analyses can be carried out for the following purposes: Understanding how species, families, or other taxonomic groups are evolutionarily connected to one another. Identifying where newly discovered species belong on the evolutionary tree. Gaining in-depth knowledge of the evolutionary history and diversity of different species. Using genetic data to examine the genetic diversity and evolutionary changes of organisms. Investigating how genetic diseases in humans or other animals have evolved from an evolutionary perspective. Understanding the geographic distribution of species and how this distribution is related to their evolutionary history. Phylogenetic analyses, combined with biological and ecological data, provide crucial insights into the past and future of organisms.

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DETERMİNATİON OF THE PHYLOGENETİC CHARACTERİSTİCS OF THE SPECİES *LUCİOBARBUS XANTHOPTERUS* HECKEL, 1843

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Abstract

Luciobarbus xanthopterus Heckel, 1843, commonly known as the Yellowfin Barbel, is a cyprinid fish species endemic to the Tigris-Euphrates River System in Asia. The species is recognizable by its distinctive yellow fins and is found in freshwater habitats in this region. The conservation status of *Luciobarbus xanthopterus*, which has decreased significantly in these habitats, is currently listed as Vulnerable (VU) by the IUCN. The main factors affecting the survival of this species are overfishing, habitat degradation, water pollution and human activities. For these reasons, this species has recently faced threats. Since the number of individuals is decreasing, conservation efforts should be initiated. For a good conservation program, genetic information should be determined. The aim of this study is to perform phylogenetic analyses based on sequences in the mtDNA cyt b gene region of this species. Muscle tissue was taken from fish samples purchased from local fishermen in Atatürk Dam Lake and DNA was isolated using a commercial kit. After DNA was obtained, mtDNA cyt b gene region was amplified by PCR. Sequence analysis was performed on the obtained PCR products with the 3500 XL Genetic Analyzer device. In order to perform the necessary analyses for the obtained sequences, a phylogenetic tree was created by comparing them with similar sequences in the NCBI gene bank.

Keywords: Cyprinidae, Yellowfin barbell, Conservation, Phylogeny, mtDNA cyt b,

Introduction

Luciobarbus xanthopterus is a species of fish belonging to the Cyprinidae family. Its body is high and strongly compressed from the sides. The dorsal profile of the body rises gradually towards the dorsal fin and then suddenly drops, taking on a narrow, elongated shape at the caudal peduncle. The maximum body height is 3.9–4.1 times the standard length. The head length is approximately equal to the body height. The top of the head is flattened, and the

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snout is pointed. There is no lobe in the middle of the lower lip. The free margin of the dorsal fin is irregular with indentations and protrusions, and the last simple ray is well ossified, forming small tooth-like structures along its posterior edge. Due to their large size, they are often preferred as a food source, making them of economic importance (Geldiay and Balık, 2007). IUCN Conservation Status: VU (Vulnerable).

Şekil 1. The general body appearance of *Luciobarbus xanthopterus*

Scientific classification:

Domain: Eukaryota
Kingdom: Animalia
Phylum: Chordata
Class: Actinopterygii
Order: Cypriniformes
Family: Cyprinidae
Subfamily: Barbinae
Genus: Luciobarbus
Species: *L. xanthopterus*

Some studies conducted in regarding the genus Luciobarbus are as follows; The levels of heavy metals in *Luciobarbus xanthopterus* and *Luciobarbus esocinus* species found in Keban and Karakaya Reservoirs have been compared (Düşükcan et al., 2014, 2017). The annual productivity of *Luciobarbus xanthopterus* and *Luciobarbus esocinus*, species with economic value, has been determined in the Kemaliye Region of Keban Reservoir (Karlıdağ and Duman, 2018). Faddagh, M. S. 2016'da Irak sularındaki *Luciobarbus xanthopterus*'un genetik çeşitliliğini ortaya çıkarmak için çalışma yapmıştır (Faddagh, 2016). The mitochondrial status of certain species, such as *Luciobarbus esocinus*, *L. schejch*, *L. xanthopterus*, and *Tor grypus*, which are referred to as Iranian carp and show good development in the wild. In this study, genetic barcodes for these fish were prepared using cytochrome oxidase I (COI) gene sequences (Abbasi et al., 2018).

In recent years, it has been observed that the population of this species (*L. xanthopterus*) has been declining due to habitat degradation, overfishing, and the introduction of invasive fish species into the Atatürk Dam reservoir. The aim of this study is to evaluate the phylogenetic

relationship of *L. xanthopterus* sequences from the Atatürk Dam reservoir by comparing them with Luciobarbus species in the gene bank.

Material and Methods

Fish Sample Collection

The fish, which constitute the study material, were obtained from fishermen and transported to the laboratory at the Department of Biology, Faculty of Arts and Sciences, Harran University, via a cold chain. Some of the samples were brought to the laboratory through the cold chain, while others were collected in the field. For sampling, a small amount of muscle tissue from the surrounding muscles and the tissue where the pectoral fins are attached was carefully removed using sterile scissors. The samples were then placed in 1.5 ml Eppendorf tubes with 96% ethanol added and stored in a refrigerator at +4°C until the isolation process.

In our study, the sequences of the primers used to amplify the mtDNA cyt-b region from muscle samples were obtained from the study conducted by Briolay in 1998, as outlined below:L15267 F: 5'-GTT TGA TCC CGT TTC GTG TA-3' ; H15891 R: 5'-AAT GAC TTG AAG AAC CAC CGT-3'

DNA Extraction

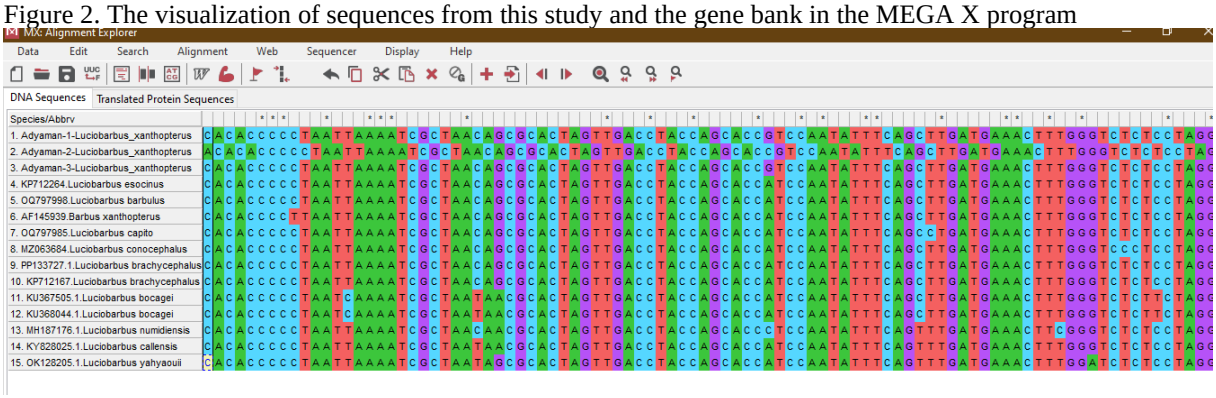
The DNA extraction in this study was performed using the Thermo Scientific GeneJET Genomic DNA Purification Kit. The protocol provided with the kit, obtained from the manufacturer, was applied in the most suitable way for the study, and DNA was successfully extracted. The kit protocol was followed exactly as instructed. The PCR conditions used in this study were as follows: Initial denaturation at 95°C for 3 minutes, Second denaturation at 95°C for 30 seconds, Annealing phase at 62°C for 45 seconds, Extension phase at 72°C for 1 minute, with a total of 35 cycles. Finally, the samples were held at 72°C for 10 minutes, and the process was completed.

In this study, the PCR mixture used for amplification of the region was prepared to a total volume of 25 µl, consisting of the following components: 15.09 µl dH_2O, 2.5 µl 1x PCR buffer, 2 µl $MgCl_2$, 0.5 µl dNTPs, 1 µl primers (F+R), 0.1 µl Taq polymerase, and 30 ng/µl template DNA. After the PCR process, the products were checked using a 1.5% agarose gel. For sequence analysis, the raw mtDNA data obtained from the commercial provider were evaluated using Chromas-Pro v 2.0.1 (Technelysium Pt Ltd). The mtDNA Cyt-b gene region sequences obtained using the forward and reverse PCR primers were visualized using BioEdit software version 7.2.5. Sequence alignment was performed using the Clustal W multiple sequence alignment program. The alignment was manually checked for discrepancies in the length of the sequences, and the alignment process was repeated for the start and end portions of the sequences to ensure proper alignment. The sequences were then prepared for analysis and saved in FASTA format.

Conclusion and Discussion

The raw data of the mtDNA cyt b sequences were analyzed using FinchTV 1.4 software, and the sequences of all individuals were aligned using BioEdit 7.2.5 software. Sequences of the target species' mtDNA cyt b region from the gene bank were included in the study, and similarity rates were determined.

Figure 2. The visualization of sequences from this study and the gene bank in the MEGA X program



In Figure 2, The sequences of *L. xanthopterus* are located at the top. the base similarities and differences between the species, as well as with other species, are shown. It was observed that there were few differences within the species, but these differences increased between species.

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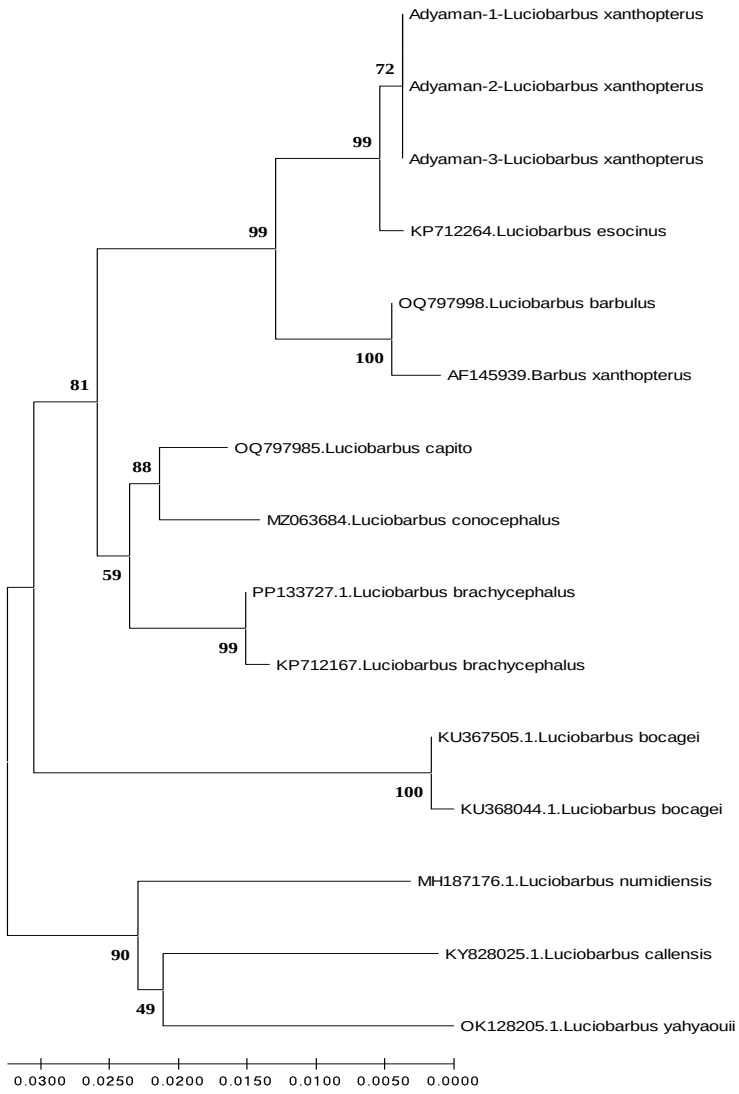
Figure 3. Phylogenetic Tree Based on mtDNA cyt b Region Sequences



The phylogenetic tree in Figure 3 is examined, it is seen that the *Luciobarbus* species first split into two main branches and formed a cluster. The species closest to *Luciobarbus xanthopterus*, which was collected from Adıyaman, is *Luciobarbus esocinus*. It has been determined that the most distantly related species are *Luciobarbus numidiensis*, *Luciobarbus callensis*, and *Luciobarbus yahyaouii*. Our studies on this topic are ongoing, and it is planned to conduct genetic marker analysis at the population level for this target species, with samples being collected from fishermen. Phylogenetic studies are conducted to understand the evolutionary relationships of organisms and to determine the ancestral connections between species. These studies use genetic, morphological, and other biological data to reveal how different organisms have evolved from common ancestors and how they have changed over time. Phylogenetic analyses can be carried out for the following purposes: Understanding how species, families, or other taxonomic groups are evolutionarily connected to one another. Identifying where newly discovered species belong on the evolutionary tree. Gaining in-depth knowledge of the evolutionary history and diversity of different species. Using genetic data to examine the genetic diversity and evolutionary changes of organisms. Investigating how genetic diseases in humans or other animals have evolved from an evolutionary perspective. Understanding the geographic distribution of species and how this distribution is related to their evolutionary history. Phylogenetic analyses, combined with biological and ecological data, provide crucial insights into the past and future of organisms.

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DYE REMOVAL BY BACTERIA ISOLATED FROM SUGAR INDUSTRY WASTEWATER

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ABSTRACT

Synthetic dyes in industrial wastewater resist degradation, harming ecosystems and biodiversity. While chemical treatments are costly, microbial dye removal provides a sustainable, cost-effective solution.

In this study, wastewater samples from three locations within the sugar industry were analyzed to isolate bacteria capable of dye bioaccumulation. From 40 initial isolates, 10 effectively bioaccumulated dyes and were selected for further testing. Serially diluted samples were cultured on nutrient agar with 50 ppm of Rose Bengal, Burazol Navy Blue Ed, Burazol Red Ed, and Burazol Yellow Ed-26 to identify potential bioaccumulators.

The three most promising candidates were selected for further testing in liquid media containing a dye concentration of 50 ppm for each dye. Dye removal efficacy was assessed by measuring optical density at dye-specific absorbance peaks (571 nm, 390.9 nm, 498 nm, and 425.7 nm, respectively) at 18, 24, 48 and 60 hours. Results showed that Isolate 1 achieved the highest dye removal for Rose Bengal at 60 hours with 64.91% and for Navy Blue at 18 hours with 31.44%, followed by dye release. Isolate 2 removed Rose Bengal most effectively at 48 hours with 61.38%, followed by dye release, while Isolate 3 removed Navy Blue at 18 hours with 27.25%, also followed by dye release. No dye removal was observed for Burazol Red or Burazol Yellow across all isolates.

These findings underscore the potential of bacterial isolates in bioaccumulating specific dyes, suggesting their applicability for eco-friendly treatment of dye-laden industrial wastewater.

Keywords: Bioaccumulation, dye removal, bacterial isolation, sugar industry wastewater

1. INTRODUCTION

Industrial wastewater enriched with synthetic dyes poses a significant environmental threat due to its resilience against natural degradation and detrimental effects on ecosystems and biodiversity. Synthetic dyes are extensively used across various industrial sectors, including textiles, paper, and sugar production, resulting in large volumes of colored effluent that, if discharged untreated, can severely impact aquatic environments [1]. These dyes reduce light penetration in water bodies, disrupting photosynthesis and leading to a cascade of negative ecological effects, including reduced biodiversity and changes in ecosystem function.

Furthermore, many dyes and their breakdown products are associated with toxicity, mutagenicity, and even carcinogenicity, thereby posing significant health risks to aquatic organisms and humans alike [2].

Conventional treatment methods for dye-laden wastewater, such as coagulation, flocculation, and activated carbon adsorption, often require high operational costs, generate secondary pollutants, and lack efficiency for certain dye types [3, 4]. In recent years, biological alternatives have gained prominence, with microbial dye removal emerging as a promising strategy due to its cost-effectiveness, environmental compatibility, and potential for efficient removal of diverse dye compounds. This approach utilizes microbial bioaccumulation, where specific microorganisms absorb and sequester dyes, effectively reducing dye concentration in wastewater and potentially allowing for further degradation of these compounds [5, 6, 7, 8, 9, 10].

In this study, bacterial isolates were sourced from sugar industry wastewater to evaluate their ability to bioaccumulate dyes. Building on prior research that demonstrates certain bacteria's capacity for dye uptake, this investigation aimed to identify bacterial strains capable of effectively bioaccumulating four synthetic dyes commonly found in industrial effluents: Rose Bengal, Burazol Navy Blue Ed, Burazol Red Ed, and Burazol Yellow Ed-26 [11, 12]. By collecting samples from three different sugar industry wastewater sites, the study sought to isolate bacteria that not only survive in dye-laden environments but also exhibit bioaccumulative activity, a key trait for sustainable wastewater treatment applications.

Rose Bengal, a pink xanthene dye with absorbance around 571 nm, is used in medical staining and cancer research but poses environmental risks due to its persistence in water bodies. Burazol Navy Blue Ed, Burazol Red Ed, and Burazol Yellow Ed-26 are synthetic azo dyes used in textiles and paper due to their strong colors and resistance to fading. However, these dyes are environmentally persistent and resist natural degradation, leading to toxicity in aquatic ecosystems and potential release of carcinogenic byproducts. Their resistance to breakdown underscores the need for sustainable microbial dye removal methods [12, 13].

2. MATERIAL AND METHOD

2.1. Materials

Rose Bengal, Burazol Navy Blue Ed, Burazol Red Ed, and Burazol Yellow Ed-26 were purchaed from BURBOYA textile company in Bursa/Turkiye.

The test solutions containing each dye were prepared by diluting a 1 mg/mL (1000 ppm) stock solution. The stock solution was prepared by dissolving the dye in distilled water and then filtering it through a 0.22 µm membrane filter to ensure sterility. To achieve a final concentration of 50 ppm for each dye in the medium, the stock solution was diluted accordingly. Dyes were added to the medium post-autoclaving to prevent degradation, ensuring that the medium itself was sterile while preserving the integrity of the dyes.

2.2. Bacterial Isolation

Wastewater samples were collected from three separate locations within the sugar industry and immediately transported to the laboratory. Serial dilutions were performed up to 10^{-5}, and each dilution was spread onto nutrient agar (NA) plates containing 50 ppm of one of the four synthetic dyes: Rose Bengal, Burazol Navy Blue Ed, Burazol Red Ed, and Burazol Yellow Ed-

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26. Plates were incubated at 37°C for 72 hours, with observations and sub-culturing every 24 hours to monitor bacterial growth and dye interaction. After incubation, distinct bacterial colonies were subcultured to obtain pure isolates, which were subsequently characterized by Gram staining. Among the isolates, three were selected based on their dye tolerance and bioaccumulative potential for further dye removal experiments in liquid media.

2.3. Dye Removal Experiments

The selected bacterial isolates were cultured in nutrient broth (NB) with a dye concentration of 50 ppm for each dye. Dye removal efficiency was assessed by measuring optical density at dye-specific absorbance wavelengths: 571 nm for Rose Bengal, 390.9 nm for Burazol Navy Blue Ed, 498 nm for Burazol Red Ed, and 425.7 nm for Burazol Yellow Ed-26. Measurements were taken at 18, 24, 48 and 60 hours, with incubation conditions set to 37°C and shaking at 150 rpm to maintain homogeneity.

3. RESULTS

3.1. Bacteria Isolation

A total of 40 bacterial isolates were obtained from sugar industry wastewater samples. Of these, 10 isolates demonstrated bioaccumulative activity on nutrient agar plates containing 50 ppm of dye. Based on their bioaccumulation potential, the top three isolates (Figure 3.1) were selected for further experiments in liquid media.

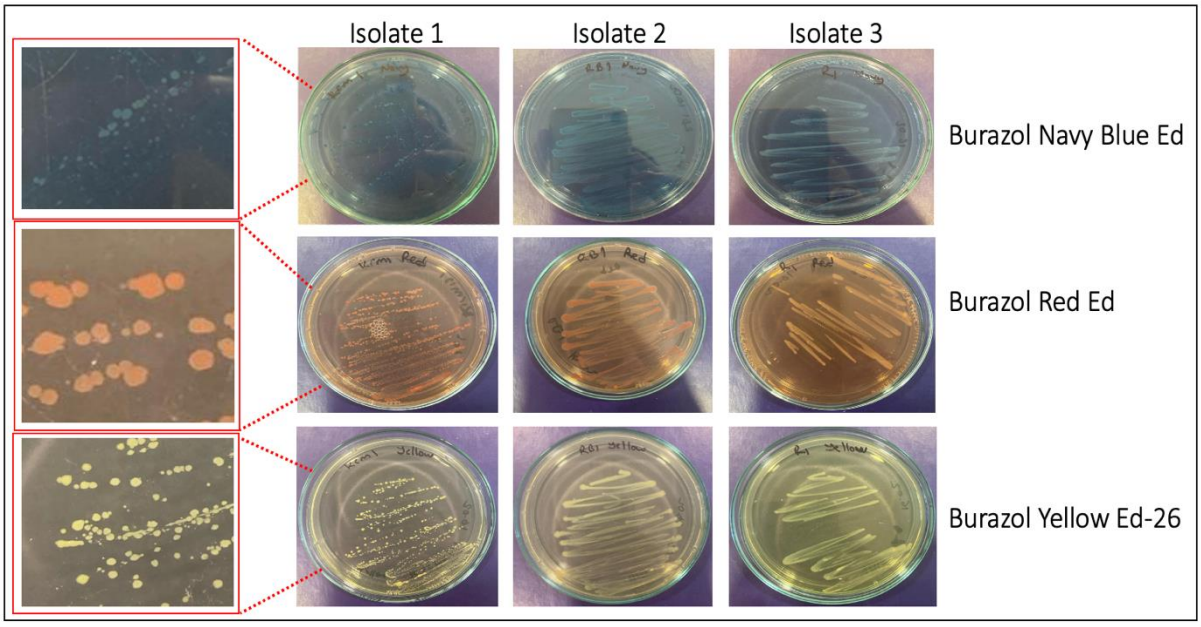

Figure 3.1. Bioaccumulation capabilities of selected tree bacterial isolates.

3.2. Dye Removal Experiments

The three selected bacterial isolates were tested in liquid media with each dye at a concentration of 50 ppm to evaluate their dye removal efficacy. Optical density measurements were taken at the dye-specific absorbance wavelengths (571 nm for Rose Bengal, 390.9 nm for Burazol Navy

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Blue Ed, 498 nm for Burazol Red Ed, and 425.7 nm for Burazol Yellow Ed-26) at 18, 24, 48, and 60 hours.

Isolate 1 exhibited the highest dye removal efficiency for Rose Bengal, achieving a 64.91% reduction at 60 hours, and removed Navy Blue by 31.44% at 24 hours before subsequently releasing the dye back into the media. Isolate 2 showed peak removal of Rose Bengal at 48 hours, with 61.38%, followed by dye release. Isolate 3 was most effective in removing Navy Blue, achieving 27.25% removal at 18 hours, also followed by dye release (Figure 3.2). None of the isolates showed significant removal of Burazol Red or Burazol Yellow Ed-26.

These results indicate a selective bioaccumulation capability among the isolates, with a dye removal for Rose Bengal and Navy Blue, yet no observable effect on Burazol Red or Burazol Yellow Ed-26.

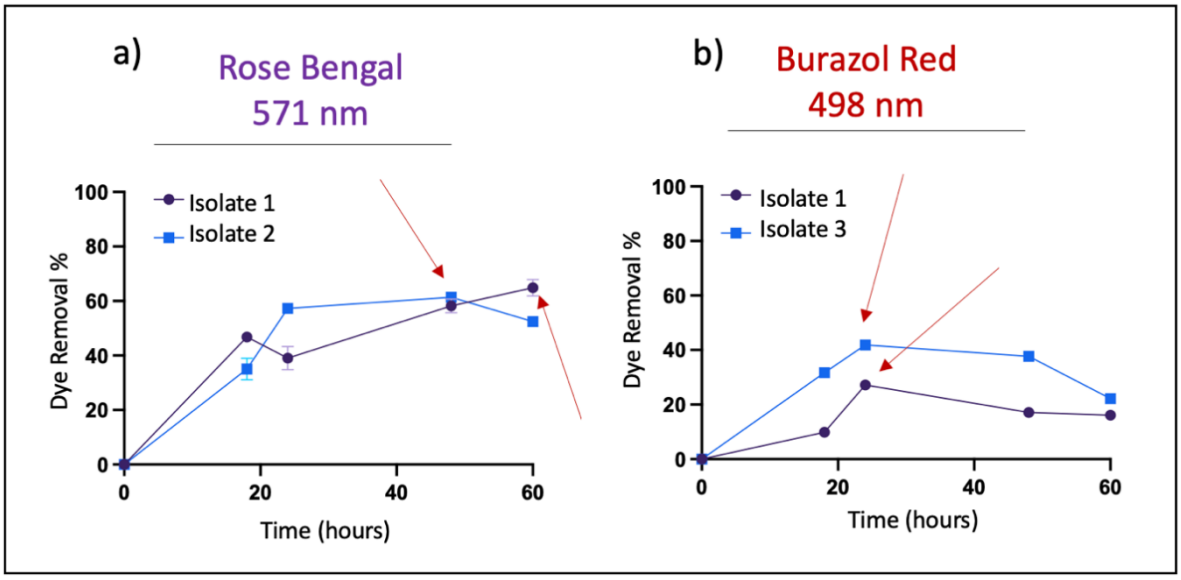

Figure 3.2. Dye removal efficiency of selected bacterial isolates over time.

4. CONCLUSION

This study demonstrates the potential of specific bacterial isolates to bioaccumulate and partially remove synthetic dyes from industrial wastewater, offering a more sustainable approach to managing dye pollution. From 40 initial isolates obtained from sugar industry wastewater, 10 showed bioaccumulative capabilities, and three isolates were selected for detailed testing in liquid media. Among these, two isolates effectively removed Rose Bengal, and one isolate demonstrated removal of Burazol Navy Blue Ed. However, none of the isolates achieved significant removal for Burazol Red or Burazol Yellow Ed-26, suggesting dye specificity in bioaccumulation efficacy.

These findings highlight the promise of bacterial bioaccumulation as a targeted, eco-friendly method for removing specific dyes from wastewater, particularly Rose Bengal and Navy Blue, though further optimization is needed to enhance removal rates and prevent dye release over time. Future studies could explore the impact of mixed microbial communities, and test scalability for industrial applications. This research underscores the potential of microbiological solutions in mitigating dye pollution, paving the way for more environmentally responsible industrial wastewater management practices.

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ISOLATION AND OPTIMIZATION OF A BROWN PIGMENT PRODUCED BY *BACILLUS ATROPHAEUS* JCM 9070 FROM PAPER INDUSTRY WASTEWATER

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ABSTRACT

Microbial pigments have gained considerable attention due to their potential applications in industries such as food, pharmaceuticals, textiles, and cosmetics. These naturally derived pigments offer advantages over synthetic dyes, including sustainability, biodegradability, and bioactivity. In this study, we isolated a pigment-producing bacterium which was identified as *Bacillus atrophaeus* JCM 9070 from paper industry wastewater treatment sludge. To investigate the properties of this pigment, we grew *Bacillus atrophaeus* in liquid culture until the culture turned dark brown. After centrifugation, the supernatant was used to measure the absorbance of the pigment, which was found to peak at 360 nm. We then optimized pigment production by testing different growth media, including LB, NB, and PGY, and by supplementing these media with 0.1 mM $CuSO_4$ or 2.5% molasses. Additionally, we evaluated the effect of different environmental conditions, including light and dark environments, shaking and static setups.

Among the conditions tested, light and shaking resulted in the fastest and highest pigment production, suggesting that both factors enhance pigment synthesis in *Bacillus atrophaeus* JCM 9070. Following the optimization experiments, we extracted the pigment using an acidification method and then lyophilized it for further analysis.

These findings provide valuable insights into the optimal conditions for producing this brown pigment. Future work will involve characterizing the pigment's structure and assessing its biological activities, including toxicity, anticancer, and antimicrobial properties. Overall, this brown pigment shows promising potential for industrial and biomedical applications, presenting a natural alternative to synthetic pigments.

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Keywords: Pigment Production, Green Synthesis of Pigment, Microbial Pigment, *Bacillus atrophaeus*, Brown Pigment

1. INTRODUCTION

Bacterial pigments have emerged as remarkable compounds with diverse applications in various industries, owing to their multifaceted properties and functionalities. These natural pigments, synthesized by a myriad of bacterial species, exhibit a broad spectrum of colors, including yellow, red, orange, green, blue, and brown [1, 2]. Among these hues, the brown-black bacterial pigments, notably produced by organisms like *Bacillus atrophaeus* JCM 9070, hold significant intrigue and promise for industrial evaluation and applications.

The fascination with bacterial pigments stems from their distinct advantages over synthetic dyes and pigments. These natural compounds boast biodegradability, non-toxicity, and eco-friendly characteristics, setting them apart from their synthetic counterparts that often pose environmental hazards during production, use, and disposal. Moreover, bacterial pigments exhibit stability under various environmental conditions, making them appealing for a wide array of industrial applications, including food, pharmaceuticals, cosmetics, textiles, and even in bioremediation processes [3, 4].

Furthermore, the scalability of production processes for these bacterial pigments is critical for their successful integration into industrial settings. Assessing the feasibility of large-scale production, cost-effectiveness, and downstream processing methods are integral aspects of evaluating the viability of utilizing *Bacillus atrophaeus* JCM 9070's brown pigment on an industrial scale [2, 5, 6]. *Bacillus atrophaeus* is a Gram-positive, rod-shaped bacterium from the Bacillus genus, known for its resilience and adaptability to diverse environments, including soil, water, and industrial waste. It is closely related to *Bacillus subtilis* and is often studied for its ability to produce bioactive compounds, including antimicrobial agents and pigments. Furthermore, *Bacillus atrophaeus* has demonstrated capabilities in bioremediation, such as the degradation of certain pollutants and heavy metal reduction, which are valuable for environmental management. Studies indicate that the bacterium's ability to withstand harsh conditions and produce secondary metabolites makes it a versatile candidate in sustainable applications across several industries [5].

The potential applications of this brown pigment extend beyond conventional industries. Its incorporation in advanced materials, such as inks, coatings, and biosensors, illustrates the breadth of opportunities these natural compounds offer. Moreover, the compatibility of bacterial pigments with ongoing trends toward sustainable practices and green technologies positions them as attractive alternatives in industries seeking eco-friendly solutions [7, 8, 9].

2. MATERIALS AND METHODS

2.1. Bacteria

The bacterial strain *B.atrophaues* JCM 9070 was isolated from biological treatment sludge of a paper industry and identified based on 16S rRNA gene sequencing and biochemical tests were performed as indicated in Oztat (2023) [10].

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2.2. Fermentation

The bacterial strain, stored in a 30% glycerol stock at -80°C, was activated by streaking on Nutrient Agar and then incubated at 30°C for 24 hours. Following incubation, a single colony was picked and inoculated into 50 mL of Nutrient Broth, then incubated overnight at 30°C at 200 rpm, constituting the primary inoculum.

After incubation, the established inoculum was utilized to inoculate %1 v/v (adjusted to McFarland 0.5) into different 100 mL liquid mediums which are indicated below, each in duplicate, and subjected to incubation at 30°C and 200 rpm for a period of 10 days.

In parallel, as a negative control, *Proteus mirabilis*, known not to produce the pigment under these conditions, were subjected to the same incubation conditions.

This methodology served to generate the bacterial culture necessary for subsequent experimentation and pigment production analysis while concurrently establishing a negative control to validate pigment production by the target strain.

Medium:

1. Nutrient Agar; 15 g/L agar, 3 g/L meat extract, 5 g/L peptone
2. Nutrient Broth + $CuSO_4$; 1 g/L D (+)-glucose, 15 g/L peptone, 6 g/L sodium chloride, 3 g/L yeast extract, 1% 0.1 mM $CuSO_4$
3. Nutrient Broth + $CuSO_4$ + Molasses; 1 g/L D (+)-glucose, 15 g/L peptone, 6 g/L sodium chloride, 3 g/L yeast extract, 1% 0.1 mM $CuSO_4$, %2.5 Molasses
4. Luria Bertani Broth + $CuSO_4$: 10g/L Tryptone, 10 g/L NaCl, 5 g/L Yeast Extract, 0.1 mM $CuSO_4$
5. Luria Bertani Broth + $CuSO_4$ + Molasses: 10g/L Tryptone, 10 g/L NaCl, 5 g/L Yeast Extract, 0.1 mM $CuSO_4$, %2.5 Molasses

- Molasses: Stock molasses has been prepared as 80 mL/L into distilled water from a 1.25 g/cm^3 main stock. To prepare %2.5 Molasses; 2.5 mL of stock molasses has been taken into 100 ml of medium.

2.3. Optimization of Culture Conditions

To optimize the culture conditions for pigment production, the effect of various environmental parameters was evaluated. After determining the peak wavelength of the pigment, four different conditions were tested in NB supplemented with 0.1 mM $CuSO_4$. The parameters included static versus shaking (150 rpm), and exposure to light versus dark conditions. All cultures were incubated at 30°C for 120 hours.

2.4. Extraction of Pigment

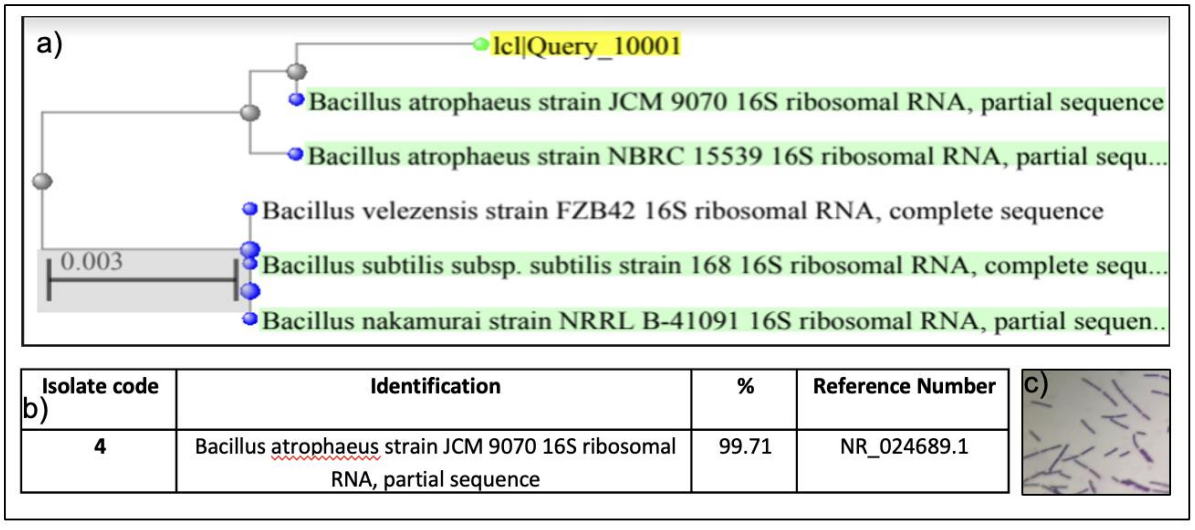
Protocol for Pigment Extraction from the Fermentation Broth

1. Culture conditions are maintained until brown pigmentation is observed in bacterial cultures. Once the brown color intensifies, cultures are harvested for centrifugation.
2. Bacterial cultures are centrifuged at 6000 xg for 15 minutes.
3. The supernatant and pellet are separated, with the pellet stored in the refrigerator. To the supernatant, 6 M HCl is added to adjust the pH to 2.
4. The acidified supernatant is allowed to incubate at room temperature for 4 hours.
5. After the incubation period, centrifugation is performed at 10000 xg for 15 minutes.
6. Following centrifugation, the pellet is washed four times with distilled water, with centrifugation repeated between each wash. If possible, supernatants are stored in the refrigerator.
7. After the final wash, the pellet and supernatant are separated, and the obtained pellet is lyophilized for drying. This represents our pigment, which should be stored at -80°C for further experiments.

3. RESULTS

3.1. Bacteria

The bacteria isolated from the paper industry wastewater sludge was identified as *Bacillus atrophaeus* JCM 9070 with a high sequence similarity of 99.71% to the reference strain, with GenBank accession number NR_024689.1 (Figure 3.1.a and Figure 3.1.b). This identification was further confirmed through Gram staining, which revealed the characteristic Gram-positive rod shape of *Bacillus* species (Figure 3.1.c). The high sequence similarity and Gram staining result collectively verify the identity of the isolated bacterium as *Bacillus atrophaeus* JCM9070, supporting its use in subsequent pigment production and optimization experiments.



Isolate code	Identification	%	Reference Number
4	Bacillus atrophaeus strain JCM 9070 16S ribosomal RNA, partial sequence	99.71	NR_024689.1

Figure 3.1. a) Phylogenetic tree b) reference number c) gram staining

3.2. Fermentation

The usage of different media revealed that after 144 hours of incubation, the *Bacillus atrophaeus* isolate produced the most significant pigment in Nutrient Broth (NB), compared to other media tested, including 2% molasses, 5% molasses, TGY-B, and Nutrient Agar (NA) as seen in Figure 3.2. Based on these observations, we decided to continue fermentation in NB and LB medium supplemented with 0.1 mM $CuSO_4$. In the second round of fermentation, we evaluated the following combinations: NB + $CuSO_4$, NB + $CuSO_4$ + molasses, and the same combinations in LB medium.

Among these conditions, NB supplemented with $CuSO_4$ produced the most substantial pigment yield, with a distinct brown coloration evident by the 72nd hour of incubation, as shown in Figure 3.3. The negative control remained clear, confirming that the pigment production was specifically attributed to the bacterial growth. Based on these results, pigment extraction was carried out using the NB + $CuSO_4$ culture medium.

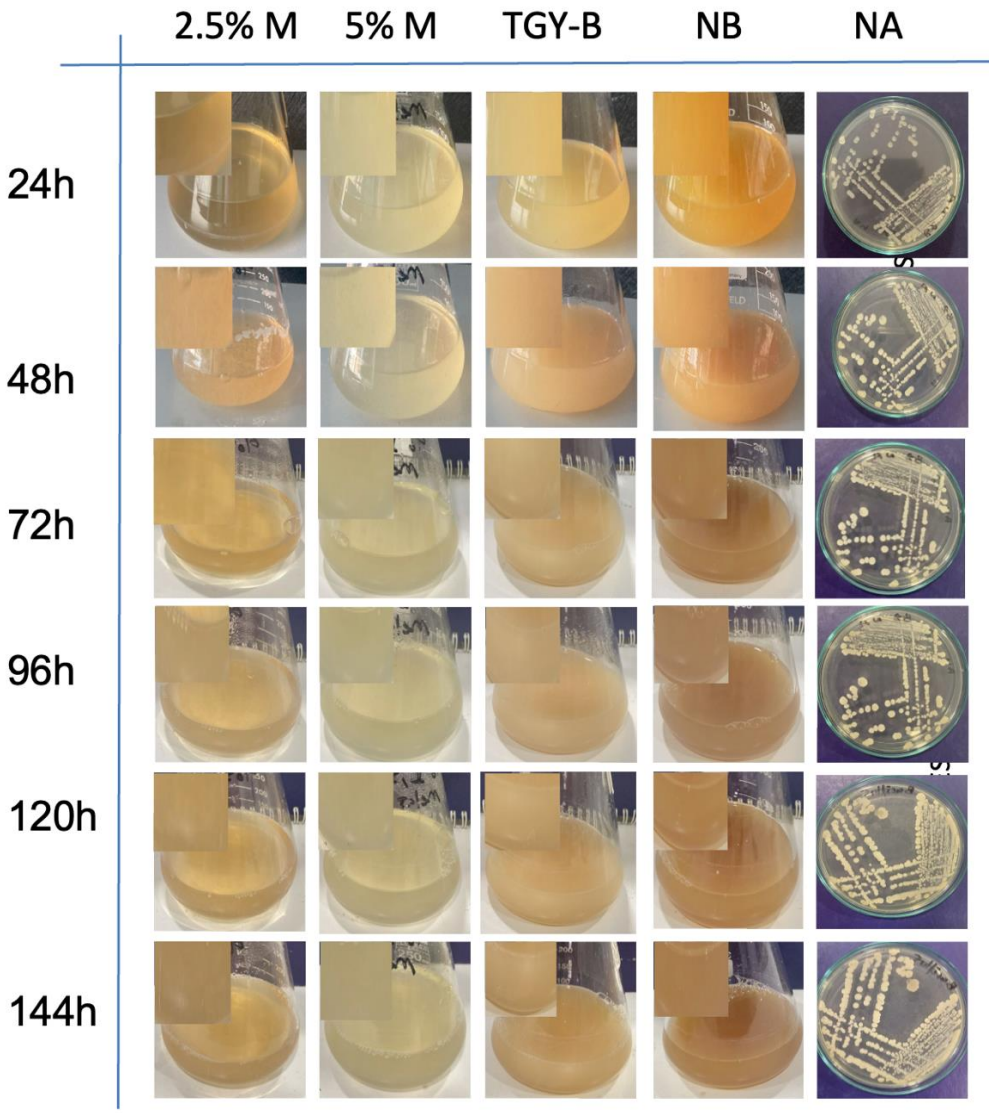


Figure 3.2. Pigment production in *Bacillus atrophaeus* under different fermentation medium

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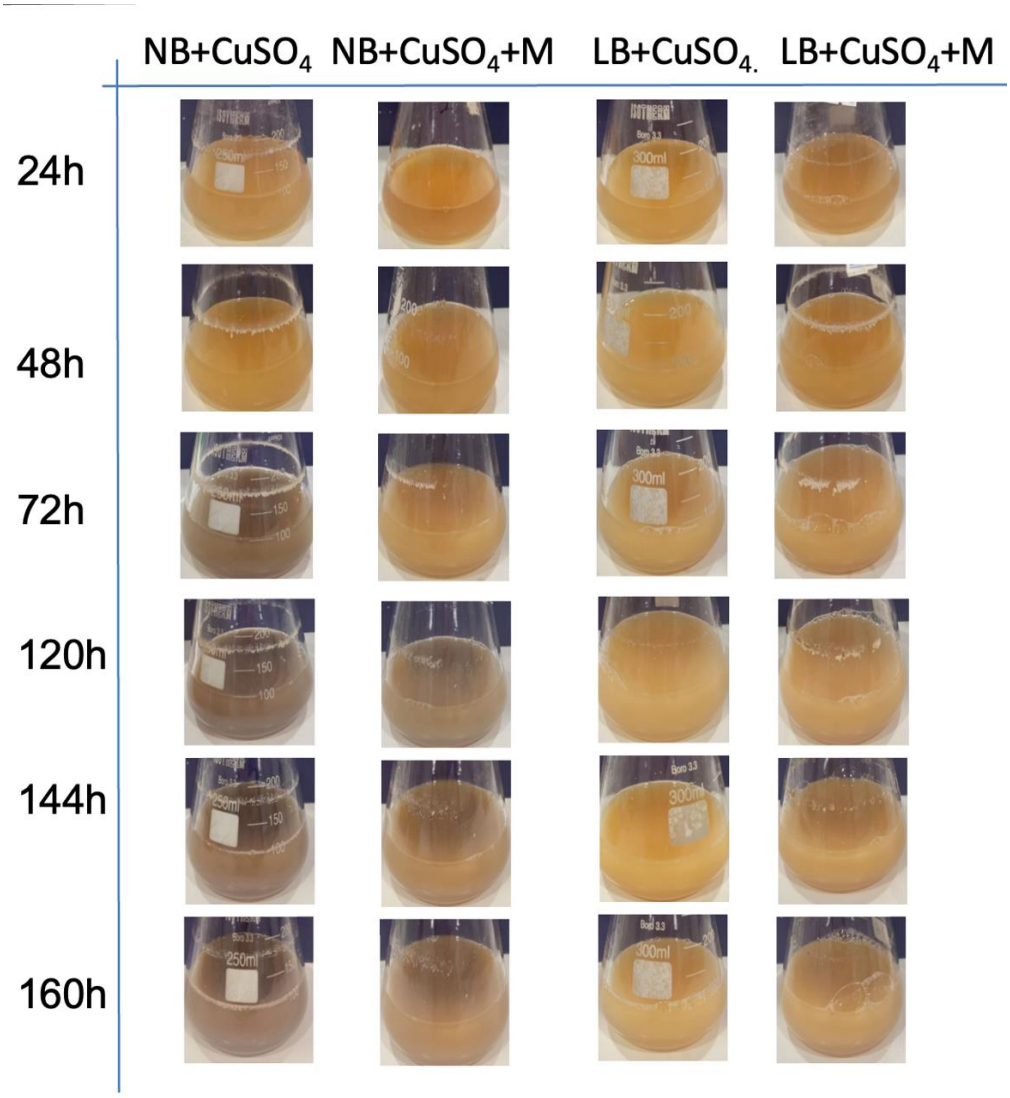

Figure 3.3. Pigment production in *Bacillus atrophaeus* under different fermentation medium with the supplement of o.1 mM $CuSO_4$. M: Molasses

3.3. Estimation and Extraction of Pigment

The spectrophotometric analysis of the extracted pigment was performed using a UV-2500PC Series spectrophotometer. The analysis revealed a peak absorbance at 360 nm, confirming the production of the brown pigment (Figure 3.4).

To further optimize the culture conditions, a second culture was established under the same conditions, and optical density (OD) measurements were taken to quantify pigment production, complementing the qualitative observations.

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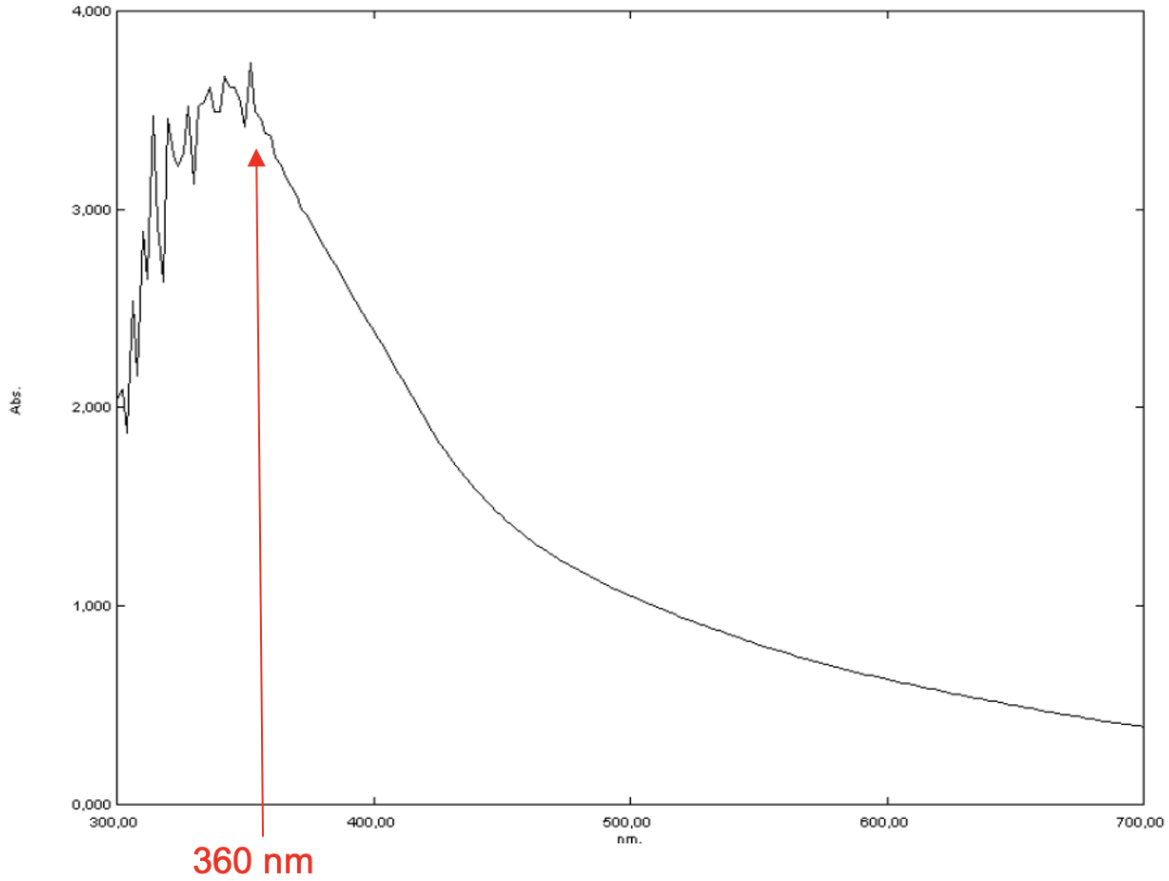

Figure 3.4. Spectrophotometric analysis of the extracted pigment from *Bacillus atrophaeus* culture.

3.4. Optimization of Culture Conditions

Among the different conditions tested, the lighted-shaked environment yielded the highest pigment production as seen in Figure 3.5. This condition showed superior results at the 48-hour mark, and pigment production continued to increase throughout the 120-hour incubation period. By the end of the 120 hours, the pigment production in the lighted-shaked condition exhibited a nearly 27.83-fold increase. Since the optimal pigment production was achieved in NB + $CuSO_4$ supplemented medium at pH 7, incubated at 30°C, with shaking at 150 rpm under light exposure, pigment has been produced in these conditions and lyophilized for further experiments.

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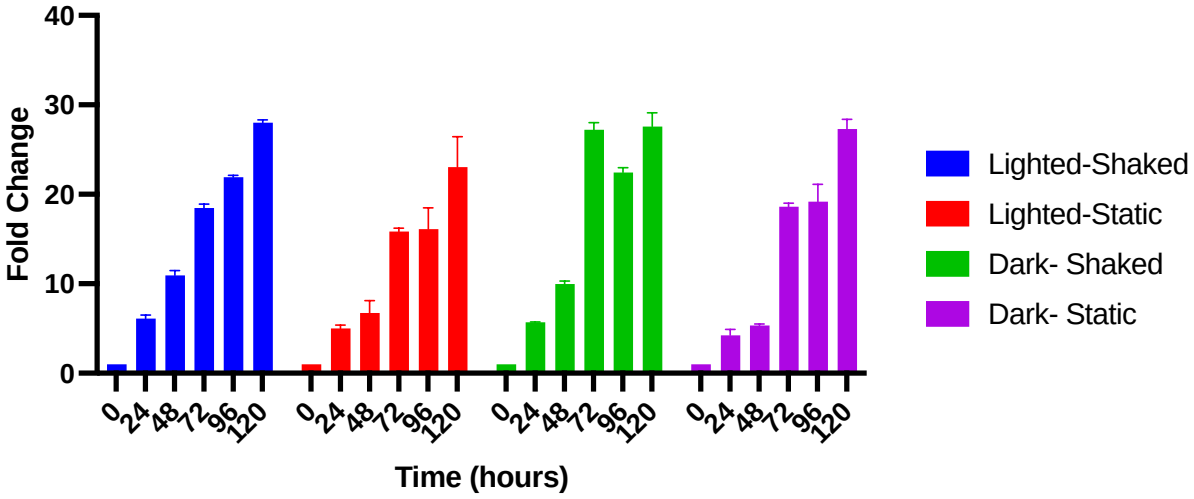

Figure 3.5. Effect of culture conditions on pigment production in *Bacillus atrophaeus*.

4. Conclusion

This study successfully demonstrated the production of a brown pigment by *Bacillus atrophaeus* JCM9070 isolated from paper industry wastewater. Through optimization of culture conditions, it was found that the highest pigment yield was achieved in Nutrient Broth (NB) supplemented with 0.1 mM $CuSO_4$, at pH 7, under light exposure, and shaking at 150 rpm, with a remarkable 27.83-fold increase in pigment production over 120 hours. Spectrophotometric analysis confirmed the peak absorbance of the extracted pigment at 360 nm, indicating the production of a brown pigment with promising potential for industrial applications. These results highlight the feasibility of utilizing *Bacillus atrophaeus* as a sustainable and eco-friendly source of microbial pigments. Future work will focus on further characterizing the pigment's chemical structure, biological activities, and its applicability in various industrial sectors, including food, pharmaceuticals, and cosmetics.

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KIYILARDA BİRİKEN MAKROALGLERİN KULLANIM OLANAKLARI ÜZERİNE BİR ARAŞTIRMA

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ÖZET

Kıyı ekosistemlerinin önemli canlı gruplarından biri olan makroalgler, deniz yaşamının devamlılığında önemli rol oynamaktadır. Oksijen üretmek, besin sağlamak, diğer organizmalar için yaşam ve üreme habitatları oluşturmak makroalglerin deniz ekosistemlerindeki işlevlerinden bazılarıdır. Ancak son yıllarda kirlilik ve iklimsel değişiklikler nedeniyle kıyılarda oluşan yoğun makroalg kütlelerinin çevresel sorunlara neden olduğu bilinmektedir. Kıyı makroalgleri, doğal ürünlerin elde edilebileceği kaynakların sağlanması açısından büyük bir potansiyele sahiptir. Bu nedenle kıyılarda biriken makroalglerin potansiyel kullanım alanlarının belirlenmesi, hem bu doğal kaynakların ekonomiye kazandırılması hem de kıyılarda makroalg birikiminin neden olduğu kirlilik sorununun giderilmesi açısından önemlidir. Bu çalışmada, kıyılarda biriken makroalgler ve farklı alanlarda kullanımları üzerine yapılan çalışmalar incelenmiş, işlevsel ve sürdürülebilir kullanım potansiyelleri tartışılmıştır.

Anahtar kelimeler: Kıyıda biriken makroalgler, biyokimyasal kompozisyon, fonksiyonel kullanım

A STUDY ON THE UTILIZATION POSSIBILITIES OF BEACH-CAST MACROALGAE

ABSTRACT

Macroalgae, one of the important living groups of coastal ecosystems, play an important role in the continuity of marine life. Producing oxygen, providing food, living and breeding habitats for other organisms are some of the functions of macroalgae in marine ecosystems. However, in recent years, it is known that dense masses of macroalgae formed on the coasts due to pollution and climatic changes have caused environmental problems. Coastal macroalgae have

a great potential in terms of providing resources from which natural products can be obtained. Therefore, determining the potential utilization areas of macroalgae accumulated on the coasts is important in terms of both bringing these natural resources to the economy and eliminating the pollution problem caused by macroalgae accumulation on the coasts. In this study, studies on beach-cast macroalgae and their utilization in different areas were examined and their functional and sustainable utilization potentials were discussed**.**

Key words: Beach-cast macroalgae, biochemical composition, functional use

1. GİRİŞ

Denizel kaynaklar, zengin besin içerikleri ve yüksek biyoaktiviteleri nedeniyle son yıllarda fonksiyonel bileşenlerin geliştirilmesi için dünya çapında ilgi görmektedir. Makroalgler sucul ekosistemlerin temel bileşenlerinden biridir ve fotosentez yoluyla sucul üretime önemli ölçüde katkıda bulunmanın yanı sıra denizel organizmalar için barınak ve üreme alanı sağlar. Tüm bunların yanı sıra makroalgler, özellikle Asya toplumlarında eski çağlardan beri insan gıdası olarak kullanılmaktadır [1]. Makroalgler gıda olarak kullanımlarının yanı sıra, zengin biyokimyasal içeriklerinden dolayı ilaç ve kozmetik endüstrisinde, hayvan yemi ve biyogübre olarak da birçok farklı kullanım alanı bulmuşlardır.

Makroalgler içerdikleri pigment maddelerine göre kırmızı (Rhodophyta), yeşil (Chlorophyta) ve kahverengi makroalgler (Phaeophyceae) olarak gruplara ayrılırlar. Makroalglerin metabolizması sıcaklık ve tuzluluk değişimleri, ışık yoğunluğu ve besin seviyeleri gibi çevresel faktörlerden etkilenir ve ekstrem koşullara karşı savunmaları ve hayatta kalmaları ikincil metabolitler üreterek mümkün olur [2,3]. Bu nedenle, çalışmalar makroalglerin çok çeşitli biyoaktif maddeler içerdiğini ortaya koymuştur. Makroalglerden elde edilen doğal antioksidanlar serbest radikallerin neden olduğu oksidatif stresi azaltabilir ve organizmaları UV radyasyon hasarı, diyabet ve inflamasyon gibi çeşitli hastalıklara karşı koruyabilir. Makroalg ürünlerinin ayrıca antimikrobiyal, antikoagülan, antioksidan ve antikanser özelliklere sahip olduğu bildirilmiş olup, bu nedenle, yüksek biyolojik aktiviteye sahip bileşikler içerdikleri için makroalgler birçok kronik hastalığın tedavisine katkıda bulunabilecek doğal bir kaynak olarak kabul edilmektedir [4, 5].

Her yıl kıyı bölgelerinde tonlarca makroalg birikmekte ve bazı türler iklimsel etkiler ve ötrofikasyon nedeniyle yoğun bir şekilde artabilmektedir. Makroalg kütleleri, yeni doğal ürünlere olan talebi karşılamak ve yeni biyoteknolojik uygulamalarda kullanılmak üzere fonksiyonel bileşenler elde etmek için önemli bir potansiyel biyokütledir. Dünyada yapılan çalışmalar, kıyılardaki makroalglerin çeşitli uygulamalar için hammadde olarak önemli kaynaklar olduğunu göstermiştir [2, 6]. Türkiye kıyı sularında da zaman zaman yoğun makroalg artışı gözlenebilmektedir. Bu çalışmada, sahilde biriken makroalglerin durumu ve potansiyel kullanımları üzerine yapılan çalışmalar incelenmiş ve bu kaynaklardan en etkin şekilde yararlanılması ve sürdürülebilir kullanımları tartışılmıştır.

2. KIYIDA BİRİKEN MAKROALGLER

Kıyılarda biriken makroalgler, doğal substratlardan kopan, dağılım alanlarından sürüklenen veya genellikle akıntılar, rüzgarlar ve gelgitler tarafından yönlendirildikten alglerdir [6, 7, 8]. Kıyı makroalgleri, besin döngüsü ve ayrışma yoluyla birçok sucul organizmanın ekolojisine

katkı sağlamaktadır. Makroalglerin ayrışması aynı zamanda kıyı suları için önemli bir azot kaynağıdır ve ayrışma sırasında besinlerin salınması fitoplanktonun birincil üretimini etkiler [8]. Bununla birlikte, kıyıda aşırı makroalg birikimi çevresel sorunlara neden olabilir. Makroalglerin kıyılarda aşırı birikimi sera gazlarının salınımına ve hatta anoksik koşullara yol açabilir. Dünya genelinde her yıl tonlarca makroalg ilgili kurumlar tarafından kıyılardan toplanmakta ve düzenli depolama sahalarında bertaraf edilmektedir [6]. Almanya, Polonya, İsveç, Danimarka ve Litvanya kıyılarında km başına ortalama 272 ton olmak üzere yaklaşık 2,1 milyon ton makroalg bulunduğu bildirilmiş ve araştırmacılar sadece Polonya kıyılarından yılda 9500 ton makroalg toplanabileceğini, korunan alanlar da dahil edilirse bu rakamın 17000 tona çıkabileceğini rapor etmişlerdir [9]. Kıyılardan toplanan makroalgler çöp olarak bırakıldığında, zengin biyokimyasal içerikleri de değerlendirilemeden heba olmaktadır. Bu alglerin gübre, hayvan yemi, biyogaz veya çeşitli kolloidlerin üretimi için hammadde olarak veya çeşitli biyoaktif maddelerin üretimi için kullanılması mümkün olabilir.

3. GÜBRE OLARAK KULLANIMLARI

Makroalgler, kıyı bölgelerinde yaşayan insan toplulukları tarafından toprak için organik gübre olarak kullanılan doğal kaynaklardır. Bununla birlikte, bu geleneksel kullanımın çoğunlukla ekonomik nedenlerle kullanımdan düştüğü bildirilmektedir, ancak kimyasal gübreler yerine doğal/organik maddelerin kullanılması sağlık ve çevresel etkiler açısından da önemlidir [2]. Bu nedenle, makroalglerin bitkiler için gübre olarak kullanılması, doğal kaynakların değerlendirilmesi ve tarımda çevre dostu ürünlerin kullanımı bağlamında önemlidir. Makroalgler besin açısından zengin materyallerdir ve doğal biyostimülan olarak yüksek bir potansiyele sahiptir. Ayrıca, yüksek lif içeriği toprağın nemi tutmasına yardımcı olur ve bu bağlamda toprak düzenleyici olarak katkıda bulunur [10]. Çalışmalar, bitki büyümesini teşvik etmek ve stres toleransını artırmak için tarımsal uygulamalarda makroalg kullanımının faydalarını göstermiştir. Pardilhó ve ark. [2] tarafından yapılan bir çalışmada, *Brassica oleracea* ve *Pastinaca sativa* bitkilerinde tohum çimlenmesini artırmak için deniz makroalg atıkları sıvı ekstrakt olarak ve katı formda kullanılmıştır. Çalışmada makroalg *Saccorhiza polischides* içeren biyokütlenin yüksek karbonhidrat ve mineral içeriği nedeniyle makroalg atıklarının tarımda kullanılabileceği vurgulanmıştır. Çalışmanın sonunda, sıvı ekstraktın katı üründen daha iyi bir büyüme destekleyicisi olduğu ve fidelerin toprak üstü ve radiküler kısımlarında %42'ye varan yüksek bir büyüme oranı sağladığı gösterilmiştir. Yapılan çalışmalar, makroalglerin bitkiler için gübre olarak kullanılmasının daha yüksek çimlenme oranları, kök gelişimi, patojenlere karşı direnç, artan yaprak sayısı gibi avantajlarını ortaya koymuştur [2, 11, 12]. Cárdenas-Aguiar ve ark. [13] kıyıda biriken makroalglerden elde edilen biyokömürün toprak ıslahı olarak kullanılmasının topraklara önemli faydalar sağlayabileceğini ve ürün verimliliğini artırabileceğini bildirmiştir. Çalışmada, incelenen iki toprağın pH ve makro besin kullanılabilirliği, kıyıda biriken makroalglerden elde edilen biyokömürün eklenmesinden sonra artmıştır. Kahverengi algler tarımda en yaygın kullanılanlardır ve domates ve mısır gibi çeşitli ürünlerin üretimi üzerinde faydalı etkileri olduğu bildirilmiştir [12, 14]. Ancak, makroalg içeriğinde bulunabilecek ağır metaller gübre olarak kullanımlarını sınırlayabileceğinden, tarımda kullanılmadan önce biyokimyasal içeriklerinin analiz edilmesi gerekmektedir.

4. HAYVAN YEMİ OLARAK KULLANIMLARI

Makroalglerin eski zamanlardan beri kullanıldığı alanlardan biri de hayvan yemi olarak kullanılmasıdır. Makroalgler geleneksel olarak deniz ve kara hayvanlarını beslemek için kullanılmıştır [15]. Makroalglerin çiftlik hayvanlarında büyüme performansını ve et kalitesini artırdığı bildirilmiş ve bu etkiler alglerin yüksek besin kalitesi, prebiyotik ve antioksidan özelliklerine bağlanmıştır [16]. Kahverengi algler, büyük boyutları ve hasat kolaylığı nedeniyle hayvan beslemede kullanılmak üzere diğer alglerden daha fazla çalışılmış ve kullanılmıştır [17]. Günümüzde, dünyanın farklı bölgelerinde sığır ve kümes hayvanları için kahverengi alg *Ascophyllum nodosum*'dan gıda takviyeleri pazarlayan şirketler bulunmaktadır [18]. Makroalgler besinsel açıdan zengin olduklarından, sucul organizmaların kültüründe de uygun tamamlayıcı gıdalar oldukları bildirilmiştir. Çoğu makroalg türünün, hayvan yemi olarak kullanılan soya fasulyesi unu ve balık unu gibi yaygın protein kaynaklarıyla karşılaştırılabilir oranlarda esansiyel amino asitler içerdiği bildirilmiştir [19, 20]. Kuzey Kutbu gibi bölgelerde, koyun yetiştiriciliği için soya ithalatı yerine makroalglerin yerel protein kaynağı olarak değerlendirildiği bildirilmiştir [21]. Yapılan bir çalışmada, Kosta Rika'da sahilde biriken *Sargassum* makroalginin prebiyotik potansiyeli araştırılmış ve *Sargassum* diyeti ile beslenen tavuklarda düşük kolesterol ve yüksek iyot içeriği elde edilmiş, ayrıca yumurta üretimi ve kalitesi üzerinde de olumlu etkiler gözlenmiştir [18]. Öte yandan, makroalg diyetiyle beslenmenin çiftlik hayvanlarından kaynaklanan metan emisyonlarını azaltabileceği öne sürülmüştür [22]. Roque ve ark. [23] besi sığırı beslenmesinde *Asparagopsis taxiformis* kullanımının 21 haftalık bir süre boyunca herhangi bir verim kaybı olmaksızın enterik metan emisyonlarını azalttığını göstermiştir. Ayrıca, *A. taxiformis* takviyesi et kalitesini veya duyusal özellikleri değiştirmemiş ve büyüyen sığırlarda genel yem verimliliğini artırmıştır. Çalışma sonunda, metan emisyonunu azaltan *A. taxiformis* takviyesi ile sığır eti üretiminin ekonomik ve çevresel olarak daha sürdürülebilir olabileceği bildirilmiştir. Ancak, hayvan yemi olarak kullanılmadan önce makroalglerde bazı kirleticilerin birikmesi gibi riskler göz önünde bulundurulmalıdır.

5. BİYOGAZ ÜRETİMİNDE KULLANIMLARI

Dünyada enerji ihtiyacı sürekli artmakta ve enerji üretiminde çevreye zararı olmayan, sürdürülebilir enerji kaynaklarının kullanımı kritik önem taşımaktadır. Son yıllarda, tarım arazilerinin enerji ve gıda sektörleri için kullanımı konusundaki rekabet önemli bir tartışma konusu olmuştur [24]. Kıyıda biriken algler, biyogaz ve biyoyakıt üretimi için hammadde kaynağı olarak bir alternatiftir. Makroalglerin yüksek organik madde içeriği nedeniyle, biyoenerji üretiminde kullanımlarına ilişkin çalışmalar artmıştır. Çalışmalar, makroalglerin anaerobik muamelesinin hem kıyıda çürüyen biyokütlenin olumsuz etkilerini azaltmak, hem de yüksek değerli yakıt üretmek için bir alternatif olabileceğini göstermektedir [6]. Makroalgler karbonhidrat bakımından zengindir ancak düşük protein ve lipid içeriğine ve çok düşük veya sıfır lignin içeriğine sahiptir. Bu özellikler, biyodönüşüm süreçlerine dirençli olan lignin bakımından zengin kara bitkilerinin aksine makroalgleri biyogaz üretimi için uygun hale getirmektedir [24]. Dünyada sahilde biriken makroalglerden biyogaz üretimi üzerine birçok çalışma yapılmıştır [25, 26]. Bazı çalışmalarda, farklı türlerin metan potansiyeli araştırılmış ve

makroalglerin bileşimindeki mevsimsel değişikliklerin metan verimini etkilediği ve bu nedenle hasat zamanının önemli olduğu bildirilmiştir [27]. Oliveira ve ark. [26] tarafından yürütülen çalışmada, *Gracilaria vermiculophylla* (Rhodophyta) biyometan potansiyelini belirlemek için iki farklı substrat ile muamele edilmiştir. Çalışma sonunda %2'lik gliserol ile anaerobik sindirim sonucunda 599 LCH4/kg VS (uçucu katı madde) biyometan potansiyeli elde edilirken, %85 arıtma çamuru ile birlikte sindirim sonucunda 605 LCH4/kg VS elde edilmiştir. Bir başka çalışmada, Akdeniz'de bol miktarda bulunan yeşil bir alg olan *Ulva rigida* biyometan potansiyeli açısından araştırılmış ve ayrışan makroalg biyokütlesi anaerobik çamur ve su ile karıştırıldığında 408 mL biyogaz elde edilmiştir [28]. Bruhn ve ark. [29] *U. lactuca* türünün metan potansiyelinin birçok karasal enerji bitkisinden daha yüksek olduğunu belirtmiştir. Ertem ve ark. [30] kahverengi alglerin %20, kırmızı alglerin %80 oranında kullanıldığı bir biyogaz üretim tesisinde alglerin tavuk gübresi ile birlikte kullanımının emisyon azaltımına etkisini incelemişlerdir. Elde edilen sonuçlar, 1 MJ enerji üretimi için sırasıyla %52, %83, %41 ve %8 daha düşük küresel ısınma, asitleşme, ötrofikasyon ve arazi dönüşüm potansiyelleri ortaya koymuştur. Sahilde biriken algler, biyoyakıt olarak kullanıldığında, fosil yakıtlara olan bağımlılığı azaltma ve küresel ısınmayı hafifletme potansiyeline sahiptir [3, 6]. Ancak, sahilde biriken makroalglerden büyük ölçekli enerji üretiminin uygun maliyetli ve sürdürülebilir olup olmadığını belirlemek için ayrıntılı çalışmalara ihtiyaç vardır.

6. ÇEŞİTLİ BİYOAKTİF MADDELERİN ÜRETİMİNDE KULLANIMLARI

Makroalgler ayrıca polisakkaritler, proteinler, lipitler ve polifenoller gibi doğal biyoaktif maddeler içerir. Makroalglerden elde edilen enzim inhibitörleri, florotanninler, polisakkaritler, peptitler, alkaloidler, halojenli tepenoitler ve pigmentler gibi maddelerin biyolojik özellikleri üzerine çok sayıda çalışma yapılmıştır [1, 31, 32, 33]. Çalışmalar, makroalglerden izole edilen biyoaktif bileşiklerin kanser, diyabet, inflamasyon, demans ve diğer birçok hastalığın tedavisinde etkili olabileceğini göstermiştir [31]. Bu biyoaktif özellikler makroalglere çeşitli bileşiklerin ekstraksiyonu için büyük bir potansiyel kazandırmıştır. Makroalgler çevresel stres faktörleriyle başa çıkmak için çeşitli ikincil metabolitler sentezler ve bu metabolitler antioksidan aktivite gibi çeşitli biyoaktif etkilere sahiptir. Zárate ve ark. [34] tarafından yürütülen çalışmada, kıyıda biriken 15 makroalg biyokütlesinden elde edilen ürünler biyoaktif özellikler açısından test edilmiştir. Sonuçlar makroalg biyokütlesinin yaşlanma karşıtı etkilere ve seçici sitotoksik metabolitlere sahip kozmetik biyoürünlerin kaynağı olarak yüksek bir potansiyele sahip olduğunu göstermiştir. Alglerde bulunan biyoaktif bileşiklerden fenolik bileşikler, sağlığa faydaları açısından yaygın olarak araştırılmıştır. Bunlar arasında fenolik asitler, flavonoidler ve florotanninler gibi maddeler bulunmaktadır. Farklı fenolik bileşiklerin varlığı makroalg türleri arasında değişiklik gösterebilmektedir. Kahverengi algler florotannin içermeleri ile karakterize edilirken, yeşil ve kırmızı algler bromofenoller, fenolik asitler ve flavonoidler bakımından zengindir [35]. Florotanninlerin çok güçlü antioksidan ve antimikrobiyal özelliklere sahip olduğu bildirilmiştir [36]. Örneğin, kahverengi alg türleri *Eisenia bicyclis, Ecklonia cava* ve *Ecklonia kurome* türlerinden elde edilen florotanninlerin askorbik asit ve α-tokoferol ile karşılaştırıldığında 2-10 kat daha yüksek antioksidan aktiviteye sahip olduğu bulunmuştur [37]. Algal polifenoller antioksidan ve antimikrobiyal özelliklerinin yanı sıra anti-enflamatuar, antiobezite, antidiyabetik ve antikanser aktiviteleri gibi birçok biyoaktif özelliğe sahiptir [33, 35]. Fas sahillerinde yetişen kırmızı makroalg *Gracilaria bursa-*

pastoris, Ramdani ve ark. [38] tarafından antioksidan özellikleri açısından incelenmiş ve sonuç olarak, antioksidan kapasiteleri ticari askorbik asit ile eşit bulunmuştur. Çalışmada etanolik ekstraktın daha yüksek antioksidan aktivitesi fenolik bileşiklerin varlığına bağlanmış ve *G. bursa-pastoris*'in doğal antioksidan bileşikler için umut verici bir kaynak olabileceği bildirilmiştir. Brezilya kıyılarından on beş makroalg türünün antioksidan aktivitesi üzerine yapılan bir araştırmaya göre, kahverengi alglerin en yüksek antioksidan aktiviteye sahip olduğu, bunu kırmızı ve yeşil alglerin takip ettiği bildirilmiş, fenolik bileşikler ve sülfatlı polisakkaritlerin antioksidan aktivite ile pozitif ilişki gösterdiği belirtilmiştir [39]. Bunlar arasında sülfatlı polisakkaritler biyoaktif özellikleri nedeniyle son yıllarda birçok bilimsel çalışmada ele alınmıştır. Bu biyoaktif maddeler arasında kırmızı alglerden elde edilen karragenan, kahverengi alglerden elde edilen fukoidan ve yeşil alglerden elde edilen ulvan yer almaktadır [3, 5].

Makroalglerde klorofil, karotenoidler ve fikobiliproteinler olmak üzere üç ana pigment grubu vardır [36]. Alglerdeki başlıca karotenoidler karotenler, likopen, fukoksantin, astaksantin, zeaksantin, lutein ve violaksantin gibi pigmentlerdir ve bunlardan fukoksantin kahverengi alglerde bulunan en bol karotenoiddir. Fikobiliproteinler, fikosiyaninler ve fikoeritrinlerden oluşan suda çözünen pigmentler grubudur. Bu pigmentler için önemli biyolojik aktiviteler (antioksidan, anti-enflamatuar, immünomodülatör, antidiyabetik ve antianjiyojenik) bildirilmiştir [35, 36].

7. SONUÇ

Kıyılardaki makroalg birikimi önemli bir potansiyel doğal kaynaktır. Makroalglerin zengin bir biyokimyasal içeriğe sahip olması ve çok değerli bileşenler içermesi, bu kaynakların doğru ve sürdürülebilir kullanımının önemini ortaya koymaktadır. Bu bağlamda, kıyılarda doğal olarak çoğalan ve kullanılmayan makroalgler de kaynak israfı olarak değerlendirilebilir. Bu kaynakların kullanım potansiyelinin belirlenmesi hem kıyılardaki kirlilik etkisini ortadan kaldıracak, hem de farklı sektörlerde ihtiyaç duyulan doğal hammaddeleri sağlayacaktır.

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DETERMINATION OF BIOCHEMICAL CONTENTS OF TWO RED MACROALGAE SPECIES (*LAURENCIA OBTUSA* AND *GANONEMA FARINOSUM*) DISTRIBUTED IN MERSİN COAST (NORTHEAST MEDITERRANEAN)

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ABSTRACT

In this study, the nutritional components of two macroalgae species distributed along the Mersin coast were investigated. Sampling was carried out from the Mersin coast and the nutritional content of two red algae species, *Laurencia obtusa* and *Ganonema farinosum* were analyzed. Crude ash, lipid and protein analyses were performed. Fatty acid composition was also determined. In the study, protein and lipid content of *L. obtusa* were higher, while ash content was higher in *G. farinosum*. The highest total SFA content was found in *G. farinosum*, and the highest total PUFA content was found in *L. obtusa*. The results revealed that *L. obtusa* was richer in protein and lipid content, while *G. farinosum* was richer in mineral content.

Key words: Macroalgae, Nutritional content, Fatty acids, Mersin, Mediterranean.

1. INTRODUCTION

Macroalgae (seaweeds) are primitive plants that live in marine ecosystems, often attached to rocks, producing food and oxygen for heterotrophic organisms. From tropical to arctic locations, they are found in the tidal, subtidal, and intertidal zones [1]. Macroalgae have long been utilized as human food, animal feed, fertilizer and traditional medicine in many countries around the world, and nowadays the uses of macroalgae are increasing. While macroalgae are abundant in vitamins and minerals, they also include bioactive components such proteins, lipids, polysaccharides, and phenolic compounds that have anti-inflammatory, antiviral, antibacterial, and antioxidant properties [2,3]. These characteristics have made macroalgae a valuable source for a broad range of bioactive chemicals and for their application as functional foods. For these reasons, the use of macroalgae products is increasing in the world. In response to declining terrestrial production due to various reasons such as climatic factors, the need for food will also increase when the population is projected to increase, and in this context, macroalgae are an important potential food source. The biochemical contents of macroalgae

may vary depending on the taxonomic groups to which they belong. For example, it has been reported that the protein level of brown algae is generally low (less than 15% on a dry basis), while the protein level of green algae and especially red algae is higher [2,4]. However, the biochemical content of macroalgae may vary according to factors such as location, season and water quality. In this study, the nutritional components of two red algal species distributed in Mersin coast, which is located on the Mediterranean coast of Turkey, were investigated.

2. MATERIAL AND METHOD

2.1. Materials

In this study macroalgae species, *Laurencia obtusa* and *Ganonema farinosum* among the red algae distributed on the coastline of Mersin Province were examined.

Ganonema farinosum (J.V.Lamouroux) K.-C.Fan & Yung C.Wang 1974

Ganonema farinosum (*Liagora farinosum*) has a heteromorphic life history with alternating upright gametophytes and filamentous tetrasporophytes. The gametophyte can grow up to 20 cm in height. They are moderately calcified, whitish-red in color and attached to the substrate by a discoid appendage. Shallow subtidal communities are distributed on rocky substrates at depths of 0-10 m. They are found worldwide in tropical and warm temperate seas. They are distributed in many different areas including the Red Sea, Mediterranean Sea, Indian Ocean, Southwest Pacific, Australia, New Zealand, Pacific Islands, Western Atlantic, Eastern Atlantic [5,6].

Laurencia obtusa (Hudson) J.V. Lamouroux 1813

In the *Laurencia* genus, thallus are mostly upright, the upright axes are cylindrical or distinctly flattened, and the branching is pinnate or radial [7]. The axis is slender, cylindrical, oppositely arranged, decreasing in length from the base to the tip, with a pyramidal appearence of frond [5]. It is a medium-sized species, up to 10-20 cm in length, with a somewhat compact or clustered growth form. This species is common in shallow wavy areas and strong currents, and is widespread on coasts up to 8 m depth [8].

2.2. Sampling and analysis

Macroalgae sampling was carried out from the coast of Mersin in 2021. The collected macroalgae samples were first washed with seawater to remove any foreign matter and then transported to the laboratory without adding any chemicals. The samples brought to the laboratory were washed with distilled water to remove possible residues and salts on the samples and the excess water was removed by keeping them on blotting paper. The macroalgae samples were dried in an oven at 45°C, ground and prepared for analysis. Crude ash and crude protein content of the samples were examined using the AOAC (935.47) and Kjeldahl method (AOAC 981.10) [9], respectively. Lipid analysis of macroalgae samples was carried out in a conventional Soxhlet extractor. The Ichihara et al. [10] method was used to assess fatty acid methyl esters from lipid isolated from macroalgae samples.

3. RESULTS AND DISCUSSION

The protein, lipid and ash contents of macroalgae species are given in Table 1. The protein content of *L. obtusa* was found to be 24.66±0.27 %, while the lipid content was found to be 6.18± 0.021 %. The ash content of the same species was 22.01±0.477 %.

Table 1. Protein, lipid and ash values determined in macroalgae species.

	Ganonema farinosum	*Laurencia obtusa*
Protein (%)	6.20±0.28	24.66±0.27
Lipid (%)	0.37±0.028	6.18±0.021
Ash (%)	74.39±0.583	22.01±0.477

Saravanavel and Pillai [11] reported protein content as 29.28% and lipid content as 1.99% in *Laurencia obtusa*. Turan et al. [12] reported protein content as 142.94 ± 3.24 mg/g (14.2%) in the same species. Ersoy Karaçuha et al. [13] found the protein content of *L. obtusa* to be between 7.15±0.03% and 12.95±0.48% and the lipid content to be between 0.28±0.06% and 0.68±0.12% in their analyses of samples collected from different seasons and localities. When compared with the results obtained from different studies, it was observed that the protein value determined in *L. obtusa* in this study was similar to the protein values reported by Saravanavel and Pillai [11], while it was higher than the values found by Turan et al. [12] and Ersoy Karaçuha et al. [13]. The lipid content of *L. obtusa* in this study was higher than the lipid values reported by Saravanavel and Pillai [11] and Ersoy Karaçuha et al. [13].

The protein content of *Ganonema farinosum* was found to be 6.20±0.28%, while the lipid content was 0.37±0.028 %. In the same species, ash content was found to be 74.39±0.583 %. Herliany et al. [14] reported protein content as 2.22±0.24% and lipid content as 0.19±0.00% in the same species and these values were lower than the protein and lipid values found in this study. Freitas et al. [15] reported similar protein (~ 6%) and lipid levels (<5%) in *Liagora viscida* species. Polat et al. [16] found the protein and lipid levels of *Liagora* sp. to be 8.01% and 0.23%, respectively, in Iskenderun Bay. Labib and Hosny [17] reported that protein levels in *Corallina officinalis*, another red algae species collected from three different localities along the Alexandria coast, ranged from 2.71% to 3.93%. In another study, the protein content of the red alga *Hypnea valentiae* was 16.5 ± 2.78% and the lipid content was 2.8 ± 0.67%, while the protein content of *Gracilaria corticata* was 19.3 ± 2.19% and the lipid content was 1.8 ± 0.46% [18]. Irkin and Erdugan [19] reported that the protein content of *Polysiphonia morrowii*, a red algal species, varied between 11.71±0.71% and 34.49±0.24% and the lipid content varied between 0.13 ± 0.86% and 2.78±0.84% depending on the season and locality. Carpena et al. [20] reported that some species of *Gracilaria*, one of the red algae, have a protein content of less than 5%, while *Pyropia tenera* can contain 37% protein, therefore, protein content in macroalgae exhibits a species-dependent situation. Indeed, studies show that the biochemical

content of macroalgae can vary according to species and, within the same species, according to season and location.

Fatty acid composition of macroalgae species are given in Table 2. The fatty acid content of *Laurencia obtusa* was found as SFA>PUFA>MUFA. Among saturated fatty acids (SFA), palmitic acid (C16:0) and lauric acid (C12:0) were found in higher proportions. Ersoy Karaçuha et al. [21] determined the fatty acid content as SFA>MUFA>PUFA in *L. obtusa*. Consistent with the findings of this study, the highest SFA was reported to be palmitic acid.

Table 2. Fatty acid analysis results of macroalgae species.

Ganonema farinosum			***Laurencia obtusa***	
C12:0	7.36±0.06		C12:0	16.09±0.41
C14:0	18.58±0.49		C14:0	0.63±0.06
C16:0	23.22±0.32		C16:0	19.20±0.62
C17:0			C17:0	
C18:0	9.94±0.86		C18:0	6.07±0.06
C20:0			C20:0	
C22: 0			C22: 0	0.92±0.06
Total SFA	59.09		Total SFA	42.91
C14:1	3.19±0.02		C14:1	
C16:1	5.50±0.01		C16:1	2.32±0.05
C17:1			C17:1	
C18:1 n9	2.42±0.16		C18:1 n9	4.16±0.06
C18:1 n7			C18:1 n7	0.69±0.09
C20:1n9			C20:1n9	
C22:1n9	0.75±0.13		C22:1n9	0.42±0.10
C24:1n9			C24:1n9	
total MUFA	11.84		total MUFA	7.58
C18:2 n6	2.24±0.14		C18:2 n6	5.89±0.46
C18:3 n6			C18:3 n6	
C18:3 n3	0.68±0.09		C18:3 n3	7.85±0.45
C20:2			C20:2	
C20:4n6	0.56±0.03		C20:4n6	0.49±0.02
C20:3n6	0.81±0.08		C20:3n6	
C20:5 n3	2.21±0.06		C20:5 n3	1.29±0.07
C22:6 n3	0.63±0.09		C22:6 n3	2.16±0.02
total PUFA	7.11		total PUFA	17.67
PUFA/SFA			PUFA/SFA	
total n6	3.61		total n6	6.37
total n3	3.51		total n3	11.30
n6/n3	1.03		n6/n3	0.56

The researchers also reported that seasons had a significant effect on the fatty acid profile. The highest monounsaturated fatty acid (MUFA) content in this species was oleic acid (4.16±0.06%), while the highest polyunsaturated fatty acid (PUFA) content was alphalinoleic acid (7.85±0.45%) in the present study. In the study conducted by El-Shenody et al. [22], 75.6% SFA, 16.1% MUFA and 8.3% PUFA were found in *Laurencia obtusa*. Polat and Özoğul [23] found the highest SFA, PUFA and MUFA ratios as 46.14%, 23.75% and 33.57%, respectively, in *Laurencia papillosa* in their seasonal study.

The fatty acid content of *Ganonema farinosum* was found as SFA>MUFA>PUFA. Among saturated fatty acids, palmitic acid (C16:0) and myristic acid (C14:0) are higher. The highest monounsaturated fatty acid was palmiteloic acid (C16:1) with 5.50±0.01%, while the highest polyunsaturated fatty acid was linoleic acid (C18:2n6) with 2.24±0.14%. Carpena et al. [20] reported that macroalgae are abundant in essential fatty acids, particularly omega-3 fatty acids, and red algae also contain polyunsaturated fatty acids such as EPA and DHA. Dietary PUFA consumption, including both ω-3 and ω-6 fatty acids, affects anti-inflammatory and anti-thrombotic processes as well as other cell functions. Diets containing a low ω-6/ω-3 ratio have also been reported to be effective in the prevention of cardiovascular diseases, osteoarthritis and diabetes [20, 24]. For these reasons, there are several health advantages to including PUFAs from macroalgae in the human diet.

In this study, it was found that EPA levels were higher in *G. farinosum*, while DHA levels were relatively higher in *Laurencia obtusa*. Caf et al. [25] reported that *L. obtusa* had the highest PUFA (29.03±0.70%) and MUFA (22.55±0.62%) content among *L. obtusa*, *Corallina elongata* and *Jania rubens*, and *L. obtusa* had the highest EPA (15.09±0.19%) in its PUFA group.

4. CONCLUSIONS

Macroalgae are increasingly used in many industries in the world, especially in the food and pharmaceutical industries, due to their rich nutritional and bioactive substance content. In this context, it is important to analyze the content of different macroalgae distributed in coastal environments in order to determine their utilization potential. In line with the findings obtained in this study, some nutritional component levels of two red algal species distributed in our coasts were revealed. The results showed that *L. obtusa* was richer in protein and lipid content, while *G. farinosum* was richer in mineral content. *L. obtusa* was also richer in polyunsaturated fatty acids. The biochemical contents of macroalgae may vary depending on the species and may also vary depending on factors such as physiological status of each species, season, location and water quality. Therefore, in addition to determining the biochemical contents of different species, it is important to analyze the contents of each species in different seasons and localities. In addition, it is recommended to investigate the metabolites of high economic value such as polysaccharides, pigment composition and phenolic substances in species that are abundant in our coasts.

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AHUDUDU (*Rubus* sp.)'NUN *IN VITRO* ÇOĞALTIMINDA EKSPLANT SEÇİMİNİN ÖNEMİ

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ÖZET

Ahududu, üzümsü meyveler grubuna giren, birçok farklı türü bulunan, oldukça lezzetli ve tatlı kırmızı, mor, siyah ve sarı renkli meyveler veren bir türdür. İnsan sağlığına yararlı bileşikler içermesi ve besin değerince zengin olması nedeniyle dünyada ve Türkiye'de yetiştiriciliği günden güne artmaktadır. Ahududunun, vejetatif çoğaltım yöntemleri oldukça sınırlıdır. *In vitro* koşullarda mikroçoğaltım yöntemi ise, az miktarda bitki materyalinden, yıl boyunca ve kısa sürede, milyonlarca sağlıklı yeni bitkinin elde edilmesine imkan vermektedir. *In vitro* çoğaltımda başarıyı etkileyen birçok faktör bulunmaktadır. Bunlardan en önemlisi bitki materyalinin seçimidir. Ahududu ile yapılan çalışmalarda farklı bitki kısımları kullanılarak mikroçoğaltım yapılmıştır. Bu çalışmada, ahududunun *in vitro* çoğaltımında kullanılan farklı eksplantların sürgün rejenerasyonuna etkileri, literatür araştırmaları ile belirlenmeye çalışılmıştır.

Anahtar Kelimeler: Ahududu, Eksplant, *In vitro* çoğaltım, Mikroçoğaltım

IMPORTANCE OF EXPLANT SELECTION IN *IN VITRO* PROPAGATION OF RASPBERRY (*Rubus* sp.)

ABSTRACT

Raspberry is a type of fruit that is included in the berry fruit group. It has different species and produces tasty and sweet fruits, including red, purple, black, and yellow fruits. Its cultivation is increasing daily in the world and in Türkiye because it contains compounds beneficial to human health and is rich in nutritional value. Vegetative propagation methods for Raspberry are limited. The *in vitro* micropropagation method allows millions of healthy new plants to be obtained from a small amount of plant material throughout the year in a short time. There are many factors that affect successful *in vitro* propagation. The most important step is plant material selection. In studies using raspberry, micropropagation was performed using different plant parts. In this study, the effects of different explants used in the *in vitro* propagation of raspberry plants on shoot regeneration were examined using literature research.

Keywords: Raspberry, Explant, *In vitro* propagation, Micropropagation

1. GİRİŞ

Ahududu (*Rubus* sp.), gülgiller (*Rosaceae*) familyasında yer alan, *Rubus* cinsi içerisinde yabani ve kültür bitkileri olmak üzere birçok farklı türü içeren, lezzetli ve tatlı meyveleri olan bir üzümsü meyve türüdür (Ağaoğlu, 1986; Onur, 1996). İnsan sağlığına yararlı bileşikler içermesi ve besin değerince zengin olması ile dünyada ve Türkiye'de yetiştiriciliği günden güne artmakta olan bir meyvedir (Onur, 1996; Pehluvan ve Güleryüz, 2004).

Dünya ahududu üretimi incelendiğinde, FAO (Food and Agriculture Organization of the United Nations) 2022 verilerine göre toplam 116.392 ha alanda 947.852 ton üretim yapılmıştır. Dünya'da en fazla ahududu üretimi yapan ülke, 27.331 ha alanda 212.300 ton üretim ile Rusya olmuştur (FAO, 2024). Türkiye İstatistik Kurumu (TÜİK) verilerine göre, Türkiye'de 2022 yılında 7.981 da alanda 6.652 ton; 2023 yılında ise, 8.674 da alanda 7.187 ton ahududu üretimi yapılmıştır (TÜİK, 2024).

Ahududu, *in vitro* koşullarda başarılı bir şekilde çoğaltılabilmektedir. *In vitro* koşullarda mikroçoğaltım yöntemi, az miktarda bitki materyalinden, yıl boyunca ve kısa sürede, milyonlarca sağlıklı yeni bitkinin elde edilmesine imkan vermektedir. *In vitro* çoğaltımda bütün bitki türleri için evrensel bir rejenerasyon protokolü bulunmamaktadır. Farklı genotiplerin, bitki büyümeyi düzenleyicilerin ortam koşullarının bitki rejenerasyonuna etkileri farklı olabilmektedir (Babaoğlu vd., 2001).

Ahududu bitkisinin *in vitro* çoğaltımında eksplant seçimi kritik öneme sahiptir. Uygun eksplant kullanımı, başarılı bir üretim süreci için temel teşkil eder. Eksplant kaynağı, sterilizasyon ve büyüme-gelişim gibi faktörler bitkinin sağlıklı çoğaltımı için dikkatle değerlendirilmelidir. Genotipik varyasyon başta olmak üzere, kültüre alınan eksplantların davranışını etkileyebilecek

çeşitli faktörler bulunmaktadır. Bunlar arasında; doku kaynağı olarak kullanılan eksplant tipi, bu eksplantın ontogenetik ve fizyolojik yaşı, eksplantın bitkiden alındığı zaman dilimi (mevsim), eksplantın boyutu ve eksplantın alındığı bitkinin diğer genel özellikleri (yetiştirme şartları, ışık, nem, toprağın besin durumu, hastalık ve zararlıdan ari ve mevsimsel faktörler vb.) yer almaktadır. Eksplant kaynağı olarak sera koşullarında yetiştirilen bitkiler genellikle tarlada yetişen bitkilere kıyasla daha iyi sonuçlar vermektedir. Ayrıca, tüm büyüme koşulları optimum seviyede sağlandığında, *in vitro* ortamda gelişen bitkiciklerden alınan eksplantlar ile de yüksek başarı oranları elde edilebilmektedir (Babaoğlu vd., 2001).

Eksplant seçimi yapılırken herhangi bir bitki doku parçası veya organ kullanılabilir. Bunlar içerisinde en yaygın kullanılanı gövdedir. Bunun dışında sürgün, sürgün ucu, yaprak, kök, çiçek sapı, yumurta hücresi, polen hücresi, hipokotil, kotiledon, embriyo, yumru, apikal meristem gibi bitki parçaları kullanılmaktadır (Babaoğlu vd., 2001). Eksplant kaynağı olarak kullanılan farklı organların, dokularında farklı seviyelerde karbonhidrat, protein ve büyüme düzenleyicileri bulunmaktadır. Bu durumda organ kaynağının eksplant rejenerasyonu üzerindeki etkisinin çoğunlukla endojen büyüme maddelerinin seviyelerindeki değişikliklerden kaynaklandığı düşünülmektedir. Genç dokulardan alınan eksplantlar genellikle daha yaşlı dokulardan alınanlara göre daha iyi doğrudan organogenez oluşumunu sağlamaktadır (Aliona vd., 2011).

Ahududu mikroçoğaltımında çoğunlukla eksplant olarak tepe (apikal) (Fidancı ve Erenoğlu, 2006) ve koltuk altı (aksiller) (Owens Y De Novoa, 1992; Gonzalez vd., 2000; Fidancı ve Erenoğlu, 2006; Hunkova vd., 2016; Yanxia vd., 2018) tomurcuklar kullanılmaktadır. Bunun dışında, apikal meristem (Snir, 1981; Gök, 1997; Fidancı ve Erenoğlu, 2006), kök (Owens Y De Novoa, 1992), yaprak ve yaprak sapı (Cousineau ve Donnelly, 1991; Owens Y De Novoa ve Conner, 1992; Lenz vd., 2015) eksplantları da kullanılmıştır.

Aynı bitki türünden elde edilen eksplantlar, organogenesis oluşturma yetenekleri açısından önemli farklılıklar sergileyebilir (Babaoğlu vd., 2001). Yapılan bir araştırmada, iki ahududu çeşidi (Opal ve Cayuga) için en uygun mikroçoğaltma koşullarını belirlemek amacıyla farklı eksplantlar (tepe tomurcuğu, koltuk altı tomurcuğu, boğum meristemi ve yaprak diski) kullanılmıştır. Bu amaçla, eksplantlar tek başına veya GA_3 ile kombinasyon halinde eklenen çeşitli konsantrasyonlarda sitokininler (BAP, TDZ ve K) ve oksinler (2,4D ve IAA) içeren MS ortamında inkübe edilmiştir. Çalışmanın sonucunda, yaprak disklerinin sadece hücre çoğalmasına etki ettiği, diğer eksplantların kültür ortamının hormonal bileşimine bağlı olarak organogenez veya hücre farklılaşması geliştirdiği belirlenmiştir (Aliona vd., 2011).

Başka bir çalışmada, cüce ahududu (*Rubus pubescens*) bitkisinin mikroçoğaltımı için bir protokol geliştirilmiştir. Bu protokol, serada yetiştirilen bitkilerden aksenik (steril) sürgün kültürlerinin oluşturulması, sürgün çoğalmasının teşvik edilmesi ve *in vitro* köklendirme süreçlerini kapsamaktadır. Kültürler, sürgün ucu ve boğum eksplantlar kullanılarak, 1/2 oranında seyreltilmiş MS makro tuzları, 8,9 µM N6-benziladenin (BA) ve 0,98 µM indol-3-bütirik asit (IBA) içeren MS mikro tuzları ve vitaminleri ile başlatılmıştır. Çalışmada sürgün ucu ve boğum eksplantlarının sürgün proliferasyonu ve kallus büyümesi üzerine farklı tepkiler

verdiği belirlenmiştir. Bu kapsamda sürgün ucu eksplantının sürgün proliferasyonu ve kallus büyümesinin daha iyi olduğu belirlenmiştir (Debnath, 2004).

Owens Y De Novoa (1992), Lloyd George, Glen Moy, Glen Prosen, Canby, Skeena ve Sumner kırmızı ahududu çeşitlerinin kök, yaprak ve tek boğum içeren sürgünlerini eksplant olarak kullanarak farklı besin ortamlarında (Anderson, MS ve Q-MS) kallus ve sürgün gelişimi üzerine bir çalışma yapmıştır. Bu çalışmada, 0, 1, 2 $mg.l^{-1}$ BA ve 0, 0.5, 1 $mg.l^{-1}$ IBA kombinasyonlarının etkileri incelenmiştir. Araştırma sonuçları, ahududu çeşitlerinin farklı uygulamalara değişen tepkiler verdiğini göstermiştir. Canby çeşidinin yaprak eksplantı, uygulamalara en iyi yanıtı verirken, kallus oluşumu en fazla kök eksplantından, sürgün gelişimi ise yaprak eksplantından elde edilmiştir.

Fidancı ve Erenoğlu (2006), bazı ahududu çeşitlerinin (Heritage, Tulameen) *in vitro* şartlarda üretilmesi ile ilgili yaptıkları çalışmada eksplant olarak meristem, sürgün ucu ve tek boğumlu sürgünleri kullanmıştır. Çalışmada, meristem ve sürgün ucunda bulaşma ve kararmalar meydana geldiğini bu yüzden üretime tek boğumlu sürgünler ile devam edildiğini bildirmiştir.

2. SONUÇ VE ÖNERİLER

Çalışmalar incelendiğinde, ahududunun mikroçoğaltımında farklı çeşitler üzerinde kullanılan eksplantların farklı tepkiler verdiği görülmektedir. Uygun eksplant seçimi, sterilizasyon ve kültür ortamı, ahududu bitkisinin sağlıklı *in vitro* çoğaltımını sağlamaktadır. Farklı çoğaltım yöntemlerinin araştırılması, bu yöntemin iyileştirilmesini destekler. Kaliteli ve sağlıklı fidanlar, ahududu yetiştiriciliğinde verimliliği ve sürdürülebilirliği artırır. Bu kapsamda, biyoteknolojik yöntemler, ahududu popülasyonlarının gen havuzunun korunmasına katkı sağlamaktadır. *In vitro* çoğaltım, daha fazla ve daha kaliteli fidan üretimine olanak sağlar. Gelişen yöntemler sayesinde daha toleranslı bitki tipleri elde edilebilir.

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IN VITRO KOŞULLARDA ABİYOTİK STRES FAKTÖRLERİNİN BÖĞÜRTLEN (*Rubus* sp.) BİTKİ GELİŞİMİ ÜZERİNE ETKİLERİ

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ÖZET

Üzümsü meyveler tarımsal üretim açısından büyük potansiyele sahip olan ancak bu potansiyelinden tam olarak yararlanamadığımız önemli bir ürün grubunu oluşturmaktadır. Bu meyve grubuna giren birçok meyve türü (çilek, ahududu, böğürtlen, mavi yemiş, kuşburnu vb.) insan sağlığına olumlu etkileri ile fonksiyonel gıda olarak değerlendirilmektedir. Günümüzde etkisi altında olduğumuz küresel iklim değişikliği, bitkiler üzerinde birçok olumsuzluğu da beraberinde getirmektedir. Doğadaki birçok biyotik ve abiyotik çevre faktörleri bitkilerde strese neden olmaktadır. Stres faktörleri, bitkilerde önemli fizyolojik ve biyokimyasal değişimlere yol açmaktadır. Bu değişimler; bitkilerde büyüme ve gelişmeyi olumsuz etkilemekte ve üründe nitelik ve niceliğin azalmasına ve hatta bitkinin, bitki organlarının ölümüne neden olmaktadır. Doku kültürü yöntemi, hızlı bir şekilde bitki çoğaltımının yanı sıra bazı stres koşullarında bitki tolerans düzeylerinin belirlenmesi için de kullanılabilir. Özellikle meyve türlerinde strese dayanım çalışmaları uzun sürmekte ayrıca fazla maliyetli olduğu için son yıllarda bu tür çalışmalar *in vitro* ve/veya *in vivo* şartlarda yapılmaktadır. Bu çalışmada, *in vitro* koşullarda bazı abiyotik stres faktörlerinin böğürtlenin bitki gelişimine etkileri ve stres faktörlerine karşı alınan bazı önlemler literatür araştırması ile ortaya konulmaya çalışılmıştır.

Anahtar Kelimeler: Abiyotik stres, Böğürtlen, Mikroçoğaltım, Üzümsü Meyveler

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EFFECTS OF ABIOTIC STRESS FACTORS ON BLACKBERRY (*Rubus* sp.) PLANT GROWTH UNDER *IN VITRO* CONDITIONS

ABSTRACT

Berry fruits constitute an important product group with great potential in terms of agricultural production, but we cannot fully exploit this potential. Many fruit species in this fruit group (strawberry, raspberry, blackberry, blueberry, rosehip, etc.) are considered functional foods due to their positive effects on human health. Global climate change, which we are currently under the influence of, also has many negative effects on plants. Many biotic and abiotic environmental factors cause stress in plants. Stress factors lead to important physiological and biochemical changes in plants. These changes negatively affect the growth and development of plants and decrease the quality and quantity of plant and organ products, possibly even death. The tissue culture method can be used for rapid plant propagation and to determine plant tolerance under specific stress conditions. Stress resistance studies, especially in fruit species, are time-consuming and costly; thus, in recent years, such studies have been conducted under *in vitro* and/or *in vivo* conditions. In this study, the effects of some abiotic stress factors on the development of blackberry plants under *in vitro* conditions and the precautions taken against these stress factors were investigated through literature research.

Keywords : Abiotic stress, Blackberry, Micropropagation, Berry fruits

1. GİRİŞ

Böğürtlen, *Rosaceae* familyasına ait en önemli meyve türlerinden biridir. *Rubus* cinsi içerisinde bulunan 12 adet alt cinsten biri olan *Eubatus* alt cinsi böğürtlenleri içermektedir (Onur, 1996). Bu cins içerisinde yer alan böğürtlenin farklı alt türleri ve melezleri bulunmaktadır (Hummer, 2017). Böğürtlen, genellikle *Rubus fructicocus* olarak bilinmektedir. Kuzey Amerika ve Avrupa doğal yayılış alanlarıdır, fakat günümüzde subtropik iklim bölgelerinden kutup iklim bölgelerine kadar yayılmıştır (Ağaoğlu, 1986; Umarusman vd., 2020).

Üzümsü meyveler grubunda yer alan böğürtlen, genellikle taze meyve olarak tüketilir. Bunun yanında dondurularak, kurutularak, reçel, meyve suyu, konsantre, püre, şurup, şarap, çay olarak da değerlendirilmektedir. Böğürtlenler lif, bazı vitaminler (C, A, E), bazı makro elementler (potasyum, kalsiyum) ve fenolik maddelerce zengindir (Dönmez vd., 2024). Sağlığa faydalı olması nedeniyle fonksiyonel gıda olarak değerlendirilmektedir.

Dünya'da böğürtlen üretimi yıldan yıla artmaktadır. Dünya'da böğürtlen üretiminde, 2000-2019 döneminde ortalama yıllık %3,4'lük bir büyüme gerçekleşmiş ve 2019 yılında 922.681 ton üretim yapılmıştır (Blackberry Analysis, 2021). Türkiye'de 2012 yılında 2.426 da alanda 2.363 ton olan üretim yapılırken, 2023 yılına gelindiğinde, 3.973 da alanda 3.583 ton böğürtlen üretimi yapılmıştır (TÜİK, 2024).

Küresel iklim değişikliğinin bitkiler üzerindeki olumsuz etkileri giderek artmaktadır. Çevredeki çeşitli abiyotik ve biyotik faktörler strese yol açarak bitkilerin sağlığını tehdit etmektedir. Bitkilerin stres altında kalması, önemli fizyolojik ve biyokimyasal değişimlere neden olarak büyüme ve gelişmelerini olumsuz yönde etkiler. Bu durum, ürünlerin kalite ve miktarında

azalmaya, hatta bitkinin, bitki organlarının ölmesine sebep olabilmektedir. Sonuç olarak, bu olumsuzluklar insan ve hayvan beslenmesi üzerinde de olumsuz etkiler yaratmaktadır (Kacar, Katkat ve Öztürk, 2013).

In vitro koşullarda bitki çoğaltmanın, genel olarak bitki yetiştiriciliği ve genetiği yönünden önemli avantajları bulunmaktadır. Bunlardan en önemlisi, aseptik koşullarda yetiştirilen bitkiler, hastalık ve zararlılardan arındırılmış olur. Bunun dışında, bitkilerin hızlı ve kitlesel üretimini mümkün kılar. Özellikle üretilen bitkilerde fenotipik ve genotipik benzerlik (homojenite), alışılagelen yöntemlerden daha kısa kültür süresi, zor üretilen türlerin daha kolay üretimi, seçilen üstün genotiplerin hızlı üretimi, üretimde daha az anaç kullanılması gibi birçok avantaj sağlamaktadır (Babaoğlu vd., 2001).

Meyve türlerinde stres dayanıklılığına yönelik araştırmalar uzun zaman almakta ve yüksek maliyet gerektirmektedir. Bu sebeple, son yıllarda bu tür çalışmalar *in vitro* ve/veya *in vivo* koşullarda gerçekleştirilmektedir. *In vitro* kültür yöntemi, bitkilerin hızlı bir şekilde çoğaltılmasının yanı sıra, çeşitli abiyotik stres koşullarına karşı dayanıklılık düzeylerinin değerlendirilmesinde kullanılan önemli bir yöntemdir. Bu yöntem, bitkileri abiyotik stres faktörlerine kontrollü bir şekilde maruz bırakma imkanı sağlar. Bu kapsamda birçok meyve türünde, *in vitro* koşullarda kuraklık, düşük ve yüksek sıcaklık, tuzluluk, kireç, ağır metal stresi gibi abiyotik stres faktörlerine dayanıklılığın belirlenmesi amacıyla çalışmalar yürütülmüştür. Böğürtlen bitkisi de, iklim değişikliği ve çevresel stres faktörlerinin etkisi altındadır. Bu çalışmada, *in vitro* koşullarda bazı abiyotik stres faktörlerinin böğürtlenin bitki gelişimine etkileri ve stres faktörlerine karşı alınan bazı önlemler literatür araştırması ile ortaya konulmaya çalışılmıştır.

2. ABİYOTİK STRES FAKTÖRLERİNİN BÖĞÜRLTEN (*Rubus* sp.) BİTKİ GELİŞİMİ ÜZERİNE ETKİSİ

In vitro koşullarda abiyotik stres uygulamaları son yıllarda giderek önem kazanmıştır. Araştırmacılar, kuraklık stresinde, polietilen glikol 6000 (PEG) (Orlikowska vd., 2008); tuzluluk stresinde, sodyum klorür (NaCl) (Marček vd., 2015; Mihaljević vd., 2024); kireç stresinde, kalsiyum karbonat ($CaCO_3$) (Karakoyun vd., 2024); ağır metal stresinde, bakır ve çinko (Ertürk vd., 2007) uygulaması yaparak bitkilerin strese tepkilerini araştırmıştır.

Tuzluluk stresi dünya çapında tarımsal ürünlerin verimliliğini kısıtlayan bir faktördür. Yapılan bir çalışmada, *in vitro* ortamda tuzluluk stresinin (15 ve 35 mM NaCl) böğürtlen (*Rubus fructicosus* L. var. čačanska Bestrna) üzerindeki etkileri incelenmiştir. 35 mM NaCl'ye maruz kalan bitkilerde protein içeriği ile POD, CAT ve APX enzim aktiviteleri artmıştır. Bu durum, böğürtlen bitkilerinin etkili bir antioksidan savunma mekanizmasına sahip olduğunu göstermektedir. Fakat, MDA seviyesinde ve prolin birikiminde belirgin bir değişiklik gözlenmemiştir, bu da čačanska Bestrna böğürtlen çeşidinin tuzluluğa karşı dirençli olduğunu göstermektedir (Marček vd., 2015). Yapılan başka bir çalışmada, iki farklı böğürtlen çeşidi (Thornfree ve Boysen) *in vitro* şartlarda tuz stresine (20, 40 ve 60 mM NaCl) maruz bırakılmıştır. Çalışmada, fotosentetik aktivite, klorofil a ve karotenoid içerikleri incelenmiştir. Çeşitler tuz stresinden önemli derecede etkilenmiştir. Çalışmada, fotosentez verimliliği düşük çıkarken, klorofil a ve karotenoid içerikleri de stres ile azalmıştır (Mihaljević vd., 2024).

Böğürtlen, genellikle kuraklık stresine dayanıklılığı yüksek bir bitkidir. Yapılan bir çalışmada, *Rubus* genotiplerinin kuraklık stresine (polietilen glikol 6000) *in vitro* ortamda tolerans gösterip göstermediği değerlendirilmiştir. Tüm çeşitler, PEG ile aksiller sürgün sayısında azalma ve prolin içeriğinde artış göstermiştir. Tepkilerin şiddeti, stres faktörünün konsantrasyonu, süresi ve genotipe göre değişiklik göstermiştir (Orlikowska vd., 2008).

Kireç, birçok meyve türünün yetiştiriciliğini sınırlayan abiyotik stres faktörlerinden biridir. Yüksek kireç içeriği, bitkilerin etkili bir şekilde fotosentez yapmasını engeller ve bu durum önemli verim kayıplarına neden olur (Karakoyun vd., 2024). Yapılan bir çalışmada, Chester çeşidi böğürtlen üzerine farklı seviyelerde uygulanan kalsiyum karbonat ($CaCO_3$) uygulamalarının *in vitro* koşullardaki etkisi belirlenmeye çalışılmıştır. Bitkiler, MS köklendirme ortamında 1 $g.l^{-1}$, 3 $g.l^{-1}$ ve 5 $g.l^{-1}$ olmak üzere üç farklı $CaCO_3$ seviyesinde yetiştirilmiştir. Çalışmanın sonucuna göre, MS koşullarında artan $CaCO_3$ seviyeleri, bitki büyümesini ve gelişimini önemli ölçüde azalttığı bildirilmiştir. Araştırmacılar, 'Chester' böğürtlen çeşidinin kireç içeriği yüksek topraklara toleransının düşük olduğunu belirlemişlerdir (Karakoyun vd., 2024).

Sanayi devriminin başlangıcından bu yana biyosferdeki ağır metal seviyeleri hızla artmış ve ağır metal toksisitesi büyük çevresel sorunlara yol açmıştır. Ağır metaller bitkilerde, hücre zararına, klorofilin azalmasına, besin dengesizliğine, kök gelişiminin ve su alımının azalmasına neden olabilmektedir. Yapılan bir çalışmada, *in vitro* koşullarda çoğaltılan böğürtlen (cv. Chester Thornless), 0.5 $mg.l^{-1}$ BAP, 30 $g.l^{-1}$ sakaroz ve 7 $g.l^{-1}$ agar ile desteklenmiş ¼ güçteki MS ortamında farklı $CuSO_4.5H_2O$ (kontrol, 50, 100 ve 150 ppm) ve $ZnSO_4.7H_2O$ (kontrol, 50, 100, 200 ppm) konsantrasyonlarına 4 hafta boyunca maruz bırakılmıştır. Çalışmada, yapraklardaki bağıl klorofil içeriğinin artan Cu ve Zn uygulamalarıyla azaldığı tespit edilmiştir. Ağır metallerle muamele edilen eksplantlarda en belirgin semptomun kloroz olduğu, ayrıca bu eksplantların mineral bileşiminde önemli değişiklikler meydana geldiği gözlemlenmiştir. Uygulanan ağır metal dozlarının mineral eksikliğine yol açtığı ifade edilmiştir (Ertürk vd., 2007).

3. ABİYOTİK STRES FAKTÖRLERİNE KARŞI ALINAN ÖNLEMLER

Stres tepkilerini anlamak için moleküler düzeydeki çalışmalar önem kazanmaktadır. Bu kapsamda, *in vitro* koşullarda abiyotik stres toleransının geliştirilmesi amacıyla gen mühendisliği ile stres toleransı genlerinin aktarılması, bitkilerde dayanıklılık sağlayabilir. Hücre kültürü ile *in vitro* şartlarda seleksiyon ve çoğaltma yapılarak strese toleranslı bitkiler elde edilebilir. Ayrıca *in vitro* kültür şartlarında; bitki büyümesini teşvik eden rizobakteriler (PGPR) (Pinter vd., 2017), elisitörler (glisin betain, melatonin, salisilik asit, jasmonik asit vb.) (Yosefi vd., 2020; Iqbal ve Khan, 2022), nanopartiküller (demir, gümüş, silisyum vb.) (Mozafari vd., 2018; Mahmoud vd., 2020) kullanılarak böğürtlende strese tolerans geliştirilebilir.

4. SONUÇ VE ÖNERİLER

Yapılan çalışmalar incelediğinde böğürtlen bitkilerinin farklı abiyotik stres faktörlerine karşı farklı fizyolojik ve biyokimyasal yanıtlar verdiği görülmektedir. Bu kapsamda, abiyotik stres faktörlerine karşı bitkilere osmoprotektanlar (örneğin, prolin veya glisin betain) (Hosseinifard

vd., 2022) ve antioksidanlar (örneğin, askorbik ve salisilik asit) (Waheed AL-Mayahi, 2016) uygulanarak stres koşullarına dayanıklılık artırılabilir. Ayrıca, hormon tedavileri (örneğin, absisik asit, jasmonik asit) (Dar vd., 2017; Yosefi vd., 2020) de uygulanabilir. Farklı stres faktörleri de denenerek böğürtlenin toleransı belirlenebilir.

Yapılacak bu uygulamalar ile stres toleransı geliştirilmiş bitkiler elde edilerek, daha yüksek verim ve kalite sağlanabilecek ve sürdürülebilir bir yetiştiricilik yapılabilecektir.

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ENHANCING FRUIT QUALITY THROUGH GOOD AGRICULTURAL PRACTICES (GAP): A SUSTAINABLE AND TECHNOLOGICAL PERSPECTIVE

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ABSTRACT

A complex interaction of agronomic, environmental, and genetic factors affects fruit quality, which together determine the sensory attributes, nutritional value, and postharvest characteristics of fruits. Genetic factors play a significant role in defining traits such as size, sweetness, acidity, and firmness, with different cultivars exhibiting wide variability. For example, apples, melons, and berries show distinct differences in aroma, texture, and nutrient concentration based on their genetic makeup. Environmental conditions, including temperature, light, and humidity, also have a profound impact on fruit quality. These factors influence the accumulation of sugars, development of color, and the levels of bioactive compounds, which are essential for the sensory and nutritional properties of fruits. Agronomic practices, such as irrigation, fertilization, and canopy management, are critical in optimizing fruit quality, affecting key attributes like sugar content, texture, and overall yield. Postharvest handling, including appropriate storage and transportation, further influences fruit quality by preventing mechanical damage and nutrient loss, ensuring fruits maintain their sensory and nutritional integrity. Good Agricultural Practices (GAPs) play a vital role in enhancing fruit quality by integrating sustainable environmental, economic, and social practices. GAP-certified farms focus on environmentally friendly methods, such as minimizing pesticide use and optimizing water management, which contribute to the production of safer and higher-quality fruits. The adoption of GAPs has been shown to improve factors such as fruit size, flavor, texture, and nutritional value, while providing farmers with access to premium markets. Furthermore, GAPs promote sustainable production systems that help reduce long-term costs, improve resource management, and enhance labor conditions. In the face of climate change, GAPs also encourage climate-resilient practices that help mitigate the effects of extreme weather, ensuring sustainable and high-quality fruit production. Ultimately, the implementation of GAPs is essential for producing fruits with superior sensory and nutritional attributes while promoting environmental sustainability and economic benefits for farmers.

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1. INTRODUCTION

Modern societies have focused on quality in all aspects of life. Quality of life is a complex concept that can be assessed at both social and individual levels, with broad social indicators often used to measure population wellbeing (Felce and Perry, 1995). Similarly, these principles extend to the quality of agricultural products, where factors such as nutritional value, safety, sustainability, and consumer satisfaction are essential components in relation to quality. However, these criteria should address the needs of a growing population while also considering the challenges posed by climate change resulting from global warming.

Fruits are an indispensable part of the human diet, providing essential macro and micronutrients, vitamins, dietary fibers, and phytochemicals to the global population (Hussein et al., 2015). Consequently, the global demand for fresh fruits and vegetables has been significantly increased by the perceptions of health benefits, as well as a shift in the lifestyles of consumers and an increased awareness of the importance of a healthy diet (Rekhy & McConchie, 2014).

Fruit quality can be assessed in a variety of ways, reflecting its subjective nature, such as the "degree of excellence," "degree of fulfillment of conditions for consumer acceptance," "fitness for purpose," or alignment with standards for specific uses, such as "nutritional quality," "industrial quality," "export quality," or "consumer quality."

The fruit quality concept includes a wide range of external and internal traits. While color, size, shape, and the absence of imperfections are external traits, taste, texture, aroma, nutritional value, sweetness, acidity (contributing to flavor), shelf life are among internal quality (Kingston, 1992). Color, size, and shape are the first factors that consumers consider while evaluating a product, but in the end, eating quality may have an impact on future purchases (Vanoli & Buccheri, 2012).

However, fruit quality is influenced by various factors, including genetic makeup, environmental conditions (such as climate and soil quality), agronomic and cultural practices, harvest time, post-harvest handling, storage conditions, and transportation methods. These elements impact both the external qualities (like color, size, and appearance) and internal attributes (such as taste, nutritional value, and shelf life) of the fruit, ultimately determining its market appeal and consumer acceptance.

There is now well-established evidence that human-driven changes to our planet’s environment are accelerating at a pace that threatens human health through the altered functioning of global systems. On the other hand, interest in systems that use sustainable approaches to improve quality through environmentally friendly methods is growing among researchers, producers, and policymakers. These systems aim to enhance productivity while reducing environmental impact, addressing consumer demand for high-quality products that are produced with minimal harm to natural resources.

Good Agricultural Practices (GAP) refer to a set of principles, standards, and practices that ensure agricultural products are grown, harvested, and processed safely, sustainably, and with high quality (Leong et al., 2020). GAP covers various aspects of farming, including pest control,

soil and water management, resource utilization, and working conditions. Its importance lies in promoting food safety, enhancing product quality, reducing environmental impacts, and meeting consumer demands for sustainable and safe food (Nain et al., 2020). GAP guidelines serve as a framework for farmers to adopt practices that align with both local and international market standards, ensuring that agricultural production meets rigorous health, safety, and environmental criteria (Nain et al., 2020).

To better understand GAPs in agricultural systems, including their limitations and potential, this chapter aims to provide an in-depth analysis of how these systems operate and explore solutions for future advancements to achieve sustainable agriculture through GAPs.

2. FRUIT QUALITY

The primary aim of agricultural practices is to achieve product quality, particularly in horticulture where fruit quality is essential. Fruit quality encompasses both external and internal traits and is influenced by various factors affecting its physical, nutritional, and sensory properties, as well as its appeal to consumers. These factors can be broadly divided into pre-harvest, harvest, and post-harvest stages, each playing a crucial role in determining the final quality of the fruit (Felce & Perry, 1995; Ramjan & Ansari, 2018).

Fruit quality is evaluated through physical, chemical, and sensory indexes. External attributes like color, size, shape, and defect absence strongly influence consumer choice (Ladaniya, 2008). Internally, sugar content, acidity, vitamin C, and antioxidants contribute to flavor and health benefits (Ramjan & Ansari, 2018). Chemical indexes, such as soluble solids content (SSC) and titratable acidity (TA), are also critical, as their ratio affects taste and sweetness, impacting preferences for fruits like apples and mandarins (Hamadziripi, 2012; Hussein et al., 2020).

Texture and firmness influence mouthfeel, shelf life, and transportability, with firmness being crucial for storage (Figueiredo et al., 2008). Secondary metabolites like phenolics and volatiles also enhance flavor and antioxidant capacity, adding sensory appeal and health benefits (Tomas-Barberan & Espin, 2001). Together, these indexes guide producers in meeting both market standards and consumer demands.

Antioxidant content, which neutralizes free radicals that cause cellular damage, is closely linked to fruit quality (Kalt, 2005). Antioxidants like vitamin C, phenolics, and carotenoids are important for reducing oxidative stress, linked to aging and chronic diseases, fueling consumer demand for antioxidant-rich fruits like berries, citrus, and apples (Ramjan & Ansari, 2018).

Environmental and agronomic factors, such as sunlight exposure, boost antioxidant levels, enhancing color and activity in fruits like apples and tomatoes (Hamadziripi, 2012). Environmental stresses, like drought, can also increase phenolic compounds, known for their antioxidative properties (Figueiredo et al., 2008). Proper post-harvest storage is essential to retain antioxidants, particularly vitamin C, ensuring that fruits maintain their health benefits until consumption (Tomas-Barberan & Espin, 2001).

Antioxidants not only benefit health but also contribute to fruit stability and shelf life by minimizing oxidation and preserving freshness and nutritional quality. Therefore, effective management throughout the pre-harvest, harvest, and post-harvest stages is essential to

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consistently produce high-quality fruit that meets consumer expectations for both nutrition and taste (Goldenberg et al., 2017).

3. FACTORS AFFECTING FRUIT QUALITY

As mentioned above, fruit qualıty is affected by many factors in the three stages of fruit products including pre-harvest, harvest, and post-harvest stages.

3.1.Factors affecting in pre-harvest stages

3.1.1. Genetics and Fruit Quality

The genetic makeup of fruits plays a substantial role in determining their quality traits, such as size, flavor, color, and nutrient content. For example, apple cultivars exhibit variability in traits like firmness, sugar-acid balance, and color due to their genetic diversity. Research has identified significant genetic loci that influence these traits, including genes affecting acidity and sugar accumulation, which are essential for taste (Liao et al., 2021; Kumar et al., 2012). Additionally, genomic selection approaches in apples have been effective in predicting and improving traits like crispness, sweetness, and color by selecting favorable genetic markers (Kostick et al., 2023).

3.1.2. Environmental Conditions

Environmental factors, particularly temperature and light exposure, significantly impact fruit quality. High temperatures can lead to faster ripening and influence color and sugar content. For example, controlled studies on apples have shown that warmer conditions lead to softer fruits with altered sugar profiles, affecting consumer preference (Chagné et al., 2014). Furthermore, increased sunlight exposure enhances anthocyanin accumulation, enriching color and antioxidant content, as observed in apples and tomatoes (Espley et al., 2023).

3.1.3. Agricultural Practices

Agricultural practices, including fertilization, irrigation, and ground cover management, are essential for optimizing fruit quality. Nitrogen fertilization has been shown to encourage growth but may reduce flavor intensity if applied in excess. Studies on irrigation practices in apples have demonstrated that adjusting irrigation frequency and timing enhances fruit size and firmness by maintaining optimal soil moisture and supporting nutrient availability and yield quality (Hardner et al., 2016). Additionally, using ground covers like mulch improves soil health, thereby increasing nutrient availability and contributing to better fruit quality and yield (Fang et al., 2022).

3.2.Harvest Factors

The timing and methods used for harvesting fruits significantly impact their final quality in terms of flavor, texture, and appearance. Fruits harvested at optimal maturity levels generally offer superior taste and nutritional benefits. For instance, mandarins and other fruits picked at their prime maturity exhibit better sweetness and texture, enhancing consumer appeal (Morris

et al., 1980). Mechanical harvesting, while efficient, can cause bruising, which may reduce shelf life and negatively affect the visual appeal of fruits such as European plums and strawberries (Lippert & Blanke, 2004; Kader, 1983).
Additionally, non-destructive techniques such as spectroscopy are emerging to assess ripeness early, enabling harvest at ideal times to ensure the best quality and reduce waste (Li et al., 2017).

3.3.Post-Harvest Factors

Post-harvest handling, including controlled storage conditions, directly influences the quality and longevity of fruits. Proper temperature and humidity control are critical to preserving nutrients and delaying spoilage. For instance, higher storage temperatures can accelerate vitamin C degradation, while cooler, controlled atmospheres help retain antioxidant levels in fruits such as mangoes and apples (Nordey et al., 2019). Moreover, post-harvest treatments, like applying 1-MCP to European plums before mechanical harvest, have been shown to prevent bruising and maintain firmness during storage, enhancing quality for longer periods (Lippert & Blanke, 2004). Modified atmospheres and coatings further extend shelf life by reducing moisture loss and slowing down the ripening process, preserving the fruit's freshness and nutritional value.

3.4.Other Factors Adversely Affecting Fruit Quality

The use of pesticides and fertilizers significantly affects fruit quality, with improper application posing hazardous risks. Residues from these chemicals can accumulate in fruit tissues, impacting safety, flavor, aroma, and nutritional content. High pesticide levels, for instance, may disrupt natural fruit flavors and reduce beneficial nutrients like antioxidants (Rekha et al., 2006; Aktar et al., 2009). Excessive fertilizers, particularly those high in nitrates, can alter the balance of sugars, acids, and other compounds, affecting taste and texture (Carvalho, 2006). Overuse of fertilizers also disrupts soil microbial health, impacting nutrient absorption and ultimately degrading fruit nutritional value (Ghorbani et al., 2008). In addition, pesticide residues may have broader environmental consequences, affecting water quality, soil biodiversity, and overall ecosystem health, which indirectly impacts long-term fruit quality and sustainability (Mostafalou & Abdollahi, 2017; Erenstein & Laxmi, 2008).

To mitigate these risks, sustainable practices, such as organic farming and integrated pest management, aim to reduce dependency on chemicals, thereby supporting safer, higher-quality fruit production that aligns with consumer expectations for health and taste (WHO, 2009). Consequently, addressing pesticide and fertilizer residues through more sustainable methods can help maintain both the immediate quality of fruits and their environmental impact over time (Hossain et al., 2017).
Several additional factors can negatively impact fruit quality, beyond pesticides and fertilizers. Environmental stresses, such as extreme temperatures, drought, and excessive rainfall, directly affect fruit development, texture, and nutritional content. Temperature extremes, for example, can lead to sunburn, cracking, or chilling injury in certain fruits, thereby reducing their visual appeal and shelf life (Hossain et al., 2017). Water stress, either from drought or excess water,

can alter the internal composition of fruits, affecting sugar and acid balance, firmness, and overall flavor (Figueiredo et al., 2008). Soil quality and nutrient availability also play crucial roles; soils deficient in essential minerals or with poor structure can limit root function, impair nutrient uptake, and thereby weaken fruit quality (Ghorbani et al., 2008).

Moreover, post-harvest handling and storage conditions are essential factors in maintaining fruit quality but can have adverse effects if not managed properly. Improper temperature, humidity, and storage duration can accelerate the degradation of nutrients like vitamin C, reduce firmness, and diminish overall freshness, leading to reduced market value and consumer acceptance (Tomas-Barberan & Espin, 2001). Additionally, mechanical damage during harvesting, transportation, and storage can lead to bruising, which not only affects appearance but also promotes microbial growth, shortening shelf life and safety (Goldenberg et al., 2017).

4. GOOD AGRICULTURAL PRACTICES (GAP)

Good Agricultural Practices (GAPs) are a comprehensive set of standards established to ensure that food is produced in a safe, sustainable, and socially responsible manner. These practices span all stages of production—from pre-production to post-harvest handling—and aim to deliver safe and healthy food, while also promoting economic, social, and environmental sustainability (FAO/WHO, 2003). The core of GAP includes three main principles: risk prevention, risk analysis, and sustainable agriculture, focusing on reducing the potential risks to human health and the environment. For example, Malaysia's National Agricultural Policy (NAP3), launched in 1999, integrates GAPs as a core strategy to increase agricultural productivity while ensuring sustainable natural resource use, targeting high productivity and sustainable practices across its agricultural programs (Murad et al., 2008).

Good Agricultural Practices (GAP) have been applied across various agricultural settings to improve productivity, environmental sustainability, and product quality, with significant examples in both crop and fruit production. For instance, the adoption of GAP in integrated maize-based systems in Tanzania has demonstrated a substantial increase in profitability due to better management practices and crop rotations, which boost soil health and reduce pest pressures (Lazaro et al., 2017). In fruit farming, GAP has been integrated into strawberry production in Iran, where structured guidelines helped enhance food safety and reduce pesticide residues, aligning with consumer demand for safer products. This application was supported by behavior models that improved grower compliance and awareness (Ranjbar et al., 2021).

In India, GAP practices in mango orchards have been applied to address the yield gap caused by inconsistent soil nutrient levels. Interventions, including soil and water conservation techniques, have helped stabilize yield variability and improve soil health, thereby supporting the resilience of mango production against climate stressors (Adak & Mishra, 2024) [47†source]. Additionally, GAP standards for quality planting materials in fruit crops, such as in the Indian Agricultural Research Institute, have improved disease resistance and plant vigor, thereby enhancing both the yield and quality of fruit crops over time (Srivastav et al., 2013).

The impact of GAP extends to value chain improvements as well. In Cuba, the application of GAP standards combined with quality certification has streamlined the management of fruit trees within the value chain. This approach has led to better product consistency, enhanced export potential, and increased market competitiveness for smallholder farmers (González et

al., 2019). Thus, GAP serves as a framework not only for sustainable production but also for expanding market access and improving the economic resilience of agricultural systems globally.

4.1.Importance of GAP

Implementing GAP is crucial for several reasons, particularly concerning food safety, environmental sustainability, and social responsibility. Firstly, GAPs ensure food safety by setting strict guidelines on chemical inputs like fertilizers and pesticides, thereby preventing contamination and reducing health risks for consumers. For instance, GAP regulations help limit chemical residues in food products, aligning with safety requirements in international markets such as the European Union, where strict pesticide residue limits must be met for export access (Kılıç et al., 2020; Akkaya et al., 2005). This alignment with global standards offers farmers expanded market opportunities and ensures that they can compete in international markets (Kirago, 2015; FAO/WHO, 2003)

Additionally, GAP contributes to environmental sustainability by encouraging resource-efficient practices, including improved soil and water management and reduced reliance on chemical inputs. Studies on GAP-certified farms in Turkey, for instance, reveal that these farms use up to 50% less nitrogen, phosphorus, and potassium fertilizers compared to conventional farms, significantly reducing environmental pollution and enhancing soil and water health (Kılıç et al., 2020). This reduction not only benefits the environment but also helps in maintaining the natural ecosystems around agricultural areas, which is increasingly important in densely cultivated regions (Altieri et al., 2022). Similarly, GAP programs in Malaysia have emphasized sustainable resoVianaurce utilization, aiming to preserve local biodiversity and minimize agricultural impact on surrounding ecosystems (Murad et al., 2008).

The social dimension of GAPs is equally significant, as they promote fair labor practices and contribute to the economic well-being of farming communities. Through GAP certification, farmers often gain access to premium markets that value quality and sustainability, which can lead to higher profits and better market stability. This aspect is particularly evident in regions such as East Africa, where the GLOBALG.A.P. certification has helped smallholder farmers secure contracts with European retailers, providing them with higher incomes and a more stable demand (Kirago, 2015). In Turkey, governmental subsidies and support for GAP implementation further support farmers by offsetting some costs and compensating for potential yield reductions associated with reduced chemical inputs (Kılıç et al., 2020). These socio-economic benefits reinforce GAP as a model that contributes to long-term agricultural sustainability.

4.2.Comparison with Organic and Conventional Agriculture

While GAP shares similarities with organic farming, such as a reduced dependency on synthetic inputs and an emphasis on environmental health, there are critical differences. Organic agriculture prohibits all synthetic chemicals, relying solely on organic fertilizers, biological pest control, and crop rotations to maintain soil fertility and control pests. This strict restriction on inputs can make organic certification challenging and expensive for farmers, especially in

developing regions where organic inputs may be scarce or costly (Altieri et al., 2017; Altieri & Nicholls, 2017). GAP, by contrast, allows limited use of synthetic fertilizers and pesticides under controlled conditions, making it more accessible for farmers who cannot entirely forego these inputs. This flexibility enables GAP-certified farmers to adopt more sustainable practices without the high entry costs of organic certification, thus expanding the range of participants in sustainable agriculture (FAO, 2011; Kılıç et al., 2020).

Conventional agriculture, which primarily focuses on maximizing yield and profitability, typically involves unrestricted use of synthetic fertilizers and pesticides, often disregarding environmental impacts. Comparatively, GAP-certified farms in Turkey show significantly reduced chemical use, with a 50% lower application rate for fertilizers and pesticides compared to conventional farms (Kılıç et al., 2020). However, this reduction in input usage can sometimes result in slightly lower yields and profits for GAP-certified farms. For example, the yield reductions on GAP farms in Turkey range from 3.3% to 20.6%, which underscores the importance of financial support and subsidies to encourage broader adoption of GAP without economically disadvantaging farmers (Kılıç et al., 2020).

5. CHALLENGES, LIMITATIONS, AND FUTURE DIRECTIONS

Implementing Good Agricultural Practices (GAP) faces numerous challenges, with structural and operational limitations impacting its broader adoption and sustainability. Key challenges include high implementation costs, limited access to training, and a lack of awareness among small-scale farmers regarding GAP standards and benefits. For instance, studies in the context of Tanzania's integrated maize farming systems highlight that smallholder farmers often lack the resources to implement GAP fully, resulting in gaps in compliance and certification (Lazaro et al., 2017). Another significant limitation is the limited availability of technology and infrastructure necessary for maintaining GAP standards, particularly in regions with inadequate digital infrastructure (Benyam et al., 2021). In Malaysia, the adoption of GAPs is constrained by limited government support for smaller farms, which could otherwise benefit from subsidies or financial assistance (Murad et al., 2008).

From a technological perspective, the cost and complexity of advanced digital tools, such as IoT-based monitoring systems and UAVs, restrict their accessibility to smaller operations despite their potential for enhancing GAP compliance (Khan et al., 2021). Moreover, challenges related to soil health management in fruit crops, as seen in Indian mango orchards, reveal that technical knowledge and resources are crucial to address nutrient deficiencies and soil compaction—issues that GAP alone cannot resolve without complementary technological support (Adak & Mishra, 2024). To address these challenges, future directions for GAP implementation should focus on increasing financial support for smallholder farmers, improving training programs, and enhancing access to affordable technology (Kirago, 2015). Emphasizing policy interventions that prioritize resource conservation, as evidenced by efforts in subtropical regions, can also support long-term sustainability by enabling farmers to maintain soil and crop health while meeting GAP standards (Srivastav et al., 2013).

6. CONCLUSION

In conclusion, enhancing fruit quality through Good Agricultural Practices (GAP) provides a balanced approach to achieving safety, sustainability, and market competitiveness in the agriculture sector. GAP ensures that fruit quality is maintained across all stages, from pre-harvest to post-harvest, addressing factors like soil health, water management, and careful handling during harvest and storage. By incorporating science-backed practices, GAP offers a middle ground between conventional and organic agriculture, allowing limited chemical use while prioritizing environmental health and consumer safety. However, challenges remain, particularly for smallholder farmers who face barriers such as high implementation costs, limited access to technology, and resource constraints. Future advancements in technology and policy support are essential to making GAP more accessible and sustainable globally, ensuring that farmers can meet rising quality standards and consumers can access safe, high-quality fruits.

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GENE EXPRESSION AND METABOLIC PATHWAYS IN FRUIT QUALITY: FLAVOR, COLOR, AND NUTRITIONAL VALUE

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ABSTRACT

Gene expression and metabolic pathways play pivotal roles in determining the quality attributes of fruits, including flavor, color, and nutritional value. Recent advances in genomic, transcriptomic, and metabolomic technologies have shed light on the intricate biochemical processes underlying fruit ripening and quality formation. Flavor is influenced by the accumulation of sugars, organic acids, and volatile compounds, with key metabolic pathways like glycolysis and the TCA cycle playing critical roles. Color changes during ripening are largely driven by the degradation of chlorophyll and the synthesis of carotenoids and anthocyanins, regulated by genes involved in pigment biosynthesis. Nutritional value is enhanced by the accumulation of bioactive compounds such as phenolic acids, flavonoids, and carotenoids, which are regulated by specific biosynthetic genes. Ripening processes, which involve coordinated changes in gene expression and metabolic activity, are governed by hormonal signals and transcription factors that control carbohydrate metabolism, cell wall restructuring, and the production of volatile compounds. Understanding these molecular and biochemical mechanisms provides valuable insights for improving fruit quality through breeding and biotechnological interventions. This knowledge enables the selection of fruit varieties with enhanced sensory qualities, better nutritional content, and longer shelf life, contributing to both consumer satisfaction and agricultural sustainability.

Keywords: Fruit Quality, Gene Expression, Biochemicals, Molecular Mechanisms, Biological Pathways

INTRODUCTION

Flavor, color, and other nutritional quality-related traits of fruit contribute to consumer preference for market competitiveness and the ultimate profit in agriculture. Such properties are mainly controlled by the fruit's metabolic pathways and gene expression profiles, dictating the biosynthesis of an array of phytochemicals and pigments that enhance their attractiveness. Gene expression and metabolic pathways are known to be well-coordinated in ways that

respond not just individually, but also in aggregate with significant environmental and genetic features contributing to the phenotype (Zhu et al., 2022; Do et al., 2023). The accumulation of sugars, organic acids, and volatile compounds controls the flavor linked to consumer satisfaction. The application of multi-omics techniques helped the researchers understand the genetic and metabolic basis of flavor, revealing key pathways regulating sugar levels, organic acids, and flavor-related volatiles in fruits like tomatoes and apricots (Gao et al., 2019). Particularly in species where flavor-associated genes have been reduced as a result of other agronomic traits, research indicates that transcriptomic and metabolomic integration may control the selection of alleles linked to flavor enhancement, enabling breeding programs that balance yield and quality (Klee & Tieman, 2018).

Another important characteristic of fruit quality is color, which is controlled by complex gene interactions that affect the production of pigments such as carotenoids and anthocyanins, which improve appearance and have health-promoting antioxidant properties. Many potential genes controlling pigment pathways have been found through transcriptome analysis, including the tomato NAC-NOR transcription factor, which affects color development and consumer acceptance (Li et al., 2020).

The expression of genes that control secondary metabolites such as flavonoids, vitamins, and vital minerals is directly linked to the nutritional value of the fruits. Recently, the advances in gene engineering techniques including CRISPR and RNAi technologies, enable precise modifications of the genome to achieve desired gene sequences enhancing nutritional compounds without affecting the overall fruit structure, as evidenced in studies on modified banana and apple varieties (Lie et al., 2014; Rodrigo et al., 2019). Thus, researchers can help to improve the quality of consumers' diets by breeding and producing more nutrient-dense plant cultivars (i.e., contain more vitamins and minerals), via genetic engineering.

In conclusion, the combination of transcriptomics, metabolomics, and genomes offers vital information about the genes and processes underlying fruit quality traits. Research into these genetic networks has the potential to promote agricultural innovation and produce fruit cultivars that are not only visually attractive and palatable but also nutritious and healthy in content (Zhu et al., 2022). Therefore, this review has focused a more depth on the importance of these studies in different species and recent advances in this field.

2. GENE EXPRESSION AND FLAVOR COMPOUNDS

Organic acids have a major impact on flavor profiles and are essential for preserving pH and improving the sensory qualities of fruits (Kader, 2008). The ratio of sugar to acid is a criterion to evaluate fruit maturity along with general fruit quality (Jiang et al., 2019). In fruits, fructose mainly acts as the major sugar. For example, in watermelon malic acid is the primary organic acid, and the proper ratio of both compounds contributes uniquely to the taste of watermelon (Jawad et al., 2020). Sucrose is a critical part of the sugar metabolic pathway, a complex of reactions regulated by a gene network, and is transported to the fruit through the phloem. Within the fruit, neutral invertase converts sucrose into glucose and fructose, while sucrose synthase transforms it into UDP-glucose and fructose, enabling further metabolic processing (Miron & Schaffer, 1991; Granot et al., 2014). The phosphorylation of fructose and glucose into fructose 6-phosphate (F6P) and glucose 6-phosphate (G6P), respectively, is mediated by hexokinase and

fructokinase (Granot et al., 2014). This process is reversible due to phosphoglucoisomerase, which allows dynamic adjustments in the sugar pathway, supporting cellular energy requirements and growth. Specialized transporters facilitate the movement of sucrose to the vacuole, where acid invertase hydrolyzes it into fructose and glucose, contributing to the unique flavor profile (Miron & Schaffer, 1991).

Metabolic transformations are key controllers of variations in gene expression and metabolic gene networks leading to genetic differences among fruits like peach, lemon, pineapple, apple, and strawberry influencing organic acid composition during development (dos Santos et al., 2015). Transcriptomics, via high-throughput sequencing, has improved our knowledge of gene expression during the stages of fruit development as seen in jackfruit (Hu et al., 2016), grape (Mao et al., 2018), and pear (Wang et al., 2018).

The discovery of gene regulatory networks has been greatly advanced by combining quantitative biology with modern omics techniques (Qin et al., 2016). One particularly effective approach is Weighted Gene Coexpression Network Analysis (WGCNA), which helps uncover coexpressed gene networks by analyzing mRNA-Seq data. This method has been successfully used to identify gene modules linked to important traits like fruit acidity, taste, and aroma, as demonstrated in studies on apricots and apples that explored flavor and flavanol production (Bai et al., 2015; Zhang et al., 2019). These findings highlight the importance of key regulatory genes and open up opportunities to enhance fruit quality through targeted genetic improvements (Umer et al., 2020).

Volatile compounds are essential in defining the unique flavor profiles of fruits and vegetables, influencing consumer preference and overall produce quality. These compounds, primarily terpenes, esters, alcohols, aldehydes, and ketones, create complex aroma and taste characteristics that make each fruit distinct (El Hadi et al., 2013). For instance, terpenes contribute floral and fruity notes, esters often add sweet, fruity aromas, and aldehydes impart fresh, green qualities. These sensory elements are essential in determining the perceived ripeness and attractiveness of fruits and vegetables (Kader, 2008).

The biosynthesis of volatile compounds is closely linked to metabolic pathways involving fatty acids, amino acids, and carbohydrates. Fatty acid oxidation produces C6 and C9 aldehydes, yielding fresh green notes that are especially common in apples and tomatoes, while amino acid catabolism leads to the formation of alcohols and aldehydes that enhance flavor complexity (Umer et al., 2020). Sugars, transported to the fruit through the phloem, undergo conversion into glucose and fructose by enzymes such as neutral invertase, while sucrose synthase enables the breakdown of sucrose into fructose and UDP-glucose, both of which contribute to the fruit's sweetness. The balance of sugar and acid metabolism in developing fruits is regulated by genetic factors, with specific gene expression patterns impacting sugar content and overall flavor (El Hadi et al., 2013).

Advanced techniques, including gas chromatography-mass spectrometry (GC-MS), have allowed researchers to profile and quantify volatiles, uncovering the complex interactions of these compounds across varieties and ripening stages (Kader, 2008). GC-MS enables the identification of hundreds of compounds in a single sample, facilitating the selection of cultivars with desirable flavor traits for breeding purposes. Such advancements make it possible to fine-

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tune volatile profiles, providing breeders with tools to enhance consumer appeal by prioritizing flavor.

Volatiles also have health-promoting properties that contribute to the functional value of fruits. Compounds like linalool, found in strawberries and tomatoes, exhibit antioxidant and antimicrobial properties, which support human health by reducing oxidative stress and combating harmful pathogens (Lewinsohn et al., 2001; Pereira et al., 2018,). These bioactive volatiles underscore the nutritional and therapeutic potential of flavor compounds in fruits, further expanding their significance beyond taste.

Understanding the genetic regulation of volatile biosynthesis can lead to significant advances in flavor quality, providing insights into the metabolic pathways that determine fruit flavor. Integrating genomics with flavor research, as demonstrated in studies on watermelon, has uncovered gene networks that control sugar and organic acid metabolism, which are critical for flavor development (Umer et al., 2020). By identifying key genes, researchers aim to develop fruit varieties with improved flavor, longer shelf life, and greater market value, ultimately enhancing consumer satisfaction and agricultural sustainability (Indurthi et al., 2024).

3. COLOR DETERMINANTS IN FRUITS

The color of fruits arises from a complex interplay of genetic, environmental, and evolutionary factors that influence pigment production, including anthocyanins, carotenoids, and chlorophyll. Genetically, specific genes drive pigment biosynthesis; for example, MYB transcription factors in apples activate anthocyanin production, which imparts red hues to both skin and flesh, with the MdMYB10 gene being a primary regulator of this color trait (Allan et al., 2008; Espley et al., 2007). Pigment composition varies across fruits, with carotenoids and anthocyanins being significant contributors. In tomatoes, for instance, high lycopene levels create a red color, while δ-carotene and β-carotene yield orange shades, underscoring the genetic diversity in color pathways that contributes to the variety of fruit colors (Yoo et al., 2017). Environmental factors like light and temperature also shape fruit coloration, as UV-B exposure stimulates anthocyanin production in apple skin, and cooler temperatures enhance pigment accumulation, making environmental conditions essential to color intensity and distribution (Dar et al., 2019). Evolutionarily, the color of fruits adapts to attract specific seed dispersers; for instance, fruits eaten by birds often exhibit red or black tones to maximize visibility and appeal to these animals, a pattern observed worldwide (Nevo et al., 2018). This adaptation extends to both biotic factors, such as frugivore preferences, and abiotic factors like climate, where color contrasts in colder regions aligns with the primary disperser type, demonstrating fruit color's dynamic role in ecological interactions (Sinnott-Armstrong et al., 2020).

3. NUTRITIONAL QUALITY AND HEALTH-RELATED METABOLITES

Fruits are invaluable for human health, providing a wealth of essential nutrients and bioactive compounds that reduce the risk of various diseases. They offer a wide range of vitamins, minerals, fibers, and phytochemicals, which together play crucial roles in supporting nutrition and promoting positive health outcomes. Fruits like mango, grape, and banana are particularly rich in vital nutrients; mangoes are packed with vitamins and amino acids, while grapes are

high in flavonoids that support cardiovascular health. Such nutrient diversity contributes to a balanced diet, offering a comprehensive array of health-promoting components (Shi et al., 2022). Exotic fruits like avocado and dragon fruit are abundant in polyphenols, flavonoids, and other metabolites that exhibit potent antioxidant properties, aiding in the improvement of lipid profiles and the reduction of cholesterol levels, key factors in preventing cardiovascular diseases (Dembitsky et al., 2011). Phytochemicals found in fruits, such as phenolic compounds and terpenoids, not only enhance sensory qualities but also offer protective health benefits; in stone fruits like peaches and plums, these compounds help shield cells from oxidative stress and support cellular health, potentially decreasing the risk of chronic diseases (Lara et al., 2020). Advanced metabolomic research continues to reveal bioactive compounds in fruits that combat oxidative stress and inflammation, contributing to the prevention of conditions such as obesity, cardiovascular diseases, and some cancers (Singh et al., 2023). Moreover, both traditional and modern breeding techniques are enhancing the nutritional quality of fruits, focusing on increasing concentrations of vitamins, carotenoids, and phenolic compounds. This biotechnological progress aims to produce nutrient-rich fruit varieties that meet the growing consumer demand for health-boosting options (Sabbadini et al., 2021).

4. TECHNOLOGICAL ADVANCES IN GENETIC MODIFICATION

The enhancement of nutrient content in fruits involves understanding the genetic pathways regulating vitamin and flavonoid biosynthesis. Advances in genetic modification and molecular breeding have facilitated targeted approaches to increase nutrient levels effectively. Genes that regulate flavonoid and vitamin biosynthesis, such as the transcription factors MYB and bHLH, are critical in influencing nutrient content by enhancing flavonoid pathways like anthocyanin and flavonol production, which improve fruit color and provide potential health benefits. Studies in tomatoes and apples demonstrate that MYB-bHLH-WD40 complexes can effectively increase flavonoid levels, reinforcing the importance of these genetic pathways in fruit quality enhancement (Pfeiffer & Hegedűs, 2011; Wang et al., 2020).

Technological advancements in genetic modification have also played a significant role. New genetic tools, such as RNA interference (RNAi), CRISPR-Cas9, and metabolic engineering, have enabled precise nutrient enhancement in fruits. For example, RNAi-mediated suppression of genes like DET1 in tomatoes has successfully increased carotenoid and flavonoid content without impacting other quality traits, showcasing the precision and effectiveness of modern genetic interventions (Davuluri et al., 2005). Similarly, CRISPR technology has allowed for precise modifications in genes associated with vitamin C production in apples, leading to a significant boost in ascorbic acid content (Mellidou et al., 2012).

Furthermore, metabolomic and epigenetic insights have deepened our understanding of nutrient profiles in fruits. Metabolomics, through techniques like transcriptome profiling in blueberries, has identified genes linked to flavonoid and antioxidant accumulation, providing insights into how these compounds increase throughout fruit development (Zifkin et al., 2011). Additionally, epigenetic modifications, such as histone adjustments, have proven useful for nutrient enhancement. For instance, in tomatoes, NF-Y transcription factors have been shown to elevate flavonoid content by modulating histone structures, suggesting that epigenetic strategies can be a powerful tool in developing nutrient-dense fruits (Wang et al., 2020).

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This combination of genetic, technological, and epigenetic approaches is pivotal for efficiently boosting vitamin and flavonoid content in fruits, ultimately leading to nutrient-rich crops with enhanced health benefits.

6. FUTURE DIRECTIONS AND CHALLENGES

Future directions in plant breeding emphasize the integration of multi-omics approaches, which combine genomics, transcriptomics, proteomics, metabolomics, and phenomics to enhance both crop yield and quality. This comprehensive strategy allows breeders to uncover complex gene-trait interactions and to develop crops that are resilient to environmental stresses and adaptable to changing climates (Mahmood et al., 2022). Multi-omics tools further facilitate a detailed understanding of molecular networks and gene functions tied to traits like ripening, nutritional quality, and resilience, which can enhance breeding accuracy by aligning genotype and phenotype data (Yang et al., 2021). This integration has proven effective in identifying genetic markers for essential traits, as seen in studies on fruit species where sweetness, color, and aroma have been linked to specific metabolic pathways, thereby advancing breeding efficiency and quality control (Freilich et al., 2015). Despite these advances, challenges remain, including technical issues in merging large datasets and the need for robust computational models to analyze complex data, which are crucial for practical breeding applications (Roychowdhury et al., 2023).

Achieving a balance between yield and quality in commercial production is particularly challenging, as these factors are controlled by intricate biochemical pathways, especially in fruit crops where quality traits like flavor and aroma are influenced by volatile and non-volatile compounds, such as sugars and acids (Xu et al., 2023). Advanced breeding techniques, including genome editing and high-throughput phenotyping, provide promising avenues to optimize these traits without compromising yield (Tester & Langridge, 2010). For example, metabolomic studies on fruits like apricots and watermelons have identified key genes involved in sweetness and texture, enabling the selection of high-quality varieties with robust yields (García-Gómez et al., 2020). Postharvest strategies, such as optimized storage conditions, also play a critical role in preserving quality traits like flavor and nutrition, further supporting balanced breeding goals (Yun et al., 2022). However, climate variability remains a significant hurdle, emphasizing the need for breeding programs to continue developing resilient, high-quality crop varieties that meet both production demands and consumer expectations (Li, 2020). By integrating multi-omics data and innovative technologies, plant breeding programs can advance toward precision breeding that prioritizes both yield and quality, making them responsive to commercial and environmental challenges.

7. CONCLUSION

Fruit quality encompasses a range of sensory and nutritional aspects, including flavor, color, texture, and nutritional value, all of which are critical to consumer preference and market success. Flavor is a complex attribute, largely influenced by the accumulation of sugars, organic acids, and volatile compounds. Sugars like fructose and glucose and organic acids, such as malic and citric acid, define the sweetness and tartness of fruits, while volatile compounds,

including terpenes and esters, contribute to unique aromas that enhance fruit appeal. Color is another essential aspect of fruit quality, primarily determined by pigments such as anthocyanins, carotenoids, and chlorophyll. These pigments not only attract consumers but also indicate ripeness and are associated with antioxidant properties beneficial to health. Texture, influenced by cell wall composition and water content, impacts the firmness and juiciness of fruits, affecting the eating experience and postharvest handling. Lastly, nutritional quality, shaped by vitamins, minerals, and bioactive compounds like flavonoids, enhances the health benefits of fruits, making them vital components of a balanced diet. Integrating these quality traits into breeding programs is crucial for developing fruit varieties that meet both consumer expectations and nutritional standards.

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TARIMSAL ATIK YEÖNETİMİNDE CEVİZ YEŞİL KABUĞU

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ÖZET

Artan nüfusun beslenme ve su ihtiyacının karşılanması ülkelerin en önemli konuları arasında başı çekmektedir. Bu ihtiyaçların karşılanması amacıyla birçok politika, tarım odaklı birçok bilimsel çalışma ve uygulama yapılmaktadır. Hepsinin merkezinde birim alanda daha fazla üretim ve azalan tarım topraklarına karşı artan nüfusun besin ihtiyaçlarının karşılanması vardır. 1970'te 3.7 milyar olan dünya nüfusunun bugünkü güncel nüfusu 8,2 milyardır. Bu nüfusun 2050 yılında 9 milyara ve 2100 yılında ise 11 milyara ulaşacağı tahmin edilmektedir. Artan nüfusun besin ihtiyaçları normal yöntemler işlediğinde artan tarım toprakları ve artan sulama imkanları ile karşılanması gerekmektedir ancak tam tersine 250 milyondan fazla insan çölleşme problemi ile yüz yüzedir. 1 milyar insan ise çölleşme riski altında bulunan bölgelerde yaşamlarını sürdürmektedir. Tarım alanları artmamakta ve aksine şehirleşme, sanayileşme gibi etkenlerle daha da azalmaktadır. Bunun en büyük sebeplerinden birisi ise sürdürülebilir olmayan yöntemler ve sonucunda ortaya çıkmış olan küresel ısınmadır.

Tarımsal üretimin giderek artması ile ortaya çıkan önemli konulardan ve sürdürülebilir bir yaşamın gereklerinden birisi de bu atıkların uygun şekillerde bertaraf edilmesi konusudur. Artan gıda talebi ile tarımsal faaliyetlerde önemli artış sağlanmış ve sonucunda tarımsal atık miktarı dramatik bir şekilde yükselmiştir. Ekonomik büyümelerini ve nüfuslarını hızlı bir şekilde artıran Çin, Hindistan ve Afrika gibi ülkeler tarımsal atık kapasitelerini de oldukça yükseltmişlerdir. Bu atıklar hem bahsi geçen ülkelerde hem diğer ülkelerde bir miktar geri dönüştürülüyor olsa da dünyada üretilen tarımsal atıkların önemli bir kısmının bertaraf edilme yöntemlerindeki yanlışlıklar bazı sera gazlarının salınımına yol açmakta dolayısıyla insan sağlığı ve doğaya zarar vermektedir. Tarımsal atık yönetimi için atıkların özelliklerinin iyi bilinmesi ve değerlendirilme şekillerinin bu özellikler ışığında planlanması önemlidir.

Ceviz yeşil kabuğu, sahip olduğu özellikler ile önemli bir tarımsal atık olmakla birlikte birçok farklı alanda değerlendirilme potansiyeli vardır. Bu çalışmada tarımsal atık yönetimi konusu ceviz yeşil kabuğu merkeze alınarak tartışılacaktır.

Anahtar Kelimeler: Ceviz, atık, yeşil kabuk, *Juglans regia*

THE GREEN WALNUT HUSK IN AGRICULTURAL WASTE MANAGEMENT

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ABSTRACT

Providing for the nutritional and water needs of a growing population remains one of the top priorities for countries. To suppliying these needs, various policies, scientific studies, and agricultural practices are being implemented. At the core of all these efforts lies the goal of increasing production per unit area and meeting the food demands of an expanding population despite decreasing agricultural lands. In 1970, the world population was 3.7 billion, and today it has reached 8.2 billion. It is estimated that by 2050, the global population will reach 9 billion and, by 2100, approximately 11 billion. As the population grows, food requirements ideally would be met by expanding agricultural lands and irrigation capabilities. However, more than 250 million people face desertification, and around 1 billion live in areas at risk of desertification. Farmland is not increasing and, in fact, is shrinking due to factors like urbanization and industrialization. One of the major reasons for this decline is unsustainable practices, which have led to global warming.

With the increasing agricultural production, an essential issue and necessity for a sustainable life is the proper disposal of agricultural waste. Rising food demand has led to a significant increase in agricultural activities, resulting in a dramatic growth in the amount of agricultural waste. Countries like China, India, and those in Africa, which have experienced rapid economic and population growth, have also significantly raised their agricultural waste capacities. While some of this waste is recycled to an extent in these and other countries, improper disposal methods for agricultural waste worldwide contribute to greenhouse gas emissions, which harm human health and the environment. It is crucial to understand the characteristics of agricultural waste and to plan disposal methods accordingly.

The green walnut husk, with its specific properties, is an important type of agricultural waste and holds potential for various applications. In this study, agricultural waste management will be discussed with a focus on the green walnut husk.

Keywords: Walnut, waste, green husk, Juglans regia

1. GİRİŞ

Dünya nüfusu her geçen gün artmakta, popülasyondaki yükseliş farklı problemlere sebep olmaktadır. Nüfusun artışı ile birlikte hızlı ve plansız kentleşme, yoğun sanayi faaliyetleri ve bu faaliyetler sonucu meydana çıkan endüstriyel atıklar, konvansiyonel tarım sonucu oluşan ekolojik kirlenme çevresel faktörleri olumsuz etkilemekte ve dünya her geçen gün çözülmesi güç problemlerin içerisine doğru çekilmektedir (Kadıoğlu, 2001).

Artan dünya nüfusunun doğru şekilde yönetilmesinin anahtarı beslenme kaynaklarından, bu kaynaklara doğru şekilde ulaşmak ise tarımdan geçmektedir. Tarımın önemi kadar, doğru yöntemlerle yapılmadığında riskleri de mevcuttur. Konvansiyonel tarımın giderek artması kimyasal girdilerin bilinçsizce kullanılması ve kaynakların kirlenmesi, su kaynaklarının bilinçsizce tüketilmesi gibi önemli problemlere sebebiyet vermektedir. Sağlıklı ve yaşanabilir bir dünyanın yollarından birisi sürdürülebilir tarımsal faaliyetlerden geçmektedir.1970 yılında 3,7 milyar olan dünya nüfusu, günümüzde 8,2 milyarı aşmıştır. 2050 yılına kadar 9 milyar ve

2100 yılına kadar yaklaşık 11 milyar olması beklenen nüfus artışı, gıda güvenliği ve sürdürülebilir tarım uygulamalarını kritik hale getirmiştir (Koops ve van Leeuwen, 2017).

Milyarlarca insanın artan besin ihtiyaçlarının karşılanması kaygısı hayvancılık ve bitkisel üretim gibi tarım kollarında önemli artışlara sebebiyet vermiş, bu durumla birlikte tarımsal atık problemi ortaya çıkmıştır. Son yüzyılda özellikle Çin, Hindistan ve Afrika hızlı nüfus ve ekonomik büyüme ile birlikte tarımsal atık kapasitelerinde de dramatik bir artış yaşamışlardır. Diğer ülkeler de benzer durumlarla karşı karşıya kalmışlardır. Tarımsal atıkların açıkta yakılması veya düzensiz bir şekilde atılması, sera gazı emisyonlarına, toprak bozulmasına ve su kirliliğine neden olmaktadır (Wang ve ark., 2018a, 2018b). Çin' den sonra ikinci büyük tarımsal atık üreticisi olan Hindistan' ın sadece çeltik sapı atığı 130 milyon ton olarak bildirilmiştir. Bu atığın yarısının yem olarak değerlendirildiği bilinse de kalan miktarın büyük kısmı yakılmaktadır. Ve bu durum halk sağlığında endişelere yol açabilecek hava kirliliğine neden olduğu rapor edilmiştir (Singh ve Sidhu, 2014). Atıklar uygun şekilde bertaraf edilmediğinde karbondioksit (CO2), diazot monoksit (N2O) ve metan (CH4) gibi sera gazlarının açığa çıkmasına neden olmakta, insan ve doğal çevre üzerinde tehdit oluşturmaktadır. Tarımsal atıkların özelliklerini anlamak ve sürdürülebilir bertaraf ve kullanım yöntemleri geliştirmek, bu çevresel etkileri azaltmak için hayati öneme sahiptir (Searchinger ve ark., 2008; Kaab ve ark., 2019)..

2. CEVİZ YEŞİL KABUĞU

Cevizler genel olarak iç ceviz üretimi amacıyla yetiştirilmektedir ve hasadı ve işleme sırasında diğer parçalar atık ürün olarak değerlendirilmektedir. Birçok çalışma cevizin diğer kısımlarının (yaprak, yeşil kabuk, sürgün, dal, kökü vb.) kimyasal ve fiziksel özellikleri üzerine önemli bulgular sunmuş ve bu kısımların da düşük maliyetli hammaddeler olarak çeşitli sektörlerde kullanılabileceğini göstermiştir (Jahanban-Esfahlan ve ark., 2018; Martinez ve ark., 2010). Kendine özgü bileşimi ve potansiyel uygulamaları nedeniyle yeşil ceviz kabuğu dikkat çeken bir tarımsal atıktır. Yeşil ceviz kabuğu, ceviz meyvesinin (*Juglans regia* L.) en dış katmanıdır. Genellikle hasat ve işleme sırasında atılan bu katman, ceviz tarımsal atıklarının önemli bir bölümünü oluşturur. Fenolikler, flavonoidler ve juglon gibi biyolojik aktif bileşikler açısından zengin olan yeşil ceviz kabuğu gıda, ilaç ve kozmetik sektörlerinde çeşitli uygulamalar için önemli bir potansiyele sahiptir (Demirbas, 2006; Srinivasan ve ark., 2010; Srinivasan ve ark., 2008). Ceviz kabuklarının açıkta bırakılması veya yakılması gibi yöntemler çevre kirliliğine neden olmaktadır. Bu uygulamalar sera gazları ve zararlı maddeler salarak toprak ve su kirliliğine yol açabilmektedir. Bu atığın çevresel etkisini en aza indirmek için uygun yönetim ve kullanım yöntemleri önemlidir.

2.1. Ceviz Yeşil Kabuğunun Kullanım Alanları

Literatürde ceviz yeşil kabuğunun gıda, tıp ve endüstri gibi farklı alanlarda uygulamalarına dair birçok bilgi vardır. Tehlikeli maddelerin uzaklaştırılmasında ceviz yeşil kabuğunun toz formu kullanılmaktadır. Tıp ve gıda alanında ise hazırlanan ceviz kabuğu özütlerinden elde edilen bioaktif bileşenler önemli kullanım alanlarına sahiptir. Antioksidan, antimikrobiyal, antifungal

antikanser ve antitrombosit gibi özellikleri ceviz yeşil kabuğunu oldukça değerli kılmaktadır. Bazı alanlardan daha detaylıca bahsedecek olursak;

2.1.1. Zararlı maddelerin uzaklaştırılması

Tarımsal atıklardan elde edilen birçok biyomateryal, son yıllarda endüstri faaliyetleri sonucu ortaya çıkan ve çevrenin kirletilmesine yol açan tehlikeli maddelerin uzaklaştırılmasında yaygın olarak kullanılmaktadır. Yeşil ceviz kabuğu bu amaçla kullanılabilecek düşük maliyetli katı atık olarak değerlendirilmektedir (Yagub ve ark., 2014). Birçok çalışmada ceviz kabuğundan elde edilen malzemelerin ve içeriğinde bulunan fonksiyonel bazı grupların (hidroksil, karboksil, hidroksil) sentetik boyaların giderilmesinde önemli rol oynadığı bildirilmiştir (Çelekli ve ark., 2016). Ayrıca sudaki fenolün giderimi için de uygun bir özelliğe sahip olduğu çalışmalarda bildirilmiştir. Ceviz yeşil kabuğundan elde edilen malzemelerin 17,8 mg/g gibi maksimum adsorpsiyon kapasitesine sahip olabildiğini tespit etmişlerdir (Godini ve ark., 2016).

Ağır metaller çevresel kirlenme ile ilgili olarak büyük problem teşkil eden gruplardandır. Toprak ve su kaynaklarının kirlenmesi ve ekolojik bozulmalara sebebiyet vermesi nedeniyle canlı yaşamını tehdit edebilmektedirler [Harrison, 2001; Köhler ve ark., 2007]. Ceviz yeşil kabuğunun bazı ağır metallerin sudan uzaklaştırılması konusunda kullanıldığı ile ilgili bazı çalışmalar yapılmıştır. Sınırlı sayıda olan bu çalışmalar arasında özellikle krom ve kadmiyum ağır metallerinin giderimi incelenmiş ve önemli sonuçlar alınmıştır. Bu çalışmalarda ceviz yeşil kabuğunun bu amaçla kullanılabilecek kolay ulaşılabilir ve ucuz malzemeler olduğu bildirilmiştir (Wang ve ark., 2009; Zafarani ve ark., 2015).

2.1.2. Kozmetik endüstrisi

Ceviz yeşil kabuklarının boyayıcı özellikleri herkes tarafından bilinmektedir. Hasat zamanlarında manuel şekilde yeşil kabukları uzaklaştırmaya çalışan kişilerin elleri kalıcılığı yüksek ve doğal şekilde boyanmaktadır. Bu özelliği dolayısıyla ceviz yeşil kabuklarının güvenli bir boya kaynağı olarak değerlendirilmesi konusu bazı araştırmacılar tarafından incelenmiştir. Sıçanlar üzerinde yapılan çalışmalarda ceviz yeşil kabuğu özütleri ve yan maddelerle oluşturulan boya maddelerinin saç üzerinde yıkama ve gün ışığına karşı mükemmel direnç gösterdiği bildirilmiştir. Ayrıca malzemenin sıçan üzerinde herhangi bir tahriş edici bir etkisi olmadığı da tespit edilmiştir. Yapılan çalışmaların ceviz yeşil kabuğunun doğal, doğa dostu ve güvenilir bir kozmetik boya kaynağı olabileceği bildirilmiştir [Beiki ve ark., 2009].

2.1.3. Gıda alanında

Ceviz yeşil kabukları önemli antioksidan kaynaklarıdır. Özellikle bu kaynakların besin oksidasyonunu engelleme konularında kullanıldıkları ancak doğal olmayan antioksidan kaynaklarının son dönemlerde bazı kaygılar oluşturduğu bilinmektedir. Bu sebeple gıda endüstrisinde doğal antioksidanların kullanılmasına yönelik bir eğilim oluşmuştur (Carocho ve ark., 2018). Yapılan çalışmalarda ceviz yeşil kabuklarının doğal antioksidan kaynağı olarak kullanılabileceği tespit edilmiştir. Doğru dozlarda kullanılan bu doğal kaynakların besinlerde

oksidasyonu azalttığı, bazı besinlerde depolama ömrüne olumlu etkilerde bulunduğu bildirilmiştir (Salejda ve ark., 2016).

Ayrıca yüksek fenolikler ve vitaminler açısında yüksek olgunlaşmamış ceviz meyveleri de besin olarak kullanılabilmektedir. Ülkemizde ve farklı ülkelerde olgunlaşmamış ceviz meyvelerinin reçel olarak kullanıldığı bilinmektedir. Bazı ülkelerde ise yine bu özelliğe sahip meyveler bazı süreçlerden geçirilerek likör elde edilmesinde kullanılır. Geleneksel halk tıbbında bu likörlerin kullanıldığı bilinmektedir (Stampar ve ark., 2006; Stampar ve ark., 2007).

2.1.4 Medikal kullanımı

Ceviz yeşil kabuk atıkları önemli bazı maddeler içerirler. Bunlar dolayısıyla medikal amaçlı bazı alanlarda kullanılma potansiyelleri yüksektir. Son yıllarda nanopartiküller insan yaşamının çeşitli alanlarında kullanılmaya başlanmıştır. Ceviz yeşil kabuklarından elde edilen gümüş klorür nanopartikülleri hem gram negatif hem gram pozitif bakterilere karşı önemli bir antibakteriyel aktivite göstermişlerdir (Kohan ve ark., 2015).

Ceviz atıklarında bulunan naftokinonlar, bazı araştırmacılar tarafından kök ur nematoduna karşı kullanılmıştır ve potansiyel olarak *Meloidogyne* türlerine karşı biyonematisit olarak kullanılabileceğini önerilmiştir (Maleita ve ark, 2017).

Birçok çalışmada ceviz yeşil kabuğu ekstraktlarının kan trombositleri üzerine etkilerini araştırılmıştır. Önemli bulguların rapor edildiği çalışmalarda ceviz yeşil kabuklarının polifenolik bileşik ve antioksidan içerikleri sayesinde anti-trombosit aktiviteye sahip olduğu bildirilmiştir (Meskini ve ark., 2017). Ayrıca ceviz yeşil kabuklarından elde edilen özütlerin bazı tümör ve kanser tiplerine karşı da önemli bir sitotoksit etki oluşturduğu birçok çalışma ile bildirilmiştir (Li ve ark., 2013; Tsasi ve ark., 2015; Zhou ve ark., 2015)

SONUÇ

Genellikle atık olarak görülen yeşil ceviz kabuğu, tarımsal atık yönetimi ve sürdürülebilir kalkınma açısından büyük bir potansiyele sahiptir. Biyolojik aktif bileşiklerinin kullanımı ve yenilikçi uygulamaların araştırılmasıyla ceviz kabuğu, çevresel sürdürülebilirliğe ve ekonomik büyümeye katkıda bulunabilir. Küresel gıda talebi arttıkça ve tarımsal faaliyetler yoğunlaştıkça, tarımsal atıkların uygun şekilde yönetimi bir zorunluluk haline gelmektedir. Yeşil ceviz kabuğu, tarımsal sanayi atıklarının değerli kaynaklara dönüştürülebileceğini gösteren önemli bir örnektir.

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CEVİZ (*Juglans regia* L.) MİKROÇOĞALTIMI

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ÖZET

Tarımsal faaliyetler içinde bazı önemli özelliklere sahip bitkilerin genetik açılımlara maruz kalmadan çoğaltılması ve kullanılması istenen bir durumdur. Meyve iriliği, verim, hastalık veya zararlılara tolerans gibi bazı ayırt edici özellikler olabilir. Bu gibi bitkilerin çoğaltılması ve çoğaltılırken herhangi bir değişime uğramaması üretici için avantajlı bir durumdur. Bunu başarabilmek için vejetatif çoğaltım metotları başvurulabilecek tek yöntemdir.

Mikroçoğaltım veya doku kültürü vejetatif çoğaltım metodlarının en önemlilerindendir. Bu teknikle kısa sürede yüksek sayıda bitki üretimi sağlanabilir, kontrollü ve standart bir üretim yapılabilir ve en önemlisi diğer vejetatif yöntemlerle çoğaltımı zor olan türler genetik değişime uğramadan çoğaltılabilir.

Ceviz (*Juglans regia* L.), önemli bir sert kabuklu meyve türü olup kerestesi, meyvesi ve atıkları (yeşil kabuk) değerlidir. Tohum dormansisi sebebiyle çimlenmesi düzensizdir, aşılama gibi yöntemler ise uzun bir çoğaltma döngüsüne sebebiyet vermektedir. Çeliklerle köklenme başarısı ise çok düşük oranlardadır. Özellikle anaç ıslahı gibi konularda doku kültürü yöntemleri ile bitki parçacığından tam bir bitki eldesi zaruri bir ihtiyaçtır.

Juglans türlerinin doku kültürü ile çoğaltımı zor olarak kabul edilmektedir. 1980' lerin başında ilk başarılı doku kültürü çoğaltımı raporları yayımlanmış olsa da, ticari anlamda bunu yaygınlaştırabilen az sayıda laboratuvar bulunmaktadır. Doku kültüründe fenoliklerin salınımı ve mikrobiyal kontaminantlar Juglans türünde başarılı bir in vitro sürecini etkileyen en önemli faktörler arasındadır. Ceviz türleri için mikroçoğaltım metodlarının başarılı olması bazı amaçları önceleyen ıslah çalışmalarının hızlı bir şekilde sonuca ulaştırılması için ayrıca öneme sahiptir.

Bu çalışmada, ceviz türlerinde yapılmış doku kültürü çalışmaları ve sağlanmış ilerlemeler hakkında bilgiler verilecektir.

Anahtar Kelimeler: Ceviz, mikroçoğaltım, *Juglans regia*

MICROPROPOGATION OF WALNUT (*Juglans regia* L.)

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ABSTRACT

In agricultural activities, it is desirable to propagate and utilize certain plants with important characteristics without exposing them to genetic alterations. Traits such as fruit size, yield, and tolerance to diseases or pests are some distinctive features that may be sought after. Propagating these plants without inducing any changes is advantageous for producers. Vegetative propagation methods are the only approach to achieve this.

Micropropagation or tissue culture is one of the most important methods of vegetative propagation. This technique allows the production of a high number of plants in a short time, enables controlled and standardized production, and most importantly, permits the propagation of species that are otherwise difficult to propagate without genetic alteration through other vegetative methods.

Walnut (Juglans regia L.) is an important nut crop species with valuable timber, fruit, and by-products (such as the green husk). Due to seed dormancy, its germination is irregular, and methods like grafting lead to a lengthy propagation cycle. The success rate of rooting with cuttings is also very low. Tissue culture methods for obtaining a complete plant from plant fragments are essential, especially in areas such as rootstock breeding.

Juglans species are considered difficult to propagate through tissue culture. Although the first successful reports on tissue culture propagation were published in the early 1980s, few laboratories have managed to extend this commercially. The release of phenolics and microbial contaminants are among the most important factors affecting a successful in vitro process for Juglans species. Successful micropropagation methods for walnut species are particularly crucial for quickly achieving the objectives of breeding studies that prioritize certain traits.

This study provides information about tissue culture studies conducted on walnut species and the advancements achieved.

Keywords: Walnut, micropropogation, *Juglans regia*

1. GİRİŞ

Tarımsal faaliyetler içinde bazı önemli özelliklere sahip bitkilerin genetik açılımlara maruz kalmadan çoğaltılması ve kullanılması istenen bir durumdur. Meyve iriliği, verim, hastalık veya zararlılara tolerans gibi bazı ayırt edici özellikler olabilir. İstenilen özelliklere sahip bitkilerin çoğaltılması ve çoğaltılırken herhangi bir değişime uğramaması üretici için avantajlı bir durumdur. Bunu başarabilmek için vejetatif çoğaltım metotları başvurulabilecek tek yöntemdir. Mikroçoğaltım veya doku kültürü vejetatif çoğaltım metodlarının en önemlilerindendir. Bu teknikle kısa sürede yüksek sayıda bitki üretimi sağlanabilir, kontrollü ve standart bir üretim yapılabilir ve en önemlisi diğer vejetatif yöntemlerle çoğaltımı zor olan türler genetik değişime uğramadan çoğaltılabilir.

Ceviz (*Juglans regia*), Juglandaceae familyasına ait bir sert kabuklu meyve türüdür ve hem ticari hem de beslenme açısından büyük öneme sahiptir. Geniş bir coğrafyada yetişebilmesi ve yüksek ekonomik değeri nedeniyle tarımın önemli bileşenlerinden biridir.

Cevizin çoğaltılması genellikle tohumdan yapılır; ancak tohumla çoğaltılan bireylerin genetik yapısı oldukça heterozigot olduğundan, bu yöntem genellikle düşük kalitede ve miktarda üretime yol açar (Vahdati, 2003). Ayrıca, tohumla çoğaltılan cevizlerde uzun bir gençlik kısırlığı dönemi görülür, bu da üretimin verimli bir şekilde başlamasını geciktirir. Klonal

çoğaltmada en yaygın yöntem aşılamadır; ancak bu süreçte hem emek yoğundur hem de zaman alıcı bir yöntemdir ve yüksek maliyetle sonuçlanır (Peyghamzadeh ve Kazemi, 2010). Bunun yanı sıra çelikleme ve gövde yatırma yöntemleri de kullanılmakla birlikte düşük başarı oranları nedeniyle sınırlı uygulama alanı bulmaktadır (Pijut ve Moore, 2002; Tajbakhsh ve ark., 2009). Cevizin aşı ile çoğaltılması yaygın bir geleneksel çoğaltım metodudur ve genellikle fidancılık ticareti amacıyla kullanılır. Ancak anaç materyali tohumla çoğaltılmaktadır ve hiçbir anaç bir diğerine genetik anlamda benzememektedir. Bu da standart bir üretim sürecini engellemektedir. Anaç ıslahı konularında da ortaya çıkartılan anaç adayının vejetatif yöntemlerle çoğaltılmasının en önemli yolu mikroçoğaltım yöntemidir.

2. MİKROÇOĞALTIMIN ÖNEMİ VE CEVİZDEKİ ROLÜ

Mikroçoğaltım, geleneksel yöntemlere kıyasla yüksek verimlilik ve kalite sağlayan modern bir çoğaltma yöntemidir. Bu teknik, geniş çaplı üretim için uygun bir çözüm sunarken, aynı zamanda genetik homojenlik sağlar ve kısır dönemi önemli ölçüde kısaltır (Driver and Kuniyuki, 1986; Scaltsoyiannes ve ark., 1998). Cevizde adventif kök oluşumunun karmaşık bir süreç olması ve çoğu genotipin in vitro kültüre direnç göstermesi, mikroçoğaltımın önemini daha da artırmaktadır. Mikroçoğaltım, köklenme oranlarını artırarak ve adaptasyon sürecini iyileştirerek cevizde ekonomik ve sürdürülebilir bir üretim modeli sunar (Jay-Allemand ve ark., 1992; Vahdati ve ark., 2004). Ceviz üretiminde genetik açıdan homojen bireyler elde etmek için güçlü bir araçtır. İlk başarılı ceviz mikroçoğaltımı raporları 1980'lere dayanmaktadır (Driver and Kuniyuki, 1986; McGranahan ve ark., 1987). Ceviz mikroçoğaltımı zor olarak kabul edilmekte idi ancak son yıllarda önemli gelişmeler kaydedilmiştir ve hem anaç ıslahında hem çoğaltmada önemli bir yer almıştır. Ancak hala birkaç ülkede uygun şekillerde uygulanmaktadır.

Adventif kök oluşum aşaması ceviz mikroçoğaltımının en kritik aşaması olarak kabul edilir. Adventif kök oluşumu üç aşamayı içermektedir. İlk aşama; köklenme kapasitesine ulaşmak için gerekli biyokimyasal ve fizyolojik dönüşümleri üreten hormonların varlığının uyarılmasıdır. İkinci aşama ise; hücre bölünmesi ve kök primordiumunun oluştuğu başlama aşamasıdır. Üçüncü aşama ise kök meristemlerinin gelişip vasküler demetlere bağlandığı ve artık kökün ifade edildiği son aşamadır. Adventif kök oluşumu iki yoldan gerçekleşir. Bunlardan birincisi, Kambiyum, korteks, perisit veya vasküler demetler gibi yerleşik hücre türlerinin yeniden farklılaştığı doğrudan organogenez iken, ikinci yol ise kallus dokusundan dolaylı oluşumdur.

Ceviz türünde bu yöntemin başarısı genotip, doku tipi, kültür ortamı ve çevresel faktörler gibi çeşitli unsurlara bağlıdır.

3. CEVİZ MİKROÇOĞALTIMINDA BAŞARIYI ETKİLEYEN FAKTÖRLER

In vitro kurulum ve çoğaltma aşamalarının aksine, in vitro köklenmeyi etkileyen faktörler üzerine daha fazla araştırma yapılmıştır. Ceviz mikroçoğaltımında kritik bir aşama olarak kabul edilir, çünkü cevizler genellikle zor köklenir ve köklenmeyen mikrofilizlerin aklimatizasyon sırasında hayatta kalma olasılığı düşüktür. Köklenme yine büyük ölçüde genotip tarafından

belirleniyor olsa da aşağıdaki fiziksel ve kimyasal koşulların yönetilmesi ile bu etkinin azaltılması mümkündür.

3.1. Hormon kullanımı

Cevizde adventif kök oluşumu, hormonların dengesiyle doğrudan ilişkilidir. Özellikle BAP ve IBA gibi sitokinin ve oksinlerin doğru konsantrasyonlarda kullanımı, köklenme ve sürgün uzamasını optimize etmektedir (Driver and Kuniyuki, 1986; Scaltsoyiannes ve ark., 1998).

3.2. Çevresel koşullar

Kültür ortamındaki ışık, sıcaklık ve nem gibi çevresel faktörler, köklenme oranlarını doğrudan etkiler. Örneğin, karanlıkta köklenme indüksiyonu, cevizde köklenme oranlarını önemli ölçüde artırabilir (Saadat ve Hennerty, 2001; Pei ve ark., 2007).
Genellikle, cevizlerin köklenmesi için birkaç gün karanlıkta tutulması gerekmektedir. Yapılmış çalışmalarda 0, 1, 2 ve 4 gün karanlıkta köklenme gözlemlememiştir; ancak 8 ve 12 günlük karanlık süresinden sonra, köklenme oranı sırasıyla %11,1 ve %33,3'e ulaşmıştır (Gruselle ve ark., 1987). 'Serr' mikrofilizlerinin in vitro koşullarda kültüre edildiği bir çalışmada, en iyi köklenme yüzdesi (%83,35) 9 gün karanlıktan elde edilmiştir (Saadat ve Hennerty, 2001). Başka bir çalışmada, 0 saat ışık altında daha iyi köklenme (%75,4) gözlemlerken, 16 saat ışık altında köklenmenin %0 olduğunu bildirmiştir (Pei ve ark., 2007). Ayrıca çalışmalar, karanlıkta indüklenen filizlerin ışıkta olanlara göre daha fazla IAA içerdiğini göstermiştir.
Sıcaklık, su alımını ve besin metabolizmasını etkileyerek ve enzimatik aktiviteleri teşvik edip engelleyerek adventif kök oluşumunu (AKO) etkileyebilir. In vitro ceviz köklenmesi üzerine sıcaklığın etkisi hakkında çok az araştırma yapılmıştır; ancak bazı benzer sonuçlar bildirilmiştir. J. nigra × J. regia 'A35' melezinin köklenmesinde, 22 °C'de indüklenme durumu (%60) 27 °C'ye göre (%45) daha yüksek olmuştur (Dolcet-Sanjuan ve ark., 2004). Benzer şekilde, başka bir çalışmada, 'Sunland' (%94 vs. %50), 'Chandler' (%42 vs. %13) ve 'Vina' (%25 vs. %3) çeşitlerinde 22 °C'de indüklenmenin 30 °C'ye göre daha fazla köklenme sağladığını bulmuştur (Vahdati ve ark., 2004). Genel olarak, 20–28 °C aralığındaki sıcaklıkların ceviz kök indüksiyonu için faydalı olduğu belirtilmiştir (Leslie ve McGranahan, 2009).

3.3. Kültür ortamı

Ceviz köklenmesi için en önemli ortamlar Driver ve Kuniyuki ortamı (DKW) ve Murashige ve Skoog ortamıdır (MS). DKW, ceviz köklenmesi için en yaygın olarak kullanılan ortamdır; ancak MS ortamı bazı genotiplerde de iyi sonuçlar vermiştir (Driver and Kuniyuki, 1986; McGranahan ve ark., 1987). Bununla birlikte, bazı araştırmacılar, dört ceviz çeşidi için DKW' nin köklenme yüzdesi ve her mikro filiz başına oluşan kök sayısı açısından MS'den üstün olduğunu göstermiştir (Yegizbayeva ve ark., 2021). Bazı araştırmacılar, cevizi mikroçoğaltımı için alternatif formülasyonlar kullanmıştır. 'Sunland' ve 'Chandler' çeşitlerinin in vitro büyümesini teşvik eden bir ortam geliştirmiş; ancak her iki çeşitte de kök oluşumunun DKW'ye göre geride kaldığı belirlenmiştir (Ashrafi ve ark., 2010).

Ceviz köklenmesi açısından besin ortamına ilave edilecek bileşenlerin konsantrasyonlarının seyrek tutulmasının köklenmeyi olumlu etkilediği belirtilmiştir (Caboni ve Damiano, 2005).

Genellikle makro besin maddelerinin normal dozundan %50 veya %25' ine kadar azaltıldığı, mikro besin maddelerinin ve vitaminlerin dozlarının ise değiştirilmediği çalışmalarda bildirilmiştir. Besin ortamlarının karbon kaynağı da önemli işlevleri vardır. Cevizler için yapılan çalışmalarda karbon kaynağı ya da konsantrasyonlarının rizogenezde önemli rol oynadığı bildirilmiştir. Sükroz açık ara en çok kullanılan karbon kaynağıdır (Driver, 1986). Sükrozun köklenme üzerinde sürgün büyümesinden daha büyük bir etkiye sahip olduğu bildirilmiştir. Sükroz dışında früktozun da köklenmede önemli etkileri olduğu hatta sükrozdan daha destekleyici olduğu bildirilse de, früktozla kültüre edilen mikro sürgünlerin dış ortama uyum sağlama oranı sükroz ile muamele edilenlere göre daha düşük olmuştur.

3.4. Mikrosürgünlerin yaşı ve kalitesi

Köklenme başarısı ve fideleme sırasındaki hayatta kalma oranı, kök başlatma aşamasına getirilen mikro-sürgünlerin kalitesine büyük ölçüde bağlıdır. 'Paradox' için, çoğaltma aşamasından alınan, 3-10 cm boyunda, güçlü mikro-sürgünlerin kullanılması önerilmiştir. Yapılmış bir çalışmada 'Persian' cevizinin fidelemeye uyum süreci için uç nekrozu ve/veya yaprak dökümü olmayan mikro-sürgünlerin fideleme aşamasında hayatta kalma olasılığının yüksek olduğu belirtilmiştir (McGranahanve ark., 1987). Hibrit Mj209 × Ra tohumlarının klonları için, sağlıklı ve güçlü, bol yeşil yapraklı mikro-sürgünlerin köklenmeye daha hazırlıklı olduğunu ve dış ortam koşullarını daha iyi tolere ettiklerini belirtilmiştir (Licea-Moren, 2016).

Bir çalışmada, sürgün kalitesinin J. regia 'Xinzaofeng'in köklenmesini güçlü bir şekilde etkilediğini bulmuştur. Dört sürgün tipinin köklenme yüzdeleri şu şekildedir: (1) küçük yapraklı ve >0.5 cm uzun boğum aralıklarına sahip, güçlü, taze sürgünler (%83.3); (2) taze yapraklı ve ≤0.5 cm kısa boğum aralıklı, güçlü sürgünler (%71.9); (3) geniş, koyu yeşil yapraklı ve >0.5 cm uzun boğum aralıklarına sahip yarı lignifiye sürgünler (%7.4); (4) sürgünün tabanında geniş etiolle olmuş yapraklar ile yarı lignifiye sürgünler (%0) (Pei ve ark., 2007). Sürgün tipinin kalitesi, biyokimyasal aktivitelerini, gençlik durumunu, bitki büyüme düzenleyicilerine (PGR) duyarlılığını veya hücre farklılaşması esnekliğini yansıtıyor olabildiği sonucuna varılmıştır.

Daha küçük sürgünler daha hızlı ve daha fazla sayıda üretilebilirken, daha büyük sürgünler serada daha başarılı bir şekilde fideleme ve hayatta kalma göstermiştir.

3.5. Genotip

Ceviz genotipleri arasındaki farklılıklar, köklenme oranlarını büyük ölçüde etkiler. Bu nedenle, genetik faktörlerin etkisini azaltmak için gençleştirme işlemleri ve uygun kültür koşullarının yönetimi kritik öneme sahiptir 【McGranahan ve ark., 1987; Gruselle ve Boxus, 1990; Rodriguez ve ark., 1989】.

3.6. Fiziksel koşullar ve yeni teknolojiler

Sıvı ortamların ve geçici daldırma sistemlerinin (TIS) kullanımı, ticari mikroçoğaltım için umut verici yenilikler sunmaktadır. Bu sistemler, daha yüksek kaliteli bitkiler üretmek ve maliyetleri azaltmak için potansiyel taşımaktadır (Licea-Moreno ve ark 2012; Licea-Moreno ve ark., 2020).

SONUÇ

Cevizin mikroçoğaltımı özellikle anaç ıslahı gibi konular için oldukça önem arz etmektedir. Daha önceleri mikroçoğaltımda yeteri kadar başarı elde edilememiş olsa da son yıllarda mikroçoğaltımda elde edilen başarılar anaç ıslahı çalışmalarını da hızlandırmış ve önemli ceviz anaçları ıslah edilerek bazı ülkelerde kullanıma sunulmuştur.

Ülkemizde de ceviz anacı konusunda ciddi bir açık vardır. Mikroçoğaltım çalışmalarının artırılması ve anaç ıslahı konusunda atılacak ileri adımlar ile önemli bir üretim kolu olan ceviz yetiştiriciliğinde daha da ileri gidilecektir.

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ÖZET

Soğanlı, rizomlu ve yumrulu bitkiler bakımından Türkiye zengin bir ülkedir. Halk arasında "Ak Zambak" olarak bilinen *Lilium candidum* L. da Türkiye'de doğal olarak yetişen, zambakgiller familyasına ait otsu, çok yıllık, soğanlı bir bitkidir. Akzambak (*Lilium candidum* L.) bitkisi özellikle hoş kokulu ve gösterişli çiçeklere sahip olduğu için tarih boyunca süs bitkisi amaçlı kullanılmıştır. Tıbbi aromatik değeri olan ak zambak, geleneksel tıbbi amaçlı kullanımının yanı sıra modern ilaç geliştirme alanında da önemli yere sahiptir. Ak zambak anti-inflamatuar ve antioksidan özellikleriyle de dikkat çekmektedir. İlaç sektöründe solunum yolu rahatsızlıkları, cilt hastalıkları ile mücadelede kullanılabilen bu takson, aynı zamanda kozmetik sektöründe de kullanılmaktadır. Kısaca ak zambak bitkisi gıda, ilaç, fitoterapi, gıda katkı maddesi, kozmetik, dekorasyon ve aromatik amaçlı kullanımları ile kendisine sektörlerde yer edinmiştir.

Anahtar Kelemeler: *Lilium candidum* L., Ak zambak, Süs bitkileri, Tıbbi kullanım, Fitoterapi

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THE IMPORTANCE OF WHİTE LILY (*Lilium candidum* L.) PLANT

ABSTRACT

Türkiye is rich in bulbous, rhizome and tuber plants. *Lilium candidum* L., popularly known as "Ak Zambak, White Lily", is a herbaceous, perennial, bulbous plant belonging to the Liliaceae family and grows naturally in Turkey. White Lily (*Lilium candidum* L.) plant has been used as an ornamental plant throughout history due to its fragrant and showy flowers. With its medicinal and aromatic value, the White Lily holds a significant place not only in traditional medicinal uses but also in the field of modern drug development. The White Lily is also notable for its anti-inflammatory and antioxidant properties. This taxon, which can be used in the pharmaceutical industry to combat respiratory ailments and skin diseases, is also utilized in the cosmetics sector. In short, the White Lily is utilized various industries with its uses in food, pharmaceuticals, phytotherapy, food additives, cosmetics, decoration, and aromatics.

Keywords: *Lilium candidum* L., White Lily, Ornamental flowers, Medical use, Phytotherapy

GİRİŞ

Soğanlı bitkiler bakımından zengin bir potansiyele sahip olan Türkiye florasında, Liliaceae familyası 35 cins ile temsil edilmektedir. Yaklaşık olarak 400'ün üzerinde türe sahip olduğu bilinmektedir (Özdemir ve Alçıtepe, 2011; Satıl ve Akan, 2006; Gürsoy ve Şık, 2010). Liliaceae familyası üyelerinden olan Lilium L. cinsi, dünyada yaklaşık 100 kadar türle temsil edilmekte, Kuzey yarıkürenin soğuk ve ılıman bölgelerinde yayılış göstermektedir. Cinsin üyesi olan türlerinin çoğu ise kültür edilmiştir. Zambaklar, kesme çiçekçilikten, saksı çiçeğine, gıdadan eczacılık ve kozmetik sektörüne birçok alanda kullanılmaktadır. Ekonomik değeri ve estetik özelliklerinden dolayı dünya genelinde yaygın olarak yetiştirilmektedirler (Eskimez vd., 2024; Uysal ve Erdal, 2013; Güneş ve Özcan, 2023; Tang vd., 2022; Wang, 2024). Zambak türleri çok sayıda çeşitlere sahiptir. Türkiye'de zambakgiller ailesinin yedi türü doğal olarak yetişmekte olup bunlar içerisinde en yaygın olanı *Lilium candidum* L.'dur. Ancak ekonomik değer bakımından genel olarak değerlendirecek olursak, ekonomik değeri yüksek olan iki tür dikkat çekmektedir. Bunlar "Ak Zambak (*Lilium candidum* L.) ve Nisan zambağı (*Lilium longiflorum* Thunb.)'dır (Eskimez vd., 2024; Güneş ve Özcan, 2023; İkinci, 2006).

Lilium candidum L. hoş kokulu, beyaz renkli, güzel görünümlü, gösterişli çiçeklere sahip, geofit, çok yıllık otsu bir bitki türüdür. *Lilium candidum* L. Türkiye'de "Ak Zambak, Beyaz

Zambak, Mis Zambak, Bey Zambağı, Mezarlık Zambağı, Desti Zambağı" olarak da adlandırılmaktadır (Güneş ve Özcan, 2023; Kahraman, 2015; Özbek vd., 2022; Şahin vd., 2022). Ak zambak Akdeniz iklimine uyum sağlamış bir takson olup, Filistin, Suriye, İsrail, Yunan Adaları, Balkan ülkelerinde yayılış göstermektedir. Türkiye de ise Güneybatı Anadolu Bölgesi, Akdeniz Bölgesi ve Batı Anadolu'nun kıyısındaki şehirlerde (Aydın, Balıkesir, Mersin, Muğla, Antalya, İzmir, Mardin, Çanakkale, İstanbul vb.) varlığını devam ettirmektedir. (Tokgöz vd., 2024; Daneshvarroyandazagh vd., 2014; Özbek vd., 2022; Şahin vd., 2022).

Gösterişli ve hoş kokulu çiçeklerinden dolayı, süs bitkisi olarak ve kesme çiçekçilikte ticari öneme sahip olan ak zambak, gıda sektörü açısından da ilginç potansiyeller sunmaktadır. *Lilium candidum* L. bitkisinden elde edilen ekstraktın antimikrobiyal aktivite gösterdiği tespit edilmiştir ve bu özelliği sayesinde gıda ya da gıda katkı maddesi olarak kullanılabileceği ifade edilmektedir. Yenilebilir süs bitkisi özelliği olan zambaklar, reçel yapımında da kullanılabilmektedir (Bişgin ve Gökçen, 2024; Güneş ve Özcan, 2023; Kahraman vd., 2017; Yazici vd., 2016).

Süs bitkisi olarak ve gıda sektöründe kullanımı dışında ayrıca, kozmetik sanayi için de çok değerli bileşenler içermektedir. Pek çok çalışma, Lilium'un amino asitler, polisakaritler ve biyoaktif bileşenler (fenoller, flavonoidler ve saponinler) açısından zengin olduğunu göstermektedir. Yapılan çalışmalarla, fitokimyasal değerlendirmede, bitkide alkaloitler, terpenoidler, saponinler, flavonoidler, fenoller ve tanenlerin varlığı ortaya konulmuştur. Hoş ve keskin kokularından dolayı kolonya, parfüm ve bazı kremlerin üretiminde kullanılmaktadır. Ayrıca antibakteriyel özellik göstermelerinden dolayı terlemeden kaynaklı oluşabilecek bakterileri öldürecek özelliklere sahip deodorant ve parfüm yapımında kullanılabilir (Al-Bayati, 2018; Tirth vd., 2021; Özbek, 2024; Özey ve Çalışkan, 2018; Rambabu ve Patnaik, 2016; Tang vd., 2022; Zaccai vd., 2020).

Bitki, anti-inflamatuar, sitotoksik, hepatoprotektif ve antitümör etkiler gösteren bir dizi biyoaktif madde içermektedir. Bu bitki geleneksel tıpta, tarih boyunca iltihaplı ve irinli yaralar, ülserler (kökleri ve çiçekleri), cilt iltihapları, yanıklar, şişlikler ve çeşitli yaralanmaların tedavisinde yara iyileştirici, mastit ve zona tedavilerinde, çıbanlarda kullanılmıştır (Patocka vd., 2019; Zhou vd., 2021; Özbek vd., 2022; Royandazagh ve Pehlivan, 2016). Yapılan bilimsel çalışmada, histopatolojik değerlendirmeler açısından, (%20) *L. candidum* L. içeren merhemle tedavi edilen yaralarda daha iyi granülasyon dokusu ve kalınlaşmış bir yenilenmiş epitel tabakası gözlemlenmiştir. Bu bulgular, *L. candidum*'un yüksek fenolik ve flavonoid içeriğinin,

bilinen antioksidan potansiyeline ek olarak, sıçanlarda önemli derecede yanık yarası iyileşmesi sağladığını ortaya koymaktadır (Momtaz vd., 2020).

Geleneksel kullanım yanında modern farmakolojik çalışmalarda da kullanılan ak zambak bitkisi üzerine yapılmış bir bilimsel çalışmada, insan meme kanseri hücre hattı MCF-7 hücreleri üzerinde güçlü anti-kanser etkileri olduğu ve gelecekteki izolasyon ve tanımlama çalışmalarının ardından, insan meme kanseri için terapötik ajan olarak geliştirilebilecek aktif bileşikler içerebileceği bildirilmiştir (Tokgun vd., 2012). Solunum yolu rahatsızlıkları tedavi amaçlı çalışmaların yanı sıra anti-astmatik özelliklere sahip bitkidir (D. Singh ve T. Singh, 2023). Antiinflamatuar ve antioksidan özellikler gösteren Lilium'un çeşitli hastalıkların tedavisinde potansiyele sahip olduğunu söylemek mümkündür (Zhou vd., 2021).

SONUÇ

Lilium candidum L., halk arasında ak zambak olarak bilinen, Zambakgiller familyasına ait önemli bir bitkidir. Tarih boyunca hem süs bitkisi olarak hem de tıbbi amaçlarla kullanılmıştır. Ak zambak, özellikle anti-inflamatuar, antioksidan ve yara iyileştirici özellikleriyle dikkat çekmektedir. İlaç sektöründe cilt hastalıkları, solunum yolu rahatsızlıkları ve enfeksiyonlarla mücadelede kullanılabilen bitki, aynı zamanda kozmetik sektöründe de yer almaktadır. Antioksidan etkileri ve bağışıklık sistemini destekleyici özellikleri ile modern fitoterapide de değerlendirilen ak zambak, hem geleneksel tıpta hem de modern ilaç geliştirme alanında önemli bir yere sahiptir., Lilium cinsi steroidal saponinler, flavonoidler, alkaloidler ve polisakkaritler açısından zengindir. Lilium'un farmakolojik etkileri arasında anti-tümör, hipoglisemik, antibakteriyel, antioksidan, antidepresan ve anti-enflamatuar aktiviteler bulunmaktadır (Rambabu ve Patnaik, 2016).

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SAFRAN (*Crocus sativus* L.) BİTKİSİNİN KULLANIM ALANLARI

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ÖZET

Eski çağlardan beri bilinen ve kullanılan, İridaceae familyası (Süsengiller) üyelerinden olan safran (*Crocus sativus* L.) önemli bir tarımsal ve tıbbi bitkidir. Üretim maliyetinden ve sahip olduğu özgün özelliklerinden dolayı dünya çapında en değerli baharat olarak adından söz ettirmektedir. Temel olarak stigması kullanılan safran gıdalarda lezzet ve renk verme amaçlı kullanımının yanı sıra, çay olarak da tüketilebilmektedir. Gıda amaçlı kullanımının yanı sıra ilaç sanayinde de kendisine yer bulan safran, potansiyel sağlık faydaları ve uygulama alanları ile yeni tedavi yöntemlerinin geliştirilmesine katkı sağlamaktadır. Krosin, picrocrosin, safranal gibi biyoaktif bileşenlere sahip safran, antioksidan, antidepresan, antiinflamatuar ve antikanser özellikler gösterebilmektedir. Kumaş ve iplik boyamada da kullanılabilen safran pahalı olması nedeni ile günümüzde yaygın olarak boyama amaçlı kullanımı azalmıştır. Sonuç olarak çok değerli çiçeklere sahip olan safran bitksinin çok çeşitli kullanım alanlarını boya sanayi, kozmetik sanayi, ilaç sanayi ve gıda sanayi olmak üzere dört ana başlık altında toplamak mümkündür. Ayrıca birçok ülkede yetiştiriciliği yapılan safranın kullanım alanları giderek yaygınlaşmaktadır.

Anahtar Kelemeler: Safran, *Crocus sativus* L., Baharat, süs bitkisi, Krosin

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SAGE AREAS OF SAFFRON (*Crocus sativus* L.) PLANT

ABSTRACT

Saffron (*Crocus* sativus L.), a member of the Iridaceae family, has been known and used since ancient times as an important agricultural and medicinal plant. Due to its cost and unique characteristics, it is recognized as the most valuable spice worldwide. The stigma of saffron is primarily used in food for flavor and coloring purposes; however, it can also be consumed as a tea. In addition to its application in the food industry, saffron finds a place in the pharmaceutical industry, contributing to the development of new treatment methods due to its potential health benefits and application areas. Containing bioactive components such as crocin, picrocrocin, and safranal, saffron can exhibit antioxidant, antidepressant, anti-inflammatory, and anticancer properties. Although saffron can also be used in dyeing fabrics and yarns, its expensive nature has reduced its use for dyeing purposes in modern times. In conclusion, the valuable flowers of the saffron plant have diverse applications that can be categorized under four main headings: the dye industry, the cosmetics industry, the pharmaceutical industry, and the food industry. Furthermore, the cultivation of saffron is becoming increasingly widespread in many countries.

Keywords: Saffron, *Crocus sativus* L., Spice, Ornamental plant, Crocin

GİRİŞ

Safran yüzyıllardır bilinen ve kullanılan bir bitki türüdür. İridaceae (Süsengiller) familyasının Crocus cinsine ait olan safran bitkisi "*Crocus sativus* L." olarak adlandırılmaktadır. Türkiye'de Crocus cinsinin 32 türü bulunmaktadır ve bu türlerin 18'i endemiktir (Şahin, 2021; Gümüş, 2021; Beiki vd., 2010). Safran bitkisinin üretimi dünya genelinde belirli coğrafi alanlarda dağılıma sahip olup, önemli üretim merkezlerinin ise İran, Hindistan, İspanya ve Yunanistan gibi ülkelerde yoğunlaştığını söylemek mümkündür. Safran (*Crocus sativus* L.) İran'ın önemli bir tarımsal ihracat bitkisi olarak yer almaktadır. Ayrıca, Türkiye, İtalya, Mısır, Azerbaycan, Çin, Pakistan ve Japonya'da da safran bitkisi yayılış göstermektedir (Şahin, 2021; Andarabı, ve Hassan, 2017).

Safran (*Crocus sativus* L.), gösterişli çiçeklere sahip, soğanlı ve çok yıllık, otsu bir bitkidir (Göktürk ve Asil, 2018; Özoğul ve Kılıç, 2023; Sayarer, 2015). Hem stigmaları kurutularak elde edilen baharat, hem de bitkinin bilinen adı "safran"dır. Safran aroması, tadı ve bazı kimyasal özellikleri ile geleneksel olarak gıda lezzetlendirme, gıdalara renk verme, ilaç yapımında kullanılabilmektedir. Günümüzde farmasötik alandaki potansiyelinin de gün geçtikçe arttığı bilinmektedir (Andarabı ve Hassan, 2017; Özoğul ve Kılıç, 2023; Muştu, 2021;

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Özellikle gıda ve ilaç sanayiinde çok geniş olarak kullanılan safran, gıda sanayiinde, çok çeşitli besin maddelerinin renklendirilmesi, tatlandırılması ve aromalandırılması amacı ile kullanılmaktadır. Lokantalarda ve ev mutfaklarında, safranla yemek ve içecek hazırlanması ve sunulması, özel bir beğeni ve önem kazanmaktadır (Ahmed vd., 2021; Spence, 2023; Sheibani, vd., 2019).

Safran; süs bitkisi, boya, gıda ve kozmetik gibi çeşitli endüstri dallarında ekonomik olarak geniş kullanım alanına sahiptir. Safran bitkisi uzun süre tekstil alanında doğal boya olarak kullanılıyor olmasının yanı sıra gıda boyama amaçlı da kullanılabilmektedir. Parfüm üretimi, losyon, krem, cilt ve saç bakım ürünlerinde de kullanılarak kozmetik sektöründe de yerini almıştır. Sahip olduğu önemli farmakolojik etkilerden dolayı da aranan bir tıbbi bitkidir (Çinar ve Önder, 2019; Muştu, 2021; Asil, 2015; Yıldırım, vd., 2017; Şahin, 2021).

Safran, geleneksel tıpta yüzyıllardır kullanılan bir bitki olmasının yanı sıra modern farmakoloji alanında da önemli bir yere sahiptir. Safranın farmakolojik kullanımı, başlıca biyoaktif bileşenleri olan krosin, picrocrocin ve safranalın terapötik etkilerinden kaynaklanmaktadır. Antidepresan etkileri, safranın en iyi bilinen farmakolojik etkilerinden biridir. Yapılan klinik çalışmalar, özellikle krosin ve safranalın serotonin düzeylerini artırarak, depresyon tedavisinde etkin olduğunu göstermektedir. Krosin, antitümör, antidepresan olarak da kullanılmaktadır (Hausenblas vd., 2013; Göktürk ve Asil, 2018). Picrocrocin ve safranal bileşikleri ayrıca antiinflamatuar etki göstermektedir. Bu bileşenler, inflamasyonla ilişkili hastalıkların gelişimini

engelleyebilmektedir. Ayrıca, mide ülserinin tedavisinde, antitussif ve antinosiseptif, antimikrobiyal, antitümör, anticonvulsant, antidepresan amaçlı da kullanılabilmektedir. (Ghaffari vd., 2019; Göktürk ve Asil, 2018). Safranın antikanser potansiyelinin, özellikle krosin ve safranalın kanser hücrelerinin çoğalmasını engelleyici etkilerinden ileri geldiğini bildiren bilimsel çalışmalar mevcuttur. Bu bileşenler, çeşitli kanser hücre hatlarında hücre döngüsünü durdurarak kanserli hücrelerin büyümesini baskılayabilmektedir (Amin vd., 2021; Uzunhisarcıklı, 2023).

Bunun yanında, safran vitaminler, mineraller (Ca, Na, K, Fe ve P gibi mineraller) ve flavonoidler açısından da zengindir. Özellikle B vitamini kompleksine ait tiamin ve riboflavin gibi vitaminleri de içerir. (Rios vd., 1996; Bolhassani vd., 2014; Hashemi ve Erim, 2016; Kıratlı, 2019).

SONUÇ

Kullanım alanları giderek yaygınlaşan, dünyanın en pahalı baharatını bünyesinde barındıran safran bitkisi (*Crocus sativus* L.), tarihi boyunca hem gıda hem de tıbbi amaçlar için geniş bir kullanım alanına sahip olmuştur. Safran görünüşü, aroması, tadı, kimyasal özellikleri ile süs bitkisi sektörü, gıda sektörü, eczacılık gibi alanlarda ulusal ve uluslararası pazarın da ilgisini çekmektedir (Andarabı ve Hassan, 2017).

Safranın stigmaları, bitkinin ticari olarak kullanılan kısmını oluşturur ve karakteristik aroma ve rengi sağlayan krosin, picrocrocin ve safranal gibi biyoaktif bileşenler içermektedir. Biyoaktif bileşenleri olan krosin, picrocrocin ve safranal, safranın sağlık üzerindeki olumlu etkilerini destekleyerek, bitkiye antioksidan, antiinflamatuar, antidepresan ve antikanser özellikler sunmaktadır. Safranın bu kimyasal bileşenlerinin, safranı hem gıda endüstrisinde hem de farmasötik uygulamalarda değerli kılan faktörler olduğunu söylemek mümkündür (Karbasi ve Zandi Dareh Gharibi, 2022; Khan vd., 2020; Siddiqui cd., 2022; Matraszek-Gawronvd., 2022; Azarabadi ve Özdemir, 2018).

Sonuç olarak, boya sanayi, kozmetik sanayi, ilaç ve gıda sanayiinde kullanılan safranın ekonomik, kültürel ve sağlık alanındaki önemi, onu sadece bir baharat değil, aynı zamanda önemli bir ilaç olarak da tanıtmayı mümkün kılmaktadır (Moghaddasi, 2010; Mzabri vd., 2019; Shahi vd., 2016).

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ANALYSİS OF PLANT STRESS RESPONSE MECHANİSMS USİNG RNA SEQUENCİNG

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ABSTRACT

RNA sequencing (RNA-seq) has revolutionized the study of plant stress responses by providing detailed insights into the molecular mechanisms that govern adaptation to biotic and abiotic stressors, such as drought, salinity, and pathogen attacks. This technique enables the identification of differentially expressed genes (DEGs) and regulatory pathways critical for stress tolerance. Key discoveries from RNA-seq studies include the activation of mitogen-activated protein kinases (MAPK), antioxidant systems, and osmotic regulation under stress conditions. Additionally, non-coding RNAs such as miRNAs and long non-coding RNAs (lncRNAs) have been shown to play essential roles in regulating gene expression during stress. For example, in salt-stressed chrysanthemum roots, RNA-seq revealed critical stress-responsive genes associated with signal transduction and cell membrane integrity, underscoring the potential of RNA-seq to inform strategies for developing stress-resistant crops and improving agricultural resilience.

Keywords: RNA sequencing, plant stress response, gene expression, miRNAs.

1. INTRODUCTION

RNA sequencing (RNA-seq) has dramatically advanced plant science by enabling comprehensive analysis of the plant transcriptome under various stress conditions. This high-throughput technology allows researchers to identify differentially expressed genes (DEGs) and stress-responsive pathways essential for plant adaptation to biotic and abiotic stressors, such as drought, salinity, and pathogen attacks, which are major constraints on agricultural productivity. Through RNA-seq, critical signaling pathways like mitogen-activated protein kinases (MAPKs) and antioxidant defenses have been shown to play pivotal roles in managing oxidative, osmotic, and ionic imbalances under stress conditions (Seki et al., 2002). For instance, MAPK cascades, such as MEKK1-MKK1/MKK2-MPK4, are central in regulating plant resilience to salt and drought by controlling reactive oxygen species (ROS) and ion homeostasis. These kinases facilitate cellular protection by activating stress-induced phosphorylation processes, reinforcing cellular stability under adverse environmental conditions (Hu et al., 2013).

A notable advancement from RNA-seq research is the identification of non-coding RNAs (ncRNAs), including microRNAs (miRNAs) and long non-coding RNAs (lncRNAs), as essential regulators of gene expression during stress responses. These ncRNAs operate through various mechanisms, such as post-transcriptional gene silencing and chromatin remodeling, allowing for rapid gene expression reprogramming under stress. For example, miRNAs modulate critical genes involved in hormone signaling, osmotic regulation, and antioxidant defense, significantly influencing stress tolerance. miRNAs like miR167, miR393, and miR474 are upregulated in drought-stressed rice, enhancing resilience by targeting key regulatory proteins (Pradhan et al., 2015). Similarly, lncRNAs in cotton and other plants have been shown to interact with protein-coding genes, modulating stress response pathways, particularly under drought and salinity conditions (Lu et al., 2016). These findings underscore the importance of RNA-seq in revealing complex regulatory networks that help plants adapt to stress by integrating hormonal and signaling pathways (Yadav et al., 2024).

Furthermore, single-cell RNA sequencing (scRNA-seq) has expanded our knowledge by enabling gene expression analysis at the cellular level. This approach has uncovered cell-type-specific responses to stress, as observed in pathogen-stressed Arabidopsis thaliana, where scRNA-seq mapped immune receptor expression within specific cell clusters. Such profiling offers a detailed understanding of plant resilience mechanisms, aiding the identification of

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novel pathways for enhancing stress tolerance in crops (Wang et al., 2021). This cellular-level perspective is particularly valuable in freezing and cold stress studies; for instance, RNA-seq analyses in chickpeas (Cicer arietinum) identified cold-responsive transcription factors like CBFs and CORs that facilitate cold acclimation by regulating ABA and gibberellin signaling, underscoring the intricate hormonal interplay during cold stress adaptation (Kalve et al., 2023).

Additionally, RNA-seq analyses in different species have provided insights into the structural adaptations plants make in response to salt and drought stress. For example, studies on salt-stressed chrysanthemum roots revealed upregulation of genes associated with cell membrane integrity and signal transduction, which helps stabilize cells under osmotic stress (Zhang et al., 2011). Similarly, salt stress studies on holly (Ilex spp.) highlighted the role of MAPKs and calcium-dependent protein kinases in maintaining cellular homeostasis under stress, while research in cotton identified GaGH3.6 as crucial in regulating oxidative stress, demonstrating the genetic targets that could be manipulated for crop improvement (Shi et al., 2024; Gong et al., 2020).

Collectively, these discoveries underscore RNA-seq's transformative impact on our understanding of plant stress physiology. By facilitating the exploration of gene expression networks, signaling pathways, and the roles of ncRNAs, RNA-seq provides valuable insights into the molecular underpinnings of stress tolerance. This technology holds vast potential not only for basic research but also for practical applications in agriculture, where it informs the development of resilient crop varieties capable of withstanding the challenges of a changing climate. Through RNA-seq-driven genetic insights, crop productivity and resilience can be enhanced, paving the way for more sustainable agricultural practices (Ding et al., 2013; Ackah et al., 2024).

In this review, we comprehensively evaluate the current literature, applications, and future research perspectives on the impact of RNA-seq technology on the molecular analysis of plant stress response mechanisms and the discovery of genetic pathways that play a critical role in adaptation to biotic and abiotic stress conditions.

2. MOLECULAR ANALYSIS OF PLANT STRESS RESPONSES USING RNA-SEQ TECHNOLOGY AND APPLICATION AREAS

2.1. Contributions of RNA-Seq to the Molecular Analysis of Plant Stress Responses

RNA-seq is a revolutionary tool for examining the adaptation processes of plants to biotic (living factors) and abiotic (environmental factors) stresses. This technique enables a detailed examination of gene expression profiles that vary under stress conditions and how these profiles influence the organism's stress tolerance. RNA-seq analyses under stress conditions are particularly used to identify genes that activate signaling pathways such as mitogen-activated protein kinases (MAPKs) and antioxidant systems. For example, RNA-seq applications have identified critical stress-responsive genes associated with signal transduction and cell membrane integrity in chrysanthemums under specific salt stress. Such analyses provide strategic insights for developing stress-resistant plant species and point to the potential for enhancing agricultural resilience (Ozsolak and Milso, 2011; Conesa et al., 2016).

2.2. Contributions of RNA-Seq to Transcriptomic Studies in Various Organisms

RNA-seq technology is used as a tool that expands our understanding of the complexity of eukaryotic transcriptomes. This technology reveals how gene expressions change in detail during developmental processes or under various physiological conditions. Studies on model organisms such as Saccharomyces cerevisiae, Schizosaccharomyces pombe, and Arabidopsis thaliana have demonstrated the critical role of RNA-seq in understanding biological diversity. The broad dynamic range offered by RNA-seq facilitates the identification of transcripts at different expression levels, laying the foundation for understanding how species adapt to environmental changes (Marguerat and Bähler; Wang et al., 2009).

2.3. Various Applications of RNA-seq Analysis and Challenges Encountered

The wide range of applications of RNA-seq has made it a powerful tool in molecular biology studies in the scientific world. This technology has unique sensitivity in measuring how gene expression levels change based on time, cell type, and environmental conditions. Additionally, RNA-seq can determine not only gene expression but also alternative splicing and gene fusion events. RNA-seq, which enables studies even in species without a reference genome, plays an important role in understanding adaptation processes by identifying the genetic material expressed in a specific environment. Data obtained from RNA-seq for investigating plant stress responses help decipher complex gene expression networks and reveal ways to enhance these networks for increased resilience (Conesa et al., 2016; Hrdlickova et al., 2017).

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2.4. Reducing Biases with Direct RNA Sequencing and More Accurate Determination of Gene Expression Under Stress

Traditional cDNA-based RNA-seq methods lead to various biases during reverse transcription, while direct RNA sequencing provides a more impartial analysis of the transcriptome by bypassing this step. In this method, RNA molecules are sequenced directly, allowing more reliable analysis of short or degraded RNA samples. This feature enables the collection of precise data, especially under environmental stresses where RNA samples are limited. It has been noted that this technology can be used in fields such as plant sciences to detect subtle changes in RNA expression due to environmental factors (Ozsolak et al., 2009).

2.5. Applications of RNA-seq for Genomic Research and the Development of Plant Stress Tolerance

RNA-seq technology has revolutionized genetic expression analysis methods, allowing us to observe how gene expression changes under cell-specific conditions. This technology not only determines gene expression levels but also offers a comprehensive transcriptome profile by identifying alternative splicing, mRNA isoforms, and gene fusions. For example, RNA-seq analyses in salt-stressed chrysanthemum roots have identified stress response genes that play a role in signal transduction and maintain cellular integrity. This provides important information for understanding plant adaptation mechanisms to stress conditions (Ozsolak and Milso, 2011; Han et al., 2015).

2.6. Non-Coding RNAs (ncRNAs) in Plant Development and Stress Response

ncRNAs are critical RNA molecules that regulate many biological processes, including stress responses in plants. These RNAs regulate gene expression at the post-transcriptional level, particularly under stress conditions such as drought, salt, heat, and cold. For example, lncRNAs and miRNAs help maintain cellular function and enable adaptation under osmotic stress. The regulatory roles of ncRNAs in these processes have the potential to increase plant resilience under stress (Yadav et al., 2024).

2.7. Drought-Sensitive miRNAs in Plants and Their Regulatory Roles

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Plant genomes contain microRNAs (miRNAs) crucial for adaptation to environmental conditions such as drought stress. Advances in high-throughput sequencing technologies in recent years have allowed for a more detailed examination of miRNAs and their functions. Drought-sensitive miRNAs activate pathways that enhance resilience by reducing water loss in plants. For instance, certain miRNAs support adaptation processes in plants under drought conditions by regulating osmotic balance and antioxidant defense mechanisms (Tombuloglu, 2022).

2.8. Stress Responses in Plants with the MADS-Box Gene Family

The MADS-box gene family plays an important role in increasing the genetic resilience of plants against stress factors, particularly those related to drought and temperature. This gene family is crucial in processes such as flowering and root development. Studies on MADS-box genes can assist in developing plants with resistance to environmental factors such as drought and high temperatures, which are intensified by climate change. Examining the expression profiles of these genes provides strategic insights for developing drought-resistant plant varieties (Roy et al., 2024).

2.9. Role of Plant RNA-Binding Proteins in Stress Response and Development

RNA-binding proteins (RBPs) play an essential role in regulating RNA metabolism in plant cells. RBPs respond to environmental stress signals, affecting intracellular dynamics and helping plants adapt to environmental changes. The aggregation of these proteins into membraneless condensates through phase separation strengthens flexibility and resilience mechanisms in plants (Fan et al., 2024).

2.10. Copper Stress and RNA Methylation in *Arabidopsis thaliana*

N6-methyladenosine (m6A) modification plays a significant regulatory role in response to copper-induced oxidative stress in Arabidopsis thaliana. This modification enhances gene expression and mRNA stability under specific stress conditions, increasing the plant's resistance to oxidative damage. Research has shown how genes enriched with m6A modification adapt to copper stress, highlighting the importance of epitranscriptomic changes in oxidative stress responses in plants (Sharma et al., 2024).

2.11. Genes and Pathways Involved in Root Development Against Cold Stress

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Transcriptomic analyses in *Sesuvium portulacastrum* have revealed key genes that support root development under low-temperature conditions. These genes include those involved in carbon fixation, starch metabolism, and plant hormone signaling pathways, which are critical for promoting root development and cold stress adaptation (Yang et al., 2024).

2.12. Analysis of Long Non-Coding RNAs (lncRNAs) in *Morus alba* for Drought Stress

The expression profiles of long non-coding RNAs (lncRNAs) in Morus alba (mulberry) under drought stress have been investigated. This analysis has shown that lncRNAs interact with genetic regulatory networks under drought conditions to direct adaptive responses. Specifically, lncRNAs are observed to support mechanisms such as osmotic regulation and antioxidant defense (Ackah et al., 2024).

2.13. Role of the EPF/EPFL Gene Family in Drought Stress Response in Maize

The EPF/EPFL gene family in Zea mays plays a significant role under drought stress. This gene family regulates stomatal development and oxidative stress response in maize. Studies show that these genes enable adaptation under water deficit conditions, contributing to the development of drought-resistant maize varieties (Xia et al., 2024).

2.14. Transcriptional Analysis of Salt Stress Response at Single-Cell Resolution in Cotton Roots

Single-cell transcriptional analysis of the response to salt stress in cotton roots provides valuable insights into cellular heterogeneity. This analysis has revealed differentiation pathways and the functions of genes that help maintain osmotic balance under salt stress in various cell types. Genes such as GaGH3.6 play a critical role in salt tolerance and protect against oxidative damage (Li et al., 2024).

2.15. Transcriptome Analysis of Salt Stress Response in Ilex dabieshanensis

The response of *Ilex dabieshanensis* (holly) to salt stress has been examined through RNA-seq analysis. Salt stress responses in this plant are regulated by mechanisms involving hormones like abscisic acid (ABA) as well as ion homeostasis and osmotic metabolism. Specifically, the expression levels of genes enhancing resistance to abiotic stresses have been determined (Chen et al., 2024).

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2.16. Freezing Stress Response in Chickpeas

Freezing stress has significant negative effects on the growth and yield of chickpeas, especially in cold climates like Canada. This study examined the freezing tolerance of wild chickpea relatives and cultivated chickpea varieties, showing that wild accessions like Kesen_075 exhibit higher tolerance. Gene expression analysis investigated the number and characteristics of genes differentially expressed under freezing stress in genotypes like CDC Consul and Kesen_075, highlighting the activation of CBF pathways in Kesen_075 that increase cold resilience. This study guides strategies for developing freeze-tolerant chickpeas (Kalve, House & Tar'an, 2024).

2.17. Role of miRNAs in Cold Stress Response in Maize Seedlings

The functions of cold-sensitive microRNAs (miRNAs) in maize seedlings under cold stress have been investigated. This research evaluated the expression of various miRNAs and their interactions with target genes under cold stress conditions. For example, miRNAs like zma-miR398 modulate antioxidant mechanisms to protect the plant under cold stress. The regulatory role of these miRNAs is a crucial factor in maize's adaptation to environmental challenges during early developmental stages (Božić et al., 2024).

2.18. Role of Heat Shock Factors and Cellulose Synthases in Temperature Stress Response in Maize

This study examined the heat shock factors (HSFs) and cellulose synthases (CesA) expressed in maize in response to temperature stress. It was observed that the gene ZmHSF20 acts as a negative regulator against temperature stress, with loss-of-function mutants exhibiting increased resilience to stress. These findings could be used as gene editing targets to improve temperature resilience in maize (Kamble et al., 2024).

2.19. Effect of Brassinolide on Cold Stress in Maize

The physiological and molecular effects of brassinolide application under cold stress in maize seedlings have been examined. The study found that 2,4-epibrassinolide application reduced ROS levels and increased antioxidant enzyme activities. Gene expression levels that support hormone balance and ROS homeostasis were also observed through RNA-seq analysis. These findings are significant for developing genotypes resilient to low temperature stress in maize (Zhao et al., 2024).

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2.20. Dual RNA-Seq Analysis of Pathogen Interactions in Coconut

Dual RNA-seq was used to investigate molecular interactions between coconut and Phytophthora palmivora. This analysis revealed plant defense responses and pathogenicity factors during infection. For instance, stress response genes in the plant and enzymes expressed by P. palmivora were regulated at different time points. This study provides valuable insights for developing resistant plant varieties against pathogenic factors (Gangaraj et al., 2024).

2.21. Use of Multi-Omics Approaches in Cadmium Stress Response

Cadmium (Cd) is one of the heavy metals causing toxicity in plants. Multi-omics analyses have thoroughly investigated cadmium accumulation and detoxification mechanisms. For example, mechanisms such as cell wall pectin accumulation and vacuolar cadmium sequestration have shown effects on cadmium resistance. These analyses contribute to the development of plant varieties that reduce cadmium accumulation (Yu, Alseekh & Fernie, 2024).

2.22. Effect of MADS-Box Genes on Stress Responses in Litchi

The MADS-box gene family in litchi plays significant regulatory roles under stress conditions. The expression levels of these genes vary under various environmental stress factors. This study examined the role of these genes in abiotic stress responses, highlighting their interactions with hormone signaling pathways such as ABA. These findings aid in developing genetic manipulation strategies to increase stress resistance in litchi (Yang et al., 2024).

2.23. Single-Cell RNA Sequencing (scRNA-Seq) Technology in Plant Research

Single-cell RNA-seq technology in plants is a valuable tool for examining cellular heterogeneity and creating cell-specific gene expression profiles. This technology is used to analyze cellular developmental pathways and construct gene regulatory networks. Research demonstrates that scRNA-seq opens new horizons in understanding plant cell types and has been successfully applied in various plant species. This enables a detailed understanding of cellular functions in plant sciences (Bian et al., 2024).

3. Future Directions and Conclusion

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While RNA-seq technology has revolutionized our understanding of plant adaptation to biotic and abiotic stress conditions, future studies offer opportunities to expand its potential. Advanced techniques like single-cell RNA sequencing (scRNA-seq) allow for more detailed exploration of gene expression dynamics at the cellular level, revealing how specific plant cell types respond to stress. Additionally, further research on non-coding RNAs, such as long non-coding RNAs (lncRNAs) and microRNAs (miRNAs), could uncover new genetic regulators that enhance stress tolerance. Combining RNA-seq with multi-omics approaches will help us gain a more comprehensive understanding of molecular adaptation mechanisms in plant biology and support the development of resilient plant varieties for sustainable agricultural practices.

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TRANSCRİPTOME AND GENOMİC ANALYSİS OF ALMOND (*Prunus dulcis*)

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ABSTRACT

Almond (*Prunus dulcis*), an economically significant nut crop, has been the focus of extensive genomic and transcriptomic studies aimed at improving its resilience to environmental stresses, kernel quality, and breeding efficiency. Recent advances have led to the sequencing of the almond genome, revealing critical insights into traits such as bud dormancy, flowering time, and stress responses. Comparative genomic studies with related species like peach have highlighted the role of transposable elements in almond's diversification and the development of key traits like kernel sweetness. Transcriptomic analyses have further illuminated almond's responses to abiotic stresses, including drought and frost, identifying numerous differentially expressed genes (DEGs) involved in stress tolerance. These findings have facilitated the development of functional markers for breeding programs. In particular, research into genes associated with self-incompatibility, stress tolerance, and flowering regulation offers promising tools for marker-assisted selection (MAS) in breeding. As almond cultivation faces increasing challenges from climate change, integrating genomic and transcriptomic data is essential for developing resilient cultivars that maintain productivity under adverse conditions.

Keywords: Almond (*Prunus dulcis*), genomic analysis, transcriptomic analysis, stress tolerance.

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1. INTRODUCTION

Almond (*Prunus dulcis*) is a nut crop of significant economic and nutritional value worldwide. Commonly cultivated in Mediterranean climates, almonds find wide use in the food industry and various by-products. In recent years, genomic and transcriptomic studies on almonds have provided significant opportunities to improve the plant's resilience to environmental stresses, enhance productivity, and improve kernel quality. Abiotic stresses such as drought and cold can lead to substantial losses in almond production, making genetic studies aimed at enhancing almond resilience crucial (Wu et al., 2023).

Sequencing the almond genome has revealed the genetic basis of important biological processes such as bud dormancy, flowering time, and stress responses. These studies have improved our understanding of the genetic mechanisms that enable almonds to adapt to various environmental conditions and provide essential knowledge for developing more resilient varieties (Zhang et al., 2024). Additionally, transposable elements in the almond genome play an important role, particularly in the evolution of phenotypic traits such as sweet kernel (Li et al., 2023).

2. GENOMIC AND TRANSCRIPTOMIC STUDIES

2.1. Genome Sequencing and Genetic Diversity

The complete sequencing of the almond genome has significantly contributed to understanding how the plant's genetic structure responds to environmental stresses. Genomic analyses have elucidated the genetic basis of agronomic traits such as bud dormancy, flowering time, and stress responses (Wu et al., 2023). Notably, genome-wide resequencing studies conducted in the Xinjiang region have demonstrated the genetic diversity among almond populations and its critical role in adaptation to environmental changes.

2.2. Role of Transposable Elements and Almond-Peach Comparisons

Comparative studies between almond and peach genomes have revealed that transposable elements play a significant role in the almond genome and are involved in the evolution of traits specific to almonds, such as sweet kernel (Zhang et al., 2022). These comparisons have provided insights into the evolutionary divergence of the almond's genetic structure and its role in environmental adaptation (Li et al., 2023).

2.3. Self-Incompatibility System and Genetic Control

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The self-incompatibility mechanism in almonds contributes to maintaining genetic diversity. This mechanism results in the inability of almonds to self-pollinate, thus increasing genetic diversity. The S-locus and the Skp1 gene family, which is part of the SCF complex, play an important role in controlling this mechanism (Gómez et al., 2019; Zhang et al., 2023). Understanding self-incompatibility mechanisms is crucial for conserving genetic diversity in almonds and developing more productive varieties.

2.4. Flowering Time and Genetic Regulatory Mechanisms

Flowering time is a crucial agronomic trait for almond productivity and environmental adaptation. Early flowering can negatively impact almond yields due to sensitivity to late spring frosts. Genes such as FLOWERING LOCUS T (FT) and SUPPRESSOR OF OVEREXPRESSION OF CONSTANS1 (SOC1) are important regulators of flowering time (Özdemir et al., 2021). Understanding these genes allows for the development of almond varieties that are more resistant to frost damage and have a delayed flowering period.

2.5. Molecular Response to Abiotic Stresses

The molecular responses of almonds to abiotic stresses such as drought, cold, and salinity have been detailed through transcriptomic analyses. It has been found that genes such as PdCBF1 and PdCBF2 are highly expressed in response to cold stress, playing a critical role in adaptation to cold conditions (Yu et al., 2022). Additionally, identifying genes related to water-use efficiency (WUE) is important for improving the adaptability of almonds to drought conditions (Bielsa et al., 2018).

2.6. AP2/ERF Transcription Factors and Stress Tolerance

AP2/ERF transcription factors play a significant role in regulating stress responses in almonds. The high expression of this gene family in response to cold stress demonstrates that these factors are critical in providing stress resilience in almonds (Yu et al., 2022). This information can be used to develop almond varieties that are more resistant to cold stress.

2.7. Methylation and Epigenetic Regulation in Almonds

Non-infectious bud failure (BF) associated with aging in almonds has been linked to epigenetic mechanisms. Methylation analyses have shown a relationship between BF and

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hypomethylation, helping us understand the impact of such epigenetic regulations on agricultural performance (D'Amico-Willman et al., 2022).

2.8. Genetic Control of Kernel Size

Kernel size is an important trait for the commercial value of almonds, and RNA-Seq analyses have helped identify genes that affect this phenotypic trait. These studies provide a foundation for developing almond varieties with larger and higher-value kernels (Hosseinpour et al., 2021).

2.9. Potential Genetic Targets for Stress Tolerance

Studies aimed at increasing stress tolerance have highlighted the expression profiles of genes such as PdCBF and AP2/ERF, which enhance tolerance to abiotic stresses like cold and drought (Yu et al., 2022; Zhang et al., 2023). These genetic targets hold significant potential for improving the resilience of almonds to environmental conditions.

2.10. Use of Genomic and Transcriptomic Information in Breeding Programs

Genomic and transcriptomic studies in almonds are effectively utilized in breeding programs to develop more resilient and high-yielding varieties. RNA-Seq analyses have enabled the identification of differentially expressed genes (DEGs) that help us understand almond responses to environmental stresses (Arismendi et al., 2015). Modern breeding techniques such as marker-assisted selection (MAS) are used to enhance the agricultural performance of almonds.

3. Conclusion and Future Perspectives

Genomic and transcriptomic studies on almonds offer great potential for enhancing resilience to environmental stresses, conserving genetic diversity, and improving commercially important traits. Genome sequencing and transcriptomic analyses help identify the genes involved in almond adaptation to different environmental conditions, and this information is used in breeding programs. These studies provide a vital foundation for increasing almond productivity and quality in agricultural production.

Future research should focus on utilizing genomic and transcriptomic data to develop almond varieties that are more resilient to environmental stresses and more productive. The use of genetic engineering and marker-assisted selection (MAS) techniques is particularly important to increase resilience to abiotic stresses. Additionally, understanding epigenetic regulation and

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genetic regulatory mechanisms will help develop more sustainable and productive practices in almond cultivation. The effective use of genomic and transcriptomic data in agriculture offers significant potential for future almond production.

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MONITORING AND EVALUATING LULC CHANGES IN MARMARA LAKE REGION USING AI-SUPPORTED SENTINEL-2 LAND COVER DATA (2017–2023)

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ABSTRACT

Land use and land cover change (LULC) is important for environmental sustainability and the management of natural resources. Remote sensing techniques enable long-term monitoring over large areas, providing decision-makers with fast and reliable information. This study examines land use and cover changes between 2017 and 2023 in Manisa province, especially around Lake Marmara. The study uses Sentinel-2 data with a 10-meter resolution obtained from ESRI's Living Atlas for the World platform. This platform is a powerful tool for land use analysis with its high-resolution and AI-assisted classification capabilities. The images were classified into nine categories: water, trees, submerged vegetation, agricultural areas, built-up areas, bare soil, snow/ice, clouds, and pasture, and were evaluated to observe changes in the land use of the region. According to the analysis results, agricultural areas increased from 32.38% in 2017 to 34.36% in 2023, and built-up areas increased from 3.43% to 4.09%. Water areas decreased from 0.72% to 0.33%, and rangeland areas decreased from 39.96% to 37.08%. The water area in Lake Marmara, which was 12% in 2017, completely disappeared after 2021. These findings show that agricultural pressure is increasing and water resources are decreasing. Land use changes threaten the sustainability of natural resources in the region and require local governments to take environmental measures. The results show that remote sensing analysis provides important environmental management and sustainable planning recommendations.

Keywords: ESRI Living Atlas, LULC, Sentinel-2, Sustainability, Remote Sensing, Artificial Intelligence-Assisted Classification

1. INTRODUCTION

Land use and land cover change (LULC) is critical for environmental sustainability, biodiversity, and natural resource management. LULC changes directly affect ecosystem health, directly affecting the conservation of natural resources such as water resources, agricultural areas, and green spaces [1]. Therefore, monitoring and analyzing LULC changes play a major role in the formulation of environmental sustainability strategies [2]. Remote sensing offers significant advantages for monitoring large areas and assessing land changes over time. This technique enables detailed, time- and cost-effective data collection through satellite data [3,4].

These advantages of remote sensing are highly valuable for understanding the dynamic nature of LULC changes and providing a scientific basis for environmental planning processes. High-resolution satellite systems such as Sentinel-2 enable detailed monitoring of land cover changes and assessment of environmental impacts [5]. Sentinel satellites have facilitated large-scale mapping of LULC at a 10 m resolution .Since 2021, three global Sentinel-based 10 m LULC maps have been released, including Google's Dynamic World (DW), ESA's World Cover 2020 (WC), and Esri's 2020 Land Cover (Esri) maps [6]. ESRI's Living Atlas for the World platform [7] provides Sentinel-2 data in a user-friendly way, enabling fast and effective analysis in this area. Thanks to high-resolution data and AI-assisted classification algorithms, it is possible to analyze land use changes more precisely and in detail. Moreover, the literature emphasizes that the accuracy of ESRI's Land Cover product is generally acceptable, based on evaluations conducted in different regions [8-10]. Studies conducted through this platform have examined LULC changes in various ecosystems and contributed to the development of sustainable land management strategies [11-14].

This study aims to analyze the land use and land cover changes in Manisa province and especially around Lake Marmara between 2017 and 2023. In the analysis process, 10-meter resolution Sentinel-2 data obtained from ESRI's Living Atlas for the World platform was used. This platform provides a significant advantage in land use and change analysis with its high-resolution satellite data and artificial intelligence-assisted classification techniques. Analyzing land use and land cover changes in and around Manisa Marmara Lake is of great importance for the environmental management, sustainability, and urban planning of the region. To identify land use changes in the region, the images were categorized into nine different categories: water, trees, submerged vegetation, agricultural areas, built-up areas, bare soil, snow/ice, clouds, and pasture. Through these categories, changes in land use and cover in the region were analyzed in detail.

2. MATERIAL AND METHOD

2.1. Study area

This study was conducted in Manisa province, located in the Aegean Region of Turkey, and especially around Lake Marmara. Lake Marmara is located at 38°39'N latitude and 27°57'D longitude coordinates and is one of the important water resources of the region [15]. Lake

Marmara is a little-studied wetland in Turkey [16]. The lake and its surroundings cover an area of approximately 41 km2, have a depth of 3–4 meters, and play a critical role in terms of ecological balance in the region[15]. Lake Marmara has a typical Mediterranean climate with hot and dry summers and mild and rainy winters. The region receives an average annual precipitation of 600–700 mm, which makes it an area where agricultural activities are intensively carried out [16]. The topography around Lake Marmara generally consists of low hills and plains. The region has very favorable soils in terms of agricultural activities and is a fertile agricultural area where products such as olive, wheat, corn, and cotton are grown [17]. However, settlements and agricultural activities around the lake put serious pressure on water resources. This pressure has caused the water level in the lake to gradually decrease and the ecological balance in the region to deteriorate in recent years. This situation makes the study area an important example for analyzing LULC changes.

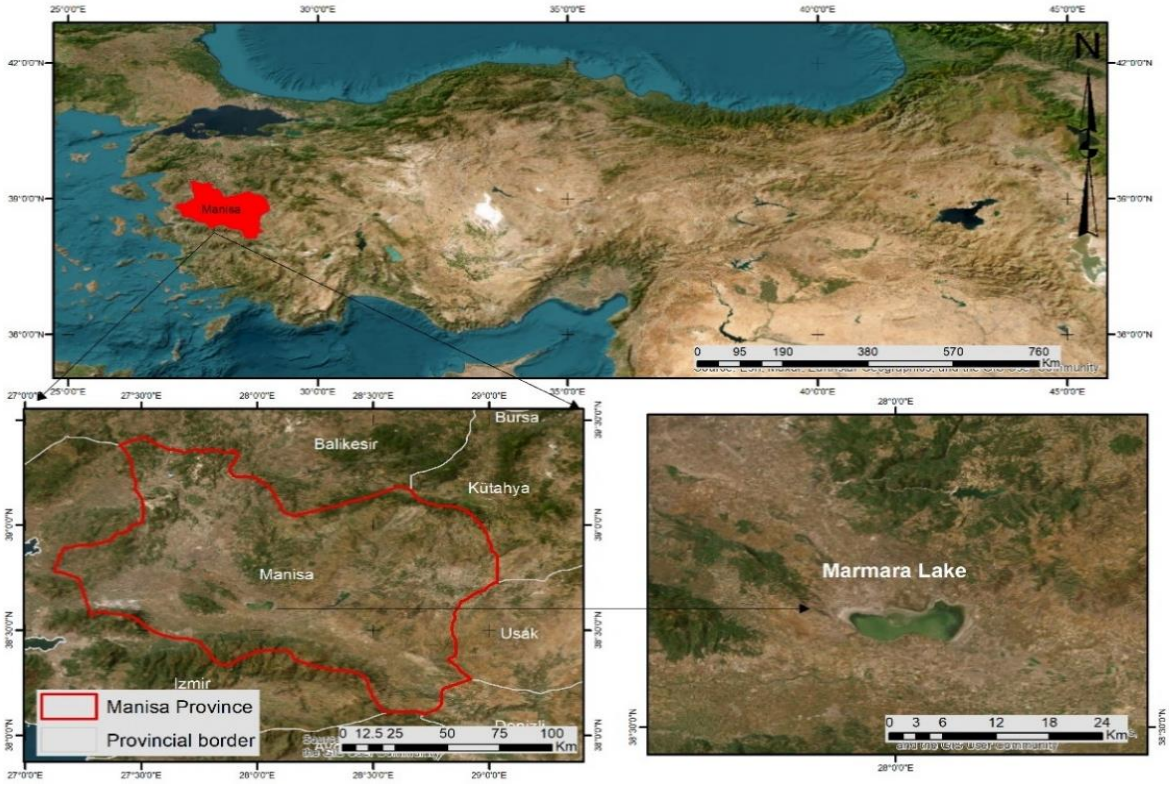

Figure 1. Study area representation

2.2. Sentinel-2 Land Cover Explorer Platform

Sentinel-2 Land Cover Explorer is a web application that allows users to analyze land cover changes around the world and is available as part of Esri's ArcGIS Living Atlas of the World collection [7]. Published in 2020, the global land cover map makes it possible to assess different ecosystems and land types on an annual basis. This platform uses Sentinel-2 satellite data from the European Space Agency (ESA) to classify land cover at a resolution of 10 meters [19]. Land cover is divided into nine categories: water, trees, submerged vegetation, agricultural areas, built-up areas, bare soil, snow/ice, clouds, and pasture. The platform provides annually updated

data from 2017 onwards, allowing changes over time to be monitored. Thanks to its user-friendly interface and artificial intelligence-supported algorithms, it is possible to accurately detect land cover changes over large areas (Figures 2–3).

Figure 2. Sentinel-2 Land Cover Explorer interface

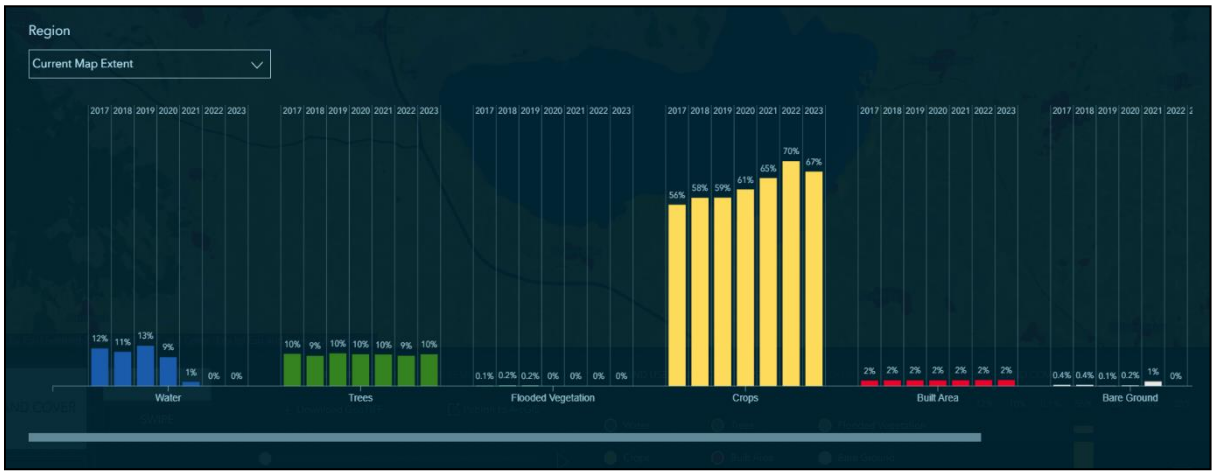

Figure 3. Land cover totals LULC data graphic interface

This high-resolution data helps decision-makers develop sustainable land management strategies. ESRI's platform has contributed to the analysis of many ecosystems around the world and has been a particularly effective tool in environmental management and natural resource conservation projects.

3. RESULTS

In this study, the Sentinel-2 Land Cover Explorer platform was used to monitor land use and land cover changes (LULC) in Manisa province and around Lake Marmara between 2017 and 2023. Thanks to the high-accuracy data and classification capabilities provided by the platform, important environmental changes such as the expansion of agricultural areas, an increase in construction, and a decrease in water resources were detected in detail. During the data

processing process, the images obtained for each year were exported via Land Cover Explorer and imported into ArcGIS (Figure 4).

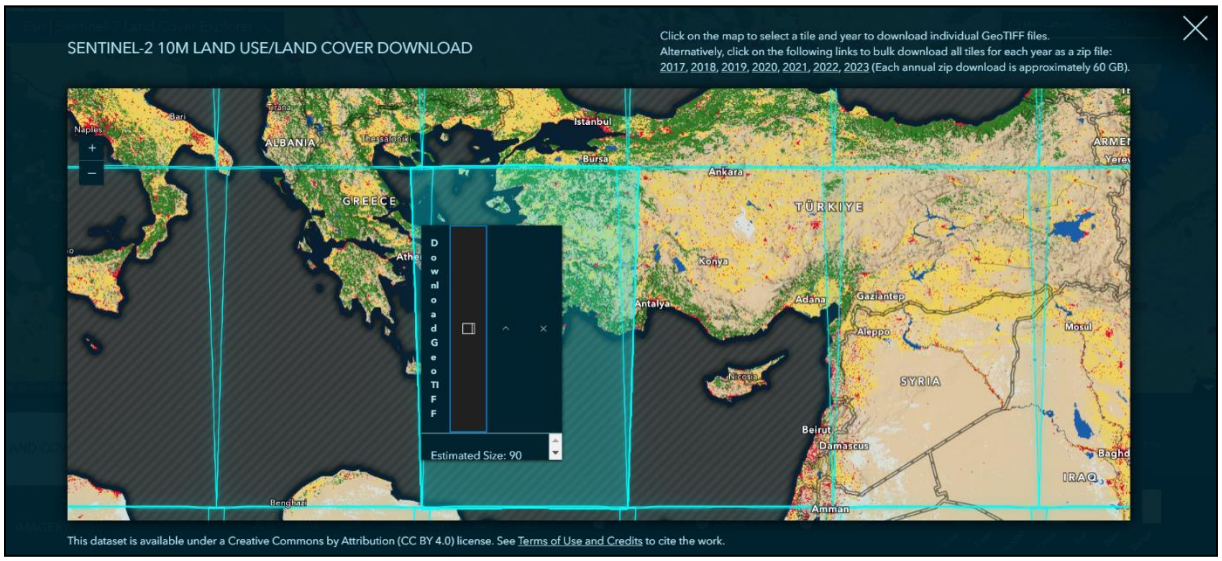

Figure 4. Sentinel-2 Land Cover Explorer data download process

The downloaded classification images were clipped from the relevant boundary, and the LULC map for each year was created separately for Manisa province and Marmara Lake surroundings. Figure 6 shows the land use and land cover map for Manisa province covering the years 2017-2023, and Figure 8 shows the land use and cover change map for Lake Marmara and its surroundings. The classes used are the nine categories provided by the platform: water, trees, submerged vegetation, agricultural areas, built-up areas, bare soil, snow/ice, clouds, and pasture. All classes in each raster image were reclassified, and the annual change percentages of these classes were calculated. Percentage representation of land use and land cover changes for Manisa province is presented in Table 1, and graphical representation is presented in Figure 5.

Table 1 Percentage of land use and land cover changes in Manisa (2017-2023)

		2017	2018	2019	2020	2021	2022	2023
Class	**Water**	0.72	0.69	0.77	0.58	0.35	0.30	0.33
	Trees	23.02	22.54	23.95	23.79	23.71	23.24	23.98
	Flooded Vegetation	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	Crops	32.38	33.30	34.06	34.25	35.73	33.80	34.36
	Built Area	3.43	3.57	3.67	3.79	3.92	4.10	4.09
	Bare Ground	0.49	0.32	0.25	0.23	0.24	0.19	0.15
	Snow/ice	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Clouds	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Rangeland	39.96	39.56	37.29	37.35	36.05	38.38	37.08
	Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

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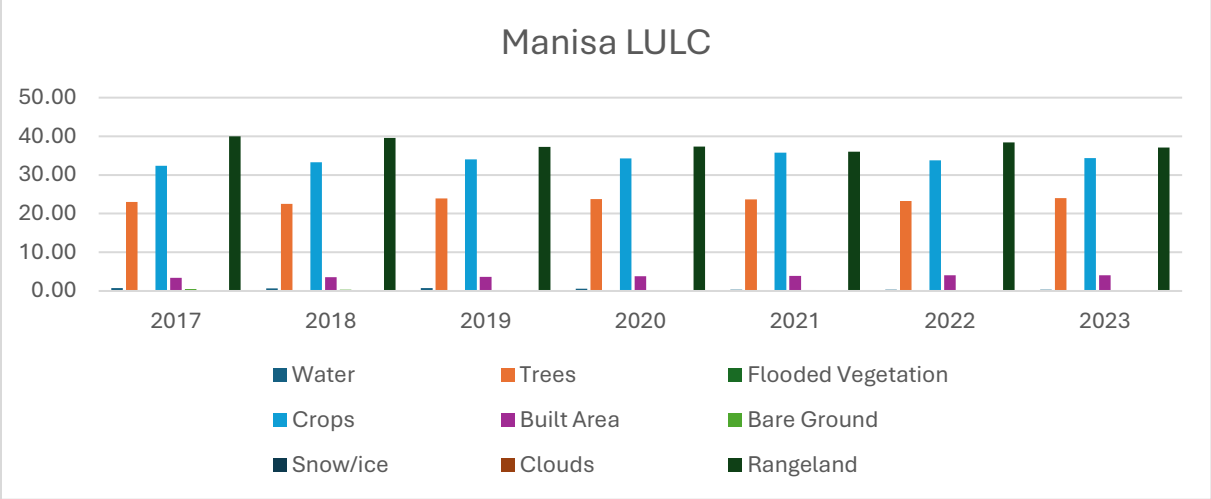

Figure 5. Percentage graph of land use and land cover changes in Manisa (2017-2023)

According to the findings, the proportion of agricultural areas increased from 32.38% in 2017 to 34.36% by 2023. This increase may be related to increasing demands for agricultural activities and the opening of new agricultural areas, possibly forced by climate change. The expansion of agricultural areas increases the pressure on natural ecosystems and especially on rangelands. Built-up areas also increased from 3.43% in 2017 to 4.09% in 2023. This increase points to the expansion of urban areas and the impacts of population growth on land. In particular, the decrease in water resources from 0.72% to 0.33% reflects the pressure of drought trends and climate change impacts on water resources in the region. The complete loss of water level in Lake Marmara emphasizes the need to re-evaluate water management strategies. The decrease in pasture areas from 39.96% to 37.08% indicates that natural pastures are shrinking due to the expansion of agricultural areas and the impact of construction. This may have negative impacts on local flora and fauna.

In this study, LULC changes in the last 5 years (2017-2023) in and around Lake Marmara, which will completely dry up after 2021, were also analyzed. The results of the analysis are tabulated in Table 2. In addition, land use and land cover changes in and around Marmara Lake are shown graphically in Figure 7.

Table 2 Percentage of land use and land cover changes in and around Lake Marmara (2017-2023)

		2017	2018	2019	2020	2021	2022	2023
Class	**Water**	12	11	13	9	1	0	0
	Trees	10	9	9	10	10	9	9
	Flooded Vegetation	0.1	0.2	0.2	0	0	0	0
	Crops	56	58	58.7	60.8	65	70	67
	Built Area	2	2	2	2	2	2	2
	Bare Ground	0.4	0.4	0.1	0.2	1	0	0
	Snow/ice	0	0	0	0	0	0	0
	Clouds	0	0	0	0	0	0	0
	Rangeland	19	19	17	18	21	19	22
	No class	0.5	0.4	0	0	0	0	0
	Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

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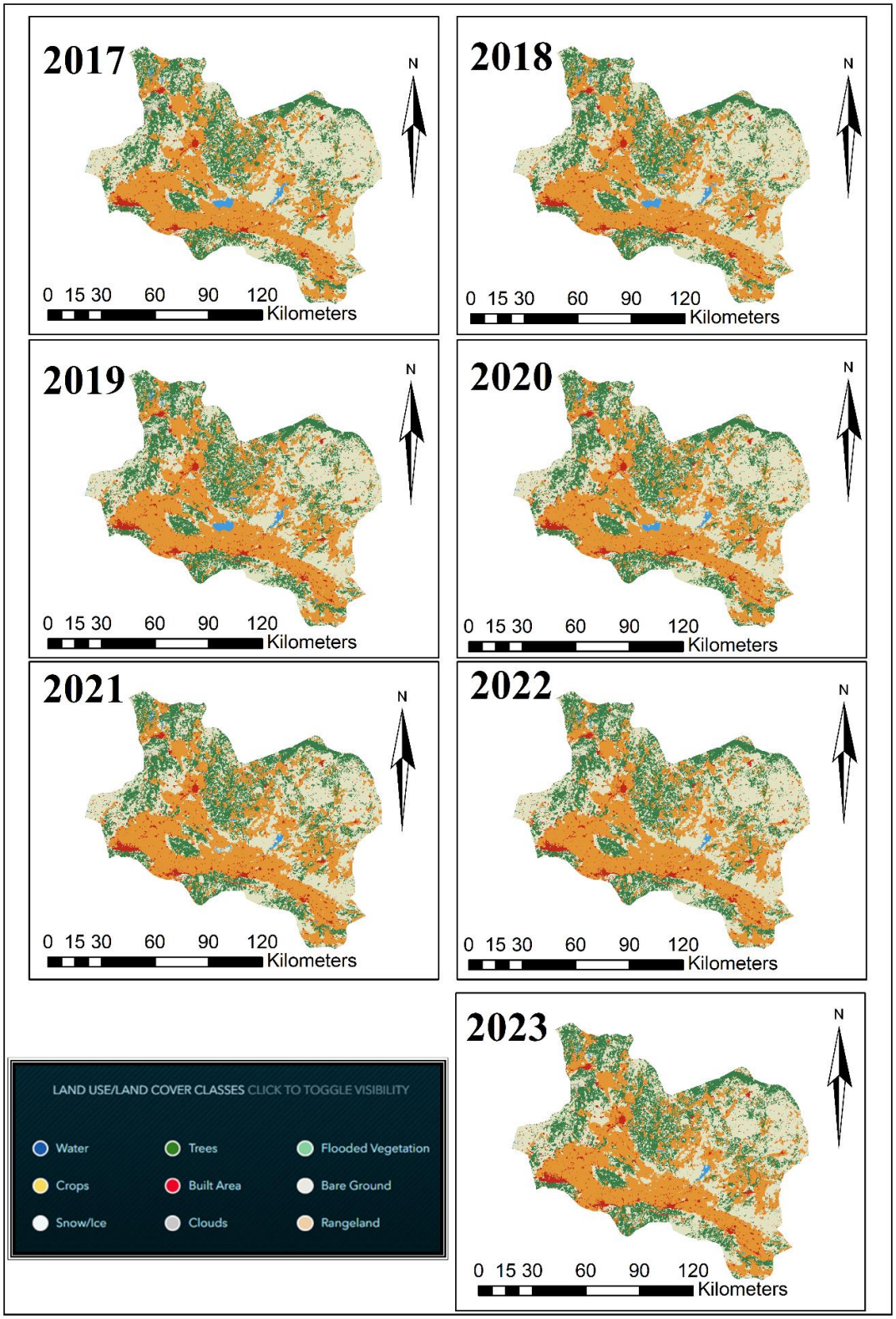

Figure 6. Land use and land cover map of Manisa province (2017-2023)

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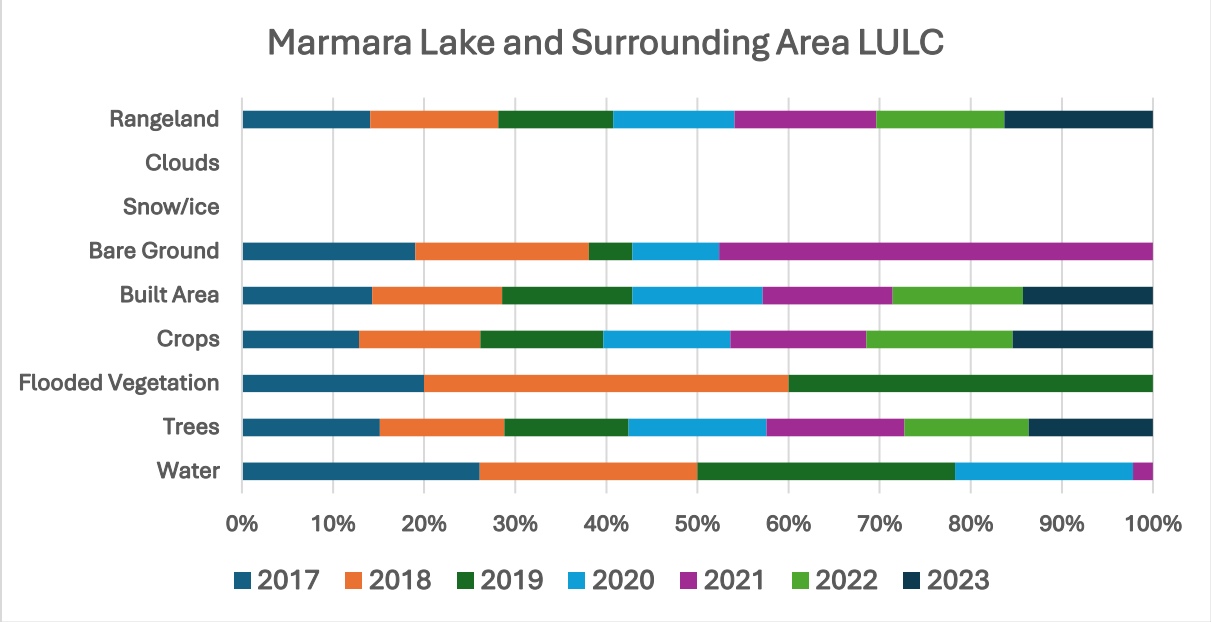

Figure 7. Percentage graph of land use and land cover changes in and around Lake Marmara (2017-2023)

Table 2 details the land use and cover changes around Lake Marmara. While Lake Marmara had a 12% water area in 2017, this ratio decreased to zero as of 2021. The complete loss of the water level in the lake poses a major threat to the sustainability of water resources. Agricultural areas have increased from 56% to 67%, indicating an increase in agricultural activities at the expense of decreasing water resources. This situation necessitates greater utilization of water resources, especially around the lake, and puts great pressure on water resources. Built-up areas have remained stable at 2%, indicating that settlements are not directly affected but existing natural areas are indirectly under pressure. The fact that pasture areas remain constant between 19% and 22% suggests that some of the natural areas are protected; however, more measures should be taken to protect these areas in the face of losses in agriculture and water resources.

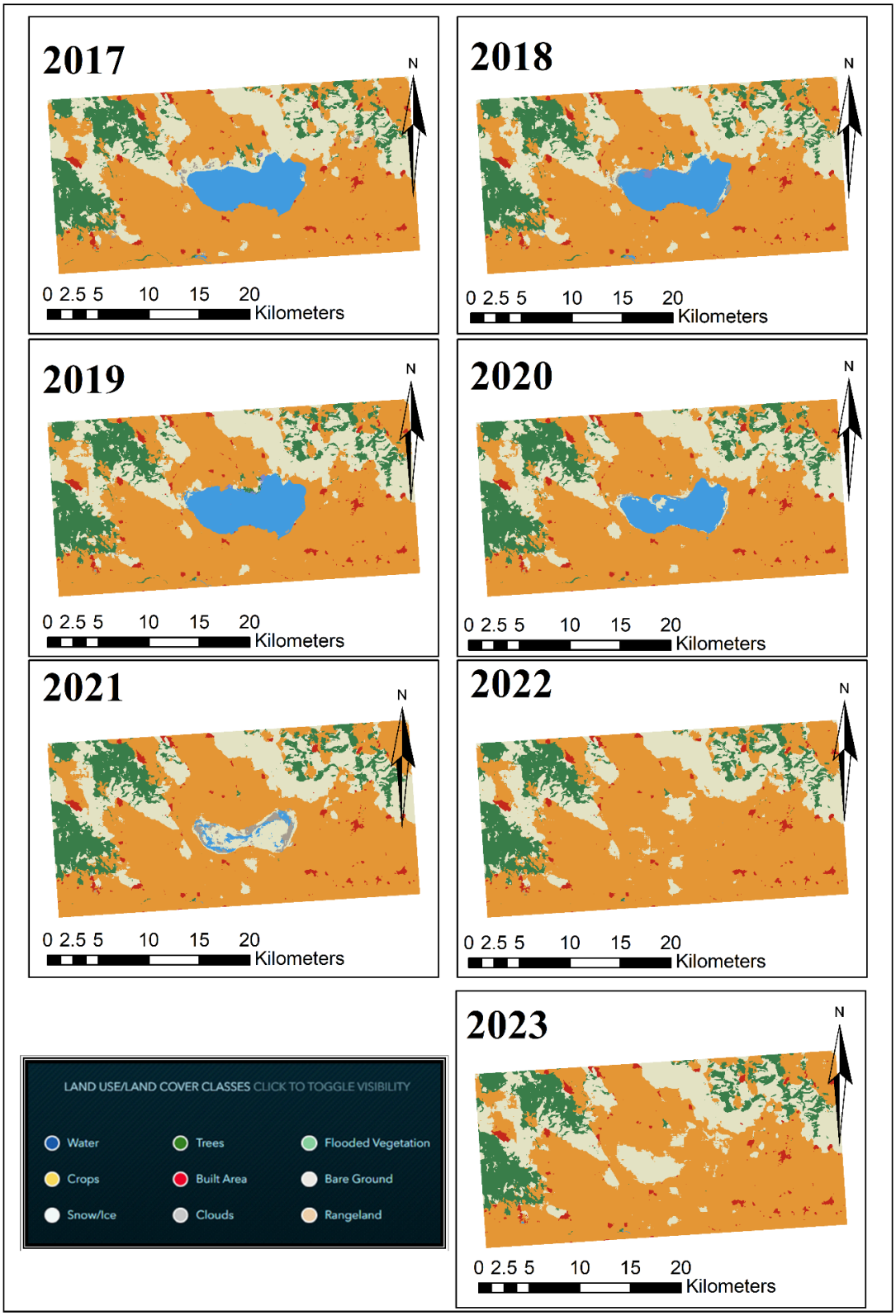

Figure 8. Land use and land cover map of Lake Marmara and its immediate surroundings (2017-2023)

4. CONCLUSION

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This study aims to analyze the land use and land cover changes (LULC) in and around Lake Marmara in Manisa province between 2017 and 2023 using the Sentinel-2 Land Cover Explorer platform. The findings of the study are clear indicators of environmental changes in the region, such as the expansion of agricultural areas, increase in construction, and decrease in water resources. These changes give important signals for the sustainable management of natural resources and increase the pressure on the ecosystem balance in the region. In particular, the complete drying up of Lake Marmara by 2021 indicates that water management and natural resource protection strategies need to be reconsidered. This situation emphasizes the need for local governments and planning institutions to take strategic measures.

Monitoring land use and land cover changes is of great importance for managing natural resources, conserving biodiversity, and assessing the environmental impacts of climate change. In this field, remote sensing technologies play a critical role in identifying and assessing environmental changes by enabling monitoring of large areas. The Sentinel-2 Land Cover Explorer platform enables detailed analysis of land classes such as agriculture, water, and pasture thanks to its high-resolution satellite data and artificial intelligence-supported classification algorithms. Remote sensing provides a powerful tool for LULC analysis thanks to its advantages of fast data provision, high accuracy, and long-term monitoring of changes over large areas.

The data obtained in this study provides valuable information for the sustainable management of Lake Marmara and its surroundings. Environmental changes such as the expansion of agricultural areas and the decrease in water resources threaten the ecological balance and the sustainability of natural resources in the region. The complete drying up of a valuable water source such as Marmara Lake makes it necessary to update water management strategies. Promoting modern and water-saving techniques in agricultural irrigation will be effective in reducing the pressure on water resources. Sustainable management of agricultural activities and controlled expansion of agricultural areas will be possible through planning that protects water resources and managing agriculture in a way that protects natural habitats in the region.
In conclusion, the high accuracy and artificial intelligence-supported classification capabilities of the Sentinel-2 Land Cover Explorer platform constitute a powerful resource for environmental management in land use analysis. The findings of this study emphasize the need for local governments to make strategic decisions for the protection of natural resources in and around Lake Marmara. It is once again revealed that remote sensing techniques have great importance in environmental sustainability studies thanks to their long-term monitoring and rapid data provision in large areas. In this context, it is foreseen that the use of remote sensing and artificial intelligence-assisted classification techniques in LULC analysis will find a wider place in environmental management strategies in the future.

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BOĞAZLIYAN DERESİ HAVZASI'NDA YAŞANAN EROZYON PROBLEMİ (YOZGAT)

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Özet

Erozyon yeryüzünde gerçekleşen aşınma ve taşınma olaylarının tamamı olarak geniş şekilde tanımlanabilir. Erozyonun bir problem teşkil etmesi ise insanların sürece müdahale ederek mevcut erozyon şartlarını değiştirmesi ve süreci hızlandırması sonucu meydana gelmektedir. Bu çalışma Karasu Çayı havzası içerisinde yer alan idari olarak da Yozgat ili sınırları içerisindeki Boğazlıyan Deresi havzasında gerçekleştirilmiştir. İlk olarak sahanın eğim ve yükselti haritaları oluşturulmuştur. Daha sonra Türkiye il envanterleri verilerinden yararlanılarak sahanı erozyon haritası oluşturulmuştur. Harita üzerinde görülen problemli alanlar saha çalışmaları ile doğrulanmış ve sahada görülen erozyon tipleri fotoğraflanmıştır. Ayrıca riskli alanların doğrudan etkilediği yerler hakkında gözlemler yapılmış ve sahadaki su yapılarının durumları farklı mevsimlerde izlenerek değerlendirilmiştir. Boğazlıyan Deresi havzası yaklaşım alanı 690 km2'dir. Havzada az ya da hiç erozyon görülen sahalar yaklaşık 85 km2'dir. Orta Derecede erozyon olan sahalar yaklaşık 358 km2'lik alanla sahanın yarısından saha fazla bir alanda karşımıza çıkmaktadır. Şiddetli erozyon yaşanan sahalar 206 km2'lik bir alanda, çok şiddetli erozyon sahaları ise yaklaşık 40 km2'lik bir alanda görülmektedir. Mevcut duruma bakıldığında sahanın önemli bir kısmının orta ve şiddetli erozyona maruz kaldığı görülmektedir. Hiç şüphesiz yaşanan erozyon havza üzerindeki sulama yapılarını olumsuz etkilemektedir. Boğazlıyan barajı başta olmak üzere sahadaki bütün sulama yapıları için problem teşkil edebilecek bir erozyon mevcuttur. Boğazlıyan barajı burada önemli risk altında görülebilir. Barajın olduğu sahaya bakıldığında yukarı havzada şiddetli erozyon sahaları görülmektedir. Erozyon tehlikesinin yüksek olduğu alanlarda uygulamalı çözümler üretilmediği sürece başta toprak olmak üzere önemli kaynaklarımızın kaybolması kaçınılmazdır. Sahada eğim değerlerini yüksek olduğu yerlerde yapılan kesimlerden acilen vazgeçilmelidir. Tarım alanları ise toprak ve Arazi kullanım kabiliyetine uygun olarak ekilip biçilmelidir.

Anahtar Kelimeler: Toprak Erozyonu, Havza, Boğazlıyan.

Abstract

Erosion can be broadly defined as all of the erosion and transport events taking place on the earth. The problem with erosion is that people can intervene in the process. change the existing erosion conditions and accelerate the process comes first. This study was carried out in the Karasu Stream basin, which is also administratively located in the Karasu Stream basin. The study was carried out in the Boğazlıyan Stream basin within the borders of Yozgat province. Firstly, slope and elevation maps of the site were prepared. Then Turkey erosion map of the area by utilising data from provincial inventories was created. The problematic areas seen on

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the map were identified by field studies. verified and the erosion types observed in the field were photographed. Also risky observations were made about the areas directly affected by the areas and the water The conditions of the structures were monitored and evaluated in different seasons. Boğazlıyan The approach area of the river basin is 690 km2 . Little or no erosion is observed in the catchment. The areas are approximately 85 km2. Areas with moderate erosion are approximately 358 With an area of km2 , it appears in more than half of the area. The areas with severe erosion are located in an area of 206 km2 and very severe erosion The fields are observed in an area of approximately 40 km2. Considering the current situation, it is seen that a significant part of the area is exposed to moderate and severe erosion. Undoubtedly, erosion negatively affects the irrigation structures in the basin.There is an erosion that may pose a problem for all irrigation structures in the field, especially Boğazlıyan dam.Boğazlıyan dam can be seen under significant risk here.When the area where the dam is located is examined, severe erosion areas are observed in the upper basin.Unless practical solutions are produced in areas with high erosion hazard, it is inevitable that our important resources, especially soil, will be lost.The cuts made in the areas where the slope values are high in the field should be urgently abandoned.Agricultural areas should be cultivated and harvested in accordance with soil and land use capability.

Key Words: Soil Erosion, Watershed, Boğazlıyan.

Giriş

Erozyon, toprağın verimli kısmının taşınması sonucu ortaya çıkan bir problemdir. Jeomorfolojik süreçte bir problem teşkil etmeyen erozyon olayı, çeşitli insan müdahaleleri ile artmakta ve toprak geri dönülmez noktalara gelmektedir (Saygın vd., 2023). Araştırmalara göre; toprağın fiziki özellikleri gelişmiş ve bitkiler için uygun şartlar oluşmuşsa erozyon direnci artmaktadır (Turgut ve Aksakal, 2010; Özdemir vd., 2015; İmamoğlu ve Dengiz, 2020).

Ülkemizdeki erozyon tehlikesinin boyutunun fazla olduğu ve uygulamaya yönelik her türlü bilimsel ve uzmansal koruma önlemleri alınmazsa, tehlike boyutlarının giderek artacağı ve özellikle toprak, topografya, su ve bitki örtüsü açısından geri-dönüşümsüz evrelere gelinebileceği açık bir şekilde bilinmektedir (Erpul ve Deviren Saygın, 2012).

Araştırma Sahası Yeri ve Sınırları

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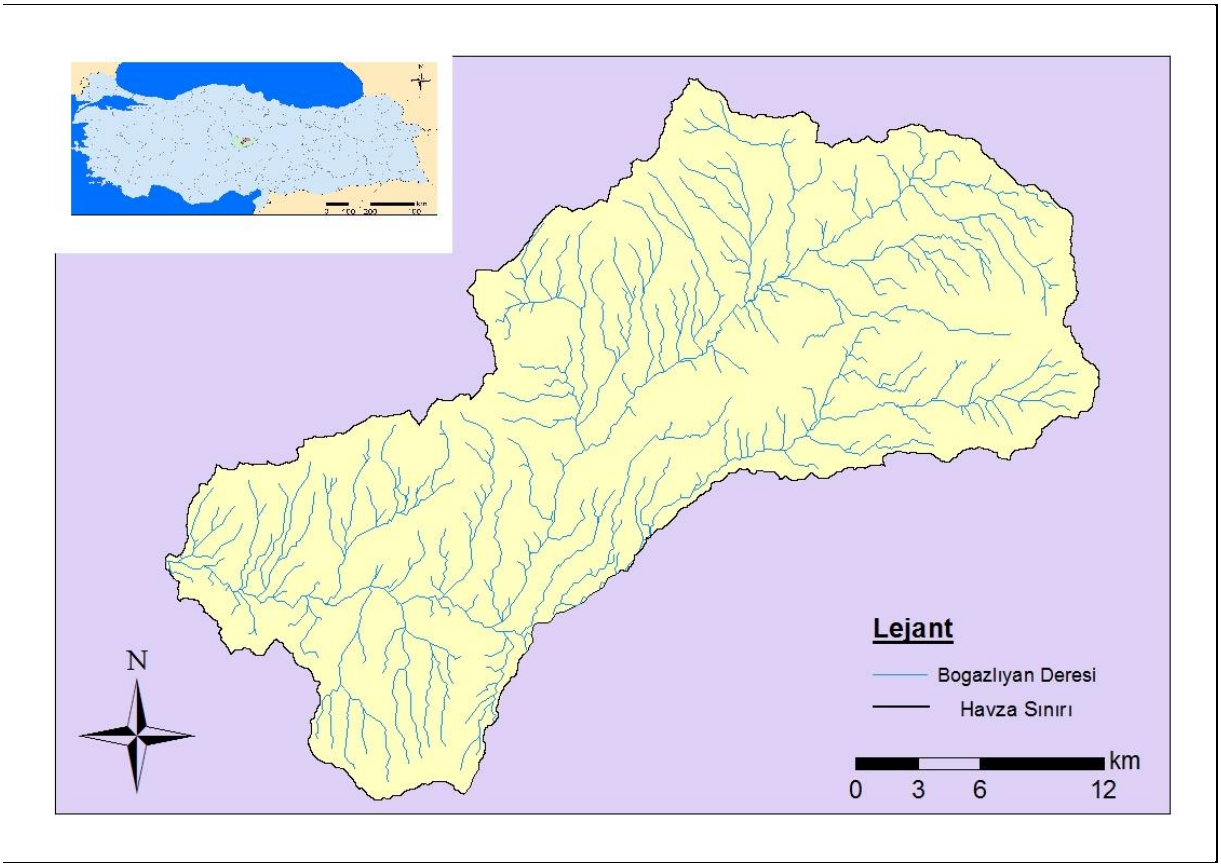

Şekil 1. Araştırma sahası lokasyon haritası.

Yöntem

İlk olarak araştırma sahasına ait eğim bakı yükselti gibi haritalar oluşturulmuştur. Daha sonra İl envanter raporlarından yararlanılarak sahanın erozyon haritası yapılmıştır. Yapılan haritalar ile birlikte arazi çalışmaları gerçekleştirilmiş ve ofis ortamında elde edilen sonuçlar arazide kontrol edilmiş ve doğrulanmıştır.

Sahada yapılan çalışmalar sırasında örnekler toplanmış, ilginç birim ünite ya da şekiller fotoğraflanmıştır. Erozyonal süreçlerin şiddetli yaşandığı görülen harita üzerindeki yerlere gidilmiş ve Erozyonun yöresel olarak sebepleri incelenmiştir.

Bulgular

Araştırma sahasının eğim yükselti gibi faktörleri incelenmiştir. Bu değerler erozyon süreçleri ile doğrudan ilgili olması sebebiyle önemlidir. Boğazlıyan havzasının genel eğim durumu değerlendirildiğinde eğimin çok az ya da az sınıfında olduğu araziler oldukça fazladır. Hafif eğimli araziler ve dik araziler de bulunmakla birlikte çok dik arazi neredeyse yok denebilecek kadar azdır. Dik eğimli araziler daha çok akarsuların yukarı çığırlarındaki kayalık alanlara karşılık gelmektedir.

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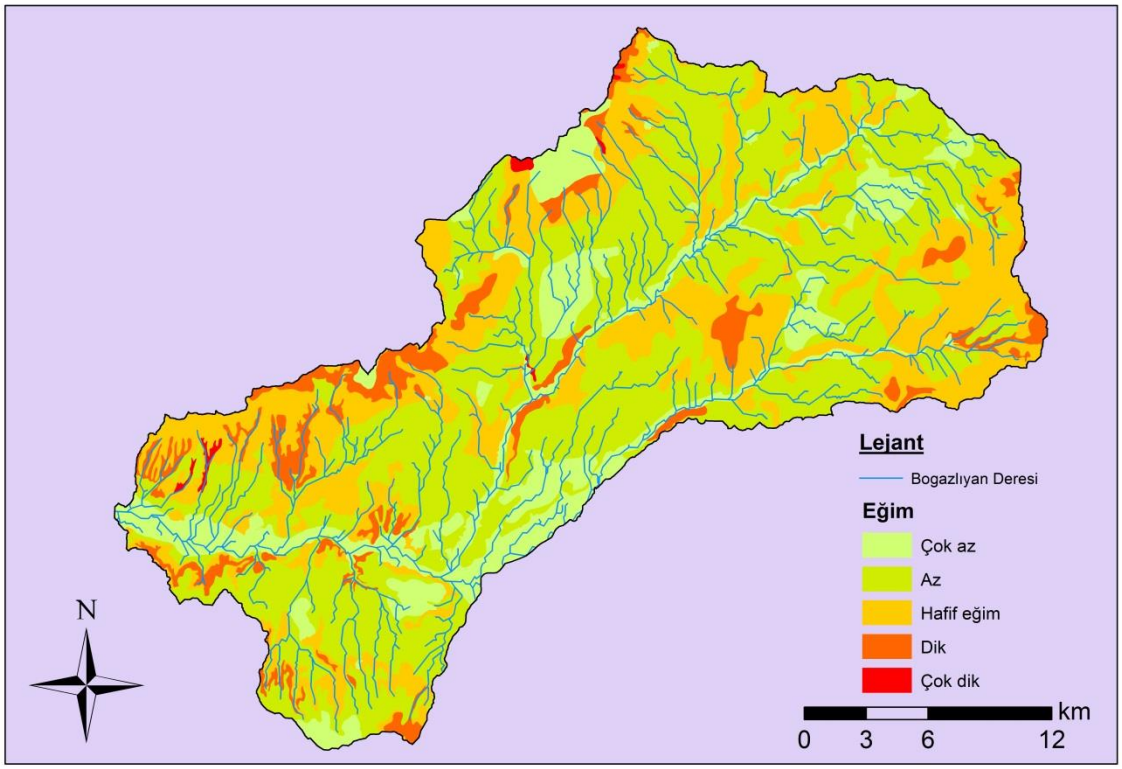
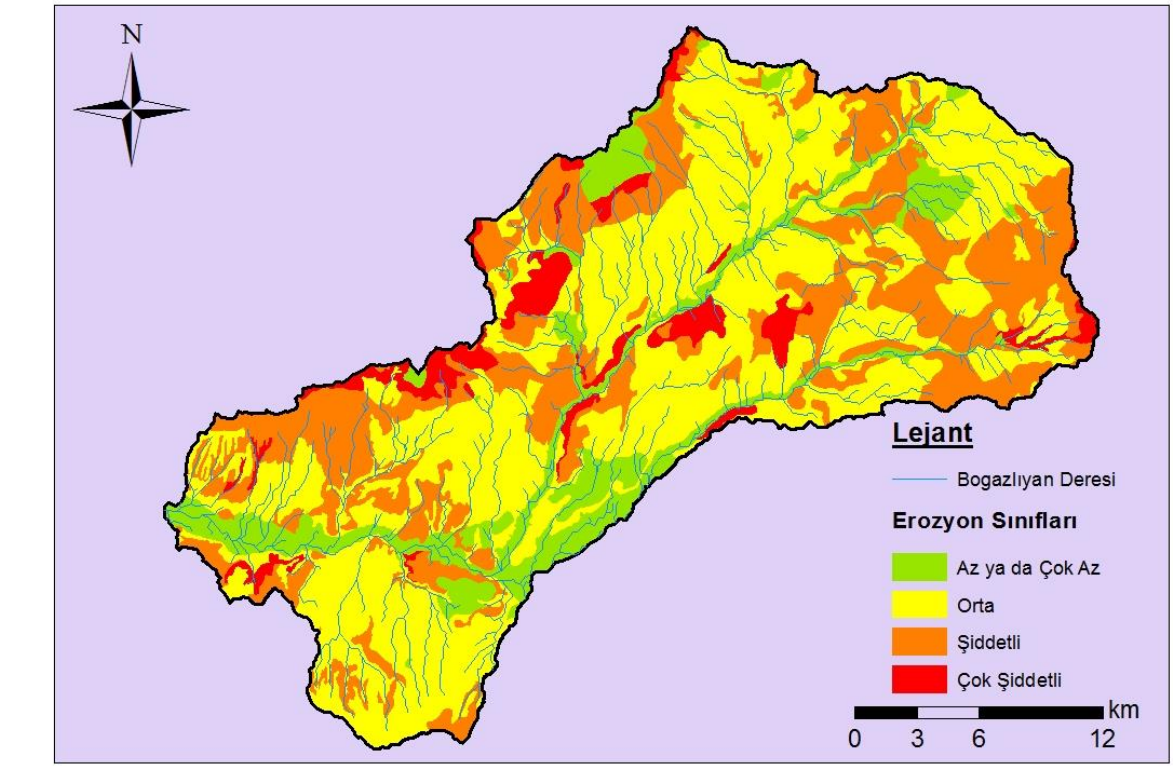


Şekil 2. Araştırma sahası eğim haritası.

Havzada az ya da hiç erozyon görülen sahalar yaklaşık 85 km2'dir. Orta Derecede erozyon olan sahalar yaklaşık 358 km2'lik alanla sahanın yarısından daha fazla bir alanda karşımıza çıkmaktadır. Şiddetli erozyon yaşanan sahalar 206 km2'lik bir alanda sahanın yaklaşık % 30'unda görülmekte, çok şiddetli erozyon sahaları ise yaklaşık 40 km2'lik bir alanda sahanın küçük bir kesiminde görülmektedir. Mevcut duruma bakıldığında sahanın önemli bir kısmının orta ve şiddetli erozyona maruz kaldığı görülmektedir. Bu alanlar nispeten yüksek sahalarda ve vadilerin yukarı çığırlarında yoğunlaşmıştır. Buda yükselti ve eğim faktörlerinin erozyon derecesi üzerinde ne derece etkili olduğunun önemli bir göstergesidir.



Şekil 3. Araştırma sahası erozyon haritası.

Tablo 1. Erozyon değerlerinin alansal ve oransal dağılışı.

Erozyon	**Alan**	**Yüzde**
Az ya da Çok az	85,5365	12,4
Orta	358,4472	51,9
Şiddetli	206,4453	29,9
Çok Şiddetli	40,26198	5,8
Toplam	690,691	**100**

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Şekil 4. Havzanın yukarı kesiminde yol yapımına bağlı gelişen yarıntı erozyonu.

Sonuç ve Öneriler

Araştırma sahası erozyonal süreçlerin yaşandığı bir havzadır. Gerek eğim değerleri gerekse yükselti gibi faktörlere bağlı olarak erozyon şiddetinin genellikle orta şiddetli erozyon ve şiddetli erozyon sınıflarında yoğun olduğu görülmüştür. Sahanın yaklaşık yarısında gerçekleşen orta dereceli erozyon miktarı düşük eğim değerlerinin olduğu yerlerde de karşımıza çıkmaktadır. Sahada yapılan gözlemler sonucunda sahada yanlış arazi kullanımının olduğu tespit edilmiştir. Özellikle mera alanlarının tarım alanına dönüştürülmesi problem teşkil etmektedir. Bununla birlikte tarımda uygulanana yanlış yöntem ve teknikler olduğu da gözlemlenmiş, eğime paralel sürüm, anız yakımı gibi yanlışlarla karşılaşılmıştır.

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VOLKANİK MAĞARA KULLANIMINA KIRSAL BİR ÖRNEK, ANINKAYA MAĞARA KOMPLEKSİ (NEVŞEHİR)

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Özet

Mağaralar farklı tanımları yapılmış olsa da genel olarak bir insanın sığabileceği büyüklükteki yeraltı boşlukları olarak tanımlanmaktadır. Tarihsel süreçte farklı amaçlarla kullanılmış olan mağaralar insan medeniyeti içerisinde önemli yer kaplamaktadır. Bölge özelinde mağaralar ise yüzyıllardır insanların kullandığı önemli yaşam alanları olarak karşımıza çıkmaktadır. Bugünde mağaraların yörede önemi yadsınamaz büyüklüktedir. Turizm otelcilik ve depoculuk gibi önemli alanlarda mağaralardan faydalanılmaktadır. Bugünkü mağaraların bölgede doğal mağaralar olmaktan daha çok ticari kaygılar ile yapılmış mağaralar olduğu da açıktır. Öte yandan sahanın Kapadokya Volkanik alanı olarak nitelendirildiği düşünüldüğünde doğal yapıların da bolca bulunduğu gözardı edilmemelidir. Jeolojik miras olarak kabul edilebilecek volkanik sahalar bir bütün olarak değerlendirildiğinde jeoturizm faaliyetleri bakımından bir bütünün parçaları olarak değerlendirilmelidir. Bu sebeple sahada yer alan her bir jeomorfolojik şekil önem arz etmektedir. Makaleye konu olan Anınkaya mağara kompleksi de bu bütünün parçası olarak değerlendirilmiş, sahada ölçümler ve gözlem yapılarak mağaraların jeoturizm potansiyeli değerlendirilmiştir. Anınkaya mağarası kompleks yapısının çok boyutlu olduğu görülmüştür. Mağaranın yaklaşık 4 m bir girişi olduğu ve girişin her iki yanında fay yüzeylerinin açıkça izlenebildiği tespit edilmiştir. Bu çatlaklı sistemler kompleksin iç ve dış cephelerinde izlenebilmektedir. Ayrıca mağaranın yanındaki mağaralarda beşeri sebeplere bağlı bozulma ve tahribatlar yaşandığı görülmektedir. Mağaraların daha çok çobanlar tarafından kullanıldığı özellikle fırtınalı havalarda çokça faydalanıldığı tespit edilmiştir. Sahada doğal oluşumlu volkanik mağara olması açısından önem arz eden mağara kompleksi sahanın jeoturizm potansiyeli açısından bir bütünlük içerisinde değerlendirildiğinde, sahadaki diğer şekillerle birlikte jeosit potansiyeli yüksek bir alan olarak görülmektedir. Özellikle Çataltepe lav akıntısına çok yakın mesafede olması ve lav akıntıları üzerinde yer alıyor olması buranın eğitici ve öğretici niteliğini arttırmaktadır.

Anahtar Kelimeler: Volkanik Mağara, Jeoturizm, Suvermez, Nevşehir.

Abstract

Cave is generally defined as underground cavities large enough for a person to fit in, although different definitions have been made. Caves, which have been used for different purposes in the historical process, occupy an important place in human civilisation. In the region, caves appear as important living spaces used by people for centuries. Today, the importance of caves in the region is undeniable. Caves are utilised in important areas such as tourism, hotel

management and warehousing. It is also clear that today's caves are caves built with commercial concerns rather than natural caves in the region. On the other hand, considering that the area is characterised as Cappadocia Volcanic area, it should not be ignored that natural structures are also abundant. When the volcanic sites that can be considered as geological heritage are evaluated as a whole, they should be considered as parts of a whole in terms of geotourism activities. For this reason, each geomorphological shape in the field is important. Anınkaya cave complex, which is the subject of the article, was also considered as a part of this whole, and the geotourism potential of the caves was evaluated by making measurements and observations in the field. It was observed that the complex structure of Anınkaya cave is multidimensional. It was determined that the cave has an entrance of approximately 4 m and fault surfaces can be clearly observed on both sides of the entrance. These fractured systems can be observed on the interior and exterior facades of the complex. It is also observed that the caves next to the cave have suffered deterioration and destruction due to human causes.It was determined that the caves were mostly used by shepherds, especially in stormy weather.When the cave complex, which is important in terms of being a naturally formed volcanic cave in the area, is evaluated as a whole in terms of the geotourism potential of the area, it is seen as an area with high geosite potential together with other shapes in the area.Especially being very close to Çataltepe lava flow and being located on lava flows increases the educational and instructive quality of this place.

Key Words: Volcanic Cave, Geotourism, Suvermez, Nevşehir.

Giriş

Birçok kaynakta farklı tanımları bulunsa da mağaralar ile ilgili yapılan tanımlarda kabaca vurgu yapılan bir insanın sığabileceği büyüklük ve yer altı boşlukları tümceleridir. Nazik (2008) mağaraları; minimum bir insanın sürünerekte olsa sığabileceği farklı yükseklik ve genişlikte olabilen yeryüzüne açılan yeraltı boşlukları olarak tanımlamaktadır. İnsan medeniyetinin ilk çağlarında önemli yeri olan mağaralar zaman içerisinde farklı önemler atfedilen yerler olarak karşımıza çıkmış, kimi zaman korunma, kimi zaman saklanma, kimi zaman yaşamını devam ettirebilecek bir depolama alanı olarak karşımıza çıkmaktadır. Mağaralar tarihsel süreçten gelen adıyla Kapadokya denilen alanda her zaman önemli bir yapı olmuştur. Çünkü birçok mağara yapısı insanlar tarafından oyulmak suretiyle yaşam alanı, depolama alanı ya da benzer faaliyetler için önemli yerler olarak kullanılmıştır. Günümüzde de hala önemli depolama alanı ve turistik olarak önemli konaklama alanı olarak önemini korumaktadır. Bugün kullanılan mağaraların önemli bir kısmı tamamen ticari kaygılar ile inşaa edilmiş alanlardan oluşmaktadır. Ayrıca bu yerlerin doğallığı ise tartışmaya açık bir konudur. Doğal olarak kabul edilen mağaralar ise kendi içerisinde birincil ve ikincil mağaralar olarak sınıflandırılmakta, volkanik mağaralar ise birincil mağara sınıfında yer almaktadır (Romero, 2012). Jeolojik miras kabul edilebilecek alanlar önceleri koruma gelecek kuşaklara aktarma amacıyla önemli kabul edilirken sonraları daha geniş bir bakış açısı ile yaklaşılarak jeomiras olabilecek alanın bütün unsurlarıyla korunması gündeme gelmiştir (Günok, 2017). Jeoturizm faaliyetleri her ne kadar doğa severleri biraraya getirse de aynı zamanda kişilerin alan bilgisi ve ilgisi olması da gerekmektedir. Nihayetinde volkanik bir kompleks içerisinde yer alan birbirinden farklı

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şekilleri gören kişiler hazır bulunuşlukları ölçüsünde ilgi ve alaka duyacaklardır. Bu sebeple bu tur turizm etkinlikleri daha çok ilgilisine hitap etmektedir demek doğru olacaktır. Arkeologlar için çok farklı anlamlar içeren mağaralar; turistler açısından bir doğa deneyimleme aracı olarak görülmektedir. Bu manada görülmesi gereken yerlerden biri olarak düşünülmüş ve araştırılmıştır.

Araştırma Sahası Yeri ve Sınırları

Nevşehir ili Derinkuyu ilçesi sınırlarında bulunan Suvermez köyü yakınlarında yer alan mağara Alankaya Tepesi güney yamaçlarında bulunmaktadır. Uzaktan bakıldığında küçük bir volkanik kayalık görüntüsü veren bu yer kompleks bir mağara olarak adlandırılabilir. Birden fazla mağara yapısının bulunduğu alanın bazı kısımlarının insanlar tarafından oyulduğu düşünülmektedir. Araştırma alanı, İç Anadolu/Kapadokya Volkanik Bölgesi (KVB) olarak tanımlanan (Pasquare, 1968; Ercan, 1987; Toprak, 1998; Aydar vd., 1995; Türkecan vd., 2004, Aydar vd., 2012) bölgede yer almaktadır.

Yöntem

Araştırma sahasında yapılan arazi çalışmaları sırasında keşfedilen mağaranın, lazermetre yardımı ile ölçümleri yapılmış ve kaydedilmiştir. Aynı zamanda sahada iki farklı çobandan ve yöre halkından bilgi alınmıştır. Yakındaki Suvermez köyü halkı ile görüşülerek kültürel olarak mağaranın bir önemi olup olmadığı araştırılmıştır. Bu görüşmeler sırasında sahada başka mağaraların da varlığı keşfedilmiştir. Mağarada yapılan incelemeler ile yapının oluşum ve gelişim aşamaları yorumlanmıştır.

Bulgular

Mağara kompleksinin bulunduğu alanın jeolojik olarak andezitik kökenli enin ve boyuna bolca çatlaklı yapıya sahip bir anakayadan müteşekkil olduğu görülmektedir. Uzaktan bakıldığında mağara yapısından ziyade küçük bir kayalık alan gibi görünmektedir (Şekil). Yörenin iklimsel faktörlerine ve anakayanın özelliklerine bağlı olarak kompleks ve yakınında çok sayıda mikro şekil varlığı tespit edilmiştir.

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Şekil . Mağara kompleksinin uzaktan görünümü (Güneyden bakış).

Bu ve yörede buna benzer oluşumlardan meydana gelmiş mağaraların birçoğu baca olarak nitelendirilebilecek lav çıkış noktalarında meydana gelmiş olup mağaraların duvar ve taban seviyelerinde görülen cüruflar bunu kanıtlar niteliktedir (İmamoğlu, 2020). Mağara yapısının gelişim aşamalarında çokça etkili olduğu düşünülen çatlaklı yapılarda yöresel bir fayın parçası olabilecek nitelikte fay kırıkları şeklinde karşımıza çıkmaktadır. Kompleks yapı üzerinde farklı kırıkların birbirini kestiği gözlemlenmiş, Anınkaya mağarasının giriş kısmında ise fayların kırık yüzeyleri ölçülmek suretiyle kaydedilmiştir.

Burada yer alan mağaraların en büyüğü Suvermez köyü halkı tarafından Anınkaya mağarası olarak adlandırılmıştır. Fırtınalı havalarda koyunlar için ağıl görevi gören mağara, çobanlar tarafından sık sık kullanılmaktadır. Mağaralar içerisinde zeminde görülen gevşek malzemeler ise altın arama ya da başka sebeplerle mağara içlerinde kazı yapıldığını düşünmemize sebep olmaktadır. Diğer mağaralar ise içinde bir sütun şekli görülen sütunlu mağara, kayalığın sağ kesiminde kalan içinde düzgün şekilde yontulmuş bir oturma yeri bulunan oturaklı mağara ve kayalık kütlenin hemen yanındaki lav akış alanı içerisinde meydana gelmiş içerisindeki kırmızı cüruflar sebebiyle adlandırdığımız kızıl mağaradır. Kompleks yapı içerisinde birkaç adet kovuk olarak nitelendirilebilecek küçük yapı da bulunmaktadır.

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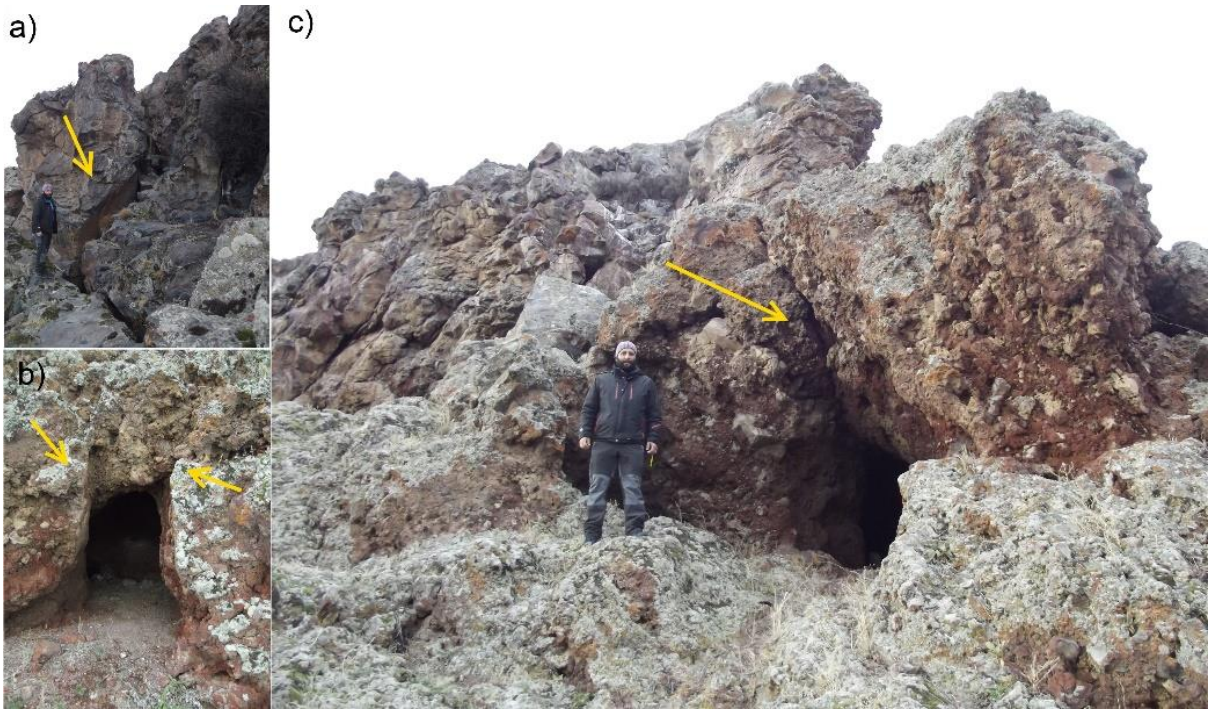

Şekil . a) Mağara kompleksinin cephesinde görülen çatlaklar b) Oturaklı mağara girişinde birbirini kesen çatlaklı yapılar. c) Sütunlu mağara giriş kısmında izlenen çatlak sistemi (İmamoğlu, 2020).

Anınkaya Mağarası

Mağara yaklaşık 4 m bir ana girişe sahip olup girişin her iki yanında 30 cm genişlikteki kırık yüzeyleri izlenebilmektedir. Bu kırık yüzeylere bağlı olarak gelişim gösterdiği düşünülen mağaranın cephesinde de aynı çatlaklı yapılar devam etmektedir. Yaklaşık 7 m genişliğinde ana salonu bulunan mağara giderek en ve boy olarak küçülmektedir. Ana salondan daralan bir tünele doğru devam eden mağarada tavanda bir daralma sonrasında tekrar bir genişleme mevcuttur. Sonrasında yukarı doğru devam ederek küçülen yaklaşık 8 m'lik bir tünel daha mevcuttur. Yukarı doğru devam ederek küçülen kısımda fazlaca gevşek malzeme bulunmaktadır. Bu malzeme antropojenik olarak görülebileceği gibi mağaranın sonlarında bulunan yüzeye yakın alandan çatlaklara bağlı gelen sular sebebiyle de olabileceği düşünülmektedir.

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Şekil . Anınkaya Mağarası Girişi.

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Şekil . Mağaranın cephesinde görülen çatlak sisteminin bir parçası.

Araştırma Sahasının Jeoturizm Potansiyeli

Araştırma alanı dünyaca önemli bir yerin çok yakınında olması ve etrafında çok sayıda volkanik farklı şekillerin yer alması sebebiyle yüksek önem arz etmektedir. Başta Göreme milli parkı olmak üzere daha yakınında bulunan Derinkuyu yeraltı şehir ya da daha yakınında bulunan Çataltepe lav konisi ve lav akıntısı ya da mağaranın bulunduğu sahadaki lav akıntıları ile bir arada düşünüldüğünde volkanik kompleks sayılan bir alanın içerisinde önemli bir unsur olarak yer almaktadır. Mağaranın volkanik yapılı olması aynı zamanda halk tarafından panayır yeri olarak kullanılan bir yerde bulunması yine sahadaki çobanlar tarafından zaman zaman korunma barınma gibi amaçlarla kullanılıyor olması mağaranın turistik değeri olan yapılar arasında bir istasyon olarak yerini almasını sağlamaktadır. Yakın çevresinde bulunan başka mağaralar olsa da Anınkaya mağarası en bilinen ve yeri gelip kullanılan mağara olması açısından tektir.

Sonuç ve Öneriler

Araştırmaya konu olan Anınkaya mağarası hemen yanındaki diğer mağaralar ile birlikte değerlendirildiğinde kompleks bir yapı olarak karşımıza çıkmaktadır. Daha çok çobanlar tarafından koyunlarla birlikte fırtınalı havaları geçirmek için kullanılan mağaralar doğal volkanik mağara olması açısından önemlidir. Mağara sistemi bir fay yapısı istikametinde gelişme göstermiş kompelksin hem içinde hem cephesinde kırıklı yapıların izleri gözlemlenmiştir. Bu açıdan mağara sistemlerinin oluşumda faylı yapılar ve fay yüzeyinin

gözlemlenebilmesi eğitim açısından önemlidir. Yine mağaraların çeşitli yerlerinde beşeri sebeplere bağlı oluşmuş şekiller olduğu hatta mağaranın birinde yatak şeklinde bir alanın oyularak düzleştirildiği görülmüştür. Bütün bunlar mağaranın görülmeye değer bir alan olmasını sağlamaktadır. Jeoturizm kavramı artan turizm çeşitliliği içerisinde giderek daha fazla önem kazanan bir turizm şeklidir. Burada ziyaretçilerin görme keşfetme isteğinin yanında öğrenme ve anlama gibi istekleri de olması jeoturizmin artan önemini açıklamak açısından önemli bir göstergedir. Araştırma sahası ve yakın çevresinde yürütülen çalışmalar sırasında bölgenin önemli volkanik alan olduğu görülmüştür. İçinde yer aldığı Kapadokya volkanik kompleksinin önemli birçok unsuru birarada barındırması buradaki her bir doğal oluşum ve şekli önemli kılmaktadır. Sahada doğal oluşumlu volkanik mağara olması açısından önem arz eden mağara kompleksi sahanın jeoturizm potansiyeli açısından bir bütünlük içerisinde değerlendirildiğinde, sahadaki diğer şekillerle birlikte jeosit potansiyeli yüksek bir alan olarak görülmektedir.

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ECONOMETRIC ANALYSIS OF EDUCATIONAL EXPENDITURES IN TURKEY

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ABSTRACT

A direct relation exists between educational expenditures and the amount and quality of education. From this point of view, the determination of the factors affecting educational expenditures of households carries much significance. In this research, the factors affecting the educational expenditures of households in Turkey were attempted to be ascertained. In this way, it is aimed to produce policy recommendations through the factors affecting education expenditures.

The data obtained by the household budget surveys conducted on 11000 households by Turkish Statistical Institute (TSI) in 2017 were utilized. Household Budget Surveys are one of the most important resources used to test the validity of the socio-economic policies implemented, giving information about the socio-economic structures, living levels and consumption patterns of the households. The data were analyzed with Log-Heckman's Sample Selection Model (SSM).

According to the obtained results, the monthly average educational expenditures of household were determined to be 55.03 TRY. The factors such as the household head's age, position in the workplace, condition of being retired, existence of an enterprise income, family's reception of financial aid, the habited house being rental, the heating of the house by a central heating boiler of a stove, presence of internet connection, the family having multiple children, different age groups of the children, car ownership, monthly total expenditure amount of the household and the monthly income level were determined to be statistically affecting the possibility of educational expense.

The research contributes to the literature in terms of researching education expenditures, which is one of the important indicators of the value given to education today. In addition, the use of the Log-Heckman's Sample Selection Model (SSM) method within the scope of education expenditures reveals the originality of the research.

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In the research, it has been determined that families with high living standards attach more importance to education. For this reason, every policy implemented to raise the living standards of the society will lead the society to give more importance to education.

Keywords: Log-Heckman's SSM, educational expenditure, household, Turkey

INTRODUCTION

Education is an irrecusable and an indispensable process which ensures the development of individuals along with the society, directs and support economic growth and provides that the cultural values are preserved, improved and are passed on to the next generations (Karaarslan, 2005). Education is a system that trains manpower with power of scientific thinking and professional qualifications in line with the interest and abilities of the individuals (Tuzcu, 2006). On the other hand, education is the set of all societal processes in which individuals improve their talents, attitudes and behaviors of positive value within the society they live in (Tezcan, 1985). Along with the benefits education provides the individual, it also has a multiple of significant impacts in terms of social and political aspects during the process of community development. An education provided with the approaches grounded on the principle of lifelong learning influences the development level of societies. Besides, education is known to provide many benefits such as a healthy life, reduction of poverty and unemployment, democratization, environmental consciousness and decrease of crime rate (Türkmen, 2002). Education carries more significance especially for countries less developed during the development period, ever-developing and failed to complete economic development intensely striving to enhance social welfare (Demir, 2006).

Each and every parent makes efforts in order to offer a better future to their children. One of these efforts, and the most essential, is to provide them to be educated in the best schools, grow up adorned with the newest information and abilities and to have a popular profession. As well as the advancing technology of our day and the increase of mass communication tools ease the access to information, they also bring along negativities such as the false, non-objective and deficient information which we call information pollution. To access educational materials containing reliable and beneficial information requires the research, recruitment and purchasing of these educational materials. In the circumstances, a better education becomes necessary for a better future. A better education predicts more educational expenditures. A positive correlation is present between educational expenses and the quality and quantity of education. Thus, in light of this idea, detection of educational expenditures of households and the factors

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that affect this quantity carries much significance in discovering the characteristics of households giving importance to education. The purposes of the policies implemented by the governments is to provide the economic, social and psychological advancement and development of individuals forming the society. Knowledge of the features of households giving importance to education and the formation and augmentation of households internalizing these characteristics will serve the aims of the governments.

The educational expenditures of households cover school fees, allowance, book, stationery, transportation and school expenses along with taxes paid for education. The payments made in the name of educational services, are also evaluated as investment expenditures as they are once again considered as tools for the distribution of income and due to their active role in ensuring economic growth, development and economic stability (Ortaç, 2003). If the current value of benefits granted by education are greater than the current value of costs individual brings in positive income from this investment (Thurow, 1970).

Educational taxes and payments made for the fees of other public schools are generally afforded by the governments in developed countries. This is the reason behind why food, accommodation, transportation, uniform, health and intelligence-wise stimulative educational materials are included in the educational investments in most of the studies conducted in the United States on the education of children. In a research done in 1992, the annual educational expenditure of families is found to be 7579 dollars per child (Haveman & Wolfe, 1995). A few studies examining the factors affecting the educational expenditures of families were encountered. In these studies, the investment variables of the working families are primarily; the income of the family, educational level and family structure (Kane, 1994; Haveman & Wolfe, 1995; Mauldin et al., 2001). Contrastingly, the social education expenditures in the United States have drawn the attentions of the researchers more. Numerous studies were executed on the policies regarding yield of tax reduction to education in public schools, financial aids, deductions in fees and other prices and helping families to make payments to send their children to high school (Kane, 1995; Dynarski, 2003; Kane, 2004; Rivard & Raymond, 2004; Deming & Dynarski, 2010).

In this study, we have aimed to determine the factors affecting the educational expenditures of households. Thereby, this study is supposed to bring light to policy makers in order for the determination of features of households giving importance to education and the formation of households of the same values.

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MATERIAL AND METHOD

Data and Model

Data of the research were obtained from the original data of the household budget expenditures survey conducted by TSI in 2017. The results of the survey done on 11000 households between the time periods 1 January-31 December 2017 were utilized.

In econometric studies, sample selection problems are frequently encountered in models such as price and consumption equations; in such cases two-phased method recommended by Heckman (1976), Heckman (1979) can be used (Puhani, 2000). In this model, the dependent variable is one that cannot be observed and includes lost observations (Arvas & Özen, 2018). In case of lost observations, smallest square predictions do not become active (Heckman, 1979). The method followed contains a two-phased process. In the first step, the probit-like equation indicating the condition of consuming or not is estimated and in the second step the amount equation showing the consumption amount is predicted (Bushway et al., 2007).

Model could be written as below (Puhani., 2000; s:54):

$$y_{1i}^{*} = x_{1i}'\beta_1 + u_{1i} \quad (1a)$$

$$y_{2i}^{*} = x_{2i}'\beta_2 + u_{2i} \quad (1b)$$

$$if\ y_{2i}^{*} > 0\ ise\ y_{1i}^{*} = y_{1i}^{*} \quad (1c)$$

$$if\ y_{2i}^{*} \leq 0\ ise\ y_{1i}^{*} = 0 \quad (1d)$$

The equation (1b) is a probit-type equation showing the condition of preferring or not. And while they are unobservable variables, it is an observable variable and consists of independent variable sets. The first equation is the selection equation and the second is the educational expenditure amount equation. They are correlational among each other and they are multiple normally distributed. Here it is: $(u_{1i}, u_{2i}) \square N(0, \Sigma), \Sigma = \begin{bmatrix} 1 & \sigma_{12} \\ \sigma_{12} & \sigma^2 \end{bmatrix}$ and it indicates the common variance and educational expenditure amount variance between the selection and educational expenditure amount equations in the order of σ_{12} and σ^2.The highest feasibility function containing the relation between the selection equation and educational expenditure amount together is shown as follows:

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$$L=\prod_{d_i=0}\left\{1-\Phi\left(z_i'\alpha\right)\right\}\prod_{d_i=1}\left\{\frac{1}{\sigma}\phi\left(\frac{y_i-x_i'\beta}{\sigma}\right)\Phi\left(\frac{z_i'\alpha+\frac{\rho}{\sigma}\left(y_i-x_i'\beta\right)}{\left(1-\rho^2\right)^{1/2}}\right)^{-1}\right\} \quad (1e)$$

Here, it reflects the single-variable cumulative normal distribution and expresses the correlational coefficients between the residuals of selection equation and the expenditure amount. Similarly, as the parameters in the selection and expenditure amount equations are not linear, the unit effects of the independent variables are obtained by taking their derivatives according to the independent variables after the determination of probability and conditional and non-conditional expenditure levels. Expenditure probability and the equation of conditional and non-conditional expenditure amount can be consumed respectively as below:

$$\Pr\left(d_i=1\right)=\Phi\left(z_i'\alpha\right)$$

$$E\left(y_{1i}^{*}\mid y_{2i}^{*}=1\right)=x_i'\beta+\rho\sigma\frac{\phi\left(z_i'\alpha\right)}{\Phi\left(z_i'\alpha\right)} \quad (1f)$$

$$E\left(y_{1i}^{*}\right)=\Phi\left(z_i'\alpha\right)x_i'\beta+\rho\sigma\phi\left(z_i'\alpha\right)$$

The effects of independent variables in each of the equations above are obtained by taking the derivative of the equation according to the independent variable. Besides, the standard deviations of the unit effects of independent variables are predicted using the delta method.

Another important feature can be put forth with the help of ordinary classical tests in which the correlation coefficients in the models of Double Impediment Censore and Heckman Sample Selection above are different than or not 0. In addition to this, model inferiority is put forth with the help of Vuong-z test in terms of the data between the Double Impediment Censore and Heckman Sample Selection Models.

RESULTS AND DISCUSSION

Deterministic statistics of households in Turkey

Statistics belonging to the variables used are given in Table 1. According to these statistics, the average educational expenditure amount, which is our dependent variable, was determined to be 55.03 TRY/per month and 22.60% of the sample magnitude constituting of 1100 families do

monthly expenditure while 77.40% do not do educational expenditure. The monthly educational expenditure amounts in 2003 and 2009 were calculated as 26.5 TRY and 35.75 TRY respectively using the data obtained from Sülkü & Abdioğlu (2014)'s TSI household budget survey. With the help of this research, it is noticed that the household educational expenditures have increased. According to the TSI (2017) data, educational expenditures, among consumption expenses, are recognized to proceed incrementally in terms of amount compared to the previous years. The results obtained with our study supports this expectation.

In Table 1, the average 0-5 years old children number of families is determined as 0.31, 6-14 years old as 0.55, 15-18 years old as 0.21 and 19 or above children number is calculated to be 2.47. The average family population is calculated to be 3.54 people.

The average year of household heads' education among the houses examined was determined to be 7,41 years. The average household home features index is calculated as 7.27 and the number of features as 1.03.

Considering the intermittent variables, 86.1% of the household heads were noticed to be male, the ratio of them under the age 30 was determined as 7.6%, between the ages 30-50 as 44.9% and 50 or above as 47.5%.

The ratio of household heads not in hold of any diploma is 12.9% and 44.3% has primary school, 11.9% middle school and 16.4% have secondary school diploma. The ratio of university graduates is 14.5%. 84.2% of the household heads own a compulsory health insurance and 83.2% are determined to be married. According to the study conducted by Urak (2016), 10.2% of the household heads were middle school, 17% were high school and 15.6% was vocational school or university graduates in 2014. Thus, the findings obtained show parallelism.

66.4% of the household heads were employees, 4.8% were in an administrative position in business life and 32.5% were retired. The section that earns an income by making use of the household heads' savings constitute the 33.9% of the houses. 30.6% of the houses receive cash aid from the government and 10.5% receive in-kind aid. 13% of the houses receive dole and 9.6% receive private in-kind aid. Among the houses examined, 2.4% were noticed to receive income from a foreign country.

49.5% of the families sit in an apartment, 22.8% in a rental house and 63.5% sit in their own house. 32% of the families live in a house heated by a central heating boiler, 54.7% in a house heated by a stove. Internet connection exists in the 34.9% of the houses.

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Prediction of the econometric model's outcomes and marginal effects

In order to determine the factors affecting the household educational expenditures analyses were performed using the Heckman SSM, Log-Heckman's SSM and Double-hurdle models in the study, the zero hypothesis asserting that the correlation coefficients of the model were zero is declined on the level of a high statistical reliability (Wald statistical value for Heckman model =303.62, Wild statistical value for Log-Heckman model =721.42 and Wald statistical value for Double-hurdle model = 589.35). The results of this test are presented in Table 2. Therefore, every equation must be predicted simultaneously and a linear relation is present between the probability and expenditure level residuals in every model. By this means, in case where each equation is predicted in two phases, the parameters assumed would be deviated and not effective. In this study in which the factors affecting the household educational expenditures in Turkey were analyzed, Log-Heckman's SSM was discovered to have better explanatory characteristics in terms of statistics compared to the Heckman's SSM, Log-Heckman's SSM and Double-hurdle Models used in the study.

In Table 2, all three models were compared with the help of Young test and the statistical superiority of Log-Heckman's SSM was demonstrated. Thus, the factors affecting the household educational expenditures were discussed according to Log-Heckman's SSM.

Estimated parameters of the Log-Heckman's SSM model used in the study are presented in Table 2. Although most of the parameter indicators coincided with the economic theories, as the magnitude of parameters did not reflect the unit effects on the probability, conditional and unconditional expenditure amounts of the independent variables, these unit effects were calculated separately.

In Log-Heckman's SSM constant, gender, families in which the family head has an age between 30-50, the family head is an employee, the family head has a compulsory health insurance, the family head is retired, receiving governmental in-kind aid, receiving private in-kind and private financial aid, heating with stove, using internet, with a single child, with 2 children, with 3 or more children, the family head is a primary, middle, secondary or a tertiary school graduate and the total monthly expenses variables were found to be statistically significant. The indicators of these variables determined to have results as expected.

The correlation coefficient between the two residuals in Log-Heckman's SSM indicates the presence of a negative relation between the residuals of the probability and the educational expenditure level residuals. Thus, in case of a variance in an out-of-system factor or one in

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which we cannot control or in a factor set, it is indicated that as probabilities of educational expenditures increase (decrease) the level of educational expenditures decreases (increases).

Log-Heckman's SSM outcomes are reflected in Table 3. According to this, households in which their heads are males, expend on education on a ratio of approximately 4.17% compared to those in which the heads are females while expending 7.26 TRY less on education among the whole population (unconditional expenditure level). Those with a household head in the age group between 30-50 have the probability to expend 3.05% more on education compared to the reference group, those belonging to the group that expend (conditional expenditure) 71.06 TRY/month more, those belonging to the whole population spend 16.41 TRY/month more. For household with a head above the age 50, the expenditure amount in the group that spend on education is discovered to be 52.94 TRY/month more compared to the reference group.

Households with a laboring head are discovered to have the possibility of expending approximately 3.00% more on education. The expenditure amount in the group that invests in education of houses in which their head is on an administrator position in business life is 52.08 TRY and the expenditure amount in the whole population is approximately 10.72 TRY more.

The families of household heads having a compulsory health insurance, are intended expend 6.79% more on education compared to families of household heads without insurance and are at the level of 8.18 TRY/month more unconditional expenditure. Families with retired households are at the intention of expending 2.44% less on education compared to the other households.

According to Table 3, while the conditional expense level of families that make income by making use of their savings (entrepreneur income) is 30.62 TRY greater than those families without an entrepreneur income, it is 5.69 TRY greater in the whole population. While the households receiving governmental in-kind aid have the intention to expend 3.82% less on education compared to those who do not, the households receiving private financial aid have the intention to expend 4.22% more on education compared to those who do not and possess the level of approximately 6.00 TRY more unconditional expense.

Households living in an apartment flat have the intention to expend 3.24% less on education and have the level of expending 4.53 TRY less among the whole population. Households heated with a stove intend to expend 2.42% less on education and have the level of 5.14 TRY less unconditional expenditure.

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Households having internet connection at home have the possibility to expend 6.48% more on education compared to those households who do not and have 9.72 TRY more of expenditure amount compared to the households who do not have internet connection at the level of unconditional expenditure constitution of the whole population.

Households with a single child are intended to expend 10.65% more on education compared to the other types of households, conditional group that spend money on education have a 16.68 TRY greater expenditure level, and the expenditure level in the whole population is determined to be 17.01 TRY greater.

It was observed that households with 2 children expend 14.70% more on education compared to the other types of households, the conditional group that spend money on education is detected to have a 17.63 TRY greater expenditure level and the expenditure level was determined to be 22.64 TRY greater in the whole population.

Households with 3 or more children, were stated to have the potential to expend 10.06% more on education compared to the other types of households and the level of unconditional expenditure of the whole population is observed to be 12.68 TRY greater compared to the other types of households.

Scoring the qualifications possessed in terms of house properties (Bath, sauna, Jacuzzi, toilet, kitchen, trash shredder, heater, floor heating, mains water system, natural gas, hot water, cable TV, elevator, garage, generator, security system, balcony, garden and children's playground) from1 to 30, households with increasing house properties that come near to 30 points are determined to have the intention of expending 7.5 TRY more on education in the conditional group compared to the other households and 1.76 TRY more in the whole population.

While the households owning a car compared to the households who do not, conditional group that expends on education have the intention of spending 12.8 TRY less, this intention is 3.79% less in the whole population.

Households with a primary school graduate head have the possibility to expend 3.15% more on education compared to those in which the head does not hold any diploma and the conditional group expending on education is on the level of spending 16.02 TRY more. It is determined to have the expenditure level of 6.68 TRY more in the whole population.

Households with middle school graduate heads were seen to have the possibility of expending 5.59% more on education compared to those in which the head does not hold any diploma and the conditional group expending on education is determined to be intended to spend 23.46 TRY

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more. The unconditional group is discovered to have the intention of spending 10.50 TRY more in the whole population.

Households with secondary school graduate heads are intended to expend 9.22% more on education compared to those in which the head does not hold any diploma, the conditional group spending money on education is identified to have the intention of spending 47.48 TRY more and 22.58 TRY more in the whole population.

Households with university graduate heads were detected to have the possibility to spend 13.48% more on education compared to those in which the head does not hold any diploma, the conditional group spending money on education is detected to spend 70.31 TRY more and the unconditional group intended to spend 35.80 TRY more on education in the whole population.

As the household heads' education level advances, the educational expenditure also increases. Within the studies executed in Turkey, United States, Korea and China, an increase in the general educational expenditure for the child is noted as the household heads' education level advances (Huston, 1995; Chung & Choe 2001; Mauldin et al., 2001; Tomul 2008). It is observed that this detection indicates parallelism with our result.

Families with children of age group 0-5 have the possibility of expending 2.7% less on education compared to other households and while the conditional group spending money on education has the intention to expend 13.73 TRY less the unconditional group in the whole population have the intention of expending 5.67 TRY less.

Families with children of age group 6-14 have the possibility of expending 2.98% less on education compared to other households and while the conditional group spending money on education has the intention to expend 15.17 TRY more the unconditional group in the whole population have the intention of expending 6.27 TRY more.

Families with children of age group 15-18 have the possibility of expending 6.45% less on education compared to other households and while the conditional group spending money on education has the intention to expend 32.83 TRY more the unconditional group in the whole population have the intention of expending 13.56 TRY less.

Families with an adult of age 19 or above have the possibility of expending 5% less on education compared to other households and while the conditional group spending money on education has the intention to expend 25.43 TRY more the unconditional group in the whole population have the intention of expend 10.05 TRY less expenditure.

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Along with the educational expenditure ratio of households among the total of expenses being 2.86% more, the conditional group spending money on education have the intention to expend 14.56 TRY more while the amount of the intention for the unconditional group in the whole population is detected to be 6.01 TRY more.

As the years of education of the household head increases it is determined as 1.97 TRY more for the conditional group spending money on education compared to the other households and 0.34 TRY more in the whole population. Chi & Qian (2016), as the number of individuals in the household increases the condition of educational expenditure is determined to be 15.24 TRY less in the conditional group compared to the other households and 2.64 TRY less for the unconditional group in the whole population.

While houses with a household income of 5000 TRY or above have the intention to expend 57.42 TRY more on education in the conditional group compared to the other households, the intention to spend money on education was determined to be 9.93 TRY more for the unconditional group in the whole population. Lazear & Michael (1988), in a study he conducted, detected a positive relation between the income level of the family and number of children and the educational expenditures.

CONCLUSION

In the study, houses with a head between the ages 30-50 were determined to expend more on education. Houses in which their head is in this group of age expend 71.06 TRY on education while for the houses with a head of age 50 or above the monthly educational expenditure amount is 52.94 TRY more. Furthermore, houses with a retired head are intended to expend 2.44% less on education compared to the others. The expenditures of the houses with a 50 or above years old or retired heads decrease as the individuals to invest educational expenses decrease compared to households with a younger household head. In other words, because of the reason that most children of these houses have completed the age of needing educational expenditure, it is possible to state that the total educational expenditure is less. Therefore, policies encouraging individuals in houses with a 50 and above years old or a retired head must be generated to have them actively contribute to the educational life.

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Gender of the household head also influences the educational expenditure. Houses with a female household head have the intention to expend more on education. However, houses with a male household head have probability to spend approximately 4.17% less compared to houses with a female head. Education, is the most crucial element that makes women stronger especially in the society. Women acting with this awareness, intent to expend more on education. At this point, generating policies that positively influence the perspectives of houses with a male head carries much significance.

Households living in an apartment flat are determined to have the intention of expending 3.24% less on education compared to the other households. Households heating with stove are detected to have the intention of expending 2.42% less on education compared to the others. When the qualifications owned in terms of house features (Bath, sauna, Jacuzzi, toilet, kitchen, trash shredder, heater, floor heating, mains water system, natural gas, hot water, cable TV, elevator, garage, generator, security system, balcony, garden and children's playground) are scored from 1 to 30, houses nearing 30 points as the house features advance, conditional group is intended to expend 7.5 TRY more on education compared to the other houses. Yet, this situation means that families with higher life standards give importance to education. Therefore, every policy applied with the purpose of advancing the life standards of the society, will direct the society to give more importance to education.

The intention of educational expenditure of households with an internet connection at home increases. Families with an internet connection at home are determined to have the possibility of expending 6.48% more on education compared to others who do not. As internet forms the base of the modern world's information source, it is a tool in education and households that have an internet connection at home expend more on education than those who do not putting forth the importance given to education. In this regard, awareness towards the internet which is a part of education, and encouragement for families to have internet connection or free access must be provided. Nowadays, considering the level electronic commerce has come, it is possible to see to what extent internet is effective in shaping individuals' shopping and consumption habits. Thus, it is possible to comment similarly on the degree that the internet will affect the educational expenditures. Yet, as the materials in the educational expenditure items such as books' stationery, online courses etc. can be accessed through the advertisements on the internet, it is highly crucial to give the necessary support and encouragement to providers of advertisements and services.

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As the household heads' educational status increases with the condition of holding a primary school or a university diploma, the educational expenditure amount is detected to indicate an advancement. For the conditional group, the monthly educational expenditure of families with a primary school graduate head is 16.02 TRY; families with a middle school graduate is 23.46 TRY; families with a high school graduate is 47.48 TRY; families with a university graduate is 70.31 TRY. As the educational status of the household head increases, the importance given to education also increases. Actions bettering the educational concept of households with a head of a low educational status are required to be taken by decision and policy makers.

Families with a children of age group between 15 and 18 expend more on education compared to the other families. While the monthly educational expenditure of families with a child of age group 0-5 is 13.73 TRY, it is 15.17 TRY for families with a child of age group 6-14, 32.93 TRY for families with a child of age group 15-18 and it is 25.43 TRY for families with an adult of age 19 or above. In Turkey, 15-18 age group students belong to the secondary education step. Thus, as this period covers mostly the preparation for university, educational expenditures are expected to demonstrate an increase. Therefore, the educational expenditures in Turkey increase during the pre-university term and occur for the purpose of having their children enter university. Through supports provided by the government to students entering universities and other (scholarship or loans with the condition of repayment after graduation) aids and the university fees not being high, students in university do not cause much cost to their families.

The job position of the household head influences the educational expenditures. Families with a head on an administrative position in business life are determined to expend 52.08 TRY more on education compared to other families. In the Turkey of our day, educational activities for employees are gaining much importance by the administrators. Looking from this point of view, the educational awareness levels of individuals on an administrative position is high. This awareness explains the educational expenditures of families with an administrator household head being high.

Families who have a laboring head, have the possibility to expend more on education compared to those families who do not. Indeed, houses with a laboring head are observed to have the intention to expend 3% more on education compared to those houses with a non-laboring head. The income of the household head also influences the educational spending. Families in which their head has an income above 5000 TRY is detected to have the intention of expending 57.42 TRY more on education. Additionally, the income of families obtained through saving also influences the educational expenditure. Families earning an income by making use of their

savings are determined to spend 30.62 TRY more on education compared to those families who do not. As the part of educational expenditure for families belonging to the low income group is high in the household's income, the consideration of the families' income levels in determination of the public support provided to students carries much significance. This situation must also be handled on a regional basis and support must be provided according to regional differences.

With reference from the findings and results of this study, micro and macro criticism studies must be performed for the educational expenditure of households especially for Turkey. As the sociodemographic and economic characteristics of households are affected, separate policies must be produced considering these factors.

Considering the educational expenditure intentions of households on average, they are observed to have a small pay in total expenditure. This situation being the result of the special benefits of educational services occurring on long term, educational awareness must be created and there must be contributions made to the raising of awareness of the society on the individual returns of education and necessary actions must be taken for encouragement.

With the purpose of ensuring the societal function of education and social justice in education, more funding for educational expenditures must be separated within public expenditures and opportunity and facility equalities must be provided with regulations regarding families that do not spend money on education. By executing researches that put forth the socio-economic features of students, scholarship application varieties must be expanded for children of families with no opportunity and that are on a low-income level.

Opportunity and facility equalities must be ensured for the suppliance of sources and accessibility in education. In order for this to happen, an organization in the budget must be performed so that a step is taken in enhancing the quality of education.

A special unit must be formed in order to ensure the opportunity and facility equalities only in education, researches on the socio-economic characteristics of families must be executed and qualified education and necessary materials must be ensured that they are provided to each and every student in the houses.

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Table 3. Log-Heckman SSM both with maximum likelihood estimates (MLE) and marginal impact parameters

Variable	Definition	Mean (Std. Dev.)	VIF
Deperndent variables			
Y	Expenses for education per month (TRY)	55.032 (216.992)	-
Dummy	Expenses for education per month if (₺) > 0 = 1, otherwise = 0	0.226 (0.418)	-
Indipended variables			
Continious explanatory variables			
Children 0-5	Number of kids aged 0-5	0.310 (0.633)	-
Children 6-14	Number of kids aged	0.552 (0.907)	-
Children 15-18	Number of kids aged 15-18	0.208 (0.474)	-
Adult 19 +	Number of adults aged over 18 years	2.468 (1.087)	-
House size	House size	3.538 (1.899)	1.766
Education	Education in years	7.412 (4.833)	1.938
House feature index	An index created by house characteristics (Bathroom, sauna, Jacuzzi, toilet, kitchen, trash shredder, heater, floor heating, piped water system, natural gas, hot water, cable TV, elevator, garage, generator, security system, balcony, garden and children's playground)	7.272(2.250)	2.502
Number of properties	Number of properties owned (number of self-contained houses, number of apartments, a number of summer houses, shop, etc.)	1.033 (1.165)	-
Binary explanatory variables: Household head and household characteristics			
Male	Gender is male	0.861 (0.346)	2.224
Age 30-50	30< Age ≤50	0.076 (0.265)	4.210
Age > 50	Age > 50	0.449 (0.497)	5.402
Age <= 30	Reference group for age	0.475 (0.499)	-
No diploma	The reference group for education	0.129 (0.335)	-
Primary school	Primary school education	0.443 (0.497)	-
Secondary school	Secondary school education	0.119 (0.324)	-
High school	High school education	0.164 (0.370)	-
College school	College school	0.145 (0.352)	-
Compulsory insurance	Has compulsory health insurance	0.842 (0.365)	1.520
Married	Married	0.832 (0.374)	2.296
Employed	Employed	0.664 (0.472)	1.937
Manager	Manager	0.048 (0.213)	1.111
Retired	Retired	0.325 (0.468)	2.072
Entrepreneurial income	Families with entrepreneurial income	0.339 (0.473)	1.443
State cash aids	Receives cash income from government	0.306 (0.461)	1.488

State in-kind aids	Receives in-kind type help income from the state	0.105 (0.306)	1.310
Alimony aids	Receives alimony, scholarship, cash income help from private persons and intuitions	0.130 (0.336)	1.188
Private in-kind aids	Receives in-kind type income help from private persons and intuitions	0.096 (0.294)	1.173
Foreign income	Has abroad retired, scholarship, or in-kind aid	0.024 (0.152)	1.034
Apartment	Resides in an apartment	0.495 (0.500)	2.113
Renter	Resides in a rented house	0.228 (0.420)	2.194
Homeowner	Resides in own house	0.635 (0.481)	2.244
Combi	Resides in a house warmed up with a combi boiler	0.320 (0.466)	2.427
Stove	Resides in a house warmed up with a stove	0.547 (0.498)	3.742
Internet	Has home internet access	0.349 (0.477)	1.455
One child	A family with only one child	0.195 (0396)	1.347
Two children	A family with only two children	0.193 (0.395)	1.518
Three and more children	Family with more than two children	0.136 (0.343)	1.598
Vehicle	Family with a vehicle	0.449 (0.497)	1.272
Income ≤ 2000 TRY	Monthly income ≤ 2000 TRY	0.377 (0.483)	1.736
Income 2000 – 5000 TRY	Monthly income 2000 – 5000 TRY	0.489 (0.500)	2.040
Income >= 5000 TRY	Reference group for income	0.135 (0.339)	-

Table 2. Some specification tests comparing independence and used models

Specification tests	**Test-statistic**
Independence	
Heckman SS model	Wald: 303.6158, df =1, p<0.0001
Log-Heckman SS model	Wald: 721.4217, df =1, p<0.0001
Double-hurdle model	Wald: 589.351, df =1, p<0.0001
Vuong's non-nested test	
Heckman SS model versus Double-hurdle model	z-test:39.4691, p<0.0001
Heckman SS model versus Log-Heckman SS model	z-test: -16.2475, p<0.0001
Log-Heckman SS model versus Double-hurdle model	z-test: -30.0218, p<0.0001

Note: The null hypothesis under Vuong's test for non-nested models is that the expected value of competing for log-likelihood ratios equals zero, indicating the competing pair models are equally away from the data being modeled. Under this test, if z > 1.96 the first listed model is preferred, while if z < -1.96 the second listed model is chosen. However, if |z| < 1.96 then no decision is made between the competing pairs.

Variables	MLE Estimates	Marginal Effects

	Probability		Level		Probability		Conditional		Unconditional	
	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Constant	-24.055***	-171.163	59.988***	17.583	-	-	-	-	-	-
Male	-0.1547**	-23.784	0.0787	0.6133	-4.165**	2.271	-10.741	0.779	-7.269**	2.003
Age 30-50	0.1185*	19.051	0.4323***	34.969	3.049*	1.892	71.061***	4.721	16.408***	4.466
Age > 50	-0.1024	-14.594	0.535***	38.546	-2.613	1.466	52.938***	3.391	5.838	1.638
Married	-0.0482	-0.7549	0.0757	0.5846	-1.251	0.744	2.963	0.22	-0.99	0.308
Employed	0.1194***	26.853	-0.2431***	-28.931	2.997***	2.739	-14.393	1.518	1.311	0.602
Manager	0.0388	0.5879	0.3192***	32.174	1.009	0.578	52.081***	3.354	10.719**	2.328
Compulsory insurance	0.3015***	5.739	-0.3451***	-3.256	6.965***	6.443	-2.537	0.221	8.177***	4.016
Retired	-0.0969**	-21.055	0.1203	14.251	-2.44**	2.139	2.060	0.229	-2.639	1.239
Entrepreneurial income	0.0117	0.3174	0.2283***	35.425	0.300	0.317	30.624***	3.944	5.694***	2.85
State cash aids	-0.0467	-11.671	0.0983	12.974	-1.184	1.178	5.970	0.729	-0.441	0.228
State in-kind aids	-0.1589***	-26.066	0.2075	1.524	-3.823***	2.784	4.604	0.304	-4.009	1.433
Alimony aids	0.1565***	32.066	-0.1325	-14.777	4.219***	3.054	4.120	0.418	5.992**	2.132
Private in-kind aids	0.0687***	12.078	-0.2485**	-23.409	1.802	1.177	-19.982**	2.054	-1.545	0.618
Foreign income	0.1467	15.007	0.0449	0.2306	3.999	1.417	26.939	1.073	10.571	1.538
Apartment	-0.1268	-30.763	0.1082	14.557	-3.241***	3.083	-3.287	0.418	-4.525**	2.295
Renter	-0.0438	-0.8643	-0.1263	-1.389	-1.107	0.874	-20.181**	2.263	-4.724**	2.165
Homeowner	-0.0606	-12.255	0.0081	0.0987	-1.561	1.217	-6.943	0.767	-3.137	1.279
Combi	0.0093	0.2039	-0.029	-0.3855	0.239	0.204	-2.322	0.289	-0.112	0.052
Stove	-0.0941*	-17.049	-0.0015	-0.0149	-2.416*	1.696	-12.477	1.188	-5.143*	1.897
Internet	0.245***	7.286	-0.1847***	-28.137	6.483***	7.083	9.315	1.395	9.722***	5.138
One child	0.3766***	84.403	-0.2654***	-29.834	10.647***	7.84	16.683*	1.669	17.014***	5.331
Two children	0.5045***	114.487	-0.3904***	-45.125	14.695***	10.396	17.634*	1.898	22.648***	6.706
Three and more children	0.3519***	67.835	-0.3565***	-35.906	10.056***	6.187	1.673	0.16	12.682***	3.68
House feature index	0.0148	1.419	0.0456***	25.811	0.379	1.42	7.498***	3.825	1.759***	3.41
Number of autos	-0.051	-15.338	-0.0512	-0.8655	-1.301	1.537	-12.817**	2.036	-3.79**	2.399
Primary school	0.1222**	21.547	-	-	3.147**	2.146	16.020**	2.121	6.683**	2.117
Secondary school	0.1692**	25.161	-	-	5.590**	2.389	23.459**	2.334	10.498**	2.199
High school	0.3272***	48.307	-	-	9.218***	4.462	47.482***	4.147	22.579***	3.827
College school	0.4596***	61.092	-	-	13.483***	5.494	70.307***	4.807	35.803***	4.357
Number of properties	0.0219	14.634	-	-	0.560	1.463	2.847	1.462	1.176	1.464
Children 0-5	-0.1055***	-44.859	-	-	-2.699***	4.473	-13.729***	4.553	-5.669***	4.532
Children 6-14	0.1166***	64.936	-	-	2.983***	6.538	15.173***	5.865	6.265***	6.296
Children 15-18	0.2523***	92.919	-	-	6.454***	9.353	32.831***	8.058	13.556***	8.948
Adult 19 +	0.1954***	130.158	-	-	4.999***	13.504	25.431***	9.645	10.050***	12.116
Total expenditures	0.1119***	148.356	-	-	2.863***	14.861	14.564***	11.412	6.013***	13.855
Education	-		0.0161**	22.001	-	-	1.966**	2.178	0.34**	2.173
House size	-		-0.1249***	-4.804	-	-	-15.242***	4.698	-2.636***	4.717
Income ≤ 2000 TRY	-		0.0593	0.7651	-	-	7.240	0.767	1.252	0.767
Income 2000 – 5000 TRY	-		0.4032***	40.407	-	-	57.417***	3.474	9.929***	3.449
σ	-		15.424***	251.679	-	-	-	-	-	-
ρ	-		-0.811***	-268.593	-	-	-	-	-	-
Log-likelihood value			-21087.61		-	-	-	-	-	-

Note: Statistical significance*** at the 1% level; ** at the 5% level; * at the 10% level.

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GELENEKSEL ALIŞVERİŞTE EN ÇOK KARŞILAŞILAN SORUNLARIN KARAR AĞACI MODELİ İLE DEĞERLENDİRİLMESİ

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ÖZET

Günümüzde geleneksel (fiziksel) alışveriş halen çok büyük miktarda kullanılmaktadır. Fakat tüketiciler alışveriş yaparken bazı problemlerle karşılaşabilmektedirler. Bu sorunlar çok çeşitlidir. Bu sorunlardan bazıları kalabalık ortam, ürün bulunurluğu, ürün kalitesi, indirimlerin yetersizliği ve kasada uzun bekleme süresi olabilmektedir.

Bu çalışmada, geleneksel alışveriş esnasında tüketicilerin karşılaştıkları sorunlar bir karar ağacı modeli kullanılarak analiz edilmiştir. Bu amaçla, öncelikle 18 yaş ve üzerindeki tüketicilerden bilgi toplamak amacıyla 11 sorudan oluşan kapsamlı bir soru formu hazırlanmıştır. Bu ankette, alışveriş sürecindeki memnuniyeti etkileyebilecek çeşitli faktörler sorgulanarak, tüketici deneyimlerinin detaylı bir şekilde incelenmesi hedeflenmiştir. Soru formu ile toplanan veriler, geleneksel alışverişte hangi faktörlerin daha belirleyici olduğunu görmek adına analiz edilmiş ve sonuçları daha anlaşılır hale getirmek için karar ağacı modeline başvurulmuştur. Karar ağacı modelinin uygulanabilmesi için RapidMiner programından yararlanılmıştır. RapidMiner yazılımı verilerin kolay ve etkili bir şekilde analiz edilmesini sağlamaktadır.

Çalışmadan elde edilen verilerin değerlendirildiğinde, karar ağacı modeli %73.91 doğruluk ile verilerin doğru tahmin edilmesini sağlamıştır. Bu oran, modelin güvenilirliğini ve kullanılabilirliğini göstermektedir. Yine yapılan çalışma kullanılan karar ağacı modeli oluşturulurken en önemli faktörün 0.260 ile mağazada geçirilen süre olduğu tespit edilmiştir.

Sonuç olarak, bu çalışmada kullanılan karar ağacı modeli ile geleneksel alışverişte karşılaşılan sorunların daha iyi anlaşılmasına yönelik önemli bir adım atılmıştır. Çalışmanın, geleneksel alışveriş süreçlerinin iyileştirilmesi için iş dünyasına ve mağaza düzenlemelerine katkı sağlayabileceği düşünülmektedir.

Anahtar Kelimeler : Geleneksel Mağaza, Sorun, Soru Formu, Karar Ağacı

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EVALUATION OF THE MOST COMMON PROBLEMS IN TRADITIONAL SHOPPING WITH THE DECISION TREE MODEL

ABSTRACT

Today, traditional (physical) shopping is still used to a great extent. However, consumers may encounter some problems while shopping. These problems are very diverse. Some of these problems can be crowded environment, product availability, product quality, insufficient discounts and long waiting times at the checkout.

In this study, the problems encountered by consumers during traditional shopping were analyzed using a decision tree model. For this purpose, a comprehensive questionnaire consisting of 11 questions was prepared to collect information primarily from consumers aged 18 and over. This survey aimed to examine consumer experiences in detail by questioning various factors that may affect satisfaction during the shopping process. The data collected with the questionnaire was analyzed to see which factors were more decisive in traditional shopping and the decision tree model was used to make the results more understandable. RapidMiner program was used to implement the decision tree model. RapidMiner software enables easy and effective analysis of data.

When the data obtained from the study were evaluated, the decision tree model provided correct prediction of the data with 73.91% accuracy. This ratio shows the reliability and usability of the model. Again, while creating the decision tree model used in the study, it was determined that the most important factor was the time spent in the store with 0.260.

As a result, the decision tree model used in this study has taken an important step towards a better understanding of the problems encountered in traditional shopping. It is thought that the study may contribute to the business world and store arrangements to improve traditional shopping processes.

Keywords : Traditional Store, Problem, Question Form, Decision Tree

1. GİRİŞ

Günümüzde geleneksel (fiziksel) alışveriş, dijitalleşmenin hızla artmasına rağmen tüketiciler tarafından hala geniş bir şekilde tercih edilmektedir. Fiziksel mağazalar, tüketicilere ürünleri doğrudan görme, deneme ve satın alma fırsatı sunar; ancak bu alışveriş türü çeşitli zorluklar içerebilir [1]. Tüketicilerin geleneksel alışveriş deneyiminde karşılaştığı sorunlar arasında kalabalık ortam, ürün bulunurluğu eksikliği, ürün kalitesinde tutarsızlık, yeterli indirimlerin olmaması ve kasada uzun bekleme süreleri gibi faktörler yer alır [2]. Bu zorluklar, tüketicilerin alışveriş davranışlarını ve memnuniyet düzeylerini önemli ölçüde etkileyebilir [3].

Bu bağlamda, veri madenciliği, tüketici davranışlarını ve alışveriş süreçlerini daha iyi anlamak için kullanılabilecek güçlü bir araç olarak öne çıkmaktadır. Veri madenciliği, büyük veri kümelerinden anlamlı desenler ve içgörüler çıkarmak için kullanılan bir süreçtir ve çeşitli alanlarda geniş uygulama alanı bulur [4]. Bu süreçte kullanılan yöntemlerden biri olan karar

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ağacı modeli, veri kümesindeki örnekleri belirli kriterlere göre dallandırarak karar süreçlerini görselleştiren ve basitleştiren güçlü bir sınıflandırma ve tahmin aracıdır [5].

Karar ağacı modelleri, tüketici davranışlarını analiz etme ve alışveriş alışkanlıklarını belirleme gibi farklı alanlarda kullanılır. Bu modelin temel avantajı, veriyi açıklayıcı ve kolay anlaşılır hale getiren bir yapı sunmasıdır [6]. Örneğin, tüketicilerin alışveriş sırasında karşılaştıkları zorlukları ve bu zorlukların satın alma davranışlarını nasıl etkilediğini incelemek için karar ağaçları kullanılabilir. Bu sayede, perakendeciler ve araştırmacılar, hangi faktörlerin alışveriş deneyimini olumsuz etkilediğini ve bu faktörlere karşı nasıl stratejiler geliştirilebileceğini daha iyi anlayabilirler [7].

Veri madenciliği ve karar ağacı gibi modellerin kullanımı, perakende sektörü ve müşteri memnuniyeti gibi alanlarda önemli içgörüler sunar. Tüketici davranışlarının modellenmesi, mağaza düzenlemeleri, ürün stoğu ve pazarlama stratejileri gibi birçok alanda daha iyi kararlar alınmasına olanak tanır [8].

2. UYGULAMALAR

Bu çalışmada tüketicilerin geleneksel alışveriş sırasında en çok yaşadıkları problemlerin belirlenebilmesi için veri madenciliği yöntemlerinden biri olan karar ağacı modeli kullanılmıştır. Karar ağacı modelinde verilerin elde edilebilmesi için 11 sorudan oluşan bir soru formu kullanılmıştır. Soru formu 18 yaş ve üzeri 228 kişiye uygulanmıştır. Çalışmada kullanılan soru formu aşağıda verilmiştir.

1. Cinsiyetiniz nedir?
- Kadın
- Erkek

2. Yaş aralığınız nedir?
- 18-24
- 25-34
- 35-44
- 45-64
- 65 ve üstü

3. Eğitim durumunuz nedir?
- İlkokul
- Ortaokul
- Lise
- Ön Lisans
- Lisans
- Yüksek Lisans
- Doktora

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4. Mesleğiniz nedir?
- Öğrenci
- Memur
- İşçi
- Çalışan (Beyaz yaka)
- Çalışan (Mavi yaka)
- Serbest meslek
- Ev hanımı
- Emekli
- İşsiz

5. Aylık gelir aralığınız nedir?
- 0-10000 TL
- 10001-20000 TL
- 20001-30000 TL
- 30001-40000 TL
- 40001 TL ve üzeri

6. Alışveriş yaparken genellikle ne tür bir mağazayı tercih edersiniz?
- Küçük yerel mağazalar
- Büyük zincir mağazalar
- Alışveriş merkezleri
- Pazarlar

7. Mağazada geçirdiğiniz süreyi genellikle nasıl buluyorsunuz?
- Kısa
- Uzun

8. Geleneksel alışveriş deneyiminizi genel olarak nasıl değerlendirirsiniz?
- Memnunum
- Kararsızım
- Memnun değilim

9. Geleneksel alışverişte hangi faktörler karar vermenizi en çok etkiler?
- Fiyat
- Ürün kalitesi
- Mağaza konumu
- Müşteri hizmetleri

10. Mağazadaki ürün çeşitliliği sizin için yeterli mi?
- Evet
- Hayır

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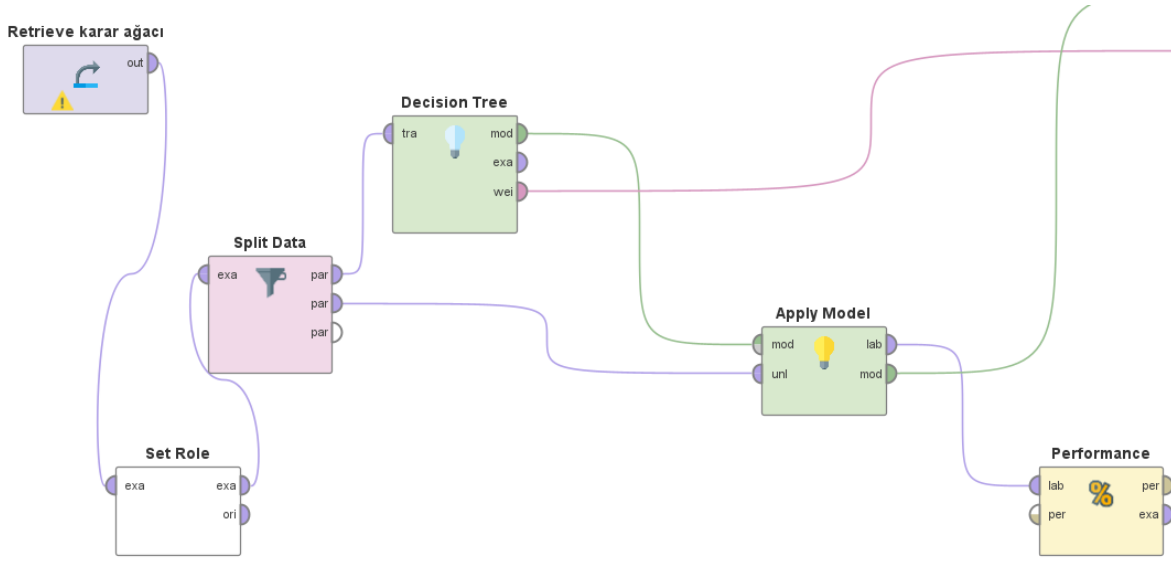
11. Geleneksel alışverişte en çok hangi sorunu yaşıyorsunuz?
- Kalabalık ortam
- Ürün bulunurluğu
- Ürünlerin kalitesi
- İndirimlerin yetersizliği
- Kasadaki uzun bekleme süresi

Veriler elde edildikten sonra RapidMiner yazılımı kullanılarak karar ağaı modeli ile veriler analiz edilmiştir. RapidMiner yazılımı birçok veri madenciliği yöntemlerinin uygulanabildiği bir programdır. Bu program bazı görevleri üstlenen operatörlerin birbirlerine bağlanması soncu oluşan prosesler ile çalışmaktadır. Karar ağacı modeli uygulanırken kullanılan proses Görsel 1'de verilmiştir.



Görsel 1. Karar ağacı modelinde kullanılan proses

Yukarıdaki görselden de anlaşılacağı üzere her operatör bir görevi yapmaktadır. Birinci operatör elde ettiğimiz verilere ulaşmamızı sağlar. İkinci Set Role operatörü istediğimiz faktörü tahmin etmemizi sağlar. Split data operatörü verilerimizi eğitim (%80) ve test verisi (%20) olarak bölmektedir. Apply model operatörü Karar ağacı modelinin uygulanmasını sağlar. Performance operatörü ise karar ağacı modelimizin performansını test etmektedir.

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3. SONUÇLAR VE DEĞERLENDİRME

Yapılan çalışmada karar ağacı modeli kullanılarak tüketicilerin geleneksel (fiziksel) alışverişte en çok karşılaştıkları sorunların tahmin edilmesi sağlanmıştır.
Elde edilen verilerin analizinde karar ağacı algoritması tüketicilerin geleneksel mağaza alışverişlerinde en çok yaşadıkları sorunları %73.91 doğruluk ile tahmin etmiştir. Oluşturulan karar ağacı modelinde faktörlerin ağırlıkları Çizelge 1'de verilmiştir.

Çizelge 1. Faktörler ve ağırlıkları

Faktörler	**Ağırlıkları**
Alışveriş mağazası tercihi	0,196
Mağazadaki ürün çeştliliğinin yeterlilik durumu	0,208
Yaş	0.038
Geleneksel alışveriş memnuniyeti	0.078
Mağazada geçirilen süre	0.260
Aylık gelir	0.027
Cinsiyet	0.156
Meslek	0.017
Geleneksel alışverişte karar vermeyi etkileyen faktör	0.020

Yukarıdaki çizelge incelendiğinde en büyük faktörün 0.260 ile mağazada geçirilen süre olduğu tespit edilmiştir.
Çalışma sonucu elde edilen karar ağacının metin hali aşağıda verilmiştir.

Geleneksel alışverişte karar vermeyi etkileyen faktör = Fiyat
| Yaşınız
= 18-24
| | Cinsiyetiniz = Erkek
| | | Alışveriş mağaza tercihi
= Alışveriş merkezleri: İndirimlerin Yetersizliği {İndirimlerin Yetersizliği=18, Kalabalık ortam=1, Ürün bulunurluğu=0, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=1}
| | | Alışveriş mağaza tercihi
= Büyük zincir mağazalar
| | | | Mağazada geçirilen süre = Kısa: Ürün bulunurluğu {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=2, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| | | | Mağazada geçirilen süre = Uzun: İndirimlerin Yetersizliği {İndirimlerin Yetersizliği=1, Kalabalık ortam=0, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| | | Alışveriş mağaza tercihi
= Küçük yerel mağazalar: Ürün bulunurluğu {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=1}
| | Cinsiyetiniz = Kadın
| | | Geleneksel alışverişte memnuniyetiniz = Kararsızım: Ürün bulunurluğu {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=5, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}

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| | | Geleneksel alışverişte memnuniyetiniz = Memnun Değilim: Ürün bulunurluğu {İndirimlerin Yetersizliği=1, Kalabalık ortam=0, Ürün bulunurluğu=8, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| | | Geleneksel alışverişte memnuniyetiniz = Memnunum: İndirimlerin Yetersizliği {İndirimlerin Yetersizliği=2, Kalabalık ortam=2, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| Yaşınız
= 25-34
| | Cinsiyetiniz = Erkek: Kalabalık ortam {İndirimlerin Yetersizliği=1, Kalabalık ortam=2, Ürün bulunurluğu=0, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| | Cinsiyetiniz = Kadın: İndirimlerin Yetersizliği {İndirimlerin Yetersizliği=6, Kalabalık ortam=0, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| Yaşınız
= 35-44
| | Mağazada geçirilen süre = Kısa
| | | Geleneksel alışverişte memnuniyetiniz = Kararsızım: İndirimlerin Yetersizliği {İndirimlerin Yetersizliği=5, Kalabalık ortam=0, Ürün bulunurluğu=0, Kasadaki uzun bekleme süreleri=1, Ürünlerin Kalitesi=1}
| | | Geleneksel alışverişte memnuniyetiniz = Memnun Değilim: Kasadaki uzun bekleme süreleri {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=0, Kasadaki uzun bekleme süreleri=1, Ürünlerin Kalitesi=1}
| | | Geleneksel alışverişte memnuniyetiniz = Memnunum: Kalabalık ortam {İndirimlerin Yetersizliği=0, Kalabalık ortam=1, Ürün bulunurluğu=0, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=1}
| | Mağazada geçirilen süre = Uzun: İndirimlerin Yetersizliği {İndirimlerin Yetersizliği=9, Kalabalık ortam=0, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| Yaşınız
= 45-64
| | Alışveriş mağaza tercihi
= Küçük yerel mağazalar
| | | Mağazadaki ürün çeşitliliği yeterlilik durumu = Evet: İndirimlerin Yetersizliği {İndirimlerin Yetersizliği=4, Kalabalık ortam=0, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| | | Mağazadaki ürün çeşitliliği yeterlilik durumu = Hayır: Ürün bulunurluğu {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=2, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| | Alışveriş mağaza tercihi
= Pazarlar: Kalabalık ortam {İndirimlerin Yetersizliği=0, Kalabalık ortam=5, Ürün bulunurluğu=0, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| Yaşınız
= 65 ve üstü: İndirimlerin Yetersizliği {İndirimlerin Yetersizliği=19, Kalabalık ortam=0, Ürün bulunurluğu=0, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
Geleneksel alışverişte karar vermeyi etkileyen faktör = Mağaza Konumu: Ürün bulunurluğu {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=1, Ürünlerin Kalitesi=0}
Geleneksel alışverişte karar vermeyi etkileyen faktör = Müşteri Hizmetleri

| Mağazadaki ürün çeşitliliği yeterlilik durumu = Evet: İndirimlerin Yetersizliği {İndirimlerin Yetersizliği=1, Kalabalık ortam=0, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=1, Ürünlerin Kalitesi=0}
| Mağazadaki ürün çeşitliliği yeterlilik durumu = Hayır: Ürünlerin Kalitesi {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=2, Kasadaki uzun bekleme süreleri=1, Ürünlerin Kalitesi=6}
Geleneksel alışverişte karar vermeyi etkileyen faktör = Ürün Kalitesi
| Geleneksel alışverişte memnuniyetiniz = Kararsızım
| | Alışveriş mağaza tercihi
= Alışveriş merkezleri: İndirimlerin Yetersizliği {İndirimlerin Yetersizliği=1, Kalabalık ortam=1, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| | Alışveriş mağaza tercihi
= Büyük zincir mağazalar
| | | Cinsiyetiniz = Erkek
| | | | Meslek = Memur
| | | | | Mağazada geçirilen süre = Kısa: Ürünlerin Kalitesi {İndirimlerin Yetersizliği=1, Kalabalık ortam=0, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=3}
| | | | | Mağazada geçirilen süre = Uzun: Kalabalık ortam {İndirimlerin Yetersizliği=0, Kalabalık ortam=2, Ürün bulunurluğu=0, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| | | | Meslek = Çalışan (Beyaz yaka): Ürünlerin Kalitesi {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=0, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=5}
| | | | Meslek = Öğrenci
| | | | | Mağazada geçirilen süre = Kısa: Kalabalık ortam {İndirimlerin Yetersizliği=0, Kalabalık ortam=2, Ürün bulunurluğu=0, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=1}
| | | | | Mağazada geçirilen süre = Uzun: Ürün bulunurluğu {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=1}
| | | Cinsiyetiniz = Kadın: Ürünlerin Kalitesi {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=8}
| | Alışveriş mağaza tercihi
= Küçük yerel mağazalar: Kalabalık ortam {İndirimlerin Yetersizliği=0, Kalabalık ortam=1, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| | Alışveriş mağaza tercihi
= Pazarlar: Ürün bulunurluğu {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=2, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| Geleneksel alışverişte memnuniyetiniz = Memnun Değilim
| | Mağazadaki ürün çeşitliliği yeterlilik durumu = Evet: İndirimlerin Yetersizliği {İndirimlerin Yetersizliği=1, Kalabalık ortam=0, Ürün bulunurluğu=0, Kasadaki uzun bekleme süreleri=1, Ürünlerin Kalitesi=0}
| | Mağazadaki ürün çeşitliliği yeterlilik durumu = Hayır
| | | Alışveriş mağaza tercihi
= Alışveriş merkezleri: Ürün bulunurluğu {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=3, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| | | Alışveriş mağaza tercihi
= Büyük zincir mağazalar
| | | | Yaşınız

= 35-44: Ürünlerin Kalitesi {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=0, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=2}
| | | | Yaşınız
= 45-64: Ürün bulunurluğu {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=1}
| Geleneksel alışverişte memnuniyetiniz = Memnunum
| | Aylık gelir = 0-10000 TL
| | | Cinsiyetiniz = Erkek: İndirimlerin Yetersizliği {İndirimlerin Yetersizliği=1, Kalabalık ortam=0, Ürün bulunurluğu=0, Kasadaki uzun bekleme süreleri=1, Ürünlerin Kalitesi=0}
| | | Cinsiyetiniz = Kadın: Ürün bulunurluğu {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=1, Ürünlerin Kalitesi=0}
| | Aylık gelir = 10001-20000 TL: Ürün bulunurluğu {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=1}
| | Aylık gelir = 30001-40000 TL: Kalabalık ortam {İndirimlerin Yetersizliği=0, Kalabalık ortam=1, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| | Aylık gelir = 40001 TL ve Üzeri
| | | Cinsiyetiniz = Erkek
| | | | Mağazadaki ürün çeşitliliği yeterlilik durumu = Evet
| | | | | Mağazada geçirilen süre = Kısa: Ürün bulunurluğu {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=1}
| | | | | Mağazada geçirilen süre = Uzun: Kalabalık ortam {İndirimlerin Yetersizliği=0, Kalabalık ortam=2, Ürün bulunurluğu=0, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| | | | Mağazadaki ürün çeşitliliği yeterlilik durumu = Hayır: Ürün bulunurluğu {İndirimlerin Yetersizliği=0, Kalabalık ortam=0, Ürün bulunurluğu=5, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}
| | | Cinsiyetiniz = Kadın: İndirimlerin Yetersizliği {İndirimlerin Yetersizliği=1, Kalabalık ortam=0, Ürün bulunurluğu=1, Kasadaki uzun bekleme süreleri=0, Ürünlerin Kalitesi=0}

Yukarıda verilen karar ağacı algoritmasının metin halinin bazılarını yorumlayacak olursak;

1. Geleneksel alışverişte karar vermesini etkileyen faktörün fiyat, yaşı 18-24, cinsiyeti erkek ve alışveriş mağazası tercihi alışveriş merkezleri olan kişilerin geleneksel alışverişte en çok karşılaştıkların sorunların indirimlerin yetersizliği söylemişlerdir.
2. Geleneksel alışverişte karar vermesini etkileyen faktörün fiyat, yaşı 18-24, cinsiyeti erkek, alışveriş mağazası tercihi büyük zincir mağazalar ve mağazada geçirilen süresi kısa olan kişiler geleneksel alışverişte en çok yaşadıkları sorunun ürün bulunurluğu olduğu tespit edilmiştir.
3. Geleneksel alışverişte karar vermesini etkileyen faktörün fiyat, yaşı 18-24, cinsiyeti kadın ve geleneksel alışverişte memnuniyeti kararsız olan kişilerin geleneksel alışverişte en çok yaşadıkları sorunun ürün bulunurluğu olduğu tespit edilmiştir.

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4. Geleneksel alışverişte karar vermesini etkileyen faktörün fiyat, yaşı 18-24, cinsiyeti kadın, ve geleneksel alışverişte memnun olan kişilerin geleneksel alışverişte en çok yaşadıkları sorunun indirimlerin yetersizliği olduğu belirlenmiştir.
5. Geleneksel alışverişte karar vermesini etkileyen faktörün fiyat, yaşı 25-34 ve cinsiyeti erkek olan kişilerin geleneksel alışverişte en çok karşılaştıkları sorunun kalabalık ortam olduğunu söylemişlerdir.
6. Geleneksel alışverişte karar vermesini etkileyen faktörün fiyat, yaşı 35-44, mağazada geçirdiği süre kısa ve geleneksel alışverişten memnun olamayan kişilerin en çok karşılaştıkları sorun kasadaki uzun bekleme süresidir.
7. Geleneksel alışverişte karar vermesini etkileyen faktörün fiyat, yaşı 35-44, mağazada geçirdiği süre kısa ve geleneksel alışverişten memnun kişilerin en çok karşılaştıkları sorun kalabalık ortamdır.
8. Geleneksel alışverişte karar vermesini etkileyen faktörün fiyat, yaşı 45-64, alışveriş merkezi tercihi küçük yerel mağazalar ve mağazadaki ürün çeşitliliğinin yeterli olduğunu söyleyen kişilerin alışverişte en fazla karşılaştıkları sorun indirimlerin yetersizliğidir.
9. Geleneksel alışverişte karar vermesini etkileyen faktörün fiyat ve yaşı 65 ve üstü olan kişilerin en çok yaşadıkları sorun indirimlerin yetersizliğidir.
10. Geleneksel alışverişte karar vermeyi etkileyen faktörün müşteri hizmetleri ve mağazadaki ürün çeşitliliğinin yetersiz olan kişilerin en çok karşılaştıkları sorun ürün kalitesidir.
11. Geleneksel alışverişte karar vermeyi etkileyen faktörün ürün kalitesi, geleneksel alışverişte memnuniyetinin kararsız ve alışveriş mağazası tercihi alışveriş merkezleri olan kişilerin geleneksel alışverişte en çok yaşadıkları sorun indirimlerin yetersizliğidir.
12. Geleneksel alışverişte karar vermeyi etkileyen faktörün ürün kalitesi, geleneksel alışverişte memnuniyetinin kararsız, alışveriş mağazası tercihi büyük zincir mağazalar, cinsiyeti erkek, mesleği memur ve mağazada geçirilen süresi kısa olan kişilerin en çok yaşadıkları sorun ürünlerin kalitesidir.
13. Geleneksel alışverişte karar vermeyi etkileyen faktörün ürün kalitesi, geleneksel alışverişte memnuniyetinin kararsız, alışveriş mağazası tercihi büyük zincir mağazalar, cinsiyeti erkek ve mesleği çalışan (beyaz yaka) olan kişilerin en çok yaşadıkları sorun ürünlerin kalitesidir.
14. Geleneksel alışverişte karar vermeyi etkileyen faktörün ürün kalitesi, geleneksel alışverişte memnuniyetinin kararsız, alışveriş mağazası tercihi büyük zincir mağazalar ve cinsiyeti kadın olan kişilerin kişilerin en çok yaşadıkları sorun ürünlerin kalitesidir.
15. Geleneksel alışverişte karar vermeyi etkileyen faktörün ürün kalitesi, geleneksel alışverişte memnuniyetinin kararsız, alışveriş mağazası tercihi büyük zincir mağazalar, cinsiyeti erkek, mesleği öğrenci ve mağazada geçirilen süresi kısa olan kişilerin en çok yaşadıkları sorun kalabalık ortamdır.
16. Geleneksel alışverişte karar vermeyi etkileyen faktörün ürün kalitesi, Geleneksel alışverişten memnun, aylık geliri 0-10000 TL ve cinsiyeti kadın olan kişilerin en çok yaşadıkları sorun ürün bulunurluğudur.

4. GENEL DEĞERLENDİRME VE SONUÇLAR

Yapılan çalışmada tüketicilerin geleneksel alışverişte en çok karşılaştıkları sorunlar karar ağacı modeli kullanılarak tahmin edilmiştir. Karar ağacı modeli %73.91 doğruluk ile tüketicilerin geleneksel alışverişte en çok yaşadıkları sorunları tahmin etmiştir. Yine yapılan çalışmada karar ağacı modelinin oluşumunda en önemli faktörün mağazada geçirilen süre (0.260) olduğu tespit edilmiştir.

Yapılan bu çalışma tüketici davranışlarını inceleyen firmalar ve araştırmacılara yararlı bilgiler sunmaktadır.

Çeşitli modeller kullanarak tüketicilerin geleneksel alışveriş sırasında yaşadıkları sorunları araştıran çalışmalar sınırlı sayıdadır. Bu alanda çalışmalar arttırılabilir.

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TÜKETİCİLERİN GELENEKSEL VE/VEYA ONLINE ALIŞVERİŞ TERCİH SEBEPLERİNİN BİRLİKTELİK ANALİZİ İLE DEĞERLENDİRİLMESİ

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ÖZET

Son yıllarda, teknoloji ve dijital platformların gelişmesiyle birlikte tüketiciler hem geleneksel (fiziksel) hem de online alışveriş seçeneklerini sıklıkla tercih edebilmektedir. Geleneksel alışveriş, fiziksel mağazalarda ürünleri doğrudan görme ve deneme imkanı sunarken, online alışveriş ise kullanıcıya zaman tasarrufu, fiyat karşılaştırması yapabilme ve ürün yorumlarını inceleyebilme gibi avantajlar sunmaktadır. Tüketicilerin bu alışveriş yöntemlerini tercih etmelerini birçok faktör etkileyebilmektedir. Bunlar arasında cinsiyet, yaş, meslek, eğitim durumu, ürün kalitesi, fiyat, zaman, kullanıcı yorumları gibi birçok faktör sayılabilmektedir.

Bu çalışmada, tüketicilerin geleneksel ve/veya online alışveriş tercihlerini belirleyen unsurların detaylı bir şekilde incelenmesi amaçlanmıştır. Tüketici davranışlarını daha iyi analiz edebilmek için birliktelik analizlerinden biri olan FP-Growth algoritması kullanılmıştır. FP-Growth analizi, büyük veri setlerindeki sık rastlanan öğe gruplarını bulmak ve bu gruplar arasında anlamlı birliktelikler çıkarmak için etkili bir yöntem olarak bilinir. Analizde kullanılacak veriler 12 sorudan oluşan soru formu ile elde edilmiştir. Bu soru formu 18 yaş ve üzeri 151 kişiye uygulanmıştır. Analizin gerçekleştirilebilmesi için RapidMiner yazılımından faydalanılmıştır. Bu yazılım çeşitli görevleri üstlenen operatörler sayesinde çalışmaktadır.

FP-Growth analizi sonucunda %70 üstü güvenirliliğe sahip 134 birliktelik kuralı belirlenmiştir. Bu kurallar, tüketicilerin alışveriş tercihlerini etkileyen faktörlerin hangi durumlarda bir araya geldiğini ve belirli özelliklerin hangi alışveriş türüyle daha fazla ilişkilendirildiğini göstermektedir. Birliktelik analizinde en düşük güven seviyesi 0.702 en yüksek güven seviyesi ise 1 olarak belirlenmiştir.

Tüketicilerin birliktelik analizi kullanılarak geleneksek ve/veya online alışveriş tercih sebeplerini inceleyen çalışmalar sınır sayıdadır. Bu alanda çalışmalar arttırılarak tüketicilerin alışveriş davranışları hakkında daha çok bilgi sahibi olunabilir. Bu durumda geleneksel veya online olarak ürün satan şirketlerin karlılıklarının arttırmasını sağlayabilmektedir.

Anahtar Kelimeler : Geleneksel Alışveriş, Online Alışveriş, Birliktelik Analizi, FP-Growth Analizi

EVALUATION OF CONSUMERS' TRADITIONAL AND/OR ONLINE SHOPPING PREFERENCE REASONS WITH COLLABORATION ANALYSIS

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ABSTRACT

In recent years, with the development of technology and digital platforms, consumers can often choose both traditional (physical) and online shopping options. While traditional shopping offers the opportunity to see and try products directly in physical stores, online shopping offers the user advantages such as saving time, comparing prices and reviewing product reviews. Many factors can influence consumers' preference for these shopping methods. These include many factors such as gender, age, profession, educational status, product quality, price, time, and user comments.

The aim of this study is to examine in detail the factors that determine consumers' traditional and/or online shopping preferences. In order to better analyze consumer behavior, the FP-Growth algorithm, one of the association analyses, was used. FP-Growth analysis is known as an effective method to find frequent groups of items in large data sets and to extract meaningful associations between these groups. The data to be used in the analysis was obtained with a questionnaire consisting of 12 questions. This questionnaire was applied to 151 people aged 18 and over. RapidMiner software was used to perform the analysis. This software works with operators who undertake various tasks.

As a result of FP-Growth analysis, 134 association rules with 70% above reliability were determined. These rules show in which situations the factors that affect consumers' shopping preferences come together and which shopping type certain features are more associated with. In the association analysis, the lowest confidence level was determined as 0.702 and the highest confidence level was determined as 1.

Studies examining the reasons for consumers' preference for traditional and/or online shopping using association analysis are limited in number. By increasing studies in this area, more information can be obtained about the shopping behavior of consumers. In this case, it can increase the profitability of companies that sell products traditionally or online.

Keywords : Traditional Shopping, Online Shopping, Association Analysis, FP-Growth Analysis

1. GİRİŞ

Günümüzde tüketiciler, alışveriş deneyimlerinde farklı seçeneklere sahip olup, geleneksel mağaza (fiziksel) alışverişi ve online alışveriş yöntemlerinden birini veya her ikisini de tercih edebilmektedirler. Her iki yöntemin de tüketiciler açısından olumlu ve olumsuz yönleri bulunmaktadır. Geleneksel alışveriş, fiziksel mağazalarda ürünleri bizzat görüp dokunabilme ve anında satın alma gibi avantajlar sunarken, online alışveriş zamandan tasarruf, geniş ürün yelpazesi ve fiyat karşılaştırması gibi kolaylıklar sağlamaktadır [1].

Tüketicilerin alışveriş tercihleri, yaş, cinsiyet, gelir durumu, eğitim seviyesi gibi demografik faktörlerden etkilenmektedir. Örneğin, genç nesiller genellikle teknolojiyi daha aktif kullandıkları için online alışverişi daha çok tercih etmektedirler [2]. Benzer şekilde, yüksek gelir seviyesine sahip tüketicilerin, hem geleneksel hem de online alışverişi daha fazla kullandıkları gözlemlenmiştir. Cinsiyet faktörü de alışveriş tercihlerinde önemli bir rol

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oynayabilir; örneğin kadın tüketicilerin genellikle moda ve güzellik ürünlerinde, erkek tüketicilerin ise teknoloji ve elektronik ürünlerde online alışverişe daha fazla yöneldiği araştırmalarla desteklenmiştir [3].

Veri madenciliği, büyük veri setlerinden anlamlı örüntüleri ve ilişkileri ortaya çıkarmada önemli bir araçtır. Veri madenciliği yöntemlerinden biri olan birliktelik analizi, tüketici davranışlarını ve alışveriş alışkanlıklarını inceleyerek farklı ürün ve hizmetlerin birlikte ne sıklıkta tercih edildiğini ve hangi faktörlerin tüketici tercihlerinde etkili olduğunu belirlememize olanak sağlar [4]. Örneğin, market sepeti analizleri ile tüketicilerin hangi ürünleri birlikte satın alma eğiliminde olduğu tespit edilebilir ve bu da pazarlama stratejilerinin belirlenmesinde yardımcı olabilir [5].

Geleneksel ve online alışveriş tercihleri arasındaki seçim, birçok faktörden etkilenmektedir. Bu faktörler arasında demografik özellikler, zaman ve maliyet gibi unsurlar bulunmaktadır. Birliktelik analizi gibi veri madenciliği yöntemleri, tüketici tercihlerine dair derinlemesine bilgi sağlayarak pazarlama ve iş stratejilerinin iyileştirilmesine katkıda bulunur.

2. UYGULAMALAR

Yapılan çalışmada tüketicilerin geleneksel (fiziksel) ve/veya online alışveriş tercihlerini belirlemek için veri madenciliği yöntemlerinden olan birliktelik analizi yöntemi kullanılmıştır. Çalışmada birliktelik analizi yöntemlerinden ise FP-Growth analizinden yararlanılmıştır. FP-Growth analizinde kullanılacak verilerin elde edilmesi için 12 sorudan oluşan bir soru formu kullanılmıştır. Bu soru formu 18 yaş ve üzeri 151 kişiye uygulanmıştır. Çalışmada kullanılan soru formu aşağıda verilmiştir.

1. Cinsiyetiniz nedir?
- Kadın
- Erkek

2. Yaş aralığınız nedir?
- 18-29
- 30-41
- 42-53
- 54-65
- 65 yaş ve üstü

3. Mesleğiniz nedir?
- Öğrenci
- Çalışan (Mavi yaka)
- Çalışan (Beyaz yaka)
- Serbest meslek
- Memur
- Ev hanımı

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- Emekli
- İşsiz

4. Eğitim Durumunuz nedir?
- İlköğretim
- Lise
- Ön Lisans
- Lisans
- Yüksek Lisans
-Doktora

5. Genel olarak hangi alışveriş yöntemini daha sık tercih edersiniz?
- Geleneksel (Fiziksel)
- Online (Çevrimiçi Mağaza)
- İkisini de eşit olarak kullanıyorum.

6. Geleneksel alışverişi tercih etmenizin en önemli sebebi nedir?
- Ürünleri anında görebilme ve deneyebilme
- Ürünleri hemen teslim alma
- Müşteri hizmetlerinden doğrudan destek alma
- Ürünlerin kalitesini kontrol etme
- Mağazaların indirim ve promosyonları

7. Online alışverişi tercih etmenizin en önemli sebebi nedir?
- Fiyat avantajı
- Zaman tasarrufu
- Daha fazla ürün seçeneği
- Kolay iade/değişim süreçleri
- Kullanıcı yorumlarına erişim

8. Alışveriş yaparken fiyat mı yoksa ürün kalitesi mi sizin için daha önemli?
- Fiyat daha önemli
- Ürün kalitesi daha önemli
- İkisi de eşit derecede önemli

9. Hangi tür ürünleri genellikle geleneksel mağazalardan almayı tercih edersiniz?
- Giyim
- Elektronik
- Mobilya
- Gıda

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- Kozmetik
- Diğer

10. Hangi tür ürünleri genellikle online mağazalardan almayı tercih edersiniz?
- Giyim
- Elektronik
- Mobilya
- Gıda
- Kozmetik
- Diğer

11. Online alışveriş yaparken ne sıklıkla çevrimiçi yorumları incelersiniz?
- Çoğu zaman
- Nadiren
- Hiç

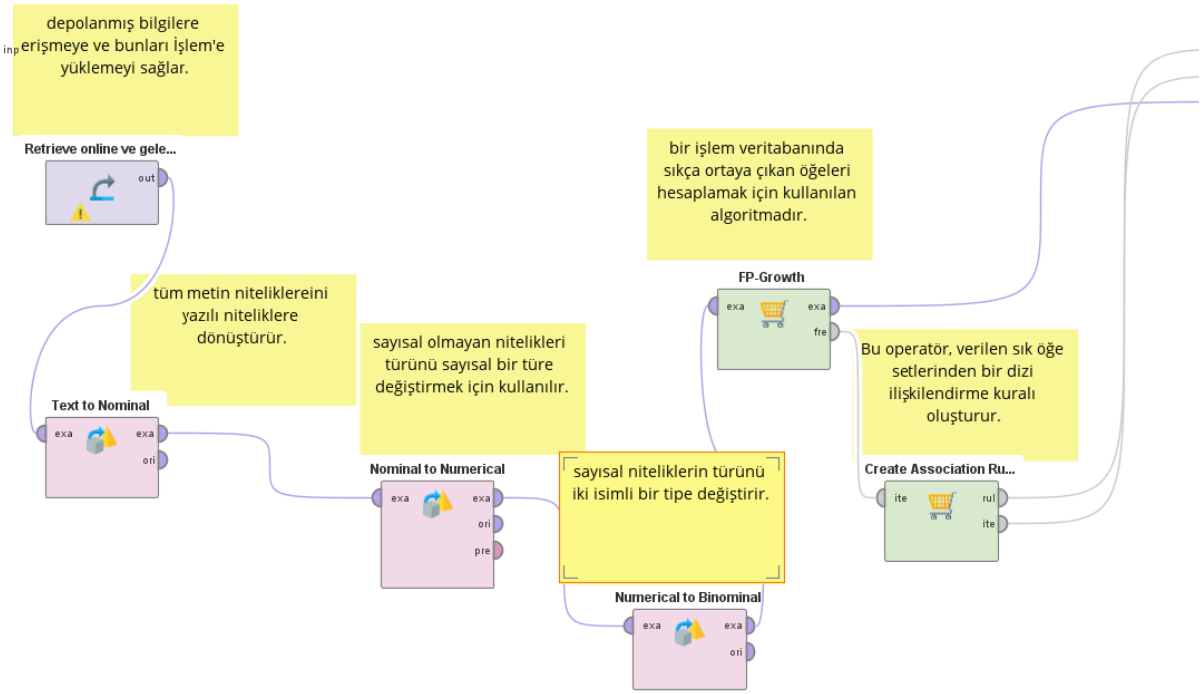
12. Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet sizin için ne kadar önemlidir?
- Önemli
- Önemli Değil

Bu analiz, RapidMiner gibi güçlü veri analitiği ve makine öğrenimi araçları kullanılarak uygulanabilmektedir. RapidMiner, kullanıcı dostu arayüzü sayesinde karmaşık veri işleme süreçlerini basitleştirir ve analizlerin hızlı bir şekilde gerçekleştirilmesini sağlar [6].

RapidMiner yazılımı, her biri belirli bir işlevi yerine getiren operatörler aracılığıyla çalışır. Operatörler, görsel bir iş akışı içinde birbirlerine bağlanarak daha karmaşık veri analizleri oluşturulmasına olanak tanır. Örneğin, veri hazırlığı, veri temizleme, model oluşturma ve değerlendirme gibi süreçlerde farklı operatörler kullanılır [7]. FP-Growth analizi için, "FP-Growth" operatörü, veri kümesinde sık öğe kümelerini belirleyip sonuçları yorumlamayı kolaylaştırır. Bu operatör, kullanıcıya destek, güven, ve kaldırma gibi önemli ölçümleri sunarak derinlemesine analiz yapılmasına imkan tanır [8].

RapidMiner'ın bu operatör tabanlı yaklaşımı, analistlerin ve araştırmacıların algoritmaları ve veri işleme adımlarını daha etkili bir şekilde kontrol etmelerine olanak tanır. Kullanıcılar, işlem sürecini ihtiyaçlarına göre özelleştirebilir ve farklı veri kaynaklarından gelen verileri entegre edebilir. Bu özellikler, FP-Growth gibi algoritmaların uygulanmasını hızlandırarak veri madenciliği projelerinde esneklik sağlar [9].

Bu yapı, veri bilimcilerin ve analistlerin büyük veri kümeleri üzerinde anlamlı çıkarımlar yapmalarına ve iş süreçlerini optimize etmelerine yardımcı olur. Aynı zamanda, FP-Growth gibi algoritmaların doğru ve verimli bir şekilde uygulanması, pazarlama stratejileri, sepet analizi ve öneri sistemleri gibi alanlarda da önemli avantajlar sunar [4]. FP-Growth analizi için kullanılan proses Görsel 1'de verilmiştir.



Görsel 1. FP-Growth algoritmasında birliktelik analizi için kurulan proses

Yukarıdaki şekilde görüldüğü üzere her operatör belli bir görevi yapmaktadır. Bu operatörleri birbirini bağlayarak birliktelik analizinde kullanacağımız modeli elde etmekteyiz.

3. SONUÇLAR VE DEĞERLENDİRME

Tüketicilerin geleneksel ve online alışveriş tercih sebeplerini belirlemek için yapılan FP-Growth analizi sonucu elde edilen %70 üstü güvenirliliğe sahip 134 kural belirlenmiştir. Bu birliktelik kurallarından %80 ve üstü güvenirliliğe sahip olanlar aşağıda verilmiştir.
[Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] --> [Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda] (confidence: 0.800)
[Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Eğitim durumunuz = Lisans] --> [Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman] (confidence: 0.804)
[Ne tür ürünleri online mağazalardan alırsınız = Elektronik] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Cinsiyetiniz = Erkek] (confidence: 0.808)
[Alışveriş yöntemi tercihiniz = İkisini de eşit olarak kullanırım] --> [Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz= Çoğu Zaman] (confidence: 0.810)

[Mesleğiniz = Memur] --> [Alışveriş yöntemi tercihiniz = İkisini de eşit olarak kullanırım] (confidence: 0.812)
[Online alışverişi tercih sebebiniz = Fiyat avantajı] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.818)
[Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda, Cinsiyetiniz = Kadın] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.826)
[Geleneksel alışveriş tercih nedeniniz = Ürünleri anında görebilme ve deneyebilme, Ne tür ürünleri online mağazalardan alırsınız = Giyim] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.830)
[Cinsiyetiniz = Kadın] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.831)
[Mesleğiniz = Memur] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman] (confidence: 0.833)
[Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] --> [Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman] (confidence: 0.835)
[Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman, Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] --> [Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda] (confidence: 0.836)
[Online alışverişi tercih sebebiniz = Fiyat avantajı, Cinsiyetiniz = Erkek] --> [Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda] (confidence: 0.840)
[Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Online alışverişi tercih sebebiniz = Fiyat avantajı, Cinsiyetiniz = Erkek] --> [Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda] (confidence: 0.841)
[Cinsiyetiniz = Erkek, Geleneksel alışveriş tercih nedeniniz = Ürünleri anında görebilme ve deneyebilme] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.844)
[Mesleğiniz = Öğrenci] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, 2. Yaşınız = 18-29] (confidence: 0.846)
[Cinsiyetiniz = Erkek] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.848)
[Alışverişte fiyat mı ürün kalitesi mi önemli = Fiyat daha önemli] --> [Online alışverişi tercih sebebiniz = Fiyat avantajı] (confidence: 0.849)
[Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.851)
[Eğitim durumunuz = Lisans] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.852)
[Cinsiyetiniz = Erkek, Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] --> [Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman] (confidence: 0.854)

[Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Ne tür ürünleri online mağazalardan alırsınız = Elektronik] --> [Cinsiyetiniz = Erkek] (confidence: 0.857)
[2. Yaşınız = 18-29] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Mesleğiniz = Öğrenci] (confidence: 0.863)
[Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda, Online alışverişte ne sıklıkla çevrimiçi yorumları incelersini = Çoğu Zaman] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] (confidence: 0.864)
[Ne tür ürünleri online mağazalardan alırsınız = Elektronik] --> [Cinsiyetiniz = Erkek] (confidence: 0.865)
[Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Alışveriş yöntemi tercihiniz = İkisini de eşit olarak kullanırım] --> [Online alışverişte ne sıklıkla çevrimiçi yorumları incelersini = Çoğu Zaman] (confidence: 0.865)
[Online alışverişi tercih sebebiniz = Fiyat avantajı, Geleneksel alışveriş tercih nedeniniz = Ürünleri anında görebilme ve deneyebilme] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.865)
[Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda, Cinsiyetiniz = Kadın] --> [Ne tür ürünleri online mağazalardan alırsınız = Giyim] (confidence: 0.870)
[Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] --> [Online alışverişte ne sıklıkla çevrimiçi yorumları incelersini = Çoğu Zaman] (confidence: 0.871)
[Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda, Cinsiyetiniz = Erkek] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.873)
[Geleneksel alışveriş tercih nedeniniz = Ürünleri anında görebilme ve deneyebilme] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.873)
[Mesleğiniz = Memur] --> [Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman] (confidence: 0.875)
[Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda, Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman] --> [Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] (confidence: 0.879)
[Online alışverişi tercih sebebiniz = Fiyat avantajı, Cinsiyetiniz = Erkek] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.880)
[Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda, Online alışverişi tercih sebebiniz = Fiyat avantajı, Cinsiyetiniz = Erkek] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.881)

[Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda, Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman] --> [Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] (confidence: 0.881)
[Yaşınız = 18-29] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.882)
[Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Cinsiyetiniz = Erkek, Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] --> [Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman] (confidence: 0.884)
[Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.886)
[Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda, Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman] (confidence: 0.895)
[Cinsiyetiniz = Erkek, Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.896)
[Alışveriş yöntemi tercihiniz = İkisini de eşit olarak kullanırım] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.897)
[Mesleğiniz = Öğrenci, Yaşınız = 18-29] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.898)
[Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman, Eğitim durumunuz = Lisans] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.902)
[Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman, Mesleğiniz = Öğrenci] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.902)
[Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli, Geleneksel alışveriş tercih nedeniniz = Ürünleri anında görebilme ve deneyebilme] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.902)
[Mesleğiniz = Öğrenci] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.904)
[Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli, Alışveriş yöntemi tercihiniz = İkisini de eşit olarak kullanırım] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.905)
[Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda, Geleneksel alışveriş tercih nedeniniz = Ürünleri anında görebilme ve deneyebilme] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.906)

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[Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Mesleğiniz = Memur] --> [Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman] (confidence: 0.909)
[Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda, Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] --> [Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman] (confidence: 0.911)
[Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda, Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] --> [Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman] (confidence: 0.912)
[Mesleğiniz = Memur] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.917)
[Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman, Cinsiyetiniz = Erkek] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.923)
[Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman, Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.924)
[Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman, Mesleğiniz = Öğrenci] --> [2. Yaşınız = 18-29] (confidence: 0.927)
[Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman, Cinsiyetiniz = Erkek, Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.927)
[Cinsiyetiniz = Erkek, Ne tür ürünleri online mağazalardan alırsınız = Elektronik] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.933)
[Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.936)
[Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Mesleğiniz = Öğrenci] --> [2. Yaşınız = 18-29] (confidence: 0.936)
[Ne tür ürünleri online mağazalardan alırsınız = Elektronik] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.942)
[Mesleğiniz = Öğrenci] --> [Yaşınız = 18-29] (confidence: 0.942)
[Eğitim durumunuz = Lisans, Yaşınız = 18-29] --> [Mesleğiniz = Öğrenci] (confidence: 0.949)
[Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman, Ne tür ürünleri online mağazalardan alırsınız = Giyim] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.952)

[Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman, Cinsiyetiniz = Kadın] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.952)
[Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman, Mesleğiniz = Memur] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.952)
[Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman, Geleneksel alışveriş tercih nedeniniz = Ürünleri anında görebilme ve deneyebilme] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.957)
[Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman, Alışveriş yöntemi tercihiniz = İkisini de eşit olarak kullanırım] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.957)
[Yaşınız = 18-29] --> [Mesleğiniz = Öğrenci] (confidence: 0.961)
[Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman, 2. Yaşınız = 18-29] --> [Mesleğiniz = Öğrenci] (confidence: 0.974)
[Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda, Alışveriş yöntemi tercihiniz = İkisini de eşit olarak kullanırım] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.976)
[Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman, Online alışverişi tercih sebebiniz = Fiyat avantajı] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.976)
[Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli, Yaşınız = 18-29] --> [Mesleğiniz = Öğrenci] (confidence: 0.978)
[Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda, Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman, Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.981)
[Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda, Alışverişte fiyat mı ürün kalitesi mi önemli = İkisi de eşit derecede önemli] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.982)
[Ne tür ürünleri geleneksel mağazalardan alırsınız = Gıda, Online alışverişte ne sıklıkla çevrimiçi yorumları incelersiniz = Çoğu Zaman] --> [Alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli mi = Önemli] (confidence: 0.983)
[Eğitim durumunuz = Lisans, Mesleğiniz = Öğrenci] --> [Yaşınız = 18-29] (confidence: 1.000)

Yukarıda verilen birliktelik kurallarından bazılarını açıklayacak olursak;
% 80 güven ile alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli, alışverişte fiyat ve ürün kalitesinin aynı derece önemli olduğunu söyleyen kişilerin geleneksel alışverişte çoğunlukla gıda aldıkları tespit edilmiştir.

% 80.8 güven seviyesi ile cinsiyeti erkek ve çoğunlukla elektronik ürünleri online alışverişle yapan kişilerin mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli olduğunu söylemişlerdir.

% 85.2 güven ile eğitim durumu lisans olan kişilerin mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli olduğunu söylemişlerdir.

% 86.5 güven seviyesi ile mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmet önemli ve her iki alışveriş yöntemini de eşit kullanan kişilerin online alışverişte çoğunlukla çevrimiçi yorumları inceledikleri tespit edilmiştir.

% 87 güven ile cinsiyeti kadın ve gıda alışverişini geleneksel mağazalardan yapan kişilerin giyim alışverişini online olarak yaptıkları belirlenmiştir.

% 89.5 güven seviyesi ile gıda alışverişini geleneksel mağazalardan yapan, alışverişte fiyat ve ürün kalitesinin aynı derecede önemli olduğunu söyleyen ve alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmetin önemli olduğunu belirten kişilerin online alışverişte çevrimiçi yorumları çoğunlukla inceledikleri tespit edilmiştir.

% 90.2 güven ile online alışverişte çevrimiçi yorumları çoğunlukla inceleyen ve eğitim durumu lisans olan kişiler için alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmetin önemli olduğu tespit edilmiştir.

% 90.4 güven seviyesi ile mesleği öğrenci olan kişilerin alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmetin önemli olduğunu söyledikleri belirlenmiştir.

% 92.7 güven seviyesi ile mesleği öğrenci ve yaşı 18-29 arasında olan kişilerin online alışverişte çevrimiçi yorumları inceledikleri belirlenmiştir.

% 93.3 güven seviyesi ile cinsiyeti erkek ve online alışverişi çoğunlukla elektronik ürün alırken kullanan kişilerin alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmetin önemli olduğunu söyledikleri tespit edilmiştir.

%95.7 güven ile online alışverişte çevrimiçi yorumları çoğunlukla inceleyen ve geleneksel alışveriş sebebinin çoğunlukla ürünleri anında görebilme ve deneyebilme olduğunu söyleyen kişilerin alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmetin önemli olduğunu söyledikleri tespit edilmiştir.

%98.1 güven seviyesi ile gıda ürünlerini daha çok geleneksel mağazalardan alan, online alışverişte çevrimiçi yorumları çoğunlukla inceleyen ve alışverişte fiyat ve ürün kalitesinin eşit derecede önemli olduğunu söyleyen kişilerin alışverişte mağaza çalışanlarının ya da müşteri hizmetlerinin size sunduğu hizmetin önemli olduğunu belirtmişlerdir.

% 100 güven seviyesi ile eğitim durumu lisans ve mesleği öğrenci olan kişilerin yaş aralıklarının 18-29 arasında oldukları tespit edilmiştir.

4. GENEL DEĞERLENDİRME VE SONUÇLAR

Yapılan bu çalışmada, Tüketicilerin geleneksel ve online alışveriş tercih sebeplerinin tespit edilebilmesi için birliktelik analizlerinden biri olan FP-Growth algoritmasından yararlanılmıştır. Yapılan birliktelik analizi sonucunda % 70 üstü güvenirliliğe sahip 134 birliktelik kuralı elde edilmiştir. Bu kurallar sayesinde geleneksel ve online olarak ürün satan firmalar karlılıklarını ve ürün kalitelerini arttırabilirler. Aynı zamanda tüketiciler hakkında daha fazla bilgilere de sahip olabilirler. Pazarlama alanında birliktelik analizi çalışmaları sınırlı sayıdadır. Bu alanda çalışmalar arttırılarak firmalar için yararlı bilgiler elde edilebilir. Bununla birlikte ileride birliktelik analizi alanında çalışma yapacak araştırmacılara faydalı bilgiler sağlanabilir.

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DEĞİŞTİRİLMİŞ Pİ-SİGMA YAPAY SİNİR AĞI İLE BORSA ÖNGÖRÜSÜ

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ÖZET

Pi-Sigma yapay sinir ağları birçok yapay sinir ağı yönteminden farklı olarak hem toplamsal hem de çarpımsal birleştirme fonksiyonuna sahiptir. Pi-Sigma yapay sinir ağlarında ağın girdi tabakası ile gizli tabakası arasında ağırlık ve yan değerleri var iken gizli ve çıktı tabakası arasındaki ağırlıklar sabit alınmaktadır. Pi-Sigma yapay sinir ağlarının aksine, Değiştirilmiş Pi-Sigma yapay sinir ağında ise gizli ve çıktı tabakası arasındaki ağırlık ve yan değerleri de optimizasyon sürecine dahil edilmiş ve böylece öngörü performansı Pi-Sigma yapay sinir ağından daha yüksek bir yapay sinir ağı olan değiştirilmiş Pi-Sigma yöntemi önerilmiştir. Değiştirilmiş Pi-Sigma yapay sinir ağının eğitimi de parçacık sürü optimizasyonu ile gerçekleştirilmiştir. Bu çalışmada değiştirilmiş Pi-Sigma yapay sinir ağı yöntemi kullanılarak Euro/Dolar paritesi zaman serisi analiz edilmiş ve değiştirilmiş Pi-Sigma yapay sinir ağı yöntemi çeşitli yapay sinir ağı yöntemleri ile karşılaştırılmıştır.

Anahtar Kelimeler: Değiştirilmiş Pi-Sigma Yapay Sinir Ağları, Parçacık Sürü Optimizasyonu, Öngörü.

1. GİRİŞ

Klasik öngörü modellerinin içerdiği varsayımları içermeyen yapay sinir ağları (YSA), klasik zaman serisi yaklaşımlarına alternatif olarak yaygın ve başarılı bir şekilde kullanılmaktadır. Literatürde en sık kullanılan yapay sinir ağı modeli Rumelhart ve ark. (1986) tarafından önerilen çok katmanlı algılayıcı yapay sinir ağı (ÇKA-YSA) modelidir. ÇKA-YSA'nın en önemli problemlerinden biri gizli tabaka birim sayısının belirlenmesidir. Bu problemi elemine etmek için gizli tabaka birim sayısı problemine

sahip olmayan bir yapay sinir ağı Yadav ve ark. (2007) tarafından önerilen çarpımsal nöron modelli yapay sinir ağlarıdır (ÇNM-YSA). ÇNM-YSA birleştirme fonksiyonu olarak sadece çarpımsal bir fonksiyon kullanmaktadır. Shin ve Ghosh (1991) tarafından önerilen Pi-Sigma yapay sinir ağları (PS-YSA) ise hem toplamsal hem de çarpımsal birleştirme fonksiyonlarına sahip olmakla birlikte, ÇKA-YSA'ya göre daha basit bir yapıya, daha az değişkenliğe ve daha hızlı yakınsama hızına sahiptir. PS - YSA girdi, gizli ve çıktı tabakalarına sahip bir yapay sinir ağı olmakla birlikte ağın parametre sayısı girdi sayısına ve gizli tabaka birim sayısına bağlı olarak değişmektedir. Gizli ve çıktı tabakası arasında herhangi bir ağırlık ya da yan değeri optimizasyon sürecine dahil olmamakla birlikte bu tabakalar arasındaki ağırlık değerleri bir alınmakta ve bu bir değeri de sabit bir değerdir. Egrioglu ve Bas (2023) çalışmasında ise değiştirilmiş bir PS-YSA (DPS-YSA) yöntemi önerilmiştir. DPS-YSA yönteminde PS-YSA'dan farklı olarak gizli ve çıktı tabakaları arasındaki ağırlıklar değiştirilebilir alınmış ve yan değerleri ilave edilmiştir. PS-YSA yöntemi zaman serisi öngörü probleminde sıklıkla kullanılmaktadır. Deepa ve ark. (2018) tümör verisi analizi için ateş böceği sürüsü optimizasyon algoritmasına dayalı bir PS-YSA önermiştir. Nayak (2020) kaotik ham petrol fiyatı zaman serisi öngörüsü için havai fişek algoritmasına dayalı bir PS-YSA önermiştir. Pattanayak ve ark. (2020) öngörü problemi için hibrit kimyasal reaksiyon optimizasyon algoritmasına dayalı bir PS-YSA önermiştir. Yılmaz ve ark. (2022) çalışmasında PS-YSA'nın eğitiminde diferansiyel gelişim algoritması kullanılmıştır. Bas ve ark. (2022) çalışmasında PS-YSA'nın eğitiminde sinüs kosinüs optimizasyon algoritması kullanılmıştır.

Bu çalışmada DPS-YSA yönteminin analiz performansı 2022 yılına ait Euro/Dolar paritesi açılış değerlerine ait zaman serisi üzerinden değerlendirilmiş ve ÇKA-YSA, ÇNM-YSA ve PS-YSA yöntemleri ile bir karşılaştırma gerçekleştirilmiştir.

Çalışmanın geri kalan bölümleri şu şekildedir: Çalışmanın ikinci bölümünde DPS-YSA yöntemi adım adım tanıtılmıştır. Çalışmanın üçüncü bölümünde DPS-YSA yönteminin parçacık sürü optimizasyonu yöntemi ile eğitimi verilmiştir. Çalışmanın dördüncü bölümünde uygulama başlığı altında Euro/Dolar paritesi zaman serisi çeşitli yapay sinir ağı yöntemleri ile analiz edilmiştir. Beşinci bölüm ise çalışmanın sonucu ve tartışması ile ilgilidir.

2. DEĞİŞTİRİLMİŞ Pİ-SİGMA YAPAY SİNİR AĞI

PS-YSA girdi, gizli ve çıktı tabakalarından oluşan bir yapay sinir ağı olmakla birlikte PS-YSA'da girdi ve gizli tabaka arasında ağırlık ve yan değerleri ile girdi tabakasından gizli

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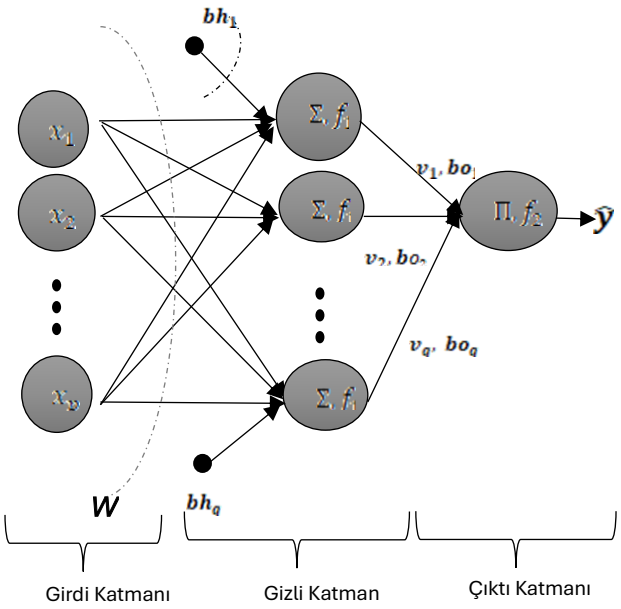
tabakaya doğru bir veri akışı bulunmaktadır. Ancak PS-YSA'da gizli tabaka ile çıktı tabakası arasındaki ağırlık değerleri sabit ve bir yan değerleri ise sabit ve sıfırdır. Egrioglu ve Bas (2023) tarafından önerilen DPS-YSA'da ise gizli tabaka ile çıktı tabakası arasındaki ağırlık ve yan değerleri sabit değil değiştirilebilirdir. DPS-YSA'nın mimarisi Görsel 1'de verilmiştir.



Görsel 1. DPS-YSA Mimarisi

Görsel 1'de $W = w_{ij}\,(i = 1,2,\cdots,p\,, j = 1,2,\cdots q)$ i. girdiden j. gizli katmana giden ağırlıkları; $\mathrm{bh_j}$ $(\mathrm{j} = 1,2,\cdots \mathrm{q})$ j. gizli katman birimi için yan değerini; $\mathrm{v_j}(\mathrm{j} = 1,2,\cdots \mathrm{q})$ ve $\mathrm{bo_j}(\mathrm{j} = 1,2,\cdots \mathrm{q})$ sırasıyla gizli katman ve çıktı arasındaki ağırlık ve yan değerleridir. $\mathrm{h_j}$gizli katman biriminin çıktısı olmak üzere Eşitlik (1) ile hesaplanır. Ağın nihai çıktısı ise Eşitlik (2) ile hesaplanmaktadır.

$$\mathrm{h_j} = \mathrm{f_1}\left(\sum_{\mathrm{i=1}}^{\mathrm{N}} \mathrm{w_{ij}x_i} + \mathrm{bh_j}\right),\ \ \mathrm{j} = 1,2,\cdots,\mathrm{q} \qquad (1)$$

$$\hat{y} = f_2\left(\prod_{j=1}^{q}(v_j \times h_j + bo_j)\right) = \frac{1}{1+exp\ \left(-\prod_{j=1}^{q}(v_j \times h_j + bo_j)\right)} \qquad (2)$$

Eşitlik (2)'de $f_2(x) = \frac{1}{1+exp(-x)}$ lojistik aktivasyon fonksiyonudur.

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3. DEĞİŞTİRİLMİŞ Pİ-SİGMA YAPAY SİNİR AĞININ PARÇACIK SÜRÜ İLE EĞİTİMİ

Egrioglu ve Bas (2023) tarafından önerilen DPS-YSA yönteminin parçacık sürü optimizasyonu ile eğitimi Algoritma 1 ile verilmektedir.

Algoritma 1. DPS-YSA yönteminin parçacık sürü optimizasyonu ile eğitimi

Adım 1. PSO parametrelerinin belirlenmesi

pn: Parçacık sayısı
c_{1i}: Bilişsel katsayı için minimum değer
c_{1f}: Bilişsel katsayı için maksimum değer
c_{2i}: Sosyal katsayı için minimum değer
c_{2f}: Sosyal katsayı için maksimum değer
w_1: Eylemsizlik ağırlığı için minimum değer
w_2:. Eylemsizlik ağırlığı için maksimum değer

Adım 2. Her bir parçacığın başlangıç hız ve pozisyon değerlerinin üretilmesi

Her bir parçacık için başlangıç hız ve konumları $U\ (0,1)$ ile rastgele oluşturulur.

Adım 3. Her bir parçacık için uygunluk değerinin hesaplanması

Her bir parçacığın uygunluk değeri eğitim kümesi üzerinden Eşitlik (3) ile verilen hata kareler ortalaması karekök (HKOK) kriteri kullanılarak hesaplanır. Eşitlik (3)'de $ntrn$, eğitim kümesi uzunluğunu ifade etmektedir.

$$HKOK = \sqrt{\frac{1}{ntrn}\sum_{i=1}^{ntrn}(y_i - \hat{y})^2} \quad (3)$$

Adım 4. $Pbest$ ve $Gbest$'in belirlenmesi.

$Pbest_k$ k. parçacığın geçerli iterasyona kadar bulunduğu en iyi pozisyonlarının vektörü ve $Gbest$ ise sürünün geçerli iterasyona kadar bulunduğu en iyi pozisyonunun vektörü olmak üzere $Pbest$ ve $Gbest$ sırası ile Eşitlik (4) ve (5)'de verildiği gibi belirlenir.

$$\mathrm{Pbest_k} = \{\mathrm{pb_{k,1}}, \dots, \mathrm{pb_{k,d}}\}, \mathrm{k} = 1,2,\cdots,\mathrm{pn} \quad (4)$$

$$\mathrm{Gbest} = \{\mathrm{P_{g,1}}, \dots, \mathrm{P_{g,d}}\} \quad (5)$$

Adım 5. c_1, c_2 ve w parametrelerini hesaplanması.

c_1, c_2 ve w parametreleri her bir iterasyonda Eşitlik (6) – (8) ile hesaplanır.

$$\mathrm{c_1(t)} = (\mathrm{c_{1f}} - \mathrm{c_{1i}})\frac{\mathrm{t}}{\mathrm{maxt}} + \mathrm{c_{1i}} \quad (6)$$

$$\mathrm{c_2(t)} = (\mathrm{c_{2f}} - \mathrm{c_{2i}})\frac{\mathrm{t}}{\mathrm{maxt}} + \mathrm{c_{2i}} \quad (7)$$

$$\mathrm{w(t)} = (\mathrm{w_2} - \mathrm{w_1})\frac{\mathrm{maxt-t}}{\mathrm{maxt}} + \mathrm{w_1} \quad (8)$$

Eşitlik (6)-(8)'de t, mevcut iterasyonu, $maxt$ ise maksimum iterasyon sayısını göstermektedir.

Adım 6. Hız ve pozisyon değerlerinin güncellenmesi

Hız ve pozisyon değerleri sırası ile Eşitlik (9) ve (10) ile güncellenmektedir.

$$v_{i,j}^{t+1} = \left[w(t) \times v_{i,j}^{t} + c_1(t) \times rand_1 \times \left(pb_{i,j} - p_{i,j}\right) + c_2(t) \times rand_2 \times \left(p_{g,j} - p_{i,j}\right)\right] \quad (9)$$

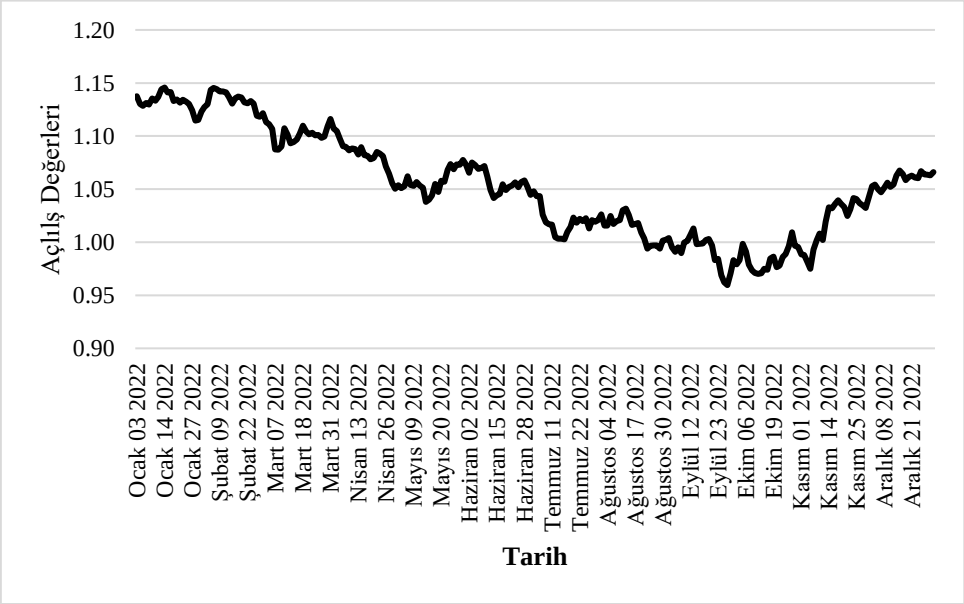
$$p_{i,j}^{t+1} = p_{i,j} + v_{i,j}^{t+1} \quad (10)$$

Adım 7. Durdurma koşulunun kontrol edilmesi

Adım 3 ve 6 arası önceden belirlenen maksimum iterasyon sayısına kadar devam ettirilir.

4. UYGULAMA

Bu çalışmada DPS-YSA yönteminin analiz performansı grafiği Görsel 2 ile verilen 2022 yılına ait Euro/Dolar paritesi açılış değerlerine ait zaman serisi üzerinden gerçekleştirilmiştir. İlgili zaman serisi blok yapıda eğitim, geçerlilik ve test kümesine ayrılmakla beraber geçerlilik ve test kümesi uzunluğu her bir zaman serisi için 20 olarak alınmıştır. Analiz sürecinde DPS-YSA yöntemi ÇKA-YSA, ÇNM-YSA ve PS-YSA yöntemleri ile karşılaştırılmıştır. İlgili yöntemlerin performans karşılaştırmasında HKOK kriteri kullanılmıştır.



Görsel 2. 2022 Yılı Euro/Dolar Paritesi Açılış Değerlerine Ait Zaman Serisi

Euro/Dolar paritesi açılış değerlerine ait zaman serisi analizinde, her bir yöntemin girdi sayısı (p) 1 ile 5 arasında birer arttırılmış ve ÇKA-YSA, PS-YSA ve DPS-YSA gizli tabaka birim sayıları (m) 1 ile 5 arasında birer arttırılmıştır. Her bir yöntem için belirlenen optimal parametreler ile her bir analiz yöntemi on farklı rasgele başlangıç ile tekrar çalıştırılarak on farklı HKOK değeri elde edilmiştir. Her bir yöntem için de elde edilen bu on farklı HKOK değerinin ortalama, standart sapma, minimum ve maksimum istatistikleri ilgili zaman serilerinin test kümeleri üzerinden hesaplanmıştır.

Euro/Dolar paritesi açılış değerlerine ait zaman serinin ilgili tüm analiz yöntemlerinden elde HKOK değerlerinin ortalama, standart sapma, minimum ve maksimum istatistikleri ve optimal parametreleri Çizelge 1'de verilmiştir.

Çizelge 1. Euro/Dolar Paritesi Zaman Serisinin Test Kümesi İçin Tüm Yöntemlerden Elde Edilen HKOK Değerlerine Ait Çeşitli İstatistikler

Yöntemler	Ortalama	Standart Sapma	Minimum	Maksimum	p	m
ÇKA-YSA	0,0193	0,0126	0,0054	0,0376	3	2
ÇNM-YSA	0,0074	0,0017	0,0045	0,0097	5	-
PS-YSA	0,0062	0,0012	0,0046	0,0088	3	3
DPS-YSA	0,0057	0,0014	0,0042	0,0102	5	4

Çizelge 1 incelendiğinde ilgili zaman serisinin analizinde en düşük ortalama ve minimum istatistiğine sahip olan yöntemin DPS-YSA olduğu görülmektedir. DP-YSA yöntemi standart sapma istatistiğine en başarılı ikinci yöntem olarak da görülmektedir.

4. SONUÇ VE TARTIŞMA

PS-YSA yönteminde gizli ve çıktı tabakası arasında kalan ağırlıklar sabit alınmakla birlikte bu tabakalar arasında kalan hem ağırlık hem de yan değerleri optimizasyon sürecine dahil edilmemektedir. DPS-YSA yönteminde ise bu tabakalar arasında kalan ağırlık ve yan değerleri de ağın eğitim sürecine dahil edilmiştir. Bu çalışmada ise DPS-YSA yönteminin öngörü performansı 2022 Yılı Euro/Dolar paritesi açılış değerlerine ait zaman serisi üzerinden ÇKA-YSA, ÇNM-YSA ve PS-YSA yöntemleri ile karşılaştırılmıştır. Elde edilen analiz sonuçları doğrultusunda DPS-YSA yönteminin diğer yapay sinir ağı yöntemlerinden üstün öngörü sonuçları ürettiği sonucuna varılmıştır. İleriki çalışmalarda DPS-YSA yönteminin eğitim algoritmasında farklı yapay zekâ optimizasyon algoritmaları kullanılabilir.

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DAYANIKLI RESİM BULANIK REGRESYON FONKSİYONLARI YAKLAŞIMI İLE BORSA ÖNGÖRÜSÜ

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ÖZET

Resim bulanık regresyonları fonksiyonları yaklaşımı en küçük kareler regresyon yöntemi ve resim bulanık kümeleme yöntemine dayalı olarak çalışan bir bulanık çıkarım sistemi yöntemidir. Bir resim bulanık regresyon fonksiyonları yaklaşımında girdiler; zaman serisinin gecikmeli değişkenleri ile resim bulanık kümeleme yöntemleri ile elde edilen pozitif, nötral ve negatif üyelik değerleridir. Bu özellikleri ile bir resim bulanık regresyon fonksiyonları yaklaşımının bir sezgici bulanık regresyon fonksiyonları yaklaşımının bir genellemesi olduğu söylenebilir. Resim bulanık regresyon fonksiyonları yaklaşımının da girdilerinin birinin zaman serisinin gecikmeli değişkenleri olması sebebi ile tıpkı sezgici bulanık regresyon fonksiyonları yaklaşımı gibi resim bulanık regresyon fonksiyonları yaklaşımı da zaman serisinde bulunan aykırı değerlerden olumsuz etkilenmektedir. Bu çalışmada aykırı değer varlığında dahi üstün öngörü performansına sahip dayanıklı bir resim bulanık regresyon fonksiyonları yaklaşımı önerilmiştir. Önerilen yöntemde, resim bulanık regresyon fonksiyonu yaklaşımı için parametre tahmini Andrews fonksiyonuna dayalı dayanıklı regresyon ile gerçekleştirilmektedir. Önerilen bu dayanıklı resim bulanık regresyon fonksiyonları yaklaşımının öngörü performansı Amerikan Doları/Japon Yeni paritesi zaman serisi üzerinden değerlendirilmiş ve ilgili yöntem çeşitli bulanık çıkarım sistemi yöntemleri ile karşılaştırılmıştır.

Anahtar Kelimeler: Resim Bulanık Regresyonları Fonksiyonları, Aykırı Değer, Öngörü.

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1. GİRİŞ

Sezgici bulanık regresyon fonksiyonları (SBRF) yaklaşımının bir genellemesi olan resim bulanık regresyon fonksiyonları (RBRF) yaklaşımı Bas ve ark. (2020) tarafından önerilmiştir. SBRF yaklaşımında sistemin girdileri zaman serisinin gecikmeli değişkenlerinin yanı sıra, Chaira (2011) tarafından önerilen sezgici bulanık kümeleme yöntemi ile elde edilen üyelik değerleri ve üyelik olmama değerleridir. RBRF yaklaşımında ise sistemin girdileri zaman serisinin gecikmeli değişkenlerinin yanı sıra, Thong ve Son (2016) tarafından önerilen resim bulanık kümeleme yöntemi ile elde edilen pozitif, nötral ve negatif üyelik değerleridir. RBRF yönteminde literatürdeki birçok bulanık çıkarım sisteminden farklı olarak bu negatif ve nötral üyelik değerlerini kullanarak sisteme ek bir bilgi girişi sağlanmaktadır. RBRF yönteminde nihai çıktı ise her bir üyelik değerine bağlı olarak elde edilen tahminlerin ağırlıklı ortalamaları ile elde edilir. RBRF yöntemi ve resim bulanık kümeleme yöntemi zaman serisi öngörü probleminde sıklıkla kullanılmaktadır. Thong (2017) çalışmasında parçacık sürüsü optimizasyonu ve resim bileşik kardinalitine dayalı yeni bir otomatik resim bulanık kümeleme yöntemi önerilmiştir. Son ve Thong (2017) çalışmasında hava durumu tahmini için resim bulanık kümelemeye dayalı hibrit öngörü yöntemleri önerilmiştir. Egrioglu ve ark. (2020) çalışmasında yeni bir resim bulanık zaman serisi öngörü yöntemi önerilmiştir. Rath ve Dutta (2024) çalışmasında parçacık sürü optimizasyonunun yeni bir varyantı ile resimli bulanık zaman serisi tahmin yöntemi önerilmiştir.

RBRF yaklaşımında, tıpkı bulanık regresyon fonksiyonları (BRF) ve SBRF yaklaşımında olduğu gibi, sistemin girdilerinden birinin zaman serisinin gecikmeli değişkenleri olması nedeni ile bu yöntemin aykırı değerlerden etkilenilmesi kaçınılmazdır. Bu amaçla aykırı değer/değerler varlığında dahi üstün öngörü performansına sahip bir RBRF yaklaşımı olan dayanıklı resim bulanık regresyon fonksiyonları yaklaşımları (DRBRF) Bas ve Egrioglu (2024) tarafından önerilmiştir. Bu çalışmada Bas ve Egrioglu (2024) çalışmasından da farklı olarak parametre tahmini, dayanıklı regresyon tabanlı Andrews fonksiyonu kullanılarak yapılmıştır. Önerilen bu yöntemin analiz performansı da 2022 yılına ait Amerikan Doları/Japon Yeni (USD/JPY) paritesi açılış değerlerine ait zaman serisi üzerinden değerlendirilmiştir.

Çalışmanın geri kalan bölümleri şu şekildedir: Çalışmanın ikinci bölümünde Andrews fonksiyonuna dayalı olarak önerilen DRBRF yaklaşımı adım adım verilmiştir. Çalışmanın üçüncü bölümünde USD/JPY zaman serisinin hem orijinal gözlemlere sahip olduğu durum hem

de aykırı değerlere sahip olduğu durum için analizler gerçekleştirilmiştir. Dördüncü bölüm ise çalışmanın sonucu ve tartışması ile ilgilidir.

2. ÖNERİLEN YÖNTEM

RBRF yönteminde parametre tahmini sıradan en küçük kareler yöntemi ile yapılmakla birlikte veri setinde aykırı değer bulunduğu durumda en küçük kareler yönteminin kullanılması uygun değildir. Bu çalışmada, veri setinde aykırı değer olduğu durumda dahi kullanılabilecek bir DRBRF yaklaşımı önerilmiştir. Önerilen bu yeni yöntemde parametre tahmini Andrews ağırlık fonksiyonunu kullanan bir dayanıklı regresyon ile yapılmıştır. Andrews ağırlık fonksiyonuna dayalı olarak önerilen dayanıklı bir resim bulanık regresyonu fonksiyonları (DRBRF-Andrews) yaklaşımının algoritması Algoritma 1 ile verilmiştir.

Algoritma 1. DRBRF-Andrews yaklaşımının algoritması

Adım 1. Resim bulanık küme sayısı (c), gecikme sayısı (p), eğitim kümesi uzunluğu (n) ve test kümesi uzunluğu $(ntest)$ belirlenir.

Adım 2. Eğitim kümesinin gecikmeli değişkenlerinden oluşan girdiler ve bu girdilere karşılık gelen çıktılar ile bir D matrisinde bir araya getirilerek Eşitlik (1) ile verilen D matrisi resim bulanık kümeleme yöntemi ile kümelenir ve pozitif üyelik değerleri $(\mu_A(x))$, nötral üyelik değerleri $(\eta_A(x))$ ve negatif üyelik değerleri $(\nu_A(x))$ elde edilir.

$$D = \begin{bmatrix} x_1 & x_2 & \cdots & x_p & x_{p+1} \\ x_2 & x_3 & \cdots & x_{p+1} & x_{p+2} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{n-p} & x_{n-p+1} & \cdots & x_{n-1} & x_n \end{bmatrix} \quad (1)$$

Adım 3. Eğitim kümesi için Eşitlik (2-3) ile verilen X matrisi ve Y vektörü oluşturulur.

$$X^{(i)} = \begin{bmatrix} 1 & \mu_{i1} & \mu_{i1}^2 & \exp(\mu_{i1}^2) & \eta_{i1} & \eta_{i1}^2 & \exp(\eta_{i1}^2) & \nu_{i1} & \nu_{i1}^2 & \exp(\nu_{i1}^2) & x_1 & x_2 & \cdots & x_p \\ 1 & \mu_{i2} & \mu_{i2}^2 & \exp(\mu_{i2}^2) & \eta_{i2} & \eta_{i2}^2 & \exp(\eta_{i2}^2) & \nu_{i2} & \nu_{i2}^2 & \exp(\nu_{i2}^2) & x_2 & x_3 & \cdots & x_{p+1} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & \mu_{in} & \mu_{in}^2 & \exp(\mu_{in}^2) & \eta_{in} & \eta_{in}^2 & \exp(\eta_{in}^2) & \nu_{in} & \nu_{in}^2 & \exp(\nu_{in}^2) & x_{n-p} & x_{n-p+1} & \cdots & x_{n-1} \end{bmatrix} \quad (2)$$

$$Y^{(i)} = \begin{bmatrix} x_{p+1} \\ x_{p+2} \\ \vdots \\ x_n \end{bmatrix} \quad (3)$$

Eşitlik (2) ile oluşturulan X matrisinde, pozitif, nötral ve negatif üyelik değerlerine ek olarak bu üyelik değerlerinin üstel ve çeşitli logaritmik dönüşümleri verilmiştir.

Adım 4. Her bir resim bulanık kümesi için, resim bulanık regresyon fonksiyonları Eşitlik (4-5) ile Andrews fonksiyonuna dayalı olarak tahmin edilir.

$$\hat{\beta}^{(i)} = (X^{(i)'} W_{Andrews} X^{(i)})^{-1} X^{(i)'} W_{Andrews} Y^{(i)} \quad (4)$$

$$\hat{Y}^{(i)} = X^{(i)} \hat{\beta}^{(i)} \; ; \; i = 1, 2, \dots c \quad (5)$$

Eşitlik (4)'de, $W_{Andrews}$ fonksiyonu Andrews ağırlık fonksiyonu olmakla birlikte bu ağırlık fonksiyonu Eşitlik (6-7) ile hesaplanır.

$$W_{Andrews} = \begin{cases} \frac{Sin(r)}{r} & |r| < \pi \\ 0 & d.d. \end{cases} \quad (6)$$

$$r = \frac{resid}{tune \times \hat{\sigma} \times \sqrt{(1-h)}} \quad (7)$$

Adım 5. Pozitif üyelik değerleri, nötral üyelik değerleri ve negatif üyelik değerleri için tahminler sırası ile Eşitlik (8-10) ile elde edilir.

$$\hat{Y}_j^{Pozitif} = \frac{\sum_{i=1}^{c} \mu_{ij} \hat{Y}_j^{(i)}}{\sum_{i=1}^{c} \mu_{ij}} \quad j = 1,2, \dots, n \quad (8)$$

$$\hat{Y}_j^{\text{nötral}} = \frac{\sum_{i=1}^{c} \nu_{ij} \hat{Y}_j^{(i)}}{\sum_{i=1}^{c} \nu_{ij}} \quad j = 1,2, \dots, n \quad (9)$$

$$\hat{Y}_j^{\text{negatif}} = \frac{\sum_{i=1}^{c} \eta_{ij} \hat{Y}_j^{(i)}}{\sum_{i=1}^{c} \eta_{ij}} \quad j = 1,2, \dots, n \quad (10)$$

Adım 6. Eğitim kümesi için nihai tahminler elde edilir.

Eğitim kümesi için nihai tahminler $\left(\hat{Y}_j^{DRBRF}\right)$, $\hat{Y}_j^{Pozitif}$, $\hat{Y}_j^{\text{nötral}}$ ve $\hat{Y}_j^{\text{negatif}}$ tahminlerinin ağırlıklı ortalaması ile Eşitlik (11)'de verildiği gibi elde edilir.

$$\hat{Y}_j^{DRBRF} = w_1\hat{Y}_j^{Pozitif} + w_2\hat{Y}_j^{\text{nötral}} + w_3\hat{Y}_j^{\text{negatif}} \quad (11)$$

Her bir w ağırlığının belirlenmesi, eğitim verileri üzerinden Eşitlik (12) ile verilen optimizasyon problemi ile genetik algoritmaya yöntemi kullanılarak gerçekleştirilir.

$$\min_{w_1,w_2,w_3} \sum_{j=p+1}^{n} \left(w_1\hat{Y}_j^{Pozitif} + w_2\hat{Y}_j^{\text{nötral}} + w_3\hat{Y}_j^{\text{negatif}} - Y_j\right)^2 \quad (12)$$
$$Yan\ Şart: \sum_{i=1}^{3} w_i = 1; 0 \leq w_i \leq 1, i = 1,2,3$$

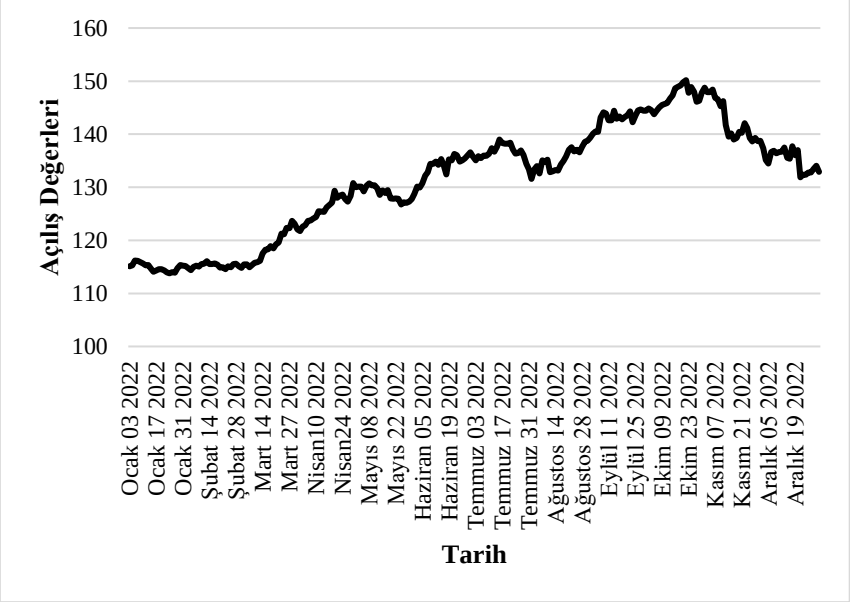
Adım 7. Test kümesi için tahminler elde edilir.

Eşitlik (2)'de verilen açıklayıcı değişkenler matrisi test kümesi için yeniden oluşturulur ve test kümesi için tahminler elde edilir.

3. UYGULAMA

Bu çalışmada önerilen DRBRF-Andrews yönteminin analiz performansı, öncelikle grafiği Görsel 1 ile verilen 2022 yılına ait USD/JPY paritesi açılış değerlerine ait zaman serisi üzerinden gerçekleştirilmiştir. Daha sonra ise USD/JPY paritesi zaman serisinin 15. gözlemi ilgili zaman serisinin maksimum değerinin on katı olacak şekilde değiştirilmiş ve aykırı değere sahip olan bu zaman serisinin de analizi gerçekleştirilmiştir. Hem orijinal hem de aykırı değere sahip USD/JPY paritesi zaman serisinin analizinde ilgili zaman serisi blok yapıda eğitim, geçerlilik ve test kümesine ayrılmakla beraber geçerlilik ve test kümesi uzunluğu her bir zaman serisi için 20 olarak alınmıştır. Önerilen DRBRF-Andrews yönteminin analiz performansı Türkşen (2008) tarafından önerilen BRF, Bas ve ark. (2021) tarafından önerilen SBRF ile Bas ve ark. (2020) tarafından önerilen RBRF yöntemi ile ilgili zaman serisinin hem orijinal hem de aykırı değer içerdiği durumu için ayrı ayrı değerlendirilmiştir. İlgili yöntemlerin performans karşılaştırmasında Eşitlik (13) ile verilen hata kareler ortalaması karekök (HKOK) kriteri kullanılmıştır.

$$HKOK = \sqrt{\frac{\sum_{t=1}^{ntest}(X_t - \hat{X}_t)^2}{ntest}} \quad (15)$$



Görsel 1. 2022 Yılı USD/JPY Paritesi Açılış Değerlerine Ait Zaman Serisi

Her bir zaman serisinin analizinde BRF, SBRF, RBRF ve DRBRF-Andrews yönteminin girdi sayısı (p) 1 ile 5 arasında birer arttırılmış ve ilgili küme sayıları (c) 3 ile 10 arasında birer arttırılmıştır. Her bir yöntem için belirlenen optimal parametreler ile her bir analiz yöntemi on farklı rasgele başlangıç ile tekrar çalıştırılarak on farklı HKOK değeri elde edilmiştir. Her bir yöntem için de elde edilen bu on farklı HKOK değerinin ortalama, standart sapma, minimum ve maksimum istatistikleri ilgili zaman serilerinin test kümeleri üzerinden hesaplanmıştır.

Orijinal gözlemlere sahip USD/JPY paritesi zaman serinin ilgili tüm analiz yöntemlerinden elde HKOK değerlerinin ortalama, standart sapma, minimum ve maksimum istatistikleri ve optimal parametreleri Çizelge 1'de verilmiştir.

Çizelge 1. USD/JPY Paritesi Zaman Serisinin Test Kümesi İçin Tüm Yöntemlerden Elde Edilen HKOK Değerlerine Ait Çeşitli İstatistikler

Yöntemler	Ortalama	Standart Sapma	Minimum	Maksimum	p	c
BRF	1,5674	1,5712	1,5587	1,5712	1	7
SBRF	1,5263	1,5264	1,5263	1,5264	1	2
RBRF	1,5231	0,0411	1,4689	1,5741	1	2
DRBRF-Andrews	1,4934	0,0000	1,4934	1,4934	2	2

Çizelge 1 incelendiğinde orijinal gözlemlere sahip USD/JPY paritesi zaman serinin analizi için en iyi yöntemin en düşük ortalama, standart sapma ve maksimum HKOK istatistiklerine sahip

olan DRBRF-Andrews yöntemi olduğu görülmektedir. DRBRF-Andrews yöntemi minimum istatistiğine göre ise en başarılı ikinci yöntem olarak görülmektedir.

Aykırı değere sahip USD/JPY paritesi zaman serinin ilgili tüm analiz yöntemlerinden elde HKOK değerlerinin ortalama, standart sapma, minimum ve maksimum istatistikleri ve optimal parametreleri Çizelge 2'de verilmiştir.

Çizelge 2. Aykırı Değere Sahip USD/JPY Paritesi Zaman Serisinin Test Kümesi İçin Tüm Yöntemlerden Elde Edilen HKOK Değerlerine Ait Çeşitli İstatistikler

Yöntemler	Ortalama	Standart Sapma	Minimum	Maksimum	p	c
BRF	2,1166	2,1166	2,1166	2,1166	3	9
SBRF	3,2751	2,3093	1,9508	10,7303	1	6
RBRF	3,8419	2,3606	2,1039	10,1154	4	9
DRBRF-Andrews	1,5354	0,0000	1,5354	1,5354	6	10

Çizelge 2 incelendiğinde aykırı değere sahip USD/JPY paritesi zaman serinin analizi için en iyi yöntemin en düşük ortalama, standart sapma, minimum ve maksimum HKOK istatistiklerine sahip olan DRBRF-Andrews yöntemi olduğu görülmektedir. Çizelge 1 ve 2 birlikte incelendiğinde BRF, SBRF, RBRF yöntemlerinin veri setinde bulunan aykırı değerden etkilendiği ortalama, standart sapma, minimum ve maksimum istatistiklerindeki artıştan açıkça görülebilmektedir. Ayrıca, DRBRF-Andrews yönteminin veri setinde bulunana aykırı değerden neredeyse hiç etkilenmediği sonucuna ilgili istatistiklerinin hemen hemen hiç değişmediğinden varılabilir.

4. SONUÇ VE TARTIŞMA

RBRF yaklaşımı üstün öngörü performansına sahip olmasına rağmen veri setinde bulunan aykırı değer varlığından etkilenmektedir. Bu çalışmada veri setinde aykırı değer olduğu durumda dahi kullanılabilecek bir RBRF yöntemi olan DRBRF-Andrews yöntemi önerilmiştir. Önerilen bu DRBRF-Andrews yönteminde parametre tahmini Andrews ağırlık fonksiyonuna dayalı olarak gerçekleştirilmiştir. USD/JPY paritesi açılış değerlerine ait zaman serisini hem orijinal gözlemlere sahip olduğu durum için hem de ilgili zaman serisine aykırı değer eklendiği durum için yapılan analiz sonuçlarına göre DRBRF-Andrews yönteminin en başarılı yöntem olduğu sonucuna varılmıştır. Veri setinde aykırı değer olduğu durumda dahi DRBRF-Andrews yöntemi bu aykırı değer varlığından hemen hemen hiç etkilenmez iken karşılaştırmada

kullanılan diğer bulanık çıkarım sistemi yöntemleri ise veri setinde bulunan aykırı değer varlığından etkilenmiştir. İleriki çalışmalarda farklı ağırlık fonksiyonlarına dayalı resim bulanık regresyonu fonksiyonları önerilebilir.

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COEFFICIENT BOUND ESTIMATES FOR THE PSEUO-STARLIKE FUNCTION CLASS OF COMPLEX ORDER

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ÖZET

Bu çalışmada, biz yıldızıl ve ünivalent fonksiyonların psevdo-yıldızıl altsınıfı olarak adlandırılan kompleks mertebeden bir sınıfını tanımladık. Burada, biz bu tanımlanan sınıfa ait olan fonksiyonların ilk iki katsayısı için üst sınır değerlendirmesi verdik. Ayrıca, tanımlanan sınıf için Fekete-Szegö problemini de çözdük.

Anahtar Kelimeler: Yıldızıl fonksiyon, ünivalent fonksiyon, psevdo-konveks fonksiyon, kompleks mertebe

ASTRACT

In this study, we defined a new subclass of starlike and univalent functions, which called pseudo-starlike function class of complex order. Here, we gave bound estimates for initial two coefficients of the functions belonging to this defined function class. The Fekete-Szegö problem for the defined class is also solved.

Keywords: Starlie function, univalent function, pseudo-starlike function, complex order

1. Introduction and Preliminaries

Let $H(U)$ be the class of analytic functions in the open unit disk $U=\{z\in\mathbb{C}:|z|<1\}$ of the complex plane $\mathbb{C}$. Let A be the class of the functions $f\in H(U)$ given by the following series expansions

$$f(z)=z+a_2z^2+a_3z^3+a_4z^4+\cdots+a_nz^n+\cdots=z+\sum_{n=2}^{\infty}a_nz^n,\ a_n\in\mathbb{C}\ . \tag{1.1}$$

The subclass of A, which is univalent functions in the open unit disk U, denoted by S. This class was introduced by Köebe [1] first time. Within a short period, Biebarch [2] published a paper in which the famous coefficient hypothesis was proposed. This hypothesis states that if $f\in S$ and has the series form (1.1), then $|a_n|\le n$ for each $n\ge 2$. It was De-Branges [3], who settled this long-lasting hypothesis. There were a lot of papers devoted to this hypothesis and its related coefficient problems (see [4-18, 26]).

The sarlike function class defined in the open unit disk U is defined analytically as follows

$$S^*=\left\{f\in S:\ \mathrm{Re}\left(\frac{zf'(z)}{f(z)}\right)>0,\ z\in U\right\}.$$

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Let's $f, g \in H(U)$, then it is said that f is subordinate to g and denoted by $f \prec g$, if there exists a Schwartz function ω, such that $f(z) = g(\omega(z))$.

In the past few years, numerous subclasses of the collection S have been introduced as special choices of the class S^* (see for example [5, 8, 10-26]).

Now, let's define some new subclass of univalent functions in the open unit disk U.

Definition 1.1. For $\lambda > \frac{1}{2}$ and $\tau \in \mathbb{C} - \{0\}$ the function $f \in S$ is said to be in the class $S^*_{\sinh}(\lambda, \tau)$, if the following condition is satisfied

$$\left\{1 + \frac{1}{\tau}\left[\frac{z\left(f'(z)\right)^{\lambda}}{f(z)} - 1\right]\right\} \prec 1 + \sinh z,\ z \in U.$$

From the Definition 1.1, in the special values of the parameters λ and τ, we have the following function classes.

Definition 1.2. For $\tau \in \mathbb{C} - \{0\}$ the function $f \in S$ is said to be in the class $S^*_{\sinh}(\tau)$, if the following condition is satisfied

$$\left\{1 + \frac{1}{\tau}\left[\frac{zf'(z)}{f(z)} - 1\right]\right\} \prec 1 + \sinh z,\ z \in U.$$

Definition 1.3. For $\lambda > \frac{1}{2}$ the function $f \in S$ is said to be in the class $S^*_{\sinh}(\lambda)$, if the following condition is satisfied

$$\frac{z\left(f'(z)\right)^{\lambda}}{f(z)} \prec 1 + \sinh z,\ z \in U.$$

Definition 1.4. For the function $f \in S$ is said to be in the class $S^*_{\sinh}$, if the following condition is satisfied

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$$\frac{zf'(z)}{f(z)} \prec 1+\sinh z,\ z \in U .$$

Let P be the class of analytic functions in U satisfied the conditions $p(0)=1$ and $\mathrm{Re}(p(z))>0$, $z \in U$. The function $p \in \mathrm{P}$ has a series expansion of the following form

$$p(z)=1+p_1 z+p_2 z^2+p_3 z^3+\cdots=1+\sum_{n=1}^{\infty} p_n z^n,\ z \in U . \tag{1.2}$$

We give some necessary lemmas for the proof of our main results.

Lemma 1.1 ([27]). Let the function p belong in the class P. Then,

$|p_n| \le 2$ for each $n \in \mathbb{N}$ and $|p_n - \nu p_k p_{n-k}| \le 2$ for $n,k \in \mathbb{N}$, $n>k$ and $\nu \in [0,1]$.

The equalities holds for the function

$$p(z)=\frac{1+z}{1-z}.$$

Lemma 1.2 ([27]) Let the an analytic function p be of the form (1.2), then

$$2p_2 = p_1^2+(4-p_1^2)x,\ 4p_3 = p_1^3+2(4-p_1^2)p_1 x-(4-p_1^2)p_1 x^2+2(4-p_1^2)(1-|x|^2)y$$

for $x,y \in \mathbb{C}$ with $|x| \le 1$ and $|y| \le 1$.

In this paper, we give some coefficient estimates and examine Fekete-Szegö problem for the class $S^*_{\sinh}(\lambda,\tau)$.

2. Main Results

In this section, we give firstly some coefficient estimates for the functions belonging to the class $S^*_{\sinh}(\lambda,\tau)$.

Theorem 2.1. Let the function f given by series expansions (1.1) belong to the class $S^*_{\sinh}(\lambda,\tau)$. Then, we have

$$|a_2|\le\frac{|\tau|}{2\lambda-1}\ \text{and}\ |a_3|\le\frac{|\tau|}{3\lambda-1}\begin{cases}1 & \text{if}\ \left|\left(2\lambda^2-4\lambda+1\right)\tau\right|\le(2\lambda-1)^2,\\ \dfrac{\left|\left(2\lambda^2-4\lambda+1\right)\tau\right|}{(2\lambda-1)^2} & \text{if}\ \left|\left(2\lambda^2-4\lambda+1\right)\tau\right|\ge(2\lambda-1)^2.\end{cases}\tag{2.1}$$

Proof. Let $f\in S^*_{\sinh}(\lambda,\tau)$, then exists Schwartz function $\omega:U\to U$, such that

$$\frac{z\left(f'(z)\right)^{\lambda}}{f(z)}=1+\tau\sinh\omega(z),\ z\in U.\tag{2.2}$$

Let the function $p\in P$ defined as follows:

$$p(z)=\frac{1+\omega(z)}{1-\omega(z)}=1+p_1z+p_2z^2+p_3z^3+\ldots=1+\sum_{n=1}^{\infty}p_nz^n,\ z\in U.\tag{2.3}$$

It follows from that

$$\omega(z)=\frac{p(z)-1}{p(z)+1}=\frac{p_1}{2}z+\frac{1}{2}\left(p_2-\frac{p_1^2}{2}\right)z^2+\frac{1}{2}\left(p_3-p_1p_2-\frac{p_1^3}{4}\right)z^3\ldots,\ z\in U.\tag{2.4}$$

From the equalities (2.2) and (2.4), can written

$$\begin{aligned}(2\lambda-1)a_2z+\left[(3\lambda-1)a_3+\left(2\lambda^2-4\lambda+1\right)a_2^2\right]z^2+\cdots\\ =\tau\left\{\frac{p_1}{2}z+\left(\frac{p_2}{2}-\frac{p_1^2}{4}\right)z^2+\cdots\right\},\ z\in U.\end{aligned}\tag{2.5}$$

Comparing the coefficients of the same degree terms on the right and left sides of the equality (2.5), we obtain the following equalities for the coefficients a_2 and a_3 of the function f

$$a_2 = \frac{\tau p_1}{2(2\lambda - 1)}, \tag{2.6}$$

$$(3\lambda - 1)a_3 + (2\lambda^2 - 4\lambda + 1)a_2^2 = \tau\left[\frac{p_2}{2} - \frac{p_1^2}{4}\right]. \tag{2.7}$$

Applying Lemma 1.1 to the equality (2.6), we obtain the first estimate of the theorem.

From the equalities (2.6) and (2.7), we obtain the following equality for the coefficient a_3

$$a_3 = \frac{1}{3\lambda - 1}\left\{\tau\left[\frac{p_2}{2} - \frac{p_1^2}{4}\right] - \frac{(2\lambda^2 - 4\lambda + 1)\tau^2}{4(2\lambda - 1)^2} p_1^2\right\};$$

that is,

$$a_3 = \frac{\tau}{2(3\lambda - 1)}\left\{p_2 - \frac{(2\lambda^2 - 4\lambda + 1)\tau + (2\lambda - 1)^2}{2(2\lambda - 1)^2} p_1^2\right\}. \tag{2.8}$$

Then, from the Lemma 1.2, we can write

$$a_3 = \frac{\tau}{4(3\lambda - 1)}\left\{(4 - p_1^2)x - \frac{(2\lambda^2 - 4\lambda + 1)\tau}{(2\lambda - 1)^2} p_1^2\right\} \tag{2.9}$$

for some $x \in \mathbb{C}$ with $|x| \le 1$. Applying triangle inequality, we obtain

$$|a_3| \le \frac{|\tau|}{4(3\lambda - 1)}\left\{(4 - t^2)\xi + \frac{\left|(2\lambda^2 - 4\lambda + 1)\tau\right|}{(2\lambda - 1)^2} t^2\right\}, \ \xi \in [0,1], \tag{2.10}$$

where $\xi = |x|$ and $t = |p_1|$. From here, easily see that

$$|a_3| \le \frac{|\tau|}{4(3\lambda - 1)(2\lambda - 1)^2}\left\{\left[\left|(2\lambda^2 - 4\lambda + 1)\tau\right| - (2\lambda - 1)^2\right]t^2 + 4(2\lambda - 1)^2\right\}, \ t \in [0,2]. \tag{2.11}$$

Then, maximizing the function

$$\chi(t)=\left[\left|\left(2\lambda^2-4\lambda+1\right)\tau\right|-\left(2\lambda-1\right)^2\right]t^2+4\left(2\lambda-1\right)^2,$$

it can easily be seen that $\chi(t)\le 4(2\lambda-1)^2$ if $\left|\left(2\lambda^2-4\lambda+1\right)\tau\right|\le(2\lambda-1)^2$ and $\chi(t)\le 4\left|\left(2\lambda^2-4\lambda+1\right)\tau\right|$ if $\left|\left(2\lambda^2-4\lambda+1\right)\tau\right|\ge(2\lambda-1)^2$.

With this, the proof of theorem is completed.

In the cases $\tau=1$, $\lambda=1$ and $\lambda=\tau=1$ from the Theorem 2.1, we obtain the following results, respectively.

Corollary 2.1. If $f\in S^*_{\sinh}(\lambda)$, then

$$|a_2|\le\frac{1}{2\lambda-1} \text{ and } |a_3|\le\frac{1}{3\lambda-1}\begin{cases}1 & \text{if } \left|2\lambda^2-4\lambda+1\right|\le(2\lambda-1)^2,\\ \dfrac{\left|2\lambda^2-4\lambda+1\right|}{(2\lambda-1)^2} & \text{if } \left|2\lambda^2-4\lambda+1\right|\ge(2\lambda-1)^2.\end{cases}$$

Corollary 2.2. If $f\in S^*_{\sinh}(\tau)$, then

$$|a_2|\le|\tau| \text{ and } |a_3|\le\frac{|\tau|}{2}\begin{cases}1 & \text{if } |\tau|\le 1,\\ |\tau| & \text{if } |\tau|\ge 1.\end{cases}$$

Corollary 2.3. If $f\in S^*_{\sinh}$, then $|a_2|\le 1$ and $|a_3|\le\frac{1}{2}$.

Now, we give the following theorem on the Fekete-Szegö prolem for the class $S^*_{\sinh}(\lambda,\tau)$.

Theorem 2.2. Let $f\in S^*_{\sinh}(\lambda,\tau)$ and $\mu\in\mathbb{R}$, then

$$\left|a_3-\mu a_2^2\right|\le\frac{|\tau|}{3\lambda-1}\begin{cases}1 & \\ \text{if } \left|\left[2\lambda^2-4\lambda+1+(3\lambda-1)\mu\right]\tau\right|\le(2\lambda-1)^2, & \\ \dfrac{\left|\left[2\lambda^2-4\lambda+1+(3\lambda-1)\mu\right]\tau\right|}{(2\lambda-1)^2} & \\ \text{if } \left|\left[2\lambda^2-4\lambda+1+(3\lambda-1)\mu\right]\tau\right|\ge(2\lambda-1)^2. & \end{cases} \tag{2.12}$$

Proof. Let $f\in S^*_{\sinh}(\lambda,\tau)$ and $\mu\in\mathbb{R}$, then from the equalities (2.6) and (2.9), we can write

$$a_3-\mu a_2^2=\frac{\tau}{4(3\lambda-1)}\left\{\left(4-p_1^2\right)x-\frac{\left[2\lambda^2-4\lambda+1+(3\lambda-1)\mu\right]\tau}{(2\lambda-1)^2}p_1^2\right\} \tag{2.13}$$

for some $x\in\square$ with $|x|\le 1$.

Applying triangle inequality to the equality (2.13), we obtain

$$\left|a_3-\mu a_2^2\right|\le\frac{|\tau|}{4(3\lambda-1)}\left\{\left(4-t^2\right)\xi+\frac{\left|\left[2\lambda^2-4\lambda+1+(3\lambda-1)\mu\right]\tau\right|}{(2\lambda-1)^2}t^2\right\},\ \xi\in[0,1],$$

where $\xi=|x|$ and $t=|p_1|$. From here easily can written

$$\left|a_3-\mu a_2^2\right|\le\frac{|\tau|}{4(3\lambda-1)}\left\{\frac{\left|\left[2\lambda^2-4\lambda+1+(3\lambda-1)\mu\right]\tau\right|-(2\lambda-1)^2}{(2\lambda-1)^2}t^2+4\right\},\ t\in[0,2]. \tag{2.14}$$

Maximizing the function $\varphi:[0,2]\to\square$ defined as follows

$$\varphi(t)=\frac{\left|\left[2\lambda^2-4\lambda+1+(3\lambda-1)\mu\right]\tau\right|-(2\lambda-1)^2}{(2\lambda-1)^2}t^2+4,\ t\in[0,2],$$

we can easily see that $\varphi(t)\le 4$ if $\left|\left[2\lambda^2-4\lambda+1+(3\lambda-1)\mu\right]\tau\right|\le(2\lambda-1)^2$ and

$$\varphi(t)\le\frac{4\left|\left[2\lambda^2-4\lambda+1+(3\lambda-1)\mu\right]\tau\right|}{(2\lambda-1)^2}$$

if $\left|\left[2\lambda^2-4\lambda+1+(3\lambda-1)\mu\right]\tau\right|\ge(2\lambda-1)^2$.

Thus, the proof of theorem is completed.

Taking $\tau=1$, $\lambda=1$ and $\lambda=\tau=1$ in the Theorem 2.2, we obtain the following results, respectively.

Corollary 2.4. If $f\in S_{\sinh}^{*}(\lambda)$ and $\mu\in\square$, then

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$$\left|a_3-\mu a_2^2\right|\le\frac{1}{3\lambda-1}\begin{cases}1 \\ if\ \left|\left[2\lambda^2-4\lambda+1+(3\lambda-1)\mu\right]\right|\le(2\lambda-1)^2, \\ \dfrac{\left|\left[2\lambda^2-4\lambda+1+(3\lambda-1)\mu\right]\right|}{(2\lambda-1)^2} \\ if\ \left|\left[2\lambda^2-4\lambda+1+(3\lambda-1)\mu\right]\right|\ge(2\lambda-1)^2.\end{cases}$$

Corollary 2.5. If $f\in S^*_{\sinh}(\tau)$ and $\mu\in\mathbb{R}$, then

$$\left|a_3-\mu a_2^2\right|\le\frac{|\tau|}{2}\begin{cases}1 & if\ \left|(1-2\mu)\tau\right|\le 1, \\ \left|(1-2\mu)\tau\right| & if\ \left|(1-2\mu)\tau\right|\ge 1.\end{cases}$$

Corollary 2.6. If $f\in S^*_{\sinh}$ and $\mu\in\mathbb{R}$, then

$$\left|a_3-\mu a_2^2\right|\le\frac{1}{2}\begin{cases}1 & if\ \left|1-2\mu\right|\le 1, \\ \left|1-2\mu\right| & if\ \left|1-2\mu\right|\ge 1.\end{cases}$$

Also, clases $\mu=0$ and $\mu=1$ from the Theorem 2.2, we obtain the following results.

Corollary 2.7. If $f\in S^*_{\sinh}(\lambda,\tau)$ and $\mu\in\mathbb{R}$, then,

$$\left|a_3\right|\le\frac{|\tau|}{3\lambda-1}\begin{cases}1 & if\ \left|\left(2\lambda^2-4\lambda+1\right)\tau\right|\le(2\lambda-1)^2, \\ \dfrac{\left|\left(2\lambda^2-4\lambda+1\right)\tau\right|}{(2\lambda-1)^2} & if\ \left|\left(2\lambda^2-4\lambda+1\right)\tau\right|\ge(2\lambda-1)^2.\end{cases}$$

Corollary 2.8. If $f\in S^*_{\sinh}(\lambda,\tau)$ and $\tau\in\mathbb{R}-\{0\}$, then,

$$\left|a_3-a_2^2\right|\le\frac{|\tau|}{3\lambda-1}\begin{cases}1 & if\ \left|\left(2\lambda^2-1\right)\tau\right|\le(2\lambda-1)^2, \\ \dfrac{\left|\left(2\lambda^2-1\right)\tau\right|}{(2\lambda-1)^2} & if\ \left|\left(2\lambda^2-1\right)\tau\right|\ge(2\lambda-1)^2.\end{cases}.$$

Remark 2.1. We note that Corollary 2.7 confirms the second result of Theorem 2.1.

3. Conclusions and Evaluations

In this study, we considered the coefficient and Fekete-Szegö prolem for the new pseudo-starlike function class of complex order of analytic functions. In this study, unlike the results available in the literature (we should note that the case $\lambda \geq 1$ is examined in the literature), the pseudo-starlike function class of complex order for $\lambda > \frac{1}{2}$ is examined. The estimates obtained for $\lambda \geq 1$ confirm the results available in the literature.

4. General Evaluation and Conclusions

For the class defined in the paper, an upper bound estimate of the second Hankel determinant can also be performed. In addition, the broader class of this class, the $q-$pseudo-starlike function class of complex order, can be defined and similar work can be done for this class.

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COEFFICIENT BOUND ESTIMATES FOR THE PSEUDO-CONVEX FUNCTION CLASS OF COMPLEX ORDER

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ÖZET

Bu çalışmada, biz konveks ve ünivalent fonksiyonların psevdo-konveks altsınıfı olarak adlandırılan kompleks mertebeden bir sınıfını tanımladık. Burada, biz bu tanımlanan sınıfa ait olan fonksiyonların ilk iki katsayısı için üst sınır değerlendirmesi verdik. Ayrıca, tanımlanan bu sınıf için Fekete-Szegö problemini de çözdük.
Anahtar Kelimeler: Konveks fonksiyon, ünivalent fonksiyon, psevdo-konveks fonksiyon, kompleks mertebe

ASTRACT

In this study, we defined a new subclass of convex and univalent functions, which called pseudo-convex function class of complex order. Here, we gave bound estimates for initial two coefficients of the functions belonging to this defined function class. The Fekete-Szegö problem for the defined class is also solved.
Keywords: Convex function, univalent function, pseudo-convex function, complex order

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2. Introduction and Preliminaries

Let $H(U)$ be the class of analytic functions in the open unit disk $U=\{z\in\mathbb{C}:|z|<1\}$ of the complex plane $\mathbb{C}$. Let A be the class of the functions $f\in H(U)$ given by the following series expansions

$$f(z)=z+a_2z^2+a_3z^3+a_4z^4+\cdots+a_nz^n+\cdots=z+\sum_{n=2}^{\infty}a_nz^n,\ a_n\in\mathbb{C}\ . \tag{1.1}$$

The subclass of A, which is univalent functions in the open unit disk U, denoted by S. This class was introduced by Köebe [1] first time. Within a short period, [2] published a paper in which the famous coefficient hypothesis was proposed. This hypothesis states that if $f\in S$ and has the series form (1.1), then $|a_n|\le n$ for each $n\ge 2$. It was De-Branges [3], who settled this long-lasting hypothesis. There were a lot of papers devoted to this hypothesis and its related coefficient problems (see [4-18, 26]).

The convex function class defined in the open unit disk U is defined analytically as follows

$$C=\left\{f\in S:\ \mathrm{Re}\left(\frac{\left(zf'(z)\right)'}{f'(z)}\right)>0,\ z\in U\right\}.$$

Let's $f,g\in H(U)$, then it is said that f is subordinate to g and denoted by $f\prec g$, if there exists a Schwartz function ω, such that $f(z)=g(\omega(z))$.

In the past few years, numerous subclasses of the collection S have been introduced as special choices of the class C (see for example [5, 8, 10-26]).

Now, let's define some new subclass of univalent functions in the open unit disk U.

Definition 1.1. For $\lambda>\frac{1}{2}$ and $\tau\in\mathbb{C}-\{0\}$ the function $f\in S$ is said to be in the class $C_{\sinh}(\lambda,\tau)$, if the following conditions is satisfied

$$\left\{1+\frac{1}{\tau}\left[\frac{\left[\left(zf'(z)\right)'\right]^{\lambda}}{f'(z)}-1\right]\right\}\prec 1+\sinh z,\ z\in U\ .$$

From the Definition 1.1, in the special cases of the parameters λ and τ, we have the following function classes.

Definition 1.2. For $\tau \in \mathbb{C} - \{0\}$ the function $f \in S$ is said to be in the class $C_{\sinh}(\tau)$, if the following condition is satisfied

$$\left\{1+\frac{1}{\tau}\left[\frac{\left(zf'(z)\right)'}{f'(z)}-1\right]\right\} \prec 1+\sinh z,\ z \in U .$$

Definition 1.3. For $\lambda > \frac{1}{2}$ the function $f \in S$ is said to be in the class $C_{\sinh}(\lambda)$, if the following condition is satisfied

$$\frac{\left[\left(zf'(z)\right)'\right]^{\lambda}}{f'(z)} \prec 1+\sinh z,\ z \in U .$$

Definition 1.4. For the function $f \in S$ is said to be in the class $C_{\sinh}$, if the following condition is satisfied

$$\frac{\left(zf'(z)\right)'}{f'(z)} \prec 1+\sinh z,\ z \in U .$$

Let P be the class of analytic functions in U satisfied the conditions $p(0)=1$ and $\mathrm{Re}\left(p(z)\right)>0$, $z \in U$. The function $p \in \mathrm{P}$ has a series expansion of the following form

$$p(z)=1+p_1 z+p_2 z^2+p_3 z^3+\cdots=1+\sum_{n=1}^{\infty} p_n z^n,\ z \in U . \tag{1.2}$$

We give some necessary lemmas for the proof of our main results.

Lemma 1.1 ([27]). Let the function p belong in the class P. Then,

$|p_n| \le 2$ for each $n \in \mathbb{N}$ and $|p_n - \nu p_k p_{n-k}| \le 2$ for $n,k \in \mathbb{N}$, $n>k$ and $\nu \in [0,1]$.

The equalities holds for the function

$$p(z)=\frac{1+z}{1-z}.$$

Lemma 1.2 ([27]) Let the an analytic function p be of the form (1.2), then

$$2p_2 = p_1^2 + \left(4 - p_1^2\right)x,\ 4p_3 = p_1^3 + 2\left(4 - p_1^2\right)p_1 x - \left(4 - p_1^2\right)p_1 x^2 + 2\left(4 - p_1^2\right)\left(1 - |x|^2\right)y$$

for $x, y \in \square$ with $|x| \le 1$ and $|y| \le 1$.

In this paper, we give some coefficient estimates and examine Fekete-Szegö problem for the class $C_{\sinh}(\lambda, \tau)$.

2. Main Results

In this section, we give some coefficient estimates and examine Fekete-Szegö problem for the function class $C_{\sinh}(\lambda, \tau)$.

Theorem 2.1. Let the function f given by (1.1) belonging to the class $C_{\sinh}(\lambda, \tau)$. Then we have

$$|a_2| \le \frac{|\tau|}{2(2\lambda - 1)} \text{ and } |a_3| \le \frac{|\tau|}{6(3\lambda - 1)} \begin{cases} 1 \quad if \quad \left|(2\lambda-1)^2 - \left(2\lambda^2 - 4\lambda + 1\right)\tau\right| \le 2(2\lambda-1)^2, \\ \dfrac{\left|(2\lambda-1)^2 - \left(2\lambda^2 - 4\lambda + 1\right)\tau\right|}{(2\lambda-1)^2} \quad if \\ \left|(2\lambda-1)^2 - \left(2\lambda^2 - 4\lambda + 1\right)\tau\right| \ge 2(2\lambda-1)^2. \end{cases} \tag{2.1}$$

Proof. Let $f \in C_{\sinh}(\lambda, \tau),\ \lambda > \frac{1}{2}$ and $\tau \in \square - \{0\}$. Then, exists Schwartz function $\omega : U \to U$, such that

$$\frac{\left[\left(zf'(z)\right)'\right]^{\lambda}}{f'(z)} = 1 + \tau \sinh \omega(z),\ z \in U \tag{2.2}$$

Let the function $p \in P$ defined as follows

$$p(z) = \frac{1 + \omega(z)}{1 - \omega(z)} = 1 + p_1 z + p_2 z^2 + p_3 z^3 + \ldots = 1 + \sum_{n=1}^{\infty} p_n z^n,\ z \in U. \tag{2.3}$$

From this equality, easily can written

$$\omega(z) = \frac{p(z) - 1}{p(z) + 1} = \frac{p_1}{2} z + \frac{1}{2}\left(p_2 - \frac{p_1^2}{2}\right)z^2 + \frac{1}{2}\left(p_3 - p_1 p_2 - \frac{p_1^3}{4}\right)z^3 \ldots,\ z \in U. \tag{2.4}$$

Considering (2.4), from the (2.2) we can write

$$\begin{aligned} &2a_2\left(2\lambda-1\right)z+\left[3\left(3\lambda-1\right)a_3+\left(8\lambda^2-16\lambda+4\right)a_2^2\right]z^2+\cdots \\ &\qquad =\tau\left\{\frac{p_1}{2}z+\left(\frac{p_2}{2}-\frac{p_1^2}{4}\right)z^2+\cdots\right\},\ z\in U, \end{aligned} \tag{2.5}$$

which, follows that

$$a_2=\frac{p_1\tau}{4\left(2\lambda-1\right)},\ 3\left(3\lambda-1\right)a_3+4\left(2\lambda^2-4\lambda+1\right)a_2^2=\tau\left(\frac{p_2}{2}-\frac{p_1^2}{4}\right). \tag{2.6}$$

From the first equality of the (2.6), using to the Lemma 1.1, we obtain the first result of theorem.

From the equalities (2.6), we obtain

$$a_3=\frac{\tau}{3\left(3\lambda-1\right)}\left\{\frac{p_2}{2}-\frac{p_1^2}{4}-\frac{\left(2\lambda^2-4\lambda+1\right)\tau}{4\left(2\lambda-1\right)^2}p_1^{\,2}\right\};$$

that is,

$$a_3=\frac{\tau}{6\left(3\lambda-1\right)}\left\{p_2-\frac{\left(2\lambda-1\right)^2+\left(2\lambda^2-4\lambda+1\right)\tau}{4\left(2\lambda-1\right)^2}p_1^{\,2}\right\}.$$

Since $p_2=\frac{p_1^2}{2}+\frac{4-p_1^2}{2}x$ for some $x\in\square$ with $\left|x\right|\le 1$, from last equality we can write

$$a_3=\frac{\tau}{12\left(3\lambda-1\right)}\left\{\frac{\left(2\lambda-1\right)^2-\left(2\lambda^2-4\lambda+1\right)\tau}{2\left(2\lambda-1\right)^2}p_1^{\,2}+\left(4-p_1^2\right)x\right\}. \tag{2.7}$$

Applying triangle inequality to the equality (2.7), we have

$$\left|a_3\right|\le\frac{\left|\tau\right|}{12\left(3\lambda-1\right)}\left\{\frac{\left|\left(2\lambda-1\right)^2-\left(2\lambda^2-4\lambda+1\right)\tau\right|}{2\left(2\lambda-1\right)^2}t^2+\left(4-t^2\right)\xi\right\},\xi\in\left[0,1\right],$$

where $\xi=\left|x\right|$ and $t=\left|p_1\right|$. From this, we can easily show that

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$$|a_3| \le \frac{|\tau|}{24(3\lambda-1)(2\lambda-1)^2}\left\{\left[\left|(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right|-2(2\lambda-1)^2\right]t^2+8(2\lambda-1)^2\right\},$$
$$t\in[0,2].$$

Then, maximizing the function

$$\phi(t)=\left[\left|(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right|-2(2\lambda-1)^2\right]t^2+8(2\lambda-1)^2,\ t\in[0,2],$$

it can easily be seen that $\phi(t)\le 8(2\lambda-1)^2$ if $\left|(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right|\le 2(2\lambda-1)^2$ and $\phi(t)\le 4\left|(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right|$ if $\left|(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right|\ge 2(2\lambda-1)^2$.

Thus,

$$|a_3| \le \frac{|\tau|}{6(3\lambda-1)}\begin{cases} 1 \quad if \quad \left|(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right|\le 2(2\lambda-1)^2, \\ \dfrac{\left|(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right|}{(2\lambda-1)^2} \ if \\ \qquad \left|(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right|\ge 2(2\lambda-1)^2. \end{cases}$$

With this, the proof of theorem is completed.

Taking $\lambda=1$, $\tau=1$ and $\lambda=1=\tau$ in the Theorem 2.1, we obtain the following results, respectively.

Corollary 2.1. If $f\in C_{\sinh}(\tau)$, then

$$|a_2|\le\frac{|\tau|}{2} \text{ and } |a_3|\le\frac{|\tau|}{12}\begin{cases}1 & if \ |1+\tau|\le 2,\\ |1+\tau| & if \ |1+\tau|\ge 2.\end{cases}$$

Corollary 2.2. If $f\in C_{\sinh}(\lambda)$, then

$$|a_2|\le\frac{1}{2(2\lambda-1)} \text{ and } |a_3|\le\frac{1}{6(3\lambda-1)}\begin{cases}\dfrac{2\lambda^2}{(2\lambda-1)^2} & if \ \lambda\in\left(\dfrac{1}{2},1\right],\\ 1 & if \quad \lambda\ge 1.\end{cases}$$

Corollary 2.3. If $f\in C_{\sinh}$, then $|a_2|\le\frac{1}{2}$ and $|a_3|\le\frac{1}{6}$.

Now, we will focused to the solution of the Fekete-Szegö problem for the class $C_{\sinh}(\lambda,\tau)$.

Theorem 2.2. Let $f \in C_{\sinh}(\lambda,\tau)$ and $\mu \in \mathbb{R}$. Then,

$$\left|a_3-\mu a_2^2\right| \le \frac{|\tau|}{3(3\lambda-1)} \begin{cases} 1 \ \text{if} \ \left|2\left[(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right]-3(3\lambda-1)\mu\right| \le 4(2\lambda-1)^2, \\ \dfrac{\left|2\left[(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right]-3(3\lambda-1)\mu\right|}{4(2\lambda-1)^2} \quad \text{if} \\ \left|2\left[(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right]-3(3\lambda-1)\mu\right| \ge 4(2\lambda-1)^2. \end{cases} \tag{2.8}$$

Proof. Let $f \in C_{\sinh}(\lambda,\tau)$ and $\mu \in \mathbb{R}$. From the first equality of the (2.6) and (2.7), we can write

$$a_3-\mu a_2^2 = \frac{\tau}{12(3\lambda-1)}\left\{\left(4-p_1^2\right)x+\frac{2\left[(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right]-3(3\lambda-1)\mu}{4(2\lambda-1)^2}p_1^2\right\} \tag{2.9}$$

for some $x \in \mathbb{R}$ with $|x| \le 1$. Applying triangle inequality to the equality (2.9), we obtain

$$\left|a_3-\mu a_2^2\right| \le \frac{|\tau|}{12(3\lambda-1)}\left\{\left(4-t^2\right)\xi+\frac{\left|2\left[(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right]-3(3\lambda-1)\mu\right|}{4(2\lambda-1)^2}t^2\right\}, \xi \in [0,1],$$

where $\xi = |x|$ and $t = |p_1|$. It follows from that

$$\left|a_3-\mu a_2^2\right| \le \frac{|\tau|}{12(3\lambda-1)}\left\{\frac{\left|2\left[(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right]-3(3\lambda-1)\mu\right|-4(2\lambda-1)^2}{4(2\lambda-1)^2}t^2+4\right\} \tag{2.10}$$

$t \in [0,2]$.

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Maximizing the function on the right hand side of the inequality (2.10) according to the parameter t, we get

$$\left|a_3-\mu a_2^2\right| \leq \frac{|\tau|}{3(3\lambda-1)} \begin{cases} 1 \ \ if \ \ \left|2\left[(2\lambda-1)^2-\left(2\lambda^2-4\lambda+1\right)\tau\right]-3(3\lambda-1)\mu\right| \leq 4(2\lambda-1)^2, \\ \dfrac{\left|2\left[(2\lambda-1)^2-\left(2\lambda^2-4\lambda+1\right)\tau\right]-3(3\lambda-1)\mu\right|}{4(2\lambda-1)^2} \qquad if \\ \qquad \left|2\left[(2\lambda-1)^2-\left(2\lambda^2-4\lambda+1\right)\tau\right]-3(3\lambda-1)\mu\right| \geq 4(2\lambda-1)^2. \end{cases}$$

Thus, the proof of teorem is completed.

Taking $\lambda=1$, $\tau=1$ and $\lambda=1=\tau$ in the Theorem 2.2, we obtain the following results, respectively.

Corollary 2.4. If $f \in C_{\sinh}(\tau)$ and $\mu \in \mathbb{R}$, then

$$\left|a_3-\mu a_2^2\right| \leq \frac{|\tau|}{6} \begin{cases} 1 & if \ \ |1+\tau-3\mu| \leq 2, \\ \dfrac{|1+\tau-3\mu|}{2} & if \ \ |1+\tau-3\mu| \geq 2. \end{cases}$$

Corollary 2.5. If $f \in C_{\sinh}(\lambda)$ and $\mu \in \mathbb{R}$, then

$$\left|a_3-\mu a_2^2\right| \leq \frac{1}{3(3\lambda-1)} \begin{cases} 1 & if \ \ \left|4\lambda^2-3(3\lambda-1)\mu\right| \leq 4(2\lambda-1)^2, \\ \dfrac{\left|4\lambda^2-3(3\lambda-1)\mu\right|}{4(2\lambda-1)^2} & if \ \ \left|4\lambda^2-3(3\lambda-1)\mu\right| \geq 4(2\lambda-1)^2. \end{cases}$$

Corollary 2.6. If $f \in C_{\sinh}$ and $\mu \in \mathbb{R}$, then

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$$\left|a_3-\mu a_2^2\right|\le\frac{1}{6}\begin{cases}1 & if\ \ \left|2-3\mu\right|\le 2,\\ \dfrac{\left|2-3\mu\right|}{2} & if\ \ \left|2-3\mu\right|\le 2.\end{cases}$$

Also, taking $\mu=0$ and $\mu=1$ in the Theorem 2.2, we obtain the following results, respectively.

Corollary 2.7. If $f\in C_{\sinh}(\lambda,\tau)$, then,

$$\left|a_3\right|\le\frac{\left|\tau\right|}{3(3\lambda-1)}\begin{cases}1\ \ if\ \ \left|(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right|\le 2(2\lambda-1)^2,\\ \dfrac{\left|(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right|}{2(2\lambda-1)^2} \qquad if\\ \qquad \left|(2\lambda-1)^2-(2\lambda^2-4\lambda+1)\tau\right|\ge 2(2\lambda-1)^2.\end{cases}$$

Corollary 2.8. If $f\in C_{\sinh}(\lambda,\tau)$, then,

$$\left|a_3-a_2^2\right|\le\frac{\left|\tau\right|}{3(3\lambda-1)}\begin{cases}1\ \ if\ \ \left|8\lambda^2-17\lambda+5-2(2\lambda^2-4\lambda+1)\tau\right|\le 4(2\lambda-1)^2,\\ \dfrac{\left|8\lambda^2-17\lambda+5-2(2\lambda^2-4\lambda+1)\tau\right|}{4(2\lambda-1)^2} \qquad if\\ \qquad \left|8\lambda^2-17\lambda+5-2(2\lambda^2-4\lambda+1)\tau\right|\ge 4(2\lambda-1)^2.\end{cases}$$

Rematk 3.1. We note that Corollary 2.7 confirms the second result of Theorem 2.1.

3. Conclusions and Evaluations

In this study, we considered the coefficient and Fekete-Szegö prolem for the new pseudo-convex function class of complex order of analytic functions. In this study, unlike the results available in the literature (we should note that the case $\lambda\ge 1$ is examined in the literature), the pseudo-convex function classof complex order for $\lambda>\frac{1}{2}$ is examined. The evaluations obtained for $\lambda\ge 1$ confirm the results available in the literature.

4. General Evaluation and Conclusions

For the class defined in the paper, an upper bound estimate of the second Hankel determinant can also be performed. In addition, the broader class of this class, the $q-$pseudo-convex function class of complex order, can be defined and similar work can be done for this class.

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COEFFICIENT PROBLEM FOR THE PSEUDO-CONVEX BI-UNIVALENT FUNCTION CLASS

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ÖZET

Bu çalışmada, biz konveks ve bi-ünivalent fonksiyonların psevdo-konveks altsınıfı olarak adlandırılan bir sınıfını tanımladık. Burada, biz bu sınıf için bazı katsayı değerlendirmesi verdik ve Fkete-Szegö problemini çözdük.

Anahtar Kelimeler: Konveks fonksiyon, bi-ünivalent fonksiyon, psevdo-konveks fonksiyon

ASTRACT

In this study, we defined a new subclass of convex and bi-univalent functions, which called pseudo-convex function class. Here, we gave some coefficient estimates and solve Fekete-Szegö problem for this class.

Keywords: Convex function, bi-univalent function, pseudo-convex function

3. Introduction and Preliminaries

We will denote by $H(U)$ the class of analytic functions in the open unit disk $U=\{z\in\mathbb{C}:|z|<1\}$ of the complex plane $\mathbb{C}$. Let A be the class of the functions $f\in H(U)$ given by series expansions

$$f(z)=z+a_2z^2+a_3z^3+a_4z^4+\cdots+a_nz^n+\cdots=z+\sum_{n=2}^{\infty}a_nz^n,\ a_n\in\mathbb{C}\ . \tag{1.1}$$

The subclass of A, which are univalent functions in U is denoted by S in the literature. Bieberbach [1] proposed a coefficient hypothesis such that if $f\in S$ and has the series form (1.1), then $|a_n|\le n$ for each $n\ge 2$. Are many articles in the literature regarding to this hypothesis (see [2-13]).

It is well known that the class of bi-univalent functions in U is denoted by Σ in the literature. For the inverse $g(w)=f^{-1}(w)$ of the function $f\in\Sigma$, can written

$$g(w)=w+A_2w^2+A_3w^3+A_4w^4+\ldots=w+\sum_{n=2}^{\infty}A_nz^n,\ w\in f(U), \tag{1.2}$$

where

$$A_2=-a_2,\ A_3=2a_2^2-a_3,\ A_4=-a_2^3+5a_2a_3-a_4,\ldots\ .$$

As is known that bi-convex function class in the open unit disk U is denoted by C_Σ and defined analytically as follows

$$C_\Sigma=\left\{f\in S:\ \mathrm{Re}\left(\frac{\left(zf'(z)\right)'}{f'(z)}\right)>0,\ z\in U\ \text{and}\ \mathrm{Re}\left(\frac{\left(wg'(w)\right)'}{g'(w)}\right)>0,\ w\in f(U)=U_{r_0}\right\}.$$

Let's $f,g\in H(U)$, then it is said that f is subordinate to g and denoted by $f\prec g$, if there exists a Schwartz function ω, such that $f(z)=g(\omega(z))$.

In the past few years, numerous subclasses of the class S have been introduced as special choices of the class C_Σ (see for example [3, 14-20]).

Now, let's we define new subclass of analytic and bi-univalent functions in the open unit disk U.

Definition 1.1. For $\lambda>\frac{1}{2}$ the function $f\in\Sigma$ is said to be in the class $C_{\Sigma,\sinh}(\lambda)$, if the following conditions are satisfied

$$\frac{\left[\left(zf'(z)\right)'\right]^{\lambda}}{f'(z)}\prec 1+\sinh z,\ z\in U\ \text{and}\ \frac{\left[\left(wg'(w)\right)'\right]^{\lambda}}{g'(w)}\prec 1+\sinh w,\ w\in U_{r_0}.$$

In the case $\lambda = 1$, we have the following class of bi-univalent functions.

Definition 1.2. The function $f \in \Sigma$ is said to be in the class $C_{\Sigma,\sinh}$, if the following conditions are satisfied

$$\frac{\left(zf'(z)\right)'}{f'(z)} \prec 1+\sinh z,\ z \in U \text{ and } \frac{\left(wg'(w)\right)'}{g'(w)} \prec 1+\sinh w,\ w \in U_{r_0}.$$

Let P be the class of analytic functions in U satisfied the conditions $p(0)=1$ and $\mathrm{Re}\left(p(z)\right)>0,\ z \in U$. Also, these functions has a series expansion as follows

$$p(z) = 1 + p_1 z + p_2 z^2 + p_3 z^3 + \cdots = 1 + \sum_{n=1}^{\infty} p_n z^n,\ z \in U. \tag{1.3}$$

Let us give some necessary lemmas for the proof of our main results.

Lemma 1.1 ([21]). Let the function p belong to the class P. Then,

$$|p_n| \le 2 \text{ for each } n \in \mathbb{N},\ |p_n - \nu p_k p_{n-k}| \le 2 \text{ for } n,\ k \in \mathbb{N},\ n > k \text{ and } \nu \in [0,1].$$

Lemma 1.2 ([21]) Let the an analytic function p be of the form (1.3), then

$$2p_2 = p_1^2 + \left(4 - p_1^2\right)x,\ 4p_3 = p_1^3 + 2\left(4 - p_1^2\right)p_1 x - \left(4 - p_1^2\right)p_1 x^2 + 2\left(4 - p_1^2\right)\left(1 - |x|^2\right)y$$

for some $x, y \in \mathbb{D}$ with $|x| \le 1$ and $|y| \le 1$.

In this paper, we give some coefficient estimates and solve Fekete-Szegö problem for the class $C_{\Sigma,\sinh}(\lambda)$.

2. Main Results

In this section, we give coefficient estimates for the functions belonging to the class $C_{\Sigma,\sinh}(\lambda)$ and solve the Fekete-Szegö problem for this class.

First, let's give the following theorem on coefficients.

Theorem 2.1. Let the function f given by series expansions (1.1) belong to the class $C_{\Sigma,\sinh}(\lambda)$. Then, we have the following estimates

$$|a_2| \le \frac{1}{2(2\lambda-1)} \quad \text{and} \quad |a_3| \le \begin{cases} \dfrac{1}{4(2\lambda-1)^2} & if \quad \lambda \in \left(\dfrac{1}{2}, \dfrac{25+\sqrt{177}}{32}\right], \\ \dfrac{1}{3(3\lambda-1)} & if \quad \lambda \ge \dfrac{25+\sqrt{177}}{32}. \end{cases} \tag{2.1}$$

Obtained here results are sharp.

Proof. Let $f \in C_{\Sigma,\sinh}(\lambda)$, then exists Schwartz functions $\omega : U \to U, \varpi : U_{r_0} \to U_{r_0}$, such that

$$\frac{\left[\left(zf'(z)\right)'\right]^{\lambda}}{f'(z)} = 1+\sinh\omega(z), z \in U \quad \text{and} \quad \frac{\left[\left(wg'(w)\right)'\right]^{\lambda}}{g'(w)} = 1+\sinh\varpi(w), w \in U_{r_0}. \tag{2.2}$$

Let's the functions $p, q \in P$ defined as follows:

$$p(z) = \frac{1+\omega(z)}{1-\omega(z)} = 1+p_1 z+p_2 z^2+p_3 z^3+\ldots = 1+\sum_{n=1}^{\infty} p_n z^n, \; z \in U,$$

$$q(w) = \frac{1+\varpi(w)}{1-\varpi(w)} = 1+q_1 w+q_2 w^2+q_3 w^3+\ldots = 1+\sum_{n=1}^{\infty} q_n w^n, \; w \in U_{r_0}. \tag{2.3}$$

It follows from that

$$\omega(z) = \frac{p(z)-1}{p(z)+1} = \frac{p_1}{2} z+\frac{1}{2}\left(p_2-\frac{p_1^2}{2}\right)z^2+\frac{1}{2}\left(p_3-p_1 p_2-\frac{p_1^3}{4}\right)z^3\ldots, \; z \in U,$$

$$\varpi(w) = \frac{q(w)-1}{q(w)+1} = \frac{q_1}{2} w+\frac{1}{2}\left(q_2-\frac{q_1^2}{2}\right)w^2+\frac{1}{2}\left(q_3-q_1 q_2-\frac{q_1^3}{4}\right)w^3\ldots, w \in U_{r_0}. \tag{2.4}$$

From the equalities (2.2) and (2.4), we obtain

$$2a_2(2\lambda-1)z+\left[3(3\lambda-1)a_3+\left(8\lambda^2-16\lambda+4\right)a_2^2\right]z^2+\cdots = \frac{p_1}{2}z+\left(\frac{p_2}{2}-\frac{p_1^2}{4}\right)z^2+\cdots, \; z \in U,$$

$$2A_2(2\lambda-1)w+\left[3(3\lambda-1)A_3+\left(8\lambda^2-16\lambda+4\right)A_2^2\right]w^2+\cdots = 1+\frac{q_1}{2}w+\left(\frac{q_2}{2}-\frac{q_1^2}{4}\right)w^2+\cdots,$$

$$w \in f(U). \tag{2.5}$$

Therefore, considering (1.2) it is true

$$a_2=\frac{p_1}{4(2\lambda-1)},\qquad 3(3\lambda-1)a_3+4(2\lambda^2-4\lambda+1)a_2^2=\frac{p_2}{2}-\frac{p_1^2}{4}, \tag{2.6}$$

$$a_2=-\frac{q_1}{4(2\lambda-1)},\ 3(3\lambda-1)(2a_2^2-a_3)+4(2\lambda^2-4\lambda+1)a_2^2=\frac{q_2}{2}-\frac{q_1^2}{4}. \tag{2.7}$$

From first equalities of the equations (2.6) and (2.7), we can write

$$-\frac{q_1}{4(2\lambda-1)}=a_2=\frac{p_1}{4(2\lambda-1)}\quad\text{and}\quad p_1=-q_1. \tag{2.8}$$

Applying Lemma 1.1 to the equality (2.8), we obtain the first estimate of (2.1).

Considering the equality $p_1=-q_1$, from the second equalities of the (2.6) and (2.7) we obtain the following equality for the coefficient a_3

$$a_3=\frac{p_1^2}{16(2\lambda-1)^2}+\frac{p_2-q_2}{12(3\lambda-1)}. \tag{2.9}$$

Then, using Lemma 1.2, we can write

$$a_3=\frac{p_1^2}{16(2\lambda-1)^2}+\frac{4-p_1^2}{24(3\lambda-1)}(x-y) \tag{2.10}$$

for some $x,y\in\square$ with $|x|\le 1$ and $|y|\le 1$. Applying triangle inequality to the last equality, we obtain

$$|a_3|\le\frac{t^2}{16(2\lambda-1)^2}+\frac{4-t^2}{24(3\lambda-1)}(\xi+\eta),\xi,\eta\in[0,1], \tag{2.11}$$

where $\xi=|x|$, $\eta=|y|$ and $t=|p_1|$. From here, we easily can write

$$|a_3|\le\left[\frac{1}{16(2\lambda-1)^2}-\frac{1}{12(3\lambda-1)}\right]t^2+\frac{1}{3(3\lambda-1)},\ t\in[0,2]. \tag{2.12}$$

Then, maximizing the function

$$\chi(t)=\left[\frac{1}{16(2\lambda-1)^2}-\frac{1}{12(3\lambda-1)}\right]t^2+\frac{1}{3(3\lambda-1)},\ t\in[0,2],$$

it can easily be seen that $\chi(t) \le \frac{1}{3(3\lambda-1)}$ if $\lambda \ge \frac{25+\sqrt{177}}{32}$ and $\chi(t) \le \frac{1}{4(2\lambda-1)^2}$

if $\lambda \in \left(\frac{1}{2}, \frac{25+\sqrt{177}}{32}\right]$.

Thus, the proof of second estimate of the equalities (2.1) is provided.

Let us now show that the consequences of the theorem are sharp. Really, the result of theorem is sharp for the function

$$f_1(z) = z + \frac{1}{2(2\lambda-1)} z^2 + \frac{1}{4(2\lambda-1)^2} z^3,\ z \in U$$

in the case $\lambda \in \left(\frac{1}{2}, \frac{25+\sqrt{177}}{32}\right]$ and for the function

$$f_2(z) = z + \frac{\tau}{2(2\lambda-1)} z^2 + \frac{\tau}{3(3\lambda-1)} z^3,\ z \in U$$

in the case $\lambda \ge \frac{25+\sqrt{177}}{32}$.

With this, the proof of theorem is completed.

In the case $\lambda = 1$, from the Theorem 2.1, we obtain the following result.

Corollary 2.1. If $f \in C_{\Sigma,\sinh}$, then

$$|a_2| \le \frac{1}{2} \quad \text{and} \quad |a_3| \le \frac{1}{4}.$$

Now, we give the following theorem on the solution of the Fekete-Szegö problem for the class $C_{\Sigma,\sinh}(\lambda)$.

Theorem 2.2. Let $f \in C_{\Sigma,\sinh}(\lambda)$ and $\mu \in$. Then,

$$\left|a_3-\mu a_2^2\right|\le\begin{cases}\dfrac{1}{3(3\lambda-1)} & \text{if } \left|1-\mu\right|\le\dfrac{4(2\lambda-1)^2}{3(3\lambda-1)},\\ \dfrac{\left|1-\mu\right|}{4(2\lambda-1)^2} & \text{if } \left|1-\mu\right|\ge\dfrac{4(2\lambda-1)^2}{3(3\lambda-1)}.\end{cases} \tag{2.13}$$

Obtained here result is sharp.

Proof. Let $f\in C_{\Sigma,\sinh}(\lambda)$ and $\mu\in\mathbb{R}$. Then, from the equalities (2.8) and (2.10), we can write

$$a_3-\mu a_2^2=\frac{(1-\mu)p_1^2}{16(2\lambda-1)^2}+\frac{4-p_1^2}{24(3\lambda-1)}(x-y) \tag{2.14}$$

for some $x,y\in\mathbb{D}$ with $\left|x\right|\le 1$ and $\left|y\right|\le 1$.

Applying triangle inequality to the equality (2.14), we obtain

$$\left|a_3-\mu a_2^2\right|\le\frac{\left|1-\mu\right|}{16(2\lambda-1)^2}t^2+\frac{4-t^2}{24(3\lambda-1)}(\xi+\eta),\ \xi,\eta\in[0,1],$$

where $\xi=\left|x\right|$, $\eta=\left|y\right|$ and $t=\left|p_1\right|$. From here easily can written

$$\left|a_3-\mu a_2^2\right|\le\frac{1}{16(2\lambda-1)^2}\left\{\left[\left|1-\mu\right|-\frac{4(2\lambda-1)^2}{3(3\lambda-1)}\right]t^2+\frac{16(2\lambda-1)^2}{3(3\lambda-1)}\right\},\ t\in[0,2]. \tag{2.15}$$

Maximizing the function $\varphi:[0,2]\to\mathbb{R}$ defined as follows

$$\varphi(t)=\left[\left|1-\mu\right|-\frac{4(2\lambda-1)^2}{3(3\lambda-1)}\right]t^2+\frac{16(2\lambda-1)^2}{3(3\lambda-1)},\ t\in[0,2],$$

we can easily see that $\varphi(t)\le\dfrac{16(2\lambda-1)^2}{3(3\lambda-1)}$ if $\left|1-\mu\right|\le\dfrac{4(2\lambda-1)^2}{3(3\lambda-1)}$ and $\varphi(t)\le 4\left|1-\mu\right|$ if

$\left|1-\mu\right|\ge\dfrac{4(2\lambda-1)^2}{3(3\lambda-1)}$.

If we take these evaluations into account in the inequality (2.15), the proof of the correctness of the estimate (2.13) will be completed.

Let us now show that the result obtained is sharp. Really, the result of the theorem is sharp for the function

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$$f_1(z) = z + \frac{1}{\sqrt{3|1-\mu|(3\lambda-1)}} z^2 + \frac{1}{3|1-\mu|(3\lambda-1)} z^3,\ z \in U$$

in the case $|1-\mu| \le \frac{4(2\lambda-1)^2}{3(3\lambda-1)}$ and for the function

$$f_2(z) = z + \frac{1}{2(2\lambda-1)} z^2 + \frac{1}{4(2\lambda-1)^2} z^3,\ z \in U$$

in the case $|1-\mu| \ge \frac{4(2\lambda-1)^2}{3(3\lambda-1)}$.

Thus, the proof of the theorem is completed.

In the case $\lambda = 1$ from the Theorem 2.2, we obtain the following result.

Corollary 2.2. If $f \in C_{\Sigma,\sinh}$ and $\mu \in \square$, then

$$\left|a_3 - \mu a_2^2\right| \le \frac{1}{6} \begin{cases} 1 & if\ |1-\mu| \le \frac{2}{3}, \\ \frac{3|1-\mu|}{2} & if\ |1-\mu| \ge \frac{2}{3}. \end{cases}$$

Also, taking $\mu = 0$ and $\mu = 1$ in the Theorem 2.2, we obtain the following results, respectively.

Corollary 2.3. Let $f \in C_{\Sigma,\sinh}(\lambda)$, then

$$|a_3| \le \begin{cases} \frac{1}{4(2\lambda-1)^2} & if\ \lambda \in \left(0, \frac{25+\sqrt{177}}{32}\right], \\ \frac{1}{3(3\lambda-1)} & if\ \lambda \ge \frac{25+\sqrt{177}}{32}. \end{cases}$$

Corollary 2.4. If $f \in C_{\Sigma,\sinh}(\lambda)$, then,

$$\left|a_3-a_2^2\right|\le\frac{1}{3(3\lambda-1)}.$$

Remark 2.1. We note that Corollary 2.3 confirms the second result of Theorem 2.1.

In the case $\mu\in\square$, we can prove the following theorem similarly to the proof of Theorem 2.2.

Theorem 2.3. Let $f\in C_{\Sigma,\sinh}(\lambda)$ and $\mu\in\square$. Then,

$$\left|a_3-\mu a_2^2\right|\le\begin{cases}\dfrac{1}{3(3\lambda-1)} & if \quad 1-\dfrac{4(2\lambda-1)^2}{3(3\lambda-1)}\le\mu\le1+\dfrac{4(2\lambda-1)^2}{3(3\lambda-1)},\\ \dfrac{|1-\mu|}{4(2\lambda-1)^2} & if\ \mu\le1-\dfrac{4(2\lambda-1)^2}{3(3\lambda-1)}\ or\ \mu\ge1+\dfrac{4(2\lambda-1)^2}{3(3\lambda-1)}.\end{cases}$$

In the case $\lambda=1$ from the Theorem 2.3, we have the following result.

Corollary 2.5. If $f\in C_{\Sigma,\sinh}$ and $\mu\in\square$. Then,

$$\left|a_3-\mu a_2^2\right|\le\begin{cases}\dfrac{1}{6} & if \quad \dfrac{1}{3}\le\mu\le\dfrac{5}{3},\\ \dfrac{|1-\mu|}{4} & if\ \mu\le\dfrac{1}{3}\ or\ \mu\ge\dfrac{5}{3}.\end{cases}$$

Setting $\mu=0$ and $\mu=1$ in the Corollary 2.5, we obtain the following results, respectively.

Corollary 2.6. If $f\in C_{\Sigma,\sinh}$, then $\left|a_3\right|\le\frac{1}{4}$.

Corollary 2.7. If $f\in C_{\Sigma,\sinh}$, then $\left|a_3-a_2^2\right|\le\frac{1}{6}$.

3. Conclusions and Evaluations

In this study, we considered the coefficient and Fekete-Szegö prolem for the new pseudo-convex bi-univalent function class of analytic functions. In this study, unlike the results available in the literature (we should note that the case $\lambda\ge1$ is examined in the literature), the

pseudo-convex bi-univalent function class for $\lambda > \frac{1}{2}$ is examined. The evaluations obtained for $\lambda \geq 1$ confirm the results available in the literature.

4. General Evaluation and Conclusions

For the class defined in the paper, an upper bound estimate of the second Hankel determinant can also be performed. In addition, the broader class of this class, the $q-$pseudo-convex bi-univalent class, can be defined and similar work can be done for this class.

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COEFFICIENT BOUND ESTIMATES FOR THE PSEUDO-STARLIKE BI-UNIVALENT FUNCTION CLASS

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ÖZET

Bu çalışmada, biz yıldızıl ve bi-ünivalent fonksiyonların psevdo-yıldızıl altsınıfı olarak adlandırılan bir sınıfını tanımladık. Burada, biz tanımlanan bu sınıfa ait olan fonksiyonların ilk iki katsayısı için üst sınır değerlendirmeleri verdik. Tanımlanan sınıf için Fekete-Szegö problemini de çözdük.

Anahtar Kelimeler: Yıldızıl fonksiyon, bi-ünivalent fonksiyon, psevdo-yıldızıl fonksiyon

ASTRACT

In this study, we defined a new subclass of starlike and bi-univalent functions, which called pseudo-starlike function class. Here, we gave bound estimates for initial two coefficient of the functions belonging to the defined class. The Fekete-Szegö problem for the defined class is also solved.

Keywords: Starlike function, bi-univalent function, pseudo-starlike function

4. Introduction and Preliminaries

We will denote by A the class of the analytic functions in the open unit disk $U = \{z \in \square : |z| < 1\}$ of the complex plane $\square$, given by series expansions

$$f(z)=z+a_2z^2+a_3z^3+a_4z^4+\cdots+a_nz^n+\cdots=z+\sum_{n=2}^{\infty}a_nz^n,\ a_n\in\square\ . \tag{1.1}$$

The subclass of A, which are univalent functions in U is denoted by S in the literature. Bieberbach [1] published a paper in which the coefficient hypothesis was proposed. This hypothesis states that if $f\in S$ and has the series form (1.1), then $|a_n|\le n$ for each $n\ge 2$. Are many articles in the literature regarding to this hypothesis (see [2-10]).

It is well known that the function f is called a bi-univalent function, if itself and inverse is univalent in U and $f(U)$, respectively. The class of bi-univalent functions in U is denoted by Σ [11].

For the inverse $g(w)=f^{-1}(w)$ of the function $f\in\Sigma$, can written

$$g(w)=w+A_2w^2+A_3w^3+A_4w^4+\ldots=w+\sum_{n=2}^{\infty}A_nz^n,\ w\in f(U), \tag{1.2}$$

where

$$A_2=-a_2,\ A_3=2a_2^2-a_3,\ A_4=-a_2^3+5a_2a_3-a_4,\ldots\ .$$

As is known that bi-starlike function class in the open unit disk U is defined analytically as follows

$$S_{\Sigma}^{*}=\left\{f\in S:\ \operatorname{Re}\left(\frac{zf'(z)}{f(z)}\right)>0,\ z\in U \text{ and } \operatorname{Re}\left(\frac{wg'(w)}{g(w)}\right)>0,\ w\in f(U)=U_{r_0}\right\}.$$

Let's $f,g\in H(U)$, then it is said that f is subordinate to g and denoted by $f\prec g$, if there exists a Schwartz function ω, such that $f(z)=g(\omega(z))$.

In the past few years, numerous subclasses of the class S have been introduced as special choices of the class S_{Σ}^{*} (see for example [3, 8-110, 12-18]).

Now, let's we define new subclass of bi-univalent functions in the open unit disk U.

Definition 1.1. For $\lambda>\frac{1}{2}$ the function $f\in\Sigma$ is said to be in the class $S_{\Sigma,\sinh}^{*}(\lambda)$, if the following conditions are satisfied

$$\frac{z\left(f'(z)\right)^{\lambda}}{f(z)}\prec 1+\sinh z,\ z\in U \text{ and } \frac{w\left(g'(w)\right)^{\lambda}}{g(w)}\prec 1+\sinh w,\ w\in U_{r_0}\ .$$

In the case $\lambda=1$ from the Definition 2.1, we have the following class of bi-univalent functions.

Definition 1.2. The function $f\in\Sigma$ is said to be in the class $S_{\Sigma,\sinh}^{*}$, if the following conditions are satisfied

$$\frac{zf'(z)}{f(z)}\prec 1+\sinh z,\ z\in U \text{ and } \frac{wg'(w)}{g(w)}\prec 1+\sinh w,\ w\in U_{r_0}\ .$$

Let P be the class of analytic functions in U satisfied the conditions $p(0)=1$ and $\mathrm{Re}(p(z))>0,\ z\in U$. Also, the function p has a series expansion as follows

$$p(z)=1+p_1z+p_2z^2+p_3z^3+\cdots=1+\sum_{n=1}^{\infty}p_nz^n,\ z\in U. \tag{1.3}$$

Let's give some necessary lemmas for the proof of our main results.

Lemma 1.1 ([19]). Let the function p belong to the class P. Then,

$$|p_n|\le 2 \text{ for each } n\in\mathbb{N},\ |p_n-\nu p_k p_{n-k}|\le 2 \text{ for } n,\ k\in\mathbb{N},\ n>k \text{ and } \nu\in[0,1].$$

The equalities hold for the function

$$p(z)=\frac{1+z}{1-z}.$$

Lemma 1.2 ([19]) Let the an analytic function p be of the form (1.3), then

$$2p_2=p_1^2+(4-p_1^2)x,$$
$$4p_3=p_1^3+2(4-p_1^2)p_1x-(4-p_1^2)p_1x^2+2(4-p_1^2)(1-|x|^2)y$$

for some $x,y\in\mathbb{D}$ with $|x|\le 1$ and $|y|\le 1$.

In this paper, we give some coefficient estimates and solve Fekete-Szegö problem for the class $S^*_{\Sigma,\sinh}(\lambda)$. Additionally, the results obtained for specific values of the parameters in our study are compared with the results obtained in the literature.

2. Main Results

In this section, we give some coefficient estimates for the functions belonging to the class $S^*_{\Sigma,\sinh}(\lambda)$.

Theorem 2.1. Let the function f given by series expansions (1.1) belong to the class $S^*_{\Sigma,\sinh}(\lambda)$. Then, are provided the following estimates

$$|a_2|\le\frac{1}{2\lambda-1} \text{ and } |a_3|\le\begin{cases}\dfrac{1}{(2\lambda-1)^2} & \text{if } \lambda\in\left(\dfrac{1}{2},\dfrac{7+\sqrt{17}}{8}\right],\\[2ex] \dfrac{1}{3\lambda-1} & \text{if } \dfrac{7+\sqrt{17}}{8}\le\lambda.\end{cases} \tag{2.1}$$

Obtained here results are sharp.

Proof. Let $f\in S^*_{\Sigma,\sinh}(\lambda)$, then exists Schwartz functions $\omega:U\to U,\varpi:U_{r_0}\to U_{r_0}$, such that

$$\frac{z\left(f'(z)\right)^{\lambda}}{f(z)}=1+\sinh\omega(z),\ z\in U \ \text{ and } \ \frac{w\left(g'(w)\right)^{\lambda}}{g(w)}=1+\sinh\varpi(w),\ w\in U_{r_0}. \quad (2.2)$$

Let's the functions $p,q\in P$ defined as follows:

$$p(z)=\frac{1+\omega(z)}{1-\omega(z)}=1+p_1z+p_2z^2+p_3z^3+\cdots=1+\sum_{n=1}^{\infty}p_nz^n,\ z\in U,$$

$$q(w)=\frac{1+\varpi(w)}{1-\varpi(w)}=1+q_1w+q_2w^2+q_3w^3+\cdots=1+\sum_{n=1}^{\infty}q_nw^n,\ w\in U_{r_0}. \quad (2.3)$$

It follows from that

$$\omega(z)=\frac{p(z)-1}{p(z)+1}=\frac{p_1}{2}z+\frac{1}{2}\left(p_2-\frac{p_1^2}{2}\right)z^2+\frac{1}{2}\left(p_3-p_1p_2-\frac{p_1^3}{4}\right)z^3+\cdots,\ z\in U,$$

$$\varpi(w)=\frac{q(w)-1}{q(w)+1}=\frac{q_1}{2}w+\frac{1}{2}\left(q_2-\frac{q_1^2}{2}\right)w^2+\frac{1}{2}\left(q_3-q_1q_2-\frac{q_1^3}{4}\right)w^3+\cdots,w\in U_{r_0}. \quad (2.4)$$

From the equalities (2.2) and (2.4), we obtain

$$(2\lambda-1)a_2z+\left[(3\lambda-1)a_3+(2\lambda^2-4\lambda+1)a_2^2\right]z^2+\cdots=\frac{p_1}{2}z+\left(\frac{p_2}{2}-\frac{p_1^2}{4}\right)z^2+\cdots,\ z\in U,$$

$$A_2(2\lambda-1)w+\left[(3\lambda-1)A_3+(2\lambda^2-4\lambda+1)A_2^2\right]w^2+\cdots=\frac{q_1}{2}w+\left(\frac{q_2}{2}-\frac{q_1^2}{4}\right)w^2+\cdots,\ w\in U_{r_0}. \quad (2.5)$$

Considering (1.2), it follows from that

$$(2\lambda-1)a_2=\frac{p_1}{2},\ (3\lambda-1)a_3+(2\lambda^2-4\lambda+1)a_2^2=\frac{p_2}{2}-\frac{p_1^2}{4} \quad (2.6)$$

and

$$-(2\lambda-1)a_2=\frac{q_1}{2},\ (3\lambda-1)\left(2a_2^2-a_3\right)+(2\lambda^2-4\lambda+1)a_2^2=\frac{q_2}{2}-\frac{q_1^2}{4}. \quad (2.7)$$

From the first equalities of the (2.6) and (2.7), we can write

$$\frac{p_1}{2(2\lambda-1)}=a_2=-\frac{q_1}{2(2\lambda-1)} \ \text{ and } \ p_1=-q_1. \quad (2.8)$$

Applying Lemma 1.1 to the first equalities (2.8), we obtain the first estimate of the theorem.

Considering the equation (2.8), from the second equalities of the (2.6) and (2.7) we obtain the following equality for the coefficient a_3

$$a_3 = \frac{p_1^2}{4(2\lambda-1)^2} + \frac{p_2 - q_2}{4(3\lambda-1)}. \tag{2.9}$$

Then, using to the Lemma 1.2 and the last equality, we can write

$$a_3 = \frac{p_1^2}{4(2\lambda-1)^2} + \frac{4-p_1^2}{8(3\lambda-1)}(x-y) \tag{2.10}$$

for some $x, y \in \mathbb{D}$ with $|x| \le 1$ and $|y| \le 1$.

Applying triangle inequality to the last equality, we obtain

$$|a_3| \le \frac{1}{4(2\lambda-1)^2} t^2 + \frac{4-t^2}{8(3\lambda-1)}(\xi+\eta),\ \xi,\eta \in [0,1], \tag{2.11}$$

where $\xi = |x|$, $\eta = |y|$ and $t = |p_1|$. From here can written

$$|a_3| \le \frac{1}{4}\left\{\left[\frac{1}{(2\lambda-1)^2} - \frac{1}{3\lambda-1}\right]t^2 + \frac{4}{3\lambda-1}\right\},\ t \in [0,2]. \tag{2.12}$$

By maximizing the expression on the right hand side with respect to the parameter $t \in [0,2]$, we complete the proof of the second inequality of the theorem.

Also, we see that the result of theorem is sharp for the function

$$f_1(z) = z + \frac{\tau}{2\lambda-1}z^2 + \frac{\tau}{3\lambda-1}z^3,\ z \in U$$

in the case $\lambda \ge \frac{7+\sqrt{17}}{8}$ and for the function

$$f_2(z) = z + \frac{\tau}{2\lambda-1}z^2 + \frac{\tau^2}{(2\lambda-1)^2}z^3,\ z \in U$$

in the case $\frac{1}{2} < \lambda \le \frac{7+\sqrt{17}}{8}$.

With this, the proof of theorem is completed.

Now, we will focused to the solution of the Fekete-Szegö problem for the class $S^*_{\Sigma,\sinh}(\lambda)$.

Theorem 2.2. Let $f \in S^*_{\Sigma,\sinh}(\lambda)$ and $\mu \in \mathbb{R}$, then

$$\left|a_3-\mu a_2^2\right| \le \begin{cases} \dfrac{1}{3\lambda-1} & \text{if } (3\lambda-1)\left|1-\mu\right| \le (2\lambda-1)^2, \\ \dfrac{\left|1-\mu\right|}{(2\lambda-1)^2} & \text{if } (3\lambda-1)\left|1-\mu\right| \ge (2\lambda-1)^2. \end{cases} \tag{2.13}$$

Obtained here result is sharp.

Proof. Let $f \in S^*_{\Sigma,\sinh}(\lambda)$ and $\mu \in \mathbb{R}$, then from the equalities (2.8) and (2.10), we can write the following equality for the expression $a_3-\mu a_2^2$

$$a_3-\mu a_2^2 = (1-\mu)\frac{p_1^2}{4(2\lambda-1)^2}+\frac{4-p_1^2}{8(3\lambda-1)}(x-y) \tag{2.14}$$

for some $x, y \in \mathbb{R}$ with $|x| \le 1$ and $|y| \le 1$.

Applying triangle inequality to the equality (2.14), we obtain

$$\left|a_3-\mu a_2^2\right| \le \left|1-\mu\right|\frac{t^2}{4(2\lambda-1)^2}+\frac{4-t^2}{8(3\lambda-1)}(\xi+\eta),\ \xi,\eta \in [0,1],$$

where $\xi = |x|$, $\eta = |y|$ and $t = |p_1|$.

From the last inequality, easily can written

$$\left|a_3-\mu a_2^2\right| \le \left|1-\mu\right|\frac{t^2}{4(2\lambda-1)^2}+\frac{4-t^2}{4(3\lambda-1)},\ t \in [0,2];$$

that is,

$$\left|a_3-\mu a_2^2\right| \le \frac{1}{4(2\lambda-1)^2}\left\{\left[\left|1-\mu\right|-\frac{(2\lambda-1)^2}{3\lambda-1}\right]t^2+\frac{4(2\lambda-1)^2}{3\lambda-1}\right\},\ t \in [0,2]. \tag{2.15}$$

Let us the function $\varphi:[0,2] \to \mathbb{R}$ defined as follows

$$\varphi(t) = \left[\left|1-\mu\right|-\frac{(2\lambda-1)^2}{3\lambda-1}\right]t^2+\frac{4(2\lambda-1)^2}{3\lambda-1},\ t \in [0,2].$$

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It is clear that the function $\varphi(t)$ is decreasing on the $[0,2]$ if $|1-\mu|-\frac{(2\lambda-1)^2}{3\lambda-1}\le 0$, $\varphi(t)\le\frac{4(2\lambda-1)^2}{3\lambda-1}$ and the function $\varphi(t)$ is increasing on the $[0,2]$ if $|1-\mu|-\frac{(2\lambda-1)^2}{3\lambda-1}\ge 0$ and $\varphi(t)\le 4|1-\mu|$.

Thus, the proof of the estimate (2.13) is completed.

Moreover, it can be easily seen that the result of theorem is sharp for the function

$$f_1(z)=z+\frac{1}{\sqrt{|1-\mu|(3\lambda-1)}}z^2+\frac{1}{|1-\mu|(3\lambda-1)}z^3,\ z\in U$$

in the case $(3\lambda-1)|1-\mu|\le(2\lambda-1)^2$ and for the function

$$f_2(z)=z+\frac{1}{2\lambda-1}z^2+\frac{1}{(2\lambda-1)^2}z^3,\ z\in U$$

in the case $(3\lambda-1)|1-\mu|\ge(2\lambda-1)^2$.

Thus, the proof of the Theorem 2.2 is completed

Taking $\mu=0$ and $\mu=1$ in the Theorem 2.2, we obtain the following results, respectively.

Corollary 2.1. If $f\in S^*_{\Sigma,\sinh}(\lambda)$, then

$$|a_3|\le\begin{cases}\dfrac{1}{(2\lambda-1)^2} & if\ \ \lambda\in\left(\dfrac{1}{2},\dfrac{7+\sqrt{17}}{8}\right],\\ \dfrac{1}{3\lambda-1} & if\ \ \ \lambda\ge\dfrac{7+\sqrt{17}}{8}.\end{cases}$$

Corollary 2.2. If $f\in S^*_{\Sigma,\sinh}(\lambda)$, then

$$|a_3-a_2^2|\le\frac{1}{3\lambda-1}.$$

Remark 2.1. We note that Corollary 2.1 confirms the second result of Theorem 2.1.

In the case $\lambda=1$ from the Theorem 2.2, we obtain the following result.

Corollary 2.3. If $f\in S^*_{\Sigma,\sinh}$ and $\mu\in$ □ , then

$$\left|a_3-\mu a_2^2\right|\leq\begin{cases}\dfrac{1}{2} & if\ \ \left|1-\mu\right|\leq\dfrac{1}{2},\\ \left|1-\mu\right| & if\ \ \left|1-\mu\right|\geq\dfrac{1}{2}.\end{cases}$$

Also, setting $\mu=0$ and $\mu=1$ in the Corollary 2.3, we obtain the following results, respectively.

Corollary 2.4. If $f\in S^*_{\Sigma,\sinh}$, then $\left|a_3\right|\leq 1$.

Corollary 2.5. If $f\in S^*_{\Sigma,\sinh}$, then

$$\left|a_3-a_2^2\right|\leq\frac{1}{2}.$$

In the case $\mu\in\square$, can prove the following theorem similarly to the proof of Theorem 2.2.

Theorem 2.3. Let $f\in S^*_{\Sigma,\sinh}(\lambda)$ and $\mu\in\square$. Then,

$$\left|a_3-\mu a_2^2\right|\leq\begin{cases}\dfrac{1}{3\lambda-1} & if\ \ \dfrac{-4\lambda^2+7\lambda-2}{3\lambda-1}\leq\mu\leq\dfrac{\lambda(4\lambda-1)}{3\lambda-1},\\ \dfrac{\left|1-\mu\right|}{(2\lambda-1)^2} & if\ \ \mu\leq\dfrac{-4\lambda^2+7\lambda-2}{3\lambda-1}\ \ or\ \ \dfrac{\lambda(4\lambda-1)}{3\lambda-1}\leq\mu.\end{cases}$$

In the case $\lambda=1$, we have the following result.

Corollary 2.5. If $f\in S^*_{\Sigma,\sinh}$ and $\mu\in\square$, then

$$\left|a_3-\mu a_2^2\right|\leq\begin{cases}\dfrac{1}{2} & if\ \ \dfrac{1}{2}\leq\mu\leq\dfrac{3}{2},\\ \left|1-\mu\right| & if\ \ \mu\leq\dfrac{1}{2}\ \ or\ \ \dfrac{3}{2}\leq\mu.\end{cases}$$

3. Conclusions and Evaluations

In this study, we considered the coefficient and Fekete-Szegö prolem for the new pseudo-starlike bi-univalent function class of analytic functions. In this study, unlike the results available in the literature (we should note that the case $\lambda\geq 1$ is examined in the literature), the pseudo-starlike bi-univalent function class for $\lambda>\dfrac{1}{2}$ is examined. The evaluations obtained for $\lambda\geq 1$ confirm the results available in the literature.

4. General Evaluation and Conclusions

For the class defined in the paper, an upper bound estimate of the second Hankel determinant can also be performed. In addition, the broader class of this class, the $q-$pseudo-starlike bi-univalent class, can be defined and similar work can be done for this class.

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COEFFICIENT BOUND ESTIMATES AND FEKETE-SZEGÖ PROBLEM FOR THE PSEUDO-CONVEX FUNCTION CLASS

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ÖZET

Bu çalışmada, biz konveks ve ünivalent fonksiyonların psevdo-konveks altsınıfı olarak adlandırılan bir sınıfını tanımladık. Burada, biz bu tanımlanan sınıfa ait olan fonksiyonların ilk iki katsayısı için üst sınır değerlendirmeleri verdik. Ayrıca, tanımlanan bu sınıf için Fekete-Szegö problemini de çözdük.

Anahtar Kelimeler: Konveks fonksiyon, ünivalent fonksiyon, psevdo-konveks fonksiyon

ASTRACT

In this study, we defined a new subclass of convex and univalent functions, which called pseudo-convex function class. Here, we gave bound estimates for initial two coefficients of the functions belonging to this defined function class. The Fekete-Szegö problem for the defined class is also solved.

Keywords: Convex function, univalent function, pseudo-convex function

5. Introduction and Preliminaries

We will denote by $H(U)$ the class of analytic functions in the open unit disk $U=\{z\in\mathbb{C}:|z|<1\}$ of the complex plane $\mathbb{C}$. Let A be the class of the functions $f\in H(U)$ given by series expansions

$$f(z)=z+a_2z^2+a_3z^3+a_4z^4+\cdots+a_nz^n+\cdots=z+\sum_{n=2}^{\infty}a_nz^n,\ a_n\in\mathbb{C}\ . \tag{1.1}$$

The subclass of A, which are univalent functions in U is denoted by S in the literature. Bieberbach [1] published a paper in which the coefficient hypothesis was proposed. This hypothesis states that if $f\in S$ and has the series form (1.1), then $|a_n|\le n$ for each $n\ge 2$. In the literature are many articles to this hypothesis (see [2-13]).
It is well known that the convex function class in the open unit disk U is defined analytically as follows and denoted by C

$$C=\left\{f\in S:\ \operatorname{Re}\left(\frac{\left(zf'(z)\right)'}{f'(z)}\right)>0,\ z\in U\right\}.$$

Let's $f,g\in H(U)$, then it is said that f is subordinate to g and denoted by $f\prec g$, if there exists a Schwartz function ω, such that $f(z)=g(\omega(z))$.
In the past few years, numerous subclasses of the class S have been introduced as special choices of the class C (see for example [3, 7-13, 14-20]).

Now, let's we define new subclass of analytic and univalent functions in the open unit disk U.

Definition 1.1. For $\lambda>\frac{1}{2}$ the function $f\in S$ is said to be in the class $C_{\sinh}(\lambda)$, if the following condition is satisfied

$$\frac{\left[\left(zf'(z)\right)'\right]^{\lambda}}{f'(z)}\prec 1+\sinh z,\ z\in U\ .$$

In the case $\lambda=1$, we have the following subclass of analytic and univalent functions.

Definition 1.2. The function $f\in S$ is said to be in the class $C_{\sinh}$, if the following condition is satisfied

$$\frac{\left(zf'(z)\right)'}{f'(z)}\prec 1+\sinh z,\ z\in U\ .$$

Let P be the class of analytic functions in U satisfied the conditions $p(0)=1$ and $\mathrm{Re}(p(z))>0,\ z\in U$. These functions that is satisfy the above conditions has a series expansion as follows

$$p(z)=1+p_1z+p_2z^2+p_3z^3+\cdots=1+\sum_{n=1}^{\infty}p_nz^n,\ z\in U. \tag{1.2}$$

Now, we give some necessary lemmas for the proof of our main results.

Lemma 1.1 ([21]). Let the function p belong to the class P. Then,

$$|p_n|\le 2 \text{ for each } n\in\mathbb{N},\ |p_n-\nu p_k p_{n-k}|\le 2 \text{ for } n,\ k\in\mathbb{N},\ n>k \text{ and } \nu\in[0,1].$$

The equalities hold for the function

$$p(z)=\frac{1+z}{1-z}.$$

Lemma 1.2 ([21]) Let the an analytic function p be of the form (1.2), then

$$2p_2=p_1^2+(4-p_1^2)x,$$
$$4p_3=p_1^3+2(4-p_1^2)p_1x-(4-p_1^2)p_1x^2+2(4-p_1^2)(1-|x|^2)y$$

for some $x,y\in\mathbb{C}$ with $|x|\le 1$ and $|y|\le 1$.

In this paper, we give some coefficient estimates and solve Fekete-Szegö problem for the class $C_{\sinh}(\lambda)$. Additionally, the results obtained in our study are compared with the results obtained in the literature.

2. Main Results

In this section, we give some coefficient estimates and examine Fekete-Szegö problem for the function class $C_{\sinh}(\lambda)$

Theorem 2.1. Let the function f given by series expansions (1.1) belonging to the class $C_{\sinh}(\lambda)$. Then, are provided the following estimates

$$|a_2| \le \frac{1}{2(2\lambda-1)} \text{ and } |a_3| \le \frac{1}{3(3\lambda-1)} \begin{cases} 1 & if \quad |2\lambda^2-4\lambda+1| \le (2\lambda-1)^2, \\ \dfrac{|2\lambda^2-4\lambda+1|}{(2\lambda-1)^2} & if \quad |2\lambda^2-4\lambda+1| \ge (2\lambda-1)^2. \end{cases} \tag{2.1}$$

Proof. Let $f \in C_{\sinh}(\lambda)$, then exists Schwartz function $\omega : U \to U$, such that

$$\frac{\left[\left(zf'(z)\right)'\right]^{\lambda}}{f'(z)} = 1+\sinh \omega(z), z \in U. \tag{2.2}$$

Let the function $p \in P$ defined as follows:

$$p(z) = \frac{1+\omega(z)}{1-\omega(z)} = 1+p_1 z + p_2 z^2 + p_3 z^3 + \ldots = 1+\sum_{n=1}^{\infty} p_n z^n, \; z \in U. \tag{2.3}$$

It follows from that

$$\omega(z) = \frac{p(z)-1}{p(z)+1} = \frac{p_1}{2} z + \frac{1}{2}\left(p_2 - \frac{p_1^2}{2}\right) z^2 + \frac{1}{2}\left(p_3 - p_1 p_2 - \frac{p_1^3}{4}\right) z^3 \ldots, \; z \in U. \tag{2.4}$$

From the equalities (2.2) and (2.4), we can easily see

$$\begin{aligned} 2a_2(2\lambda-1)z + \left[3(3\lambda-1)a_3 + \left(8\lambda^2-16\lambda+4\right)a_2^2\right] z^2 + \cdots \\ = \frac{p_1}{2} z + \left(\frac{p_2}{2} - \frac{p_1^2}{4}\right) z^2 + \cdots, \; z \in U. \end{aligned} \tag{2.5}$$

Comparing the coefficients of the same degree terms on the right and left sides of the equalities (2.5), we obtain the following equalities

$$a_2 = \frac{p_1}{4(2\lambda-1)}, \quad 3(3\lambda-1)a_3 + 4\left(2\lambda^2-4\lambda+1\right)a_2^2 = \frac{p_2}{2} - \frac{p_1^2}{4}. \tag{2.6}$$

Applying Lemma 1.1 to the first equality of the equalities (2.6), we obtain the first result of the theorem.

From the equalities (2.6), we obtain

$$a_3 = \frac{1}{3(3\lambda-1)} \left\{ \frac{p_2}{2} - \frac{p_1^2}{4} - \frac{2\lambda^2-4\lambda+1}{4(2\lambda-1)^2} p_1^2 \right\};$$

that is,

$$a_3 = \frac{1}{6(3\lambda-1)}\left\{p_2 - \frac{3\lambda^2-4\lambda+1}{(2\lambda-1)^2}p_1^2\right\}.$$

Using Lemma 1.2, we can write

$$a_3 = \frac{1}{12(3\lambda-1)}\left\{\left(4-p_1^2\right)x - \frac{3\lambda^2-4\lambda+1}{(2\lambda-1)^2}p_1^2\right\} \tag{2.7}$$

for some $x \in \square$ with $|x| \le 1$.

Applying triangle inequality to the last equality, we write the following estimates

$$|a_3| \le \frac{1}{12(3\lambda-1)}\left\{\left(4-t^2\right)\xi + \frac{\left|2\lambda^2-4\lambda+1\right|}{(2\lambda-1)^2}t^2\right\},\ \xi \in [0,1],$$

where $\xi = |x|$ and $t = |p_1|$. From this, we can easily show that

$$|a_3| \le \frac{1}{12(3\lambda-1)}\left\{\frac{\left|2\lambda^2-4\lambda+1\right|-(2\lambda-1)^2}{(2\lambda-1)^2}t^2 + 4\right\},\ t \in [0,2].$$

Then, maximizing the function

$$\varphi(t) = \frac{\left|2\lambda^2-4\lambda+1\right|-(2\lambda-1)^2}{(2\lambda-1)^2}t^2 + 4,$$

it can easily be seen that $\varphi(t) \le 4$ if $\left|2\lambda^2-4\lambda+1\right| \le (2\lambda-1)^2$ and

$$\varphi(t) \le \frac{4\left|2\lambda^2-4\lambda+1\right|}{(2\lambda-1)^2}$$

if $\left|2\lambda^2-4\lambda+1\right| \ge (2\lambda-1)^2$.

If we substitute these into the inequality we obtained above for $|a_3|$, the truth of the second provision of the theorem is seen.

Thus, the proof of theorem is completed.

Taking $\lambda = 1$ in the Theorem 2.1, we obtain the following result.

Corollary 2.1. If $f \in C_{\sinh}$, then

$$|a_2| \le \frac{1}{2} \quad \text{and} \quad |a_3| \le \frac{1}{6}.$$

Now, we give the following theorem on the solution of the Fekete-Szegö problem for the class $C_{\sinh}(\lambda)$.

Theorem 2.2. Let $f \in C_{\sinh}(\lambda)$ and $\mu \in \mathbb{R}$, then

$$|a_3 - \mu a_2^2| \le \frac{1}{3(3\lambda-1)} \begin{cases} 1 & \text{if} \\ & |4(3\lambda^2-4\lambda+1)+3(3\lambda-1)\mu| \le 4(2\lambda-1)^2, \\ \dfrac{|4(3\lambda^2-4\lambda+1)+3(3\lambda-1)\mu|}{4(2\lambda-1)^2} & \text{if} \\ & |4(3\lambda^2-4\lambda+1)+3(3\lambda-1)\mu| \ge 4(2\lambda-1)^2. \end{cases} \tag{2.8}$$

Proof. Let $f \in C_{\sinh}(\lambda)$ and $\mu \in \mathbb{R}$, then from the equalities (2.6) and (2.7), we can write the following equality

$$a_3 - \mu a_2^2 = \frac{1}{12(3\lambda-1)} \left\{ (4-p_1^2)x - \frac{4(3\lambda^2-4\lambda+1)+3(3\lambda-1)\mu}{4(2\lambda-1)^2} p_1^2 \right\} \tag{2.9}$$

for some $x \in \mathbb{R}$ with $|x| \le 1$. Applying triangle inequality, we obtain

$$|a_3 - \mu a_2^2| \le \frac{1}{12(3\lambda-1)} \left\{ (4-t^2)\xi + \frac{|4(3\lambda^2-4\lambda+1)+3(3\lambda-1)\mu|}{4(2\lambda-1)^2} t^2 \right\}, \ \xi \in [0,1],$$

where $\xi = |x|$ and $t = |p_1|$. From this, easily can written

$$|a_3 - \mu a_2^2| \le \frac{1}{12(3\lambda-1)} \left\{ \frac{|4(3\lambda^2-4\lambda+1)+3(3\lambda-1)\mu| - 4(2\lambda-1)^2}{4(2\lambda-1)^2} t^2 + 4 \right\}, \ t \in [0,2]. \tag{2.10}$$

Maximizing the function $\psi : [0,2] \to \mathbb{R}$ defined as follows

$$\psi(t) = \frac{|4(3\lambda^2-4\lambda+1)+3(3\lambda-1)\mu| - 4(2\lambda-1)^2}{4(2\lambda-1)^2} t^2 + 4, \ t \in [0,2],$$

we can easily see that $\psi(t) \le 4$ if $\left|4\left(3\lambda^2-4\lambda+1\right)+3(3\lambda-1)\mu\right| \le 4(2\lambda-1)^2$ and

$$\psi(t) \le \frac{\left|4\left(3\lambda^2-4\lambda+1\right)+3(3\lambda-1)\mu\right|}{(2\lambda-1)^2}$$

if $\left|4\left(3\lambda^2-4\lambda+1\right)+3(3\lambda-1)\mu\right| \ge 4(2\lambda-1)^2$.

Thus, the proof of theorem is completed.

In the case $\mu=0$ and $\mu=1$ from the Theorem 2.2, we obtain the following results, respectively.

Corollary 2.2. If $f \in C_{\sinh}(\lambda)$, then

$$|a_3| \le \frac{1}{3(3\lambda-1)}\begin{cases} 1 & if \quad \left|3\lambda^2-4\lambda+1\right| \le (2\lambda-1)^2, \\ \dfrac{\left|3\lambda^2-4\lambda+1\right|}{(2\lambda-1)^2} & if \quad \left|3\lambda^2-4\lambda+1\right| \ge (2\lambda-1)^2. \end{cases}$$

Corollary 2.3. If $f \in C_{\sinh}(\lambda)$, then

$$\left|a_3-a_2^2\right| \le \frac{1}{3(3\lambda-1)}\begin{cases} \dfrac{(4\lambda-1)(3\lambda-1)}{4(2\lambda-1)^2} & if \ \ \lambda \in \left(\dfrac{1}{2}, \dfrac{9+\sqrt{33}}{8}\right], \\ 1 & if \ \ \lambda \ge \dfrac{9+\sqrt{33}}{8}. \end{cases}$$

Remark 2.1. We note that Corollary 2.2 confirms the second result of Theorem 2.1.

In the case $\lambda=1$ from the Theorem 2.2, we obtain the following result.

Corollary 2.4. If $f \in C_{\sinh}$ and $\mu \in \square$, then

$$\left|a_3-\mu a_2^2\right| \le \frac{1}{6}\begin{cases} 1 & if \quad |\mu| \le \dfrac{2}{3}, \\ \dfrac{3|\mu|}{2} & if \quad |\mu| \ge \dfrac{2}{3}. \end{cases}$$

In the case $\mu \in \square$, we can prove the following theorem similarly to the proof of Theorem 2.2.

Theorem 2.3. Let $f \in C_{\sinh}(\lambda)$ and $\mu \in \square$. Then,

$$\left|a_3-\mu a_2^2\right| \leq \frac{1}{3(3\lambda-1)} \begin{cases} 1 & \text{if} \quad \dfrac{-4\left(7\lambda^2-8\lambda+2\right)}{3(3\lambda-1)} \leq \mu \leq \dfrac{4\lambda^2}{3(3\lambda-1)}, \\ \dfrac{\left|4\left(3\lambda^2-4\lambda+1\right)+3(3\lambda-1)\mu\right|}{4(2\lambda-1)^2} & \text{if} \quad \begin{cases} \mu \leq \dfrac{-4\left(7\lambda^2-8\lambda+2\right)}{3(3\lambda-1)} \ \text{or} \\ \dfrac{4\lambda^2}{3(3\lambda-1)} \leq \mu. \end{cases} \end{cases}$$

In the case $\lambda=1$ from the Theorem 2.3, we have the following result.

Corollary 2.5. If $f \in C_{\sinh}$ and $\mu \in \square$. Then,

$$\left|a_3-\mu a_2^2\right| \leq \frac{1}{6} \begin{cases} 1 & \text{if} \quad \mu \in \left[-\dfrac{2}{3}, \dfrac{2}{3}\right], \\ \dfrac{3}{2}|\mu| & \text{if} \quad \begin{cases} \mu \leq -\dfrac{2}{3} \ \text{or} \\ \mu \geq \dfrac{2}{3}. \end{cases} \end{cases}$$

Taking $\mu=1$ in the Corollary 2.5, we have the following result.

Corollary 2.6. If $f \in C_{\sinh}$ and $\mu \in \square$. Then,

$$\left|a_3-a_2^2\right| \leq \frac{1}{4}.$$

3. Conclusions and Evaluations

In this study, we considered the coefficient and Fekete-Szegö prolem for the new pseudo-convex function class of analytic functions. In this study, unlike the results available in the literature (we should note that the case $\lambda \geq 1$ is examined in the literature), the pseudo-convex function class for $\lambda > \frac{1}{2}$ is examined. The evaluations obtained for $\lambda \geq 1$ confirm the results available in the literature.

4. General Evaluation and Conclusions

For the class defined in the paper, an upper bound estimate of the second Hankel determinant can also be performed. In addition, the broader class of this class, the $q-$ pseudo-convex class, can be defined and similar work can be done for this class.

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COEFFICIENT ESTIMATES AND FEKETE-SZEGÖ PROBLEM FOR THE PSEUDO-STARLIKE UNIVALENT FUNCTION CLASS

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ÖZET

Bu çalışmada, biz yıldızıl ve ünivalent fonksiyonların psevdo-yıldızıl altsınıfı olarak adlandırılan bir sınıfını tanımladık. Burada, biz bu tanımlanan sınıfa ait olan fonksiyonların ilk iki katsayısı için üst sınır değerlendirmeleri verdik. Ayrıca, tanımlanan bu sınıf için Fekete-Szegö problemi de çözdük.

Anahtar Kelimeler: Yıldızıl fonksiyon, ünivalent fonksiyon, psevdo-yıldızıl fonksiyon

ASTRACT

In this study, we defined a new subclass of starlike and univalent functions, which called pseudo-starlike function class. Here, we gave bound estimates for initial two coefficients of the functions belonging to this defined function class. The Fekete-Szegö problem for the defined class is also solved.

Keywords: Starlike function, univalent function, pseudo-stalike function

6. Introduction and Preliminaries

Let $H(U)$ be the class of analytic functions in the open unit disk $U=\{z\in\mathbb{C}:|z|<1\}$ of the complex plane $\mathbb{C}$. We will denote by A the class of the functions $f\in H(U)$ given by series expansions

$$f(z)=z+a_2z^2+a_3z^3+a_4z^4+\cdots+a_nz^n+\cdots=z+\sum_{n=2}^{\infty}a_nz^n,\ a_n\in\mathbb{C}\ . \tag{1.1}$$

The subclass of A, which are univalent functions in U is denoted by S. In the literature. Bieberbach [1] published a paper in which the coefficient hypothesis was proposed. This hypothesis states that if $f\in S$ and has the series form (1.1), then $|a_n|\le n$ for each $n\ge 2$. Are many articles in the literature regarding to this hypothesis (see [2-13]).
It is well known that the starlike function class in the open unit disk U is defined analytically as follows and denoted by S^*

$$\left\{f\in S:\ \operatorname{Re}\left(\frac{zf'(z)}{f(z)}\right)>0,\ z\in U\right\}.$$

Let's $f,g\in H(U)$, then it is said that f is subordinate to g and denoted by $f\prec g$, if there exists a Schwartz function ω, such that $f(z)=g(\omega(z))$.
In the past few years, numerous subclasses of the class S have been introduced as special choices of the class $S^*(\varphi)$ (see for example [3, 7-13, 14-20]).

Now, let's we define new subclass of analytic and univalent functions in the open unit disk U.

Definition 1.1. For $\lambda>\frac{1}{2}$ the function $f\in S$ is said to be in the class $S^*_{\sinh}(\lambda)$, if the following condition is satisfied

$$\frac{z\left(f'(z)\right)^{\lambda}}{f(z)}\prec 1+\sinh z,\ z\in U\ .$$

In the case $\lambda=1$, we have following subclass of analytic and univalent function class.

Definition 1.2. The function $f\in S$ is said to be in the class $S^*_{\sinh}$, if the following condition is satisfied

$$\frac{zf'(z)}{f(z)}\prec 1+\sinh z,\ z\in U\ .$$

Let P be the class of analytic functions in U satisfied the conditions $p(0)=1$ and $\mathrm{Re}(p(z))>0,\ z\in U$. Also, these functions has a series expansion as follows

$$p(z)=1+p_1z+p_2z^2+p_3z^3+\cdots=1+\sum_{n=1}^{\infty}p_nz^n,\ z\in U. \tag{1.2}$$

Now, let us give some necessary lemmas for the proof of our main results.

Lemma 1.1 ([21]). Let the function p belong to the class P. Then,

$$|p_n|\le 2 \text{ for each } n\in\mathbb{N},\ |p_n-\nu p_k p_{n-k}|\le 2 \text{ for } n,\ k\in\mathbb{N},\ n>k \text{ and } \nu\in[0,1].$$

The equalities hold for the function

$$p(z)=\frac{1+z}{1-z}.$$

Lemma 1.2 ([21]) Let the an analytic function p be of the form (1.2), then

$$2p_2=p_1^2+(4-p_1^2)x,\ 4p_3=p_1^3+2(4-p_1^2)p_1x-(4-p_1^2)p_1x^2+2(4-p_1^2)(1-|x|^2)y$$

for some $x,y\in\mathbb{D}$ with $|x|\le 1$ and $|y|\le 1$.

In this paper, we give some coefficient estimates and solve Fekete-Szegö problem for the class $S^*_{\sinh}(\lambda)$. Additionally, the results obtained for specific values of the parameters in our study are compared with the results obtained in the literature.

2. Main Results

In this section, we give some coefficient estimates for the functions belonging to the class $S^*_{\sinh}(\lambda)$ and solve the Fekete-Szegö problem for this class.

Theorem 2.1. Let the function f given by series expansions (1.1) belong to the class $S^*_{\sinh}(\lambda)$. Then, we have

$$|a_2|\le\frac{1}{2\lambda-1} \quad \text{and}$$

$$|a_3| \le \frac{1}{3\lambda-1}\begin{cases} 1 & if \quad |2\lambda^2-4\lambda+1| \le (2\lambda-1)^2, \\ \dfrac{|2\lambda^2-4\lambda+1|}{(2\lambda-1)^2} & if \quad |2\lambda^2-4\lambda+1| \ge (2\lambda-1)^2. \end{cases} \tag{2.1}$$

Proof. Let $f \in S^*_{\sinh}(\lambda)$, then exists Schwartz function $\omega : U \to U$, such that

$$\frac{z\left(f'(z)\right)^{\lambda}}{f(z)} = 1+\sinh\omega(z), z \in U. \tag{2.2}$$

Let's the function $p \in P$ defined as follows:

$$p(z) = \frac{1+\omega(z)}{1-\omega(z)} = 1+p_1 z+p_2 z^2+p_3 z^3+\ldots = 1+\sum_{n=1}^{\infty} p_n z^n,\ z \in U. \tag{2.3}$$

It follows from that

$$\omega(z) = \frac{p(z)-1}{p(z)+1} = \frac{p_1}{2}z+\frac{1}{2}\left(p_2-\frac{p_1^2}{2}\right)z^2+\frac{1}{2}\left(p_3-p_1p_2-\frac{p_1^3}{4}\right)z^3\ldots,\ z \in U. \tag{2.4}$$

From the equalities (2.2) and (2.4), can written

$$(2\lambda-1)a_2 z+\left[(3\lambda-1)a_3+(2\lambda^2-4\lambda+1)a_2^2\right]z^2+\cdots = \frac{p_1}{2}z+\left(\frac{p_2}{2}-\frac{p_1^2}{4}\right)z^2+\cdots,\ z \in U. \tag{2.5}$$

Comparing the coefficients of the same degree terms on the right and left sides of the equality (2.5), we obtain the following equalities for the coefficients a_2 and a_3 of the function f

$$a_2 = \frac{p_1}{2(2\lambda-1)}, \tag{2.6}$$

$$(3\lambda-1)a_3+(2\lambda^2-4\lambda+1)a_2^2 = \frac{p_2}{2}-\frac{p_1^2}{4}. \tag{2.7}$$

Applying Lemma 1.1 to the equality (2.6), we obtain the first estimate of the theorem.

From the equalities (2.6) and (2.7), we obtain the following equality for the coefficient a_3

$$a_3=\frac{1}{3\lambda-1}\left\{\frac{p_2}{2}-\frac{p_1^2}{4}-\frac{2\lambda^2-4\lambda+1}{4(2\lambda-1)^2}p_1^2\right\};$$

that is,

$$a_3=\frac{1}{2(3\lambda-1)}\left\{p_2-\frac{3\lambda^2-4\lambda+1}{(2\lambda-1)^2}p_1^2\right\}. \tag{2.8}$$

Then, from the Lemma 1.2, we can write

$$a_3=\frac{1}{2(3\lambda-1)}\left\{\frac{4-p_1^2}{2}x-\frac{2\lambda^2-4\lambda+1}{2(2\lambda-1)^2}p_1^2\right\} \tag{2.9}$$

for some $x\in\square$ with $|x|\le 1$. Applying triangle inequality, we obtain

$$|a_3|\le\frac{1}{4(3\lambda-1)}\left\{(4-t^2)\xi+\frac{|2\lambda^2-4\lambda+1|}{(2\lambda-1)^2}t^2\right\},\ \xi\in[0,1], \tag{2.10}$$

where $\xi=|x|$ and $t=|p_1|$. From here, easily see that

$$|a_3|\le\frac{1}{4(3\lambda-1)(2\lambda-1)^2}\left\{\left[|2\lambda^2-4\lambda+1|-(2\lambda-1)^2\right]t^2+4(2\lambda-1)^2\right\},\ t\in[0,2]. \tag{2.11}$$

Then, maximizing the function

$$\chi(t)=\left[|2\lambda^2-4\lambda+1|-(2\lambda-1)^2\right]t^2+4(2\lambda-1)^2,$$

it can easily be seen that $\chi(t)\le 4(2\lambda-1)^2$ if $|2\lambda^2-4\lambda+1|\le(2\lambda-1)^2$ and $\chi(t)\le 4|2\lambda^2-4\lambda+1|$ if $|2\lambda^2-4\lambda+1|\ge(2\lambda-1)^2$.

With this, the proof of the theorem is completed.

In the case $\lambda=1$ from the Theorem 2.1, we obtain the following result.

Corollary 2.1. If $f\in S^*_{\sinh}$, then

$$|a_2|\le 1 \quad\text{and}\quad |a_3|\le\frac{1}{2}.$$

Now, we focused on the solution of the Fekete-Szegö problem for the class $S^*_{\sinh}(\lambda)$.

Theorem 2.2. Let $f \in S^*_{\sinh}(\lambda)$ and $\mu \in \mathbb{R}$, then

$$\left|a_3 - \mu a_2^2\right| \le \frac{1}{3\lambda - 1}\begin{cases} 1 & \text{if } \left|2\lambda^2 - 4\lambda + 1 + (3\lambda - 1)\mu\right| \le (2\lambda - 1)^2, \\ \dfrac{\left|2\lambda^2 - 4\lambda + 1 + (3\lambda - 1)\mu\right|}{(2\lambda - 1)^2} & \text{if } \left|2\lambda^2 - 4\lambda + 1 + (3\lambda - 1)\mu\right| \ge (2\lambda - 1)^2. \end{cases} \quad (2.12)$$

Proof. Let $f \in S^*_{\sinh}(\lambda)$ and $\mu \in \mathbb{R}$, then from the equalities (2.6) and (2.9), we can write

$$a_3 - \mu a_2^2 = \frac{1}{4(3\lambda - 1)}\left\{\left(4 - p_1^2\right)x - \frac{1}{(2\lambda - 1)^2}\left[2\lambda^2 - 4\lambda + 1 + (3\lambda - 1)\mu\right]p_1^2\right\} \quad (2.13)$$

for some $x \in \mathbb{R}$ with $|x| \le 1$.

Applying triangle inequality to the equality (2.13), we obtain

$$\left|a_3 - \mu a_2^2\right| \le \frac{1}{4(3\lambda - 1)}\left\{\left(4 - t^2\right)\xi + \frac{\left|2\lambda^2 - 4\lambda + 1 + (3\lambda - 1)\mu\right|}{(2\lambda - 1)^2}t^2\right\}, \ \xi \in [0,1],$$

where $\xi = |x|$ and $t = |p_1|$. From here easily can written

$$\left|a_3 - \mu a_2^2\right| \le \frac{1}{4(3\lambda - 1)}\left\{\frac{\left|2\lambda^2 - 4\lambda + 1 + (3\lambda - 1)\mu\right| - (2\lambda - 1)^2}{(2\lambda - 1)^2}t^2 + 4\right\}, \ t \in [0,2]. \quad (2.14)$$

Maximizing the function $\varphi : [0,2] \to \mathbb{R}$ defined as follows

$$\varphi(t) = \frac{\left|2\lambda^2 - 4\lambda + 1 + (3\lambda - 1)\mu\right| - (2\lambda - 1)^2}{(2\lambda - 1)^2}t^2 + 4, \ t \in [0,2],$$

we can easily see that $\varphi(t) \le 4$ if $\left|2\lambda^2 - 4\lambda + 1 + (3\lambda - 1)\mu\right| \le (2\lambda - 1)^2$ and

$$\varphi(t) \le \frac{4\left|2\lambda^2 - 4\lambda + 1 + (3\lambda - 1)\mu\right|}{(2\lambda - 1)^2}$$

if $\left|2\lambda^2 - 4\lambda + 1 + (3\lambda - 1)\mu\right| \ge (2\lambda - 1)^2$.

Thus, the proof of theorem is completed.

In the case $\mu = 0$ and $\mu = 1$ from the Theorem 2.2, we obtain the following results, respectively.

Corollary 2.2. If $f \in S^*_{\sinh}(\lambda)$, then

$$|a_3| \le \frac{1}{3\lambda - 1} \begin{cases} 1 & if \ \left|2\lambda^2 - 4\lambda + 1\right| \le (2\lambda - 1)^2, \\ \dfrac{\left|2\lambda^2 - 4\lambda + 1\right|}{(2\lambda - 1)^2} & if \ \left|2\lambda^2 - 4\lambda + 1\right| \ge (2\lambda - 1)^2. \end{cases}$$

Corollary 2.3. If $f \in S^*_{\sinh}(\lambda)$, then

$$\left|a_3 - a_2^2\right| \le \frac{1}{3\lambda - 1} \begin{cases} \dfrac{\lambda}{2\lambda - 1} & if \ \lambda \in \left(\dfrac{1}{2}, 1\right], \\ 1 & if \quad 1 \le \lambda. \end{cases}$$

Remark 2.1. We note that Corollary 2.2 confirms the second result of Theorem 2.1.
In the case $\lambda = 1$ from the Theorem 2.2, we obtain the following result.

Corollary 2.4. If $f \in S^*_{\sinh}$ and $\mu \in \mathbb{R}$, then

$$\left|a_3 - \mu a_2^2\right| \le \frac{1}{2} \begin{cases} 1 & if \ |1 - 2\mu| \le 1, \\ |1 - 2\mu| & if \ |1 - 2\mu| \ge 1. \end{cases}$$

In the case $\mu \in \mathbb{R}$, we can prove the following theorem similarly.

Theorem 2.3. Let $f \in S^*_{\sinh}(\lambda)$ and $\mu \in \mathbb{R}$. Then,

$$\left|a_3 - \mu a_2^2\right| \le \frac{1}{3\lambda - 1} \begin{cases} 1 & if \ \dfrac{-6\lambda^2 + 8\lambda - 2}{3\lambda - 1} \le \mu \le \dfrac{2\lambda^2}{3\lambda - 1}, \\ \dfrac{\left|2\lambda^2 - 4\lambda + 1 + (3\lambda - 1)\mu\right|}{(2\lambda - 1)^2} & if \quad \begin{cases} \dfrac{-6\lambda^2 + 8\lambda - 2}{3\lambda - 1} \le \mu \ \ or \\ \mu \le \dfrac{2\lambda^2}{3\lambda - 1}. \end{cases} \end{cases}$$

3. Conclusions and Evaluations

In this study, we considered the coefficient and Fekete-Szegö prolem for the new pseudo-starlike function class of analytic functions. In this study, unlike the results available in the literature (we should note that the case $\lambda \geq 1$ is examined in the literature), the pseudo-starlike function class for $\lambda > \frac{1}{2}$ is examined. The evaluations obtained for $\lambda \geq 1$ confirm the results available in the literature.

4. General Evaluation and Conclusions

For the class defined in the paper, an upper bound estimate of the second Hankel determinant can also be performed. In addition, the broader class of this class, the $q-$ pseudo-starlike class, can be defined and similar work can be done for this class.

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LARGE CLASSES IN A KÖTHE-TOEPLITZ DUAL OF A DIFFERENCE SEQUENCE SPACE AND THEIR FIXED POINT PROPERTY FOR NONEXPANSIVE MAPPINGS

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ABSTRACT

In 2000, Et and Esi introduced new type of generalized difference sequences by using the structure of Çolak's work from 1989 where he defined new types of sequence spaces while Çolak was also inspired by Kızmaz's idea about the difference operator he studied in 1981. In this study, we consider Et and Esi's work and study a Köthe-Toeplitz dual of their generalized difference sequence spaces. We take their study in terms of fixed point theory and find large classes of closed, bounded and convex subsets in that dual with fixed point property for nonexpansive mappings. The Banach space we consider is given by the following:

$$D_1^2 = \left\{ a = (a_n)_n \subset \mathbb{R}: \quad \|a\|^{(2)} = \sum_{k=1}^{\infty} \frac{k^2 |a_k|}{|v_k|} < \infty \right\}.$$

Key Words : Nonexpansive Mapping, Fixed Point Property, Closed Bounded Convex Set, Difference Sequences, Köthe-Toeplitz duals.

1. INTRODUCTION AND PRELIMINARIES

Researches have shown that the fixed point exists for some function classes defined on certain

classes of sets in some spaces, while it cannot be found at all in others. Fixed point theory has examined how this happens or does not happen. Researchers have made classifications and characterizations. In 1965, Browder [3] proved that every Hilbert space has a property satisfying that every nonexpansive mapping defined on any closed, bounded, and convex (cbc) nonempty subset domain with the same range has a fixed point. Since that time, spaces with this property have been considered to have the fixed point property for nonexpansive mappings (fppne). Then, researchers considered looking for the spaces with the property and if the property still exists when larger classes of mappings are taken. Then also they have seen spaces failing the properties. For example, in 1965, Browder [4] and Göhde [14] with independent studies, they saw that uniform convex Banach spaces have the fppne. Then, Kirk [17] generalized the result for the reflexive Banach spaces with normal structure. In fact, Goebel and Kirk [11] noticed that Kirk's result was able to extend for uniformly Lipschitz mappings and some researchers have studied estimating the Lipschitz coefficient satisfying the property for uniform Lipschitz mappings on different Banach spaces. For example, Goebel and Kirk [12] showed that for Hilbert spaces, the best Lipschitz coefficient would be a scalar less than a number in the interval $\left[\sqrt{2}, \frac{\pi}{2}\right]$, and Goebel and Kirk [11] and Lim [18] showed independently that for a Lebesgue space L^p when $2 < p < \infty$, the coefficient is smaller by a scalar larger than or equal to $\left(1+\frac{1}{2^p}\right)^{\frac{1}{p}}$ while Alspach [1] showed that when $p = 2$, there exists a fixed point free Lipschitz mapping with Lispchitz coefficient $\sqrt{2}$ defined on a cbc subset. In fact, $\sqrt{2}$ is the smallest Lipschitz coefficient for Alspach's mapping. We need to note that, similar to the definition of the Banach spaces satisfying the fppne, if a Banach space has a property that every uniformly Lipschitz mapping defined on any cbc nonempty subset domain with the same range has a fixed point, then that Banach space has the fixed point property for uniformly Lischitz mapping (fppul). In terms of fixed point property for uniformly Lipschitz mappings, Dowling, Lennard, and Turett [6] showed that if a Banach space contains an isomorphic copy of ℓ^1, then it fails the fppul. It is a well-known fact by researchers that c_0 or ℓ^1 is almost isometrically embedded in every non-reflexive Banach space with an unconditional basis (see [21]). For this reason, classical non-reflexive Banach spaces fail the fixed point property for non-expansive mappings, that is, in these spaces, there can be a closed, convex and bounded subset and a non-expansive invariant T mapping defined on that set such that T has no fixed point. This result is based on well-known theorems in the literature (see for example Theorem 1.c.12 in [21] and Theorem 1.c.5 in [22]). These theorems state that for a Banach lattice or Banach space with an unconditional basis to be reflexive, it is necessary and sufficient if it does not contain any isomorphic copies of c_0 or ℓ^1. Therefore, this close relation to the reflexivity or nonreflexivity of Banach space, researchers have worked for years and questioned whether c_0 or ℓ^1 can be renormed to have a fixed point for nonexpansive mappings. Lin [19] showed in his study that what was thought was not true and that at least ℓ^1 could be renormed to have the fixed point property for nonexpansive mappings. Then, the remaining question was if the same could have been done for c_0, but the answer still remains open. Since the researchers have considered trying to obtain the analogous results for well-known other classical nonreflexive Banach spaces, another experiment was done for Lebesgue integrable functions

space $L_1[0,1]$ by Hernandes-Lineares and Maria [20] but they were able to obtain the positive answer when they restricted the nonexpansive mappings by assuming they were affine as well. One can say that there is no doubt most research has been inspired by the ideas of the study [13] where Goebel and Kuczumow proved that while ℓ^1 fails the fixed point property since one can easily find a cbc nonweakly compact subset there and a fixed point free invariant nonexpansive map, it is possible to find a very large class subsets in target such that invariant nonexpansive mappings defined on the members of the class have fixed points. In fact, it is easy to notice the traces of those ideas in [19] work. Even Goebel and Kuczumow's work has inspired many other researchers to investigate if there exist more example of nonreflexive Banach spaces with large classes satisfying fixed point property. For example, in 2004, Kaczor and Prus [15] wanted to generalize Goebel and Kuczumow's findings and they proved that affine asymptotically nonexpansive invariant mappings defined on a large class of cbc subsets in ℓ^1 can have fixed points. Moreover, in [10], Kaczor and Prus' results were extended by having been found larger classes satisfying the fixed point property for affine asymptotically nonexpansive mappings. Thus, affinity condition became a tool for their works. In fact, another well-known nonreflexive Banach space, Lebesgue space $L_1[0,1]$, was studied in [20] and in their study they obtained an analogous result to [19] as they showed that $L_1[0,1]$ can be renormed to have the fixed point property for affine nonexpansive mappings. In this study, we will investigate some Banach spaces analogous to ℓ^1. In the present work, we study Goebel-Kuczumow analogy for Köthe-Toeplitz duals of certain generalized difference sequence spaces investigated by Et and Esi [9]. We prove that a very large class of closed, bounded and convex subsets in Köthe-Toeplitz duals of the difference sequence spaces generalized by Et and Esi has the fixed point property for nonexpansive mappings. Therefore, firstly we would like to give the definition of Cesàro sequence spaces which was defined by Shiue [25] in 1970, and next we present Kzmaz's difference sequence space definition in [16] by noting that we work on a space which is derived from his ideas' generalizations such that many researchers (see for example [5, 7, 8, 9, 23, 26]) have generalized his work as well.

In fact, we need to note that Et and Esi's work [9] and Et and Çolak's work [8] used a common difference sequence definition from Çolak's work [5].

Now, first we recall that Shiue [25], in 1970, introduced the Cesàro sequence spaces written as

$$\mathrm{ces}_p = \left\{(x_n)_n \subset \mathbb{R} \left| \left(\sum_{n=1}^{\infty} \left(\frac{1}{n}\sum_{k=1}^{n} |x_k|\right)^p\right)^{1/p} < \infty \right.\right\}$$

such that $\ell^p \subset \mathrm{ces}_p$ and

$$\mathrm{ces}_\infty = \left\{x = (x_n)_n \subset \mathbb{R} \left| \sup_n \frac{1}{n}\sum_{k=1}^{n} |x_k| \ < \infty \right.\right\}$$

such that $\ell^\infty \subset ces_\infty$ where $1 \leq p < \infty$. Then, from the definition of Cesàro sequence spaces, Kzmaz [16], defined difference sequence spaces for ℓ^∞, c, and c_0 and symbolized them by $\ell^\infty(\Delta)$, $c(\Delta)$, and $c_0(\Delta)$, respectively. In his introduction, he defined the difference operator Δ applied to the sequence $x = (x_n)_n$ using the formula $\Delta x = (x_k - x_{k+1})_k$. In fact, he investigated Köthe-Toeplitz duals and their topological properties.

As one of the researchers generalizing his ideas, Çolak [5] in 1989, introduced firstly a generalized difference sequence space by taking an arbitrary sequence of nonzero complex values $v = (v_n)_n$ and then denoting a new difference operator by Δ_v such that for any sequence $x = (x_n)_n$, he defined the difference sequence of that $\Delta_v x = (v_k x_k - v_{k+1} x_{k+1})_k$. Then, Et and Esi [9] in 2000, generalized Çolak's difference sequence space by defining

$$\Delta_v(\ell^\infty) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v x \in \ell^\infty\},$$
$$\Delta_v(c) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v x \in c\},$$
$$\Delta_v(c_0) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v x \in c_0\}.$$

Furthermore, their m^{th} order generalized difference sequence space is given for any $m \in \mathbb{N}$ by $\Delta_v^0 x = (v_k x_k)_k$, $\Delta_v^m x = (\Delta_v^m x_k)_k = (\Delta_v^{m-1} x_k - \Delta_v^{m-1} x_{k+1})_k$ with $\Delta_v^m x_k = \sum_{i=0}^m (-1)^i \binom{m}{i} v_{k+i} x_{k+i}$ for each $k \in \mathbb{N}$.

Next, in 2004, Bektaş, Et and Çolak [2] obtained the Köthe-Toeplitz duals for the generalized difference sequence space of Et and Esi's. We may recall here that their m^{th} order difference sequence space has the following norm for any $m \in \mathbb{N}$:

$$\|x\|_v^{(m)} = \sum_{k=1}^{m} |v_k x_k| + \|\Delta_v^m x\|_\infty$$

Then, the corresponding Köthe-Toeplitz dual was obtained as in [2] and [9] such that it is written as below:

$$D_1^m := \{a = (a_n)_n \subset \mathbb{R} | (n^m v_n^{-1} a_n)_n \in \ell^1\}$$
$$= \left\{a = (a_n)_n \subset \mathbb{R}: \ \|a\|^{(m)} = \sum_{k=1}^{\infty} \frac{k^m |a_k|}{|v_k|} < \infty\right\}.$$

Note that $D_1^m \subset \ell^1$ if $k^m |v_k^{-1}| > 1$ for each $k, m \in \mathbb{N}$ and $\ell^1 \subset D_1^m$ if $k^m |v_k^{-1}| < 1$ for each $k, m \in \mathbb{N}$.

Now, we will need the following well-known preliminaries before giving our main results. [12] may be suggested as a good reference for these fundamentals.

Definition 1.1 *Consider that $(X, \|\cdot\|)$ is a Banach space and let C be a non-empty cbc subset. Let $T: C \to C$ be a mapping. We say that*

1. *T is an affine mapping if for every $t \in [0,1]$ and $a, b \in C$, $T((1-t)a + tb) = (1-t)T(a) + t\ T(b)$.*
2. *T is a nonexpansive mapping if for every $a, b \in C$, $\| T(a) - T(b) \| \leq \| a - b \|$.*

Then, we will easily obtain an anologous key lemma from the below lemma in the work [13].

Lemma 1.2 *Let* $\{u_n\}$ *be a sequence in* ℓ^1 *converging to* u *in weak-star topology. Then, for every* $w \in \ell^1$,

$$r(w) = r(u) + \|w - u\|_1$$

where

$$r(w) = \limsup_n \|u_n - w\|_1.$$

Note that our scalar field in this study will be real numbers although Çolak [5] considers complex values of $v = (v_n)_n$ while introducing his structer of the difference sequence which is taken as the fundamental concept in this study.

2. MAIN RESULTS

In this section, we will present our results. As mentioned in the first section, we investigate Goebel and Kuzmunow analogy for the space D_1^2. We aim to show that there is a large class of cbc subsets in D_1^2 such that every nonexpansive invariant mapping defined on the subsets in the class taken has a fixed point. Recall that the invariant mappings have the same domain and the range.

First, due to isometric isomorphism, using Lemma 1.2, we will provide the straight analogous result as a lemma below which will be a key step as in the works such as [13], and [10] and in fact the methods in the study [10] will be our lead in this work.

Lemma 2.1 *Let* $\{u_n\}$ *be a sequence in the Banach space* D_1^2 *and assume* $\{u_n\}$ *converges to* u *in weak-star topology. Then, for every* $w \in D_1^2$,

$$r(w) = r(u) + \|w - u\|^{(2)}$$

where

$$r(w) = \limsup_n \|u_n - w\|^{(2)}.$$

Then, we obtain our results by the following theorems.

Theorem 2.2 *Let* $t \in (0,1)$. *Let* $(f_n)_{n\in\mathbb{N}}$ *be a sequence defined by* $f_1 := tv_1e_1$, $f_2 := \frac{t\ v_2}{2^2}e_2$, $f_3 := \frac{t\ v_3}{3^2}e_3$, $f_4 := \frac{t\ v_4}{4^2}e_4$, $f_5 := \frac{t\ v_5}{5^2}e_5$, $f_6 := \frac{t\ v_6}{6^2}e_6$, *and* $f_n := \frac{v_n}{n^2}e_n$ *for all integers* $n \geq 7$ *where the sequence* $(e_n)_{n\in\mathbb{N}}$ *is the canonical basis of both* c_0 *and* ℓ^1. *Then, consider the cbc subset* $E^{(2)} = E_t{}^{(2)}$ *of* D_1^2 *by*

$$E^{(2)} := \left\{ \sum_{n=1}^{\infty} \alpha_n f_n : \forall n \in \mathbb{N}, \quad \alpha_n \geq 0 \text{ and } \sum_{n=1}^{\infty} \alpha_n = 1 \right\}.$$

Then, $E^{(2)}$ has the fixed point property for $\|\ .\ \|^{(2)}$-nonexpansive mappings.

Proof. Fix $t \in (0,1)$. Let $T: E^{(2)} \to E^{(2)}$ be a $\|\ .\ \|^{(2)}$-nonexpansive mapping. Then, there

exists a sequence so called aproximate fixed point sequence $\left(u^{(n)}\right)_{n\in\mathbb{N}} \in E^{(2)}$ such that $\left\|Tu^{(n)} - u^{(n)}\right\|^{(2)} \underset{n}{\to} 0$. Due to isometric isomorphism, D_1^2 shares common geometric properties with ℓ^1 and so both D_1^2 and its predual have similar fixed point theory properties to ℓ^1 and c_0, respectively. Thus, considering that on bounded subsets the weak star topology on ℓ^1 is equivalent to the coardinate-wise convergence topology, and c_0 is separable, in D_1^2, the unit closed ball is weak*-sequentially compact due to Banach-Alaoglu theorem. Then, we can say that we may denote the weak* closure of the set $E^{(2)}$ by

$$C^{(2)} := \overline{E^{(2)}}^{w^*} = \left\{\sum_{n=1}^{\infty} \alpha_n f_n :\ each\ \ \alpha_n \geq 0\ \ and\ \ \sum_{n=1}^{\infty} \alpha_n \leq 1\right\}$$

and without loss of generality, we may pass to a subsequence if necessary and get a weak* limit $u \in C^{(2)}$ of $u^{(n)}$. Then, by Lemma 2.1, we have a function $r: D_1^2 \to [0,\infty)$ defined by

$$r(w) = \limsup_n \left\|u^{(n)} - w\right\|^{(2)}, \quad \forall w \in D_1^2$$

such that for every $w \in D_1^2$,

$$r(w) = r(u) + \|u - w\|^{(2)}.$$

Case 1. $u \in E^{(2)}$.

Then, $r(Tu) = r(u) + \|Tu - u\|^{(2)}$ and

$$\begin{aligned} r(Tu) &= \limsup_n \left\|Tu - u^{(n)}\right\|^{(2)} \\ &\leq \limsup_n \left\|Tu - T\left(u^{(n)}\right)\right\|^{(2)} + \limsup_n \left\|u^{(n)} - T\left(u^{(n)}\right)\right\|^{(2)} \\ &\leq \limsup_n \left\|u - u^{(n)}\right\|^{(2)} + 0 \\ &= r(u). \end{aligned} \tag{1}$$

Thus, $r(Tu) = r(u) + \|Tu - u\|^{(2)} \leq r(u)$ and so $\|Tu - u\|^{(2)} = 0$. Therefore, $Tu = u$.

Case 2. $u \in C^{(2)} \backslash E^{(2)}$.

Then, we may find scalars satisfying $u = \sum_{n=1}^{\infty} \delta_n f_n$ such that $\sum_{n=1}^{\infty} \delta_n < 1$ *and* $\delta_n \geq 0$, $\forall n \in \mathbb{N}$. Now define $\xi := 1 - \sum_{n=1}^{\infty} \delta_n$ and for $\beta \in \left[\frac{-\delta_1}{\xi}, \frac{\delta_2}{\xi} + 1\right]$ define

$$\begin{aligned} h_\beta &:= \left(\delta_1 + \frac{\beta}{5}\xi\right) f_1 + \left(\delta_2 + \frac{\beta}{5}\xi\right) f_2 + \left(\delta_3 + \frac{\beta}{5}\xi\right) f_3 + \left(\delta_4 + \frac{\beta}{5}\xi\right) f_4 \\ &+ \left(\delta_5 + \frac{\beta}{5}\xi\right) f_5 + (\delta_6 + (1-\beta)\xi) f_6 + \sum_{n=7}^{\infty} \delta_n f_n. \end{aligned}$$

Then,

$$\left\|h_\beta - u\right\|^{(2)} = \left\| \begin{array}{c} \frac{\beta}{5} t\xi v_1 e_1 + \frac{\beta}{5} t\xi \frac{v_2}{2^2} e_2 + \frac{\beta}{5} t\xi \frac{v_3}{3^2} e_3 \\ + \frac{\beta}{5} t\xi \frac{v_4}{4^2} e_4 + \frac{\beta}{5} t\xi \frac{v_5}{5^2} e_5 + (1-\beta)\xi \frac{t v_6 e_6}{6^2} \end{array} \right\|^{(2)}$$

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$$= t\left|\frac{\beta}{5}\right|\xi + t\left|\frac{\beta}{5}\right|\xi + t\left|\frac{\beta}{5}\right|\xi + t\left|\frac{\beta}{5}\right|\xi + t\left|\frac{\beta}{5}\right|\xi + t|1-\beta|\xi.$$

$\|h_\beta - u\|^{(2)}$ is minimized for $\beta \in [0,1]$ and its minimum value would be $t\xi$.

Now fix $w \in E^{(2)}$. Then, we may find scalars satisfying $w = \sum_{n=1}^{\infty} \alpha_n f_n$ such that $\sum_{n=1}^{\infty} \alpha_n = 1$ with $\alpha_n \geq 0, \forall n \in \mathbb{N}$. We may also write each f_k with coefficients γ_k for each $k \in \mathbb{N}$ where $\gamma_1 := tv_1$, $\gamma_2 := \frac{tv_2}{2^2}$, $\gamma_3 := \frac{tv_3}{3^2}$, $\gamma_4 := \frac{tv_4}{4^2}$, $\gamma_5 := \frac{tv_5}{5^2}$, $\gamma_6 := \frac{tv_6}{6^2}$, and $\gamma_n := \frac{v_n}{n^2}$ for all integers $n \geq 7$ such that for each $n \in \mathbb{N}$, $f_n = \gamma_n e_n$.

Then,

$$\begin{aligned}
\|w - u\|^{(2)} &= \left\|\sum_{k=1}^{\infty} \alpha_k f_k - \sum_{k=1}^{\infty} \delta_k f_k\right\|^{(2)} \\
&= \left\|\sum_{k=1}^{\infty} (\alpha_k - \delta_k) f_k\right\|^{(2)} \\
&= \sum_{k=1}^{\infty} \left|(\alpha_k - \delta_k)\frac{k^2\gamma_k}{v_k}\right|. \\
&\geq \sum_{k=1}^{\infty} t\,|\alpha_k - \delta_k| \\
&\geq t\left|\sum_{k=1}^{\infty} (\alpha_k - \delta_k)\right| \\
&= t\left|1 - \sum_{k=1}^{\infty} \delta_k\right| \\
&= t\xi.
\end{aligned}$$

Hence,

$$\|w - u\|^{(2)} \geq t\xi = \|h_\beta - u\|^{(2)}$$

and the equality is obtained if and only if $(1-t)\sum_{k=7}^{\infty} |\alpha_k - \delta_k| = 0$; that is, we have $\|w - u\|^{(2)} = t\xi$ if and only if $\alpha_k = \delta_k$ for every $k \geq 7$; or say, $\|w - u\|^{(2)} = t\xi$ if and only if $w = h_\beta$ for some $\beta \in [0,1]$.

Then, there exists a continuous function $\rho: [0,1] \to E^{(2)}$ defined by $\rho(\beta) = h_\beta$ and $\Lambda\rho([0,1])$ is a compact convex subset and so $\|w - u\|^{(2)}$ achieves its minimum value at $w = h_\beta$ and for any $h_\beta \in \Lambda$, we get

$$\begin{aligned}
Q(h_\beta) &= Q(u) + \|h_\beta - u\|^{(2)} \\
&\leq Q(u) + \|Th_\beta - u\|^{(2)} \\
&= Q(Th_\beta) = \limsup_n \|Th_\beta - u^{(n)}\|^{(2)}
\end{aligned}$$

then, like the inequality (1), we get

$$\begin{aligned} Q(h_\beta) &\le \limsup_n \left\|Th_\beta - T(u^{(n)})\right\|^{(2)} + \limsup_n \left\|u^{(n)} - T(u^{(n)})\right\|^{(2)} \\ &\le \limsup_n \left\|h_\beta - u^{(n)}\right\|^{(2)} + \limsup_n \left\|u^{(n)} - T(u^{(n)})\right\|^{(2)} \\ &\le \limsup_n \left\|h_\beta - u^{(n)}\right\|^{(2)} + 0 \\ &= Q(h_\beta). \end{aligned}$$

Hence, $r(h_\beta) \le Q(Th_\beta) \le r(h_\beta)$ and so $Q(Th_\beta) = Q(h_\beta)$.
Therefore,

$$Q(u) + \left\|Th_\beta - u\right\|^{(2)} = Q(u) + \left\|h_\beta - u\right\|^{(2)}.$$

Thus, $\left\|Th_\beta - u\right\|^{(2)} = \left\|h_\beta - u\right\|^{(2)}$ and so $Th_\beta \in \Lambda$ but this shows $T(\Lambda) \subseteq \Lambda$ and using Schauder's fixed point theorem in [24], easily we get the result T has a fixed point since T is continuous; thus, h_β is the unique minimizer of $\|w - u\|^{(2)} : w \in E^{(2)}$ and $Th_\beta = h_\beta$.

Therefore, $E^{(2)}$ has the fixed point property for nonexpansive mappings.

Theorem 2.3 *Let $t \in (0,1)$. Let $(f_n)_{n\in\mathbb{N}}$ be a sequence defined by $f_1 := tv_1e_1$, $f_2 := \frac{t\,v_2}{2^2}e_2$, $f_3 := \frac{t\,v_3}{3^2}e_3$, $f_4 := \frac{t\,v_4}{4^2}e_4$, $f_5 := \frac{t\,v_5}{5^2}e_5$, $f_6 := \frac{t\,v_6}{6^2}e_6$, $f_7 := \frac{t\,v_7}{7^2}e_7$, and $f_n := \frac{v_n}{n^2}e_n$ for all integers $n \ge 8$ where the sequence $(e_n)_{n\in\mathbb{N}}$ is the canonical basis of both c_0 and ℓ^1. Then, consider the cbc subset $E^{(2)} = E_t{}^{(2)}$ of D_1^2 by*

$$E^{(2)} = \left\{ \sum_{n=1}^{\infty} \alpha_n f_n : \quad \forall n \in \mathbb{N}, \quad \alpha_n \ge 0 \quad and \quad \sum_{n=1}^{\infty} \alpha_n = 1 \right\} .$$

Then, $E^{(2)}$ has the fixed point property for $\|\ .\ \|^{(2)}$-nonexpansive mappings.

Proof. Fix $t \in (0,1)$. Let $T: E^{(2)} \to E^{(2)}$ be a $\|\ .\ \|^{(2)}$-nonexpansive mapping. Then, there exists a sequence so called aproximate fixed point sequence $\left(u^{(n)}\right)_{n\in\mathbb{N}} \in E^{(2)}$ such that $\left\|Tu^{(n)} - u^{(n)}\right\|^{(2)} \underset{n}{\to} 0$. Due to isometric isomorphism, D_1^2 shares common geometric properties with ℓ^1 and so both D_1^2 and its predual have similar fixed point theory properties to ℓ^1 and c_0, respectively. Thus, considering that on bounded subsets the weak star topology on ℓ^1 is equivalent to the coardinate-wise convergence topology, and c_0 is separable, in D_1^2, the unit closed ball is weak*-sequentially compact due to Banach-Alaoglu theorem. Then, we can say that we may denote the weak* closure of the set $E^{(2)}$ by

$$C^{(2)} := \overline{E^{(2)}}^{w^*} = \left\{ \sum_{n=1}^{\infty} \alpha_n f_n : \ each \ \ \alpha_n \ge 0 \ \ and \ \ \sum_{n=1}^{\infty} \alpha_n \le 1 \right\}$$

and without loss of generality, we may pass to a subsequence if necessary and get a weak* limit $u \in C^{(2)}$ of $u^{(n)}$. Then, by Lemma 2.1, we have a function $r: D_1^2 \to [0,\infty)$ defined by

$$r(w) = \limsup_n \left\|u^{(n)} - w\right\|^{(2)} , \quad \forall w \in D_1^2$$

such that for every $w \in D_1^2$,

$$r(w) = r(u) + \|u - w\|^{(2)}.$$

Case 1. $u \in E^{(2)}$.

Then, $r(Tu) = r(u) + \|Tu - u\|^{(2)}$ and

$$\begin{aligned} r(Tu) &= \limsup_n \left\|Tu - u^{(n)}\right\|^{(2)} \\ &\leq \limsup_n \left\|Tu - T\left(u^{(n)}\right)\right\|^{(2)} + \limsup_n \left\|u^{(n)} - T\left(u^{(n)}\right)\right\|^{(2)} \\ &\leq \limsup_n \left\|u - u^{(n)}\right\|^{(2)} + 0 \\ &= r(u). \end{aligned} \tag{2}$$

Thus, $r(Tu) = r(u) + \|Tu - u\|^{(2)} \leq r(u)$ and so $\|Tu - u\|^{(2)} = 0$. Therefore, $Tu = u$.

Case 2. $u \in C^{(2)} \backslash E^{(2)}$.

Then, we may find scalars satisfying $u = \sum_{n=1}^{\infty} \delta_n f_n$ such that $\sum_{n=1}^{\infty} \delta_n < 1$ and $\delta_n \geq 0$, $\forall n \in \mathbb{N}$.

Define $\xi := 1 - \sum_{n=1}^{\infty} \delta_n$ and for $\beta \in \left[\frac{-\delta_1}{\xi}, \frac{\delta_2}{\xi} + 1\right]$, define

$$\begin{aligned} \mathrm{h}_\beta := &\left(\delta_1 + \frac{\beta}{6}\xi\right) f_1 + \left(\delta_2 + \frac{\beta}{6}\xi\right) f_2 + \left(\delta_3 + \frac{\beta}{6}\xi\right) f_3 + \left(\delta_4 + \frac{\beta}{6}\xi\right) f_4 + \left(\delta_5 + \frac{\beta}{6}\xi\right) f_5 \\ &+ \left(\delta_6 + \frac{\beta}{6}\xi\right) f_6 + (\delta_7 + (1-\beta)\xi) f_7 + \sum_{n=8}^{\infty} \delta_n f_n. \end{aligned}$$

Then,

$$\left\|h_\beta - u\right\|^{(2)} = \left\| \begin{matrix} \frac{\beta}{6} t\xi v_1 e_1 + \frac{\beta}{6} t\xi \frac{v_2}{2^2} e_2 + \frac{\beta}{6} t\xi \frac{v_3}{3^2} e_3 + \frac{\beta}{6} t\xi \frac{v_4}{4^2} e_4 \\ + \frac{\beta}{6} t\xi \frac{v_5}{5^2} e_5 + \frac{\beta}{6} t\xi \frac{v_6}{6^2} e_6 + (1-\beta)\xi \frac{t v_7 e_7}{7^2} \end{matrix} \right\|^{(2)}$$

$$= t\left|\frac{\beta}{6}\right| \xi + t\left|\frac{\beta}{6}\right| \xi + t\left|\frac{\beta}{6}\right| \xi + t\left|\frac{\beta}{6}\right| \xi + t\left|\frac{\beta}{6}\right| \xi + t\left|\frac{\beta}{6}\right| \xi + t|1-\beta|\xi.$$

$\left\|h_\beta - u\right\|^{(2)}$ is minimized for $\beta \in [0,1]$ and its minimum value would be $t\xi$.

Now fix $w \in E^{(2)}$. Then, we may find scalars satisfying $w = \sum_{n=1}^{\infty} \alpha_n f_n$ such that $\sum_{n=1}^{\infty} \alpha_n = 1$ with $\alpha_n \geq 0$, $\forall n \in \mathbb{N}$. We may also write each f_k with coefficients γ_k for each $k \in \mathbb{N}$ where $\gamma_1 := tv_1$, $\gamma_2 := \frac{tv_2}{2^2}$, $\gamma_3 := \frac{tv_3}{3^2}$, $\gamma_4 := \frac{tv_4}{4^2}$, $\gamma_5 := \frac{tv_5}{5^2}$, $\gamma_6 := \frac{tv_6}{6^2}$, $\gamma_7 := \frac{tv_7}{7^2}$, and $\gamma_n := \frac{v_n}{n^2}$ for all integers $n \geq 8$ such that for each $n \in \mathbb{N}$, $f_n = \gamma_n e_n$. Then,

$$\|\mathrm{w} - u\|^{(2)} = \left\| \sum_{k=1}^{\infty} \alpha_k f_k - \sum_{k=1}^{\infty} \delta_k f_k \right\|^{(2)}$$

$$
\begin{aligned}
&= \left\| \sum_{k=1}^{\infty} (\alpha_k - \delta_k) f_k \right\|^{(2)} \\
&= \sum_{k=1}^{\infty} \left| (\alpha_k - \delta_k) \frac{k^2 \gamma_k}{v_k} \right|. \\
&\geq \sum_{k=1}^{\infty} t \, |\alpha_k - \delta_k| \\
&\geq t \left| \sum_{k=1}^{\infty} (\alpha_k - \delta_k) \right| \\
&= t \left| 1 - \sum_{k=1}^{\infty} \delta_k \right| \\
&= t\xi.
\end{aligned}
$$

Hence,

$$\|\mathrm{w} - u\|^{(2)} \geq t\xi = \|h_\beta - u\|^{(2)}$$

and the equality is obtained if and only if $(1-t)\sum_{k=8}^{\infty} |\alpha_k - \delta_k| = 0$; that is, we have $\|\mathrm{w} - u\|^{(2)} = t\xi$ if and only if $\alpha_k = \delta_k$ for every $k \geq 8$; or say, $\|\mathrm{w} - u\|^{(2)} = t\xi$ if and only if $\mathrm{w} = h_\beta$ for some $\beta \in [0,1]$.

Then, there exists a continuous function $\rho: [0,1] \to E^{(2)}$ defined by $\rho(\beta) = h_\beta$ and $\Lambda\rho([0,1])$ is a compact convex subset and so $\|\mathrm{w} - u\|^{(2)}$ achieves its minimum value at $\mathrm{w} = h_\beta$ and for any $\mathrm{h}_\beta \in \Lambda$, we get

$$
\begin{aligned}
Q(h_\beta) &= Q(u) + \|h_\beta - u\|^{(2)} \\
&\leq Q(u) + \|Th_\beta - u\|^{(2)} \\
&= Q(Th_\beta) = \limsup_n \|Th_\beta - u^{(n)}\|^{(2)}
\end{aligned}
$$

then, like the inequality (2), we get

$$
\begin{aligned}
Q(h_\beta) &\leq \limsup_n \|Th_\beta - T(u^{(n)})\|^{(2)} + \limsup_n \|u^{(n)} - T(u^{(n)})\|^{(2)} \\
&\leq \limsup_n \|h_\beta - u^{(n)}\|^{(2)} + \limsup_n \|u^{(n)} - T(u^{(n)})\|^{(2)} \\
&\leq \limsup_n \|h_\beta - u^{(n)}\|^{(2)} + 0 \\
&= Q(h_\beta).
\end{aligned}
$$

Hence, $r(h_\beta) \leq Q(Th_\beta) \leq r(h_\beta)$ and so $Q(Th_\beta) = Q(h_\beta)$.
Therefore,

$$Q(u) + \|Th_\beta - u\|^{(2)} = Q(u) + \|h_\beta - u\|^{(2)}.$$

Thus, $\|Th_\beta - u\|^{(2)} = \|h_\beta - u\|^{(2)}$ and so $Th_\beta \in \Lambda$ but this shows $T(\Lambda) \subseteq \Lambda$ and using Schauder's fixed point theorem in [24], easily we get the result T has a fixed point since T is

continuous; thus, h_β is the unique minimizer of $\|w-u\|^{(2)} : w \in E^{(2)}$ and $Th_\beta = h_\beta$.

Therefore, $E^{(2)}$ has the fixed point property for nonexpansive mappings.

3. DISCUSSION

As it has been mentioned in earlier sections of the study, investigating and looking for large classes of closed, bounded and convex subsets in Banach spaces alike the Banach spaces of absolutely summable scalars are center of interests for many fixed point theorists. One can investigate to get larger classes for more general spaces than those in the present study and due to isometry, that would not be hard by following the ideas of Goebel and Kuczumows. However, trying to generalize their ideas and looking for different examples of the sets and spaces would be valuable studies.

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FIXED POINT PROPERTY FOR NONEXPANSIVE MAPPINGS ON LARGE CLASSES IN A KÖTHE-TOEPLITZ DUAL OF A DIFFERENCE SEQUENCE SPACE

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ABSTRACT

In 2000, Et and Esi introduced new type of generalized difference sequences by using the structure of Çolak's work from 1989 where he defined new types of sequence spaces while Çolak was also inspired by Kızmaz's idea about the difference operator he studied in 1981. In this study, we consider Et and Esi's work and study a Köthe-Toeplitz dual of their generalized difference sequence spaces. We take their study in terms of fixed point theory and find large classes of closed, bounded and convex subsets in that dual with fixed point property for nonexpansive mappings. The Banach space we consider is given by the following:

$$D_1^3 = \left\{ a = (a_n)_n \subset \mathbb{R}: \quad \|a\|^{(3)} = \sum_{k=1}^{\infty} \frac{k^2 |a_k|}{|v_k|} < \infty \right\}.$$

Key Words : Nonexpansive Mapping, Fixed Point Property, Closed Bounded Convex Set, Difference Sequences, Köthe-Toeplitz duals.

1. INTRODUCTION AND PRELIMINARIES

Researches have shown that the fixed point exists for some function classes defined on certain classes of sets in some spaces, while it cannot be found at all in others. Fixed point theory has examined how this happens or does not happen. Researchers have made classifications and characterizations. In 1965, Browder [3] proved that every Hilbert space has a property

satisfying that every nonexpansive mapping defined on any closed, bounded, and convex (cbc) nonempty subset domain with the same range has a fixed point. Since that time, spaces with this property have been considered to have the fixed point property for nonexpansive mappings (fppne). Then, researchers considered looking for the spaces with the property and if the property still exists when larger classes of mappings are taken. Then also they have seen spaces failing the properties. For example, in 1965, Browder [4] and Göhde [14] with independent studies, they saw that uniform convex Banach spaces have the fppne. Then, Kirk [17] generalized the result for the reflexive Banach spaces with normal structure. In fact, Goebel and Kirk [11] noticed that Kirk's result was able to extend for uniformly Lipschitz mappings and some researchers have studied estimating the Lipschitz coefficient satisfying the property for uniform Lipschitz mappings on different Banach spaces. For example, Goebel and Kirk [12] showed that for Hilbert spaces, the best Lipschitz coefficient would be a scalar less than a number in the interval $\left[\sqrt{2}\ ,\ \frac{\pi}{2}\right]$, and Goebel and Kirk [11] and Lim [18] showed independently that for a Lebesgue space L^p when $2 < p < \infty$, the coefficient is smaller by a scalar larger than or equal to $\left(1+\frac{1}{2^p}\right)^{\frac{1}{p}}$ while Alspach [1] showed that when $p = 2$, there exists a fixed point free Lipschitz mapping with Lispchitz coefficient $\sqrt{2}$ defined on a cbc subset. In fact, $\sqrt{2}$ is the smallest Lipschitz coefficient for Alspach's mapping. We need to note that, similar to the definition of the Banach spaces satisfying the fppne, if a Banach space has a property that every uniformly Lipschitz mapping defined on any cbc nonempty subset domain with the same range has a fixed point, then that Banach space has the fixed point property for uniformly Lischitz mapping (fppul). In terms of fixed point property for uniformly Lipschitz mappings, Dowling, Lennard, and Turett [6] showed that if a Banach space contains an isomorphic copy of ℓ^1, then it fails the fppul. It is a well-known fact by researchers that c_0 or ℓ^1 is almost isometrically embedded in every non-reflexive Banach space with an unconditional basis (see [21]). For this reason, classical non-reflexive Banach spaces fail the fixed point property for non-expansive mappings, that is, in these spaces, there can be a closed, convex and bounded subset and a non-expansive invariant T mapping defined on that set such that T has no fixed point. This result is based on well-known theorems in the literature (see for example Theorem 1.c.12 in [21] and Theorem 1.c.5 in [22]). These theorems state that for a Banach lattice or Banach space with an unconditional basis to be reflexive, it is necessary and sufficient if it does not contain any isomorphic copies of c_0 or ℓ^1. Therefore, this close relation to the reflexivity or nonreflexivity of Banach space, researchers have worked for years and questioned whether c_0 or ℓ^1 can be renormed to have a fixed point for nonexpansive mappings. Lin [19] showed in his study that what was thought was not true and that at least ℓ^1 could be renormed to have the fixed point property for nonexpansive mappings. Then, the remaining question was if the same could have been done for c_0, but the answer still remains open. Since the researchers have considered trying to obtain the analogous results for well-known other classical nonreflexive Banach spaces, another experiment was done for Lebesgue integrable functions space $L_1[0,1]$ by Hernandes-Lineares and Maria [20] but they were able to obtain the positive answer when they restricted the nonexpansive mappings by assuming they were affine as well. One can say that there is no doubt most research has been inspired by the ideas of the study [13]

where Goebel and Kuczumow proved that while ℓ^1 fails the fixed point property since one can easily find a cbc nonweakly compact subset there and a fixed point free invariant nonexpansive map, it is possible to find a very large class subsets in target such that invariant nonexpansive mappings defined on the members of the class have fixed points. In fact, it is easy to notice the traces of those ideas in [19] work. Even Goebel and Kuczumow's work has inspired many other researchers to investigate if there exist more example of nonreflexive Banach spaces with large classes satisfying fixed point property. For example, in 2004, Kaczor and Prus [15] wanted to generalize Goebel and Kuczumow's findings and they proved that affine asymptotically nonexpansive invariant mappings defined on a large class of cbc subsets in ℓ^1 can have fixed points. Moreover, in [10], Kaczor and Prus' results were extended by having been found larger classes satisfying the fixed point property for affine asymptotically nonexpansive mappings. Thus, affinity condition became a tool for their works. In fact, another well-known nonreflexive Banach space, Lebesgue space $L_1[0,1]$, was studied in [20] and in their study they obtained an analogous result to [19] as they showed that $L_1[0,1]$ can be renormed to have the fixed point property for affine nonexpansive mappings. In this study, we will investigate some Banach spaces analogous to ℓ^1. In the present work, we study Goebel-Kuczumow analogy for Köthe-Toeplitz duals of certain generalized difference sequence spaces investigated by Et and Esi [9]. We prove that a very large class of closed, bounded and convex subsets in Köthe-Toeplitz duals of the difference sequence spaces generalized by Et and Esi has the fixed point property for nonexpansive mappings. Therefore, firstly we would like to give the definition of Cesàro sequence spaces which was defined by Shiue [25] in 1970, and next we present Kzmaz's difference sequence space definition in [16] by noting that we work on a space which is derived from his ideas' generalizations such that many researchers (see for example [5, 7, 8, 9, 23, 26]) have generalized his work as well.

In fact, we need to note that Et and Esi's work [9] and Et and Çolak's work [8] used a common difference sequence definition from Çolak's work [5].

Now, first we recall that Shiue [25], in 1970, introduced the Cesàro sequence spaces written as

$$\mathrm{ces}_p = \left\{(x_n)_n \subset \mathbb{R} \left| \left(\sum_{n=1}^{\infty} \left(\frac{1}{n}\sum_{k=1}^{n} |x_k|\right)^p\right)^{1/p} < \infty \right.\right\}$$

such that $\ell^p \subset \mathrm{ces}_p$ and

$$\mathrm{ces}_\infty = \left\{x = (x_n)_n \subset \mathbb{R} \left| \sup_n \frac{1}{n}\sum_{k=1}^{n} |x_k| \ < \infty \right.\right\}$$

such that $\ell^\infty \subset ces_\infty$ where $1 \leq p < \infty$. Then, from the definition of Cesàro sequence spaces, Kzmaz [16], defined difference sequence spaces for ℓ^∞, c, and c_0 and symbolized them by $\ell^\infty(\Delta)$, $\mathrm{c}(\Delta)$, and $\mathrm{c}_0(\Delta)$, respectively. In his introduction, he defined the difference operator Δ applied to the sequence $x = (x_n)_n$ using the formula $\Delta x = (x_k - x_{k+1})_k$. In fact, he investigated Köthe-Toeplitz duals and their topological properties.

As one of the researchers generalizing his ideas, Çolak [5] in 1989, introduced firstly a generalized difference sequence space by taking an arbitrary sequence of nonzero complex

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values $v = (v_n)_n$ and then denoting a new difference operator by Δ_v such that for any sequence $x = (x_n)_n$, he defined the difference sequence of that $\Delta_v x = (v_k x_k - v_{k+1} x_{k+1})_k$. Then, Et and Esi [9] in 2000, generalized Çolak's difference sequence space by defining

$$\Delta_v(\ell^\infty) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v x \in \ell^\infty\},$$
$$\Delta_v(c) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v x \in c\},$$
$$\Delta_v(c_0) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v x \in c_0\}.$$

Furthermore, their m^{th} order generalized difference sequence space is given for any $m \in \mathbb{N}$ by $\Delta_v^0 x = (v_k x_k)_k$, $\Delta_v^m x = (\Delta_v^m x_k)_k = (\Delta_v^{m-1} x_k - \Delta_v^{m-1} x_{k+1})_k$ with $\Delta_v^m x_k = \sum_{i=0}^m (-1)^i \binom{m}{i} v_{k+i} x_{k+i}$ for each $k \in \mathbb{N}$.

Next, in 2004, Bektaş, Et and Çolak [2] obtained the Köthe-Toeplitz duals for the generalized difference sequence space of Et and Esi's. We may recall here that their m^{th} order difference sequence space has the following norm for any $m \in \mathbb{N}$:

$$\|x\|_v^{(m)} = \sum_{k=1}^m |v_k x_k| + \|\Delta_v^m x\|_\infty$$

Then, the corresponding Köthe-Toeplitz dual was obtained as in [2] and [9] such that it is written as below:

$$D_1^m := \{a = (a_n)_n \subset \mathbb{R} | (n^m {v_n}^{-1} a_n)_n \in \ell^1\}$$
$$= \left\{a = (a_n)_n \subset \mathbb{R}: \ \|a\|^{(m)} = \sum_{k=1}^\infty \frac{k^m |a_k|}{|v_k|} < \infty\right\}.$$

Note that $D_1^m \subset \ell^1$ if $k^m |{v_k}^{-1}| > 1$ for each $k, m \in \mathbb{N}$ and $\ell^1 \subset D_1^m$ if $k^m |{v_k}^{-1}| < 1$ for each $k, m \in \mathbb{N}$.

Now, we will need the following well-known preliminaries before giving our main results. [12] may be suggested as a good reference for these fundamentals.

Definition 1.1 *Consider that $(X, \|\cdot\|)$ is a Banach space and let C be a non-empty cbc subset. Let $T: C \to C$ be a mapping. We say that*

1. *T is an affine mapping if for every $t \in [0,1]$ and $a, b \in C$, $T\big((1-t)a + tb\big) = (1-t)T(a) + t\ T(b)$.*
2. *T is a nonexpansive mapping if for every $a, b \in C$, $\| T(a) - T(b) \| \leq \| a - b \|$.*

Then, we will easily obtain an anologous key lemma from the below lemma in the work [13].

Lemma 1.2 *Let $\{u_n\}$ be a sequence in ℓ^1 converging to u in weak-star topology. Then, for every $w \in \ell^1$,*

$$r(w) = r(u) + \|w - u\|_1$$

where

$$r(w) = \limsup_n \|u_n - w\|_1.$$

Note that our scalar field in this study will be real numbers although Çolak [5] considers complex values of $v = (v_n)_n$ while introducing his structer of the difference sequence which is taken as the fundamental concept in this study.

2. MAIN RESULTS

In this section, we will present our results. As mentioned in the first section, we investigate Goebel and Kuzmunow analogy for the space D_1^3. We aim to show that there is a large class of cbc subsets in D_1^3 such that every nonexpansive invariant mapping defined on the subsets in the class taken has a fixed point. Recall that the invariant mappings have the same domain and the range.

First, due to isometric isomorphism, using Lemma 1.2, we will provide the straight analogous result as a lemma below which will be a key step as in the works such as [13], and [10] and in fact the methods in the study [10] will be our lead in this work.

Lemma 2.1 *Let $\{u_n\}$ be a sequence in the Banach space D_1^3 and assume $\{u_n\}$ converges to u in weak-star topology. Then, for every $w \in D_1^3$,*

$$r(w) = r(u) + \|w - u\|^{(3)}$$

where

$$r(w) = \limsup_n \|u_n - w\|^{(3)}.$$

Then, we obtain our results by the following theorems.

Theorem 2.2 *Let $t \in (0,1)$. Let $(f_n)_{n\in\mathbb{N}}$ be a sequence defined by $f_1 := tv_1e_1$, $f_2 := \frac{t\ v_2}{2^3}e_2$, $f_3 := \frac{t\ v_3}{3^3}e_3$, $f_4 := \frac{t\ v_4}{4^3}e_4$, $f_5 := \frac{t\ v_5}{5^3}e_5$, $f_6 := \frac{t\ v_6}{6^3}e_6$, and $f_n := \frac{v_n}{n^3}e_n$ for all integers $n \geq 7$ where the sequence $(e_n)_{n\in\mathbb{N}}$ is the canonical basis of both c_0 and ℓ^1. Then, consider the cbc subset $E^{(3)} = E_t{}^{(3)}$ of D_1^3 by*

$$E^{(3)} := \left\{ \sum_{n=1}^{\infty} \alpha_n f_n :\ \forall n \in \mathbb{N}, \qquad \alpha_n \geq 0 \ \text{ and } \ \sum_{n=1}^{\infty} \alpha_n = 1 \right\}.$$

Then, $E^{(3)}$ has the fixed point property for $\|\ .\ \|^{(3)}$-nonexpansive mappings.

Proof. Fix $t \in (0,1)$. Let $T: E^{(3)} \to E^{(3)}$ be a $\|\ .\ \|^{(3)}$-nonexpansive mapping. Then, there exists a sequence so called aproximate fixed point sequence $\left(u^{(n)}\right)_{n\in\mathbb{N}} \in E^{(3)}$ such that $\left\|Tu^{(n)} - u^{(n)}\right\|^{(3)} \underset{n}{\to} 0$. Due to isometric isomorphism, D_1^3 shares common geometric properties with ℓ^1 and so both D_1^3 and its predual have similar fixed point theory properties to ℓ^1 and c_0, respectively. Thus, considering that on bounded subsets the weak star topology on

ℓ^1 is equivalent to the coardinate-wise convergence topology, and c_0 is separable, in D_1^3, the unit closed ball is weak*-sequentially compact due to Banach-Alaoglu theorem. Then, we can say that we may denote the weak* closure of the set $E^{(3)}$ by

$$C^{(3)} := \overline{E^{(3)}}^{w^*} = \left\{ \sum_{n=1}^{\infty} \alpha_n f_n : \text{ each } \alpha_n \geq 0 \text{ and } \sum_{n=1}^{\infty} \alpha_n \leq 1 \right\}$$

and without loss of generality, we may pass to a subsequence if necessary and get a weak* limit $u \in C^{(3)}$ of $u^{(n)}$. Then, by Lemma 2.1, we have a function $r: D_1^3 \to [0,\infty)$ defined by

$$r(w) = \limsup_n \left\| u^{(n)} - w \right\|^{(3)}, \quad \forall w \in D_1^3$$

such that for every $w \in D_1^3$,

$$r(w) = r(u) + \|u - w\|^{(3)}.$$

Case 1. $u \in E^{(3)}$.

Then, $r(Tu) = r(u) + \|Tu - u\|^{(3)}$ and

$$\begin{aligned} r(Tu) &= \limsup_n \left\| Tu - u^{(n)} \right\|^{(3)} \\ &\leq \limsup_n \left\| Tu - T\left(u^{(n)}\right) \right\|^{(3)} + \limsup_n \left\| u^{(n)} - T\left(u^{(n)}\right) \right\|^{(3)} \\ &\leq \limsup_n \left\| u - u^{(n)} \right\|^{(3)} + 0 \\ &= r(u). \end{aligned} \tag{1}$$

Thus, $r(Tu) = r(u) + \|Tu - u\|^{(3)} \leq r(u)$ and so $\|Tu - u\|^{(3)} = 0$. Therefore, $Tu = u$.

Case 2. $u \in C^{(3)} \backslash E^{(3)}$.

Then, we may find scalars satisfying $u = \sum_{n=1}^{\infty} \delta_n f_n$ such that $\sum_{n=1}^{\infty} \delta_n < 1$ and $\delta_n \geq 0, \forall n \in \mathbb{N}$.

Define $\xi := 1 - \sum_{n=1}^{\infty} \delta_n$ and for $\beta \in \left[\frac{-\delta_1}{\xi}, \frac{\delta_2}{\xi} + 1\right]$ define

$$\begin{aligned} h_\beta &:= \left(\delta_1 + \frac{\beta}{5}\xi\right) f_1 + \left(\delta_2 + \frac{\beta}{5}\xi\right) f_2 + \left(\delta_3 + \frac{\beta}{5}\xi\right) f_3 + \left(\delta_4 + \frac{\beta}{5}\xi\right) f_4 \\ &+ \left(\delta_5 + \frac{\beta}{5}\xi\right) f_5 + (\delta_6 + (1-\beta)\xi) f_6 + \sum_{n=7}^{\infty} \delta_n f_n. \end{aligned}$$

Then,

$$\begin{aligned} \|h_\beta - u\|^{(3)} &= \left\| \begin{array}{c} \frac{\beta}{5} t\xi v_1 e_1 + \frac{\beta}{5} t\xi \frac{v_2}{2^3} e_2 + \frac{\beta}{5} t\xi \frac{v_3}{3^3} e_3 \\ + \frac{\beta}{5} t\xi \frac{v_4}{4^3} e_4 + \frac{\beta}{5} t\xi \frac{v_5}{5^3} e_5 + (1-\beta)\xi \frac{t v_6 e_6}{6^3} \end{array} \right\|^{(3)} \\ &= t\left|\frac{\beta}{5}\right|\xi + t\left|\frac{\beta}{5}\right|\xi + t\left|\frac{\beta}{5}\right|\xi + t\left|\frac{\beta}{5}\right|\xi + t\left|\frac{\beta}{5}\right|\xi + t|1-\beta|\xi. \end{aligned}$$

$\|h_\beta - u\|^{(3)}$ is minimized for $\beta \in [0,1]$ and its minimum value would be $t\xi$.

Now fix $w \in E^{(3)}$. Then, we may find scalars satisfying $w = \sum_{n=1}^{\infty} \alpha_n f_n$ such that

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$\sum_{n=1}^{\infty} \alpha_n = 1$ with $\alpha_n \geq 0, \forall n \in \mathbb{N}$. We may also write each f_k with coefficients γ_k for each $k \in \mathbb{N}$ where $\gamma_1 := tv_1$, $\gamma_2 := \frac{tv_2}{2^3}$, $\gamma_3 := \frac{tv_3}{3^3}$, $\gamma_4 := \frac{tv_4}{4^3}$, $\gamma_5 := \frac{tv_5}{5^3}$, $\gamma_6 := \frac{tv_6}{6^3}$,and $\gamma_n := \frac{v_n}{n^3}$ for all integers $n \geq 7$ such that for each $n \in \mathbb{N}$, $f_n = \gamma_n e_n$.

Then,

$$\begin{aligned}
\|\mathrm{w} - u\|^{(3)} &= \left\| \sum_{k=1}^{\infty} \alpha_k f_k - \sum_{k=1}^{\infty} \delta_k f_k \right\|^{(3)} \\
&= \left\| \sum_{k=1}^{\infty} (\alpha_k - \delta_k) f_k \right\|^{(3)} \\
&= \sum_{k=1}^{\infty} \left| (\alpha_k - \delta_k) \frac{k^3 \gamma_k}{v_k} \right|. \\
&\geq \sum_{k=1}^{\infty} t \, |\alpha_k - \delta_k| \\
&\geq t \left| \sum_{k=1}^{\infty} (\alpha_k - \delta_k) \right| \\
&= t \left| 1 - \sum_{k=1}^{\infty} \delta_k \right| \\
&= t\xi.
\end{aligned}$$

Hence,

$$\|\mathrm{w} - u\|^{(3)} \geq t\xi = \|h_\beta - u\|^{(3)}$$

and the equality is obtained if and only if $(1-t)\sum_{k=7}^{\infty} |\alpha_k - \delta_k| = 0$; that is, we have $\|\mathrm{w} - u\|^{(3)} = t\xi$ if and only if $\alpha_k = \delta_k$ for every $k \geq 7$; or say, $\|\mathrm{w} - u\|^{(3)} = t\xi$ if and only if $\mathrm{w} = h_\beta$ for some $\beta \in [0,1]$.

Then, there exists a continuous function $\rho: [0,1] \to E^{(3)}$ defined by $\rho(\beta) = h_\beta$ and $\Lambda\rho([0,1])$ is a compact convex subset and so $\|\mathrm{w} - u\|^{(3)}$ achieves its minimum value at $\mathrm{w} = h_\beta$ and for any $\mathrm{h}_\beta \in \Lambda$, we get

$$\begin{aligned}
Q(h_\beta) &= Q(u) + \|h_\beta - u\|^{(3)} \\
&\leq Q(u) + \|Th_\beta - u\|^{(3)} \\
&= Q(Th_\beta) = \limsup_n \|Th_\beta - u^{(n)}\|^{(3)}
\end{aligned}$$

then, like the inequality (1), we get

$$\begin{aligned}
Q(h_\beta) &\leq \limsup_n \|Th_\beta - T(u^{(n)})\|^{(3)} + \limsup_n \|u^{(n)} - T(u^{(n)})\|^{(3)} \\
&\leq \limsup_n \|h_\beta - u^{(n)}\|^{(3)} + \limsup_n \|u^{(n)} - T(u^{(n)})\|^{(3)} \\
&\leq \limsup_n \|h_\beta - u^{(n)}\|^{(3)} + 0
\end{aligned}$$

$$= Q(h_\beta).$$

Hence, $r(h_\beta) \leq Q(Th_\beta) \leq r(h_\beta)$ and so $Q(Th_\beta) = Q(h_\beta)$.
Therefore,

$$Q(u) + \|Th_\beta - u\|^{(3)} = Q(u) + \|h_\beta - u\|^{(3)}.$$

Thus, $\|Th_\beta - u\|^{(3)} = \|h_\beta - u\|^{(3)}$ and so $Th_\beta \in \Lambda$ but this shows $T(\Lambda) \subseteq \Lambda$ and using Schauder's fixed point theorem in [24], easily we get the result T has a fixed point since T is continuous; thus, h_β is the unique minimizer of $\|w - u\|^{(3)} : w \in E^{(3)}$ and $Th_\beta = h_\beta$.

Therefore, $E^{(3)}$ has the fixed point property for nonexpansive mappings.

Theorem 2.3 *Let $t \in (0,1)$. Let $(f_n)_{n\in\mathbb{N}}$ be a sequence defined by $f_1 := tv_1e_1$, $f_2 := \frac{t\,v_2}{2^3}e_2$, $f_3 := \frac{t\,v_3}{3^3}e_3$, $f_4 := \frac{t\,v_4}{4^3}e_4$, $f_5 := \frac{t\,v_5}{5^3}e_5$, $f_6 := \frac{t\,v_6}{6^3}e_6$, $f_7 := \frac{t\,v_7}{7^3}e_7$, and $f_n := \frac{v_n}{n^3}e_n$ for all integers $n \geq 8$ where the sequence $(e_n)_{n\in\mathbb{N}}$ is the canonical basis of both c_0 and ℓ^1. Then, consider the cbc subset $E^{(3)} = E_t{}^{(3)}$ of D_1^3 by*

$$E^{(2)} = \left\{ \sum_{n=1}^{\infty} \alpha_n f_n : \quad \forall n \in \mathbb{N}, \quad \alpha_n \geq 0 \quad and \quad \sum_{n=1}^{\infty} \alpha_n = 1 \right\} .$$

Then, $E^{(3)}$ has the fixed point property for $\|\ .\ \|^{(3)}$-nonexpansive mappings.

Proof. Fix $t \in (0,1)$. Let $T: E^{(3)} \to E^{(3)}$ be a $\|\ .\ \|^{(3)}$-nonexpansive mapping. Then, there exists a sequence so called aproximate fixed point sequence $\left(u^{(n)}\right)_{n\in\mathbb{N}} \in E^{(3)}$ such that $\left\|Tu^{(n)} - u^{(n)}\right\|^{(3)} \underset{n}{\to} 0$. Due to isometric isomorphism, D_1^3 shares common geometric properties with ℓ^1 and so both D_1^2 and its predual have similar fixed point theory properties to ℓ^1 and c_0, respectively. Thus, considering that on bounded subsets the weak star topology on ℓ^1 is equivalent to the coardinate-wise convergence topology, and c_0 is separable, in D_1^3, the unit closed ball is weak*-sequentially compact due to Banach-Alaoglu theorem. Then, we can say that we may denote the weak* closure of the set $E^{(3)}$ by

$$C^{(3)} := \overline{E^{(3)}}^{w^*} = \left\{ \sum_{n=1}^{\infty} \alpha_n f_n : \ each \ \ \alpha_n \geq 0 \ \ and \ \ \sum_{n=1}^{\infty} \alpha_n \leq 1 \right\}$$

and without loss of generality, we may pass to a subsequence if necessary and get a weak* limit $u \in C^{(3)}$ of $u^{(n)}$. Then, by Lemma 2.1, we have a function $r: D_1^3 \to [0,\infty)$ defined by

$$r(w) = \limsup_n \left\|u^{(n)} - w\right\|^{(3)} , \quad \forall w \in D_1^3$$

such that for every $w \in D_1^3$,

$$r(w) = r(u) + \|u - w\|^{(3)}.$$

Case 1. $u \in E^{(3)}$.
Then, $r(Tu) = r(u) + \|Tu - u\|^{(3)}$ and

$$
\begin{aligned}
r(Tu) &= \limsup_n \left\|Tu - u^{(n)}\right\|^{(3)} \\
&\leq \limsup_n \left\|Tu - T\left(u^{(n)}\right)\right\|^{(3)} + \limsup_n \left\|u^{(n)} - T\left(u^{(n)}\right)\right\|^{(3)} \\
&\leq \limsup_n \left\|u - u^{(n)}\right\|^{(3)} + 0 \\
&= r(u).
\end{aligned} \tag{2}
$$

Thus, $r(Tu) = r(u) + \|Tu - u\|^{(3)} \leq r(u)$ and so $\|Tu - u\|^{(3)} = 0$. Therefore, $Tu = u$.

Case 2. $u \in C^{(3)} \backslash E^{(3)}$.

Then, we may find scalars satisfying $u = \sum_{n=1}^{\infty} \delta_n f_n$ such that $\sum_{n=1}^{\infty} \delta_n < 1$ and $\delta_n \geq 0$, $\forall n \in \mathbb{N}$.

Define $\xi := 1 - \sum_{n=1}^{\infty} \delta_n$ and for $\beta \in \left[\frac{-\delta_1}{\xi}, \frac{\delta_2}{\xi} + 1\right]$, define

$$
\begin{aligned}
\mathrm{h}_\beta := &\left(\delta_1 + \frac{\beta}{6}\xi\right) f_1 + \left(\delta_2 + \frac{\beta}{6}\xi\right) f_2 + \left(\delta_3 + \frac{\beta}{6}\xi\right) f_3 + \left(\delta_4 + \frac{\beta}{6}\xi\right) f_4 + \left(\delta_5 + \frac{\beta}{6}\xi\right) f_5 \\
&+ \left(\delta_6 + \frac{\beta}{6}\xi\right) f_6 + (\delta_7 + (1-\beta)\xi) f_7 + \sum_{n=8}^{\infty} \delta_n f_n.
\end{aligned}
$$

Then,

$$
\left\|h_\beta - u\right\|^{(3)} = \left\| \begin{matrix} \frac{\beta}{6} t\xi v_1 e_1 + \frac{\beta}{6} t\xi \frac{v_2}{2^3} e_2 + \frac{\beta}{6} t\xi \frac{v_3}{3^3} e_3 + \frac{\beta}{6} t\xi \frac{v_4}{4^3} e_4 \\ + \frac{\beta}{6} t\xi \frac{v_5}{5^3} e_5 + \frac{\beta}{6} t\xi \frac{v_6}{6^3} e_6 + (1-\beta)\xi \frac{t v_7 e_7}{7^3} \end{matrix} \right\|^{(3)}
$$

$$
= t\left|\frac{\beta}{6}\right| \xi + t\left|\frac{\beta}{6}\right| \xi + t\left|\frac{\beta}{6}\right| \xi + t\left|\frac{\beta}{6}\right| \xi + t\left|\frac{\beta}{6}\right| \xi + t\left|\frac{\beta}{6}\right| \xi + t|1-\beta|\xi.
$$

$\left\|h_\beta - u\right\|^{(3)}$ is minimized for $\beta \in [0,1]$ and its minimum value would be $t\xi$.

Now fix $w \in E^{(3)}$. Then, we may find scalars satisfying $w = \sum_{n=1}^{\infty} \alpha_n f_n$ such that $\sum_{n=1}^{\infty} \alpha_n = 1$ with $\alpha_n \geq 0$, $\forall n \in \mathbb{N}$. We may also write each f_k with coefficients γ_k for each $k \in \mathbb{N}$ where $\gamma_1 := tv_1$, $\gamma_2 := \frac{tv_2}{2^3}$, $\gamma_3 := \frac{tv_3}{3^3}$, $\gamma_4 := \frac{tv_4}{4^3}$, $\gamma_5 := \frac{tv_5}{5^3}$, $\gamma_6 := \frac{tv_6}{6^3}$, $\gamma_7 := \frac{tv_7}{7^3}$, and $\gamma_n := \frac{v_n}{n^3}$ for all integers $n \geq 8$ such that for each $n \in \mathbb{N}$, $f_n = \gamma_n e_n$. Then,

$$
\begin{aligned}
\|\mathrm{w} - u\|^{(3)} &= \left\| \sum_{k=1}^{\infty} \alpha_k f_k - \sum_{k=1}^{\infty} \delta_k f_k \right\|^{(3)} \\
&= \left\| \sum_{k=1}^{\infty} (\alpha_k - \delta_k) f_k \right\|^{(3)} \\
&= \sum_{k=1}^{\infty} \left| (\alpha_k - \delta_k) \frac{k^3 \gamma_k}{v_k} \right|.
\end{aligned}
$$

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$$\geq \sum_{k=1}^{\infty} t\,|\alpha_k - \delta_k|$$
$$\geq t\left|\sum_{k=1}^{\infty}(\alpha_k - \delta_k)\right|$$
$$= t\left|1 - \sum_{k=1}^{\infty}\delta_k\right|$$
$$= t\xi.$$

Hence,

$$\|\mathrm{w} - u\|^{(3)} \geq t\xi = \|h_\beta - u\|^{(3)}$$

and the equality is obtained if and only if $(1-t)\sum_{k=6}^{\infty}|\alpha_k - \delta_k| = 0$; that is, we have $\|\mathrm{w} - u\|^{(3)} = t\xi$ if and only if $\alpha_k = \delta_k$ for every $k \geq 8$; or say, $\|\mathrm{w} - u\|^{(3)} = t\xi$ if and only if $\mathrm{w} = h_\beta$ for some $\beta \in [0,1]$.

Then, there exists a continuous function $\rho: [0,1] \to E^{(3)}$ defined by $\rho(\beta) = h_\beta$ and $\Lambda\rho([0,1])$ is a compact convex subset and so $\|\mathrm{w} - u\|^{(3)}$ achieves its minimum value at $\mathrm{w} = h_\beta$ and for any $\mathrm{h}_\beta \in \Lambda$, we get

$$Q(h_\beta) = Q(u) + \|h_\beta - u\|^{(3)}$$
$$\leq Q(u) + \|Th_\beta - u\|^{(3)}$$
$$= Q(Th_\beta) = \limsup_n \|Th_\beta - u^{(n)}\|^{(3)}$$

then, like the inequality (2), we get

$$Q(h_\beta) \leq \limsup_n \|Th_\beta - T(u^{(n)})\|^{(3)} + \limsup_n \|u^{(n)} - T(u^{(n)})\|^{(3)}$$
$$\leq \limsup_n \|h_\beta - u^{(n)}\|^{(3)} + \limsup_n \|u^{(n)} - T(u^{(n)})\|^{(3)}$$
$$\leq \limsup_n \|h_\beta - u^{(n)}\|^{(3)} + 0$$
$$= Q(h_\beta).$$

Hence, $r(h_\beta) \leq Q(Th_\beta) \leq r(h_\beta)$ and so $Q(Th_\beta) = Q(h_\beta)$.
Therefore,

$$Q(u) + \|Th_\beta - u\|^{(3)} = Q(u) + \|h_\beta - u\|^{(3)}.$$

Thus, $\|Th_\beta - u\|^{(3)} = \|h_\beta - u\|^{(3)}$ and so $Th_\beta \in \Lambda$ but this shows $T(\Lambda) \subseteq \Lambda$ and using Schauder's fixed point theorem in [24], easily we get the result T has a fixed point since T is continuous; thus, h_β is the unique minimizer of $\|\mathrm{w} - u\|^{(3)} : w \in E^{(3)}$ and $Th_\beta = h_\beta$.

Therefore, $E^{(3)}$ has the fixed point property for nonexpansive mappings.

3. DISCUSSION

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As it has been mentioned in earlier sections of the study, investigating and looking for large classes of closed, bounded and convex subsets in Banach spaces alike the Banach spaces of absolutely summable scalars are center of interests for many fixed point theorists. One can investigate to get larger classes for more general spaces than those in the present study and due to isometry, that would not be hard by following the ideas of Goebel and Kuczumows. However, trying to generalize their ideas and looking for different examples of the sets and spaces would be valuable studies.

4. ACKNOWLEDGEMENT

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LARGE CLASSES IN A BANACH SPACES IN CLOSE RELATION TO AN α-DUAL OF A DIFFERENCE SEQUENCE SPACE AND THEIR FIXED POINT PROPERTIES FOR NONEXPANSIVE MAPPINGS

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ABSTRACT

In 2000, Et and Esi introduced new type of generalized difference sequences by using the structure of Çolak's work from 1989 where he defined new types of sequence spaces while Çolak was also inspired by Kızmaz's idea about the difference operator he studied in 1981. Then, using Et and Esi's structure, Ansari and Chaudhry, in 2012, introduced a new type of generalized difference sequence spaces. Changing Ansari and Chaudhry's construction slightly, Et and Işık, in 2012, obtained new type of generalized difference sequence spaces which have equivalent norm to that of Ansari and Chaudhry's type Banach spaces. Then, Et and Işık found α-duals of the Banach spaces they got and investigated geometric properties for them. In this study, we consider α-duals of Et and Işık's generalized difference sequence spaces but we study a Banach space closely related with those such that it is a degenerate Lorentz-Marcinkiewicz space. We take that Banach space related with an α-dual of Et and Işık's generalized difference sequence space in terms of fixed point theory and find large classes of closed, bounded and convex subsets in those with fixed point property for nonexpansive mappings. The Banach space we consider is given by the following for any $r \in \mathbb{R}$:

$$W_1^2 = \left\{ a = (a_k)_k \subset \mathbb{R} : \quad \|a\|_{(2)}^{\sim} = \sum_{k=1}^{\infty} \frac{|a_k|}{k^{2-r}|v_k|} < \infty \right\}.$$

Key Words : Nonexpansive Mapping, Fixed Point Property, Closed Bounded Convex Set, Difference Sequences, α-duals.

1. INTRODUCTION AND PRELIMINARIES

The fact that the fixed point exists for some function classes defined on certain classes of sets in some spaces while it cannot be found at all in others has been seen by many researches. Fixed point theory has examined how this happens or does not happen.

Researchers have made classifications and characterizations. In 1965, Browder [4] proved that every Hilbert space has a property satisfying that every nonexpansive mapping defined on any

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closed, bounded, and convex (cbc) nonempty subset domain with the same range has a fixed point. Since that time, spaces with this property have been considered to have the fixed point property for nonexpansive mappings (fppne). Then, researchers considered looking for the spaces with the property and if the property still exists when larger classes of mappings are taken. Then also they have seen spaces failing the properties. For example, in 1965, Browder [5] and Göhde [16] with independent studies, they saw that uniform convex Banach spaces have the fppne. Then, Kirk [19] generalized the result for the reflexive Banach spaces with normal structure. In fact, Goebel and Kirk [13] noticed that Kirk's result was able to extend for uniformly Lipschitz mappings and some researchers have studied estimating the Lipschitz coefficient satisfying the property for uniform Lipschitz mappings on different Banach spaces. For example, Goebel and Kirk [14] showed that for Hilbert spaces, the best Lipschitz coefficient would be a scalar less than a number in the interval $\left[\sqrt{2}\ ,\ \frac{\pi}{2}\right]$, and Goebel and Kirk [13] and Lim [20] showed independently that for a Lebesgue space L^p when $2 < p < \infty$, the coefficient is smaller by a scalar larger than or equal to $\left(1+\frac{1}{2^p}\right)^{\frac{1}{p}}$ while Alspach [1] showed that when $p = 2$, there exists a fixed point free Lipschitz mapping with Lispchitz coefficient $\sqrt{2}$ defined on a cbc subset. In fact, $\sqrt{2}$ is the smallest Lipschitz coefficient for Alspach's mapping. We need to note that, similar to the definition of the Banach spaces satisfying the fppne, if a Banach space has a property that every uniformly Lipschitz mapping defined on any cbc nonempty subset domain with the same range has a fixed point, then that Banach space has the fixed point property for uniformly Lischitz mapping (fppul). In terms of fixed point property for uniformly Lipschitz mappings, Dowling, Lennard, and Turett [7] showed that if a Banach space contains an isomorphic copy of ℓ^1, then it fails the fppul. It is a well-known fact by researchers that c_0 or ℓ^1 is almost isometrically embedded in every non-reflexive Banach space with an unconditional basis (see [23]). For this reason, classical non-reflexive Banach spaces fail the fixed point property for non-expansive mappings, that is, in these spaces, there can be a closed, convex and bounded subset and a non-expansive invariant T mapping defined on that set such that T has no fixed point. This result is based on well-known theorems in literature (see for example Theorem 1.c.12 in [23] and Theorem 1.c.5 in [24]). These theorems state that for a Banach lattice or Banach space with an unconditional basis to be reflexive, it is necessary and sufficient if it does not contain any isomorphic copies of c_0 or ℓ^1. Therefore, this close relation to the reflexivity or nonreflexivity of Banach space, researchers have worked for years and questioned whether c_0 or ℓ^1 can be renormed to have a fixed point for nonexpansive mappings. Lin [21] showed in his study that what was thought was not true and that at least ℓ^1 could be renormed to have the fixed point property for nonexpansive mappings. Then, the remaining question was if the same could have been done for c_0, but the answer still remains open. Since the researchers have considered trying to obtain the analogous results for well-known other classical nonreflexive Banach spaces, another experiment was done for Lebesgue integrable functions space $L_1[0,1]$ by Hernandes-Lineares and Maria [22] but they were able to obtain the positive answer when they restricted the nonexpansive mappings by assuming they were affine as well. One can say that there is no doubt most research has been inspired by the ideas of the study [15] where Goebel and Kuczumow proved that while ℓ^1 fails the fixed point property

since one can easily find a cbc nonweakly compact subset there and a fixed point free invariant nonexpansive map, it is possible to find a very large class subsets in target such that invariant nonexpansive mappings defined on the members of the class have fixed points. In fact, it is easy to notice the traces of those ideas in [21] work. Even Goebel and Kuczumow's work has inspired many other researchers to investigate if there exist more example of nonreflexive Banach spaces with large classes satisfying fixed point property. For example, in 2004, Kaczor and Prus [17] wanted to generalize Goebel and Kuczumow's findings and they proved that affine asymptotically nonexpansive invariant mappings defined on a large class of cbc subsets in ℓ^1 can have fixed points. Moreover, in [12], Kaczor and Prus' results were extended by having been found larger classes satisfying the fixed point property for affine asymptotically nonexpansive mappings. Thus, affinity condition became a tool for their works. In fact, another well-known nonreflexive Banach space, Lebesgue space $L_1[0,1]$, was studied in [22] and in their study they obtained an analogous result to [21] as they showed that $L_1[0,1]$ can be renormed to have the fixed point property for affine nonexpansive mappings. In this study, we will investigate some Banach spaces analogous to ℓ^1. We actually consider α-duals of Et and Işık's generalized difference sequence spaces but we study some Banach spaces closely related with those such that they are degenerate Lorentz-Marcinkiewicz spaces. We take those Banach spaces related with the α-duals of Et and Işık's generalized difference sequence spaces and study Goebel-Kuczumow analogy for them. We prove that very large classes of closed, bounded and convex subsets in some Banach spaces which are closely related with α-duals of their generalized difference sequence spaces investigated by Et and Işık [11] and actually are degenerate Lorentz-Marcinkiewicz spaces have the fixed point property for nonexpansive mappings. Therefore, firstly we would like to give the definition of Cesàro sequence spaces which was defined by Shiue [28] in 1970, and next we present Kızmaz's difference sequence space definition in [18] by noting that we work on a space which is derived from his ideas' generalizations such that many researchers (see for example [6, 8, 9, 10, 25, 28]) have generalized his work as well.

In fact, we need to note that Et and Esi's work [10] and Et and Çolak's work [9] used a common difference sequence definition from Çolak's work [6].

Now, first we recall that Shiue [28], in 1970, introduced the Cesàro sequence spaces written as

$$\mathrm{ces}_p = \left\{ (x_n)_n \subset \mathbb{R} \left| \left(\sum_{n=1}^{\infty} \left(\frac{1}{n} \sum_{k=1}^{n} |x_k| \right)^p \right)^{1/p} < \infty \right. \right\}$$

such that $\ell^p \subset \mathrm{ces}_p$ and

$$\mathrm{ces}_\infty = \left\{ x = (x_n)_n \subset \mathbb{R} \left| \sup_n \frac{1}{n} \sum_{k=1}^{n} |x_k| < \infty \right. \right\}$$

such that $\ell^\infty \subset ces_\infty$ where $1 \leq p < \infty$. Then, from the definition of Cesàro sequence spaces, Kızmaz [18], defined difference sequence spaces for ℓ^∞, c, and c_0 and symbolized them by $\ell^\infty(\Delta)$, $\mathrm{c}(\Delta)$, and $\mathrm{c}_0(\Delta)$, respectively. In his introduction, he defined the difference operator Δ

applied to the sequence $x = (x_n)_n$ using the formula $\Delta x = (x_k - x_{k+1})_k$. In fact, he investigated Köthe-Toeplitz duals and their topological properties.

As one of the researchers generalizing his ideas, Çolak [6] in 1989, introduced firstly a generalized difference sequence space by taking an arbitrary sequence of nonzero complex values $v = (v_n)_n$ and then denoting a new difference operator by Δ_v such that for any sequence $x = (x_n)_n$, he defined the difference sequence of that $\Delta_v x = (v_k x_k - v_{k+1} x_{k+1})_k$. Then, Et and Esi [10] in 2000, generalized Çolak's difference sequence space by defining

$\Delta_v(\ell^\infty) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v x \in \ell^\infty\}$,

$\Delta_v(c) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v x \in c\}$

$$\Delta_v(c_0) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v x \in c_0\}.$$

Furthermore, their m^{th} order generalized difference sequence space is given for any $m \in \mathbb{N}$ by $\Delta_v^0 x = (v_k x_k)_k$, $\Delta_v^m x = (\Delta_v^m x_k) = (\Delta_v^{m-1} x_k - \Delta_v^{m-1} x_{k+1})_k$ with $\Delta_v^m x_k = \sum_{i=0}^m (-1)^i \binom{m}{i} v_{k+i} x_{k+i}$ for each $k \in \mathbb{N}$.

Next, in 2004, Bektaş, Et and Çolak [3] obtained the Köthe-Toeplitz duals for the generalized difference sequence space of Et and Esi's. We may recall here that their m^{th} order difference sequence space has the following norm for any $m \in \mathbb{N}$:

$$\|x\|_v^{(m)} = \sum_{k=1}^{m} |v_k x_k| + \|\Delta_v^m x\|_\infty$$

Then, the corresponding Köthe-Toeplitz dual was obtained as in [3] and [10] such that it is written as below:

$$D_1^m = \{a = (a_n)_n \subset \mathbb{R} | (n^m v_n{}^{-1} a_n)_n \in \ell^1\} = \left\{a = (a_n)_n \subset \mathbb{R}: \ \|a\|^{(m)} = \sum_{k=1}^{\infty} \frac{k^m |a_k|}{|v_k|} < \infty\right\}.$$

Note that $D_1^m \subset \ell^1$ if $k^m |v_k{}^{-1}| > 1$ for each $k, m \in \mathbb{N}$ and $\ell^1 \subset D_1^m$ if $k^m |v_k{}^{-1}| < 1$ for each $k, m \in \mathbb{N}$.

Ansari and Chaudhry [2], in 2012, introduced a new type of generalized difference sequence spaces by picking an arbitrary sequence of nonzero complex values $v = (v_n)_n$ as Çolak [6] did and next by symbolizing the new difference sequence space as $\Delta_{v,r}^m(E)$ for arbitrary $r \in \mathbb{R}, m \in \mathbb{N}$ and writing that space as below where X is any of the sequence spaces ℓ^∞, c or c_0.

$$\Delta_{v,r}^m(X) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v^m x \in X\}$$

where Ansari and Chaudhry [2] defined the norm by

$$\|x\|_{\Delta,v}^m = \sum_{k=1}^{m} |v_k x_k| + \sup_{k \in \mathbb{N}} |k^r \Delta_v^m x_k|$$

Then, by obtaining an equivalent norm to Ansari and Chaudhry's Banach space, Et and Işık [11] defined m^{th} order generalized type difference sequence for any $m \in \mathbb{N}$ given by

$\Delta_{v,r}^{(m)}(X) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v^m x \in X\}$
where the norm is as follows:
$\|x\|_{\Delta,v}^{(m)} = \sup_{k\in\mathbb{N}} |k^r \Delta_v^m x_k|$

Then, Et and Işık found α-duals of the Banach spaces they got and investigated geometric properties for them such that m^{th} order α-duals for their Banach spaces are written as
$U_1^m = \{a = (a_n)_n \subset \mathbb{R} | (n^{m-r} {v_n}^{-1} a_n)_n \in \ell^1\}$
$$= \left\{a = (a_n)_n \subset \mathbb{R}: \ \|a\|_{\sim}^{(m)} = \sum_{k=1}^{\infty} \frac{k^{m-r}|a_k|}{|v_k|} < \infty\right\}$$
Note that $U_1^m \subset \ell^1$ if $k^{m-r}|{v_k}^{-1}| > 1$ for each $k, m \in \mathbb{N}$ and $\ell^1 \subset U_1^m$ if $k^{m-r}|{v_k}^{-1}| < 1$ for each $k, m \in \mathbb{N}$.

The space we are studying is given by below.
$$W_1^2 = \left\{a = (a_k)_k \subset \mathbb{R} : \ \|a\|_{(2)}^{\sim} = \sum_{k=1}^{\infty} \frac{|a_k|}{k^{2-r}|v_k|} < \infty\right\}.$$
Note that $\ell^1 \subset W_1^2$ if $k^{2-r}|v_k| > 1$ for each $k \in \mathbb{N}$ and $W_1^2 \subset \ell^1$ if $k^{2-r}|v_k| < 1$ for each $k \in \mathbb{N}$.

Now, we will need the following well-known preliminaries before giving our main results. [14] may be suggested as a good reference for these fundamentals.

Definition 1.1 *Consider that $(X, \|\cdot\|)$ is a Banach space and let C be a non-empty cbc subset. Let $T: C \to C$ be a mapping. We say that*
1. *T is an affine mapping if for every $t \in [0,1]$ and $a, b \in C$, $T\big((1-t)a + tb\big) = (1-t)T(a) + t\ T(b)$.*
2. *T is a nonexpansive mapping if for every $a, b \in C$, $\| T(a) - T(b) \| \leq \| a - b \|$.*
Then, we will easily obtain an analogous key lemma from the below lemma in the work [15].

Lemma 1.2 *Let $\{u_n\}$ be a sequence in ℓ^1 converging to u in weak-star topology. Then, for every $w \in \ell^1$, $Q(w) = Q(u) + \|w - u\|_1$ where $Q(w) = \limsup_n \|u_n - w\|_1$.*
Note that our scalar field in this study will be real numbers although Çolak [6] considers complex values of $v = (v_n)_n$ but for our study we take them as a sequence of real numbers.

2. MAIN RESULTS

In this section, we will present our results. As mentioned in the first section, we investigate Goebel and Kuzmunow analogy for the space W_1^2. We aim to show that there is a large class of cbc subsets in W_1^2 such that every nonexpansive invariant mapping defined on the subsets in the class taken has a fixed point. Recall that the invariant mappings have the same domain and the range. Note that we will assume that $r \in \mathbb{R}$ is arbitrary due to the definition of the space.

First, due to isometric isomorphism, using Lemma 1.2, we will provide the straight analogous result as a lemma below which will be a key step as in the works such as [15], and [12] and in fact the methods in the study [12] will be our lead in this work.

Lemma 2.1 *Let* $\{u_n\}$ *be a sequence in the Banach space* W_1^2 *and assume* $\{u_n\}$ *converges to* u *in weak-star topology. Then, for every* $w \in W_1^2$, $Q(w) = Q(u) + \|w-u\|_{\sim}^{(m)}$ where $Q(w) = \limsup_n \|u_n - w\|_{\sim}^{(m)}$.

Then, we obtain our results by the following theorems.

Theorem 2.2 *Fix* $r \in \mathbb{R}$ *and* $t \in (0,1)$. *Let* $(f_n)_{n\in\mathbb{N}}$ *be a sequence defined by* $f_1 := tv_1e_1$, $f_2 := t2^{2-r}v_2e_2$, $f_3 := t\,3^{2-r}v_3e_3$, $f_4 := t\,4^{2-r}v_4e_4$, *and* $f_n := n^{2-r}v_ne_n$ *for all integers* $n \geq 5$ *where the sequence* $(e_n)_{n\in\mathbb{N}}$ *is the canonical basis of both* c_0 *and* ℓ^1. *Then, consider the cbc subset* $E^{(2)} = E_t{}^{(2)}$ *of* W_1^2 *by*

$$E^{(2)} := \left\{ \sum_{n=1}^{\infty} \alpha_n f_n \colon \forall n \in \mathbb{N}, \quad \alpha_n \geq 0 \text{ and } \sum_{n=1}^{\infty} \alpha_n = 1 \right\}.$$

Then, $E^{(2)}$ has the fixed point property for $\|\ .\ \|_{(2)}^{\sim}$-nonexpansive mappings.

Proof. Fix $r \in \mathbb{R}$ *and* $t \in (0,1)$. Let $T: E^{(2)} \to E^{(2)}$ be a $\|\ .\ \|_{\sim}^{(2)}$-nonexpansive mapping. Then, there exists a sequence so called aproximate fixed point sequence $\left(u^{(n)}\right)_{n\in\mathbb{N}} \in E^{(2)}$ such that $\left\|Tu^{(n)} - u^{(n)}\right\|_{(2)}^{\sim} \underset{n}{\to} 0$. Due to isometric isomorphism, W_1^2 shares common geometric properties with ℓ^1 and so both W_1^2 and its predual have similar fixed point theory properties to ℓ^1 and c_0, respectively. Thus, considering that on bounded subsets the weak star topology on ℓ^1 is equivalent to the coardinate-wise convergence topology, and c_0 is separable, in W_1^2, the unit closed ball is weak*-sequentially compact due to Banach-Alaoglu theorem. Then, we can say that we may denote the weak* closure of the set $E^{(2)}$ by

$$C^{(2)} := \overline{E^{(2)}}^{w^*} = \left\{ \sum_{n=1}^{\infty} \alpha_n f_n \colon \text{each } \alpha_n \geq 0 \text{ and } \sum_{n=1}^{\infty} \alpha_n \leq 1 \right\}$$

and without loss of generality, we may pass to a subsequence if necessary and get a weak* limit $u \in C^{(2)}$ of $u^{(n)}$. Then, by Lemma 2.1, we have a function $r: W_1^2 \to [0,\infty)$ defined by

$$Q(w) = \limsup_n \left\|u^{(n)} - w\right\|_{(2)}^{\sim}, \quad \forall w \in W_1^2$$

such that for every $w \in W_1^2$,

$$Q(w) = Q(u) + \|u - w\|_{(2)}^{\sim}.$$

Case 1. $u \in E^{(2)}$.

Then, $r(Tu) = r(u) + \|Tu - u\|_{(2)}^{\sim}$ and

$$Q(Tu) = \limsup_n \left\| Tu - u^{(n)} \right\|_{(2)}^{\sim} \leq \limsup_n \left\|Tu - T\left(u^{(n)}\right)\right\|_{(2)}^{\sim} + \limsup_n \left\|u^{(n)} - T\left(u^{(n)}\right)\right\|_{(2)}^{\sim}$$

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$$\leq \limsup_n \|u - u^{(n)}\|_{(2)}^{\sim} + 0 = Q(u). \quad (1)$$

Thus, $Q(Tu) = Q(u) + \|Tu - u\|_{(2)}^{\sim} \leq r(u)$ and so $\|Tu - u\|_{(2)}^{\sim} = 0$. Therefore, $Tu = u$.

Case 2. $u \in C^{(2)} \backslash E^{(2)}$.
Then, we may find scalars satisfying $u = \sum_{n=1}^{\infty} \delta_n f_n$ such that $\sum_{n=1}^{\infty} \delta_n < 1$ and $\delta_n \geq 0, \forall n \in \mathbb{N}$.

Define $\xi := 1 - \sum_{n=1}^{\infty} \delta_n$ and for $\beta \in \left[\frac{-\delta_1}{\xi}, \frac{\delta_2}{\xi} + 1\right]$ define

$$h_\beta := \left(\delta_1 + \frac{\beta}{3}\xi\right) f_1 + \left(\delta_2 + \frac{\beta}{3}\xi\right) f_2 + \left(\delta_3 + \frac{\beta}{3}\xi\right) f_3 + (\delta_4 + (1-\beta)\xi) f_4 + \sum_{n=5}^{\infty} \delta_n f_n.$$

Then,

$$\|h_\beta - u\|_{(2)}^{\sim} = \left\| \frac{\beta}{3} t\xi v_1 e_1 + \frac{\beta}{3} t\xi 2^{2-r} v_2 e_2 + \frac{\beta}{3} t\xi 3^{2-r} v_3 e_3 + (1-\beta)\xi t\, 4^{2-r}\, v_4 e_4 \right\|_{(2)}^{\sim}$$

$$= t\left|\frac{\beta}{3}\right|\xi + t\left|\frac{\beta}{3}\right|\xi + t\left|\frac{\beta}{3}\right|\xi + t|1-\beta|\xi.$$

$\|h_\beta - u\|_{(2)}^{\sim}$ is minimized for $\beta \in [0,1]$ and its minimum value would be $t\xi$.

Now fix $w \in E^{(2)}$. Then, we may find scalars satisfying $w = \sum_{n=1}^{\infty} \alpha_n f_n$ such that $\sum_{n=1}^{\infty} \alpha_n = 1$ with $\alpha_n \geq 0, \quad \forall n \in \mathbb{N}$. We may also write each f_k with coefficients γ_k for each $k \in \mathbb{N}$ where $\gamma_1 := tv_1, \gamma_2 := t2^{2-r}v_2, \gamma_3 := t3^{2-r}v_3, \gamma_4 := t4^{2-r}v_4$, and $\gamma_n := n^{2-r}v_n$ for all integers $n \geq 5$ such that for each $n \in \mathbb{N}$, $f_n = \gamma_n e_n$.

Then,

$$\|w - u\|_{(2)}^{\sim} = \left\| \sum_{k=1}^{\infty} \alpha_k f_k - \sum_{k=1}^{\infty} \delta_k f_k \right\|_{(2)}^{\sim}$$

$$= \left\| \sum_{k=1}^{\infty} (\alpha_k - \delta_k) f_k \right\|_{(2)}^{\sim}$$

$$= \sum_{k=1}^{\infty} \left| (\alpha_k - \delta_k) \frac{\gamma_k}{k^{2-r} v_k} \right|$$

$$\geq \sum_{k=1}^{\infty} t\, |\alpha_k - \delta_k|$$

$$\geq t \left| \sum_{k=1}^{\infty} (\alpha_k - \delta_k) \right|$$

$$= t\left|1 - \sum_{k=1}^{\infty} \delta_k\right|$$

$= t\xi.$

Hence,

$\|w - u\|_{(2)}^{\sim} \geq t\xi = \|h_\beta - u\|_{(2)}^{\sim}$

and the equality is obtained if and only if $(1-t)\sum_{k=5}^{\infty} |\alpha_k - \delta_k| = 0$; that is, we have $\|w - u\|_{(2)}^{\sim} = t\xi$ if and only if $\alpha_k = \delta_k$ for every $k \geq 5$; or say, $\|w - u\|_{(2)}^{\sim} = t\xi$ if and only if $w = h_\beta$ for some $\beta \in [0,1]$.

Then, there exists a continuous function $\rho\colon [0,1] \to E^{(2)}$ defined by $\rho(\beta) = h_\beta$ and $\Lambda\rho([0,1])$ is a compact convex subset and so $\|w - u\|_{(2)}^{\sim}$ achieves its minimum value at $w = h_\beta$ and for any $h_\beta \in \Lambda$, we get

$$Q(h_\beta) = Q(u) + \|h_\beta - u\|_{(2)}^{\sim}$$
$$\leq Q(u) + \|Th_\beta - u\|_{(2)}^{\sim}$$
$$= Q(Th_\beta) = \limsup_n \|Th_\beta - u^{(n)}\|_{(2)}^{\sim}$$

then, like the inequality (1), we get

$$Q(h_\beta) \leq \limsup_n \|Th_\beta - T(u^{(n)})\|_{(2)}^{\sim} + \limsup_n \|u^{(n)} - T(u^{(n)})\|_{(2)}^{\sim}$$
$$\leq \limsup_n \|h_\beta - u^{(n)}\|_{(2)}^{\sim} + \limsup_n \|u^{(n)} - T(u^{(n)})\|_{(2)}^{\sim}$$
$$\leq \limsup_n \|h_\beta - u^{(n)}\|_{(2)}^{\sim} + 0 = Q(h_\beta).$$

Hence, $r(h_\beta) \leq Q(Th_\beta) \leq r(h_\beta)$ and so $Q(Th_\beta) = Q(h_\beta)$.

Therefore,

$Q(u) + \|Th_\beta - u\|_{(2)}^{\sim} = Q(u) + \|h_\beta - u\|_{(2)}^{\sim}$.

Thus, $\|Th_\beta - u\|_{(2)}^{\sim} = \|h_\beta - u\|_{(2)}^{\sim}$ and so $Th_\beta \in \Lambda$ but this shows $T(\Lambda) \subseteq \Lambda$ and using Schauder's fixed point theorem [26] easily we get the result T has a fixed point since T is continuous; thus, h_β is the unique minimizer of $\|w - u\|_{(2)}^{\sim}$: $w \in E^{(2)}$ and $Th_\beta = h_\beta$.

Therefore, $E^{(2)}$ has the fixed point property for nonexpansive mappings.

Theorem 2.3 *Fix $r \in \mathbb{R}$ and $t \in (0,1)$. Let $(f_n)_{n\in\mathbb{N}}$ be a sequence defined by $f_1 := tv_1e_1$, $f_2 := t\,2^{2-r}\,v_2e_2$, $f_3 := t\,3^{2-r}\,v_3e_3$, $f_4 := t\,4^{2-r}\,v_4e_4$, $f_5 := t\,5^{2-r}\,v_5e_5$, and $f_n := n^{2-r}v_ne_n$ for all integers $n \geq 6$ where the sequence $(e_n)_{n\in\mathbb{N}}$ is the canonical basis of both c_0 and ℓ^1. Then, consider the cbc subset $E^{(2)} = E_t{}^{(2)}$ of W_1^2 by*

$$E^{(2)} := \left\{\sum_{n=1}^{\infty} \alpha_n f_n\colon\ \forall n \in \mathbb{N},\qquad \alpha_n \geq 0 \ \text{and}\ \sum_{n=1}^{\infty} \alpha_n = 1\right\}.$$

Then, $E^{(2)}$ has the fixed point property for $\|\ .\ \|_{(2)}^{\sim}$-nonexpansive mappings.

Proof. Fix $r \in \mathbb{R}$ *and* $t \in (0,1)$. Let $T\colon E^{(2)} \to E^{(2)}$ be a $\|\ .\ \|_{\sim}^{(2)}$-nonexpansive mapping. Then,

there exists a sequence so called aproximate fixed point sequence $\left(u^{(n)}\right)_{n\in\mathbb{N}} \in E^{(2)}$ such that $\left\|Tu^{(n)} - u^{(n)}\right\|_{(2)}^{\sim} \underset{n}{\to} 0$. Due to isometric isomorphism, W_1^2 shares common geometric properties with ℓ^1 and so both W_1^2 and its predual have similar fixed point theory properties to ℓ^1 and c_0, respectively. Thus, considering that on bounded subsets the weak star topology on ℓ^1 is equivalent to the coardinate-wise convergence topology, and c_0 is separable, in W_1^2, the unit closed ball is weak*-sequentially compact due to Banach-Alaoglu theorem. Then, we can say that we may denote the weak* closure of the set $E^{(2)}$ by

$$C^{(2)} := \overline{E^{(2)}}^{w^*} = \left\{\sum_{n=1}^{\infty} \alpha_n f_n : \text{ each } \alpha_n \geq 0 \text{ and } \sum_{n=1}^{\infty} \alpha_n \leq 1\right\}$$

and without loss of generality, we may pass to a subsequence if necessary and get a weak* limit $u \in C^{(2)}$ of $u^{(n)}$. Then, by Lemma 2.1, we have a function $r: W_1^2 \to [0,\infty)$ defined by

$$Q(w) = \limsup_n \left\|u^{(n)} - w\right\|_{(2)}^{\sim}, \quad \forall w \in W_1^2$$

such that for every $w \in W_1^2$,

$$Q(w) = Q(u) + \|u - w\|_{(2)}^{\sim}.$$

Case 1. $u \in E^{(2)}$.

Then, $r(Tu) = r(u) + \|Tu - u\|_{(2)}^{\sim}$ and

$$Q(Tu) = \limsup_n \left\| Tu - u^{(n)} \right\|_{(2)}^{\sim} \leq \limsup_n \left\|Tu - T\left(u^{(n)}\right)\right\|_{(2)}^{\sim} + \limsup_n \left\|u^{(n)} - T\left(u^{(n)}\right)\right\|_{(2)}^{\sim}$$
$$\leq \limsup_n \left\|u - u^{(n)}\right\|_{(2)}^{\sim} + 0 = Q(u). \qquad (2)$$

Thus, $Q(Tu) = Q(u) + \|Tu - u\|_{(2)}^{\sim} \leq r(u)$ and so $\|Tu - u\|_{(2)}^{\sim} = 0$. Therefore, $Tu = u$.

Case 2. $u \in C^{(2)} \backslash E^{(2)}$.

Then, we may find scalars satisfying $u = \sum_{n=1}^{\infty} \delta_n f_n$ such that $\sum_{n=1}^{\infty} \delta_n < 1$ and $\delta_n \geq 0, \forall n \in \mathbb{N}$.

Define $\xi := 1 - \sum_{n=1}^{\infty} \delta_n$ and for $\beta \in \left[\frac{-\delta_1}{\xi}, \frac{\delta_2}{\xi} + 1\right]$, define

$$h_\beta := \left(\delta_1 + \frac{\beta}{4}\xi\right) f_1 + \left(\delta_2 + \frac{\beta}{4}\xi\right) f_2 + \left(\delta_3 + \frac{\beta}{4}\xi\right) f_3 + \left(\delta_4 + \frac{\beta}{4}\xi\right) f_4 + (\delta_5 + (1-\beta)\xi) f_5 + \sum_{n=6}^{\infty} \delta_n f_n.$$

Then,

$$\left\|h_\beta - u\right\|_{(2)}^{\sim} = \left\| \frac{\beta}{4} t\xi v_1 e_1 + \frac{\beta}{4} t\xi 2^{2-r} v_2 e_2 + \frac{\beta}{4} t\xi 3^{2-r} v_3 e_3 + \frac{\beta}{4} t\xi 4^{2-r} v_4 e_4 + (1-\beta)\xi t\, 5^{2-r}\, v_5 e_5 \right\|_{(2)}^{\sim}$$
$$= t\left|\frac{\beta}{4}\right|\xi + t\left|\frac{\beta}{4}\right|\xi + t\left|\frac{\beta}{4}\right|\xi + t\left|\frac{\beta}{4}\right|\xi + t|1-\beta|\xi.$$

$\|h_\beta - u\|_{(2)}^{\sim}$ is minimized for $\beta \in [0,1]$ and its minimum value would be $t\xi$.

Now fix $w \in E^{(2)}$. Then, we may find scalars satisfying $w = \sum_{n=1}^{\infty} \alpha_n f_n$ such that $\sum_{n=1}^{\infty} \alpha_n = 1$ with $\alpha_n \geq 0, \quad \forall n \in \mathbb{N}$. We may also write each f_k with coefficients γ_k for each $k \in \mathbb{N}$ where $\gamma_1 := tv_1$, $\gamma_2 := t2^{2-r}v_2$, $\gamma_3 := t3^{2-r}v_3$, $\gamma_4 := t4^{2-r}v_4$, $\gamma_5 := t5^{2-r}v_5$,and $\gamma_n := n^{2-r}v_n$ for all integers $n \geq 6$ such that for each $n \in \mathbb{N}$, $f_n = \gamma_n e_n$.

Then,

$$\|w - u\|_{(2)}^{\sim} = \left\| \sum_{k=1}^{\infty} \alpha_k f_k - \sum_{k=1}^{\infty} \delta_k f_k \right\|_{(2)}^{\sim}$$

$$= \left\| \sum_{k=1}^{\infty} (\alpha_k - \delta_k) f_k \right\|_{(2)}^{\sim}$$

$$= \sum_{k=1}^{\infty} \left| (\alpha_k - \delta_k) \frac{\gamma_k}{k^{2-r} v_k} \right|$$

$$\geq \sum_{k=1}^{\infty} t \ |\alpha_k - \delta_k|$$

$$\geq t \left| \sum_{k=1}^{\infty} (\alpha_k - \delta_k) \right|$$

$$= t \left| 1 - \sum_{k=1}^{\infty} \delta_k \right|$$

$$= t\xi.$$

Hence,

$$\|w - u\|_{(2)}^{\sim} \geq t\xi = \|h_\beta - u\|_{(2)}^{\sim}$$

and the equality is obtained if and only if $(1-t)\sum_{k=6}^{\infty} |\alpha_k - \delta_k| = 0$; that is, we have $\|w - u\|_{(2)}^{\sim} = t\xi$ if and only if $\alpha_k = \delta_k$ for every $k \geq 6$; or say, $\|w - u\|_{(2)}^{\sim} = t\xi$ if and only if $w = h_\beta$ for some $\beta \in [0,1]$.

Then, there exists a continuous function $\rho: [0,1] \to E^{(2)}$ defined by $\rho(\beta) = h_\beta$ and $\Lambda\rho([0,1])$ is a compact convex subset and so $\|w - u\|_{(2)}^{\sim}$ achieves its minimum value at $w = h_\beta$ and for any $h_\beta \in \Lambda$, we get

$$Q(h_\beta) = Q(u) + \|h_\beta - u\|_{(2)}^{\sim}$$

$$\leq Q(u) + \|Th_\beta - u\|_{(2)}^{\sim}$$

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then, like the inequality (1), we get

$$Q(h_\beta) \leq \limsup_n \|Th_\beta - T(u^{(n)})\|_{(2)}^{\sim} + \limsup_n \|u^{(n)} - T(u^{(n)})\|_{(2)}^{\sim}$$

$$\leq \limsup_n \left\|h_\beta - u^{(n)}\right\|_{(2)}^{\sim} + \limsup_n \left\|u^{(n)} - T\left(u^{(n)}\right)\right\|_{(2)}^{\sim}$$
$$\leq \limsup_n \left\|h_\beta - u^{(n)}\right\|_{(2)}^{\sim} + 0 = Q\left(h_\beta\right).$$

Hence, $r(h_\beta) \leq Q(Th_\beta) \leq r(h_\beta)$ and so $Q(Th_\beta) = Q(h_\beta)$.

Therefore,

$$Q(u) + \left\|Th_\beta - u\right\|_{(2)}^{\sim} = Q(u) + \left\|h_\beta - u\right\|_{(2)}^{\sim}.$$

Thus, $\left\|Th_\beta - u\right\|_{(2)}^{\sim} = \left\|h_\beta - u\right\|_{(2)}^{\sim}$ and so $Th_\beta \in \Lambda$ but this shows $T(\Lambda) \subseteq \Lambda$ and using Schauder's fixed point theorem [26] easily we get the result T has a fixed point since T is continuous; thus, h_β is the unique minimizer of $\|w - u\|_{(2)}^{\sim} : w \in E^{(2)}$ and $Th_\beta = h_\beta$.

Therefore, $E^{(2)}$ has the fixed point property for nonexpansive mappings.

3. DISCUSSION

As it has been mentioned in earlier sections of the study, investigating and looking for large classes of closed, bounded and convex subsets in Banach spaces alike the Banach spaces of absolutely summable scalars are center of interests for many fixed point theorists. One can investigate to get larger classes for more general spaces than those in the present study and due to isometry, that would not be hard by following the ideas of Goebel and Kuczumows. However, trying to generalize their ideas and looking for different examples of the sets and spaces would be valuable studies.

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FIXED POINT PROPERTY FOR NONEXPANSIVE MAPPINGS ON LARGE CLASSES IN AN α-DUAL OF A DIFFERENCE SEQUENCE SPACE

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ABSTRACT

In 2000, Et and Esi introduced new type of generalized difference sequences by using the structure of Çolak's work from 1989 where he defined new types of sequence spaces while Çolak was also inspired by Kızmaz's idea about the difference operator he studied in 1981. Then, using Et and Esi's structure, Ansari and Chaudhry, in 2012, introduced a new type of generalized difference sequence spaces. Changing Ansari and Chaudhry's construction slightly, Et and Işık, in 2012, obtained new type of generalized difference sequence spaces which have equivalent norm to that of Ansari and Chaudhry's type Banach spaces. Then, Et and Işık found α-duals of the Banach spaces they got and investigated geometric properties for them. In this study, we consider Et and Işık's work and study α-dual of one of their generalized difference sequence spaces. We take their study in terms of fixed point theory and find large classes of closed, bounded and convex subsets in those duals with fixed point property for nonexpansive mappings. The Banach space we consider is given by the following for any $r \in \mathbb{R}$:

$$U_1^3 = \left\{a = (a_n)_n \subset \mathbb{R}: \quad \|a\|_{\sim}^{(3)} = \sum_{k=1}^{\infty} \frac{k^{3-r}|a_k|}{|v_k|} < \infty\right\}$$

Key Words : Nonexpansive Mapping, Fixed Point Property, Closed Bounded Convex Set, Difference Sequences, α-duals.

1. INTRODUCTION AND PRELIMINARIES

It has been seen by many researches that the fixed point exists for some function classes defined on certain classes of sets in some spaces, while it cannot be found at all in others. Fixed point theory has examined how this happens or does not happen.

Researchers have made classifications and characterizations. In 1965, Browder [4] proved that every Hilbert space has a property satisfying that every nonexpansive mapping defined on any closed, bounded, and convex (cbc) nonempty subset domain with the same range has a fixed point. Since that time, spaces with this property have been considered to have the fixed point property for nonexpansive mappings (fppne). Then, researchers considered looking for the spaces with the property and if the property still exists when larger classes of mappings are

taken. Then also they have seen spaces failing the properties. For example, Browder [5] and Göhde [16] independently saw in 1965 that uniform convex Banach spaces have the fppne. Then, again in the same year, Kirk [19] generalized the result for the reflexive Banach spaces with normal structure. In fact, Goebel and Kirk in 1973 noticed that Kirk's result was able to extend for uniformly Lipschitz mappings and some researchers have studied estimating the Lipschitz coefficient satisfying the property for uniform Lipschitz mappings on different Banach spaces [13]. Furthermore, Goebel and Kirk in 1990 [14] showed that for Hilbert spaces, the best Lipschitz coefficient would be a scalar less than a number in the interval $\left[\sqrt{2}, \frac{\pi}{2}\right]$, and in 1973, Goebel and Kirk with their study [13] and in 1983, Lim's work [20] showed independently that for a Lebesgue space L^p when $2 < p < \infty$, the coefficient is smaller by a scalar larger than or equal to $\left(1 + \frac{1}{2^p}\right)^{\frac{1}{p}}$ while Alspach in 1981 with his study [1] showed that when $p = 2$, there exists a fixed point free Lipschitz mapping with Lispchitz coefficient $\sqrt{2}$ defined on a cbc subset. In fact, $\sqrt{2}$ is the smallest Lipschitz coefficient for Alspach's mapping. We need to note that, similar to the definition of the Banach spaces satisfying the fppne, if a Banach space has a property that every uniformly Lipschitz mapping defined on any cbc nonempty subset domain with the same range has a fixed point, then that Banach space has the fixed point property for uniformly Lischitz mapping (fppul). In terms of fixed point property for uniformly Lipschitz mappings, Dowling, Lennard, and Turett in 2000 with their study [7] showed that if a Banach space contains an isomorphic copy of ℓ^1, then it fails the fppul. It is a well-known fact by researchers that c_0 or ℓ^1 is almost isometrically embedded in every non-reflexive Banach space with an unconditional basis as in Lindenstraus and Tzafriri's study [23] in 1977. For this reason, classical non-reflexive Banach spaces fail the fixed point property for non-expansive mappings, that is, in these spaces, there can be found a closed, convex and bounded subset and a non-expansive invariant T mapping defined on that set such that T has no fixed point. This result is based on well-known theorems in literature (see for example Theorem 1.c.12 in Lindenstraus and Tzafriri's work [23] and Theorem 1.c.5 in their other work [24]). These theorems state that for a Banach lattice or Banach space with an unconditional basis to be reflexive, it is necessary and sufficient if it does not contain any isomorphic copies of c_0 or ℓ^1. Therefore, this close relation to the reflexivity or nonreflexivity of Banach space, researchers have worked for years and questioned whether c_0 or ℓ^1 can be renormed to have a fixed point for nonexpansive mappings. In 2008, Lin showed in his study [21] that what was thought was not true and that at least ℓ^1 could be renormed to have the fixed point property for nonexpansive mappings. Then, the remaining question was if the same could have been done for c_0, but the answer still remains open. Since the researchers have considered trying to obtain the analogous results for well-known other classical nonreflexive Banach spaces, another experiment was done for Lebesgue integrable functions space $L_1[0,1]$ by Hernandes-Lineares and Maria's work [22] in 2012 but they were able to obtain the positive answer when they restricted the nonexpansive mappings by assuming they were affine as well. One can say that there is no doubt most research has been inspired by the ideas of Goebel and Kuczumow's work [15] where they proved that while ℓ^1 fails the fixed point property since one can easily find a cbc nonweakly compact subset there and a fixed point free invariant nonexpansive map, it is

possible to find a very large class subsets in target such that invariant nonexpansive mappings defined on the members of the class have fixed points. In fact, it is easy to notice the traces of those ideas in Lin's work [21]. Even Goebel and Kuczumow's work has inspired many other researchers to investigate if there exist more example of nonreflexive Banach spaces with large classes satisfying fixed point property. For example, in 2004, Kaczor and Prus [17] wanted to generalize Goebel and Kuczumow's findings and they proved that affine asymptotically nonexpansive invariant mappings defined on a large class of cbc subsets in ℓ^1 can have fixed points. Moreover, in 2013, under supervision of Lennard, Everest showed in his PhD thesis [12] that Kaczor and Prus' results were extended by having been found larger classes satisfying the fixed point property for affine asymptotically nonexpansive mappings. Thus, affinity condition became a tool for their works. In fact, another well-known nonreflexive Banach space, Lebesgue space $L_1[0,1]$, was studied in 2012 by Hernández-Linares and Japón and in their study [22], an analogous result to Lin's [21] was obrained as they showed that $L_1[0,1]$ can be renormed to have the fixed point property for affine nonexpansive mappings. In this study, we will investigate some Banach spaces analogous to ℓ^1. In the present work, we study Goebel-Kuczumow analogy for α-duals of their generalized difference sequence spaces investigated by Et and Işık's work [11] in 2012. We prove that a very large class of closed, bounded and convex subsets in α-duals of their generalized difference sequence spaces investigated by Et and Işık has the fixed point property for nonexpansive mappings. Therefore, firstly we would like to give the definition of Cesàro sequence spaces which was defined in [27] by Shiue in 1970, and next we present Kızmaz's difference sequence space definition in 1981 with his study [18] by noting that we work on a space which is derived from his ideas' generalizations such that many researchers (see for example [6, 8, 9, 10, 25, 28]) have generalized his work as well.

In fact, we need to note that Et and Esi's work [10] in 2000 and Et and Çolak's study [9] in 1995 used a common difference sequence definition from Çolak's study [6] in 1989.

Shiue in 1970 defined in [27] the Cesàro sequence spaces by

$$\mathrm{ces}_p = \left\{ (x_n)_n \subset \mathbb{R} \left| \left(\sum_{n=1}^{\infty} \left(\frac{1}{n} \sum_{k=1}^{n} |x_k| \right)^p \right)^{1/p} < \infty \right. \right\}$$

such that $\ell^p \subset \mathrm{ces}_p$ and

$$\mathrm{ces}_\infty = \left\{ x = (x_n)_n \subset \mathbb{R} \left| \sup_n \frac{1}{n} \sum_{k=1}^{n} |x_k| < \infty \right. \right\}$$

such that $\ell^\infty \subset ces_\infty$ where $1 \leq p < \infty$. Then, from the definition of Cesàro sequence spaces, Kızmaz in 1981 with his study [18] defined difference sequence spaces for ℓ^∞, c, and c_0 and symbolized them by $\ell^\infty(\Delta)$, $c(\Delta)$, and $c_0(\Delta)$, respectively. In his introduction, he defined the difference operator Δ applied to the sequence $x = (x_n)_n$ using the formula $\Delta x = (x_k - x_{k+1})_k$. In fact, he investigated Köthe-Toeplitz duals and their topological properties.

As one of the researchers generalizing his ideas, in 1989, Çolak's work [6] introduced firstly a

generalized difference sequence space by taking an arbitrary sequence of nonzero complex values $v = (v_n)_n$ and then denoting a new difference operator by Δ_v such that for any sequence $x = (x_n)_n$, he defined the difference sequence of that $\Delta_v x = (v_k x_k - v_{k+1} x_{k+1})_k$. Then, Et and Esi (2000) generalized Çolak's difference sequence space by defining

$$\Delta_v(\ell^\infty) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v x \in \ell^\infty\},$$
$$\Delta_v(c) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v x \in c\},$$
$$\Delta_v(c_0) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v x \in c_0\}.$$

Furthermore, their m^{th} order generalized difference sequence space is given for any $m \in \mathbb{N}$ by $\Delta_v^0 x = (v_k x_k)_k$, $\Delta_v^m x = (\Delta_v^m x_k)_k = (\Delta_v^{m-1} x_k - \Delta_v^{m-1} x_{k+1})_k$ with $\Delta_v^m x_k = \sum_{i=0}^m (-1)^i \binom{m}{i} v_{k+i} x_{k+i}$ for each $k \in \mathbb{N}$.

Next Bektaş, Et and Çolak in 2004 with their study [3] obtained the Köthe-Toeplitz duals for the generalized difference sequence space of Et and Esi's. We may recall here that their m^{th} order difference sequence space has the following norm for any $m \in \mathbb{N}$:

$$\|x\|_v^{(m)} = \sum_{k=1}^m |v_k x_k| + \|\Delta_v^m x\|_\infty$$

Then, the corresponding Köthe-Toeplitz dual was obtained as in Bektaş, Et and Çolak's work [3] and in 2000 Et and Esi's work [10] such that it is written as below:

$$D_1^m = \{a = (a_n)_n \subset \mathbb{R} | (n^m {v_n}^{-1} a_n)_n \in \ell^1\}$$
$$= \left\{a = (a_n)_n \subset \mathbb{R}: \|a\|^{(m)} = \sum_{k=1}^\infty \frac{k^m |a_k|}{|v_k|} < \infty\right\}.$$

Note that $D_1^m \subset \ell^1$ if $k^m |{v_k}^{-1}| > 1$ for each $k, m \in \mathbb{N}$ and $\ell^1 \subset D_1^m$ if $k^m |{v_k}^{-1}| < 1$ for each $k, m \in \mathbb{N}$.

In 2012, Ansari and Chaudhry introduced in their study [2] a new type of generalized difference sequence spaces by picking an arbitrary sequence of nonzero complex values $v = (v_n)_n$ as Çolak's work in 1989 [6] and next by symbolizing the new difference sequence space as $\Delta_{v,r}^m(E)$ for arbitrary $r \in \mathbb{R}$, $m \in \mathbb{N}$ and writing that space as below where X is any of the sequence spaces ℓ^∞, c or c_0.

$$\Delta_{v,r}^m(X) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v^m x \in X\}$$

where Ansari and Chaudhry in [2] defined the norm by

$$\|x\|_{\Delta,v}^m = \sum_{k=1}^m |v_k x_k| + \sup_{k \in \mathbb{N}} |k^r \Delta_v^m x_k|$$

Then, by obtaining an equivalent norm to Ansari and Chaudhry's Banach space, Et and Işık in 2012 with their work [11] defined m^{th} order generalized type difference sequence for any $m \in \mathbb{N}$ given by

$$\Delta_{v,r}^{(m)}(X) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v^m x \in X\}$$

where the norm is as follows:

$$\|x\|_{\Delta,v}^{(m)} = \sup_{k \in \mathbb{N}} |k^r \Delta_v^m x_k|$$

Then, Et and Işık found α-duals of the Banach spaces they got and investigated geometric properties for them such that m^{th} order α-duals for their Banach spaces are written as

$$U_1^m = \{a = (a_n)_n \subset \mathbb{R} | (n^{m-r} v_n{}^{-1} a_n)_n \in \ell^1\}$$
$$= \left\{a = (a_n)_n \subset \mathbb{R}: \|a\|_{\sim}^{(m)} = \sum_{k=1}^{\infty} \frac{k^{m-r}|a_k|}{|v_k|} < \infty\right\}$$

Note that $U_1^m \subset \ell^1$ if $k^{m-r}|v_k{}^{-1}| > 1$ for each $k, m \in \mathbb{N}$ and $\ell^1 \subset U_1^m$ if $k^{m-r}|v_k{}^{-1}| < 1$ for each $k, m \in \mathbb{N}$.

Before starting to introduce our work and results, we would like to give some well-known and important facts. One may see in 1990's work of Goebel and Kirk [14] for the fundamentals given below.

Definition 1.1 *Consider that $(X, \|\cdot\|)$ is a Banach space and let C be a non-empty cbc subset. Let $T: C \to C$ be a mapping. We say that*

1. *T is an affine mapping if for every $t \in [0,1]$ and $a, b \in C$,*
$T\big((1-t)a + tb\big) = (1-t)T(a) + t\,T(b)$.
2. *T is a nonexpansive mapping if for every $a, b \in C$, $\| T(a) - T(b) \| \leq \| a - b \|$.*

Then, we will easily obtain an analogous key lemma from the below lemma in Goebel and Kuczumow's study [15] in 1979.

Lemma 1.2 *Let $\{u_n\}$ be a sequence in ℓ^1 converging to u in weak-star topology. Then, for every $w \in \ell^1$,*

$$Q(w) = Q(u) + \|w - u\|_1$$

where

$$Q(w) = \limsup_n \|u_n - w\|_1.$$

Note that our scalar field in this study will be real numbers although in 1989, Çolak with his study [6] considers complex values of $v = (v_n)_n$ while introducing his structer of the difference sequence which is taken as the fundamental concept in this study.

2. MAIN RESULTS

In this section, we will present our results. As mentioned in the first section, we investigate Goebel and Kuczumow analogy for the space U_1^3. We aim to show that there is a large class of cbc subsets in U_1^3 such that every nonexpansive invariant mapping defined on the subsets in the class taken has a fixed point. Recall that the invariant mappings have the same domain and the range. Note that we will assume that $r \in \mathbb{R}$ is arbitrary due to the definition of the space.

First, due to isometric isomorphism, using Lemma 1.2, we will provide the straight analogous result as a lemma below which will be a key step as in the works such as Goebel and Kuczumow's work [15] from 1979, and Everest's study [12] from 2013 and in fact the methods

in the study Everest's work [12] from 2013 will be our lead in this work.

Lemma 2.1 *Let $\{u_n\}$ be a sequence in the Banach space U_1^3 and assume $\{u_n\}$ converges to u in weak-star topology. Then, for every $w \in U_1^3$,*

$$Q(w) = Q(u) + \|w-u\|_{\sim}^{(3)}$$

where

$$Q(w) = \limsup_n \|u_n - w\|_{\sim}^{(3)}.$$

Then, we obtain our results by the following theorems.

Theorem 2.2 *Let $r \in \mathbb{R}$ and $t \in (0,1)$. Let $(f_n)_{n\in\mathbb{N}}$ be a sequence defined by $f_1 := t\,v_1\,e_1$, $f_2 := \frac{t\,v_2}{2^{3-r}}e_2$, $f_3 := \frac{t\,v_3}{3^{3-r}}e_3$, $f_4 := \frac{t\,v_4}{4^{3-r}}e_4$, and $f_n := \frac{v_n}{n^{3-r}}e_n$ for all integers $n \geq 5$ where the sequence $(e_n)_{n\in\mathbb{N}}$ is the canonical basis of both c_0 and ℓ^1. Then, consider the cbc subset $E^{(3)} = E_t{}^{(3)}$ of U_1^3 by*

$$E^{(3)} = \left\{\sum_{n=1}^{\infty} \alpha_n f_n : \forall n \in \mathbb{N}, \alpha_n \geq 0 \text{ and } \sum_{n=1}^{\infty} \alpha_n = 1\right\} .$$

Then, $E^{(3)}$ has the fixed point property for $\|\,.\,\|_{\sim}^{(3)}$-nonexpansive mappings.

Proof. Let $r \in \mathbb{R}$ and $t \in (0,1)$. Let $T: E^{(3)} \to E^{(3)}$ be a $\|\,.\,\|_{\sim}^{(3)}$-nonexpansive mapping. Then, there exists a sequence so called aproximate fixed point sequence $\left(u^{(n)}\right)_{n\in\mathbb{N}} \in E^{(3)}$ such that $\left\|Tu^{(n)} - u^{(n)}\right\|_{\sim}^{(3)} \to_n 0$. Due to isometric isomorphism, U_1^3 shares common geometric properties with ℓ^1 and so both U_1^3 and its predual have similar fixed point theory properties to ℓ^1 and c_0, respectively. Thus, considering that on bounded subsets the weak star topology on ℓ^1 is equivalent to the coardinate-wise convergence topology, and c_0 is separable, in U_1^3, the unit closed ball is weak*-sequentially compact due to Banach-Alaoglu theorem. Then, we can say that we may denote the weak* closure of the set $E^{(3)}$ by

$$C^{(3)} = \overline{E^{(3)}}^{w^*} = \left\{\sum_{n=1}^{\infty} \alpha_n f_n : \text{each } \alpha_n \geq 0 \text{ and } \sum_{n=1}^{\infty} \alpha_n \leq 1\right\}$$

and without loss of generality, we may pass to a subsequence if necessary and get a weak* limit $u \in C^{(3)}$ of $u^{(n)}$. Then, by Lemma 2.1, we have a function $r: U_1^3 \to [0,\infty)$ defined by

$$Q(w) = \limsup_n \left\|u^{(n)} - w\right\|_{\sim}^{(3)}, \forall w \in U_1^3$$

such that for every $w \in U_1^3$,

$$Q(w) = Q(u) + \|u-w\|_{\sim}^{(3)}.$$

Case 1. $u \in E^{(3)}$.

Then, $r(Tu) = r(u) + \|Tu-u\|_{\sim}^{(3)}$ and

$$Q(Tu) = \limsup_n \left\|Tu - u^{(n)}\right\|_{\sim}^{(3)}$$

$$\leq \limsup_n \left\|Tu - T\left(u^{(n)}\right)\right\|_{\sim}^{(3)} + \limsup_n \left\|u^{(n)} - T\left(u^{(n)}\right)\right\|_{\sim}^{(3)}$$
$$\leq \limsup_n \left\|u - u^{(n)}\right\|_{\sim}^{(3)} + 0$$
$$= Q(u). \qquad (1)$$

Thus, $Q(Tu) = Q(u) + \|Tu - u\|_{\sim}^{(3)} \leq r(u)$ and so $\|Tu - u\|_{\sim}^{(3)} = 0$. Therefore, $Tu = u$.

Case 2. $u \in C^{(3)} \backslash E^{(3)}$.

Then, we may find scalars satisfying $u = \sum_{n=1}^{\infty} \delta_n f_n$ such that $\sum_{n=1}^{\infty} \delta_n < 1$ and $\delta_n \geq 0$, $\forall n \in \mathbb{N}$.

Define $\xi := 1 - \sum_{n=1}^{\infty} \delta_n$ and for $\beta \in \left[\frac{-\delta_1}{\xi}, \frac{\delta_2}{\xi} + 1\right]$ define

$$h_\beta := \left(\delta_1 + \frac{\beta}{3}\xi\right) f_1 + \left(\delta_2 + \frac{\beta}{3}\xi\right) f_2 + \left(\delta_3 + \frac{\beta}{3}\xi\right) f_3 + (\delta_4 + (1-\beta)\xi) f_4 + \sum_{n=5}^{\infty} \delta_n f_n.$$

Then,

$$\|h_\beta - u\|_{\sim}^{(3)} = \left\|\frac{\beta}{3} t\xi v_1 e_1 + \frac{\beta}{3} t\xi \frac{v_2}{2^{3-r}} e_2 + \frac{\beta}{3} t\xi \frac{v_3}{3^{3-r}} e_3 + (1-\beta)\xi \frac{t v_4 e_4}{4^{3-r}}\right\|_{\sim}^{(3)}$$
$$= t\left|\frac{\beta}{3}\right| \xi + t\left|\frac{\beta}{3}\right| \xi + t\left|\frac{\beta}{3}\right| \xi + t|1-\beta|\xi.$$

$\|h_\beta - u\|_{\sim}^{(3)}$ is minimized for $\beta \in [0,1]$ and its minimum value would be $t\xi$.

Now fix $w \in E^{(3)}$. Then, we may find scalars satisfying $w = \sum_{n=1}^{\infty} \alpha_n f_n$ such that $\sum_{n=1}^{\infty} \alpha_n = 1$ with $\alpha_n \geq 0, \forall n \in \mathbb{N}$. We may also write each f_k with coefficients γ_k for each $k \in \mathbb{N}$ where $\gamma_1 := t v_1$, $\gamma_2 := \frac{t v_2}{2^{2-r}}$, $\gamma_3 := \frac{t v_3}{3^{2-r}}$, $\gamma_4 := \frac{t v_4}{4^{2-r}}$, and $\gamma_n := \frac{v_n}{n^{2-r}}$ for all integers $n \geq 5$ such that for each $n \in \mathbb{N}$, $f_n = \gamma_n e_n$.

Then,

$$\|w - u\|_{\sim}^{(3)} = \left\|\sum_{k=1}^{\infty} \alpha_k f_k - \sum_{k=1}^{\infty} \delta_k f_k\right\|_{\sim}^{(3)}$$
$$= \left\|\sum_{k=1}^{\infty} (\alpha_k - \delta_k) f_k\right\|_{\sim}^{(3)}$$
$$= \sum_{k=1}^{\infty} \left|(\alpha_k - \delta_k) \frac{k^{3-r}\gamma_k}{v_k}\right|.$$
$$\geq \sum_{k=1}^{\infty} t\,|\alpha_k - \delta_k|$$
$$\geq t\left|\sum_{k=1}^{\infty} (\alpha_k - \delta_k)\right|$$

$$= t\left|1 - \sum_{k=1}^{\infty} \delta_k\right|$$
$$= t\xi.$$

Hence,

$$\|w - u\|_{\sim}^{(3)} \geq t\xi = \|h_\beta - u\|_{\sim}^{(3)}$$

and the equality is obtained if and only if $(1-t)\sum_{k=5}^{\infty} |\alpha_k - \delta_k| = 0$; that is, we have $\|w - u\|_{\sim}^{(3)} = t\xi$ if and only if $\alpha_k = \delta_k$ for every $k \geq 5$; or say, $\|w - u\|_{\sim}^{(3)} = t\xi$ if and only if $w = h_\beta$ for some $\beta \in [0,1]$.

Then, there exists a continuous function $\rho: [0,1] \to E^{(3)}$ defined by $\rho(\beta) = h_\beta$ and $\Lambda\rho([0,1])$ is a compact convex subset and so $\|w - u\|_{\sim}^{(3)}$ achieves its minimum value at $w = h_\beta$ and for any $h_\beta \in \Lambda$, we get

$$Q(h_\beta) = Q(u) + \|h_\beta - u\|_{\sim}^{(3)}$$
$$\leq Q(u) + \|Th_\beta - u\|_{\sim}^{(3)}$$
$$= Q(Th_\beta) = \limsup_n \|Th_\beta - u^{(n)}\|_{\sim}^{(3)}$$

then, like the inequality (1), we get

$$Q(h_\beta) \leq \limsup_n \|Th_\beta - T(u^{(n)})\|_{\sim}^{(3)} + \limsup_n \|u^{(n)} - T(u^{(n)})\|_{\sim}^{(3)}$$
$$\leq \limsup_n \|h_\beta - u^{(n)}\|_{\sim}^{(3)} + \limsup_n \|u^{(n)} - T(u^{(n)})\|_{\sim}^{(3)}$$
$$\leq \limsup_n \|h_\beta - u^{(n)}\|_{\sim}^{(3)} + 0$$
$$= Q(h_\beta).$$

Hence, $r(h_\beta) \leq Q(Th_\beta) \leq r(h_\beta)$ and so $Q(Th_\beta) = Q(h_\beta)$.
Therefore,

$$Q(u) + \|Th_\beta - u\|_{\sim}^{(3)} = Q(u) + \|h_\beta - u\|_{\sim}^{(3)}.$$

Thus, $\|Th_\beta - u\|_{\sim}^{(3)} = \|h_\beta - u\|_{\sim}^{(3)}$ and so $Th_\beta \in \Lambda$ but this shows $T(\Lambda) \subseteq \Lambda$ and using Schauder's fixed point theorem from 1930 in [26], easily we get the result T has a fixed point since T is continuous; thus, h_β is the unique minimizer of $\|w - u\|_{\sim}^{(3)} : w \in E^{(3)}$ and $Th_\beta = h_\beta$.

Therefore, $E^{(3)}$ has the fixed point property for nonexpansive mappings.

Theorem 2.3 *Let $r \in \mathbb{R}$ and $t \in (0,1)$. Let $(f_n)_{n\in\mathbb{N}}$ be a sequence defined by $f_1 := tv_1e_1$, $f_2 := \frac{t\,v_2}{2^{2-r}}e_2$, $f_3 := \frac{t\,v_3}{3^{2-r}}e_3$, $f_4 := \frac{t\,v_4}{4^{2-r}}e_4$, $f_5 := \frac{t\,v_5}{5^{2-r}}e_5$, and $f_n := \frac{v_n}{n^{2-r}}e_n$ for all integers $n \geq 6$ where the sequence $(e_n)_{n\in\mathbb{N}}$ is the canonical basis of both c_0 and ℓ^1. Then, consider the cbc subset $E^{(3)} = E_t{}^{(3)}$ of U_1^3 by*

$$E^{(3)} = \left\{ \sum_{n=1}^{\infty} \alpha_n f_n : \forall n \in \mathbb{N}, \alpha_n \geq 0 \text{ and } \sum_{n=1}^{\infty} \alpha_n = 1 \right\} .$$

Then, $E^{(3)}$ has the fixed point property for $\|.\|_{\sim}^{(3)}$-nonexpansive mappings.

Proof. Let $r \in \mathbb{R}$ and $t \in (0,1)$. Let $T: E^{(3)} \to E^{(3)}$ be a $\|.\|_{\sim}^{(3)}$-nonexpansive mapping. Then, there exists a sequence so called aproximate fixed point sequence $\left(u^{(n)}\right)_{n\in\mathbb{N}} \in E^{(3)}$ such that $\left\|Tu^{(n)} - u^{(n)}\right\|_{\sim}^{(3)} \to_n 0$. Due to isometric isomorphism, U_1^3 shares common geometric properties with ℓ^1 and so both U_1^3 and its predual have similar fixed point theory properties to ℓ^1 and c_0, respectively. Thus, considering that on bounded subsets the weak star topology on ℓ^1 is equivalent to the coardinate-wise convergence topology and c_0 is separable, in U_1^3, the unit closed ball is weak*-sequentially compact due to Banach-Alaoğlu theorem. Then, we can say that we may denote the weak* closure of the set $E^{(3)}$ by

$$C^{(3)} := \overline{E^{(3)}}^{w^*} = \left\{ \sum_{n=1}^{\infty} \alpha_n f_n : each\ \alpha_n \geq 0 \text{ and } \sum_{n=1}^{\infty} \alpha_n \leq 1 \right\}$$

and without loss of generality, we may pass to a subsequence if necessary and get a weak* limit $u \in C^{(3)}$ of $u^{(n)}$. Then, by Lemma 2.1, we have a function $r: U_1^3 \to [0,\infty)$ defined by

$$Q(w) = \limsup_n \left\|u^{(n)} - w\right\|_{\sim}^{(3)}, \forall w \in U_1^3$$

such that for every $w \in U_1^3$,

$$Q(w) = Q(u) + \|u - w\|_{\sim}^{(3)}.$$

Case 1. $u \in E^{(3)}$.

Then, $r(Tu) = r(u) + \|Tu - u\|_{\sim}^{(3)}$ and

$$\begin{aligned} Q(Tu) &= \limsup_n \left\|Tu - u^{(n)}\right\|_{\sim}^{(3)} \\ &\leq \limsup_n \left\|Tu - T\left(u^{(n)}\right)\right\|_{\sim}^{(3)} + \limsup_n \left\|u^{(n)} - T\left(u^{(n)}\right)\right\|_{\sim}^{(3)} \\ &\leq \limsup_n \left\|u - u^{(n)}\right\|_{\sim}^{(3)} + 0 \\ &= Q(u). \end{aligned} \tag{2}$$

Thus, $Q(Tu) = Q(u) + \|Tu - u\|_{\sim}^{(3)} \leq r(u)$ and so $\|Tu - u\|_{\sim}^{(3)} = 0$. Therefore, $Tu = u$.

Case 2. $u \in C^{(3)} \backslash E^{(3)}$.

Then, we may find scalars satisfying $u = \sum_{n=1}^{\infty} \delta_n f_n$ such that $\sum_{n=1}^{\infty} \delta_n < 1$ *and* $\delta_n \geq 0$, $\forall n \in \mathbb{N}$.

Define $\xi := 1 - \sum_{n=1}^{\infty} \delta_n$ and for $\beta \in \left[\frac{-\delta_1}{\xi}, \frac{\delta_2}{\xi} + 1\right]$, define

$$\mathrm{h}_\beta := \left(\delta_1 + \frac{\beta}{4}\xi\right) f_1 + \left(\delta_2 + \frac{\beta}{4}\xi\right) f_2 + \left(\delta_3 + \frac{\beta}{4}\xi\right) f_3 + \left(\delta_4 + \frac{\beta}{4}\xi\right) f_4 + (\delta_5 + (1-\beta)\xi) f_5 + \sum_{n=6}^{\infty} \delta_n f_n.$$

Then,

$$\|h_\beta - u\|_{\sim}^{(3)} = \left\| \frac{\beta}{4} t\xi v_1 e_1 + \frac{\beta}{4} t\xi \frac{v_2}{2^{3-r}} e_2 + \frac{\beta}{4} t\xi \frac{v_3}{3^{3-r}} e_3 + \frac{\beta}{4} t\xi \frac{v_4}{4^{3-r}} e_4 + (1-\beta)\xi \frac{tv_5 e_5}{5^{3-r}} \right\|_{\sim}^{(3)}$$
$$= t\left|\frac{\beta}{4}\right| \xi + t\left|\frac{\beta}{4}\right| \xi + t\left|\frac{\beta}{4}\right| \xi + t\left|\frac{\beta}{4}\right| \xi + t|1-\beta|\xi.$$

$\|h_\beta - u\|_{\sim}^{(3)}$ is minimized for $\beta \in [0,1]$ and its minimum value would be $t\xi$.

Now fix $w \in E^{(3)}$. Then, we may find scalars satisfying $w = \sum_{n=1}^{\infty} \alpha_n f_n$ such that $\sum_{n=1}^{\infty} \alpha_n = 1$ with $\alpha_n \geq 0,\ \forall n \in \mathbb{N}$. We may also write each f_k with coefficients γ_k for each $k \in \mathbb{N}$ where $\gamma_1 := tv_1$, $\gamma_2 := \frac{tv_2}{2^{3-r}}$, $\gamma_3 := \frac{tv_3}{3^{3-r}}$, $\gamma_4 := \frac{tv_4}{4^{3-r}}$, $\gamma_5 := \frac{tv_5}{5^{3-r}}$, and $\gamma_n := \frac{v_n}{n^{3-r}}$ for all integers $n \geq 6$ such that for each $n \in \mathbb{N}$, $f_n = \gamma_n e_n$.

Then,

$$\|\mathrm{w} - u\|_{\sim}^{(3)} = \left\| \sum_{k=1}^{\infty} \alpha_k f_k - \sum_{k=1}^{\infty} \delta_k f_k \right\|_{\sim}^{(3)}$$
$$= \left\| \sum_{k=1}^{\infty} (\alpha_k - \delta_k) f_k \right\|_{\sim}^{(3)}$$
$$= \sum_{k=1}^{\infty} \left| (\alpha_k - \delta_k) \frac{k^{3-r}\gamma_k}{v_k} \right|.$$
$$\geq \sum_{k=1}^{\infty} t\,|\alpha_k - \delta_k|$$
$$\geq t \left| \sum_{k=1}^{\infty} (\alpha_k - \delta_k) \right|$$
$$= t \left| 1 - \sum_{k=1}^{\infty} \delta_k \right|$$
$$= t\xi.$$

Hence,

$$\|\mathrm{w} - u\|_{\sim}^{(3)} \geq t\xi = \|h_\beta - u\|_{\sim}^{(3)}$$

and the equality is obtained if and only if $(1-t)\sum_{k=6}^{\infty} |\alpha_k - \delta_k| = 0$; that is, we have $\|\mathrm{w} - u\|_{\sim}^{(3)} = t\xi$ if and only if $\alpha_k = \delta_k$ for every $k \geq 6$; or say, $\|\mathrm{w} - u\|_{\sim}^{(3)} = t\xi$ if and only if $\mathrm{w} = h_\beta$ for some $\beta \in [0,1]$.

Then, there exists a continuous function $\rho: [0,1] \to E^{(3)}$ defined by $\rho(\beta) = h_\beta$ and $\Lambda\rho([0,1])$ is a compact convex subset and so $\|w - u\|_{\sim}^{(3)}$ achieves its minimum value at $w = h_\beta$ and for any $h_\beta \in \Lambda$, we get

$$Q(h_\beta) = Q(u) + \|h_\beta - u\|_{\sim}^{(3)} \leq Q(u) + \|Th_\beta - u\|_{\sim}^{(3)}$$
$$= Q(Th_\beta) = \limsup_n \|Th_\beta - u^{(n)}\|_{\sim}^{(3)}$$

then same as the inequality (2), we get

$$Q(h_\beta) \leq \limsup_n \|Th_\beta - T(u^{(n)})\|_{\sim}^{(3)} + \limsup_n \|u^{(n)} - T(u^{(n)})\|_{\sim}^{(3)}$$
$$\leq \limsup_n \|h_\beta - u^{(n)}\|_{\sim}^{(3)} + \limsup_n \|u^{(n)} - T(u^{(n)})\|_{\sim}^{(3)}$$
$$\leq \limsup_n \|h_\beta - u^{(n)}\|_{\sim}^{(3)} + 0$$
$$= Q(h_\beta).$$

Hence, $r(h_\beta) \leq Q(Th_\beta) \leq r(h_\beta)$ and so $Q(Th_\beta) = Q(h_\beta)$.

Therefore,

$$Q(u) + \|Th_\beta - u\|_{\sim}^{(3)} = Q(u) + \|h_\beta - u\|_{\sim}^{(3)}.$$

Thus, $\|Th_\beta - u\|_{\sim}^{(3)} = \|h_\beta - u\|_{\sim}^{(3)}$ and so $Th_\beta \in \Lambda$ but this shows $T(\Lambda) \subseteq \Lambda$ and using Schauder's fixed point theorem from 1930 in [26], we can easily we get the result T has a fixed point since T is continuous. Thus, h_β is the unique minimizer of $\|w - u\|_{\sim}^{(3)} : w \in E^{(3)}$ and $Th_\beta = h_\beta$.

Therefore, $E^{(3)}$ has the fixed point property for nonexpansive mappings.

3. DISCUSSION

As it has been mentioned in earlier sections of the study, investigating and looking for large classes of closed, bounded and convex subsets in Banach spaces alike the Banach spaces of absolutely summable scalars are center of interests for many fixed point theorists. One can investigate to get larger classes for more general spaces than those in the present study and due to isometry, that would not be hard by following the ideas of Goebel and Kuczumows. However, trying to generalize their ideas and looking for different examples of the sets and spaces would be valuable studies.

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LARGE CLASSES IN α-DUAL OF A DIFFERENCE SEQUENCE SPACE AND THEIR FIXED POINT PROPERTIES FOR NONEXPANSIVE MAPPINGS

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ABSTRACT
In 2000, Et and Esi introduced new type of generalized difference sequences by using the structure of Çolak's work from 1989 where he defined new types of sequence spaces while Çolak was also inspired by Kızmaz's idea about the difference operator he studied in 1981. Then, using Et and Esi's structure, Ansari and Chaudhry, in 2012, introduced a new type of generalized difference sequence spaces. Changing Ansari and Chaudhry's construction slightly, Et and Işık, in 2012, obtained new type of generalized difference sequence spaces which have equivalent norm to that of Ansari and Chaudhry's type Banach spaces. Then, Et and Işık found α-duals of the Banach spaces they got and investigated geometric properties for them. In this study, we consider Et and Işık's work and study α-dual of one of their generalized difference sequence spaces. We take their study in terms of fixed point theory and find large classes of closed, bounded and convex subsets in those duals with fixed point property for nonexpansive mappings. The Banach space we consider is given by the following for any $r \in \mathbb{R}$:

$$U_1^2 = \left\{a = (a_n)_n \subset \mathbb{R}: \quad \|a\|_{\sim}^{(2)} = \sum_{k=1}^{\infty} \frac{k^{2-r}|a_k|}{|v_k|} < \infty\right\}$$

Key Words : Nonexpansive Mapping, Fixed Point Property, Closed Bounded Convex Set, Difference Sequences, α-duals.

1. INTRODUCTION AND PRELIMINARIES

Researches have shown that the fixed point exists for some function classes defined on certain classes of sets in some spaces, while it cannot be found at all in others. Fixed point theory has examined how this happens or does not happen.

Researchers have made classifications and characterizations. In [4], it was proved that every Hilbert space has a property satisfying that every nonexpansive mapping defined on any closed, bounded, and convex (cbc) nonempty subset domain with the same range has a fixed point. Since that time, spaces with this property have been considered to have the fixed point property for nonexpansive mappings (fppne). Then, researchers considered looking for the spaces with the property and if the property still exists when larger classes of mappings are taken. Then also

they have seen spaces failing the properties. For example, in [5] and [16] with independent studies, they saw that uniform convex Banach spaces have the fppne. Then, Kirk [19] generalized the result for the reflexive Banach spaces with normal structure. In fact, Goebel and Kirk [13] noticed that Kirk's result was able to extend for uniformly Lipschitz mappings and some researchers have studied estimating the Lipschitz coefficient satisfying the property for uniform Lipschitz mappings on different Banach spaces. For example, Goebel and Kirk [14] showed that for Hilbert spaces, the best Lipschitz coefficient would be a scalar less than a number in the interval $\left[\sqrt{2}, \frac{\pi}{2}\right]$, and Goebel and Kirk [13] and Lim [20] showed independently that for a Lebesgue space L^p when $2 < p < \infty$, the coefficient is smaller by a scalar larger than or equal to $\left(1 + \frac{1}{2^p}\right)^{\frac{1}{p}}$ while Alspach [1] showed that when $p = 2$, there exists a fixed point free Lipschitz mapping with Lispchitz coefficient $\sqrt{2}$ defined on a cbc subset. In fact, $\sqrt{2}$ is the smallest Lipschitz coefficient for Alspach's mapping. We need to note that, similar to the definition of the Banach spaces satisfying the fppne, if a Banach space has a property that every uniformly Lipschitz mapping defined on any cbc nonempty subset domain with the same range has a fixed point, then that Banach space has the fixed point property for uniformly Lischitz mapping (fppul). In terms of fixed point property for uniformly Lipschitz mappings, Dowling, Lennard, and Turett [7] showed that if a Banach space contains an isomorphic copy of ℓ^1, then it fails the fppul. It is a well-known fact by researchers that c_0 or ℓ^1 is almost isometrically embedded in every non-reflexive Banach space with an unconditional basis (see for example [23]). For this reason, classical non-reflexive Banach spaces fail the fixed point property for non-expansive mappings, that is, in these spaces, there can be a closed, convex and bounded subset and a non-expansive invariant T mapping defined on that set such that T has no fixed point. This result is based on well-known theorems in literature (see for example Theorem 1.c.12 in [23] and Theorem 1.c.5 in [24]. These theorems state that for a Banach lattice or Banach space with an unconditional basis to be reflexive, it is necessary and sufficient if it does not contain any isomorphic copies of c_0 or ℓ^1. Therefore, this close relation to the reflexivity or nonreflexivity of Banach space, researchers have worked for years and questioned whether c_0 or ℓ^1 can be renormed to have a fixed point for nonexpansive mappings. Lin [21] showed that what was thought was not true and that at least ℓ^1 could be renormed to have the fixed point property for nonexpansive mappings. Then, the remaining question was if the same could have been done for c_0, but the answer still remains open. Since the researchers have considered trying to obtain the analogous results for well-known other classical nonreflexive Banach spaces, another experiment was done for Lebesgue integrable functions space $L_1[0,1]$ by Hernandes-Lineares and Maria [22] but they were able to obtain the positive answer when they restricted the nonexpansive mappings by assuming they were affine as well. One can say that there is no doubt most research has been inspired by the ideas of the study [15] where Goebel and Kuczumow proved that while ℓ^1 fails the fixed point property since one can easily find a cbc nonweakly compact subset there and a fixed point free invariant nonexpansive map, it is possible to find a very large class subsets in target such that invariant nonexpansive mappings defined on the members of the class have fixed points. In fact, it is easy to notice the traces of those ideas in Lin's [21] work. Even Goebel and Kuczumow's work has inspired many other

researchers to investigate if there exist more example of nonreflexive Banach spaces with large classes satisfying fixed point property. For example, in [17], they wanted to generalize Goebel and Kuczumow's findings and they proved that affine asymptotically nonexpansive invariant mappings defined on a large class of cbc subsets in ℓ^1 can have fixed points. Moreover, in [12], Kaczor and Prus' results were extended by having been found larger classes satisfying the fixed point property for affine asymptotically nonexpansive mappings. Thus, affinity condition became a tool for their works. In fact, another well-known nonreflexive Banach space, Lebesgue space $L_1[0,1]$, was studied in [22] and in their study they obtained an analogous result to [21] as they showed that $L_1[0,1]$ can be renormed to have the fixed point property for affine nonexpansive mappings. In this study, we will investigate some Banach spaces analogous to ℓ^1 . In the present work, we study Goebel-Kuczumow analogy for α-duals of their generalized difference sequence spaces investigated by Et and Işık [11]. We prove that a very large class of closed, bounded and convex subsets in α-duals of their generalized difference sequence spaces investigated by Et and Işık has the fixed point property for nonexpansive mappings. Therefore, firstly we would like to give the definition of Cesàro sequence spaces which was defined by Shiue [27], and next we present Kızmaz's difference sequence space definition in [18] by noting that we work on a space which is derived from his ideas' generalizations such that many researchers (see for example [6, 8, 9, 10, 25, 28]) have generalized his work as well.

In fact, we need to note that Et and Esi's [10] work and Et and Çolak's [9] work used a common difference sequence definition from Çolak's [6] work.

Shiue [27] defined the Cesàro sequence spaces by

$$\mathrm{ces}_p = \left\{ (x_n)_n \subset \mathbb{R} \left| \left(\sum_{n=1}^{\infty} \left(\frac{1}{n} \sum_{k=1}^{n} |x_k| \right)^p \right)^{1/p} < \infty \right. \right\}$$

such that $\ell^p \subset \mathrm{ces}_p$ and

$$\mathrm{ces}_\infty = \left\{ x = (x_n)_n \subset \mathbb{R} \left| \sup_n \frac{1}{n} \sum_{k=1}^{n} |x_k| < \infty \right. \right\}$$

such that $\ell^\infty \subset ces_\infty$ where $1 \leq p < \infty$. Then, from the definition of Cesàro sequence spaces, Kızmaz [18] defined difference sequence spaces for ℓ^∞, c, and c_0 and symbolized them by $\ell^\infty(\Delta)$, $\mathrm{c}(\Delta)$, and $\mathrm{c}_0(\Delta)$, respectively. In his introduction, he defined the difference operator Δ applied to the sequence $x = (x_n)_n$ using the formula $\Delta x = (x_k - x_{k+1})_k$. In fact, he investigated Köthe-Toeplitz duals and their topological properties.

As one of the researchers generalizing his ideas, Çolak [6] introduced firstly a generalized difference sequence space by taking an arbitrary sequence of nonzero complex values $v = (v_n)_n$ and then denoting a new difference operator by Δ_v such that for any sequence $x = (x_n)_n$, he defined the difference sequence of that $\Delta_v x = (v_k x_k - v_{k+1} x_{k+1})_k$. Then, Et and Esi [10] generalized Çolak's difference sequence space by defining

$$\Delta_v(\ell^\infty) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v x \in \ell^\infty\},$$

$$\Delta_v(c) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v x \in c\},$$
$$\Delta_v(c_0) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v x \in c_0\}.$$

Furthermore, their m^{th} order generalized difference sequence space is given for any $m \in \mathbb{N}$ by $\Delta_v^0 x = (v_k x_k)_k$, $\Delta_v^m x = (\Delta_v^m x_k)_k = (\Delta_v^{m-1} x_k - \Delta_v^{m-1} x_{k+1})_k$ with $\Delta_v^m x_k = \sum_{i=0}^m (-1)^i \binom{m}{i} v_{k+i} x_{k+i}$ for each $k \in \mathbb{N}$.

Next Bektaş, Et and Çolak [3] obtained the Köthe-Toeplitz duals for the generalized difference sequence space of Et and Esi's. We may recall here that their m^{th} order difference sequence space has the following norm for any $m \in \mathbb{N}$:

$$\|x\|_v^{(m)} = \sum_{k=1}^m |v_k x_k| + \|\Delta_v^m x\|_\infty$$

Then, the corresponding Köthe-Toeplitz dual was obtained as in [3] and [10] such that it is written as below:

$$D_1^m = \{a = (a_n)_n \subset \mathbb{R} | (n^m v_n^{-1} a_n)_n \in \ell^1\}$$
$$= \left\{a = (a_n)_n \subset \mathbb{R}: \|a\|^{(m)} = \sum_{k=1}^\infty \frac{k^m |a_k|}{|v_k|} < \infty\right\}.$$

Note that $D_1^m \subset \ell^1$ if $k^m |v_k^{-1}| > 1$ for each $k, m \in \mathbb{N}$ and $\ell^1 \subset D_1^m$ if $k^m |v_k^{-1}| < 1$ for each $k, m \in \mathbb{N}$.

Ansari and Chaudhry [2] introduced a new type of generalized difference sequence spaces by picking an arbitrary sequence of nonzero complex values $v = (v_n)_n$ as Çolak [6] did and next by symbolizing the new difference sequence space as $\Delta_{v,r}^m(E)$ for arbitrary $r \in \mathbb{R}$, $m \in \mathbb{N}$ and writing that space as below where X is any of the sequence spaces ℓ^∞, c or c_0.

$$\Delta_{v,r}^m(X) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v^m x \in X\}$$

where Ansari and Chaudhry [2] defined the norm by

$$\|x\|_{\Delta,v}^m = \sum_{k=1}^m |v_k x_k| + \sup_{k \in \mathbb{N}} |k^r \Delta_v^m x_k|$$

Then, by obtaining an equivalent norm to Ansari and Chaudhry's Banach space, Et and Işık [11] defined m^{th} order generalized type difference sequence for any $m \in \mathbb{N}$ given by

$$\Delta_{v,r}^{(m)}(X) = \{x = (x_n)_n \subset \mathbb{R} | \Delta_v^m x \in X\}$$

where the norm is as follows:

$$\|x\|_{\Delta,v}^{(m)} = \sup_{k \in \mathbb{N}} |k^r \Delta_v^m x_k|$$

Then, Et and Işık found α-duals of the Banach spaces they got and investigated geometric properties for them such that m^{th} order α-duals for their Banach spaces are written as

$$U_1^m = \{a = (a_n)_n \subset \mathbb{R} | (n^{m-r} v_n^{-1} a_n)_n \in \ell^1\}$$
$$= \left\{a = (a_n)_n \subset \mathbb{R}: \|a\|_\sim^{(m)} = \sum_{k=1}^\infty \frac{k^{m-r} |a_k|}{|v_k|} < \infty\right\}$$

Note that $U_1^m \subset \ell^1$ if $k^{m-r} |v_k^{-1}| > 1$ for each $k, m \in \mathbb{N}$ and $\ell^1 \subset U_1^m$ if $k^{m-r} |v_k^{-1}| < 1$ for

each $k, m \in \mathbb{N}$.

Before starting to introduce our work and results, we would like to give some well-known and important facts. One may see [14] for the fundamentals given below.

Definition 1.1 *Consider that $(X, \|\cdot\|)$ is a Banach space and let C be a non-empty cbc subset. Let $T: C \to C$ be a mapping. We say that*

1. *T is an affine mapping if for every $t \in [0,1]$ and $a, b \in C$,*
$$T\big((1-t)a + tb\big) = (1-t)T(a) + tT(b).$$
2. *T is a nonexpansive mapping if for every $a, b \in C$, $\| T(a) - T(b) \| \leq \| a - b \|$.*

Then, we will easily obtain an analogous key lemma from the below lemma in the work [15].

Lemma 1.2 *Let $\{u_n\}$ be a sequence in ℓ^1 converging to u in weak-star topology. Then, for every $w \in \ell^1$, $Q(w) = Q(u) + \|w - u\|_1$ where $Q(w) = \limsup_n \|u_n - w\|_1$.*

Note that our scalar field in this study will be real numbers although Çolak [6] considers complex values of $v = (v_n)_n$ while introducing his structer of the difference sequence which is taken as the fundamental concept in this study.

2. MAIN RESULTS

In this section, we will present our results. As mentioned in the first section, we investigate Goebel and Kuczumow analogy for the space U_1^2. We aim to show that there is a large class of cbc subsets in U_1^2 such that every nonexpansive invariant mapping defined on the subsets in the class taken has a fixed point. Recall that the invariant mappings have the same domain and the range. Note that we will assume that $r \in \mathbb{R}$ is arbitrary due to the definition of the space.

First, due to isometric isomorphism, using Lemma 1.2, we will provide the straight analogous result as a lemma below which will be a key step as in the works such as [15], and [12] and in fact the methods in the study [12] will be our lead in this work.

Lemma 2.1 *Let $\{u_n\}$ be a sequence in U_1^2 and assume $\{u_n\}$ converges to u in weak-star topology.*
Then, for every $w \in U_1^2$, $Q(w) = Q(u) + \|w - u\|_{\sim}^{(2)}$ where $Q(w) = \limsup_n \|u_n - w\|_{\sim}^{(2)}$.

Then, we obtain our results by the following theorems.

Theorem 2.2 *Let $r \in \mathbb{R}$ and $t \in (0,1)$. Let $(f_n)_{n\in\mathbb{N}}$ be a sequence defined by $f_1 := tv_1 e_1$, $f_2 := \frac{t\ v_2}{2^{2-r}} e_2$, $f_3 := \frac{t\, v_3}{3^{2-r}} e_3$, $f_4 := \frac{t\, v_4}{4^{2-r}} e_4$, and $f_n := \frac{v_n}{n^{2-r}} e_n$ for all integers $n \geq 5$ where the sequence $(e_n)_{n\in\mathbb{N}}$ is the canonical basis of both c_0 and ℓ^1. Then, consider the cbc subset $E^{(2)} = E_t{}^{(2)}$ of U_1^2 by*

$$E^{(2)} = \left\{ \sum_{n=1}^{\infty} \alpha_n f_n : \ \forall n \in \mathbb{N}, \ \ \alpha_n \geq 0 \ \text{and} \ \sum_{n=1}^{\infty} \alpha_n = 1 \right\} .$$

Then, $E^{(2)}$ has the fixed point property for $\|.\|_{\sim}^{(2)}$-nonexpansive mappings.

Proof. Let $r \in \mathbb{R}$ and $t \in (0,1)$. Let $T: E^{(2)} \to E^{(2)}$ be a $\|.\|_{\sim}^{(2)}$-nonexpansive mapping. Then, there exists a sequence so called aproximate fixed point sequence $\left(u^{(n)}\right)_{n\in\mathbb{N}} \in E^{(2)}$ such that $\left\|Tu^{(n)} - u^{(n)}\right\|_{\sim}^{(2)} \to_n 0$. Due to isometric isomorphism, U_1^2 shares common geometric properties with ℓ^1 and so both U_1^2 and its predual have similar fixed point theory properties to ℓ^1 and c_0, respectively. Thus, considering that on bounded subsets the weak star topology on ℓ^1 is equivalent to the coardinate-wise convergence topology, and c_0 is separable, in U_1^2, the unit closed ball is weak*-sequentially compact due to Banach-Alaoglu theorem. Then, we can say that we may denote the weak* closure of the set $E^{(2)}$ by

$$C^{(2)} = \overline{E^{(2)}}^{w^*} = \left\{ \sum_{n=1}^{\infty} \alpha_n f_n : \ \ each \ \alpha_n \geq 0 \ and \ \sum_{n=1}^{\infty} \alpha_n \leq 1 \right\}$$

and without loss of generality, we may pass to a subsequence if necessary and get a weak* limit $u \in C^{(2)}$ of $u^{(n)}$. Then, by Lemma 2.1, we have a function $r: U_1^2 \to [0,\infty)$ defined by

$$Q(w) = \limsup_n \left\|u^{(n)} - w\right\|_{\sim}^{(2)}, \ \forall w \in U_1^2$$

such that for every $w \in U_1^2$,

$$Q(w) = Q(u) + \|u - w\|_{\sim}^{(2)}.$$

Case 1. $u \in E^{(2)}$.

Then, $r(Tu) = r(u) + \|Tu - u\|_{\sim}^{(2)}$ and

$$\begin{aligned} Q(Tu) &= \limsup_n \left\|Tu - u^{(n)}\right\|_{\sim}^{(2)} \\ &\leq \limsup_n \left\|Tu - T\left(u^{(n)}\right)\right\|_{\sim}^{(2)} + \limsup_n \left\|u^{(n)} - T\left(u^{(n)}\right)\right\|_{\sim}^{(2)} \\ &\leq \limsup_n \left\|u - u^{(n)}\right\|_{\sim}^{(2)} + 0 \\ &= Q(u). \end{aligned} \qquad (1)$$

Thus, $Q(Tu) = Q(u) + \|Tu - u\|_{\sim}^{(2)} \leq r(u)$ and so $\|Tu - u\|_{\sim}^{(2)} = 0$. Therefore, $Tu = u$.

Case 2. $u \in C^{(2)} \backslash E^{(2)}$.

Then, we may find scalars satisfying $u = \sum_{n=1}^{\infty} \delta_n f_n$ such that $\sum_{n=1}^{\infty} \delta_n < 1$ and $\delta_n \geq 0$, $\forall n \in \mathbb{N}$.

Define $\xi := 1 - \sum_{n=1}^{\infty} \delta_n$ and for $\beta \in \left[\frac{-\delta_1}{\xi}, \frac{\delta_2}{\xi} + 1\right]$ define

$$h_\beta := \left(\delta_1 + \frac{\beta}{3}\xi\right) f_1 + \left(\delta_2 + \frac{\beta}{3}\xi\right) f_2 + \left(\delta_3 + \frac{\beta}{3}\xi\right) f_3 + (\delta_4 + (1-\beta)\xi) f_4 + \sum_{n=5}^{\infty} \delta_n f_n.$$

Then,

$$\left\|h_\beta - u\right\|_{\sim}^{(2)} = \left\|\frac{\beta}{3} t\xi v_1 e_1 + \frac{\beta}{3} t\xi \frac{v_2}{2^{2-r}} e_2 + \frac{\beta}{3} t\xi \frac{v_3}{3^{2-r}} e_3 + (1-\beta)\xi \frac{t v_4 e_4}{4^{2-r}}\right\|_{\sim}^{(2)}$$

$$= t\left|\frac{\beta}{3}\right|\xi + t\left|\frac{\beta}{3}\right|\xi + t\left|\frac{\beta}{3}\right|\xi + t|1-\beta|\xi.$$

$\|h_\beta - u\|_{\sim}^{(2)}$ is minimized for $\beta \in [0,1]$ and its minimum value would be $t\xi$.

Now fix $w \in E^{(2)}$. Then, we may find scalars satisfying $w = \sum_{n=1}^{\infty} \alpha_n f_n$ such that $\sum_{n=1}^{\infty} \alpha_n = 1$ with $\alpha_n \geq 0, \forall n \in \mathbb{N}$. We may also write each f_k with coefficients γ_k for each $k \in \mathbb{N}$ where $\gamma_1 := tv_1, \gamma_2 := \frac{tv_2}{2^{2-r}}, \gamma_3 := \frac{tv_3}{3^{2-r}}, \gamma_4 := \frac{tv_4}{4^{2-r}}$, and $\gamma_n := \frac{v_n}{n^{2-r}}$ for all integers $n \geq 5$ such that for each $n \in \mathbb{N}$, $f_n = \gamma_n e_n$.

Then,

$$\begin{aligned}
\|w-u\|_{\sim}^{(2)} &= \left\|\sum_{k=1}^{\infty}\alpha_k f_k - \sum_{k=1}^{\infty}\delta_k f_k\right\|_{\sim}^{(2)} \\
&= \left\|\sum_{k=1}^{\infty}(\alpha_k-\delta_k)f_k\right\|_{\sim}^{(2)} \\
&= \sum_{k=1}^{\infty}\left|(\alpha_k-\delta_k)\frac{k^{2-r}\gamma_k}{v_k}\right|. \\
&\geq \sum_{k=1}^{\infty} t\,|\alpha_k-\delta_k| \\
&\geq t\left|\sum_{k=1}^{\infty}(\alpha_k-\delta_k)\right| \\
&= t\left|1-\sum_{k=1}^{\infty}\delta_k\right| \\
&= t\xi.
\end{aligned}$$

Hence,

$$\|w-u\|_{\sim}^{(2)} \geq t\xi = \|h_\beta - u\|_{\sim}^{(2)}$$

and the equality is obtained if and only if $(1-t)\sum_{k=5}^{\infty}|\alpha_k-\delta_k| = 0$; that is, we have $\|w-u\|_{\sim}^{(2)} = t\xi$ if and only if $\alpha_k = \delta_k$ for every $k \geq 5$; or say, $\|w-u\|_{\sim}^{(2)} = t\xi$ if and only if $w = h_\beta$ for some $\beta \in [0,1]$.

Then, there exists a continuous function $\rho: [0,1] \to E^{(2)}$ defined by $\rho(\beta) = h_\beta$ and $\Lambda\rho([0,1])$ is a compact convex subset and so $\|w-u\|_{\sim}^{(2)}$ achieves its minimum value at $w = h_\beta$ and for any $h_\beta \in \Lambda$, we get

$$\begin{aligned}
Q(h_\beta) &= Q(u) + \|h_\beta - u\|_{\sim}^{(2)} \\
&\leq Q(u) + \|Th_\beta - u\|_{\sim}^{(2)} \\
&= Q(Th_\beta) = \limsup_n \|Th_\beta - u^{(n)}\|_{\sim}^{(2)}
\end{aligned}$$

then, like the inequality (1), we get

$$\begin{aligned} Q(h_\beta) &\le \limsup_n \left\|Th_\beta - T(u^{(n)})\right\|_{\sim}^{(2)} + \limsup_n \left\|u^{(n)} - T(u^{(n)})\right\|_{\sim}^{(2)} \\ &\le \limsup_n \left\|h_\beta - u^{(n)}\right\|_{\sim}^{(2)} + \limsup_n \left\|u^{(n)} - T(u^{(n)})\right\|_{\sim}^{(2)} \\ &\le \limsup_n \left\|h_\beta - u^{(n)}\right\|_{\sim}^{(2)} + 0 \\ &= Q(h_\beta). \end{aligned}$$

Hence, $r(h_\beta) \le Q(Th_\beta) \le r(h_\beta)$ and so $Q(Th_\beta) = Q(h_\beta)$.
Therefore,

$$Q(u) + \left\|Th_\beta - u\right\|_{\sim}^{(2)} = Q(u) + \left\|h_\beta - u\right\|_{\sim}^{(2)}.$$

Thus, $\left\|Th_\beta - u\right\|_{\sim}^{(2)} = \left\|h_\beta - u\right\|_{\sim}^{(2)}$ and so $Th_\beta \in \Lambda$ but this shows $T(\Lambda) \subseteq \Lambda$ and using Schauder's fixed point theorem in [26], easily we get the result T has a fixed point since T is continuous; thus, h_β is the unique minimizer of $\|w - u\|_{\sim}^{(2)} : w \in E^{(2)}$ and $Th_\beta = h_\beta$.

Therefore, $E^{(2)}$ has the fixed point property for nonexpansive mappings.

Theorem 2.3 *Let $r \in \mathbb{R}$ and $t \in (0,1)$. Let $(f_n)_{n\in\mathbb{N}}$ be a sequence defined by $f_1 := tv_1e_1$, $f_2 := \frac{t\,v_2}{2^{2-r}}e_2$, $f_3 := \frac{t\,v_3}{3^{2-r}}e_3$, $f_4 := \frac{t\,v_4}{4^{2-r}}e_4$, $f_5 := \frac{t\,v_5}{5^{2-r}}e_5$, and $f_n := \frac{v_n}{n^{2-r}}e_n$ for all integers $n \ge 6$ where the sequence $(e_n)_{n\in\mathbb{N}}$ is the canonical basis of both c_0 and ℓ^1. Then, consider the cbc subset $E^{(2)} = E_t{}^{(2)}$ of U_1^2 by*

$$E^{(2)} = \left\{ \sum_{n=1}^{\infty} \alpha_n f_n : \quad \forall n \in \mathbb{N}, \quad \alpha_n \ge 0 \quad and \quad \sum_{n=1}^{\infty} \alpha_n = 1 \right\}.$$

Then, $E^{(2)}$ has the fixed point property for $\|.\|_{\sim}^{(2)}$-nonexpansive mappings.
Proof. Let $r \in \mathbb{R}$ and $t \in (0,1)$. Let $T: E^{(2)} \to E^{(2)}$ be a $\|.\|_{\sim}^{(2)}$-nonexpansive mapping. Then, there exists a sequence so called aproximate fixed point sequence $\left(u^{(n)}\right)_{n\in\mathbb{N}} \in E^{(2)}$ such that $\left\|Tu^{(n)} - u^{(n)}\right\|_{\sim}^{(2)} \to_n 0$. Due to isometric isomorphism, U_1^2 shares common geometric properties with ℓ^1 and so both U_1^2 and its predual have similar fixed point theory properties to ℓ^1 and c_0, respectively. Thus, considering that on bounded subsets the weak star topology on ℓ^1 is equivalent to the coardinate-wise convergence topology and c_0 is separable, in U_1^2, the unit closed ball is weak*-sequentially compact due to Banach-Alaoğlu theorem. Then, we can say that we may denote the weak* closure of the set $E^{(2)}$ by

$$C^{(2)} := \overline{E^{(2)}}^{w^*} = \left\{ \sum_{n=1}^{\infty} \alpha_n f_n : each\ \alpha_n \ge 0\ and \sum_{n=1}^{\infty} \alpha_n \le 1 \right\}$$

and without loss of generality, we may pass to a subsequence if necessary and get a weak* limit $u \in C^{(2)}$ of $u^{(n)}$. Then, by Lemma 2.1, we have a function $r: U_1^2 \to [0,\infty)$ defined by

$$Q(w) = \limsup_n \left\|u^{(n)} - w\right\|_{\sim}^{(2)}, \forall w \in U_1^2$$

such that for every $w \in U_1^2$,

$$Q(w) = Q(u) + \|u - w\|_{\sim}^{(2)}.$$

Case 1. $u \in E^{(2)}$.

Then, $r(Tu) = r(u) + \|Tu - u\|_{\sim}^{(2)}$ and

$$\begin{aligned} Q(Tu) &= \limsup_n \left\|Tu - u^{(n)}\right\|_{\sim}^{(2)} \\ &\leq \limsup_n \left\|Tu - T\left(u^{(n)}\right)\right\|_{\sim}^{(2)} + \limsup_n \left\|u^{(n)} - T\left(u^{(n)}\right)\right\|_{\sim}^{(2)} \\ &\leq \limsup_n \left\|u - u^{(n)}\right\|_{\sim}^{(2)} + 0 \\ &= Q(u). \end{aligned} \tag{2}$$

Thus, $Q(Tu) = Q(u) + \|Tu - u\|_{\sim}^{(2)} \leq r(u)$ and so $\|Tu - u\|_{\sim}^{(2)} = 0$. Therefore, $Tu = u$.

Case 2. $u \in C^{(2)} \backslash E^{(2)}$.

Then, we may find scalars satisfying $u = \sum_{n=1}^{\infty} \delta_n f_n$ such that $\sum_{n=1}^{\infty} \delta_n < 1$ and $\delta_n \geq 0$, $\forall n \in \mathbb{N}$.

Define $\xi := 1 - \sum_{n=1}^{\infty} \delta_n$ and for $\beta \in \left[\frac{-\delta_1}{\xi}, \frac{\delta_2}{\xi} + 1\right]$, define

$$\mathrm{h}_\beta := \left(\delta_1 + \frac{\beta}{4}\xi\right) f_1 + \left(\delta_2 + \frac{\beta}{4}\xi\right) f_2 + \left(\delta_3 + \frac{\beta}{4}\xi\right) f_3 + \left(\delta_4 + \frac{\beta}{4}\xi\right) f_4 + (\delta_5 + (1-\beta)\xi) f_5 + \sum_{n=6}^{\infty} \delta_n f_n.$$

Then,

$$\begin{aligned} \|h_\beta - u\|_{\sim}^{(2)} &= \left\|\frac{\beta}{4} t\xi v_1 e_1 + \frac{\beta}{4} t\xi \frac{v_2}{2^{2-r}} e_2 + \frac{\beta}{4} t\xi \frac{v_3}{3^{2-r}} e_3 + \frac{\beta}{4} t\xi \frac{v_4}{4^{2-r}} e_4 + (1-\beta)\xi \frac{tv_5 e_5}{5^{2-r}}\right\|_{\sim}^{(2)} \\ &= t\left|\frac{\beta}{4}\right|\xi + t\left|\frac{\beta}{4}\right|\xi + t\left|\frac{\beta}{4}\right|\xi + t\left|\frac{\beta}{4}\right|\xi + t|1-\beta|\xi. \end{aligned}$$

$\|h_\beta - u\|_{\sim}^{(2)}$ is minimized for $\beta \in [0,1]$ and its minimum value would be $t\xi$.

Now fix $w \in E^{(2)}$. Then, we may find scalars satisfying $w = \sum_{n=1}^{\infty} \alpha_n f_n$ such that $\sum_{n=1}^{\infty} \alpha_n = 1$ with $\alpha_n \geq 0$, $\forall n \in \mathbb{N}$. We may also write each f_k with coefficients γ_k for each $k \in \mathbb{N}$ where $\gamma_1 := tv_1$, $\gamma_2 := \frac{tv_2}{2^{2-r}}$, $\gamma_3 := \frac{tv_3}{3^{2-r}}$, $\gamma_4 := \frac{tv_4}{4^{2-r}}$, $\gamma_5 := \frac{tv_5}{5^{2-r}}$, and $\gamma_n := \frac{v_n}{n^{2-r}}$ for all integers $n \geq 6$ such that for each $n \in \mathbb{N}$, $f_n = \gamma_n e_n$.

Then,

$$\|\mathrm{w} - u\|_{\sim}^{(2)} = \left\|\sum_{k=1}^{\infty} \alpha_k f_k - \sum_{k=1}^{\infty} \delta_k f_k\right\|_{\sim}^{(2)}$$

$$
\begin{aligned}
&= \left\| \sum_{k=1}^{\infty} (\alpha_k - \delta_k) f_k \right\|_{\sim}^{(2)} \\
&= \sum_{k=1}^{\infty} \left| (\alpha_k - \delta_k) \frac{k^{2-r}\gamma_k}{v_k} \right|. \\
&\geq \sum_{k=1}^{\infty} t\,|\alpha_k - \delta_k| \\
&\geq t \left| \sum_{k=1}^{\infty} (\alpha_k - \delta_k) \right| \\
&= t \left| 1 - \sum_{k=1}^{\infty} \delta_k \right| \\
&= t\xi.
\end{aligned}
$$

Hence,

$$\|\mathrm{w} - u\|_{\sim}^{(2)} \geq t\xi = \|h_\beta - u\|_{\sim}^{(2)}$$

and the equality is obtained if and only if $(1-t)\sum_{k=6}^{\infty} |\alpha_k - \delta_k| = 0$; that is, we have $\|\mathrm{w} - u\|_{\sim}^{(2)} = t\xi$ if and only if $\alpha_k = \delta_k$ for every $k \geq 6$; or say, $\|\mathrm{w} - u\|_{\sim}^{(2)} = t\xi$ if and only if $\mathrm{w} = h_\beta$ for some $\beta \in [0,1]$.

Then, there exists a continuous function $\rho: [0,1] \to E^{(2)}$ defined by $\rho(\beta) = h_\beta$ and $\Lambda\rho([0,1])$ is a compact convex subset and so $\|\mathrm{w} - u\|_{\sim}^{(2)}$ achieves its minimum value at $\mathrm{w} = h_\beta$ and for any $\mathrm{h}_\beta \in \Lambda$, we get

$$
\begin{aligned}
Q(h_\beta) &= Q(u) + \|h_\beta - u\|_{\sim}^{(2)} \\
&\leq Q(u) + \|Th_\beta - u\|_{\sim}^{(2)} \\
&= Q(Th_\beta) = \limsup_n \|Th_\beta - u^{(n)}\|_{\sim}^{(2)}
\end{aligned}
$$

then same as the inequality (2), we get

$$
\begin{aligned}
Q(h_\beta) &\leq \limsup_n \|Th_\beta - T(u^{(n)})\|_{\sim}^{(2)} + \limsup_n \|u^{(n)} - T(u^{(n)})\|_{\sim}^{(2)} \\
&\leq \limsup_n \|h_\beta - u^{(n)}\|_{\sim}^{(2)} + \limsup_n \|u^{(n)} - T(u^{(n)})\|_{\sim}^{(2)} \\
&\leq \limsup_n \|h_\beta - u^{(n)}\|_{\sim}^{(2)} + 0 \\
&= Q(h_\beta).
\end{aligned}
$$

Hence, $r(h_\beta) \leq Q(Th_\beta) \leq r(h_\beta)$ and so $Q(Th_\beta) = Q(h_\beta)$.

Therefore,

$$Q(u) + \|Th_\beta - u\|_{\sim}^{(2)} = Q(u) + \|h_\beta - u\|_{\sim}^{(2)}.$$

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Thus, $\|Th_\beta - u\|_{\sim}^{(2)} = \|h_\beta - u\|_{\sim}^{(2)}$ and so $Th_\beta \in \Lambda$ but this shows $T(\Lambda) \subseteq \Lambda$ and using Schauder's fixed point theorem in [26], we can easily we get the result T has a fixed point since T is continuous. Thus, h_β is the unique minimizer of $\|w - u\|_{\sim}^{(2)} : w \in E^{(2)}$ and $Th_\beta = h_\beta$.

Therefore, $E^{(2)}$ has the fixed point property for nonexpansive mappings.

3. DISCUSSION

As it has been mentioned in earlier sections of the study, investigating and looking for large classes of closed, bounded and convex subsets in Banach spaces alike the Banach spaces of absolutely summable scalars are center of interests for many fixed point theorists. One can investigate to get larger classes for more general spaces than those in the present study and due to isometry, that would not be hard by following the ideas of Goebel and Kuczumows. However, trying to generalize their ideas and looking for different examples of the sets and spaces would be valuable studies.

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MATERNAL KANDA SERBEST FETAL DNA VE RNA: PRENATAL TESTLER ARASINDAKİ YERİ

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ÖZET

Gebelikte anne kanında bulunan serbest fetal DNA (ve RNA), belirli genetik özelliklerin invaziv olmayan doğum öncesi tanısı için kullanılabilir. Potansiyel uygulamalar arasında fetal cinsiyetin belirlenmesi, belirli tek gen bozukluklarının teşhisi, fetal kan genotiplemesi ve Down sendromu taraması yer alır. Yüksek riskli gebelikler için invaziv olmayan fetal cinsiyet belirleme ve Rh faktörü belirlemeyi sunmaktadır ve bu teknik kısa bir süre içerisinde diğer endikasyonlar için yaygın olarak kullanılabilir hale geleceği tahmin edilmektedir.

Bu teknoloji, mevcut standart uygulamadan daha güvenli, daha erken ve daha kolay doğum öncesi test imkânı sunmaktadır. Ancak bilgilendirilmiş onam ve erişim eşitliği, maliyet de dahil olmak üzere etik, yasal ve sosyal endişeleri gündeme getirmektedir.

Non-invaziv doğum öncesi tanı ile ilgili araştırmalar devam etmektedir. Kamuoyu ve sağlık profesyonelleri bu teknolojinin ilerlemesi ve sınırlamaları hakkında bilgilendirilmelidir. Serbest fetal DNA'nın gebelik sırasında anne kanında dolaştığına dair çığır açıcı keşif, obstetrik bakımda birçok potansiyel uygulama konusunda dünya çapında araştırmaları teşvik etmiştir. Moleküler genetik teknolojisindeki gelişmeler, serbest fetal DNA testinin bazı genetik özelliklerinin erken non-invaziv doğum öncesi sorunları tanımlanması için klinik uygulamaya aktarılmasını sağlamıştır. Ancak, teknolojiyle ilişkili karmaşık, daha geniş etik, yasal ve sosyal sorunlar ve klinik/laboratuvar hizmetleri için çıkarımlar ele alınmalıdır.

Anahtar Kelimeler: Serbest Fetal DNA, RNA, Prenatal test, Maternal kan

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FREE FETAL DNA AND RNA IN MATERNAL BLOOD: THEIR PLACE AMONG PRENATAL TESTS

ABSTRACT

Free fetal DNA (and RNA) found in maternal blood during pregnancy can be used for noninvasive prenatal diagnosis of certain genetic traits. Potential applications include fetal sex determination, diagnosis of certain single-gene disorders, fetal blood genotyping, and screening for Down syndrome. It offers noninvasive fetal sex determination and Rh factor determination for high-risk pregnancies, and it is anticipated that this technique will soon become widely available for other indications.

This technology offers safer, earlier, and easier prenatal testing than current standard practice. However, informed consent and access equity raise ethical, legal, and social concerns, including cost.

Research into noninvasive prenatal diagnosis is ongoing. The public and health professionals should be informed about the progress and limitations of this technology. The groundbreaking discovery that free fetal DNA circulates in the maternal blood during pregnancy has stimulated worldwide research into many potential applications in obstetric care. Advances in molecular genetic technology have enabled the translation of some of the genetic features of free fetal DNA testing into clinical practice for early noninvasive prenatal diagnosis. However, the complex broader ethical, legal and social issues associated with the technology and the implications for clinical/laboratory services must be addressed.

Keywords: Free Fetal DNA, RNA, Prenatal testing, Maternal blood

1. GİRİŞ

2011 yılın invaziv olmayan doğum öncesi testi (NIPT) olarak ilk kez tanıtıldığından beri, doğum öncesi bakımda büyük bir yankı uyandırmıştır. 2019'da 3,9 milyar ABD doları küresel pazara ve 2024'e kadar 7,3 milyar ABD dolarına çıkması beklenen bir büyümeye sahip olarak 60'tan fazla ülkede kullanılabilir hale gelmiştir (MarketsandMarkets, 2019). Çok sayıda fayda sağlamakla birlikte, aynı zamanda genellikle kültürel, sosyal, yasal ve ekonomik bağlamlarla ilgili zorluklar da ortaya çıkardığı düşünülmektedir.

Literatürde NIPT'i tanımlamak için şu anda birkaç terim kullanılmaktadır: invaziv olmayan doğum öncesi tarama, serbest DNA taraması ve serbest fetal DNA taraması. İlk zamanlarda, teknoloji yaygın olarak invaziv olmayan doğum öncesi tanı olarak adlandırmaktaydı, ancak yöntemin tanısal olmadığı anlaşıldıkça, terminoloji giderek invaziv olmayan doğum öncesi taramaya doğru kaymıştır (Haidar ve ark., 2016). Ancak, bu teknolojinin doğum öncesi tarama yolunda uygulanmasını tartışırken hala yaygın olduğu ve birçok ülkede kullanıldığı için NIPT terimi daha sık kullanılmaktadır.

2. İNVAZİV OLMAYAN DOĞUM ÖNCESİ TESTİ

1997'de, Lo ve ark., tarafından maternal plazmada serbest fetal DNA'nın varlığını keşfetti. On yıl sonra, Lo ve ark. (2007) serbest fetal DNA analizinin fetüste trizomi 21 (T21) veya Down sendromunun tespit edilmesini sağladığını saptadı. Sonraki çalışmalar serbest fetal DNA'nın plasental kökenli olduğunu tespit etti (Alberry ve ark., 2007). Annenin plazmasındaki plasental serbest fetal DNA'nın oranı, fetal fraksiyon olarak adlandırılır ve gebeliğin 10. ve 20. haftaları arasında ölçüldüğünde %3 ila %30 arasında değişmektedir (Canick ve ark., 2013). NIPT, fetal fraksiyonun genetik varyasyonlarını tespit etmek için yeterince yüksek olduğu 9. haftadan itibaren güvenilir bir şekilde uygulanmaktadır. Düşük fetal fraksiyon, erken gebelik yaşı, yüksek maternal vücut kitle indeksi, annede sigara kullanımı ve ikiz gebelik ile ilişkili olduğu belirtilmiştir (Ashoor ve ark., 2013). Test başarısızlığıyla ilişkili diğer faktörler, kan örneği kontaminasyonu veya bozulması gibi teknik zorluklardır (Palomaki&Kloza, 2018).

NIPT, öncelikle T21, T18 (Edwards sendromu), T13 (Patau sendromu) ve cinsiyet kromozomu aneuploidilerini [45,X (Turner sendromu), 47,XXY (Klinefelter sendromu), 47,XYY ve 47,XXX (üçlü X sendromu)] taramak için kullanılır, çünkü bu durumlara duyarlılığı yüksektir: T21, T18 ve T13 için sırasıyla %99,7, %97,9 ve %99,0; Turner sendromu için %95,8; ve diğer cinsiyet kromozomu aneuploidileri için %95'in üzerinde (bazıları %100 olduğunu iddia etmektedir) (Gill ve ark., 2017). Test üreticileri daha nadir trizomiler, kopya sayısı varyantları ve 15q delesyonu (Prader-Willi ve Angelman sendromları), 22q11.2 delesyonu (DiGeorge sendromu), 4p delesyonu (Wolf-Hirschhorn sendromu), 15p delesyonu (cri-du-chat sendromu) ve 11q delesyonu (Jacobsen sendromu) (Hui&Bianchi, 2017) dahil olmak üzere mikrodelesyonlar için testler gibi başka seçenekler sunar, ancak bu durumlar için duyarlılık ve pozitif öngörü değeri önemli ölçüde daha düşüktür (Meredith ve ark., 2017) ve daha fazla durum için tarama yapıldığında genel yanlış pozitif oranının artma riski vardır. Amerikan Kadın Hastalıkları ve Doğum Uzmanları Koleji'nin (ACOG) en son doğum öncesi tarama yönergeleri, geçerliliğine ilişkin kanıt eksikliği nedeniyle daha nadir görülen genetik bozukluklar için NIPT kullanılmasını önermemektedir (ACOG, 2020). Belirli durumlarda taramaya ek olarak, yaygın trizomiler için NIPT taraması, hedefli bir analiz veya genom çapında dizileme tabanlı bir yaklaşım kullanılarak yapılabilir ve bu da diğer sapmaları da ortaya çıkarabilmektedir.

NIPT ikiz gebeliklerde yapılabilir. Bu, daha yüksek bir test başarısızlık oranıyla ilişkilendirilmesine rağmen, çalışmalar NIPT'in T21 duyarlılığının ikiz ve tekil gebelikler için benzer olduğunu göstermektedir (Gill ve ark., 2019). Monogenik durumlar için invaziv olmayan doğum öncesi tanı testleri geliştirilmiştir, ancak teknik ve etik zorluklar nedeniyle NIPT'den çok daha az ilgi görmüştür (Hayward&Chitty, 2018). Dahası, bu tür testler için küresel pazar nispeten küçüktür, çünkü öncelikle bilinen bir aile öyküsü (örn. kistik fibroz) veya ultrason anormallikleri (örn. akondroplazi) olan vakalarda de novo dominant veya resesif durumların tespiti veya dışlanması için bir tanı ortamında kullanılır.

2.1.İnvaziv Olmayan Doğum Öncesi Testlerin Küresel Kapsamı

- NIPT 60'tan fazla ülkede mevcuttur.
- 2018'de 10 milyon NIPT testi yapılmıştır.
- NIPT'nin tahmini küresel piyasa değeri önemli ölçüde değişmektedir ve yaklaşık olarak 2019'da 3,9 milyar ABD dolarından, 2020'de 2,83 milyar ABD dolarına kadar değişmektedir.

- NIPT'nin tahmini bileşik yıllık büyüme oranı %10,9 ile %17,15 arasında değişmektedir.
- NIPT'nin gelecekteki küresel piyasa değerine ilişkin tahminler değişmektedir ve 2024'e kadar 7,3 milyar ABD doları, 2027'ye kadar 13,1 milyar ABD doları ve 2028'e kadar 6,5 milyar ABD doları kapsayacağı düşünülmektedir.
- 2019-2020'de en büyük pazar payına sahip olan ülke Amerika'ydı, bunu Avrupa izledi (Ravitsky ve ark., 2021).

2.2.Fetal Aneuploidiye Yakalanma Riski Yüksek Kadınlarda Doğum Öncesi Tarama

Bazı kılavuzlar, bu yaygın otozomal aneuploidiler için en hassas test olmasından cfDNA testinin tüm kadınlar için yapılmasını da desteklemektedir (Gregg ve ark., 2016). Aslında, düşük riskli kadınlarda cfDNA testinin pozitif öngörü değerleri, yüksek riskli kadınlarda çoklu belirteç taramasının pozitif öngörü değerlerinden daha yüksektir (Benn ve ark., 2015). Ancak, cfDNA analizi çoklu belirteç taramasından daha pahalıdır. Amerika Birleşik Devletleri'nde, maternal risk durumuna bağlı olarak, cfDNA aneuploidisi taraması bazı sigortacılar, bazı kamu ödeyicileri ve Kaliforniya eyalet tarama programı aracılığıyla ve ayrıca kendi kendine ödeme temelinde erişilebilir. Diğer ülkelerdeki sağlık sistemleri, cfDNA testini kamu tarafından finanse edilen doğum öncesi tarama programlarına dahil etmek için çeşitli yaklaşımlar benimsemiştir (Nshimyumukiza ve ark., 2018). Bu yaklaşımlar arasında taramanın gebeler için birinci kademe test olarak sunulması (Belçika), birinci kademe standart doğum öncesi taramaya göre 150'de 1'den yüksek risk taşıyan kadınlar için ikinci kademe test olarak sunulması (Birleşik Krallık) ve yalnızca yüksek risk altında olduğu düşünülen kadınlar yerine tüm gebeler için cfDNA taramasının prospektif olarak incelenmesi (Hollanda) yer almaktadır (Oepkes ve ark., 2016). Uygulamalar mevcut kanıtlar göz önüne alındığında, profesyonel kılavuzlar, trizomi 21, 18 ve 13 için cfDNA testini gebeler için bir seçenek olarak evrensel olarak önermektedir. Maternal plazma cfDNA testi ile ilişkili test öncesi danışmanlık için gereken kaynaklar ve çabalar, standart tarama ile ilişkili danışmanlık için gerekenlerden daha fazladır. Fetal risk oluşturmayan bir kan testine onay veren bazı kadınlar, testin sınırlamalarının tam olarak farkında olmayabilir veya potansiyel olarak pozitif bir sonuç almanın etkisini yeterince dikkate almayabilirler (Minear ve ark., 2015). Danışmanlık sürecini kolaylaştırmak için kılavuzlar ve araçlar geliştirilmiştir (Sachs ve ark., 2015). Ayrıca, yaygın trizomilerin, tanısal karyotip veya mikrodizi çalışmasıyla belirlenebilen kromozomal aberasyonların yalnızca üçte birini oluşturduğunu kabul etmek önemlidir (Evans ve ark., 2016). Negatif cfDNA test raporuna rağmen aneuploidiye işaret eden sonografik özelliklere sahip gebelikler için daha fazla araştırma yapılması gerekmektedir.

2.3.Serbest Fetal DNA ve Ebelik

Ebelik bakım felsefesi, geleneksel obstetrik tıbbi yaklaşımdan birkaç temel noktada farklılık göstermektedir. Genel olarak ebeler, bilgilendirilmiş onama, hasta özerkliğini teşvik etmeye ve hasta isteklerini ebe uzmanlığıyla dengeleyen, paylaşılan karar alma ile karakterize edilen bir ortaklık içinde ailelerle çalışmaya değer verirler (American College of Nurse-Midwives, 2017). Ebelik, ayrıca, özellikle invaziv olan veya gebeliği riske atan testlerin veya prosedürlerin (örneğin, tanı testleri) kullanılmasının risklerinin, faydalarının ve endikasyonlarının dikkatli bir şekilde değerlendirilmesini içeren, gebeliğe yönelik müdahaleci olmayan yaklaşımıyla da benzersizdir. Bu müdahaleci olmayan felsefe, hekimler tarafından gebeliğin tıbbileştirilmesiyle (gereksiz elektif prosedürlerin kullanılmasına yol açabilir) çelişir; ancak doğum bakım ekibinin

önemli üyeleri olan hekimler tarafından benimsenen yönlendirmecilik olmayan (hasta özerkliğine ve isteklerine dayalı karar alma) ethos ile paralellik gösterir. Ebelik felsefesinin bu ayırt edici bileşenleri, tüm gebelikler için NIPT'nin giderek artan bulunabilirliği, ebelerin doğum sağlayıcısı olarak giderek artan kullanımı ile NIPT konusunda danışmanlık ve eğitim verme becerisine sahip olmalıdır (Dettwyler ve ark., 2017).

3. SONUÇ

NIPT, küresel olarak en hızlı yayılan genetik teknolojilerden biridir. NIPT, bazı ülkelerde kamu sağlık sistemi tarafından benimsenmeden önce özel sektörde ticari bir uygulama ile karakterize edilir. Birçok fayda sağlar ve genel olarak gebeler ve sağlık personeli tarafından iyi karşılanır. Uygulanması ve benimsenmesi, sağlık sisteminin yapısı; doğum öncesi test programının ve kamu fonlamasının varlığı veya yokluğu ve sosyokültürel, yasal ve politik bağlamlar gibi birçok yerel ve ulusal faktörden etkilenir. Bu faktörler iç içe geçmiştir ve NIPT'nin uygulanmasını karmaşık hale getirir.

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FETAL MONİTÖRİZASYON İZLEM TÜRLERİ VE EBELİK YAKLAŞIMLARI

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ÖZET

Doğum sırasındaki dönem hem anne hem de fetüs için en kritik aşamalardan biridir. Doğum süreci sırasında, fetüsün durumunda bozulmaya yol açan ve hayatını tehdit eden komplikasyonlar gelişebilir. Bu nedenle, doğumun sonucu fetal izlemenin etkinliğine bağlıdır. Doğum ve doğum ünitelerinde kardiyotokografi ile sürekli doğum içi Elektronik Fetal Monitörizasyon (EFM) kullanımı istisna değil kural haline gelmiştir. Bu tür bir teknolojinin kullanımı çoğu doğumhanede kolayca yapılabilir çünkü doktorlar ve ebeler Fetal Kalp Hızı (FKH) ve kontraksiyon modellerinin sürekli kağıt veya elektronik kayıtlarını takip eder ve neredeyse tüm hastalar doğum ve doğuma bakımlarında bu aracın kullanılacağını bekleyerek gelirler. Artık her yerde kullanılmasına rağmen, sürekli elektronik izleme ve ilişkili riskleri ve faydaları dikkate alınmaya değerdir.

Sürekli elektronik fetal izleme, doğum sırasında hipoksik-iskemik ensefalopati, serebral palsi ve yaklaşan fetal ölüm belirtilerini taramak için geliştirilmiştir. Bu olayların yaygınlığı düşük olduğundan, sürekli elektronik fetal izleme %99'luk yanlış pozitif orana sahiptir. Sürekli elektronik fetal izlemenin yaygın kullanımı, neonatal sonuçları iyileştirmeden operatif ve sezaryen doğum oranlarını artırmıştır, ancak kullanımı yüksek riskli doğumlarda uygundur. Yapılandırılmış aralıklı oskültasyon, yeterince kullanılmayan bir fetal izleme biçimidir. Düşük riskli doğum sırasında kullanıldığında, sürekli elektronik fetal izlemeninkine benzer neonatal sonuçlarla operatif ve sezaryen doğum oranlarını düşürebilir. Ancak, ebe ve hekim gözetimindeki engeller nedeniyle yapılandırılmış aralıklı oskültasyonun uygulanması hala zordur.

Anahtar Kelimeler: Fetal monitörizasyon, Ebelik, İzlem

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FETAL MONITORING TYPES AND MIDWIFERY APPROACHES

ABSTRACT

The peripartum period is one of the most critical stages for both mother and fetus. During the labor process, complications that may lead to deterioration in the condition of the fetus and threaten its life may develop. Therefore, the outcome of the labor depends on the effectiveness of fetal monitoring. In labor and delivery units, the use of continuous intrapartum Electronic Fetal Monitoring (EFM) with cardiotocography has become the rule rather than the exception. The use of such technology is easily implemented in most delivery rooms because doctors and midwives follow continuous paper or electronic records of Fetal Heart Rate (FHR) and contraction patterns, and almost all patients come to labor and delivery expecting this tool to be used in their care. Although it is now used everywhere, continuous electronic monitoring and its associated risks and benefits are worth considering.

Continuous electronic fetal monitoring was developed to screen for hypoxic-ischemic encephalopathy, cerebral palsy, and signs of impending fetal death during labor. Because the prevalence of these events is low, continuous electronic fetal monitoring has a false-positive rate of 99%. The widespread use of continuous electronic fetal monitoring has increased operative and cesarean delivery rates without improving neonatal outcomes, but its use is appropriate in high-risk deliveries. Structured intermittent auscultation is an underutilized form of fetal monitoring. When used during low-risk deliveries, it can reduce operative and cesarean delivery rates with neonatal outcomes similar to those of continuous electronic fetal monitoring. However, structured intermittent auscultation remains difficult to implement because of barriers to midwife and physician supervision.

Keywords: Fetal monitoring, Midwifery, Monitoring

1. GİRİŞ

Fetal kalp sesi ilk olarak 1600'lerde bir şiirde tanımlanmış olsa da, anormal fetal kalp atış hızlarının forseps müdahalesine ihtiyaç duyulduğunu gösteren fetal sıkıntı ile ilişkilendirilmesi 1800'lerin ortalarına kadar gerçekleşmemiştir. O zamanlar, bir fetüsün değerlendirilmesi öncelikle kulağın anne karnına dayanması veya fetal kalp atış hızını dinlemek için bir Laennec aleti (silindirik şekilli ve Pinard'a benzer) kullanılmasıyla gerçekleştiriliyordu (Freeman & Garite, 1981). İlk fetal elektrokardiyogram kaydı 1906'da yapıldı. 50 yıl sonra, Yale Üniversitesi'nden Dr. Hon, fetal kalp hızını anne karnından sürekli izleyerek fetal sıkıntıya yol açan bradikardi nedenlerini belirleyebildi (Hon & Lee, 1963).

Sürekli EFM, düşük riskli kadınlarda aralıklı oskültasyon ile karşılaştırıldığında kullanımını destekleyen bir kanıt göstermemiş olmasına rağmen, ebeler ve hekimler tarafından benimsendi (Sandelowski, 2000). Zamanla, Elektronik Fetal Monitörizasyon (EFM) makinesi daha küçük ve daha az hacimli hale geldi ve bu da bu teknolojinin yatağın yanına daha kolay sığmasını ve kullanılmasını sağladı. 1978'e gelindiğinde, EFM tüm doğumların yarısında rutin olarak

kullanılıyordu (Williams & Hawes, 1979). 2002'de tüm kadınların %85'i EFM ile değerlendirildi (Martin ve ark., 2003). Kanıtlar bu tür teknolojinin düşük riskli gebeliklerde kullanılmasını desteklemese de, EFM tüm dünyadaki kadınlar için doğum pratiğinde bir bakım standardı haline gelmiştir.

Doğumun ilk iki evresinde, fetüs pozisyon değiştirdikçe ve uterus kasılmaları meydana geldikçe fetal dolaşım sıkışmaya maruz kalır ve bu kötü sonuçlara yatkınlık oluşturan fetal sıkıntıya neden olabilen hipoksi ve/veya asidoza yol açma potansiyeline sahiptir (Macones ve ark., 2008). Fetal durumu izlerken, ebeler fetal kalp hızına (FKH), variabilite, akselerasyon ve deselerasyonlara dikkat etmelidir. Bazal FKH ve variabilite, merkezi sinir sistemi aktivitesinde, hacim durumundaki, baroreseptör stimülasyonundaki ve kemoreseptör stimülasyonundaki değişikliklerden etkilenir (Ugwumadu, 2023).

FKH akselerasyonları, fetal merkezi sinir sistemi stimülasyonu ve fetal motor fonksiyonunda artış dönemleriyle ilişkilidir. Erken deselerasyonlar, özellikle uterus kontraksiyonları sırasında fetal baş sıkışmasıyla ilişkilidir. Çünkü artan fetal intrakraniyal basınç fetal bradikardiye neden olur. Bu refleks hızla gerçekleşir, bu nedenle deselerasyonun başlangıcı kontraksiyonun başlangıcıyla birlikte gözlenir ve deselerasyonların en düşük noktası kontraksiyonun zirvesiyle yaklaşık olarak aynı zamanda gerçekleşir. Uygun bazal FKH, variabilite, akselerasyonlar ve erken deselerasyonların varlığı fetal nörolojik, otonomik ve kardiyovasküler sistemlerin güven verici işlevini gösterir.

2. FETAL KALP ATIŞ HIZI DEĞİŞİKLİKLERİNİ ETKİLEYEN FAKTÖRLER

Fetal izleme, doğum sırasında fetal oksijenasyonun yeterliliğini değerlendirmek için kullanılır (ACOG, 2009). Amaç metabolik asidemiyi önlemektir. Metabolik asidemi, bir fetüsün yeterli oksijenasyondan mahrum bırakılmasından sonraki 60 dakika içinde gelişebilir (Parer ve ark., 2006). Doğum sırasında hipoksi, göbek kordonunun sıkışması veya daha ciddi vakalarda geç deselerasyon görülen uterus kasılması sırasında plasenta perfüzyonunun azalması nedeniyle oluşabilir (Miller & Miller, 2012).

Metabolik asidemi, özellikle serebral palsi olmak üzere neonatal morbidite oranlarının artmasıyla ilişkilidir (Miller & Miller, 2012). Ancak doğum sırasında fetal hipoksi, serebral palsinin çok nadir bir nedenidir (Blair ve Stanley, 1988). Yaklaşık 1.000 çocuktan 2'sinde serebral palsi vardır ve serebral palsi için ana risk faktörleri düşük doğum ağırlığı, intrauterin enfeksiyonlar ve çoğul gebeliklerdir (Odding ve ark., 2006).

Fetal kalp hızında olumsuz değişikliklere neden olabilen, hipoksi ile doğrudan ilişkili olmayan faktörler arasında maternal ateş, enfeksiyon, ilaçlar ve hipertiroidizm bulunurMaternal enfeksi. yon düşük Apgar skorları, yenidoğan nöbetleri ve serebral palsi ile ilişkilendirilmiştir. Fetal kalp hızı değişikliklerinin diğer nedenleri arasında fetüsü ilgilendiren durumlar da bulunur: uyku döngüsü, enfeksiyon, anemi, aritmi, önceden var olan nörolojik yaralanma, kalp bloğu ve konjenital anomalilerdir (Miller & Miller, 2012).

2.1.Fetal İzleme Tipleri

Fetüs, genellikle doğum sırasında annenin karnından dışarıdan kardiyotokograf makinesi (EFM), Pinard fetal stetoskop veya ultrason el tipi fetal doppler (Alfirevic ve ark., 2006) kullanılarak izlenir.

2.1.1. Sürekli Elektronik Fetal İzleme

Sürekli fetal izleme veya kardiyotokografi, FKH ve kontraksiyonları birlikte izleme yöntemidir. Bu iki değişken arasındaki ilişkinin, fetüsün oksijenasyon durumuyla ilişkili olduğu yaygın olarak kabul edilmektedir. Bu durum ebe ve hekimlere herhangi bir müdahalenin gerekli olup olmadığını belirlemek için kullanabilecekleri gerçek zamanlı bilgiler sağlayarak anne ve fetüse fayda sağlamayı amaçlamaktadır. Dünyanın birçok bölgesinde, sürekli intrapartum fetal izleme, doğum ve doğum yapan çoğu kadın için rutin olarak kullanılmıştır. Ancak, bunun kanıt temeli tartışmalıdır. Çünkü araştırmalar, rutin FKH izlemesinin, çoğu yenidoğan veya çocukluk sonuçlarını önemli ölçüde iyileştirmeden hem operatif vajinal doğum hem de sezaryen oranlarında artışlarla ilişkili olduğunu göstermiştir (Alfirevic ve ark., 2017).

FKH izlemesinin yenidoğan mortalitesi üzerindeki etkisine ilişkin kanıtlar karışıktır ve fetal izlem kullanıldığında yenidoğan nöbetlerinin sıklığında küçük bir azalma gözlemlenmiştir. Ancak, Apgar skorları, nörolojik yaralanma insidansı, serebral palsi, gelişimsel gecikme ve yenidoğan yoğun bakım ünitesine yatış dahil olmak üzere diğer perinatal sonuçlarda fetal izlemenin kullanımından hiçbir fayda gösterilmemiştir. Doğumdan hemen sonraki dönem dışında, fetal izlem, genellikle bir obstetrik hastanın abdominal travma sonrası plasenta abrupsiyonunu değerlendirmek için kullanılabilir. Ayrıca gerçek ve yanlış doğumu ayırt etmeye yardımcı olmak için de kullanılabilir. FKH izlemesini uygulama ve yorumlama yeteneği, ebelerden büyük ölçüde beklenir ve yüksek riskli gebeliklerde ve doğum dışında fetal iyilik halinin değerlendirilmesinde daha önemli bir rol oynadığına inanılmaktadır (Arnold & Gawrys, 2020).

Sürekli elektronik fetal izlemeyi incelerken Ulusal Çocuk Sağlığı ve İnsan Gelişimi Enstitüsü terminolojisi kullanılır ve fetal riski üç kategoriye ayırır. Kategori I izlemeleri fetal asidoz eksikliğini yansıtır ve müdahale gerektirmez. Kategori II izleri belirsizdir, doğum yapan hastaların çoğunda mevcuttur ve klinik olarak normalden hızla gelişen asidozu tahmin eden izlemeyi kapsayabilir. Orta düzeyde fetal kalp hızı değişkenliği ve tekrarlayan patolojik yavaşlamaların yokluğunda hızlanmaların varlığı, asidozun mevcut olmadığına dair güvence sağlar. Kategori II izleme anormallikleri, geri döndürülebilir nedenlerin tedavi edilmesi ve rahim uyarıcı ajanların, fetal kafa derisi stimülasyonunun ve/veya maternal yeniden konumlandırmanın, intravenöz sıvıların veya oksijenin durdurulmasını içeren intrauterin resüsitasyon sağlanmasıyla ele alınabilir. Tekrarlayan derin değişken yavaşlamalar amniyoinfüzyonla düzeltilebilir. Kategori III izleri, fetal asidoz açısından oldukça endişe vericidir ve acil müdahaleler izlemeyi iyileştirmezse doğum hızlandırılmalıdır (Arnold & Gawrys, 2020).

2.1.2. Merkezi Fetal İzleme

Birçok hastane, ebelerin istasyonunda kalıp aynı anda birçok fetal izleme izini gözlemlemelerine olanak tanıyan bir izleme sistemi türü olan merkezi fetal izleme sistemine geçti. Bakımın bu şekilde merkezileştirilmesi, ebelerin doğum yapan bir kadının odasına sık sık girmemesi riskini taşır. Merkezi fetal izlemenin kurulumu ve bakımı pahalıdır. Yatağın başında EFM ile karşılaştırıldığında faydalı olduğu gösterilmemiştir (Withiam-Leitch ve ark., 2006). Merkezi fetal izlemeyi merkezi izleme yapılmayan durumlarla karşılaştıran bir çalışmada, merkezi izlemeyle ilişkili güven verici olmayan fetal kalp hızı izlemelerinde sezaryenlerde (p

= .01) ve operatif vajinal doğumlarda (p = .05) istatistiksel olarak anlamlı bir artış olmuştur (Weiss ve ark., 1997).

2.1.3. Aralıklı Oskültasyon

Pinard fetal stetoskopu ve elde taşınan Doppler, fetüsü aralıklı olarak değerlendirmek için kullanılır ve bu da kadının daha özgürce hareket etmesini ve daha fazla kontrol sahibi olmasını sağlar. Pinard fetal stetoskopu 1880'lerde geliştirilmiş ve 1950'lerde yaygın olarak kullanılmaya başlanmıştır. Elde taşınan Doppler ise 1960'larda geliştirilmiştir (Hale, 2008). Bu yöntemlerin her ikisi de kullanımı nispeten basittir ve doğum öncesi ziyaretler sırasında yaygın olarak kullanılır. Elde taşınan Doppler'in avantajı, kadının ve odadaki diğer kişilerin de fetal kalp atışlarını duyabilmesidir. Oysa Pinard ile yalnızca klinisyen fetal kalp seslerini duyabilir. Aralıklı oskültasyon ayrıca bir makine değil, bir kişi tarafından dokunulması ve bakılması gibi insani bir unsur sağlar.

2.2.İzleme Sıklığı

Mesleki örgütler tarafından önerilen yönergelerin çoğu uzman fikir birliğine ve aynı çalışmalarda düşük riskli ve yüksek riskli gebelikler arasında ayrım yapmayan araştırmalara dayanmaktadır. Bu, tutarsız ve kanıta dayanmayan politikalara yol açmıştır (Sholapurkar, 2010).

Aralıklı oskültasyon kullanırken, doğumun ilk aşamasının aktif fazı sırasında her 15 dakikada bir ve doğumun ikinci aşaması sırasında her 5 dakikada bir değerlendirme önerilmektedir (ACOG, 2009). Ayrıca doğumun ilk aşamasının aktif fazı sırasında her 15-30 dakikada bir (RANZCOG, 2006) ve ikinci aşama sırasında her 5-15 dakikada bir değerlendirme önermektedir (AWHONN, 2008). Bu protokoller, aralıklı oskültasyon kullanıldığında doğumun birinci evresinin aktif fazında beklenen birebir ebelik bakımı oranı için önemli çıkarımlara sahiptir.

Komplikasyonsuz gebelikleri olan sağlıklı kadınlarda EFM izlem sıklığının, doğumun birinci evresinin aktif fazı sırasında her 30 dakikada bir ve ikinci evrede her 15 dakikada bir değerlendirilmesi gereklidir. Komplikasyonsuz gebelikleri olan sağlıklı kadınlara yönelik kılavuzlar sürekli izlemeyi önermemektedir (AWHONN, 2008; ACOG, 2009).

2.3.EFM'de Ebenin Rolleri

Ebeler EFM kullanma kararını iki kritik zamanda verirler: ilk değerlendirme (sağlıklı ve komplikasyonsuz gebeliklere sahip kadınlarda yenidoğan sonuçlarını iyileştirmede etkisizdir) ve ebenin kadını kendi kişisel klinik risk şemasına göre yüksek riskli veya düşük riskli olarak kategorize ettiği ve kanıta dayalı klinik yönergelere dayanmadığı zaman (Devane ve ark., 2012).

Bir ebenin doğumunun ilerleyişini görme biçimi sezaryen ameliyat oranlarını etkiler (Regan ve Liaschenko, 2007) ve izlem protokollerine uyumu etkileyebilir. Doğumu doğal bir fizyolojik süreç olarak gören ebeler, doğum yapan kadını doğumu gerçekleştirebilecek yeterliliğe sahip "güvenilir bilgi sahibi" olarak destekler. Ebenin rolü uzman bir rehber olmaktır. Bu bilişsel referans çerçevesine sahip ebeler, doğum yapan kadını ve fetüsü ayrılmaz bir bütün olarak görürler. Doğumu gizli bir risk olarak gören ebeler, uzman bilgi sahibi olanın doğum yapan kadın değil, ebeler olduğuna inanır. Doğumu riskli olarak gören ebeler ise fetüsü bakımın odak

noktası ve doğum sürecini kaçınılmaz olarak riskle dolu olarak görür. Doğumu riskli olarak gören ebelerin EFM'yi sürekli kullanma ve epidural aneljezi sunma olasılıkları daha yüksektir. Bilinçli seçim yapmanın önündeki engeller arasında, ebenin teknolojinin mesleki statüsünü geliştirdiğine ve sezgisel bilgi ve becerilerinden daha değerli olduğuna inanması; doğum ünitesinin yoğunluğu ve dava korkusu yer alır (Hindley ve Thomson, 2005).

3. SONUÇ

Doğum eğitiminin genel amacı sağlıklı bir doğum yapmaktır. Doğum uygulamaları tek tip bir yaklaşım oluşturmamalıdır. Doğumhanede EFM'nin ayrım gözetmeksizin kullanılması sonuçları iyileştirmemekte ve aslında sorunsuz gebelik geçiren sağlıklı kadınlara zarar vermektedir. Düşük teknolojili, yüksek temaslı bir yaklaşımın kullanılması, doğum yapan çoğu kadına ebelik bakımı sağlarken ana felsefe olmalıdır.

Fetal izlemeyle ilgili tartışmalar ideal olarak doğum başlamadan önce yapılmalıdır, kadının durumu değişirse, devam eden tartışmaların yapılması gerektiği anlayışıyla; eğitim yoluyla edinilen bilginin kadınları güçlendirdiği düşünülmektedir.

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TÜRKİYE'DEKİ SAĞLIK POLİTİKALARI VE EBELİĞE ETKİLERİ

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ÖZET

Politika, belirli bir grup politik aktörün çeşitli konulara yönelik amaçların belirlenmesi ve bu amaçların gerçekleşmesinde kullanılacak olan araçlar yönünde vermiş oldukları kararlardır. Sağlık politikası ise; sağlık sisteminin kurumlarını, hizmetlerini ve finansman düzenlemelerini etkileyen tüm eylemleri içerir ve sağlık hizmetlerinin ötesinde, sağlık üzerinde etkisi olan tüm kamu, özel ve gönüllü örgütlerin eylemlerini kapsamaktadır. Bir ülkede uygulanan resmi sağlık politikası o ülkenin sağlıkla ilgili göstergelerinin en önemli belirleyicisidir. Sağlık politikalarının esas amacı, sağlık risklerinden birey ve toplumu korumak, sağlığı geliştirmek, sağlığı erişilebilir hale getirmek, insan merkezli ve bütüncül yaklaşımla sağlık gereksinimlerine cevap vermektir. Ülkemizde pek çok sağlık politikaları ve kampanyaları yürütülmektedir. Özellikle ebelik mesleğinin odak noktası olan anne ve yenidoğan sağlığı hizmetleri ile ilgili fazlasıyla politika mevcuttur. Ebelerin bu politikaları bilerek sağlık hizmeti sunması önemlidir. Özellikle toplum eğitimi, bilinçlendirilmesi, toplumun sağlık inançlarının değerlendirilip sağlığa zararlı uygulamaların risklerinin anlatılması konularında primer sorumludur. Politika, ebeleri ve onların uygulamalarını etkileyen en önemli faktörlerden birisidir. Bu nedenle, ebelerin kendi uygulamalarını yönlendirmek ve topluma daha nitelikli hizmet sunmak için politik kararları bilmek ve politik güçlerini arttırmaları gerekir.

Anahtar Kelimeler: Sağlık, Sağlık Politikaları, Ebelik.

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HEALTH POLICIES IN TURKEY AND THEIR EFFECTS ON MIDWIFERY

ABSTRACT

Policy is the decision of a group of political actors to set objectives for various issues and the means to be used to achieve those objectives. Health policy, on the other hand, includes all actions that affect the institutions, services and financing arrangements of the health system and goes beyond health services to include the actions of all public, private and voluntary organizations that have an impact on health. The official health policy implemented in a country is the most important determinant of its health indicators. The main purpose of health policies is to protect individuals and society from health risks, to improve health, to make health accessible, and to respond to health needs with a human-centered and holistic approach. Many health policies and campaigns are carried out in our country. In particular, there are many policies related to maternal and newborn health services, which are the focus of the midwifery profession. It is important for midwives to provide health services by knowing these policies. They have primary responsibility for community education, awareness raising, assessing the health beliefs of the community and explaining the risks of practices that are harmful to health. Policy is one of the most important factors affecting midwives and their practice. Therefore, midwives need to know about political decisions and increase their political power in order to direct their own practice and provide better quality services to the community.

Keywords: Health, Health Policies, Midwifery.

1. POLİTİKA KAVRAMI VE TÜRKİYEDEKİ SAĞLIK POLİTİKALARI

1.1.Politika Kavramı

En genel tanıma göre, politika, belirli bir grup siyasi aktör tarafından çeşitli meselelerle ilgili hedeflerin belirlenmesi ve bu hedeflere ulaşmak için kullanılacak araçların seçilmesi sürecinde alınan kararlardır. Günümüz sözlüklerinde ise politika, devletin faaliyetlerini amaç, yöntem ve içerik açısından düzenleme ve gerçekleştirme ilkelerinin bütünü, bir davranış biçimi veya bir düşünce tarzı olarak tanımlanmaktadır. Türkçe ve bazı diğer dillerde "politika" ve "siyaset" terimleri genellikle birbirinin yerine kullanılmaktadır. Bunun sebebi, politika oluşturma, uygulama ve denetleme süreçlerinin siyasi bir boyut taşımasıdır. Bu nedenle, politika ile siyaset arasında ayrı bir ayrım yapmak zordur (Er, 2011).

Politikalar yalnızca devletin ne yapacağı ile ilgili değil, aynı zamanda ne yaptığı ya da yapmadığı ile de ilişkilidir. Politika çalışmaları çerçevesinde yürütülen faaliyetlerin ortak amacı toplumun faydasıdır. Alınacak kararlar ve uygulanacak stratejiler, toplumun genel refahını artırmayı hedeflemektedir (Atabey, 2012).

1.2.Sağlık Politikası Kavramı

Sağlık hakkı, İnsan Hakları Evrensel Beyannamesi'nin 25. Maddesi doğrultusunda temel insan haklarından biri olarak kabul edilmektedir. Bu madde, herkesin "yiyecek, giyecek, barınma,

tıbbi bakım ve gerekli sosyal hizmetler gibi unsurları içeren yeterli bir yaşam standardına sahip olma" hakkını güvence altına alır. Ayrıca, işsizlik, hastalık, sakatlık, yaşlılık ya da diğer zorlu durumlarla karşı karşıya kalan bireylerin korunmasını da sağlar. Bu çerçevede sağlık hakkı, güvenlik hakkının önemli bir bileşeni olarak kabul edilmektedir (Alcan, 2015).

Sağlık politikası, sağlık sisteminin yapısını, hizmetlerini ve finansman düzenlemelerini etkileyen her türlü eylemi kapsayan daha geniş bir kavrama sahiptir. Bunun yanında, sağlık politikası yalnızca sağlık hizmetlerinin sunumunu değil, sağlık üzerinde etkisi bulunan kamu, özel ve gönüllü kuruluşların faaliyetlerini de içerir. Başka bir deyişle, sağlık politikası; sağlık hizmetlerinin sağlanmasına yönelik stratejiler geliştiren ve bu stratejilerle bağlantılı olan kararların bir ağı olarak tanımlanabilir. Ayrıca, etkili bir sağlık politikası geliştirme sürecinde mevcut sağlık hizmetlerinin yanı sıra çevresel ve sosyo-ekonomik faktörlerin de dikkate alınması gerektiği vurgulanmaktadır (Atabey, 2012).

1.3.Sağlık Politikalarının Amaçları

Sağlık politikalarının doğru bir biçimde analiz edilmesi ve planlanması, toplumun sürdürülebilirliği için son derece kritik bir öneme sahiptir. Önceki bölümlerde sağlık hakkının her birey için en temel hak olarak kabul edildiği ve anayasal olarak güvence altına alındığı vurgulanmıştır. "Sağlık hizmetlerinin, bir ülkenin yaşanabilir olmasını sağlayan en temel faktörlerden biri olduğu bilinciyle, bireylere kaliteli, erişilebilir ve güler yüzlü hizmet sunabilmek için tüm kaynakların seferber edilmesi, sağlık politikalarının başlıca hedeflerinden biridir" (Akdağ, 2011).

Sağlık politikalarının bir diğer önemli hedefi ise, İnsan Hakları Evrensel Beyannamesi ve Tıp Etiği ilkeleri doğrultusunda sağlıklı bireylerden oluşan bir toplum yaratmaktır. Bu amaca ulaşmak için belirli hedefler belirlenmiştir (Akdağ, 2011).

Bu hedefler şunlardır:
• Sağlığın iyileştirilmesi için sektörler arası işbirliğinin güçlendirilmesi,
• Çevre sağlığına yönelik gerekli önlemlerin alınması ve bu alanda gelişmeler sağlanması,
• İnsanların yaşam standartlarının iyileştirilmesi için çalışmalar yapılması,
• Sağlık hizmetlerinin sunumu ile ilgili plan ve programların hazırlanması.

Bu bağlamda, sağlık hizmetlerinin tüm sektörlerle işbirliği içinde yürütülmesi gerektiği vurgulanmaktadır. Örneğin, Sağlık Bakanlığı'nın sigara ve soba zehirlenmeleri hakkında hazırladığı kısa filmler, bireyler üzerinde caydırıcı bir etki yaratmaktadır. Sağlık konusunda bilinçli bir toplum, yaşam kalitesini artırır. Bu nedenle, sağlık politikalarının etkili ve doğru bir şekilde tasarlanması, aynı zamanda toplumun sağlık bilincini geliştirmekte ve sağlıklı yaşamı teşvik etmektedir (Önal, 2013).

1.4.Sağlık Politikası Oluşturma

Bir ülkede uygulanan resmi sağlık politikası, o ülkenin sağlık göstergeleri üzerinde önemli bir etkiye sahiptir. Ülkemizde sağlık hakkı, Anayasa'nın 60. maddesinde "Herkes, sosyal güvenlik

hakkına sahiptir. Devlet, bu güvenliği sağlayacak gerekli tedbirleri alır ve teşkilatı kurar" şeklinde yer alarak güvence altına alınmıştır (İleri vd., 2016).

"Sağlık politikasının amacı ne olmalıdır?" sorusu, sağlık politikalarının oluşturulmasında siyasi aktörlerin dikkatle değerlendirmeleri gereken temel sorulardan biridir. Sağlık hizmetlerinin amacını sadece "her hastaya tedavi sağlamak" olarak tanımlamak yetersiz olacaktır; çünkü sağlıklı bireyleri hastalıklardan ve kazalardan korumak, tedavi etmek kadar önemlidir. Bu yüzden, sağlık hizmetlerinin amacını Dünya Sağlık Örgütü'nün ilkeleri doğrultusunda daha geniş bir perspektifle belirlemek daha uygun olacaktır.

Günümüzde sağlık politikalarının yanı sıra birçok alandaki politikaların hazırlanması, planlanması, uygulanması ve denetlenmesi devletler ve hükümetler tarafından yürütülmektedir. Ancak sağlık sektörü, karmaşık ve hassas bir yapı arz ettiği için, sağlık politikalarının devlet kontrolü olmadan geliştirilmesi mümkün değildir. Devletin sağlık hizmetlerinin üretiminde ve sonraki aşamalarda en büyük rolü oynamasının nedeni, sağlık hizmetlerinin olağanüstü karmaşıklığı ve hassasiyetidir (Işık, 2015).

1.5.Sağlık Politikalarının Toplumsal Önemi

Devletler, uyguladıkları politikalarla ekonomiye müdahale ederek, sosyal adalet, adil gelir dağılımı ve ekonomik faaliyetler aracılığıyla halkın refahını artırmayı hedefler. Bu hedefe ulaşabilmek için sağlık hizmetleri, eğitim, sosyal sigorta ve kaynakların adil dağılımı gibi unsurlar önemli araçlar arasında yer alır (Koçak, 2014).

Eğitim ve sosyal sigorta gibi sağlık hizmetleri de toplumdaki her bireyin ihtiyaç duyduğu, gerektiğinde ulaşabildiği ve kullanabildiği temel hizmetler arasında bulunmaktadır. Bireylerin temel sağlık hizmetlerine erişimindeki eksiklik, toplumu ciddi sorunlarla karşı karşıya bırakabilir. Özellikle koruyucu sağlık hizmetlerinin yetersizliği, tedavi maliyetleri yüksek ve ölüm riski taşıyan hastalıkların sayısını artırarak, toplumu ek bir yük altında bırakır (Tosun ve Aktan, 2010).

Bir ülkenin en değerli kaynağı olan insanlarının ekonomik faaliyetlere etkin bir şekilde katılabilmesi için öncelikle sağlık koşullarının iyileştirilmesi, ardından da eğitim seviyesinin artırılması gerekmektedir. Sağlık düzeyine ilişkin veriler, bir ülkenin gelişmişlik seviyesini de gösterir. Genel olarak sağlık hizmetlerinin amacı, toplumu olumsuz etkileyen hastalıkları önleyerek daha sağlıklı ve üretken bir toplum oluşturmaktır (Tosun ve Aktan, 2010).

2. SAĞLIKLI KAMU POLİTİKALARI

Sağlığın iyileştirilmesi, yalnızca sağlık hizmetleriyle sınırlı kalmayıp, tüm sektörlerde ve her düzeyde politika yapıcıların gündeminde sağlık konusunun yer almasını gerektirir. Bu yaklaşım, insanların kararlarının sağlık üzerindeki etkilerini fark etmelerini ve sağlıkları için sorumluluk üstlenmelerini sağlar. Bu sayede, sağlığın iyileştirilmesi için siyasi düzeyde koordinasyonun sağlanması önemli hale gelir (Ottawa, 2018).

Gelir, sosyal güvenlik, çalışma, eğitim, konut, istihdam, tarım, ulaşım, bilim ve teknoloji gibi pek çok alandaki politikalar, sağlık açısından dikkate alınmalı ve bu alanlarda sağlığa öncelik verilmelidir. Bu hedef doğrultusunda, mevzuat hazırlama, mali destek sağlama ve kamu alanında organizasyonel değişiklikler gibi stratejik politikaların geliştirilmesi gerekmektedir (Ottawa, 2018).

Ülkemizde, Sağlık Bakanlığı'nın belirlediği üç ana stratejik amaç şunlardır:

1. Bireyleri ve toplumu sağlık risklerinden korumak, sağlıklı yaşam tarzlarını teşvik etmek,
2. Bireylere ve topluma erişilebilir, uygun, etkili ve verimli sağlık hizmetleri sunmak,
3. İnsan merkezli ve bütüncül bir yaklaşımla, bireylerin sağlık ihtiyaçlarını ve beklentilerini karşılamak (Sağlık Bakanlığı, 2012).

2.1. TÜRKİYE'DE SAĞLIK POLİTİKALARI VE KAMPANYALARI

2.1.1. Tütün ve Sigarayla Mücadele Kampanyası

5727 sayılı Tütün Mamullerinin Zararlarının Önlenmesine Dair Kanun, 2008 yılında yürürlüğe girmiş olup, kapalı alanlarda sigara içmenin yasaklanmasını öngörmektedir. Bu düzenlemeyle birlikte kamuoyunu bilinçlendirmek ve farkındalık oluşturmak amacıyla "Dumansız Hava Sahası" ve "Havanı Koru" gibi sloganlarla ulusal çapta bir medya kampanyası başlatılmıştır (Şener & Samur, 2013).

Kampanya, geniş bir işbirliği yaklaşımıyla hayata geçirilmiş olup, Sağlık Bakanlığı, Tütün ve Alkol Piyasası Düzenleme Kurumu (TAPDK), Dünya Sağlık Örgütü (WHO), Tüberküloz ve Akciğer Hastalıklarına Karşı Uluslararası Birlik (UNION) ve Tütünsüz Çocuklar Kampanyası (CTFK) gibi organizasyonlar tarafından çeşitli afişler, broşürler ve kitapçıklar hazırlanmış, ayrıca bir web sitesi oluşturulmuştur.

Kampanya kapsamında, reklam filmleri, radyo reklamları, broşürler, afişler, gazete ilanları, sloganlar, logolar, billboardlar, posterler ve çıkartmalar gibi çeşitli materyaller tasarlanmıştır. Farklı sosyo-ekonomik gruplardan bireyler, rol modeller ve politikacılar kampanyanın sözcüleri olarak seçilmiş ve toplumun farklı kesimlerinden bu yasa ve kampanyaya destek verilmesi, medya aracılığıyla duyurulmuştur (Özvarış, 2012).

2.1.2. "Obezite Mücadele Hareketi" Kampanyası

Obezite, evrensel bir sağlık sorunu olarak kabul edilmekte olup, bu konuya dikkat çekmek amacıyla 2006 yılında İstanbul'da düzenlenen "Avrupa Obezite ile Mücadele Bakanlar Konferansı" sonucunda "Avrupa Obezite ile Mücadele Belgesi" imzalanmıştır. Aynı yıl, Sağlık Bakanlığı bünyesinde Obezite, Diyabet ve Metabolik Hastalıklar Daire Başkanlığı kurulmuştur.

27 Haziran 2012 tarihinde, "Beden Kitle İndeksi" ve "Hareket Et" başlıklı iki kamu spotu yayımlanmış, ayrıca "porsiyon küçültme" ve "günde 10.000 adım" gibi temalarla afişler hazırlanarak, ülke genelinde "Obezite ile Mücadele Hareketi" kampanyası başlatılmıştır. Bu

çalışmalar, Milli Eğitim Bakanlığı, Gıda, Tarım ve Hayvancılık Bakanlığı ve diğer kamu kurumlarıyla işbirliği içinde yürütülmektedir (Özvarış, 2012).

2.1.3. Okul Sütü Kampanyası

Gıda, Tarım ve Hayvancılık Bakanlığı, Milli Eğitim Bakanlığı, Sağlık Bakanlığı ve Ulusal Süt Konseyi tarafından ortaklaşa başlatılan "Okul Sütü Programı"nın amacı, ana sınıfları da dahil olmak üzere ilköğretim öğrencilerine süt içme alışkanlığını kazandırmak ve çocukların sağlıklı büyüme ile gelişimlerini desteklemektir.

Bu program kapsamında, 2012-2013 eğitim-öğretim yılının ikinci döneminde, Şubat-Haziran 2013 tarihleri arasında, anaokulu, ilkokul ve özel okullar dahil olmak üzere toplam 30.752 okula 60.000 ton süt (48 kutu) dağıtılmıştır (Şener ve Samur, 2013). Bu süreçte, 6.171.692 öğrenciye haftada üç gün (Pazartesi, Çarşamba ve Cuma) 200 ml yağlı (%3-3,5) ve sade, yüksek işlenmiş (uzun ömürlü) süt verilmiştir (Şener ve Samur, 2013).

2.1.4. Osteoporozdan Korunmak İçin... Sağlık İçin... Sağlıklı Süt İçin! Programı

2006 yılında 11 ilde başlatılan "Osteoporozu Önlemek İçin Sağlıklı Süt İçelim Programı", 2007 yılında osteoporozun da dahil edilmesiyle "Sağlık İçin Sağlıklı Süt İçelim" adı altında 40 ilde uygulanmaya başlanmıştır. Bu program, 2009 yılında tüm Türkiye genelinde 81 ilde hayata geçirilmiştir (Şener ve Samur, 2013).

2.1.5. Diyabeti Önlenme ve Kontrol Programı

Diyabet ve risk faktörleri konusunda toplumsal farkındalığın artırılması, sağlıklı yaşam alışkanlıklarının benimsenmesi, diyabetin erken teşhisi, güncel tedavi standartlarına uygun takip ve tedavi süreçlerinin sağlanması ve komplikasyonların önlenmesi hedeflenmektedir (Sağlık Bakanlığı, 2012).

2.1.6. "Engelli Çocukların Fiziksel Aktiviteye Teşviki" Projesi

2009 yılında, engelli ilköğretim çağındaki çocukları fiziksel aktiviteye teşvik etmek ve engellerine uygun spor dallarına yönlendirmek amacıyla, ilgili kurum ve kuruluşlarla işbirliği içinde "Engelli Çocukların Fiziksel Aktiviteye Teşvik Edilmesi Projesi" başlatılmıştır (Sağlık Bakanlığı, 2012).

2.1.7. Yenidoğana Temel Yaklaşımın Sağlanması Programı

-Yenidoğan Canlandırması Programı (NRP) (Sağlık Bakanlığı, 2012).

- Yenidoğan Temel Bakım Programı

-Bebek ve Çocuk İzlemleri Programı

Bebek ve çocuk izlem sürecinin kalitesini yükseltmek ve standartları belirlemek amacıyla "Bebek ve Çocuk İzlem Protokolleri" hazırlanmıştır (Sağlık Bakanlığı, 2012).

-Yenidoğan Yoğun Bakım Programı

Sağlık Bakanlığı, yenidoğan yoğun bakım ünitelerinin organizasyonunu iyileştirmek amacıyla yeni girişimler başlatmış ve bu doğrultuda çocuk doktorları ile yoğun bakım hemşirelerine eğitim verilmiştir (Sağlık Bakanlığı, 2012).

2.1.8. Yenidoğan Taramaları Programı

-Neonatal Tarama Programı (Fenilketonüri, Kongenital Hipotroidi, Biyotinidaz)

Sağlık Bakanlığı tarafından Türkiye genelinde uygulamaya konulan Yenidoğan Tarama Programı, tüm yenidoğan bebeklerin Konjenital Hipotiroidi ve Fenilketonüri açısından taranmasını amaçlamaktadır. Programın hedefleri arasında, zeka geriliği, beyin hasarı ve geri dönüşü olmayan zararların önlenmesi, bu hastalıkların toplum üzerindeki ekonomik etkilerinin azaltılması, akraba evliliklerine yönelik toplumsal farkındalığın artırılması ve tarama sonucu tanı alan bebeklerin zarar görmesinin engellenmesi bulunmaktadır (Sağlık Bakanlığı, 2012).

-İşitme

Bu programın amacı, "işitme kaybı ile doğan veya doğum sonrasında işitme kaybı gelişen çocukların, konuşma gelişimlerini olumsuz etkilemeden ve psikolojik ile sosyal açıdan sağlıklı bireyler olarak toplumda yer almalarını sağlamak" için işitme kayıplarının erken tespit edilmesidir. Ayrıca, sağlık personelinin ve toplumun bu konunun önemine dair bilinçlendirilmesi de hedeflenmektedir (Sağlık Bakanlığı, 2012).

2.1.9. Ana ve Çocuk Beslenmesi Programı

-Anne Sütünün Özendirilmesi, Sürdürülmesi, Desteklenmesi ve Bebek Dostu Sağlık Kuruluşları Programı

Türkiye'de emzirmenin teşviki, "Anne Sütünün Teşviki ve Bebek Dostu Sağlık Kuruluşları Programı" çerçevesinde yürütülmektedir. Bu programın hedefi, doğum yapılan tüm hastanelere ulaşarak annelere, eğitimli sağlık personeli desteğiyle bebeklerini erken dönemde emzirmeye başlamaları konusunda yardımcı olmak ve emzirme sürecini sürdürmeleri için destek sağlamaktır (Sağlık Bakanlığı, 2012).

-Emzirmenin Korunması, Özendirilmesi, Desteklenmesi ile Demir Yetersizliği Anemisinin Önlenmesi ve Kontrolü Programı "Demir Gibi Türkiye"

Nisan 2004'te başlatılan bu proje ile amaçlanan, toplumda demir eksikliği konusunda farkındalık yaratmak, bebeklerin ilk altı ay boyunca yalnızca anne sütü almalarını sağlamak ve altıncı ayın sonunda uygun miktarda ek gıdaya geçiş yaparak emzirme sürecini iki yaşına kadar sürdürmektir. Ayrıca, 4-12 ay arasındaki her bebeğe koruyucu amaçlı ücretsiz demir takviyesi verilmesi, 13-24 ay arasındaki anemisi olan bebeklere ise demir tedavisi önerilmesi planlanmıştır (SGGM, 2018).

-Bebeklerde D Vitamini Yetersizliğinin Önlenmesi ve Kemik Sağlığının Geliştirilmesi Programı

Subklinik D vitamini eksikliği, Türkiye'de yaygın bir sağlık sorunu olup, özellikle bebek ve çocukların sağlığını olumsuz yönde etkilemektedir. Bu sorunu çözmek amacıyla, Mayıs 2005'te "Bebeklerde D Vitamini Eksikliğinin Önlenmesi ve Kemik Sağlığının Korunması Projesi" başlatılmış ve sağlık hizmetleri kapsamında ücretsiz D vitamini desteği sağlanmıştır (SGGM, 2018).

-İyot Yetersizliğinin Önlenmesi ve Tuzun İyotlanması Programı

1994 yılından bu yana uygulanan "İyot Yetersizliği Hastalıklarının Önlenmesi ve Tuzun İyotlanması Programı" kapsamında, iyot eksikliğinin en ciddi etkilerinin özellikle doğurganlık çağındaki kadınlar, gebeler, bebekler ve çocuklar gibi hassas gruplarda görüldüğü vurgulanmaktadır (SGGM, 2018).

-"Tamamlayıcı Beslenme"

Program, beş yaş altı çocuklarda akut ve kronik malnütrisyonun önlenmesini hedeflemektedir. Bu doğrultuda, eğitimli sağlık personeli tarafından birinci basamakta annelere kişiselleştirilmiş beslenme danışmanlığı sunulması ve sağlıklı beslenme alışkanlıklarının çocukların erken yaşlardan itibaren yaşamlarına entegre edilmesi amaçlanmaktadır (SGGM, 2018).

2.1.10. Çocuk Enfeksiyonlarını Önleme Programı

-İshalli Hastalıkların Kontrolü Programı

Sağlık Bakanlığı, çocuk ölümlerinin önde gelen nedenlerinden biri olan ishalin önlenmesi amacıyla 1986 yılından bu yana **İshalli Hastalıklar Kontrol Programı**'nı uygulamaktadır. Bu program, sağlık personelinin eğitimine, halkın ishalden korunma ve ishalde oral sıvı tedavisi konusunda eğitilmesine büyük önem verir. Ayrıca, sektörel işbirliği teşvik edilerek, ishalli hastalıkların kontrolüne yönelik multidisipliner bir yaklaşım benimsenir. Dünya Sağlık Örgütü (DSÖ) ve Birleşmiş Milletler Çocuklara Yardım Fonu (UNICEF), ishalli hastalıkların kontrolü için toplumun sağlıklı suya ve hijyenik koşullara erişiminin iyileştirilmesine de vurgu yapmaktadır (Sağlık Bakanlığı, 2012).

Bu tür programlar, hem bireylerin sağlığını koruma hem de toplumda sağlık okuryazarlığını artırma adına önemli adımlar atılmasına olanak tanımaktadır.

-Alt Solunum Yolu Enfeksiyonlarının Kontrolü Programı "ASYE"

Türkiye'de bakteriyel kaynaklı zatürre, özellikle çocuklarda sıkça görülen sağlık sorunlarından biridir. Bu durum, genellikle ailelerin öksürükle başlayan basit gribal enfeksiyonlar için evde uygulayacakları tedavi yöntemlerini bilmemeleri ve buna bağlı olarak enfeksiyonların ilerlemesine yol açmaktadır. Yetersiz beslenme ve kötü çevre koşulları da bu süreçte önemli bir rol oynar; basit enfeksiyonlar, bu koşullar nedeniyle kolayca zatürreye dönüşebilir. Ayrıca, aileler zatürre belirtilerini tanımadıkları için, çocuklarını sağlık kuruluşlarına götürmeyi genellikle geciktirmektedir. Ancak, komplikasyonlar, özellikle kalp

yetmezliği gibi ciddi durumlar geliştiğinde başvurular yapılmaktadır. Bu durumu önlemek ve çocuk ölümlerini azaltmak amacıyla **Akut Solunum Yolu Enfeksiyonları (ISY)**'na yönelik bir program 1988 yılından itibaren uygulanmaktadır. Bu program, özellikle bebek ve çocuk ölümlerinin önde gelen nedenlerinden biri olan bu enfeksiyonların önlenmesi ve tedavi edilmesine odaklanmaktadır. Program kapsamında, ailelerin enfeksiyon belirtilerini tanıması, zamanında tıbbi yardım alması ve uygun tedavi yöntemlerini öğrenmesi sağlanarak, hastalıkların erken aşamalarda tedavi edilmesi hedeflenmektedir (Özvarış, 2012).

Bu tür sağlık programları, aileleri bilgilendirme, erken tanı ve tedavi, aynı zamanda toplumda sağlık okuryazarlığını artırma açısından büyük önem taşır.

-Çocuklarda Ayaktan Sık Görülen Enfeksiyonlarda Akılcı Antibiyotik Kullanımı Mezuniyet Sonrası Eğitim Kursu

Çocukluk çağında sık görülen enfeksiyonların tedavisini geliştirmek ve gerektiğinde ilaç kullanımını desteklemek amacıyla Çocuk Enfeksiyon Hastalıkları Derneği ile işbirliği içinde çocuk doktorlarına yönelik teorik eğitimler verilmektedir (Özvarış, 2012).

2.1.11. Bebek Ölümlerini İzleme Programı

Bebek Ölümleri Kayıt-Bildirim Formu, çocuk sağlığı alanında önemli bir izleme ve değerlendirme aracıdır. 2005 yılında raporlanmaya başlanmış olan bu form, bebek ölümlerinin azaltılması amacıyla her ölümün detaylı şekilde incelenmesini sağlayarak, aynı nedenlerle meydana gelebilecek yeni bebek ölümlerinin önlenmesine katkı sunmayı hedeflemiştir. Bebek ölümlerinin sistematik olarak izlenmesi ve analiz edilmesi, sağlık politikalarının geliştirilmesinde kritik bir rol oynamaktadır. Bu tür çalışmalar, hem rutin hizmetlerin etkinliğini izlemek hem de özel sağlık programlarının başarısını değerlendirmek için kaynak teşkil etmektedir (Sağlık Bakanlığı, 2012).

2009 yılında, bebek ölümlerini tespit etmek, nedenlerini araştırmak ve alınacak önlemleri planlamak amacıyla yeni bir **Bebek Ölümleri Kayıt Sistemi** hayata geçirilmiştir. Bu sistem, bebek ölümlerinin tespiti, ölüm nedenlerinin araştırılması ve sonuçların analizi ve ilanı aşamalarından oluşmaktadır. Her bir ölüm vakası detaylı şekilde incelenip aylık olarak raporlanmaktadır. Böylece, belirli ölümlerin sebepleri tespit edilerek, sağlık hizmetlerinin kalitesini artırmak ve bebek ölümlerini azaltmak amacıyla hedef odaklı stratejiler geliştirilmesi sağlanmaktadır.

Ayrıca, **Bebek Ölümleri İnceleme Kurulları**, illerde kurulmuş olup, ölümlerle ilgili ayrıntılı incelemeler yapmaktadır. Bu kurullar, bebek ölümlerinin nedenlerini belirleyerek, aynı sebeplerin gelecekteki ölümler üzerinde etkili bir şekilde önlenmesi için gerekli sağlık önlemlerinin alınmasını sağlamaktadır (Sağlık Bakanlığı, 2012).

Bu tür sistematik izleme ve analiz mekanizmaları, bebek ölümlerinin önlenmesi ve çocuk sağlığının iyileştirilmesi adına kritik önem taşımaktadır.

2.1.12. Evlilik ve Gebelik Öncesi Danışmanlık Programı

Program, önlenebilir nedenlerden kaynaklanan anne ölümlerinin boyutunu azaltmayı amaçlamaktadır. Anne ölüm riski yaşla birlikte artmaktadır. Türkiye'de her beş evlilikten biri akraba evliliğidir. Akraba evliliklerinin çoğu (%70) birinci derece akrabalar arasında gerçekleşmektedir. Akraba evlilikleri nadir görülen otozomal kalıtımlı hastalıkların görülme sıklığını artırmaktadır (Sağlık Bakanlığı, 2012).

2.1.13. Gebelikte Demir Destek Program

Türkiye'de kadınlarda demir eksikliği daha çok gebelik döneminde görülmektedir. Gebelikte artan demir ihtiyacını karşılamak için her gebeye gebeliğin 16. haftasından itibaren 5 ay süreyle ve doğumdan sonra 3 ay süreyle 40-60 mg/gün demir takviyesi yapılmaktadır (Sağlık Bakanlığı, 2012).

2.1.14. Gebelere D-vit Destek Programı

Gebelik ve emzirme dönemindeki annelere yönelik D vitamini destek programı Mayıs 2011'de başlatılmıştır. Programda gebeliğin 12. haftasından itibaren 12 ay, gebelik süresince 6 ay ve doğumdan sonra 6 ay süreyle D vitamini desteği verilmektedir (Sağlık Bakanlığı, 2012).

2.1.15. Anne Dostu Hastane Programı

Program, kaliteli gebelik ve doğum takibi sağlayarak ve tüm doğumların hastanede güvenli koşullar altında gerçekleşmesini sağlayarak anne ve bebek ölümlerini azaltmayı amaçlamaktadır. Yeni bir hareket olan Annelik Hizmetlerini İyileştirme Koalisyonu (CIMS) 1996 yılında kurulmuştur. Bu koalisyon, anne dostu doğum merkezleri için “10 adımda anne dostu bakım rehberi” geliştirmiştir. Kanıta dayalı tıp bilgisine dayanan bu rehber 2007 yılında revize edilerek bugünkü halini almıştır. Doğumda Anne Dostu uygulamaları takip eden ve rutin uygulamaları yerine getiren kurumlara, hastanelere ve doğum merkezlerine Anne Dostu Hastane unvanı verilmesini başlatmıştır (Sağlık Bakanlığı, 2012).

2.1.16. Üreme Sağlığı Programları

-15- 49 Yaş Kadın İzlemleri

15-49 yaş arasındaki kadınlar, doğurganlık davranışlarını incelemek, riskli durumları belirlemek, gebelikleri erken tespit etmek, aile planlaması yöntemlerini kullanmak, kadın sağlığı ve aile planlaması konularında danışmanlık sağlamak ve yerinde eğitim vermek amacıyla, birinci basamak sağlık hizmetleri tarafından yılda en az iki kez izlenmektedir. Bu izleme süreçlerinin sonuçları ise yılda iki kez AÇSAP Şube Müdürlüğü’ne raporlanmaktadır (Sağlık Bakanlığı, 2012).

-Doğum Öncesi Bakım Hizmetleri

Anne sağlığını iyileştirmek ve anne ölümlerini azaltmak için rutin hizmetler arasındadır ve ülke genelinde uygulanmaktadır (Sağlık Bakanlığı, 2012).

- Doğum-Sezaryen Programı

Her kadının sağlıklı ve güvenli bir hastane doğumu gerçekleştirmesi, sezaryen oranlarının makul seviyelere çekilmesi ve bölgesel, yerleşim yeri, yaş gibi eşitsizliklerin ortadan kaldırılması hedeflenmektedir. Ayrıca, doğum sonrası anne ve yenidoğanın herhangi bir sağlık riski bulunmadığı takdirde, en az 24 saat hastanede kalması gerekmektedir (Sağlık Bakanlığı, 2012).

-Doğum Sonu Bakım Programı

Doğum sonrası dönemde önlenebilir nedenlere (kanama, eklampsi-pre-eklampsi ve enfeksiyon) bağlı anne ve bebek ölümlerini önlemek amacıyla geliştirilmiş bir programdır (Sağlık Bakanlığı, 2012).

-Anne Ölümleri İzleme Programı

Her anne ölümünün nedenleri, üç gecikme modeli ve ICD-10 sınıflaması çerçevesinde incelenmekte ve önlenebilir nedenler belirlenerek bu ölümlerin önüne geçmek amacıyla çalışmalar yapılmaktadır (Sağlık Bakanlığı, 2012).

-Üreme Sağlığı Hizmet İçi Eğitimleri

Üreme sağlığı hizmetlerinin kalitesinin iyileştirilmesi amacıyla, sağlık personeline sağlık alanındaki yenilikler ve gelişmeler konusunda gerekli bilgi ve becerilerin kazandırılmasına yönelik çalışmalar yürütülmektedir (Sağlık Bakanlığı, 2012).

3. SAĞLIKLI KAMU POLİTİKALARINA YÖNELİK EBELİK GİRİŞİMLERİ

Ebeler toplum sağlığını iyileştirmek ve yaşam beklentisini artırmak için son derece kapsamlı ve bütüncül bir yaklaşım sunmaktadır. Her bir adım, toplumsal düzeyde sağlığı iyileştirmek için gerekli olan stratejik müdahalelere odaklanmaktadır. Her birini detaylı şekilde ele alalım:

1. Toplum Eğitimi

Toplum sağlığını iyileştirmek için sağlıklı yaşam alışkanlıkları konusunda toplumun bilinçlendirilmesi kritik bir adımdır. Sağlığa zarar veren yanlış inançlar ve alışkanlıklar, toplumda sağlık sorunlarına yol açabilir. Bu sebeple, sağlıklı yaşam tarzlarının teşvik edilmesi ve sağlığa zarar veren inançların ortadan kaldırılması için eğitim ve farkındalık çalışmaları yapılmalıdır. Örneğin, doğru beslenme, düzenli egzersiz, tütün ve alkolün zararları, hijyen kuralları gibi konularda bilgilendirme kampanyaları düzenlenebilir.

2. Risk Değerlendirmesi

Sağlık risklerinin doğru bir şekilde belirlenmesi ve riskli grupların tanımlanması, sağlık hizmetlerinin etkin bir şekilde sunulabilmesi için önemlidir. Risk değerlendirmesi yaparak, örneğin kalp hastalıkları, diyabet, obezite veya mental sağlık sorunları gibi kronik hastalıkların yaygın olduğu gruplar için özel sağlık önlemleri alınabilir. Riskli gruplara yönelik farkındalık yaratacak eğitimler, sağlık taramaları ve önleyici tedbirler uygulanmalıdır.

3. Sosyo-ekonomik Farklılıkların Azaltılması

Sosyo-ekonomik farklılıklar, bireylerin sağlık durumlarını doğrudan etkileyebilir. Gelir düzeyi düşük olan bireylerin sağlık hizmetlerine erişim konusunda zorluklar yaşaması, sağlıklı yaşam koşullarına sahip olmamaları gibi faktörler, hastalık ve sakatlık riskini artırabilir. Bu nedenle, toplumun çeşitli gelir seviyelerindeki bireylerine yönelik sağlık hizmetlerinin erişilebilirliğini artırmak için sivil toplum kuruluşları ve kamu kurumlarıyla işbirliği yapılmalıdır. Sosyo-ekonomik eşitsizlikleri azaltarak, herkes için eşit sağlık fırsatları sağlanabilir.

4. Yenidoğan ve Çocuk Sağlığı

Yenidoğanların ve bebeklerin sağlıklı bir başlangıç yapabilmesi, toplumsal sağlık açısından büyük önem taşır. Aile Hekimliği (AÇS) hizmetlerine erişimdeki engellerin ortadan kaldırılması ve 5 yaş altı çocuklar için sağlık hizmetlerinin iyileştirilmesi gereklidir. Ayrıca, bu yaş grubu için kazalar ve şiddet gibi mortalite ve sakatlık risklerini azaltmaya yönelik ebeveyn eğitimleri ve farkındalık kampanyaları düzenlenmelidir. Çocukların fiziksel, duygusal ve psikolojik gelişimi açısından koruyucu sağlık önlemleri hayati önem taşır.

5. Gençlerin Desteklenmesi

Gençlerin sağlıklı alışkanlıklar edinmeleri ve zararlı alışkanlıklardan (alkol, tütün, uyuşturucu vb.) kaçınmaları, toplum sağlığını artıran önemli bir adımdır. Erken yaşta gebelik riski taşıyan gençler için eğitim ve danışmanlık hizmetleri sunulmalıdır. Ayrıca, öfke, şiddet ve stres yönetimi gibi konularla ilgili psikolojik destekler sağlanarak, sağlıklı yaşam becerilerinin kazandırılması hedeflenmelidir. Gençlerin sağlıklı seçimler yapabilmesi için okullarda ve toplum merkezlerinde sağlıklı yaşam becerilerini geliştirecek programlar oluşturulabilir.

6. Sağlıklı Yaşlanma Programları

Yaşlılık dönemi, özellikle kronik hastalıkların arttığı ve bireylerin bağımsızlıklarını kaybetmeye başladığı bir dönemi ifade eder. Bu dönemde sağlıklı yaşlanmayı teşvik eden programlar, yaşlı bireylerin daha kaliteli ve bağımsız bir yaşam sürmelerine katkı sağlar. Aile içindeki desteklerin güçlendirilmesi, yaşlıların toplumda daha aktif rol alabilmesi için sosyal katılım imkanlarının artırılması gerekmektedir. Ayrıca, yaşlılara yönelik sağlık ve bakım hizmetlerinin erişilebilirliğinin sağlanması önemlidir.

7. Politika ve Uygulamalar

Sağlık politikalarının, özellikle sağlık profesyonelleri (örneğin ebeler) üzerindeki etkisi göz önünde bulundurulmalıdır. Ebelerin, doğum öncesi ve sonrası bakımda etkin rol oynamaları sağlanmalı ve onların mesleki güçlerinin artırılması için gerekli politika düzenlemeleri yapılmalıdır. Aynı zamanda, sağlık hizmetlerinin kalitesinin artırılması için politikaların güçlendirilmesi gereklidir. Bu, sağlık çalışanlarının daha kaliteli hizmet sunabilmeleri için eğitim ve donanım desteği almasını sağlar.

Genel Değerlendirme:

Toplum sağlığını iyileştirme yolunda bu adımlar, sağlık hizmetlerinin sadece tedavi değil, aynı zamanda **öngörücü ve koruyucu** bir yaklaşımla sunulmasını sağlar. Her bireyin sağlıklı bir yaşam sürdürebilmesi için çeşitli toplumsal gruplara yönelik stratejiler geliştirilmesi, sağlık eşitsizliklerinin ortadan kaldırılması ve sağlık hizmetlerine erişimin artırılması kritik önemdedir. Ayrıca, sağlık politikalarının daha güçlü hale getirilmesi, uygulamalarla desteklenmesi ve tüm toplumun bu doğrultuda eğitilmesi, sağlık hedeflerine ulaşmada önemli bir etken olacaktır.

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SAĞLIKTA EŞİTSİZLİKLER VE EBELİK YAKLAŞIMLARI

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ÖZET

Sağlık eşitsizlikleri küresel bir halk sağlığı sorunudur. Sağlıkta eşitsizlik; temelde gelir, sosyal sınıf, etnik köken, coğrafi koşullar, yoksunluk gibi değişkenlerden oluşan sosyal belirleyicilerden ve bireyin işinin olup olmaması, bekâr bir ebeveyn olup olmaması, sosyal entegrasyon, meslek, gelir düzeyi gibi belirleyicilerden etkilenen bir kavramdır. Sağlık eşitsizliklerinin ana nedeni kapitalizm ve sınıflı toplum yapısıdır. Sağlıkta eşitsizlikler, toplumda çoğunlukla dezavantajlı gruplar olarak ifade edilen kesimleri daha çok etkilemektedir. Bu kesimler kadınlar/çocuklar, göçmenler, işsizler, evsizler, azınlıklar ve mahkumlar olarak sınıflandırılabilir. Dünyada özellikle gelişmekte olan ülkelerde bebek ve çocuk ölümlerinin nedenleri önlenebilir sorunlardır. Bu sorunlardan kaynaklanan eşitsizlikleri azaltmak için ebeler çalıştıkları bölgelerde en uç kırsal yerleşim alanlarına ulaşarak hizmet vermektedirler. Hizmet ettiği bölgedeki yoksulları belirlemeli, yoksulların sağlık hizmetine ulaşmasını ve eldeki kaynakları uygun kullanmasını sağlamada rehberlik ve danışmanlık hizmeti vermeli, yoksul annelere/kadınlara ev ziyaretleri yaparak anne sağlığı, doğum öncesi ve erken çocukluk evrelerinde sağlık ve refahı arttırmak üzere çalışmalı, sağlık eğitimleri planlamalıdır. Böylece kırsal alanda yaşayan ailelere sağlık hizmetlerinin ulaştırılması sağlanarak sağlıkta eşitsizliklerin azaltılması sağlanmış olacaktır.

Anahtar Kelimeler: Sağlık Eşitsizlikler, Ebelik, Kadın.

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INEQUALITIES IN HEALTH AND MIDWIFERY APPROACHES

ABSTRACT

Health inequalities are a global public health problem. Health inequalities are influenced by social determinants such as income, social class, ethnicity, geographical conditions, deprivation and other determinants such as whether an individual has a job, is a single parent, social integration, occupation and income level. The main cause of health inequalities is capitalism and the class structure of society. Inequalities in health affect segments of society that are often referred to as disadvantaged groups. These groups can be categorized as women/children, migrants, unemployed, homeless, minorities and prisoners. The causes of infant and child mortality in the world, especially in developing countries, are preventable problems. In order to reduce inequalities arising from these problems, midwives provide services by reaching the most extreme rural settlements in the regions where they work. They should identify the poor in the region they serve, provide guidance and counseling services to ensure that the poor access health services and use the available resources appropriately, work to increase health and welfare in maternal health, prenatal and early childhood stages by making home visits to poor mothers/women, and plan health trainings. In this way, health services will be provided to families living in rural areas and inequalities in health will be reduced.

Keywords: Health Inequalities, Midwifery, Women.

1. TEMEL KAVRAMLAR

Sağlık alanındaki eşitsizlikler, Dünya Sağlık Örgütü (DSÖ) tarafından "farklı toplumsal gruplar arasında sağlık belirleyicilerinin ya da sağlık durumunun farklı dağılımı" olarak tanımlanmaktadır (Masseria, 2009). Bir diğer ifadeyle, daha düşük yaşam beklentisine sahip, fakir ve/veya sosyal olarak dezavantajlı gruplar arasında, belirli hastalıklar ya da engellilik durumlarıyla ilgili sağlık sonuçlarında sistematik ve önlenebilir farklılıklar gözlemlenir (Masseria, 2009). Whitehead, sağlık eşitsizliklerini, sosyoekonomik faktörlerden kaynaklanan ve ortadan kaldırılması mümkün olan sağlık düzeyi ile sağlık hizmetlerinden yararlanmadaki farklar olarak tanımlamıştır (Whitehead, 2007). Bir başka tanım ise, "sağlık eşitsizlikleri, daha yüksek ve daha düşük sosyoekonomik düzeylere sahip bireyler arasındaki sağlık sorunlarının prevalansı ve insidansı arasındaki farklar" olarak yapılmaktadır (Hill ve Dixon, 2005).

Sağlıkta eşitsizlikler, ilk kez 1978 yılında Alma-Ata Deklarasyonu'nda uluslararası düzeyde gündeme getirilmiştir (Crombie ve ark., 2005). Deklarasyonda, dünya genelinde yüz milyonlarca insanın sağlık koşullarının kabul edilemeyecek derecede kötü olduğu ifade edilerek, sağlığı iyileştirmek için yeni bir yaklaşımın benimsenmesi gerektiği vurgulanmıştır. Bu yeni yaklaşımda, zengin ve yoksul arasındaki farkların azaltılması, sağlık hizmetlerinin daha adil bir biçimde dağıtılması ve her bireyin toplumsal ve ekonomik açıdan üretken bir yaşam sürebileceği bir sağlık seviyesine ulaşması hedeflenmiştir (Aba, 2014).

1980 yılında İngiltere'de Douglas Black'in liderliğindeki bir araştırmacı grubu tarafından hazırlanan raporda, sağlık hizmetlerinin yanı sıra sosyoekonomik faktörlerin de sağlık durumu

ve sosyal sınıflar arasındaki gradyan farklılıklarını etkilediği vurgulanmıştır (Aba, 2014). Bu bağlamda, 1998'de Donald Acheson tarafından yayımlanan raporda ise biyolojik, ekonomik, çevresel, kültürel ve davranışsal faktörlerin, sağlık eşitsizliklerinin ortaya çıkmasında ve azaltılmasında önemli bir rol oynadığı belirtilmiştir (Lloyd ve ark., 2004).

Dünya Sağlık Örgütü'nün *21. Yüzyılda Herkes İçin Sağlık* başlıklı bildirgesinde, 2000 yılına kadar ülkeler arasındaki sosyoekonomik gruplar arasındaki sağlık farklılıklarının, dezavantajlı grupların sağlık düzeyleri iyileştirilerek %25 oranında azaltılması gerektiği belirtilmiştir (World Health Report, 1998). DSÖ'nün Sağlığın Sosyal Belirleyicileri Komisyonu, 2008 yılında yayımladığı raporda, ülkeler arası ve içindeki bölgeler arasındaki sağlık eşitsizliklerini azaltmayı en önemli hedef olarak ifade etmiştir (Lloyd ve ark., 2004).

2011'de Rio Deklarasyonu'nda DSÖ, ülkeler içindeki ve ülkeler arasındaki sağlık eşitsizliklerinin politik, sosyal ve ekonomik açıdan kabul edilemez olduğunu vurgulamış ve bu eşitsizliklerin büyük ölçüde önlenebilir ve adaletsiz olduğuna dikkat çekmiştir. Sağlıkta eşitliğin artırılması, sürdürülebilir kalkınma, daha yüksek yaşam kalitesi ve evrensel sağlık açısından kritik bir öneme sahiptir ve barış ile güvenliğe de katkı sağlamaktadır (WHO, 2011; WHO, 2012).

Belek'e göre, sağlıkta eşitsizlik kavramı üç kuramdan oluşmaktadır (Tekingündüz ve ark, 2016).

Geleneksel, epidemiyolojik ve sosyo-politik modeller, sağlık eşitsizliklerini anlamak ve ele almak için farklı bakış açıları sunar:

a) Geleneksel Tıbbi Model

Bu model, hekim-hasta ilişkisine odaklanır ve iyi bir tıbbi bakımın sağlığın gelişmesine katkı sağladığını savunur. Sağlıktaki eşitsizlikler, tıbbi bakım hizmetlerinin eşitsiz kullanımından kaynaklanır. Yani, bireylerin sağlık hizmetlerine erişiminde yaşanan farklılıklar, sağlık sonuçlarını etkileyen önemli bir faktördür. Bu modelde, sağlık hizmetlerinin kalitesi ve hekimlerin hastalarla olan ilişkileri ön plandadır.

b) Epidemiyolojik Model

Epidemiyolojik model, sağlığa toplumsal bir perspektiften bakar. Bu model, bölgeler arasındaki sağlık düzeyi farklılıklarını sosyal farklılıkların bir yansıması olarak değerlendirir. Sağlıkta eşitsizliklerin azaltılması için risk altındaki gruplara yönelik özel tıbbi programlar geliştirilmesi önerilir. Ayrıca, sağlığa ayrılan kaynakların, toplumsal ihtiyaçlar ve gereksinimler doğrultusunda yeniden dağıtılması gerektiğini savunur.

c) Sosyo-Politik Model

Sosyo-politik model, sağlıkta eşitsizliklerin toplum yapısı ve içindeki güç ilişkileri tarafından belirlendiğini vurgular. Bu model, eşitsizliklerin ortadan kaldırılması için refah politikalarının geliştirilmesi ve yaşam standartlarının yükseltilmesi gibi sosyal değişikliklere ihtiyaç duyulduğunu savunur. Yani, sağlık sadece bireysel bir mesele değil, aynı zamanda sosyal ve politik bir sorundur.

Bu üç model, sağlık eşitsizliklerinin anlaşılmasında ve bu eşitsizliklerin azaltılması için atılacak adımlarda önemli bir çerçeve sunar.

1.1.Sağlığı Etkileyen Sosyal Belirleyiciler ve Sağlıkta Eşitsizliğe Etkiler

Sağlıkta eşitsizlikler, bireylerin sağlık durumunu etkileyen çok çeşitli sosyal belirleyicilerden kaynaklanmaktadır. McCartney ve arkadaşlarının (2013) vurguladığı gibi, bu belirleyiciler arasında gelir, sosyal sınıf, etnik köken, coğrafi koşullar ve yoksunluk gibi faktörler önemli bir rol oynar. Ayrıca bireylerin iş durumu, aile yapısı (örneğin bekâr ebeveyn olma durumu), sosyal entegrasyon ve gelir düzeyi de sağlık eşitsizliklerini şekillendiren diğer unsurlardır.

Dahlgren ve Whitehead'in Gökkuşağı Modeli (Rainbow Model), bu sosyal belirleyicileri daha iyi anlamamıza yardımcı olur. Modelde, bireyin merkezde yer aldığı ve etrafında farklı katmanlar olduğu görülmektedir:

1. **Bireysel Özellikler**: Yaş, cinsiyet gibi demografik faktörler.
2. **Kişisel Alışkanlıklar**: Sigara içmek, beslenme alışkanlıkları gibi bireysel davranışlar.
3. **Sosyal ve Toplumsal Etkiler**: Aile, arkadaş çevresi ve sosyal destek sistemleri.
4. **Yapısal Faktörler**: Çalışma koşulları, sağlık hizmetlerine erişim gibi daha geniş sosyal ve ekonomik koşullar.

Bu model, sağlık eşitsizliklerinin sadece bireysel seçimler ve davranışlarla değil, aynı zamanda sosyal ve yapısal faktörlerle de belirlendiğini vurgular. Böylece, sağlık politikalarının bu karmaşık ilişkileri göz önünde bulundurarak tasarlanması gerekmektedir.

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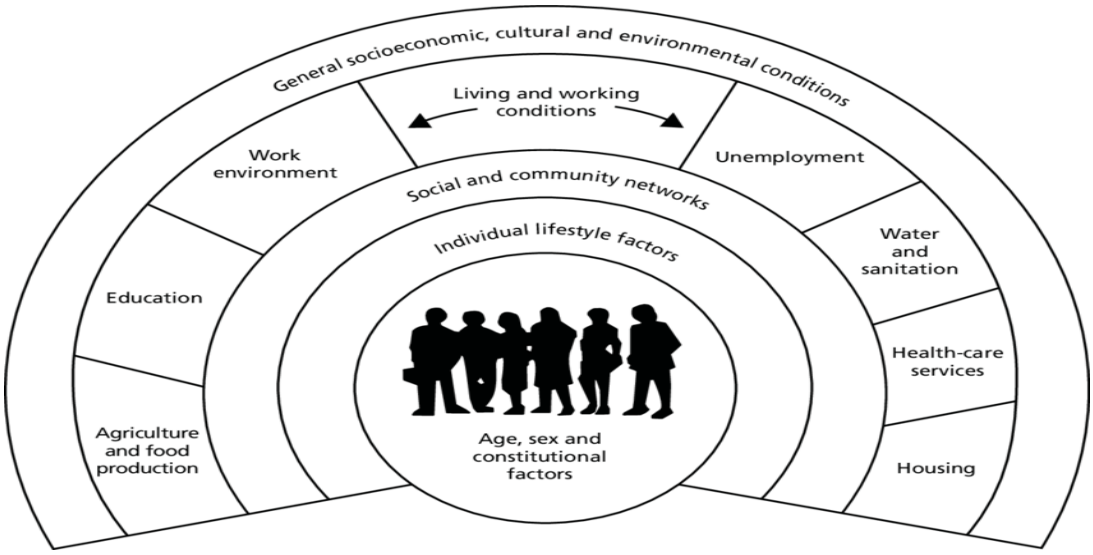


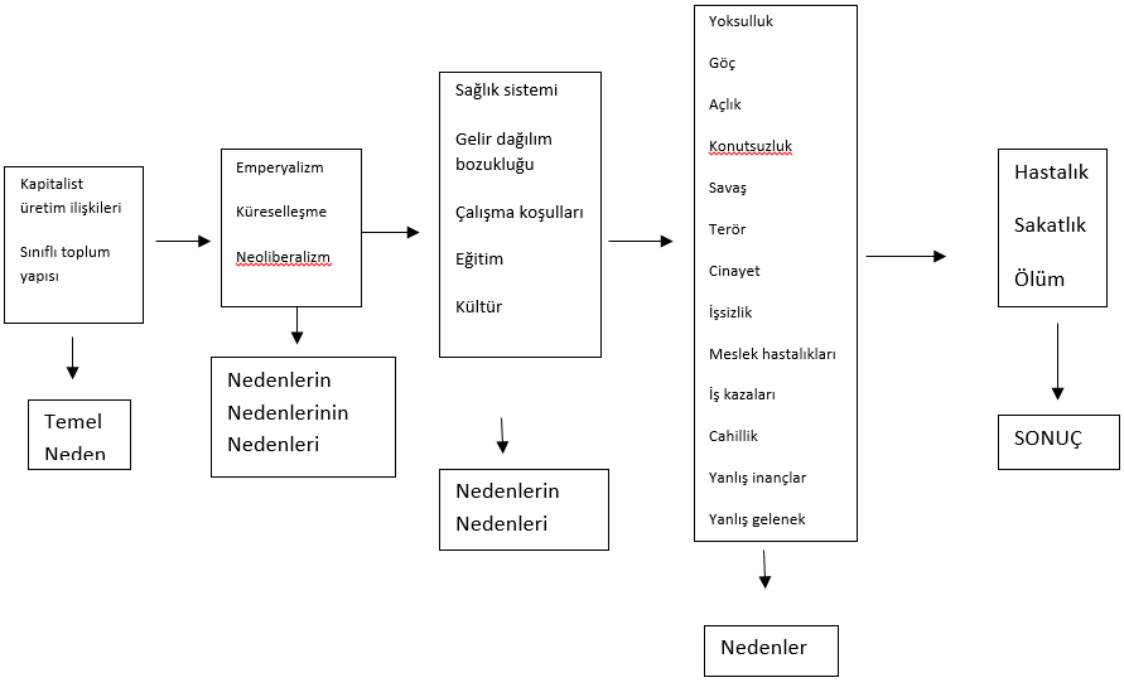
Görsel 1. Gökkuşağı Modeli (Tekingündüz ve ark, 2016).

1.2.Sağlıkta Eşitsizliklerin Temel Nedenleri

DSÖ'nün tanımına göre sağlık eşitsizlikleri, "gereksiz ve kaçınılabilir" olmanın yanı sıra "haksız ve adaletli olmayan" farklılıklar olarak kabul edilir. Bu noktada, sağlık istatistiklerine dayanan farklılıkların hepsinin sağlık eşitsizliği olarak değerlendirilmemesi önemlidir. Whitehead (2007), her farklılığın eşitsizlik olmadığını belirtir.

Eşitsizlikler, haksızlık ve adaletsizlik içeren, önlenebilir farklılıklardır. Doğal veya biyolojik nedenlerden kaynaklanan farklılıklar, ya da bireylerin kendi tercihleriyle yapılan seçimler eşitsizlik olarak sayılmaz. Örneğin, yaşlı bir erkeğin genç bir erkeğe göre kalp hastalığına yakalanma riskinin yüksek olması, biyolojik bir farklılıktır ve bu bir eşitsizlik değildir. Ancak, benzer yaş grubundaki yoksul bir erkeğin zengin bir erkeğe göre daha fazla hastalığa yakalanma oranı, sağlıkta eşitsizliktir çünkü bu durum önlenebilir.

Aynı şekilde, biyolojik nedenlerle kadınların bazı hastalıklara erkeklerden daha yatkın olması bir eşitsizlik olarak değerlendirilmez. Fakat cinsiyete dayalı ayrımcılık, örneğin erkek çocuklara kıyasla kız çocuklarına daha az sağlık hizmeti sunmak ya da kadınların sosyal statüsünü düşürerek sağlıklı beslenme koşullarını olumsuz etkilemek, kesinlikle bir eşitsizliktir (Şimşek ve Kılıç, 2012). Bu tür örnekler, sağlık politikalarının eşitsizlikleri önleyecek şekilde tasarlanmasının gerekliliğini vurgulamaktadır.



Görsel 2. Sağlıkta eşitsizliğin nedenleri ve temel neden(Aba, 2014).

2. Sağlıkta Eşitsizlikler ve Dezavantajlı Gruplar

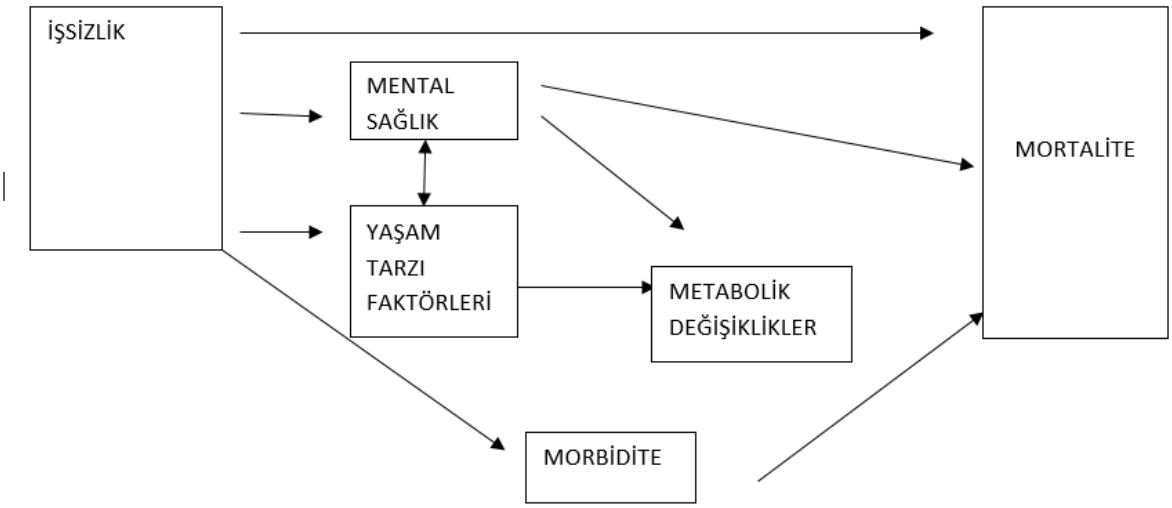
Sağlıkta eşitsizlikler, özellikle dezavantajlı grupları daha fazla etkilemektedir. Bu gruplar, sosyoekonomik durumu düşük, etnik kökeni farklı veya coğrafi olarak izole bölgelerde yaşayan bireyler olabilir. Ülkelerin gelişmişlik düzeyine bakılmaksızın, bazı kesimlerin sağlık hizmetlerine erişimi diğerlerine göre daha sınırlıdır.

Bu durum, sağlık hizmetlerinin sunumunda sistematik farklılıkların olduğunu gösterir ve bu eşitsizliklerin azaltılması, toplumsal sağlığın iyileştirilmesi açısından büyük önem taşır. Sağlık politikalarının bu dezavantajlı gruplara odaklanarak, onlara özel hizmetler ve destek sunması, sağlıkta eşitliğin sağlanmasında kritik bir adımdır (Aba, 2014). Bu dezavantajlı gruplar;

2.1.İşsizler

Uzun yıllardır yapılan araştırmalar, işsizliğin sağlık üzerindeki olumsuz etkilerini açıkça ortaya koymaktadır. İşsizlik, mortalite oranlarının artması, ruh sağlığının bozulması, intihar oranlarının yükselmesi ve yüksek morbidite oranları ile ilişkilidir. Ayrıca, işsiz bireyler genellikle uzun dönemli hastalıklara daha yatkın hale gelir ve sağlıksız yaşam tarzı risk faktörlerine, örneğin artan sigara ve alkol tüketimine daha fazla maruz kalırlar (Möller, 2012).

Bu ilişki çift yönlüdür; işsizlik, bireylerin sağlığını olumsuz etkileyebildiği gibi, kötü sağlık durumu da işsizliğe neden olabilir. Ayrıca, işsizlik yalnızca işsiz kalan bireyin sağlığını değil, aynı zamanda onun aile üyelerinin sağlığını da olumsuz yönde etkiler. Dolayısıyla, işsizlik ve sağlık arasındaki bu karmaşık ilişki, toplumsal sağlığın korunması açısından önemli bir konudur (Möller, 2012).



Görsel 3. İşsizlik ve sağlık ilişkisi (Möller, 2012)

2.2.Kadınlar

Kadın cinsiyetinin biyolojik özellikleri ve üreme ile ilgili fizyolojik süreçler, kadınların karşılaştığı sağlık sorunları üzerinde önemli bir etkiye sahiptir. Bunun yanı sıra, toplumsal cinsiyet rolleri ve kadınların toplumdaki yeri ile ilgili ayrımcı uygulamalar, sağlık eşitsizliklerini derinleştirmektedir (Aba, 2014). Kadınlar, sağlık hizmetlerine erişim konusunda birçok engelle karşılaşmakta, bu durum onların genel sağlık durumunu olumsuz etkilemektedir. Bu bağlamda, toplumsal cinsiyet eşitliği sağlanmadan sağlık alanındaki eşitsizliklerin ortadan kaldırılması mümkün değildir. Kadınların sağlık haklarına ve hizmetlerine erişiminin artırılması, bu eşitsizliklerin azaltılması açısından kritik bir öneme sahiptir.

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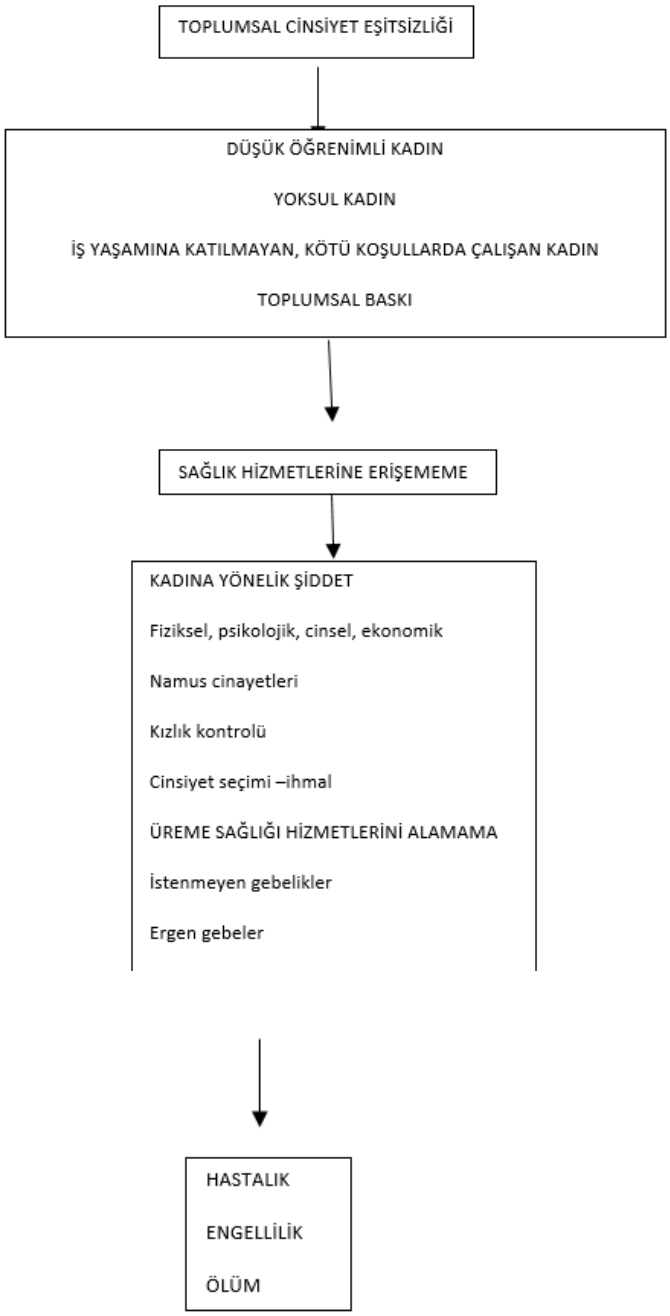

Görsel 4. Toplumsal cinsiyet eşitsizliğinin kadın üreme sağlığına etkisi (Şimşek, 2011).

2.3.Göçmenler/Mülteciler/Sığınmacılar

Göçmenler, yoksulluk, savaş ve siyasi baskılar gibi nedenlerle ülkelerini terk ettiklerinde sağlık hizmetlerine erişimde ciddi dezavantajlarla karşılaşmaktadır. Bu durum, göç öncesi yaşadıkları sağlık sorunlarının yanı sıra, göç yolculuğu sırasında ve hedef ülkedeki yaşam koşullarıyla da doğrudan ilişkilidir (Aba, 2014).

Göçmenlerin yaşadığı ülkelerde genellikle şiddet, siyasi ve ekonomik istikrarsızlık gibi olumsuz koşullar hâkimdir. Göç yolculuğu ise çoğunlukla güvensiz şartlarda gerçekleşir ve bu

da sağlıklarını olumsuz etkileyebilir. Hedef ülkede sosyal hakların eksikliği, mevcut hakları bilmemek veya yasal konumları nedeniyle sağlık hizmetlerinden yararlanamamaları gibi sorunlar, sağlık hizmetlerine erişimlerini daha da zorlaştırmaktadır (Hassoy ve Davas, 2010).

Sığınmacı ve mülteciler, yaşam koşulları, barınma, beslenme ve sağlık hizmetlerine ulaşım konularında ciddi zorluklarla karşılaşarak en savunmasız gruplar arasında yer alırlar. Sağlık hizmetleri, ülkeden ülkeye değişiklik göstermekte, ancak gelişmiş ülkelerde bile genellikle istenen düzeyde olmamaktadır. Mülteciler, dünya genelinde temel sağlık hizmetleri, koruyucu hizmetler, tanı ve tedavi olanakları ile ilaca erişim gibi konularda büyük sorunlar yaşamaktadır (Karadağ ve Altıntaş, 2010). Bu bağlamda, sığınmacı ve mültecilerin sağlık haklarına erişiminin iyileştirilmesi, hem insani bir zorunluluk hem de toplum sağlığı açısından kritik bir öneme sahiptir.

2.4.Evsizler

Evsizlik, hem gelişmiş hem de gelişmekte olan ülkelerde büyük bir sosyal ve halk sağlığı sorunu olarak karşımıza çıkmaktadır. Dünya genelinde yaklaşık yüz milyondan fazla insan evsizdir. Evsizlik, bireylerin sağlık statüsünü olumsuz etkileyen önemli bir belirleyicidir; evsizler, fiziksel hastalıklara (kardiyovasküler hastalıklar, solunum yolu hastalıkları, diyabet gibi) ve ruhsal sağlık problemlerine (depresyon, psikotik bozukluklar, demans gibi) daha fazla maruz kalmaktadır (Aba, 2014).

Evsizler ayrıca cinsel taciz, şiddet, yaralanma, istenmeyen gebelik, AIDS ve madde bağımlılığı gibi ciddi sorunlarla da karşı karşıya kalmaktadır. Örneğin, Amerika'da düşük gelir düzeyine sahip toplumlardaki sağlık kuruluşlarına başvuran hastaların sağlık durumlarını inceleyen bir araştırma, evsiz bireyler ile evsiz olmayanlar arasında anlamlı bir sağlık eşitsizliği olduğunu ortaya koymuştur (NHCHC, 2011).

Bu bağlamda, evsizliğin neden olduğu sağlık sorunlarının çözümü, toplumsal bir sorumluluk olarak ele alınmalı ve etkili politikalar geliştirilmelidir. Evsizlerin sağlık hizmetlerine erişiminin artırılması, toplumsal destek sistemlerinin güçlendirilmesi ve zihinsel sağlık hizmetlerine ulaşımın kolaylaştırılması bu sorunun çözümüne önemli katkılar sağlayabilir.

2.5.Irk/Etnik azınlıkları

Irksal ve etnik azınlıklar, sağlık eşitsizlikleri açısından toplumun diğer kesimlerine göre daha dezavantajlıdır. Bu gruplar, belirli hastalıklar için daha yüksek risk altındadır ve sağlık hizmetlerine erişim konusunda daha fazla engelle karşılaşmaktadırlar. Örneğin, Amerika'da ırksal ve etnik azınlıklar, toplam nüfusun yaklaşık %34'ünü oluşturmaktadır ve bu gruplar, dolaşım sistemi hastalıkları, diyabet ve kanser gibi önlenebilir hastalıklarla daha sık karşılaşmakta ve bu hastalıklar sonucu daha fazla ölüm meydana gelmektedir (Aba, 2014).

Özellikle kalp krizinden ölüm oranı, Afrika kökenli Amerikalılarda beyaz Amerikalılara göre iki kat daha fazladır. Ayrıca, diyabet ve diyabetin komplikasyonları, örneğin bacak ya da ayak

ampütasyonu riski, bu grupta 2,1 kat daha fazladır. Bu durum, sadece azınlık grupların genetik özelliklerinden değil, aynı zamanda sağlıksız yaşam koşullarından da kaynaklanmaktadır.

Bunun yanı sıra, ırksal ve etnik azınlıkların sağlık sigortası kullanma oranları daha düşük olup, dil ve kültür farklılıkları ile birlikte sosyoekonomik düzeylerinin de daha düşük olması, bu grupların sağlık hizmetlerine erişimini olumsuz yönde etkilemektedir (Aba, 2014). Bu eşitsizliklerin ortadan kaldırılabilmesi için, sağlık politikalarının bu grupların ihtiyaçlarını göz önünde bulundurarak şekillendirilmesi ve toplumda farkındalık yaratıcı çalışmaların yapılması büyük önem taşımaktadır.

2.6.Mahkûmlar

Mahkûmlar, bulundukları ortamın fiziksel koşulları ve psikolojik durumları nedeniyle sağlık açısından çeşitli olumsuzluklarla karşılaşmaktadır. Bu gruptaki bireyler, özellikle madde kullanımı (sigara, alkol ve ilaçlar), bulaşıcı hastalıklar (tüberküloz, AIDS) ve ruhsal bozukluklar gibi sağlık sorunlarına daha fazla maruz kalmaktadır (Lögd, 2003).

Bu durum, sadece mahkûmların kendi sağlıklarını tehdit etmekle kalmayıp, özgürlüklerine kavuştuklarında toplum sağlığı açısından da riskler taşımaktadır. Bulaşıcı hastalıkların yayılması, mahkûmların topluma yeniden entegrasyonunda zorluklar yaratmakta ve genel halk sağlığı üzerinde olumsuz etkiler yaratmaktadır (Aba, 2014). Bu nedenle, ceza infaz kurumlarında sağlık hizmetlerinin iyileştirilmesi, ruhsal destek programlarının uygulanması ve sağlıklı yaşam alışkanlıklarının teşvik edilmesi kritik öneme sahiptir.

3. SAĞLIKTA EŞİTSİZLİĞİ ÖNLEMEYE YÖNELİK EBELİK GİRİŞİMLERİ

- Dünyada, özellikle gelişmekte olan ülkelerde bebek ve çocuk ölümleri, çoğunlukla önlenebilir sağlık sorunlarından kaynaklanmaktadır. Bu ölümleri azaltmak ve sağlık hizmetlerine erişimi artırmak için ebeler, bulundukları bölgelerde en uzak kırsal alanlara kadar ulaşarak hizmet sunmaktadır. Bu yaklaşım, sağlık hizmetlerindeki eşitsizlikleri azaltmak için önemli bir adım olup, anne ve çocuk sağlığının iyileştirilmesine büyük katkı sağlamaktadır (Bahar ve Gördes, 2011).
- Bu çerçevede;
  • Gelişmenin izlenmesi (Growth Monitoring),
  • Ağızdan sıvı tedavisi (Oral Rehydration Therapy),
  • Emzirme (Breast Feeding),
  • Bağışıklama (Immunization),
  • Aralıklı doğum (Family Spacing),
  • Gıda desteği (Food Entitlement),
  • Kadınların eğitimine (Female Education) yönelik faaliyetler, her ülkede sağlıkta eşitsizliklerin önlenmesinde temel prensipler olarak kabul edilen ‘minimum hizmet paketi’ ve ‘çocuk yaşatma paketi’ içinde yer almaktadır (Bahar ve Gördes, 2011).

- Ayrıca,

  • Çalışılan bölgedeki yoksul nüfus belirlenmeli ve izlenmeli, yoksulların sağlık hizmetlerine erişimi sağlanmalı ve kaynakların etkili kullanımı konusunda rehberlik edilmelidir. Yoksul annelere ev ziyaretleri yapılarak, anne sağlığı, doğum öncesi bakım ve erken çocukluk döneminde sağlık ve refah düzeyleri artırılmalıdır.
  • Ev ziyaretlerinde sağlık eğitimi verilmesi; aile planlaması, madde bağımlılığı, hijyen, kadına yönelik şiddet, Alzheimer hastalığı ve korunma yöntemleri, menopoz ve osteoporoz, kazalar ve ilk yardım, bulaşıcı hastalıklar, meme kanseri ve korunma, kronik hastalıklar ve korunma gibi konuları kapsamalıdır.
  • Toplumun ve sağlık personelinin yoksullara karşı duyarlılıkları artırılmalı,
  • Kırsal alanlarda yaşayan ailelere sağlık hizmetleri ulaştırılmalı,
  • Meme ve serviks kanseri erken teşhisi için KETEM ile işbirliği yapılarak kadınların taramaya yönlendirilmesi ve sağlık eğitimleri verilmelidir.

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HYPOFRACTİONATED INTRAPROSTATİC BOOST RADİOTHERAPY WİTH PSMA-PET FUSİON İN PROSTATE CANCER

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Introduction/Purpose: Recent studies claim that focal intraprostatic boost (IPB) radiotherapy (RT) to the gross tumor volume seen on MRI in prostate cancer improves disease-free survival and regional/distant metastasis-free survival without increasing toxicity in prostate cancer patients. The aim of this study was to evaluate the efficacy of focal IPB in patients scheduled for RT with PSMA PET fusion during prostate radiotherapy.

Materials and Methods: We evaluated 40 patients with prostate cancer who received hypofractionated RT with PSMA PET fusion for RT planning between 2021 and 2024. Patients with hypofractionated RT planning using standard PSMA PET fusion were included in the study. Patients who received 2.5 Gy daily/total 28 fractions of 70 Gy RT to the whole prostate (HIPO group) and patients who received single fraction focal IPB to the lesion visible in the prostate on PSMA PET fusion for a total of 72.5 Gy RT (IPB group) were divided into two groups (Figure 1a, b). Organ at risk dose limits were controlled and boost was performed in case of focal uptake on PSMA PET. The primary endpoint of our study was early PSA response and secondary endpoints were toxicity and radiation doses to surrounding organs.

Figure 1a. RT planning in a sample patient of the HIPO group.

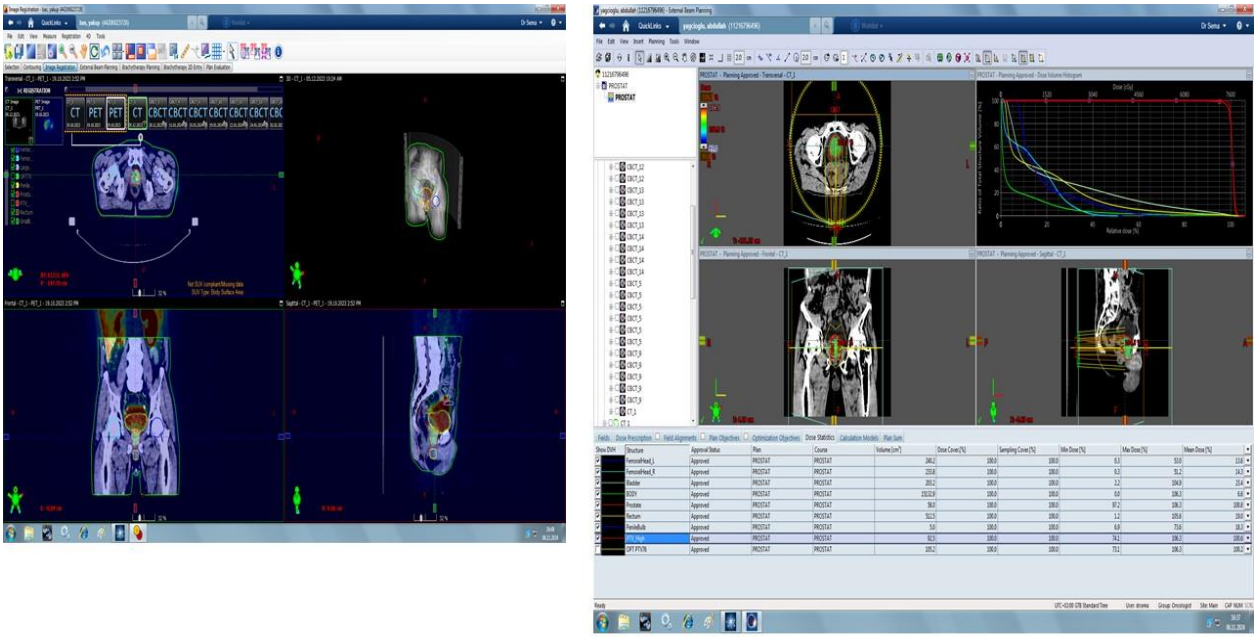
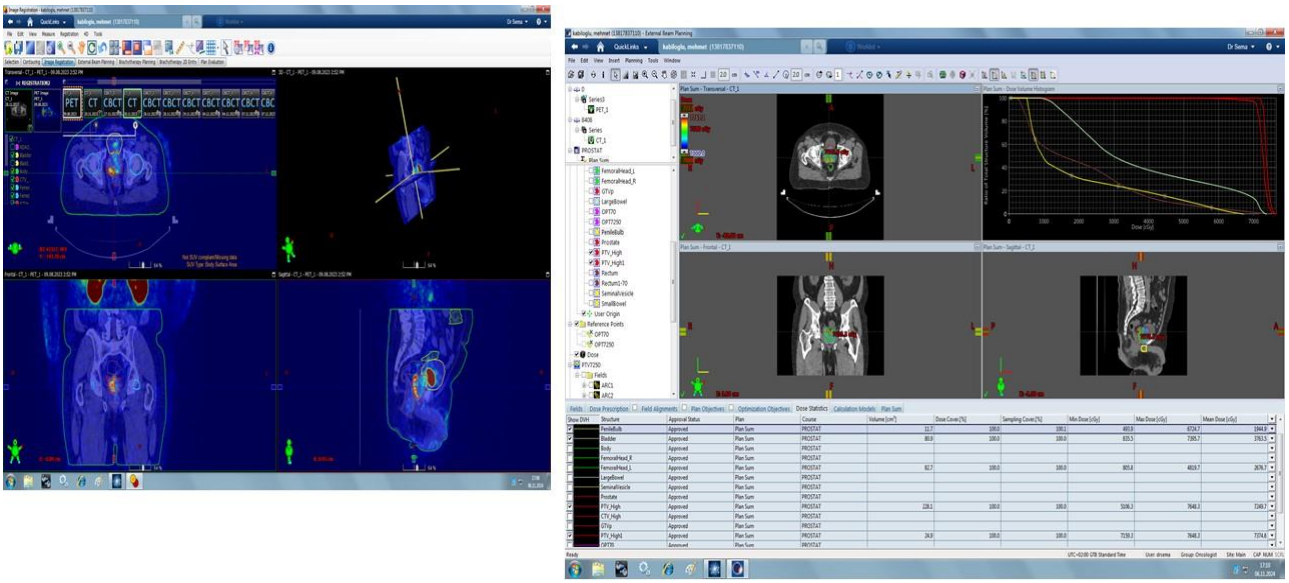


Figure 1b. RT planning in a sample patient in the IPB group.



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Statistical Evaluation: After the data obtained from the study were coded, they were transferred to the computer for analysis using the Statistical Package for Social Sciences (SPSS) (Version 22 for Windows, SPSS Inc, Chicago, IL, USA) package program and evaluated. Continuous variables were expressed as mean ± standard deviation and median (minimum value - maximum value), while categorical variables were defined using number (%). In statistical analyses, the conformity of continuous variables to normal distribution was evaluated with the "Shapiro Wilk Test". "Mann-Whitney U Test" was used for the comparison of the data which were determined not to conform to normal distribution between two groups. The changes in PSA values over time were evaluated by Friedman Test and Bonferroni correction was applied for further analysis. Statistical significance level was accepted as $p<0.05$ in all comparisons.

Results: The study included 20 patients. There was no significant difference in PSA and age characteristics between HIPO and IPB groups. Table 1.

Table 1. PSA and age characteristics of the patients.

Variables	HİPO		İPB		p
	mean ±SD	Median(min-max)	mean ±SD	Median (min-max)	
AGE	64,8±6,36	64,5 (53-74)	69,4±4,48	68,5 (64-79)	0,11
PSA	22,04±27,59	14,17 (5,48-99)	12,97±8,31	11,24 (3,0-33,0)	0,36

In both groups, the decrease in PSA value was statistically significant after RT (p=0.002 and p<0.001, respectively). The rate of PSA decrease was higher in the IPB group (Figure 2).

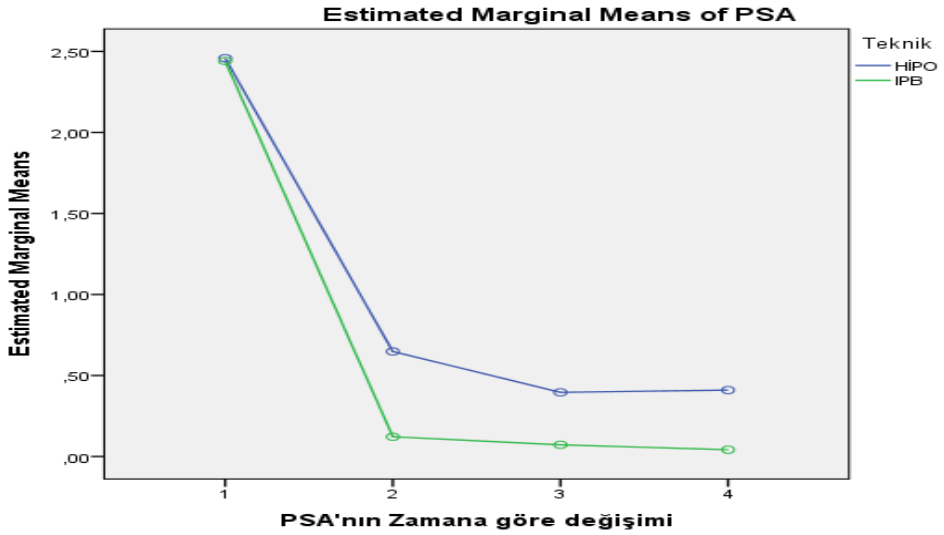

Figure 2. PSA decrease graph in both groups after RT.

PSA follow-up values are shown in table 2. There was no significant difference in the median PSA values between the groups at each time point (p>0.05 in all comparisons).

Table 2. PSA follow-up after RT.

PSA	HIPO		IPB		P value*
	Mean ±SD	Median (min-max)	Mean ±SD	Median (min-max)	
Before RT	2,45±2,99	1,41 (0,02-9,3)	2,44±2,85	0,73 (0,32-8,72)	0,81
After RT (1st week-1st month)	0,64±1,11	0,16 (0,03-3,57)	0,12±0,09	0,09 (0,04-0,34)	0,54
After RT (3 months)	0,39±0,93	0,04 (0,01-3,03)	0,07±0,07	0,06 (0,01-0,24)	1,00
Last control	0,41±0,93	0,05 (0,02-3,03)	0,04±0,05	0,03 (0,01-0,18)	0,07
P value**		**0,002**		**<0,001**	

*Mann Whitney U test; **Friedman Test (with Bonferroni correction).

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There was no statistically significant difference in the irradiated target and risk at organ (OAR) doses (rectum, penile bulb and body dose) in both groups. However, the minimum doses in the prostate (min dose), which may result in failure of local control, were better in the IPB group than in the HIPO group (91.1 versus 94.3).

Table 3. Target and OAR doses in RT plans.

	HİPO Median (min-max) %	IPB Median (min-max) %	P value*
Prostate-min dose	**97,2 (91,1-98,0)**	**97,3 (94,2-98,3)**	0,97
Prostate-mean dose	101,0 (99,6-101,2)	100,7 (98,9-105,5)	0,65
Rectum max dose	103,7 (101,9-105,6)	104,1 (102,4-106,7)	0,97
Rectum-mean dose	28,1 (19,0-33,2)	28,9 (23,3-42,7)	0,43
Penile bulb-mean dose	36,2 (16,6-64,6)	31,5 (25,2-43,7)	0,50
Body-max dose	106,5 (103,6-108,5)	106,6 (103,6-108,0)	0,73

Conclusion: We believe that contouring the gross tumor and adding a focal boost to the intraprostatic lesion with PSMA PET fuson in prostate cancer will improve disease-free survival in patients with localized prostate cancer due to early PSA reduction without adversely affecting toxicity and quality of life. After long-term side effect follow-up, the boost dose can be increased to higher ablative doses, so that high focal boost applications that will improve tumor control by adhering to “OAR” restrictions can be applied effectively and safely with future studies.

Key words: Prostate cancer, PSMA-PET fusion, hypofractionation, intraprostatic focal boost.

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EXPERİMENTAL INVESTIGATION OF MECHANICAL PERFORMANCE OF SİLİCA FUME-BASED GEOPOLYMER CONCRETE CONTAINING MİCRO SYNTHETİC FİBER EXPOSED TO HİGH TEMPERATURE

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ABSTRACT

Geopolymer concrete (GPC) is a type of concrete with higher high temperature resistance compared to traditional Portland cement. For this reason, it is more ideal for industrial and fire risk structures exposed to high temperatures because it contains aluminosilicate-based materials and alkali activators. Another important feature of GPC is that it can maintain its mechanical properties at high temperatures. Therefore, the aim of this study is to investigate the compressive and flexural strength of silica fume-based GPC produced using two different ratios (0.5% and 1%) of microsynthetic fibers when exposed to different high temperatures (20 °C, 200 °C, 400 °C and 600 °C). It was determined that the compressive strength of GPC increased with the increase of the temperature by 200 °C and 400 °C. However, increasing the temperature by 600 °C caused a significant decrease in the compressive strength. However, increasing the fiber ratio (from 0,5% to 1%) in the mixture caused a decrease in the compressive strength. The increase in temperature decreased the bending strength of samples. Also, the increase in fiber ratio decreased the bending strength.

Keywords: Geopolymer concrete, High temperature, Microsynthetic fibers

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1. INTRODUCTION

Traditional cement is one of the most widely used building materials today. With the increasing world population and urbanization, the use of this material, which is not very environmentally friendly, is increasing. When we consider population and development, it is estimated that global cement production will increase by 12-23% by 2050. It is known that the cement sector is responsible for 7% of global CO_2 emissions. As can be understood from the information given, finding alternative materials to cement is important for a sustainable environment. These emissions are being reduced with traditional methods, and another material are being researched. One of the alternative binders that are being researched today is geopolymer material [1-3]. Although the history of geopolymer material dates back to the 1940s, its research and popularization are more recent. The term geopolymer was introduced by French scientist Joseph Davidovits in the late 1970s. Geopolymer material, which uses industrial waste as a source (fly ash, rice husk ash or slag, etc.), is used as an alkali activator (sodium hydroxide (NaOH), sodium silicate (Na_2SiO_3), potassium hydroxide (KOH) or potassium silicate (K_2SiO_3) solutions). In geopolymer concrete, these alkaline liquids can be used alone or by mixing the two liquids [4-7].

Geopolymer concrete has many advantages over traditional concrete. The most important of these advantages is the difference between the amount of carbon dioxide produced during the production of geopolymer material and traditional cement. This amount is significantly reduced during the production of geopolymer concrete, and since industrial waste is used as a source, it is more economical and more environmentally friendly than concrete made with cement [8-10]. In addition, industrial waste used in the production of geopolymer material will both reduce waste in the environment and reduce the consumption of natural resources (clay, limestone, etc.) used in conventional cement production. Geopolymer material has a different production process than conventional cement. Very high-temperature furnaces and large amounts of fuel are not required. Therefore, geopolymer concrete becomes a sustainable and environmentally friendly building material [11-13].

Davidovits stated in his research on geopolymer concrete that geopolymer concrete can reach its strength value in 24 hours at room temperature, and that a strength of 20 MPa can be achieved at 20 °C and a 4-hour curing process, and a compressive strength of approximately 70-100 MPa can be achieved in 28 days. He stated that an aircraft runway can be made usable at the end of 6-hour hardening period thanks to the rapid strength gain of geopolymer concrete. In addition, geopolymer concrete can be used in various structural applications due to its higher compressive strength. Compared to traditional concrete, geopolymer concrete has been well sulfate resistance and superior resistance to acids, which is evidence that geopolymer concrete is equal or superior in terms of strength and durability. Its low permeability reduces the possibility of water infiltration and provides long-term durability. It is known that geopolymer concrete has improved fire resistance. It is used in applications where fire safety is important, including tunnels and high-rise buildings. Since geopolymer concrete is cured faster than traditional concrete, construction projects can be completed more practically and more efficiently. Compared to traditional concrete, geopolymer concrete has less shrinkage and

cracking rates, which increases durability and overall performance. It prevents environmental damage by retaining heavy metals that can be used in its structure. Geopolymer technology is applied in different areas. In addition, there are very little knowledge and experience in the production and application of geopolymer concrete compared to traditional concrete. The raw material supply and mixing ratios of geopolymer materials may vary regionally, which can make standardization difficult. The processes performed may also be complex and the material costs high, but the fact that it causes more costs than traditional concrete in the production phase can be compensated by the superior properties it provides [14-17].

The aim of this study is to experimentally investigate the effect of micro synthetic fiber ratio on compressive and flexural strength in geopolymer concrete produced based on silica fume under high temperature. The test samples were divided into two groups according to micro synthetic fiber ratio. In the first group, 0,5% by volume and in the second group, 1% by volume micro synthetic fiber were used. All samples were exposed to high temperatures of 200, 400, 600 and 800 °C. Cube samples with dimensions of 50x50x50 mm were used for compressive strength and prism samples with dimensions of 40x40x160 mm were used for flexural strength. The samples were tested 7 days after production.

2. MATERIALS AND METHODS

In this study, silica fume (SF) based geopolymer concrete was produced. The mixing ratios are presented in **Table 1**. The unit volume weight of SF is 2,24 g/cm^3. Chemical composition of SF is shown in **Table 2**. Particle seize analysis and XRD pattern of silica fume are presented in **Figure 1**. Quartz powder (QP) and sand were used as fine aggregate in the geopolymer concrete mixture. The unit volume weights of quartz powder and sand are 2,71 g/cm^3 and 2,65 g/cm^3, respectively. Particle seize analysis of QP and sand are presented in **Figure 2**. In addition, the chemical properties of quartz powder are presented in **Table 3**. The XRD pattern of quartz powder is also presented in **Figure 3**. Sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) were used as chemical activators in the geopolymer mixture. The sodium silicate/sodium hydroxide ratio was preferred as 2,5 in terms of workability.

Table 1. Mix proportion (kg/m3)

SF	QP	Sand	Na_2SiO_3	NaOH
700	250	200	577	230

Table 2. Chemical composition of SF

CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	Na_2O	K_2O	SO_3	LOI
0,3	95,6	0,2	0,2	0,2	0,1	0,2	0,3	2,1

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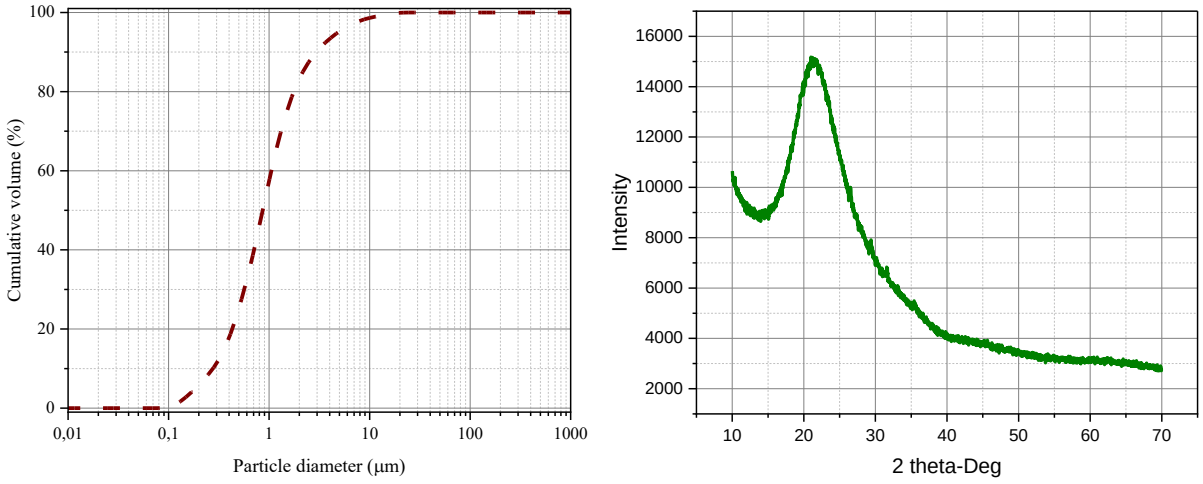
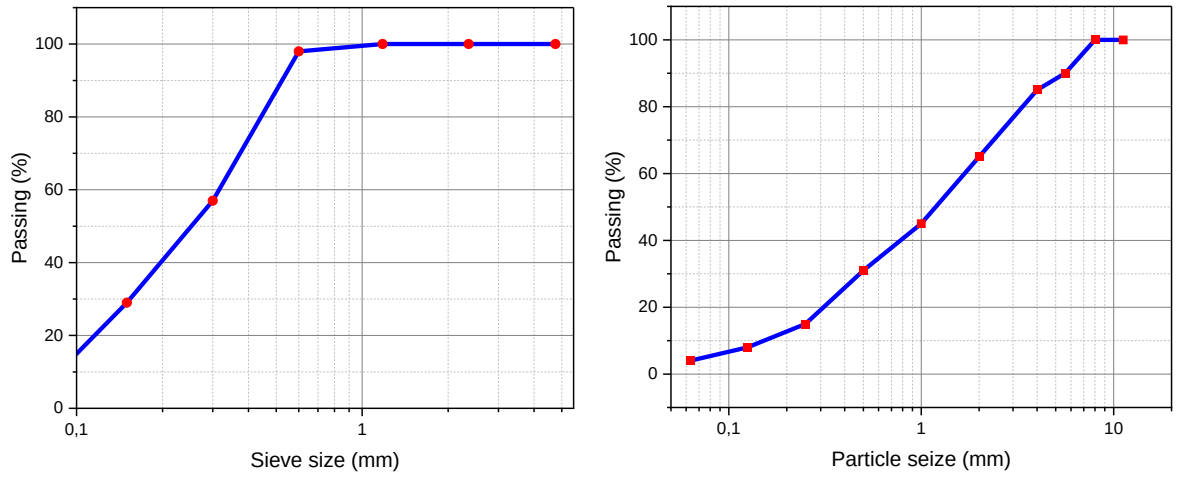


(a) (b)

Figure 1. (a) Particle seize analysis (b) XRD pattern of SF



(a) (b)

Figure 2. Particle seize analysis of (a) QP (b) sand

Table 3. Chemical composition of GGBS, silica fume (SF) and quartz powder (QP)

CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	Na_2O	K_2O	SO_3
53,2	0,4	0,1	0,1	0,4	0,2	0,1	0,1

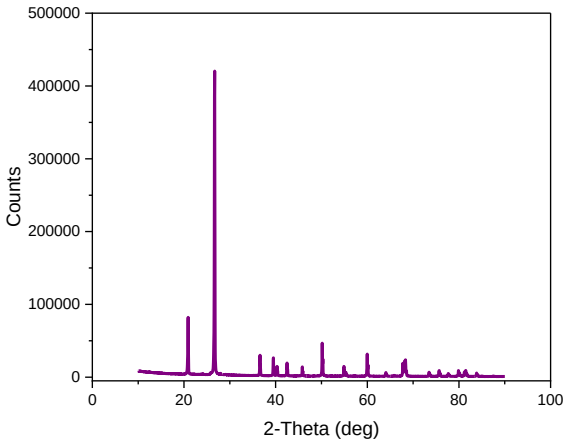


Figure 3. XRD pattern of QP

All samples were produced in a laboratory environment using a 5 dm^3 capacity mixer. In the concrete mixture, solid materials such as SF, QP and sand were first mixed for 3 minutes. In the second stage, alkali activators were added to the mixture and mixed for another 3 minutes. In the last stage, micro synthetic fibers were added and the mixture was mixed for another 3 minutes.

Three pieces of each sample were produced. Cube samples with dimensions of 50x50x50 mm were produced for determination of compressive strength. Prism samples with dimensions of 40x40x160 mm were produced for bending strength. All samples were heat cured 1 hour after production. Heat cured at 60 °C for 4 hours. After heat cured, the samples were left to cool in a natural environment. The samples were kept in a laboratory environment for 6 days. High temperature was applied to some samples before pressure and bending tests. In order to investigate the effect of high temperature, a group of samples were kept in a laboratory environment (20 °C) as a reference. High temperatures of 200 °C, 400 °C and 800 °C were applied to the other samples for 2 hours. After applying high temperature, the samples were left to cool in a laboratory environment.

In order to investigate the effect of microsynthetic fiber type in geopolymer concrete mixture, two different fiber ratios were used. Microsynthetic fibers were used at 0.5% and 1% by volume. Technical properties of microsynthetic fibers are presented in **Table 4**. Microsynthetic fibers comply with ASTM C1579-13 [18] standard and their unit volume weight is 1 gr/cm^3. The appearance of micro synthetic fibers is presented in **Figure 4**.

Table 4. Technical properties of micro synthetic fiber

Length (mm)	Diameter (mikron)	Tensile strength (MPa)	Melting point (°C)	Number of fibers (~/kg)
12	15-18	750-1000	245-255	180 million

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Figure 4. The appearance of micro synthetic fibers

For compressive strength and flexural strength, 24 cube and 24 prism samples were produced, respectively. The properties of the samples are presented in **Table 5**. In addition, the samples were named according to the fiber volume and the temperature value they were exposed to.

Table 5. Properties of samples

	Fiber ratio (%)	Temperature (°C)
B2-0,5-20	0,5	20
B2-0,5-200	0,5	200
B2-0,5-400	0,5	400
B2-0,5-800	0,5	800
B2-1-20	1,0	20
B2-1-200	1,0	200
B2-1-400	1,0	400
B2-1-800	1,0	800
B2-0,5-20	0,5	20

Compressive and flexural strength tests were carried out in accordance with TS EN 12390-3 [19] and TS EN 12390-4 [20] standards, respectively (**Figure 5**). The results were recorded instantly in a computer environment.

(a) (b)

Figure 5. Test set up (a) compressive test (b) bending test

3. RESULTS AND DISCUSSION

3.1. Compressive Strength

The results presented in **Table 6** demonstrates the understanding of possible influence by variations in micro synthetic fiber content and temperature on the compressive strength performance of geopolymer concrete. Moreover, the average compressive strength of tested samples is shown in **Figure 6**. Images of the samples after the compressive strength test are also presented in **Figure 7**. The compressive strength of 26,71 MPa observed at 20 °C is taken as the reference value for comparison. A major drop in compressive strength is observed at 200 °C, where the compressive strength reaches over 30,63 MPa. This enhancement is due to additional geopolymer matrix polymerization and stiffness increment at high temperatures. It might be considered that although such a mid-range temperature results in improvement mechanical properties of this geopolymer matrix, the compressive strength is peak observed at 400 °C with value of 33,52 MPa and decreases up to very high thermal transition zone. At this stage, microstructure is densified and outfits the unit to mechanical loads. However, the strength drastically drops to 20 °C 16,74 MPa (below the baseline value) at 800 °C. This significant loss of strength indicates serious damage in micro structure of the matrix induced by thermal stresses and also some degradation from fibers are expected at temperatures higher than their melting point (245-255 °C). This temperature seems to lead the matrix to crack and fiber melt, which weakens the whole sample.

Table 6. Summary of compressive strength (MPa)

	Sample 1	Sample 2	Sample 3	Average
B2-0,5-20	26,96	26,04	27,14	26,71
B2-0,5-200	30,65	30,11	31,13	30,63
B2-0,5-400	33,45	33,18	33,94	33,52
B2-0,5-800	16,82	16,24	17,17	16,74
B2-1-20	24,41	24,21	25,21	24,61
B2-1-200	28,69	28,31	29,18	28,73

B2-1-400	30,65	30,22	31,14	30,67
B2-1-800	14,32	14,11	14,78	14,40
B2-0,5-20	26,96	26,04	27,14	26,71

The compressive strength at 20 °C is 24,61 MPa, which is lower than the respective value for the 0,5% fiber sample, most likely due to possible fibre agglomeration and poor bond formation at this fibre ratio The strength is increased to 28,73 MPa at the temperature of 200 °C, presenting a similar trend as seen with the sample containing 0,5% fiber but with less significant gain in strength. This implies that at the high fiber contents, the combination of matrix may not gain much from additional exposure to heat and/or the distribution of fiber within the matrix could actually limit further polymerisation. The strength obtained at 400 °C is 30,67 MPa that was slightly less than the value for the sample with 0,5% fiber, suggesting that having higher percentages of fiber content may not assist in improving compressive strength, in this temperature range. The strength at 800 °C still lowers to 14,40 MPa, which is lower than that from the sample with a fiber content of only 0,5%. Once more, this indicates the elevated fiber content could have meant that at high temperatures a greater amount will degrade making sample weaker.

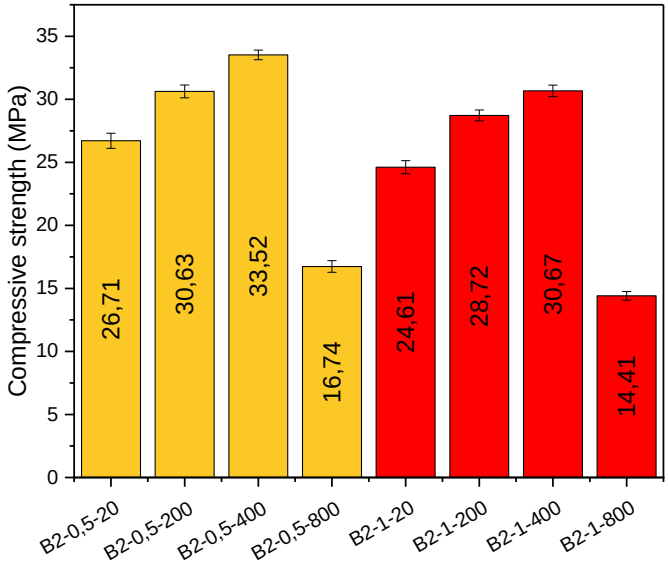

Figure 6. Average compressive strength of tested samples

The compressive strength at all temperatures for 0,5% fiber content samples is always greater than the 1% fiber content samples. This suggests a certain optimum fiber content– approximately 0,5% or less, where the fibers help reinforce, but do not disadvantage by causing poor fiber-matrix adhesion and/or bundles of fibers. For both fiber ratios, the maximum compressive strength is found at 400 °C and given that the 0,5% fibre samples outperform their counterparts reinforced with 1wt% of fibre, it can be concluded that effect of coupled processes (fiber reinforcement and densification) would be better in a lower fiber content level where matrix still remains as a weak phase.

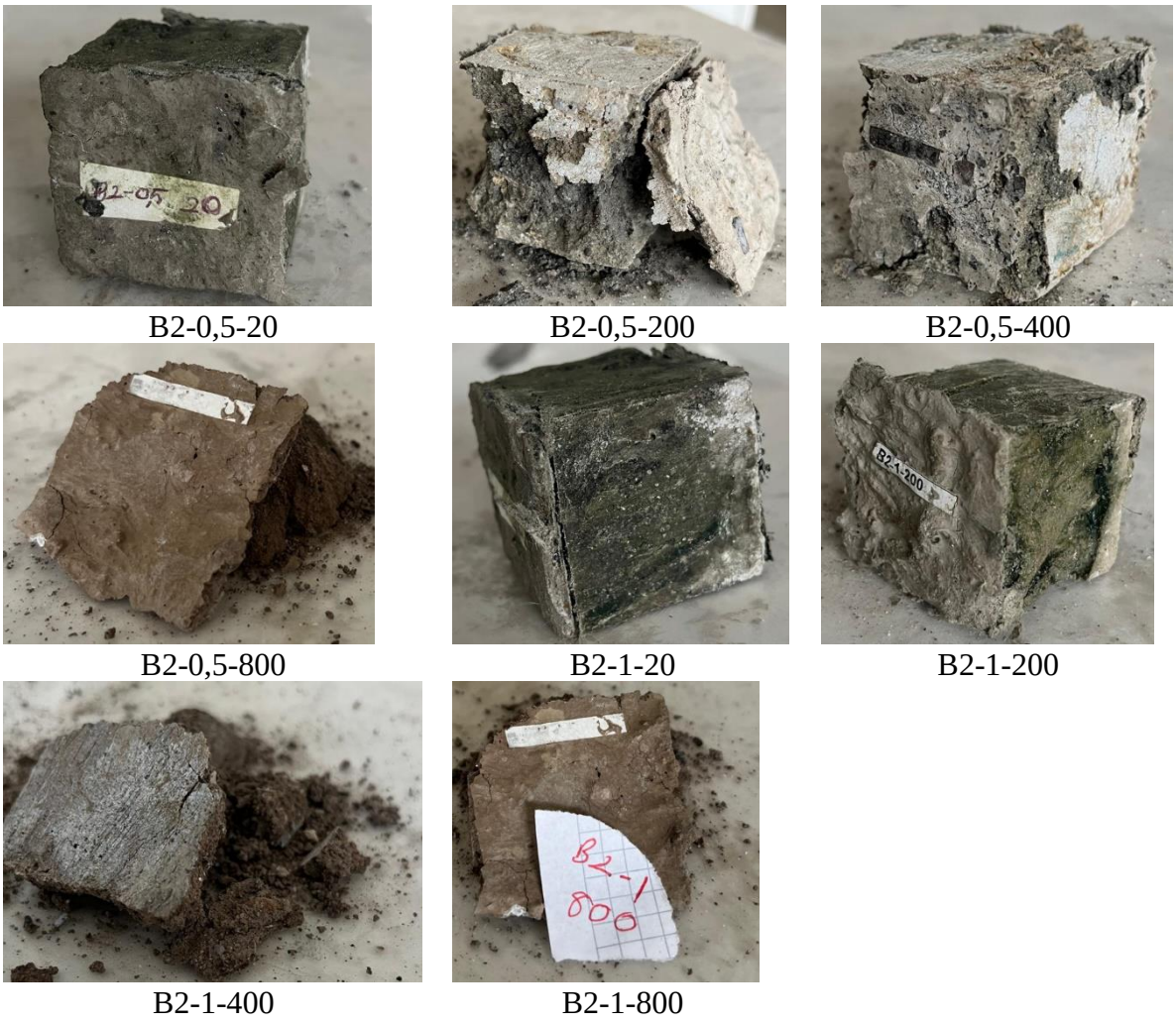

Figure 7. Images of the samples after the compressive strength test

For both dosages of fiber, the compressive strength rises with temperature to 400 °C and then drops sharply at 800 °C. It implied that micro synthetic fiber-reinforced geopolymer concrete has a good level of tolerance towards moderate heat exposure (up to 400 °C) due to its fibrous resistance but a severe deterioration at higher temperatures (800°C) because of the loss of matrix integrity caused by thermal breakdown process and possible cracking. The samples with 0.5% fiber content outperforming the samples with 1% fiber content across the board, indicating that an excessive amount of fiber in contrast to optimum may result harmful influence on compressive strength at elevated temperature.

3.2. Flexural Strength

The flexural strength results in **Table 7** provide a detailed look at the performance of geopolymer concrete reinforced with micro synthetic fibers when subjected to various high temperatures. Moreover, the average flexural strength of tested samples is shown in **Figure 8**. Images of the samples after the flexural strength test are also presented in **Figure 9**. The average flexural strength is 26,71 MPa at baseline condition (20 °C). It is the baseline against which we

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will compare the geopolymer concrete, its behavior or response to different application temperatures. The flexural strength shows a massive improvement at 200 °C (30,63 MPa), which means that the material will gain stiffness with moderate heat-loads. Such enhancement is due to the additional curing and compaction of the geopolymer matrix at high temperature conditions. The strength exhibits a maximum of 33,52 MPa, which is the highest flexural strength recorded at 400 °C. This increase indicates that the geopolymer matrix is strengthen at intermediate temperature with possible densification and porosity reduction effects, contributing to its resistance against bending loads. Flexural strength at 800 °C falls abruptly to just 16,74 MPa, much lower than the initial value at 20 °C, due mostly to degradation of fiber reinforcement and microcracking in composite matrix resulting in reduction of load-bearing capacity.

Table 7. Summary of flexural strength (MPa)

	Sample 1	Sample 2	Sample 3	Average
B2-0,5-20	26,96	26,04	27,14	26,71
B2-0,5-200	30,65	30,11	31,13	30,63
B2-0,5-400	33,45	33,18	33,94	33,52
B2-0,5-800	16,82	16,24	17,17	16,74
B2-1-20	24,41	24,21	25,21	24,61
B2-1-200	28,69	28,31	29,18	28,73
B2-1-400	30,65	30,22	31,14	30,67
B2-1-800	14,32	14,11	14,78	14,40
B2-0,5-20	26,96	26,04	27,14	26,71

It can be seen from Figure 8 that the flexural strength is 24,61 MPa at 20 °C, which is less than that of the 0,5% sample. It could be inferred that higher fiber content is not necessarily related to improved performance at room temperature, and too much may even hinder the matrix-fiber interaction because of fiber agglomeration. When the temperature is 200 °C, the flexural strength is 28,73 MPa. It also shows an increasing trend, but the increasing pattern of the 0,5% sample is similar, and the strength increase is lower. It could be inferred that the added fiber is not working at this temperature and reveals that the fiber dispersion is key to performance. When the temperature reaches 400 °C, the flexural strength is reached 30,67 MPa. Although the strength is higher than the previous two conditions, the residual strength is less than that of the 0,5% sample. High fiber content does not determine that the residual strength of the material will reach better performance. When the temperature rises to 800 °C, the flexural strength is 14,40 MPa. The drop is even more severe than the 0,5% sample. Due to the increased fiber volume, more structural defects have been generated, and the fiber may melt due to the high temperature at most and the fiber's melting point is around 245-255 °C. The interaction with the geopolymer matrix causes more severe damage.

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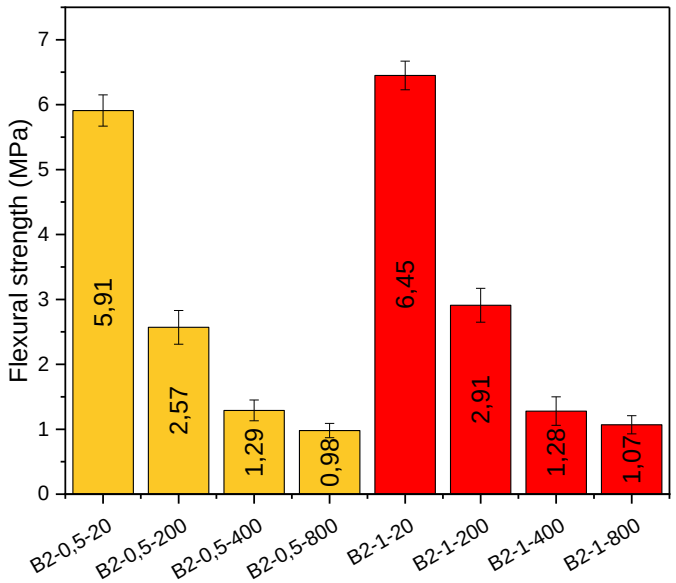

Figure 8. Average flexural strength of tested samples

Inclusion of 0,5% fiber content shows higher flexural strength values compared to 1% fiber content in all temperature ranges. It also indicates that 0,5% is more of the required fibre content to increase flexural performance in this geopolymer mix as increasing fibre content alone does not result in greater improvements. Both contents of fiber experience the increase of flexural strength until 400 °C, and reduce significantly at 800 °C with higher reduction for 1% fiber samples which are indicative that a maximum amount of fiber content can be negated the contribution to material performance at high temperature.


B2-0,5-20

B2-0,5-200


B2-0,5-400


B2-0,5-800


B2-1-20


B2-1-200

B2-1-400 B2-1-800

Figure 9. Images of the samples after the flexural strength test

4. CONCLUSION

The aim of this study is to experimentally investigate the effect of micro synthetic fiber ratio on compressive and flexural strength in samples produced from geopolymer concrete under the high temperatures of 200 °C, 400 °C and 800 °C. For this purpose, cube samples of 50x50x50 mm dimensions were produced for the determination of compressive strength in which prism samples of 40x40x160 mm dimensions were produced for the determination of bending strength. The following results were obtained as a result of the experimental study:

i. For geopolymer concrete at elevated temperatures, micro synthetic fibers (0.5%) are used to improve the compressive strength of hardened geopolymer paste.
ii. Although the temperature is 800°C, which can significantly degrade fiber and matrix to increase strength loss.
iii. For geopolymer concrete reinforced with micro synthetic fibers, the flexural strength performance is seamlessly to provide higher enhancement up to moderate temperatures and reaches a peak around 400 °C before declining rapidly at 800 °C, with the 0,5% fiber content being more efficient in preserving greater flexural strengths across all temperatures than the 1% incorporation that needs to account for synergetic effects such as limited bonding efficiency at relatively lower distresses or more rapid degradation from heating history at excessive high extremes.
iv. This implies that both the proportion of fiber and its proper dispersion are vital to maximizing the thermal and mechanical properties of geopolymer concrete based on flexural behavior.

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DEVELOPMENT OF DRYING CRACKS IN CLAYEY SOILS ADDED WITH RESIDUAL LIGNITE DUST UNDER WETTING-DRYING CYCLES

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ABSTRACT

Clayey soils develop cracks in their structures when they dry due to their high swelling and shrinkage potential. This cyclic swelling and shrinkage can cause cracks and deformations in engineering structures. This cycle can also affect expanding soils' compressibility and hydraulic conductivity properties. The solution to this problem, commonly seen in clayey soils, is possible by improving the clayey soil using natural, chemical, or synthetic additives. Due to the frequent occurrence of global climate changes today, this study was conducted to investigate the usability of residual lignite dust added to clayey soil at different rates as an improvement material in reducing the development of drying cracks frequently seen in clayey soils. For this study, five samples were prepared by adding residual lignite dust to clayey soil (5%, 10%, 15%, and 20% of dry weight) and subjected to three consecutive wetting-drying cycles. Observational results have shown that the addition of residual lignite dust to clayey soil can reduce the development of drying cracks in such mixtures.

Keywords: Clay, lignite, stabilization, wetting-drying

1. INTRODUCTION

It is possible to improve the geotechnical properties of natural soils that do not have the desired geotechnical properties by improving the soil. For this purpose, the soil is improved by adding natural, synthetic, or chemical additives. In this way, the physical and mechanical properties of the ground can be improved and the engineering structures to be constructed can be placed on a safe and solid foundation. Today, more attention is paid to ensuring that the additives used are cheap, locally available, biodegradable, and environmentally friendly (Yarbaş and Kalkan, 2022, Sengul and Vitosoglu, 2023).

Clayey soils (CS) cause structural damage to engineering structures due to their spread over large areas and physical-mechanical properties and pose significant challenges in civil engineering. CS are formed by the erosion, transportation and accumulation of rocks such as igneous rocks, greywacke, claystone, clayey schist rich in felspars in basins. The composition of clay minerals consists of hydrous aluminum silicate. Here, SiO_2 and Al_2O_3 teraedes combine in various ways to form plates and form various clay minerals. For this reason, clayey soils (montmorillonite), which have the potential to swell and shrink under different water content,

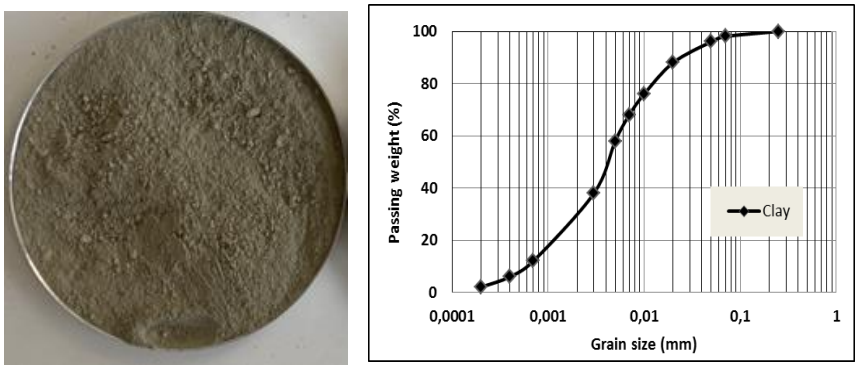
exhibit the properties of expanding as they absorb water and shrinking as they absorb water (Erguvanlı, 1982; Kalkan and Bayraktutan, 2008; Chaudhari and Muchhara, 2021). Since clayey soils are well known to be problematic and sensitive to ground movements, it is necessary to know their swelling properties for the reliability of engineering structure foundations (Guney et al., 2007; Yarbaş and Kalkan, 2022).

In this study, the effects of global climate change are widely observed today, and the formation of drying cracks due to water loss, especially in clay soils, is widely seen today. This situation significantly affects the geo-mechanics properties of clay soils. To minimize this effect, the aim was to reduce the formation of drying cracks by pulverizing residual lignite pieces and adding them to clay soil in different proportions. Because, the presence of cracks, especially in CS, will increase compressibility (Morris et al., 1992) and crack systems that develop in the ground will also affect the hydraulic properties of the soil (Chertkov, 2000).

2. MATERIAL and METHODS

2.1. Clayey Soil (CS)

CS samples were taken from the west of Oltu (Erzurum-Türkiye) district. This green colored, plastic CS is extremely consolidated and has the character of clayey rock under natural conditions (Kalkan and Bayraktutan, 2008). The green CS sample and its granulometry curve are shown in Visual 1.



Visual 1. CS sample and granulometry curve

2.2. Residual lignite dust (RLD)

Lignite solid waste, one of the fossil fuel types, was obtained in pieces from the mine operated under the name of Balkaya Lignite Mines in the Oltu district of Erzurum and was used by grinding. The lignite coal used in our study was taken in pieces from the Oltu (Erzurum-Turkey) Balkaya coal mine where lignite was produced, broken and crushed, and then pulverized in a Los Angeles grinding machine at 4000 rpm. The powdered lignite sample and granulometry curve where laboratory experiments were conducted are shown in Visual 2.

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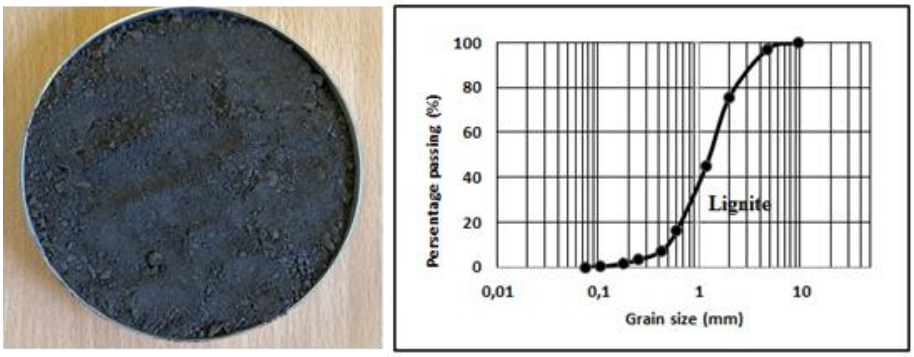

Visual 2. RLD sample and granulometry curve

2.3. Experimental Procedure

CS and four different RLD mixtures added to CS were compressed at optimum moisture content in a cylindrical sample mold with a diameter of 50 mm and a height of 30 mm. These samples were subjected to three wetting-drying (W-D) cycles at room temperature (18 ± 2°C). Each cycle lasted five days. Images of the samples were taken at the end of the W-T cycles (Yarbaş and Kalkan, 2022).

3. Experimental Results and Discussion

In this study, the effect of RLD added to CS in order to reduce the formation of drying cracks seen in CS was investigated (Visuals 3-6).

As a result of the observations, at the end of the first drying cycle, crack formation was observed only in the pure clay soil sample shown as sample a (Visual 4). After the second drying process, cracks were observed in samples **a** (0% lignite) and **b** (5% lignite) while very small capillarity cracks or no cracks occurred in samples **c** (10% lignite), **d** (15% lignite), and **e** (20% lignite) (Visual 5). In the third drying cycle, cracks continued to develop in samples a and **b**, no cracks occurred in samples **c** and **d**, and partial cracks were observed on the edges of the sample container in sample **e** (Visual 6).

The increase in the resistance of the mixture samples formed with the addition of RLD against the development of drying cracks under W-D cycles was attributed to the addition of RLD, which has pozzolanic material properties, to the CS (Di Maio et al., 2004) RLD defined as pozzolanic material are siliceous and aluminous materials that have no or very little binding value on their own; however, in finely ground form and in the presence of moisture, they form compounds with binding properties (Sengul and Vitosoglu, 2023). Particularly, the openings formed on the edges of the sample container at the end of the drying process in Visuals 5-6 are interpreted as soil shrinkage during the drying process (Tang et al., 2011, Cheng et al., 2021).

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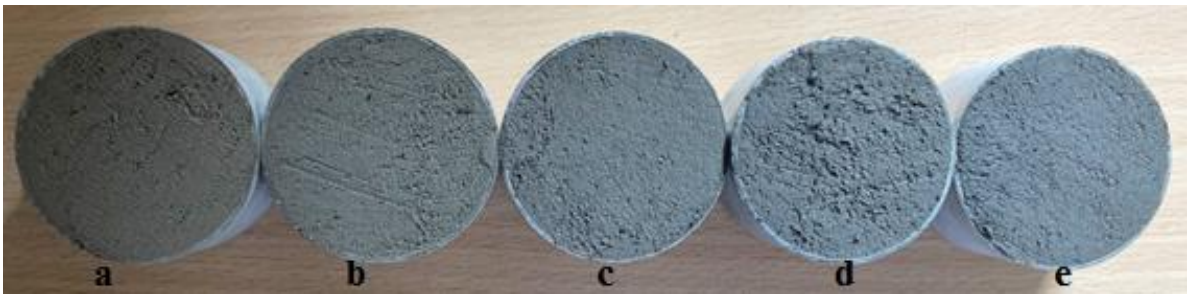
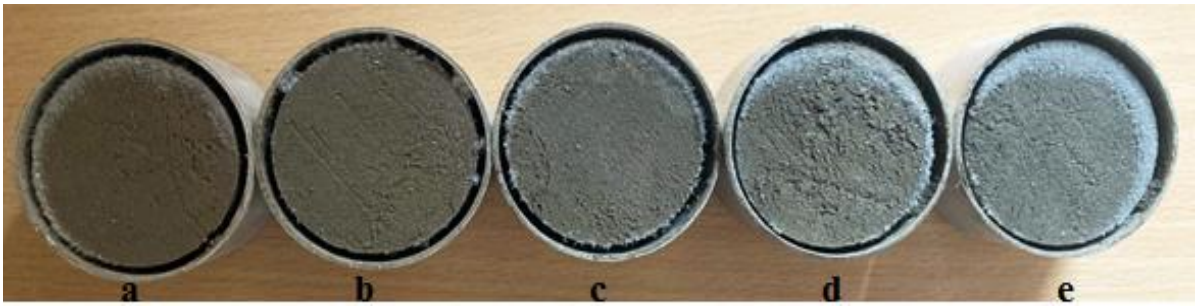
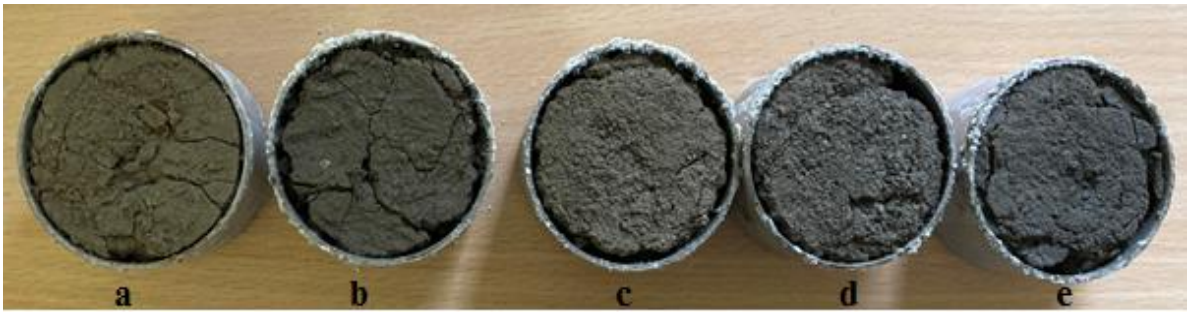


Visual 3. Initial state of the W-D cycles of the samples



Visual 4. First drying process crack patterns

Visual 5. Second drying process crack patterns



Visual 6. Third drying process crack patterns

3. CONCLUSIONS

In this study, the effect of RLD material added to CS subjected to W-T cycles on drying crack behavior was investigated. It was observed that CS-RLD mixture samples obtained by adding RLD material reduced the formation of drying cracks under W-T cycles. As a result, it can be said that lignite, a natural material, can be used to minimize the development of drying cracks under W-T cycles of CS, will provide economy in the stabilization of CS, and will also make significant contributions to the prevention of environmental problems.

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EFFECT OF DISTANCE METRICS ON DIABETES PREDICTION USING K-NEAREST NEIGHBOR ALGORITHM

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ABSTRACT

Diabetes is the name given to the chronic disease in which the body is unable to balance blood sugar levels effectively. Diabetes has negative effects on human health in many different ways. Diabetes also predisposes to many different diseases. If diabetes is not controlled, it damages many different organs. Diabetes continues to be an important health problem, increasing rapidly all over the world. Today, artificial intelligence and its applications are frequently used in many fields and studies. One of the areas where artificial intelligence is used is the field of health. With the developing sensor technology, obtaining biomedical data has become both easier and faster. K-Nearest Neighbor (K-NN) algorithm is an artificial intelligence model that can be used for classification problems. In this study, a diabetes dataset created by the National Institute of Diabetes and Digestive and Kidney Diseases is tried to be classified with the K-NN algorithm. The dataset contains a total of 768 person data. The dataset contains features such as Body Mass Index (BMI), pregnancies, glucose, diabetes pedigree function, skin thickness, insulin, blood pressure, age. In the study, 10 different distance metrics such as euclidean, hamming, chebyshev, city block, mahalanobis, cosine, minkowski, jaccard correlation, and spearman are used and their effect on prediction performance is analyzed. The results are evaluated with accuracy and F1score performance metrics.

Anahtar Kelimeler: Diabetes, Distance metrics, K-nearest neighbor algorithm.

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1. INTRODUCTION

Diabetes is a chronic condition in which the insulin hormone in the human body is produced less or insufficiently than necessary and the insulin produced cannot be used effectively. Immunological factors, genetic causes and environmental factors play a role in the development of diabetes. Diabetes is classified under four main headings: Type I, Type II, gestational and other specific types (beta cell dysfunction, insulin dysfunction, exocrine pancreatic disease, drugs, infections, genetic syndromes, etc.) [1-2]. According to the World Health Organization (WHO), approximately 422 million people have diabetes in the world. Annually, 1.5 million people die directly from diabetes [3]. Diabetes has been increasing rapidly over the last few decades.

People's quality of life is increasing. Technological advances in the field of health have provided improvements in the field of diagnosis and treatment. One of the biggest developments in the field of health is the introduction of artificial intelligence applications. Artificial intelligence in healthcare is used in different areas such as administrative and clinical applications [4]. Artificial intelligence applications are utilized in areas such as arterial hypertension management, cardiovascular diseases, diabetes management, chronic disease management [5]. In addition, there are many studies on the diagnosis, classification, prediction and risk assessment of diseases [6]. As in the industry, Health 4.0 has started to be mentioned in the field of health [7].

Özer conducted research on early detection of diabetes using long short-term memory [8]. A dataset of 520 patients and 16 features for each patient is used. The results obtained are evaluated according to the F1score performance metric. Sevimli Deniz compared and analyzed partial decision algorithm, fuzzy unordered rule algorithm, repetitive incremental pruning algorithms, and decision trees [9]. For this purpose, diabetes, wine, sensor, labor, credi card, hypothyroid, soybean, messidor futures datasets are used. The fuzzy unordered rule algorithm gave the best results. Ergün and İlhan conducted a study on early stage diabetes prediction [10]. Neural network gave the highest result with 99.04% and naive bayes gave the lowest result with 88.5%. Yıldırım and Çalhan, created a machine learning based Apache Spark model for early diagnosis of diabetes in their study [11]. The results showed that the Apache Spark model can be used in the health field. Başer et al. tried to diagnose diabetes using K-Nearest Neighbor (K-NN), decision trees, logistic regression, Naive Bayes, and random forest [12]. They used a dataset of 70000 records from 130 hospitals in the USA. Random forest gave the best classification performance. Kivrak emphasizes the early diagnosis of diabetes in his study [13]. Stochastic gradient boosting, multilayer perceptron, and support vector machine are used in the study. As a result of the study, support vector machine gave the highest accuracy rates.

In this study, a diabetes dataset consisting of Pima Indian women at least 21 years old is attempted to classify. The K-NN algorithm is used for this purpose. 10 different distance metrics are used and the effect of distance metrics on classification success is analyzed. The results are evaluated with accuracy and F1score performance metrics and are presented in tables and graphs

2. MATERIAL AND METHODS

K-NN is an powerful machine learning easy-to-use algorithm. K-NN is an instance-based machine learning algorithm. In instance-based learning, when a new instance enters the model, it assigns the new instance to a class by comparing it with other data stored in memory [14-15]. In order to determine the K clusters with the least squared error, the K-Means Method iteratively partitions the data to reduce the distances to the cluster. This methodical process is carried out repeatedly until the data stabilizes. The following stages are used to do the computations in K-NN [16-17]:

1. Clusters are represented by allocated centers.
2. Determining the data's new distances from the cluster centers and clustering them
3. Assign the data to new clusters in order to calculate the new cluster centers.
4. Continue doing the preceding 2 actions until the cluster centers stay the same.

The correct choice of K value is important for classification. If K is set to 1, the bias is low but the variance can be large. At the same time, a K value of 1 means that the predictions of the new models (patterns) to be predicted are made using the closest single training sample. Depending on the size of the data set, K can take different values [18-19]. When classifying, K-NN calculates the distances for a given value of K and creates a group. The data to be classified is included in the most appropriate group [20].

3. SIMULATION RESULTS

In this study, diabetes prediction is performed using K-NN, an artificial intelligence based classifier. the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) conducts research on diabetes, obesity, urologic and hematologic diseases and supports studies in the field of health. The dataset used in the study is created by the NIDDK [21-22]. The dataset consists of a total of 768 individuals. The data set includes 500 people without diabetes and 268 people with diabetes. The data set constitutes of Pima Indian women at least 21 years old. The dataset includes Body Mass Index (BMI), pregnancies, glucose, diabetes pedigree function, skin thickness, insulin, blood pressure, age features of individuals. Descriptions of the features used in the dataset are given in Table 1. Validation and test results are given in Table 2.

Table 1. Descriptions of the features used in the dataset

Features	**Descriptions**
BMI	Body mass index (weight in kg/(height in m)^2)
Pregnancies	Number of times pregnant
Glucose	Plasma glucose concentration a 2 hours in an oral glucose tolerance test
Diabetes pedigree function	Diabetes pedigree function
Skin thickness	Triceps skin fold thickness (mm)
Insulin	2-Hour serum insulin (mu U/ml)
Blood pressure	Diastolic blood pressure (mm Hg)
Age	Age (years)

Outcome	Class variable (0 or 1)

Table 2. Validation and test results

Number	Distance Metric	Validation Accuracy (%)	Validation F1score	Test Accuracy (%)	Test F1score
1	Euclidean	72.3	0.5041	78.3	0.6032
2	Hamming	64.6	0.2759	67.0	0.2692
3	Chebyshev	72.3	0.5068	77.4	0.5667
4	City Block	73.2	0.5079	72.2	0.4667
5	Mahalanobis	71.5	0.4716	73	0.4561
6	Cosine	75.0	0.5831	76.5	0.5846
7	Minkowski	74.3	0.5532	77.4	0.5667
8	Jaccard	64.6	0.2759	67.0	0. 2692
9	Correlation	68.6	0.3953	67.8	0.3509
10	Spearman	68.3	0.3894	71.3	0.4211

As seen in Table 2, the highest validation accuracy rate belongs to the cosine distance metric, which is 75.0% in number 6. Also, the highest test accuracy rate belongs to the Euclidean distance metric, which is 78.3% in number 1. The lowest validation accuracy rate belongs to the hamming and jaccard distance metrics, which is 64.6%. The lowest test accuracy rate again belongs to the hamming and jaccard distance metrics, which is 67.0%. It is observed that F1score values are in parallel with accuracy values.

An accuracy of a classification model is displayed in a confusion matrix. The confusion matrix is used to show the number of false positives, false negatives, true positives, and true negatives. The validation and test confusion matrices for the euclidean and cosine distance metrics are given in Figure 1 and Figure 2 respectively. Since the validation and test confusion matrices for hamming and jaccard distance metrics are the same, they are given in Figure 3.

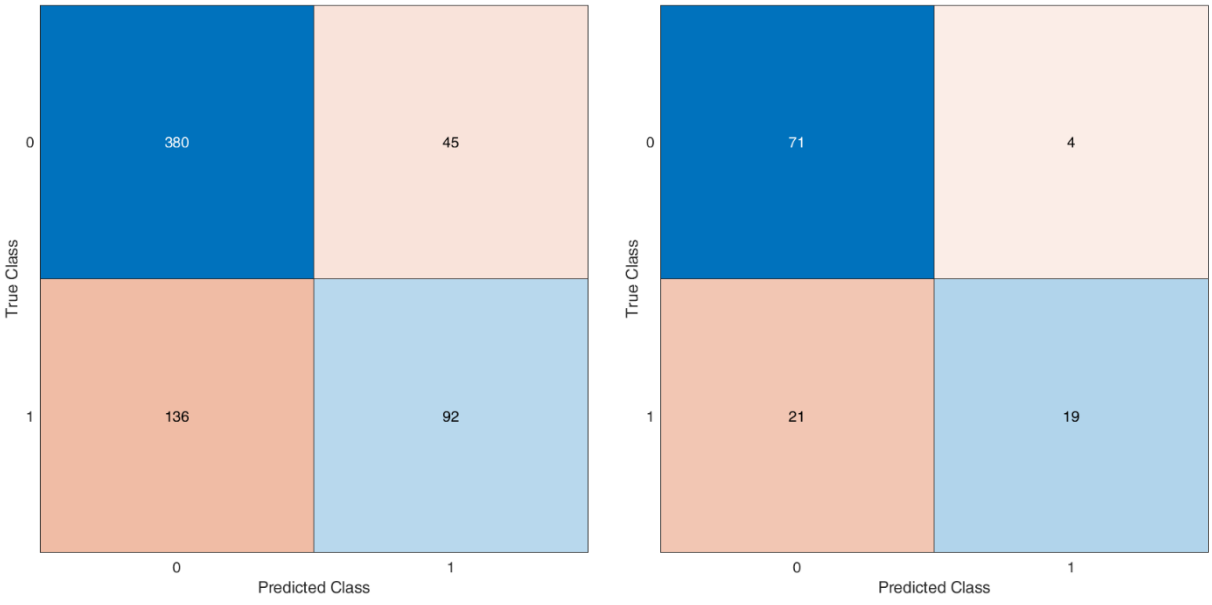

Figure 1. Euclidean distance metric (a) Validation (b) Test confusion matrices

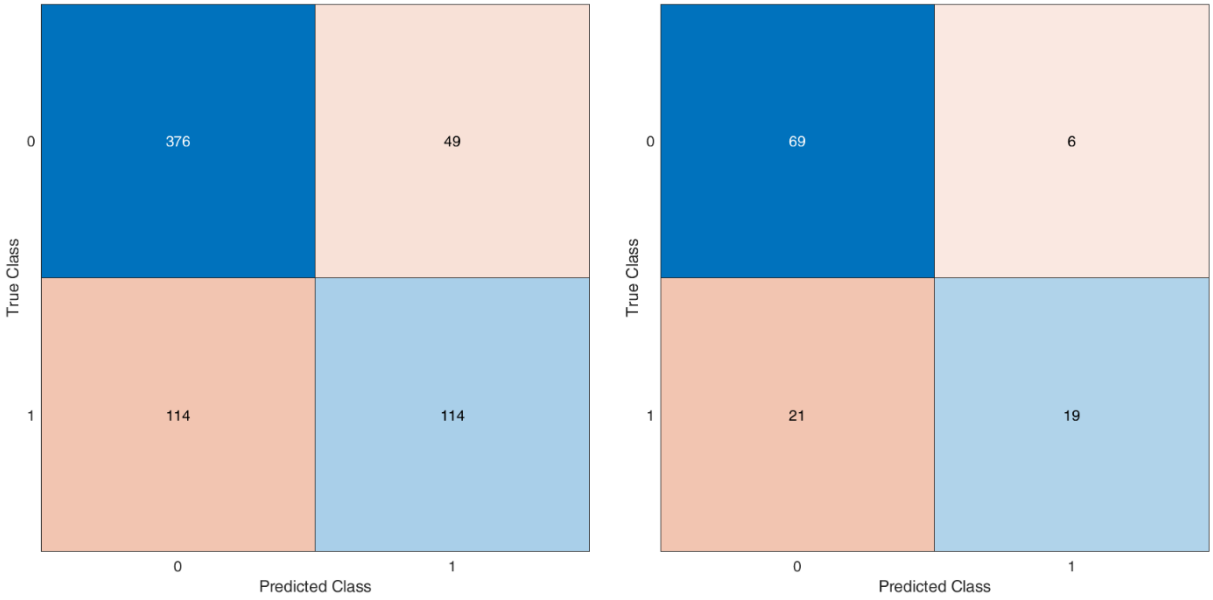

Figure 2. Cosine distance metric (a) Validation (b) Test confusion matrices

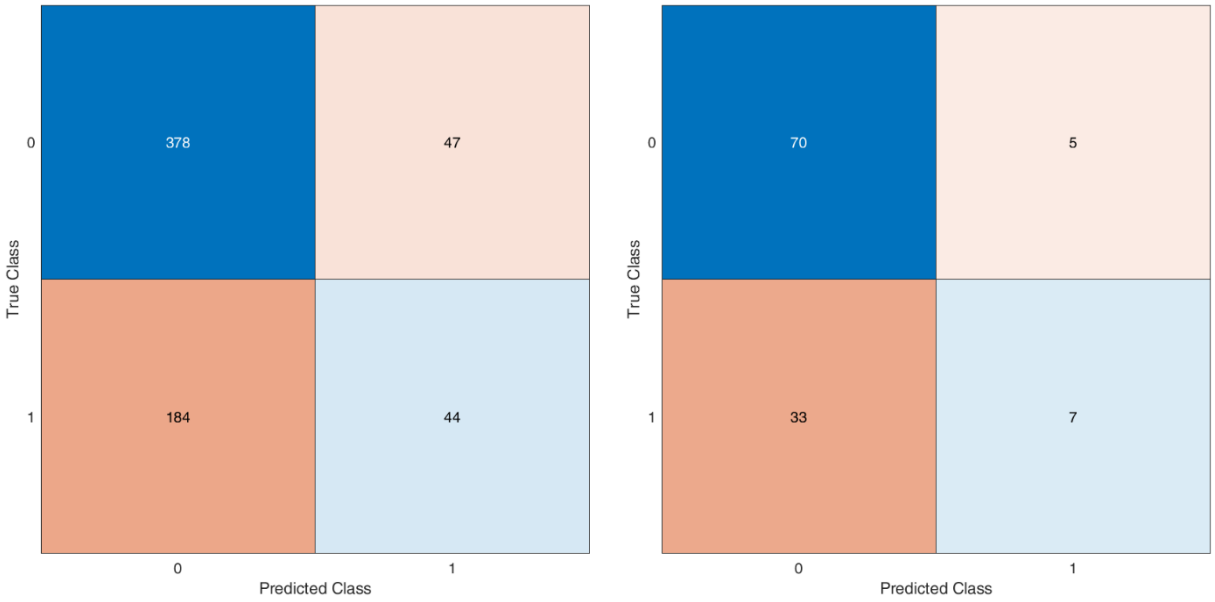

Figure 3. Hamming and jaccard distance metric (a) Validation (b) Test confusion matrices

For classification difficulties, the Receiver Operating Characteristic (ROC) curve is a key performance metric. The area under the curve, or AUC, is represented by a probability curve called the ROC. The performance of classification improves as the AUC value gets closer to 1. The validation ROC curves for the classifications using the euclidean and cosine distance metrics are displayed in Figure 4.

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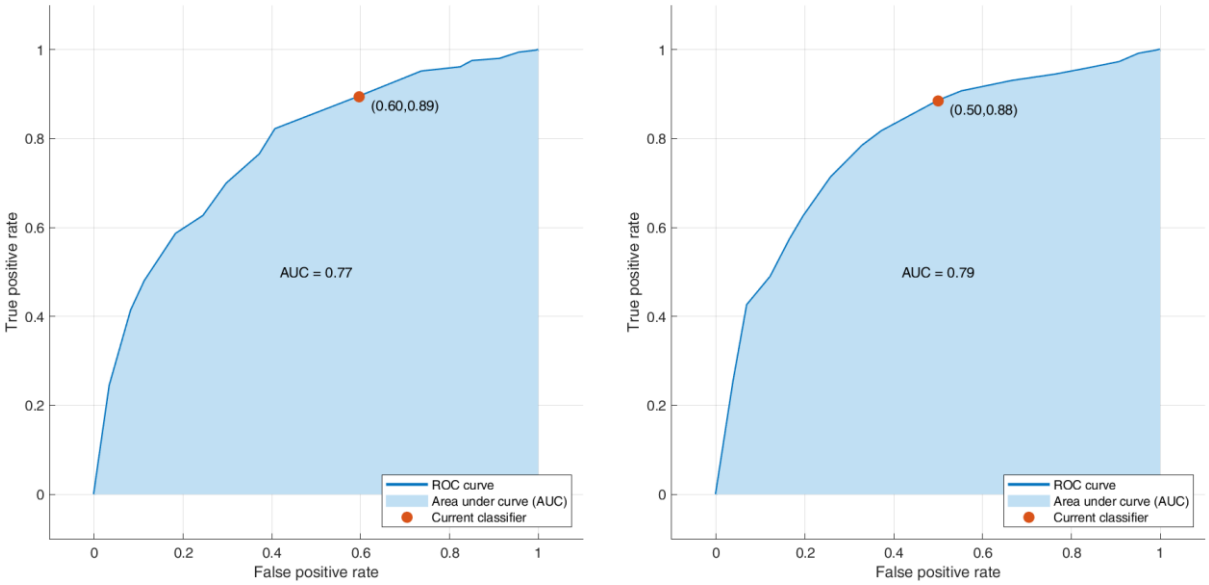

Figure 4. ROC curve (a) Euclidean (b) Cosine distance metrics

As can be seen in Figure 4, as in the validation accuracy values, the cosine distance metric AUC value of 0.79 is higher than the Euclidean distance metric value of 0.77.

4. CONCLUSIONS AND DISCUSSIONS

In this study, diabetes prediction, which is one of the uses of artificial intelligence in the health field due to the rapidly increasing diabetes in the world, is studied. For this purpose, a dataset consisting of 768 people and created by NIDDK is used. 15% of the dataset is allocated as a test set. K-NN algorithm is used for classification. In the K-NN algorithm, 10 different distance metrics are used during training and it is seen that it is one of the important parameters affecting the performance of the K-NN algorithm. The results obtained from the study showed that while some distance metrics gave similar results, some of them differed positively (euclidean, cosine) and some of them differed negatively (hamming, jaccard). The F1score performance metric is found to be in parallel with accuracy rate. Through this study, one of the application areas of artificial intelligence in healthcare has been demonstrated.

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DIODE PERFORMANCE OF MGO MATERIAL

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ABSTRACT

MgO material is a material with electrical conductivity in liquid state. Especially acidic solutions are frequently prepared. Due to these properties, it has become a preferred material in semiconductor technology. In this study, MgO material was dissolved in 5% HCl acid and used as an interface material in diode production. Morphological analyses of this solution were performed using SEM and TEM imaging techniques. p-Si material was used as the base material and Au metal was used for the upper contact and Al metal was used for the back contact. Current-voltage (I-V) measurements of the Au/MgO/p-Si/Al diode obtained as a result of these processes were carried out. From these measurements, some electrical diode parameters (ideality factor, series resistance and barrier height) were calculated. These calculated values were compared with the parameters of the reference diode (Au/p-Si/Al). It was observed that there were significant improvements in the electrical parameters of the target diode compared to the reference diode. In particular, it was determined that the ideality factor value approached 1, which is the ideal value. Additionally, capacitance-voltage (C-V) measurements were performed for different frequency values of the target diode. From these measurements, electrical parameters such as average barrier height (Φ_b), diffusion potential (V_d), carrier concentration (N_a) and Fermi energy level (E_f) were calculated. The variation of these values against frequency change was analyzed.

Key Words: MgO, Schottky Diode, Thermionic Emission, Current-Voltage, Capacitance-Voltage

1. INTRODUCTION

Nowadays, materials are examined in three different ways in terms of electrical conductivity: conductors, semiconductors and insulators. In order to understand semiconductor materials, which form the basis of this study, we must examine the band structures of semiconductors and other materials. Because band structures have their own characteristics in each solid, and when examining the electrical properties of a solid, when looking at its band structure, it can be understood why it is a good insulator or conductor.

Semiconductors have a very important advantage. The conductivity properties of the material can be changed by doping in a controlled manner. Therefore, charge carriers can be created by

adding impurity atoms to semiconductors. The semiconductor created as a result of such a process is called a doped semiconductor. As a result of doping, new energy levels are formed within the forbidden band gap. If we evaluate this with an example, when Arsenic, a VA group element, is doped to Silicon, which is the original semiconductor in the IVA group, four electrons of Silicon and four electrons of Arsenic form a tight covalent bond, while the fifth electron of Arsenic creates a new energy level under the conduction band. This level is called the donor energy level.

Depending on the interface layer thickness between the metal and semiconductor, MS structures transform into MIS/MOS or MPS structures. Examining the electrical and dielectric properties of these structures gives us important information about device performance. In recent years, how different characteristics of the structures change by changing the interface materials in MIS/MOS/MPS structures has been investigated and the results obtained are expected to contribute to semiconductor technology. In this study, it was aimed to examine the electrical properties of the MOS structure produced by preparing MgO/p type Si structures **[1]**.
When research was done on metal oxides, it was seen that MgO was preferred in many areas from electronic device structure to defense industry systems. The main reasons for this situation are its high melting temperature, its stable structure and its dielectric properties suitable for increasing capacity. MgO in cubic structure is also advantageous due to its wide band gap, thermal insulation and low optical loss **[2]**.

2. EXPERIMENTAL DETAILS

The choice of base material is important in diode production. In this study, p-Si crystal was chosen as the base material. Si can be easily found in nature, it is cheap and durable. In addition, its band gap is compatible with many metals. RCA1 and RCA2 solutions are used to clean the p-Si crystal from chemical impurities **[3]**. In order to examine the morphological properties of the MgO material, the MgO material in the liquid phase was coated on a thin glass using the spin coating method to obtain MgO thin films. TEM and SEM images of this thin film were taken, respectively. The TEM image of the MgO thin film is given in **Fig 1**. The particle size was determined to be around 34 nm from the TEM analysis of the MgO inc film. **Fig 2** shows the SEM image of the MgO thin film. The coating thickness was calculated to be around 20 nm from the SEM analysis of the MgO thin film, The MgO particles show a nearly homogeneous distribution. During the production process of the diode, Al metal was evaporated on the matte surface of the p-Si crystal using a thermal evaporation unit. The shiny surface of the diode was coated with MgO material using the spin coating method. Finally, Au metal was evaporated on the MgO layer using thermal coating. Thus, Au/MgO/p-Si/Al diode and Au/p-Si/Al reference diode were obtained. I-V measurements of these diodes were carried out at room temperature. Also, C-V measurements were carried out for different frequency values of Au/MgO/p-Si/Al diode.

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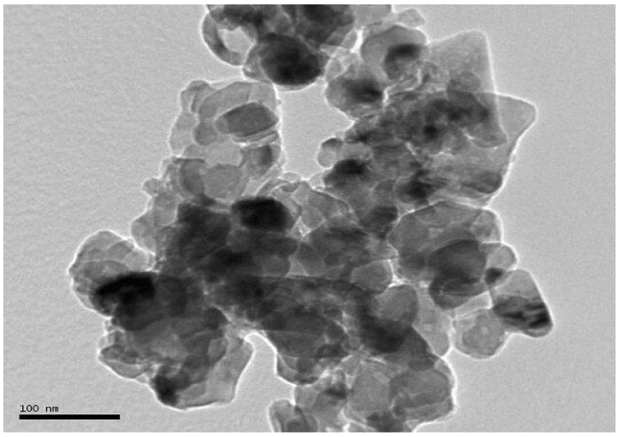

Fig. 1 The TEM image of MgO thin film

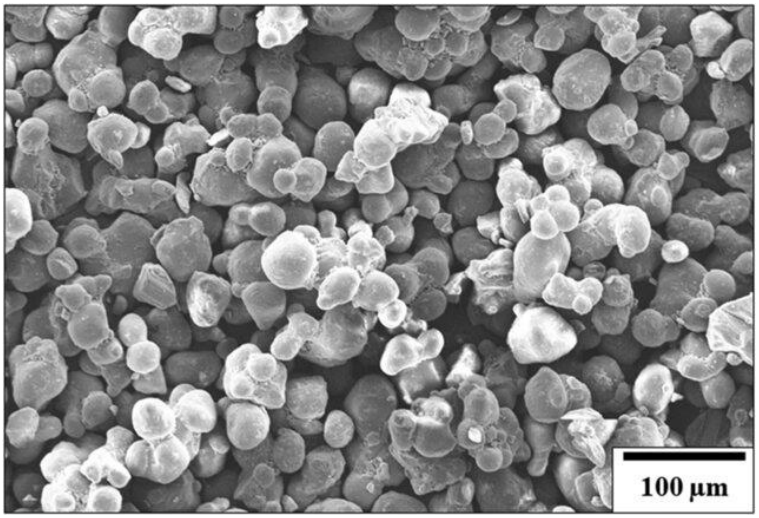

Fig. 2 The SEM pattern of MgO thin film

3. RESULTS AND EVALUATION

The basic diode parameters of the diodes were compared from the I-V measurements performed at room temperature. The comparative I-V graph of the diodes is given in **Fig 3**. The n and Φ_b values of the diodes were calculated using TE theory **[4]**. Also the Rs values of diodes calculated using Cheung methods **[5]**. These values are given in Table 1. When we examine Table 1, it is seen that the n and R_s values of the target diode are lower than the reference diode. It was determined that the Φ_b value of the target diode is higher than the reference diode. This situation is seen that the interface material (MgO) improves the diode parameters. The n value of an ideal diode is 1. Therefore, the closer the n value is to 1, the closer it gets to ideality **[6]**. R_s plays an important role in the I-V characteristics of diodes, especially in high voltage regions. The R_s effect moves the I-V characteristic of the diode away from linearity and causes bending at high

flat supply voltage values. For this reason, a low R_s value is desired in diodes **[7]**. In addition, the higher the Φ_b value in diodes, the higher the quality of the diode.

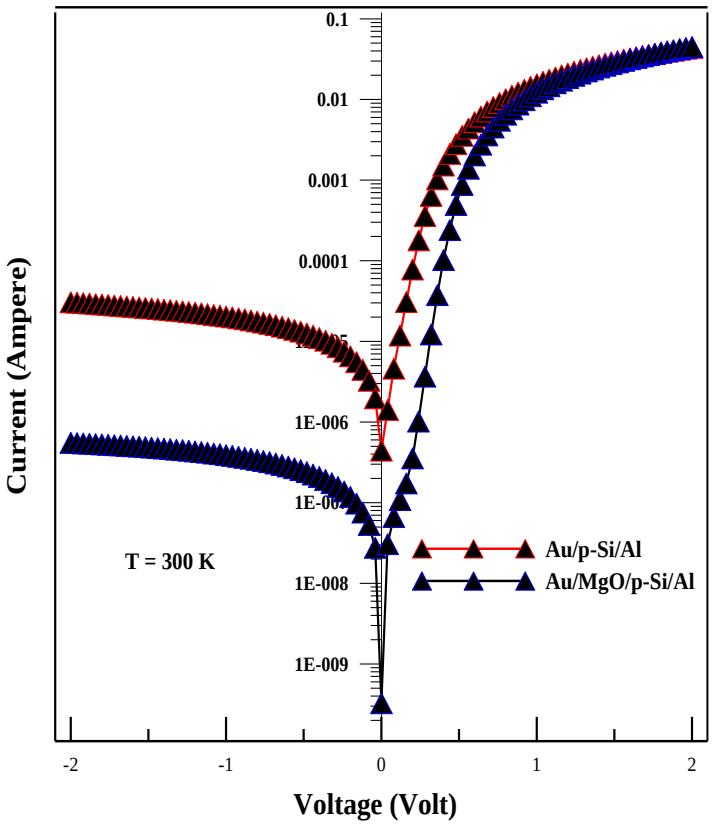

Fig. 3 The I-V plots of diodes

Table 1 The n, Φ_b and R_s values of diodes

Diodes	n	Φ_b (eV)	R_s (Ω)
Au/p-Si/Al	2.21	0.65	3107
Au/MgO/p-Si/Al	1.54	0.73	1810

The I-V measurements are not always sufficient to understand the current conduction mechanisms of diodes. Since the depletion region formed at the interface of metal-semiconductor (MS) contacts acts like a capacitor, the data obtained from C-V measurements of diodes are analyzed **[8]**. From these data, values such as diffusion potential, carrier concentration, barrier height and Fermi energy level are calculated. **Fig 4** shows the C-V graphs of Au/p-Si/Al and Au/MgO/p-Si/Al diodes. When we examine this graph, it is seen that the capacity of the target diode is higher than the reference diode. The MgO interface material has an increasing effect on the diode capacity.

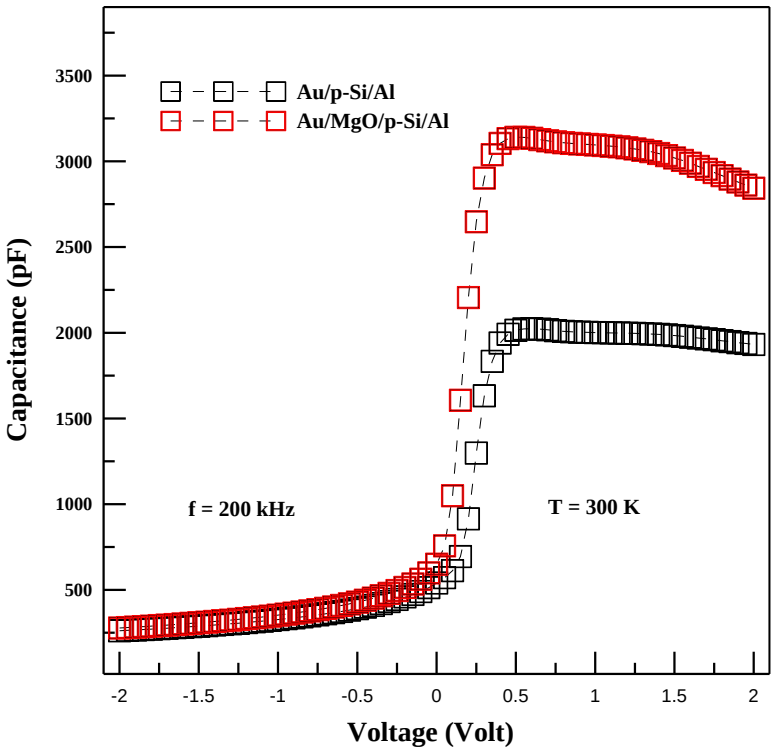

Fig. 4 The C-V plots of diodes

To investigate the effect of frequency change on the capacitance, C-V measurements of the Au/MgO/p-Si/Al diode were carried out for the frequency values of 200 kHz, 500 kHz and 1000 kHz, respectively. The C-V graph for different frequency values of the target diode is given in **Fig 5**. The V_d, Φ_b, E_f and N_a values calculated with the help of this graph were calculated **[9]** and these values are given in **Table 2**. As seen in Fig 5, the diode capacitance decreases with increasing frequency value.

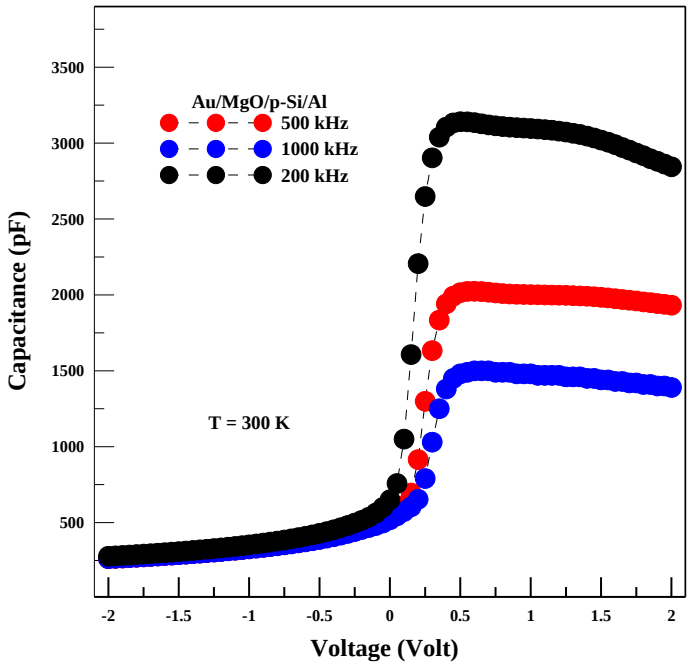

Fig. 5 The C-V-f graphs of Au/MgO/p-Si/Al diode

The E_f value does not change with increasing frequency when **Table 2** is examined, This is because the E_f value is constant in the equilibrium state. The N_a, V_d, and Φb values decrease with increasing frequency values, In this case, the interface states can follow AC signals at low frequency values, but cannot follow them at high frequencies **[10]**.

Table 2 The E_f, N_a, V_d, and Φ_b values of Au/MgO/p-Si/Al diode

Frequency (kHz)	V_d (V)	N_a (cm^{-3}) x 10^{13}	E_f (eV)	Φ_b (eV)
200	0.69	1.88	0.32	0.96
500	0.62	1.56	0.32	0.88
1000	0.58	1.08	0.32	0.79

4. CONCLUSIONS

The basic diode parameters were calculated from the I-V characteristics of the Au/MgO/p-Si/Al diode obtained by using MgO material as the interface coating material. When the n, Φ_b and R_s values of the target diode and the reference diode were compared, it was determined that the MgO material improved the diode parameters. In addition, when the C-V measurements of the diodes at room temperature were compared at a fixed frequency, it was observed that the capacitance value of the target diode was higher. It was determined that the MgO material contributed to the diode capacitance. The E_f, Φ_b, N_a and V_d values of the Au/MgO/p-Si/Al diode were calculated from the C-V measurements performed for different frequency values. It was determined that the Φ_b, N_a and V_d values of the diode decreased with increasing frequency values.

Acknowledgments
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EFFECTS OF TEMPERATURE AND RADIATION ON ELECTRICAL PARAMETERS OF Au/MgO/p-Si/Al DIODE

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ABSTRACT

Due to the electrical conductivity properties of aqueous solutions of MgO material, it has begun to be used frequently in semiconductor technology. In this study, Au/MgO/p-Si/Al diode was produced by coating MgO aqueous solution onto p-Si by spin coating method. Current-voltage (I-V) measurements of this diode were carried out at different temperatures. From these measurements, ideality factor (n), barrier height (Φ_b) and series resistance (R_s) values were calculated for each temperature value. It was determined that with increasing temperature value, ideality factor and series resistance values decreased while the barrier height value increased. This was attributed to the inhomogeneous structure of the potential barrier at the diode interface and the increase in the number of ionized electrons as the temperature increases. It was determined that the diode parameters were strongly dependent on the temperature gradient.
One of the important parameters affecting the performance of semiconductor circuit elements is the radiation effect. For this reason, different doses of X-Ray radiation were applied to the diode. As a result of each application, I-V measurements of the diode were performed and diode parameters were calculated. It was determined that as the radiation dose increased, the n and R_s values increased and the Φ_b value decreased. It was determined that radiation was quite effective on the diode parameters. This is attributed to the destructive nature of the radiation and the defects it creates at the diode interface.

Key Words: MgO, Schottky Diode, Thermionic Emission, Cheng Fuctions, Radiation.

1. INTRODUCTION

The importance and industrial importance of Schottky diodes, which have been increasingly important since the beginning of the last century and are still being studied theoretically and experimentally, is indisputable. These circuit elements, which are used in almost all electronic devices, are also used in solar cells, low voltage circuits, microwave receivers as mixers, detectors, sensors, modulators and demodulators, and other different areas. For metal-semiconductors, current conduction over the barrier height, i.e. the I-V characteristics of Schottky contacts, is related to two parameters. These are the barrier height and the ideality factor. It was suggested in 1987 that the barrier height emerging between the metal and semiconductor may exhibit inhomogeneous behavior. It is also known that these two parameters will differ in each diode due to the inhomogeneity of the barrier height. In a study conducted by Tung in 2001, it was stated that as a result of the experimental data obtained, if the ideality

factor is greater than 1.03, the current-conduction mechanism cannot be explained only by the thermionic emission model, and this situation can be explained by other suitable mechanisms such as tunneling, production-recombination **[1]**.

Temperature-dependent I-V characteristics of metal-semiconductor (MS) junctions are used to explain dominant current mechanisms. However, detailed information about the nature of the barrier formation and conduction mechanism at MS interfaces requires measurements and interpretation over a wide temperature range. In metal-semiconductor Schottky diodes, many current conduction mechanisms can occur. However, in a certain voltage region and temperature range, only one, two or more current conduction mechanisms can be dominant **[2]**. In the field of nanotechnology, magnesium oxide (MgO) nanoparticles have attracted great attention due to their unique physical and chemical properties. With their dimensions in the nanometer scale, these nanoparticles exhibit unique characteristics not observed in their macroscopic form. These properties offer potential applications in various fields such as catalysis, energy, and environmental remediation. The increasing research on MgO nanoparticles is supported by their properties such as high thermal stability, excellent dielectric properties, and robustness as antioxidants. These properties make them a versatile material for technological advances. Magnesium oxide nanoparticles produced by nanography are designed to the highest standards and offer researchers and technologists a reliable and versatile nanomaterial that enables innovation and efficiency in multiple applications **[3]**.

In this study, Au/MgO/p-Si/Al Schotty diode obtained by vacuum metal evaporation method on p-type Si semiconductor was prepared and current-voltage measurements were made at different temperatures and some basic parameters such as ideality factor (n), barrier height (Φ_b) and series resistance (R_s) were investigated.

2. EXPERIMENTAL DETAILS

The chemical cleaning of p-Si used for the production of the diode was carried out using RCA1 and RCA2 solutions, respectively **[4]**. The bottom of the p-Si crystal was coated with Al metal in the thermal evaporation unit. The top of the crystal was coated with MgO material using a spin coating device. Au metal was coated on the MgO layer to create the top contact. Thus, Au/MgO/p-Si/Al diode was produced. The schematic representation of this diode is given in **Fig 1**. In this figure, the upper and lower contact layers of the diode as well as the interface layer are shown. In addition, the connection of the measurement system to the diode is shown. The energy-band diagram of the Au/MgO/p-Si/Al diode before and after contact is given in **Fig 2**. In this figure, the before contact and after contact energy levels of the diode are shown. After the contact, it is seen that the Fermi energy level is aligned as well as the bending of the bands.

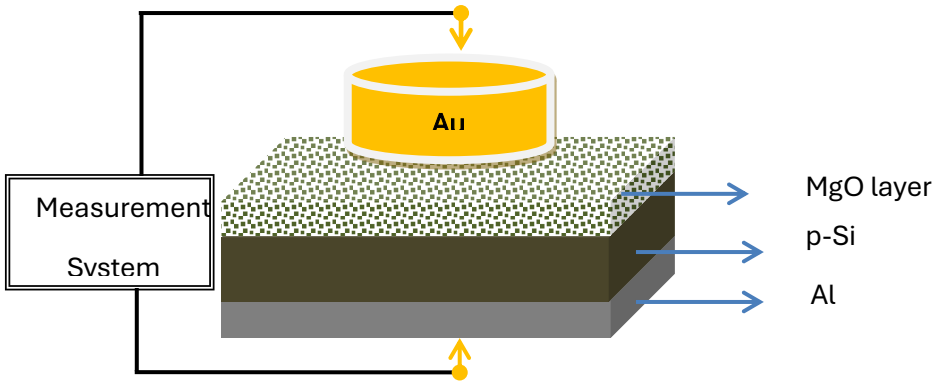

Fig.1 Schematic representation of Au/MgO/p-Si/Al diode

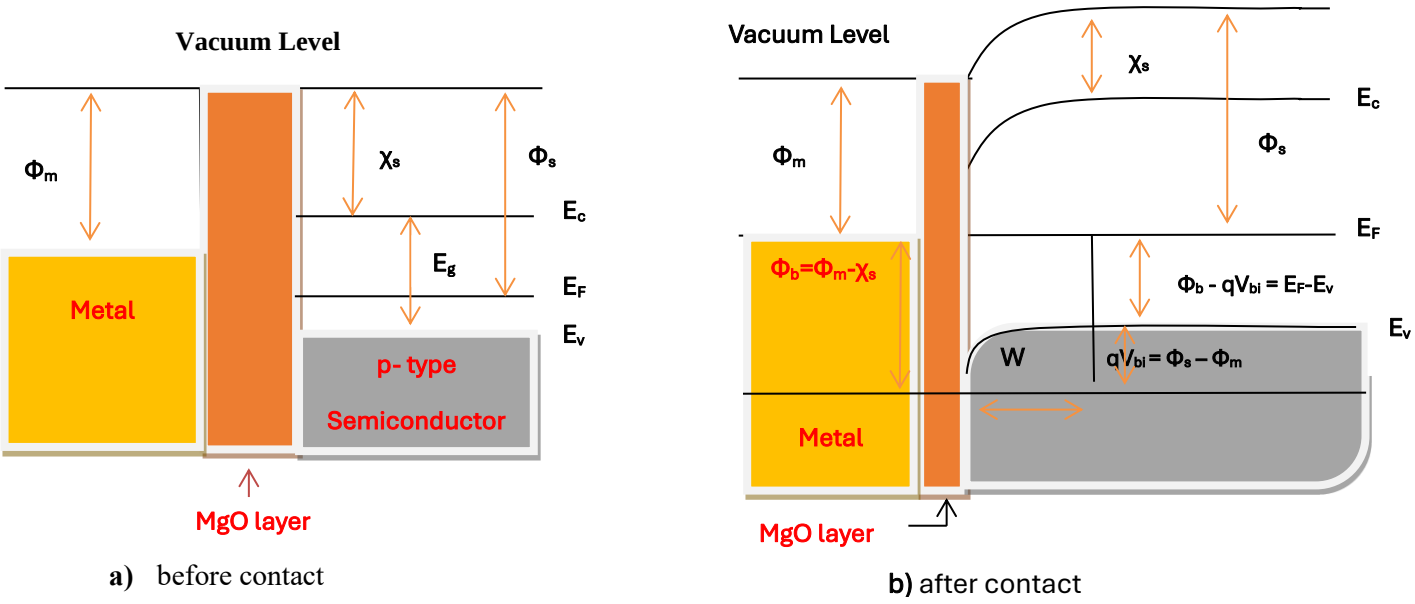

Fig. 2 The energy-band diagram of Au/MgO/p-Si/Al diode

3. RESULTS AND DISCUSSIONS

The I-V measurements of the Au/MgO/p-Si/Al diode were carried out between the temperature values of 100 K and 350 K in 50 K steps with the help of a cryostat and temperature control unit. The I-V graph of the diode depending on temperature is given in **Fig 3**. The diode parameters calculated usin the Thermionic Emission (TE) theory **[5]**. **Table 1** shows the ideality factor (n) and barrier height (Φ_b) values calculated for different temperature values of the diode. As can be seen from the table, the n of the diode starts from 1.56 and increases to 2.77 with decreasing temperature. In addition, the Φ_b value starts from 0.32 eV and increases to 0.69 eV with increasing temperature. An ideality factor greater than 1 is an indication that the diode is far from ideality. In Schottky diodes, the current conduction mechanism at the interface changes with temperature. At low temperatures, the electron encounters a low potential barrier, while at

high temperatures it encounters a greater barrier. This situation makes electron transfer dominant as the temperature decreases and the ideality factor value increases **[6]**. Electrons will have more energy with the increase in temperature. Thanks to this energy they have, they can easily pass through the potential barrier. For this reason, the flat supply voltage and the increase in temperature increase the height of the potential barrier **[7]**.

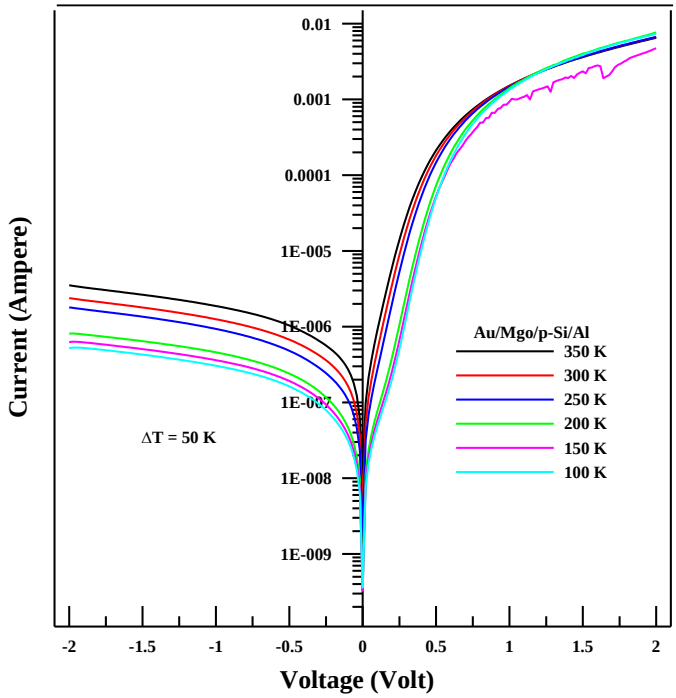

Fig. 3 The I-V-T plots of Au/MgO/p-Si/Al diode

Table 1 The n and Φ_b values of Au/MgO/p-Si/Al diode

T (K)	n	Φ_b (eV)
350	1.56	0.69
300	1.77	0.61
250	1.94	0.54
200	2.23	0.45
150	2.49	0.38
100	2.77	0.32

One of the important parameters in diodes is the series resistance. The large series resistance (R_s) value provides linearity in the direct supply I-V curve in a smaller range. While the series resistance value is calculated in this nonlinear region, linear and nonlinear regions are needed to calculate the ideality factor and barrier height values. One of the important methods for calculating the R_s value in diodes is the Norde functions **[8]**. The F(V) - V graph of the Au/MgO/p-Si/Al diode is given in **Fig 4**. The Rs values calculated using the Norde functions depending on the temperature of the diode were given in **Table 2**. When the values in the table are examined, the R_s value decreases with increasing temperature. This situation is explained

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by the contribution of the number of electrons ionized with increasing temperature to conductivity **[9]**.

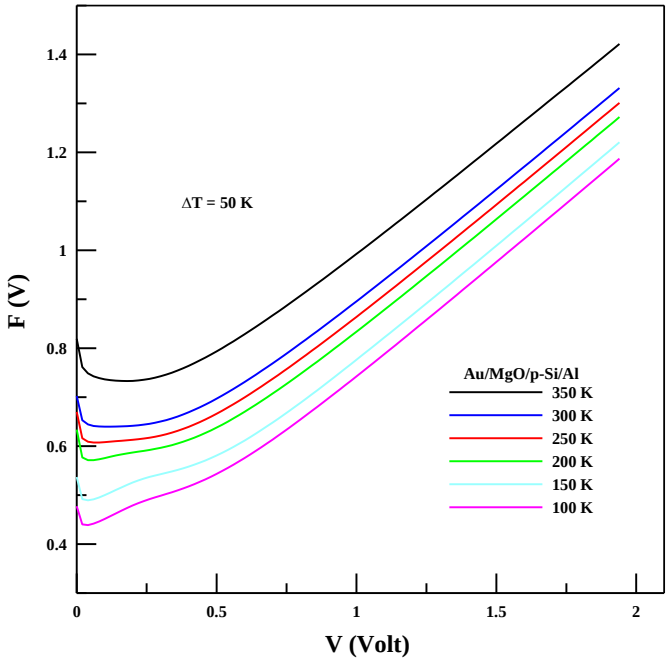

Fig. 4 The F(V) – V plots of Au/MgO/p-Si/Al diode

Table 2 The Rs values of Au/MgO/p-Si/Al diode

T (K)	R_s (kΩ)
350	4.4
300	7.2
250	9.4
200	13.6
150	17.2
100	21.8

Electronic semiconductor devices are prone to radiation damage. Many semiconductor materials are exposed to photons or particles as a result of radiation, depending on the environment in which they are used. High-energy photons or particles transfer their energy to semiconductor materials, causing defects in the semiconductor. In the study, Au/MgO/p-Si/Al diode was irradiated at two different doses, 25 Gray and 50 Gray. At the end of each irradiation, I-V measurements of the diode were taken. The forward and reverse bias I-V characteristics of the diode before and after irradiation at different doses are given in **Fig 5**. As can be seen from **Fig 5,** it is seen that the forward and reverse bias currents decrease with increasing doses. The reverse bias current for the diode decreases due to the decrease in electron mobility due to the increased scattering centers and the increase in majority carriers in trap levels such as acceptors **[10]**.

Before irradiation, the n value, Φ_b and R_s values for the Au/MgO/p-Si/Al diode were calculated as 1.56, 0.71 eV and 7.2 kΩ, respectively. After 25 Gray irradiation, these values were calculated as 2.13, 0.62 eV and 9.3 kΩ, respectively, while after 50 Gray irradiation, they were calculated as 2.56, 0.58 eV and 15.6 kΩ. The ideality factor value of the diode increases due to the increase in the probability of recombination of carriers in the trap centers within the intrinsic region.

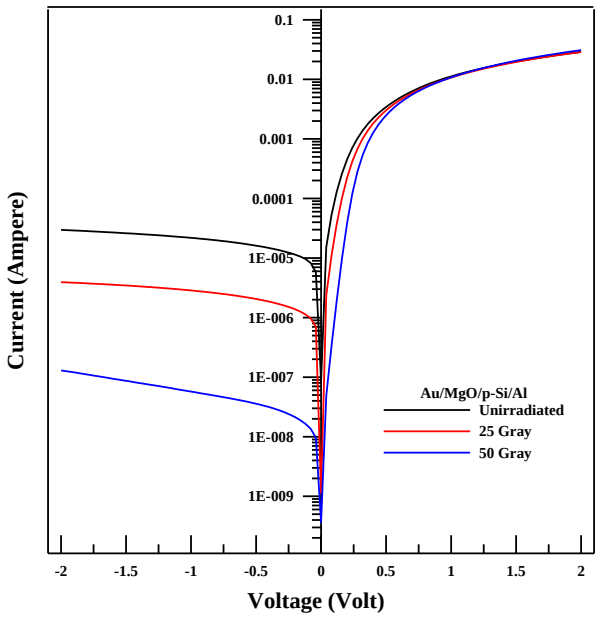

Fig. 5 The I-V graph of Au/MgO/p-Si/Al diode depending on radiation

4. CONCLUSIONS

Using the analysis of temperature dependent I-V measurements of Au/MgO/p-Si/Al diode, it was determined that diode parameters are strongly dependent on temperature. The n and R_s values of the diode decrease with increasing temperature, Also, Φ_b value increases with increasing temperature. This situation is due to the inhomogeneous potential barrier structure of the diode. In addition, the I-V characteristics of the diode were analyzed at various radiation values. It was determined that the I-V characteristics and diode parameters deteriorated with increasing dose.

Acknowledgments

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INVESTIGATION OF THE EFFECTS OF STATCOM IN STEADY STATE OPERATION IN GRID-CONNECTED DFIG-BASED WIND TURBINES

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ABSTRACT

Due to the increase in the prices of fossil fuels and their future depletion, renewable energy sources have started to be used in recent years. One of the most popular renewable energy sources is wind energy. A Doubly Fed Induction Generator (DFIG) with good torque and power control is used in wind turbines preferred in the conversion of wind energy to electrical energy. Due to the system dynamics in DFIG connected to the grid, the use of Static Synchronous Generator (STATCOM) from Flexible AC Transmission System (FACTS) devices is common to ensure stability. In this study, the effects of STATCOM during the modeling of a Fuzzy Logic Controller (FLC) in a 3-bus power system were analyzed. The 3-bus system consists of the grid, the DFIG-based wind turbine, and the load bus. In AC and DC voltage modeling of the STATCOM, Proportional-Integral (PI), Fuzzy-PI, and Fuzzy-Fuzzy were used. In steady state analysis, during the modeling of STATCOM, its voltage, DC link voltage, reactive power, d-q axis currents, and load bus were analyzed. PI-PI, Fuzzy-PI, and Fuzzy-Fuzzy time responses are presented in tabular form separately for the parameters. According to the results of FLC modeling in STATCOM, it was seen that FLC modeling makes the system stable in a very short time.

Keywords: DFIG, STATCOM, FLC, PI,

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1. INTRODUCTION

Electricity companies are now engaging in as many transactions in an hour in electricity markets as they used to conduct in a day. Such increased demand, along with uncertainty of transactions, will further strain the power systems. Furthermore, the large amount of embedded generation connected to the grid will result in further uncertainty in the power flow distribution and impose additional strain on the power systems. Therefore, ensuring the transmission flexibility to meet new and less predictable supply and demand conditions in competitive electricity markets will be a very real challenge. Fortunately, new technologies are becoming available that will help electricity companies maintain power system reliability while handling large volumes of transactions, among which the Flexible AC Transmission System (FACTS) [1-2]. FACTS devices consist of Static Synchronous Compensator (STATCOM), Static Var Compensator (SVC), Static Synchronous Series Compensator (SSSC), Tristor Controlled Series Compesantor and Unified Power Flow Controller (UPFC). Control of STATCOM, which is based on a converter, is made by Proportional-Integral (PI). PI control is negative about the stabilization of the system in terms of time in the analysis compared with other control circuits. Fuzzy Logic Control (FLC) is widely used in order to stabilize the parameters for a short period of time. If the field of use of STATCOM in FLC is analyzed, usage of STATCOM with FLC provides a harmonic elimination in power systems [3-4]. In power systems, in order to improve loadability states, usage of STATCOM with FLC and bus voltage profile changes were analyzed [5]. In conditions of malfunction, STATCOM's effects on voltage and angle of were analyzed by doing it adaptive with FLC [6].In power systems, STATCOM's one of the fields of use is load changes. By using FLC in STATCOM, effects on voltage, active power, and reactive power were analyzed [7]. In power systems, STATCOM's different control modeling and its effects on Critical Clear Time (CCT) were seen, and a comparison of FLC with other control circuits was made [8-9]. In STATCOM with Power System Stabilizer (PSS) analyses, time responses of FLC against great and small distributions were analyzed [10-11]. In this study, PI, Fuzzy-PI, and Fuzzy-Fuzzy comparisons of AC and DC voltage changes of STATCOM that has 2 controller units were made in a steady-state situation. It was seen that the system was stable in a shorter period of time in Fuzzy-Fuzzy usage compared with other scenarios.

2. STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

STATCOM is a FACTS device used for shunt reactive power compensation. The principle of STATCOM is the reactive power compensation, where the reactive power and voltage magnitude of the system can be adjusted, as shown in Figure 1.

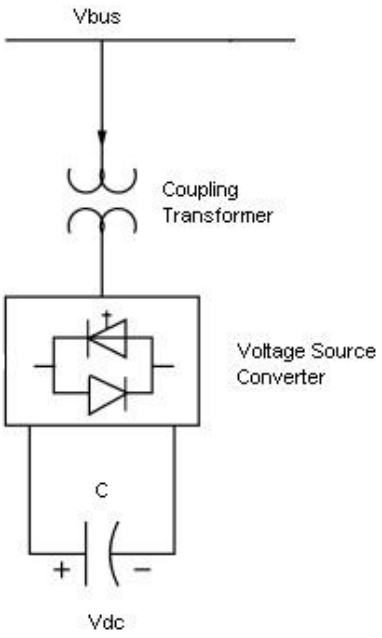

Figure 1. STATCOM model

The STATCOM is a combination of a voltage-sourced converter and an inductive reactance and shunt connected to a power system [12]. The control limits of the controller are directly defined in terms of both the current limits in the electronic switches, which is the main limiting factor in VSC-based controllers, and the DC voltage, which is a secondary operational limit in the controller. This direct implementation of limits allows the steady state V–I characteristics of the controller shown in Figure 2.

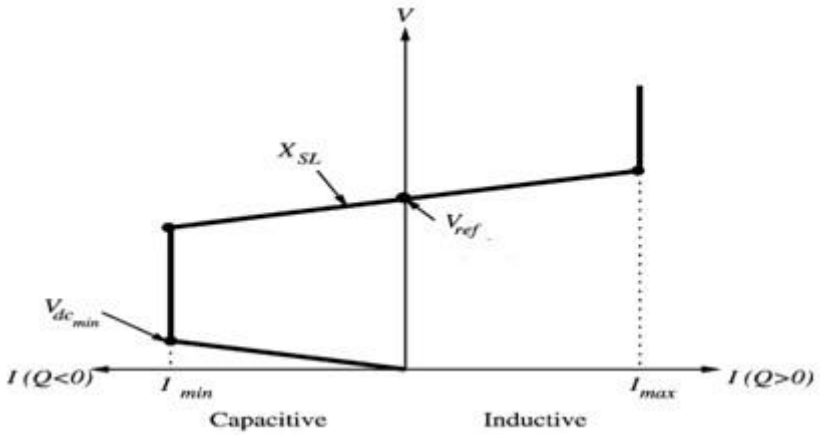

Fig. 2. Steady-State V-I characteristics of STATCOM

In the STATCOM steady-state study, current either pushes power to the system or pulls power from the system according to the parts that it is maximum and minimum. STATCOM steady-state control equations are given in Equations 1-7.

$$V - V_{ref} \pm X_{SL} I = 0 \tag{1}$$

$$V_{dc} - V_{dcref} = 0 \quad (2)$$

$$P - V_{dc}^2 G_c - RI^2 = 0 \quad (3)$$

$$P - VI\cos(\delta - \theta) = 0 \quad (4)$$

$$Q - VI\sin(\delta - \theta) = 0 \quad (5)$$

$$P - V^2 G + kV_{dc} VG\cos(\delta - \theta) + kV_{dc} VB\sin(\delta - \theta) = 0 \quad (6)$$

$$Q + V^2 G - kV_{dc} VG\cos(\delta - \theta) + kV_{dc} VB\sin(\delta - \theta) = 0 \quad (7)$$

where, I measurement current, V_{ref} reference voltage, V_{dc} DC link voltage, V_{dcref} reference DC voltage, P active power, Q reactive power, G conductance, B susceptance, θ admittance angle, δ voltage angle [13].

2.1. STATCOM Control Units

STATCOM AC and DC voltage control are controlled by two PI controllers separately. STATCOM control unit is given in Figure 3.

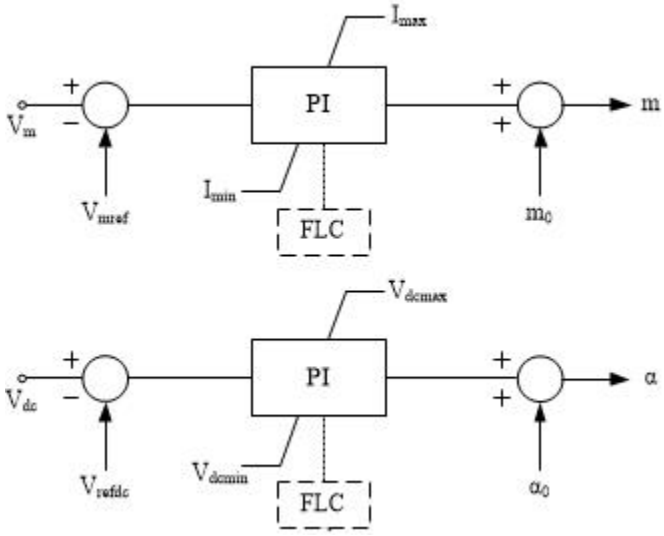

Figure 3. STATCOM voltage control

AC voltage enters to PI controller by comparing reference voltage. Depending on the values that the current is maximum and minimum, the modulation index coefficient is calculated. DC voltage value enters the PI controller with the signal that is accepted as a reference. Angles of converter triggering are produced in maximum and minimum values of capacitor voltage. Triggering angles of tristors and –in order to provide control with FLC- parts of the modulation index that have PI check are converted to FLC.

3. FUZZY CONTROLLER

3.1. Membership Functions

The proposed fuzzy controller is based on Mandani's controllers, which use an 'if-then' ruler for the inference engine. A fuzzy variable is considered for each controller input, and these inputs are fuzzyfied by proper membership functions. Crips output is calculated by the center of area method. The proper membership functions are defined for the output variable.

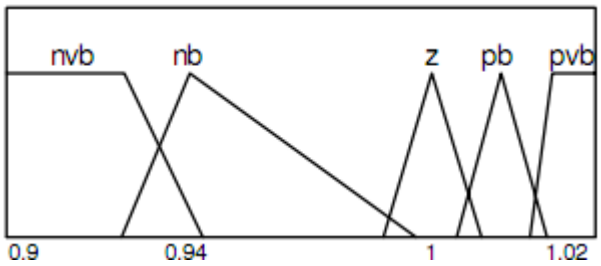

Figure 4(a) Input membership functions V_{ac}

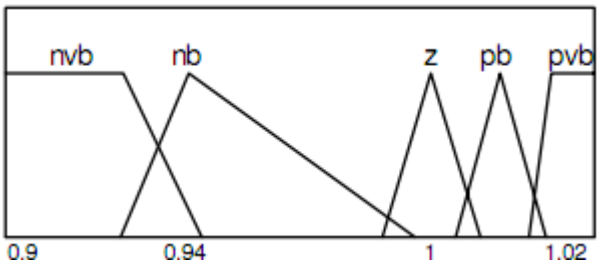

Figure 4(b) Input membership functions V_{dc}

The proper range for each term and the number of membership functions can be defined based on designer experiment and the systems configurations. Membership functions of V_{ac} and V_{dc} are defined in different ways. Figure 5 shows the output membership functions which are used to build controller crips output from the fuzzy output.

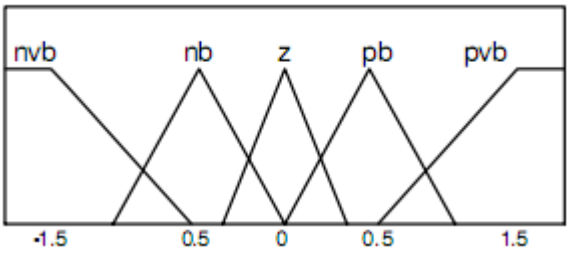

Figure 5. Output membership functions

3.2. Rule Base

The fuzzy control method is realized in the inference engine, which is a rule base containing all possible combinations of input and proper outputs for each of them. Table 1 shows the rule base which is used for the proposed controller [14].

Table 1. Rule base of fuzzy controller

V_{ac}, V_{dc}	nvb	nb	z	pb	pvb
nvb	nb	nb	n	n	n
nb	nb	nb	n	n	n
z	n	n	z	p	p
pb	p	p	p	pb	pb
pvb	p	p	p	pb	pb

4. SIMULATION SYSTEM

In this study, a 3-buses system analysis was made. The modified system model is shown in Figure 6.

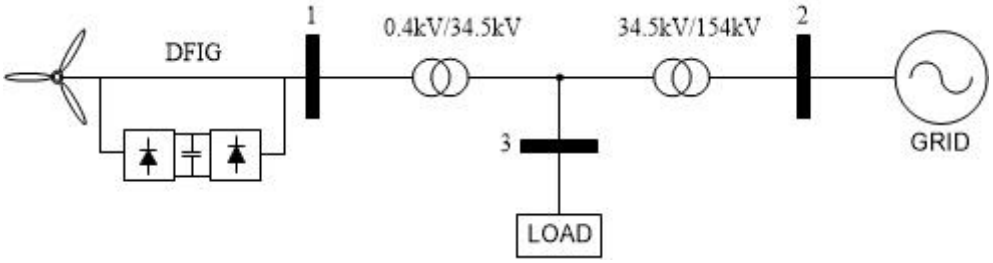

Figure 6. Simulation System Modeling

Bus numbers 1 and 2 are modeled DFIG-based wind turbines and 154 kV grid, respectively. Bus number 3 is modeled as a load bus. In the system, 2 transformers were used. Grid short circuit powers were adjusted to 100MVA. Besides, the Network X/R ratio was chosen as 7. In bus number 3, a 5MW-3MVAr RL load was used. The power of DFIG was used as 9 MW. The load bus was connected to a 10 MVA STATCOM. In the STATCOM control unit, PI-PI, FLC (to the AC side), PI control (to the DC side), and finally, FLC-FLC control combinations were adapted respectively to the AC voltage and DC voltage control parts. In FLC 5x5 order table was formed. In the stable situation analysis, the effects of STATCOM on the system were analyzed.

4.1. Simulation Result

STATCOM's voltage, DC link voltage, reactive power, d-q axes currents, and load bus voltage changes are given in Figure 7-12, during the period STATCOM is connected to the system.

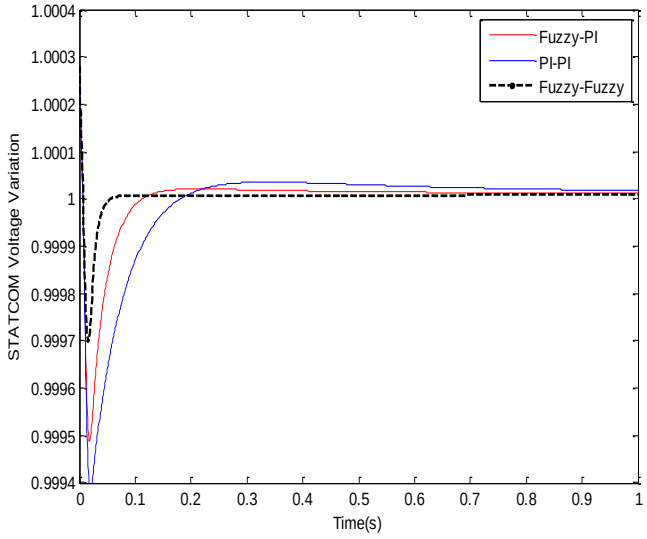

Figure 7. STATCOM voltage variations

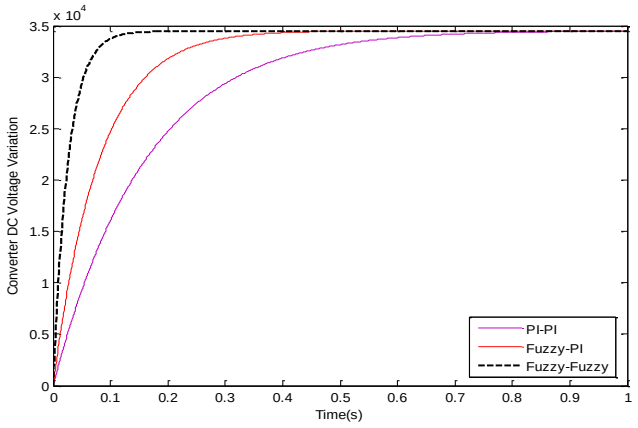

Figure 8. STATCOM DC voltage variations

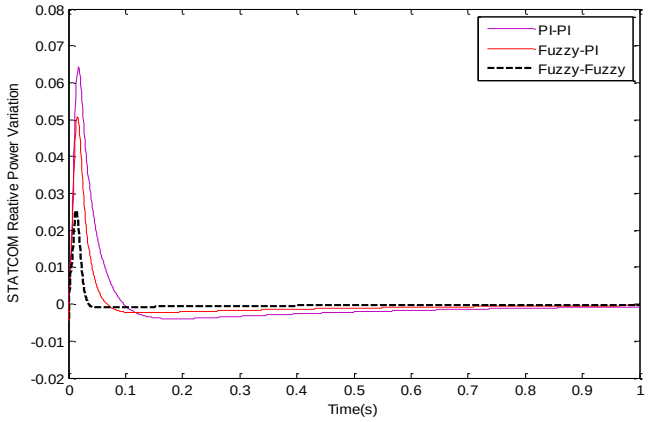

Figure 9. STATCOM reactive power variations

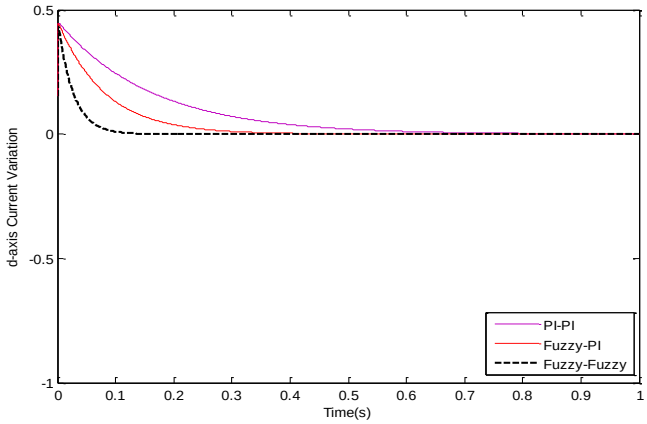

Figure 10. STATCOM d-axis current variations

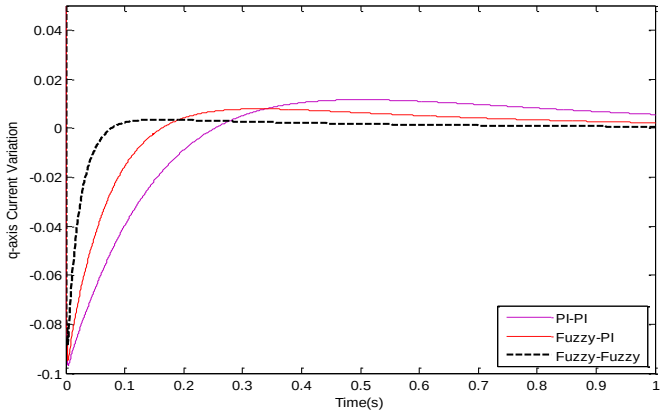

Figure 11. STATCOM q-axis current variations

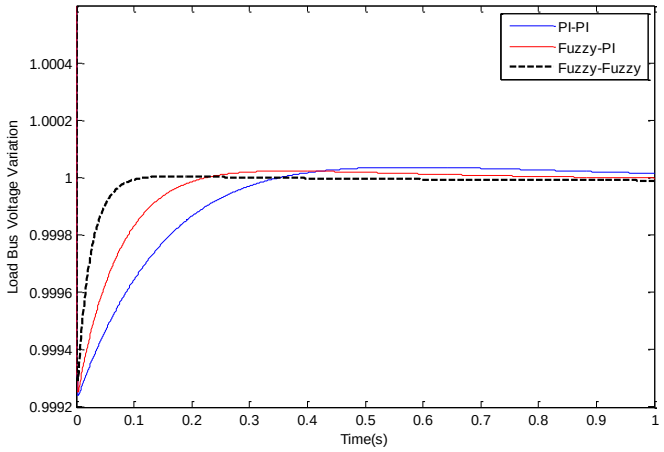

Figure 12. Load bus voltage variations

According to the obtained results, time responses of load bus voltage change, STATCOM's voltage, DC link voltage, reactive power, and d-q axes currents are shown in Table 2.

Table 2. Variables time responses numerical result

Variables	Time Responses (s)		
	Fuzzy-Fuzzy	Fuzzy-PI	PI-PI
STATCOM voltage	0.1	0.2	0.3
STATCOM DC voltage	0.1	0.35	0.6
STATCOM reactive power	0.03	0.1	0.15
d-axis current	0.1	0.3	0.5
q-axis current	0.1	0.3	0.5
Load bus voltage	0.1	0.25	0.4

According to the results, in STATCOM, it was seen that Fuzzy-Fuzzy control rendered the system stable in a shorter period of time compared with the other methods.

5. CONCLUSIONS

In this study, the responses of STATCOM, one of the FACTS devices, in different controllers in DFIG-based wind turbines connected to the grid are discussed in detail. In steady state analysis of the 3-buses system, when the load is in charge, it was seen that STATCOM rendered the system stable in a short period of time. In the controller unit, it was seen that carrying out AC and DC voltage control by Fuzzy-Fuzzy is more efficient than PI–PI and Fuzzy–PI. In STATCOM inside the variable, it was seen that when STATCOM reactive power change is stable in the shortest time, STATCOM DC voltage change is stable in the longest time. In general, as stability, being more efficient and secure of power systems is possible with the usage of STATCOM. This study reveals that different controllers can be used in STATCOM connected to the load bus. Moreover, the ability to obtain the optimal parameter values in the controllers to be preferred with optimization algorithms paves the way for future studies.

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2D MOSE$_2$ BASED SELF-POWERED SCHOTTKY PHOTODIODE DESIGN FOR VISIBLE AND NEAR INFRARED DETECTION

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ABSTRACT

$MoSe_2$ is a two-dimensional transition metal dichalcogenides material and a favourable candidate for broad-range photodetection and optoelectronic applications due to its unique properties, such as composition-dependant optics and electronics properties. Schottky junction-based photodetectors are ultrafast light sensing devices that do not require complex fabrication processes. In this study, a p-type $MoSe_2$-based Schottky photodiode is designed, and its performance is simulated at different physical conditions using the 1D-SCAPS program. It is found that the photodiode's responsivity depends on the $MoSe_2$ thickness and back contact material, whereas it is independent of the incident light intensity, wavelength, and temperature. On the other hand, it is observed that the thickness, back contact, light intensity, wavelength, and temperature affect the device's current density (J)- voltage (V) properties, significantly. The ideal $MoSe_2$ thickness was found to be 1 micrometre (μm), whereas, the best back contact materials were observed to be Nickel (Ni) and Molybdenum (Mo) materials. The proposed device displays a responsivity of about 0.8 A/W at 800 nm, showing that p-$MoSe_2$ has a promising future as an alternative light-sensing material for detecting near-infrared and visible electromagnetic spectrum.

Keywords: $MoSe_2$, Schottky junction, photodetector

GÖRÜNÜR VE YAKIN KIZILÖTESİ ALGILAMA İÇİN İKİ BOYUTLU MoSe$_2$ TABANLI KENDİNDEN GÜÇALABİLEN SCHOTTKY FOTODİYOT TASARIMI

ÖZET

$MoSe_2$, iki boyutlu bir geçiş metali dikalkogenit malzemesidir ve içeriğe bağlı optik ve elektronik özellikleri gibi benzersiz özellikleri nedeniyle geniş bandda foto algılama ve optoelektronik uygulamalar için ideal bir malzeme adayıdır. Schottky bağlantı tabanlı fotodetektörler, karmaşık üretim süreçleri gerektirmeyen ultra hızlı ışık algılama cihazlarıdır. Bu çalışmada p tipi $MoSe_2$ tabanlı Schottky fotodiyot tasarlanmış ve SCAPS programı kullanılarak farklı fiziksel koşullardaki performansı simüle edilmiştir. Fotodiyot duyarlılığı $MoSe_2$ kalınlığına ve arka kontak malzemesine bağlı olduğu, ancak gelen ışık yoğunluğundan, dalga boyundan ve sıcaklıktan bağımsız olduğu bulunmuştur. Öte yandan kalınlık, arka temas

malzemesi, gelen ışık şiddeti, ışığın dalga boyu ve sıcaklık gibi parametrelerin cihazın akım yoğunluğu (J)-gerilim (V) özelliklerini önemli ölçüde etkilediği görülmektedir. İdeal $MoSe_2$ kalınlığı 1 mikrometre (µm) olarak bulunurken, en iyi geri temas malzemelerinin Nikel (Ni) ve Molibden (Mo) malzemeleri olduğu görüldü. Önerilen cihaz, 800 nm'de yaklaşık 0,8 A/W'lik bir duyarlılık sergiliyor; bu, p-$MoSe_2$'nin yakın kızılötesi ve görünür elektromanyetik spektrumu tespit etmek için alternatif bir ışık algılama malzemesi olarak umut verici bir geleceğe sahip olduğunu göstermektedir.

Anahtar Kelimeler: $MoSe_2$, Schottky jonksiyonu, fotodetektör

Introduction

Molybdenum diselenide ($MoSe_2$) is a 2D layered semiconductor material with unique electronic and optical properties and a wide application area. It belongs to a class of layered transition metal dichalcogenides (TMDCs) materials with a formula of MX2 wherein M is a transition metal element and X is a chalcogen. The band gap of $MoSe_2$ is tuneable over a broad spectrum based on the composition of the content materials and the layer of the materials [1]. In addition, $MoSe_2$ has high free charge mobility, low Gibbs free energy and high layer separation (~0.647 nm) compared with its counterparts[2]. These distinctive properties make $MoSe_2$ material suitable for numerous optoelectronic and energy storage applications; hence these materials have been widely studied recently.

Schottky photodetectors are fed through the Schottky barrier formed between the p- or n-type semiconductor and metal[3]. Designing this type of device is easy and cost-effective. Schottky photodiodes have many advantages over their competitor photodetectors, including being highly efficient, fast sensing, broadband responding, and flexible[4]. 2D material based-Schottky photodetectors have been widely discussed recently due to their tailored detectability over UV and Infrared regions. The existence of defects and vacancies on the surface $MoSe_2$ makes the material show p-type properties which is favourable for Schottky-type photodetectors.

In this study, a p-type 2D $MoSe_2$ semiconductor is used to design and simulate a Schottky photodetector using SCAPS -1D software. The photovoltaic and photoresponse performances of the device are simulated at different physical conditions including, temperature, light power, wavelength and semiconductor thickness. The outcomes indicate that fast Schottky photodiodes operating in the visible and near-infrared region are possible with the use of a p-type 2D $MoSe_2$ semiconductor.

Device structure and simulation

In this study, numerical simulation of the 2D $MoSe_2$-based Schottky photodetector was completed using SCAPS. To obtain the current density–voltage (J-V) and responsivity performance of the device Poisson drift and diffusion equations for holes and electrons are solved[5]. The graphic architecture and the energy band diagram of the simulated device are revealed in Figures 1 a) and b), respectively. The MoS_{e2} semiconductor layer is inserted between the back contact and fluorine-doped tin oxide (FTO) conductive glass and the light is illuminated from the transparent FTO glass. Each electrical and optical property values of materials were obtained from previous reports and are showed in Table I.

The defect type was set to neutral and the energy with respect to reference was fixed to 0.6 eV for the $MoSe_2$ layer. The carrier capture-cross sections for electron and holes were set to be 1.0×10^{-15} cm^2. Unless otherwise stated, the device performances were implemented under an incident light of 800 nm and power density of 310 W/m^2.

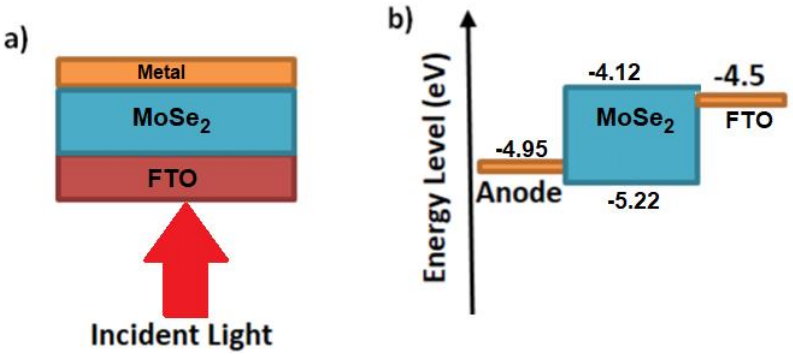

Figure 1. The graphical representation of the device layers(a) and the energy band diagram of each layer(b)

Table 1. The electronic and optical property values for each material used in the design of the Schottky photodiode device.

Parameters	**FTO**[6]	**p-$MoSe_2$** [7]
Thickness (μm)	0.2	1
Band gap (eV)	3.5	1.1
Electron affinity (eV)	4	4.12
Dielectric permittivity	9	8.76
CB density of states(cm^{-3})	2.2×10^{18}	2.8×10^{19}
VB density of states(cm^{-3})	1.8×10^{19}	2.65×10^{19}
Electron thermal velocity (cm/s)	1.0×10^{7}	1.0×10^{7}
Hole thermal velocity (cm/s)	1.0×10^{7}	1.0×10^{7}
Electron Mobility(cm^2/V.s)	20	100
Hole Mobility(cm^2/V.s)	10	50
Donor density(cm^{-3})	10^{19}	1.0×10^{15}
Acceptor density(cm^{-3})	0	0
Defects density(cm^{-3})	1.0×10^{15}	1.0×10^{14}

Initially, to obtain the best p-$MoSe_2$ thickness to operate the device we conducted thickness-dependant J-V and photoresponsivity performance of the photodetector, as seen in Figure 2. It is clear that as the $MoSe_2$ thickness increases both the J and responsivity increase and saturate at about 1 μm. The reason for J to increase with the thickness is that as thickness increases more light is absorbed and hence more free carriers are generated. The reason why J saturates at about 1 μm thickness is that the thickness of the $MoSe_2$ layer exceeds the carrier diffusion length and the photogenerated carriers recombine before reaching the edges of the device. The maximum

short circuit current density (J_{sc}) and responsivity values are recorded to be about 20 mA/cm^2 and 0.7 A/W, respectively. On the other hand, V_{oc} is found to be around 0.4 V and it does not change with variation of the absorber thickness.

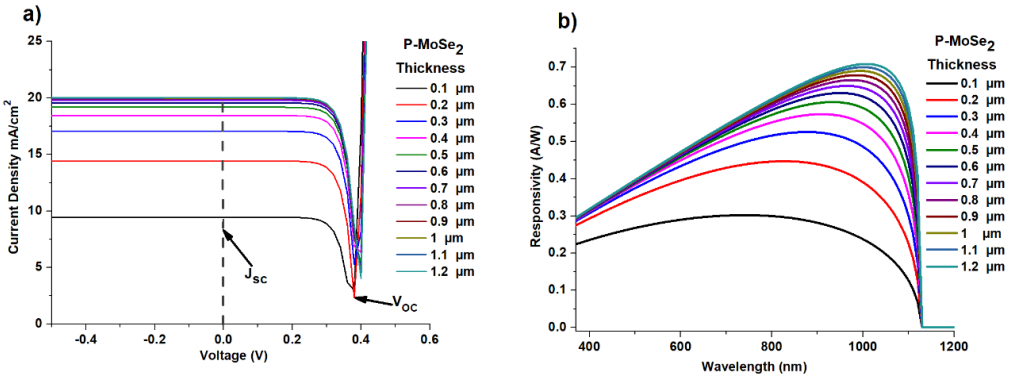

Figure 2. The Thickness dependent J-V (a) and responsivity(b) curves of the photodiode.

The back contact material is significantly important for effectively collecting the photogenerated carriers from the device. The Schottky barrier is formed between the $MoSe_2$ and back contact material. Herein, to obtain the optimum results from the device, we tried several different back contact materials, as seen in Figure 3. Among them, Molybdenum (Mo) and Nickel (Ni) were seen to be the best candidates because of their high work functions in regards to other metals. Therefore, we used Mo for the rest of the study.

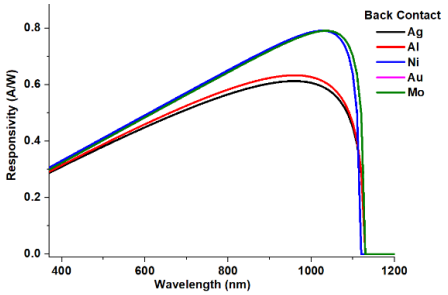

Figure 3. Photoresponsivity characteristics of the photodiode at different back contact materials.

The incident power-dependent J-V and responsivity curves for the device are shown in Figure 4. As expected, as the incident power increases the current density increases as well. That is due to more light absorbed at high power levels. It is observed that V_{oc} does not change with light intensity meaning that light intensity variation does not affect the non-radiative recombinations. On the other hand, the responsivity does not change with light power variation. That contradicts the experimental results wherein it is reported that the increasing light power decreases the responsivity [8].

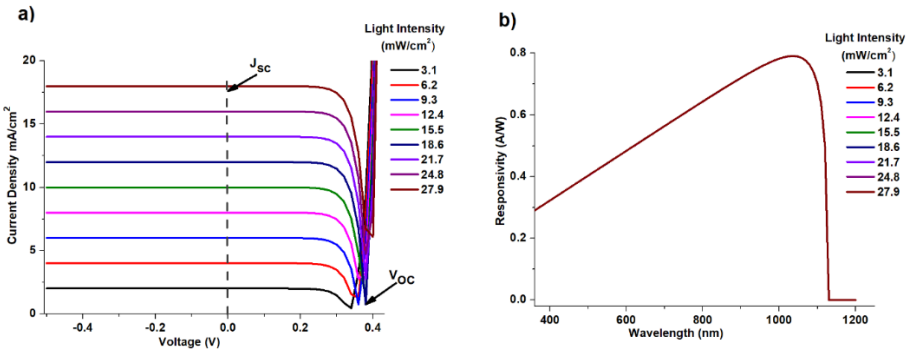

Figure 4. The light intensity variation dependent photovoltaic (a) and photoresponsivity(b) curves.

The incident light wavelength-dependent photovoltaic and photoresponsivity characteristics show the band detectivity of the photodetector. Here, we simulated J-V and responsivity of the device at different light wavelengths as shown in Figure 5. It is clear that J_{sc}, V_{oc} and responsivity does not vary with wavelength. Ideally, as the wavelength decreases the absorption coefficient increases and hence J_{sc} normally is expected to increases. However, it suspected that the FTO glass layer prevent this mechanism. Overall, it can be say that the $MoSe_2$ based Schottky photodetector has potential to operate at NIR and visible ranges of the electromagnetic spectrum.

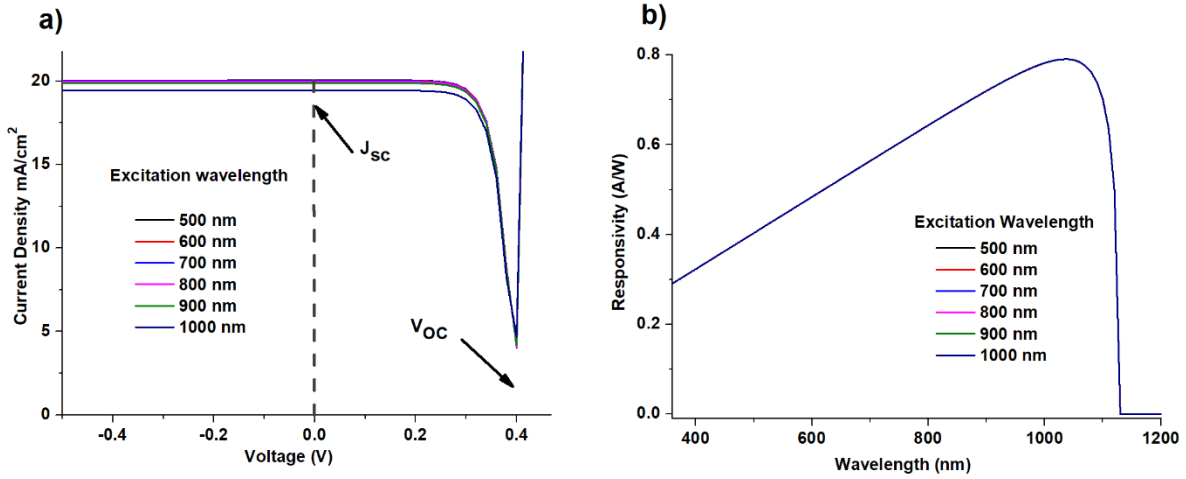

Figure 5. Incident wavelength dependant photovoltaic (a) and responsivity (b) characteristics of the photodiode.

Temperature has substantial effects on the characteristics of Schottky photodiodes by affecting the dark current, band gap, noise, quantum efficiency, etc. Therefore, we reported the temperature-dependent performance and characteristics of photodiodes, as shown in Figure 6. The photocurrent does not change with the temperature, whereas, V_{oc} significantly decreases as the temperature increase. That is because of the fact that increasing temperature will increase the non-radiative losses in the device. In addition, the dark current photocurrent significantly decreases as temperature decreases which is the due to the trap-assisted tunnelling and thermionic emission mechanisms.

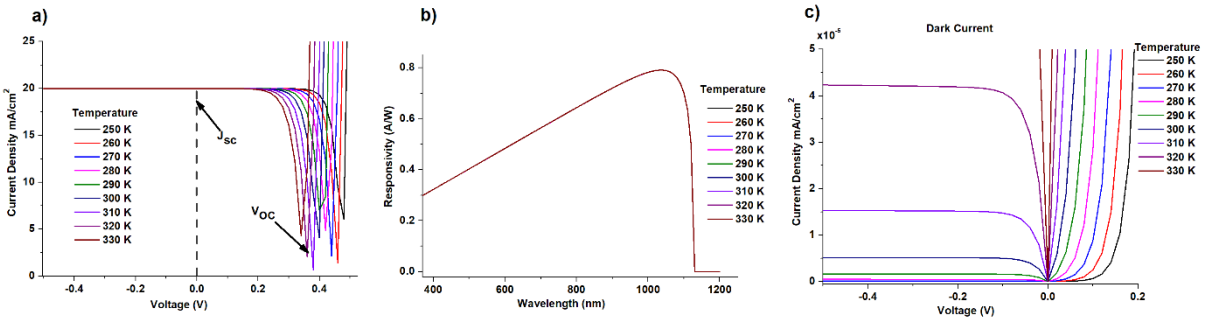

Figure 6. Temperature dependent J-V (a), responsivity (b) and dark current(c) curves of the photodiode.

Conclusion

In conclusion, we simulated the performance and characteristics of a 2D $MoSe_2$-based Schottky photodiode. The $MoSe_2$ was found to be an effective material for photodiodes operating in visible and NIR regions of the electromagnetic spectrum. We found that the proposed device is sensitive to $MoSe_2$ thickness, back contact material, incident light power and operating temperature. A maximum responsivity of ~0.8 A/W was observed. This work shows the way to building simple, fast, and sensitive $MoSe_2$-based Schottky photodiodes

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ÜÇ FAZLI ÇİFT AKTİF KÖPRÜLÜ DA-DA DÖNÜŞTÜRÜCÜNÜN METASEZGİSEL ALGORİTMA TABANLI PI DENETLEYİCİ İLE KONTROLÜ

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ÖZET

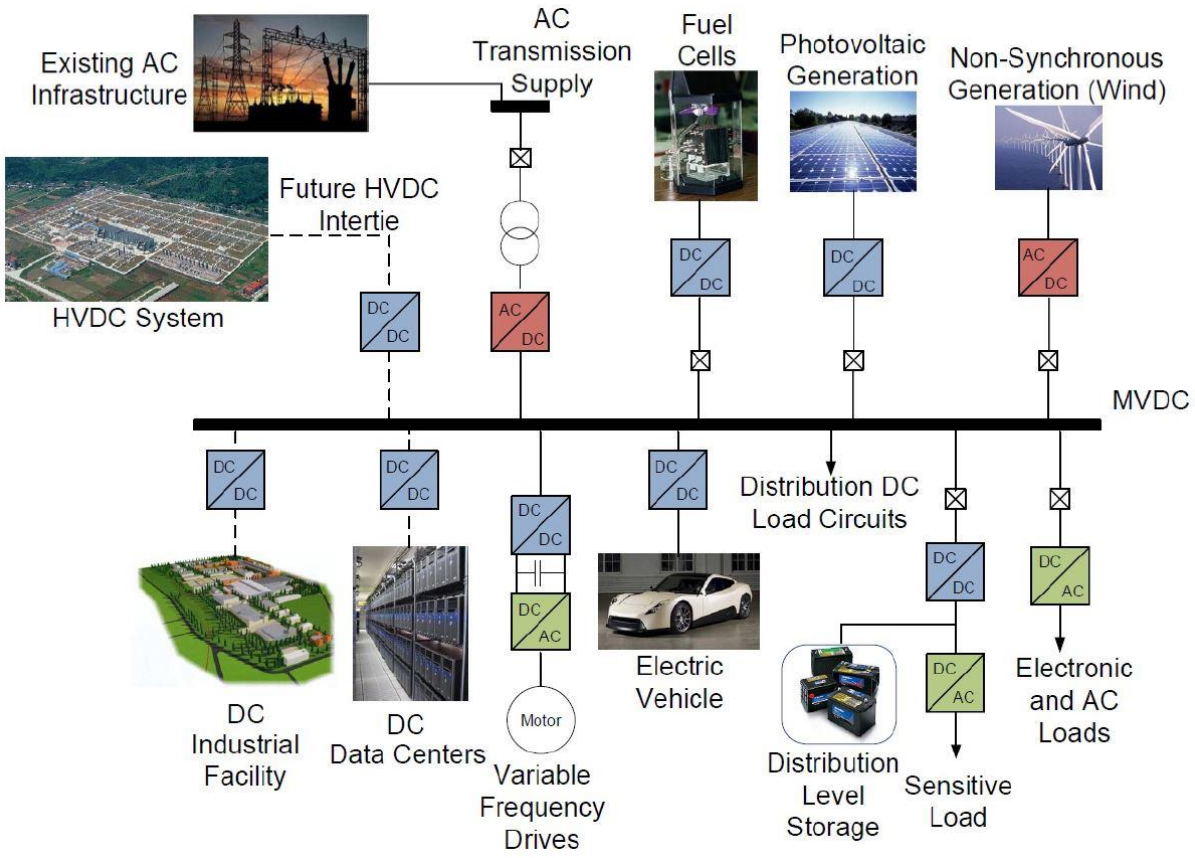
Üç fazlı çift aktif köprülü (DAB, Dual Active Bridge) DA-DA dönüştürücüsü, çift yönlü enerji akışını sağlayarak yüksek verimlilik, geniş voltaj aralığı ve galvanik izolasyon özellikleri ile güç elektroniği uygulamalarında yaygın olarak tercih edilmektedir. Dönüştürücünün çıkış geriliminin istenilen değerde tutulması ve ani gerilim dalgalanmalarına karşı kararlı bir performans sergilemesi için etkin bir denetleyici tasarımı gerekmektedir. Bu çalışma, DAB dönüştürücüsünün metasezgisel algoritma tabanlı PI denetleyici ile kontrolünü ele almaktadır. PSO, BEES ve ACO algoritmaları kullanılarak dönüştürücünün ITAE, IAE ve ISE gibi performans ölçütleri üzerinden analizleri yapılmıştır. Yapılan analizlerde, PSO algoritması ile elde edilen kontrolcü parametreleri ile ITAE değeri 0,007425, IAE değeri 0,2129 ve ISE değeri 10,5100 olarak elde edilmiş ve diğer algoritmalara göre daha iyi sonuçlar verdiği görülmüştür. Denetleyicinin referans gerilimi değişimi sonrası performansı incelenmiştir. 400V referans gerilimi ile başlayan simülasyon, 0,15 sn de referans gerilimi 500V a yükseltilmiştir. Yük gerilimi yükselme süresi 0,9175 msn, oturma süresi 1,3244 msn, tepe süresi 2,5058 msn ve üst aşım oranı %0,1141 olarak gözlemlenmiştir. Ayrıca, giriş geriliminde ani düşüşlerin etkisi analiz edilmiştir. Bu amaçla, giriş gerilimi 800V'tan 700V'ta düşürülerek çıkış üzerindeki etkiler PI kontrol altında değerlendirilmiştir. Bu analizler, DAB dönüştürücünün giriş dalgalanmalarına ve referans gerilim değişimlerine karşı kararlı çıkış sağlama kabiliyetini göstermektedir.

Anahtar Kelimeler: Üç Fazlı Çift Aktif Köprülü (DAB) Dönüştürücü, Metasezgisel Algoritmalar, PI Denetleyici, PSO Algoritması, Amaç Fonksiyonları, ITAE

1. GİRİŞ

Her geçen gün artan enerji ihtiyacı, fosil yakıt kaynaklarının azalması, fosil yakıt tüketiminin çevre ve insan sağlığına olumsuz etkisi insanları farklı enerji kaynakları arayışına yöneltmiştir [1-2]. Yeşil enerji diye nitelendirebileceğimiz karbon salınımının en az olduğu dolayısıyla çevre ve insan sağlığına en az zarar veren enerji üretim çeşitlerinden biri olan yenilenebilir enerji kaynakları alanındaki gelişmeler, elektrikli araçlar alanındaki gelişmeler, demiryolu uygulamaları, uçak uygulamaları, uzay yolu uygulamaları alanlarındaki gelişmeler enerji dönüşüm sistemlerine olan ilgiyi arttırmıştır [3].

Enerji dönüşüm sistemlerinin şebeke mimarisinde, kaynak ve yük bağlantısı arasında ne denli önemli rol oynadığı Görsel 1'deki örnek şebeke mimarisinde gözükmektedir. Kaynak tarafında yenilenebilir enerji kaynaklarının örnek olarak güneş enerjisi sistemlerinin veya rüzgar türbinlerinin şebekeye bağlanması, hidroelektrik veya termik santraller gibi enerji kaynaklarının şebekeye bağlanması yük tarafında ise endüstriyel tesisleri, veri merkezleri, elektrikli araç şarj istasyonları gibi yüklerin şebekeye bağlantısında enerji dönüşüm sistemlerinin üstlendiği sorumluluk açıkça gözükmektedir [5].



Görsel 1. Farklı Yenilenebilir Enerji Kaynakları ve yükleri gösteren temsili bir Orta Gerilim Doğru Akım şebekesi [6-7]

Son yıllarda ulaşım sektöründe hızla yaygınlaşan elektrikli araçlar temiz ve yeşil ulaşım için kritik öneme sahiptir. İçten yanmalı motorlara sahip araçların fosil yakıt tüketimi ve çevre kirliliğini arttırmasına yol açtığı göz önüne alındığında elektrikli araçların sürdürülebilir bir ulaşım aracı olarak benimsenmesi gerekmektedir. Elektrikli araçların fosil yakıtlı araçlarla rekabet edebilmesi için şarj süreçlerinde gelişmeler sağlanması, etkili, hızlı ve ekonomik şarj istasyonlarının geliştirilmesi önem taşımaktadır [9].

Modern akıllı şebekeler, rüzgar türbinleri ve güneş panelleri gibi dinamik enerji kaynakları içerdiğinden, güç üretimindeki dalgalanmalara karşı şebekenin sürdürülebilirliğini sağlamak için enerji depolama gereklidir. Önerilen enerji depolama elemanları arasında şarj edilebilir hibrit elektrik araçlar ve batarya bankları bulunmaktadır. Bu sistemler doğru akım enerji depolama elemanlarını alternatif akıllı şebekeye bağlamak için güç elektroniği dönüştürücüleri kullanır. Bu sistemler çift yönlü DA-DA enerji transfer yeteneği ve galvanik izolasyon gerektirir. Bu karmaşık güç akışı gereksinimleri genellikle çift aktif köprülü iki yönlü DA-DA dönüştürücü ile karşılanır [11-12].

Çift aktif köprülü DA-DA dönüştürücü çift yönlü enerji akışı sağlayabilmesi, basit yapısı, yüksek verimlilik, geniş giriş ve çıkış voltaj aralığı, galvanik izolasyon, simetrik devre yapısı minimum sayıda harici eleman barındırması ve gelişmiş kontrol algoritmaları ile denetlenebilmesi özellikleri sayesinde enerji dönüşüm sistemleri arasında öne çıkmaktadır [4-10].

Çift aktif köprülü DA-DA dönüştürücünün verimliliğini artırabilmek için literatürde farklı modülasyon teknikleri kullanılmaktadır. Bunlar tek faz kaydırma (SPS), genişletilmiş faz kaydırma (EPS), çift faz kaydırma (DPS) ve üçlü faz kaydırma (TPS) olarak rapor edilmiştir [13-14]. Ancak bazı yöntemler, kontrol ve uygulama karmaşasını artırmaktadır. Tek faz kaydırma yöntemi, daha basit bir kontrol yapısına sahip olduğu için diğer yöntemlere kıyasla tasarım koşullarına bağlı olarak daha uygun görülmektedir [13].

Çift aktif köprülü DA-DA dönüştürücüler yüksek güçlü uygulamalar için en uygun dönüştürücülerdendir. Minimum sayıda harici eleman (endüktans, kapasite) barındırmakta, dönüştürücünün güvenilirliğini arttırmaktadır. Sıfır gerilim anahtarlama (ZVS) çalışma aralığı genişletilerek sistemin daha yumuşak anahtarlama yapması sağlanır [16]. ZVS Anlık olarak sistemde yüksek akımın oluşmasını engellemek için kullanılır, sistem elemanlarını korur [15].

Yüksek performanslı çift aktif köprülü DA-DA dönüştürücünün önemli bir gereksinimi, tüm çalışma koşulları altında DC çıkış voltajını hızlı ve doğru bir şekilde korumaktır [12].

2. YÖNTEM

Bu çalışmada üç fazlı çift aktif köprülü DA-DA dönüştürücü tek fazlı kaydırma modülasyon tekniği kullanılarak PI denetleyici ile tasarlanmış, metasezgisel algoritmalarla optimum değerlere sahip PI değerleri hesaplanmıştır. Yapılan simülasyonlar ile kontrolcü referans

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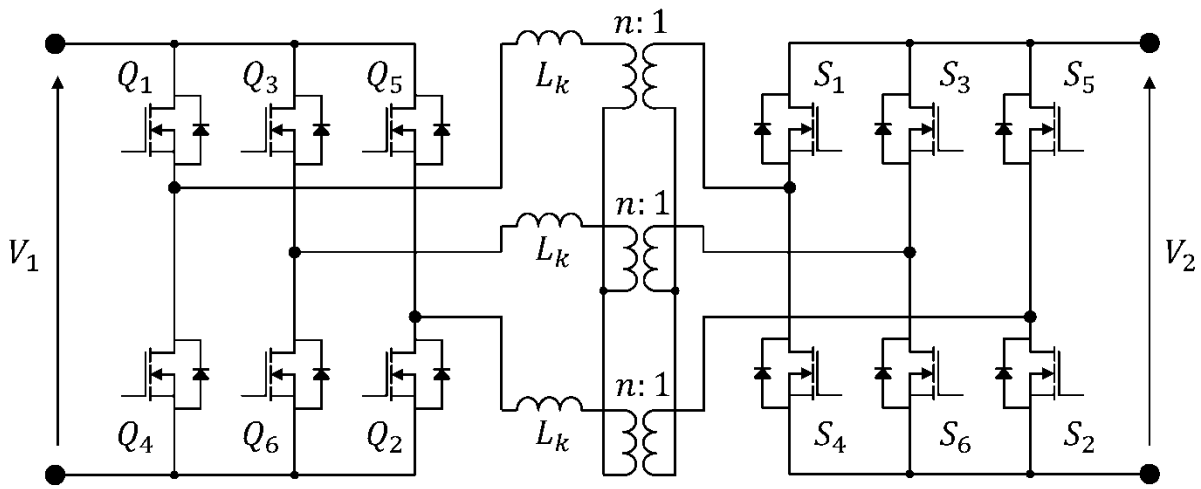
gerilim değişimine ve gerilim değişimindeki bozucu etkiye karşı dönüştürücünün performansı gözlemlenmiştir.

2.1. Üç Fazlı Çift Aktif Köprülü DA-DA Dönüştürücü

Çift aktif köprülü DA-DA dönüştürücü, iki aktif köprüyü izole edici bir trafonun birbirine bağladığı bir yapı olarak çalışır (Görsel 2). Bu yapı iki köprü arasında izolasyon oluşmasını sağlar. Üç fazlı çift aktif köprülü DA-DA dönüştürücü, iletim modunda çalışan üç fazlı dönüştürücülerden oluşur. İki yönlü (bidirectional) köprü olarak çalışır. Burada bir köprü "birincil köprü" olarak adlandırılırken, diğeri "ikincil köprü" olarak adlandırılır.



Görsel 2. Üç Fazlı Çift Aktif Köprülü DA-DA Dönüştürücü Topolojisi [8]

Herhangi bir çalışma modunda, birincil köprü DC-AC dönüştürücü olarak işlev görür ve izole edici trafodan ikincil köprüye AC çıkış sağlar. İkincil köprü ise DC çıkış sağlamak için bir doğrultucu olarak görev yapar (Görsel 3). Yüksek frekanslı trafonun her iki tarafındaki simetrik yapı sayesinde iki yönlü güç akışını sağlar. Ayrıca, köprüler gerilim dalga formlarını kontrol eder ve reaktif güç kontrolü sağlar.

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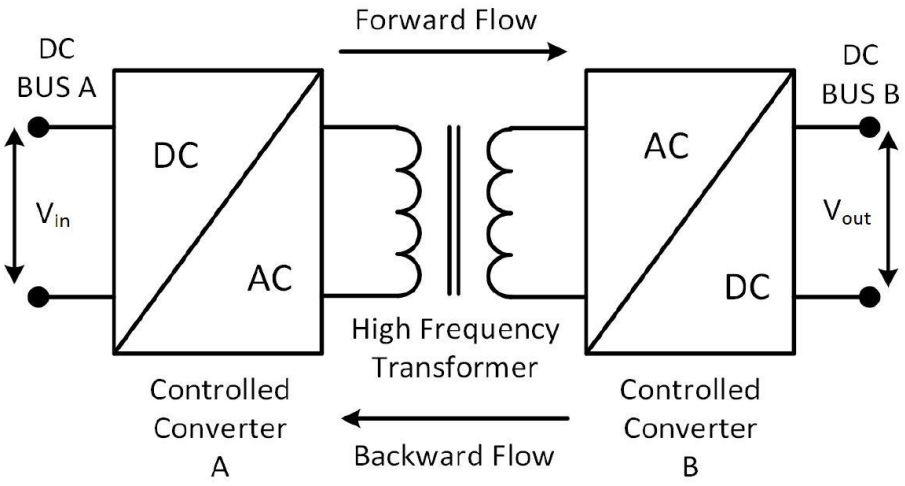
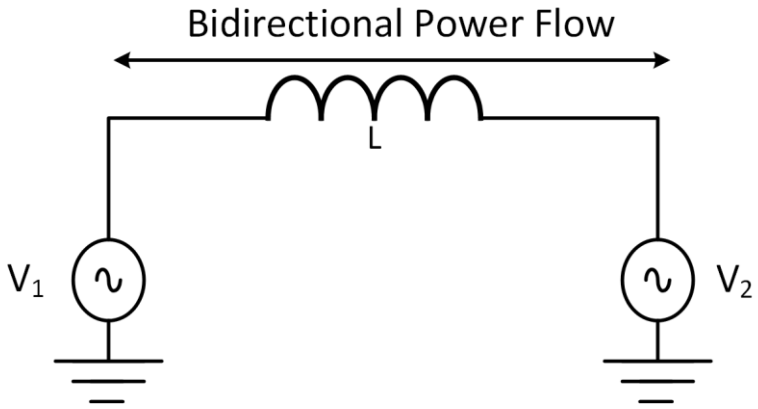


Görsel 3. Çift Aktif Köprülü DA-DA Dönüştürücü Blok Şeması [9]

Üç fazlı çift aktif köprülü DA-DA dönüştürücünün iki aktif köprüsü arasındaki güç transferi, bir güç sisteminde kaynak ve alıcı uç arasındaki güç akışına benzer ve Denklem 1'deki gibi formülize edilir.

$$p = \frac{V_1 * V_2 * \sin(\emptyset)}{\omega L} \quad (1)$$

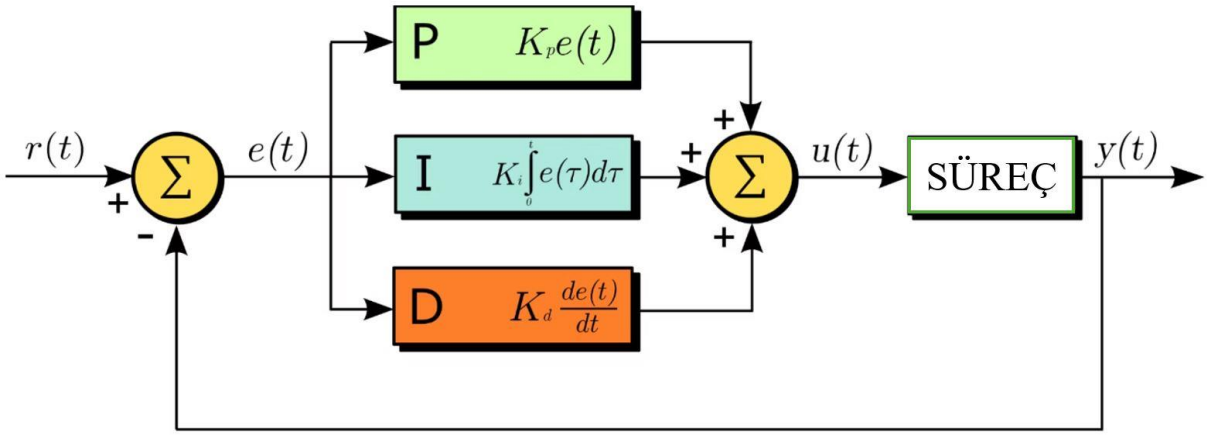
Güç akışı, kaynak tarafı gerilimi (V_1) ve yük tarafı gerilimi (V_2) ile bağlantı hattının endüktansına (L) bağlıdır. Köprüler, trafonun kaçak endüktansı ve bağlantı endüktansı ile ilgili gerilim kaynakları olarak temsil edilebilir (Görsel 4). Birincil köprü ile ikinci köprü arasındaki faz farkı, aktarılacak güç miktarını ve güç yönünü belirleyerek güç akışını kontrol etme olanağı sağlar. Bu nedenle, köprüler arası faz kaydırma modülasyonları kullanarak istenilen güç akış yönünü sağlanabilir.



Görsel 4. Çift Aktif Köprülü DA-DA Dönüştürücü Temsili Gösterimi

2.2. PI Kontrol Yöntemi

PID (Proportional Integral Derivate) Kontrol yöntemi aslında bir kontrol geri bildirim mekanizmasıdır. Otomasyon sistemlerinde yaygın olarak kullanılır. PID kontrolcüsü, bir sistemin çıktısını istenen bir referans değeri ile karşılaştırarak, hatayı minimize etmek için gereken kontrol sinyalini üretir. PID kontrolcüsünün ayarlanması önemlidir, çünkü kazanç değerlerinin (Kp, Ki, Kd) doğru bir şekilde belirlenmesi sistemin performansını doğrudan etkiler [17]. PID Denetleyicisinin genel yapısı ve çalışma prensibi Görsel 5'teki gibidir.



Görsel 5. PID Kontrol Yöntemi Çalışma Prensibi

PID Denetleyicinin transfer fonksiyonunu, Laplace dönüşümü kullanılarak s domeninde Denklem 2'deki gibi ifade edilir.

$$C(s) = \frac{U(s)}{E(s)} = K_P + \frac{K_I}{s} + K_D.s \quad (2)$$

Literatür araştırmaları incelendiğinde çift aktif köprülü DA-DA dönüştürücülerinin denetiminde PI Denetleyicinin, PID denetleyiciye göre daha az hatalı sonuçlar ürettiği görülmüştür [14-18].

2.3. Metasezgisel Algoritmalar

Sezgisel algoritmalar, doğada var olan bazı davranışların taklit edilerek çeşitli problemlerin çözümünü amaçlayan algoritmalardır. Bu algoritmalar, genellikle büyük ve karmaşık arama alanlarında etkin çözümler bulmak amacıyla tasarlanmıştır. Metasezgisel algoritmalar, belirli bir probleme özgü olmayan genel bir yapı sunarak, çeşitli problemleri çözme yeteneğine sahip olurlar. Çalışmada üç farklı metasezgisel algoritma kullanılmıştır.

Parçacık sürüsü optimizasyonu (PSO), doğadaki kuş sürülerinin hareketlerinden esinlenerek geliştirilen bu yöntem, parçacıkların yani çözümlerin bir arama alanında birlikte hareket

etmesini sağlar. Parçacıklar, kendi en iyi çözümlerini ve gruptaki en iyi çözümü referans alarak konumlarını günceller.

Yapay arı kolonisi (BEES), arıların besin kaynaklarını bulma davranışlarından esinlenerek geliştirilen bu algoritma, çözümler arasında arama yapmak için arıların iş birliği yapma yeteneğini kullanır. Arılar, çözüm alanında keşif yapar ve daha iyi çözümleri paylaşarak toplu bir optimizasyon süreci oluşturur.

Karınca Koloni Optimizasyonu (ACO), doğal karınca davranışlarından ilham alarak geliştirilmiş bir metasezgisel optimizasyon algoritmasıdır. Algoritma, sanal karıncaların belirli bir çözüm uzayında gezinerek ve feromon izleri bırakarak, optimal veya yaklaşık optimal çözümleri keşfetmelerine dayanır. Karıncaların bıraktığı feromonlar, sonraki karıncaların tercihlerini etkileyerek, çözüm kalitesini zamanla artırır.

2.4. Amaç Fonksiyonları

Amaç fonksiyonu, optimizasyon problemlerinde bir çözümün kalitesini belirlemek için kullanılan matematiksel bir yapıdır. Denetleyici parametrelerinin optimizasyon algoritmaları ile belirlenmesi esnasında hatayı minimize edebilmek için kullanılan fonksiyonlardır [19]. PID algoritmaların optimizasyonu için literatürde kullanılan amaç fonksiyonları;

ISE (Integral of Squared Error): Zamanla hata sinyalinin karelerinin integrali alınarak hesaplanan bir ölçüdür. Sistem yanıtındaki toplam hata miktarını değerlendirmek için kullanılır. ISE Amaç fonksiyonunun elde edilebileceği ifade Denklem 3'te verilmiştir.

$$f(ISE) = \int_0^T e^2(t)dt \tag{3}$$

IAE (Integral of Absolute Error): Zamanla hata sinyalinin mutlak değerlerinin integrali olarak tanımlanır. Hata miktarının toplam etkisini değerlendirir. IAE Amaç fonksiyonunun elde edilebileceği ifade Denklem 4'te verilmiştir.

$$f(IAE) = \int_0^T |e(t)|dt \tag{4}$$

ITSE (Integral of Time-weighted Squared Error): Hata sinyalinin zamanla çarpılarak karelerinin integrali alınarak hesaplanır. Geçmiş hata değerlerini daha fazla önemseyen bir ölçüt oluşturur. ITSE Amaç fonksiyonunun elde edilebileceği ifade Denklem 5'te verilmiştir.

$$f(ITSE) = \int_0^T t.e^2(t)dt \quad (5)$$

ITAE (Integral of Time-weighted Absolute Error): Hata sinyalinin zamanla çarpılarak mutlak değerinin integrali alınır. Hataların zamanla daha fazla önem taşıdığı durumlarda kullanılır. ITAE Amaç fonksiyonunun elde edilebileceği ifade Denklem 6'te verilmiştir.

$$f(ITAE) = \int_0^T t|e(t)|dt \quad (6)$$

3. YAPILAN ÇALIŞMA VE BULGULAR

Üç fazlı çift aktif köprülü DA-DA dönüştürücü simülasyonu MATLAB/SIMULINK ortamında oluşturulmuştur. Tek faz kaydırma (SPS) modülasyon tekniği kullanılarak PI parametrelerinin belirlenebilmesi için üç farklı metasezgisel algoritma kullanıldı. Yapılan çalışmada parçacık sürü optimizasyonu (PSO) algoritması ile elde edilen sonuçlar en düşük hata değerini vermiştir (Çizelge 1).

Çizelge 1. Üç Fazlı Çift Aktif Köprülü DA-DA Dönüştürücü Metasezgisel Algoritmalarla Elde Edilen En Düşük Hata Fonksiyon Değerleri

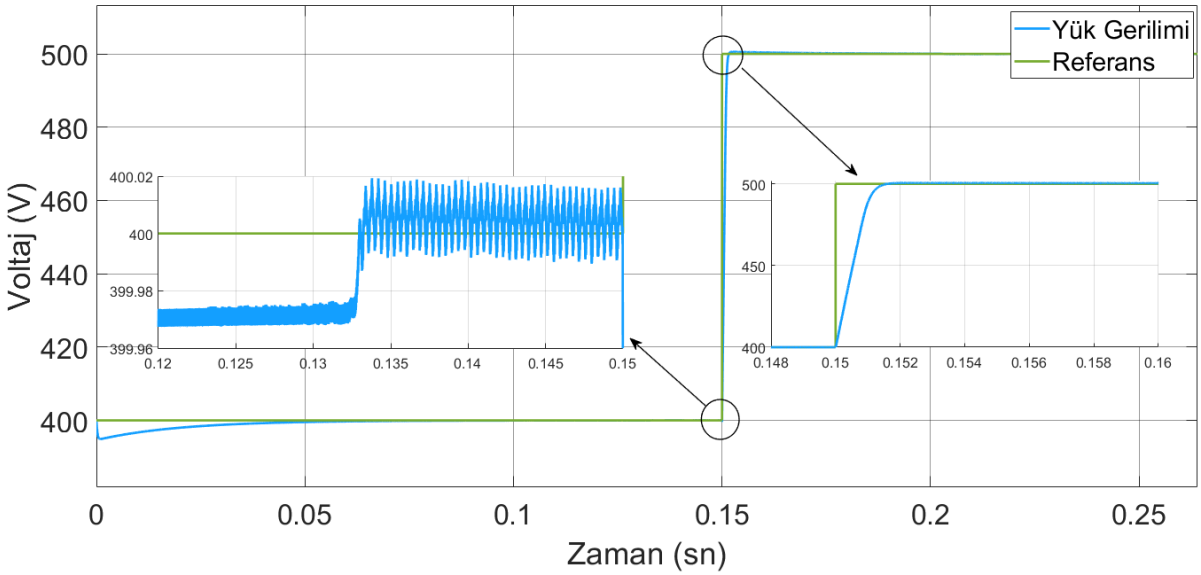
Algoritma	ITAE	ITSE	IAE	ISE
PSO	0,007425	0,007241	0,2129	10,5100
BEES	0,007632	0,007127	0,2267	10,6400
ACO	0,008147	0,008147	0,1721	10,2600

PSO Algoritması ile elde edilen en düşük hata değerine sahip K_p ve K_i değerleri (Çizelge 2) simülasyonda kullanılarak referans gerilim değişimine karşı çıkış gerilim değişimi gözlemlenmiştir.

Çizelge 2. PSO Algoritması ile Elde Edilen En Düşük Hata Değerine Sahip Kp ve Ki Değerleri

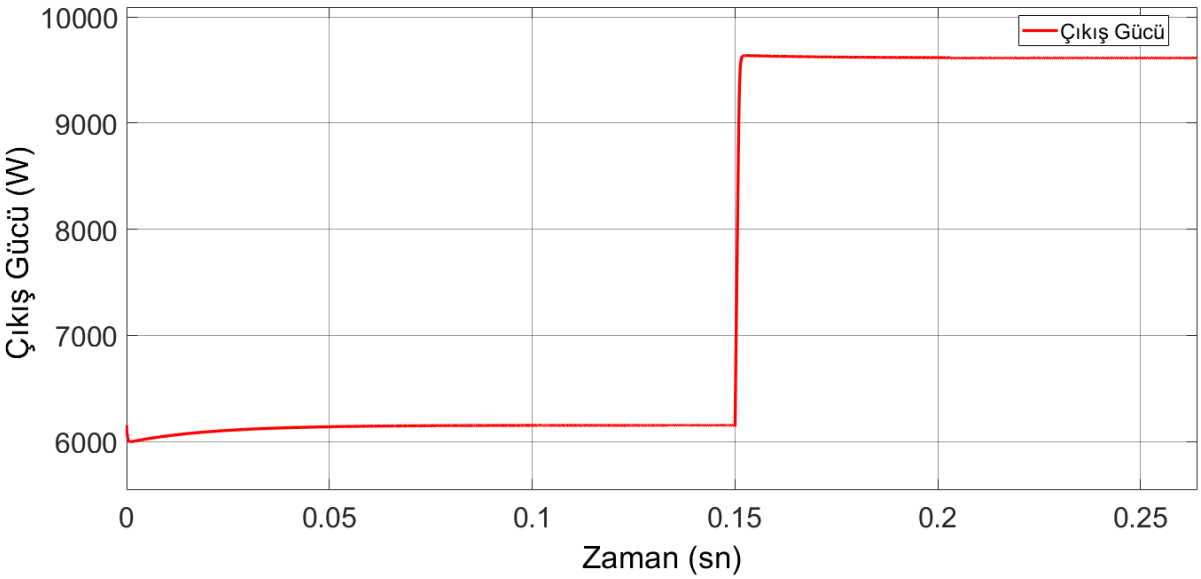
Algoritma	ITAE	IAE	ISE	K_p Degeri	K_i Değeri
PSO	0,007425	0,2129	10,5100	2,0103	100,00

Simülasyon başlangıcından 0,15 saniye sonra referans gerilimi 400 volt tan 500 volta çıkartılmış, çıkış yani yük geriliminin referans gerilimini hızlı bir şekilde yakaladığı gözlemlenmiştir. Referans gerilim değişikliği ve yük gerilim değişikliğini gösteren simülasyon sonucu Görsel 6'daki gibi olmuştur.



Görsel 6. Üç Fazlı Çift Aktif Köprülü DA-DA Dönüştürücü Referans Gerilim Değişimi Yük Gerilimi Tepkisi

Referans geriliminin değişimi sonrası çıkış gücünün değişim tepkisi Görsel 7 de gözükmektedir.



Görsel 7. Üç Fazlı Çift Aktif Köprülü DA-DA Dönüştürücü Referans Gerilim Değişimi Çıkış Gücü Tepkisi

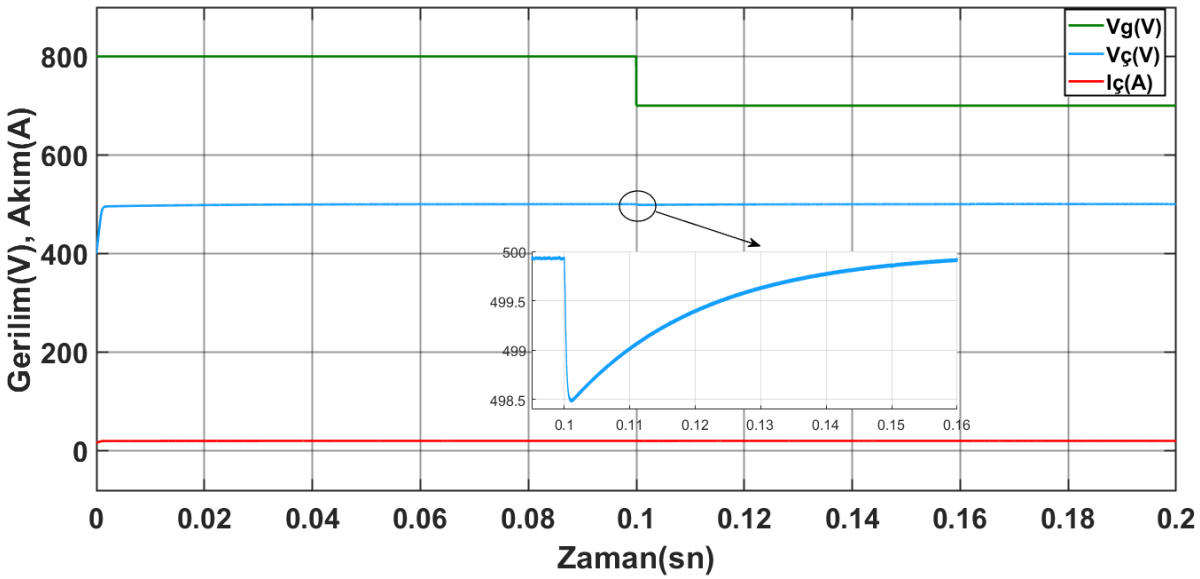
Referans gerilimi değişimi anında, sistemin çıkış geriliminin referans gerilimini yakalaması esnasında oluşan, simülasyonun adım tepki verisi Çizelge 3'teki gibi olmuştur.

Çizelge 3. Referans Gerilim Değişimi Sonrası Yük Gerilim Değişim Adım Tepki Verisi

Optimizasyon Tekniği	Kontrolcü	Yükselme	Oturma	Tepe	Tepe Değeri (V)	Üst Aşım (%)

		Süresi (ms)	Süresi (ms)	Süresi (ms)		
PSO	PI	0,9175	1,3244	2,5058	500,5707	0,1141

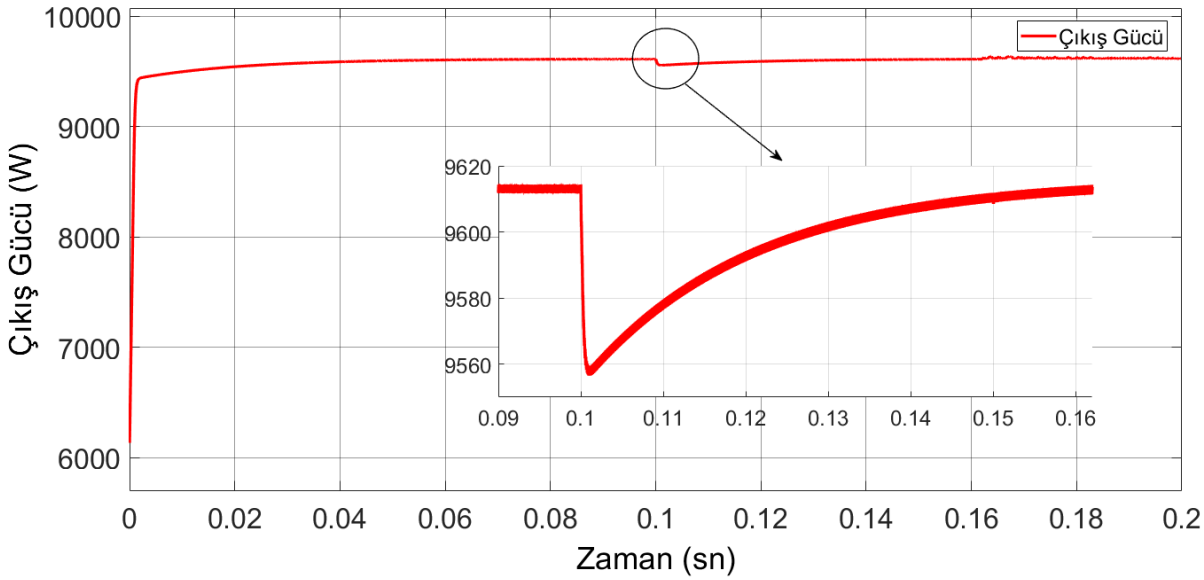
Üç Fazlı Çift Aktif Köprülü DA-DA Dönüştürücünün belirlenen optimum K_p ve K_i değerleriyle bozucu etkilere karşı performansını gözlemlemek için simülasyon tasarladık. Giriş gerilimindeki dalgalanma sunucu sistemin çıkış gelişimindeki tepkisini gözlemlemek için simülasyon başlangıcının 0,1. saniyesinde sistemin giriş gerilimini 800 volt tan 700 volta düşürerek çıkış gerilimini ve çıkış akımının değişimi Görsel 8'deki gibi olmuştur.



Görsel 8. Üç Fazlı Çift Aktif Köprülü DA-DA Dönüştürücü Giriş Gerilim Değişimi Sonrası Çıkış Derilimi ve Çıkış Akımı Tepkisi

Yapılan çalışma sonucu bozucu etkiyle karşılaşılan simülasyon devrimimiz yaklaşık 0,06 saniye gibi kısa bir sürede referans gerilimini yakalamıştır.

Giriş gerilim değişimi sonrası çıkış gücünün değişimi Görsel 9'daki gibi olmuştur.



Görsel 9. Üç Fazlı Çift Aktif Köprülü DA-DA Dönüştürücü Giriş Gerilim Değişimi Sonrası Çıkış Gücü Tepkisi

3. SONUÇLAR VE DEĞERLENDİRME

Üç fazlı çift aktif köprülü DA-DA dönüştürücü teorik incelemesi ve simülasyonu yapılmıştır. Farklı modülasyon teknikleri incelenerek simülasyonda tek faz kaydırma yöntemi kullanılmıştır. Dönüştürücü denetlenmesi için PID denetleyici incelenmiş, yapılan literatür araştırması üzerine dönüştürücünün daha kararlı ve daha hızlı çalışması için denetleyici olarak PI denetleyici kullanılmıştır. PI Denetleyicinin kazanç değerlerini (K_p ve K_i) belirleyebilmek için amaç fonksiyonları ve metasezgisel algoritmalar incelenmiştir. Kullanılan üç farklı metasezgisel algoritma (PSO, BEES, ACO) ile en düşük hata değerine sahip kazanç değerleri PSO algoritması ile elde edilmiştir.

PSO Algoritması ile elde edilen kazanç değerleri simülasyonda kullanılarak, referans gerilimi değişimi ve giriş gerilimindeki bozucu etkiye (ani gerilim düşümü) karşı dönüştürücünün performansı incelenmiştir.

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PARÇACIK SÜRÜ OPTİMİZASYONU YÖNTEMİ İLE DENKLEŞTİRİCİ KAT SAYILARININ BULUNMASI

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ÖZET

Bu çalışmada, Parçacık Sürü Optimizasyonu (PSO) algoritması kullanılarak çok yollu bir haberleşme kanalındaki bozucu etkilerin minimuma indirgenmesi gerçeklenmiştir. PSO algoritması, doğadaki sürü davranışlarından ilham alarak, karmaşık problemlerin çözümlerine ulaşmak için uyarlanabilir ve verimli bir yaklaşım sunmaktadır. Çalışma kapsamında, denkleştirici katsayılarının optimizasyonu sağlanarak kanaldan geçen bozulmuş sinyalin asıl veriye en yakın haliyle geri elde edilmesi amaçlanmıştır. Rastgele üretilmiş veriler çok yollu kanal ve denkleştiriciden geçirilmiş, ardından ortalama karesel hata değeri minimize edilmiştir. PSO algoritması ile her bir parçacık, çözüm uzayında tanımlanan sınırlar dahilinde en iyi konumu arayarak ilerlerken, komşu parçacıkların deneyimlerinden de faydalanmıştır. Sonuçlar, PSO algoritmasının haberleşme sistemlerinin optimizasyon süreçlerinde sunduğu hız, esneklik ve yüksek çözüm kalitesi ile sistem performansını artırmada güçlü bir katkı sağladığını göstermektedir.

Anahtar Kelimeler : Parçacık Sürü Optimizasyonu (PSO), Meta-Sezgisel Algoritmalar, Denkleştirici Katsayıları, Haberleşme Kanalı, Ortalama Karesel Hata

1. GİRİŞ

Günümüz iletişim teknolojilerinde, veri aktarımının güvenilirliği ve doğruluğu kritik bir öneme sahiptir. Özellikle kablosuz iletişim sistemlerinde, sinyallerin alıcıya ulaşana kadar karşılaştığı bozucu etkiler, veri iletim kalitesini ciddi şekilde etkilemektedir. Sinyal gücünün azalması, çok yollu yayılım, yansıma ve gürültü gibi faktörler, sinyallerin orijinal veriden sapmasına ve alıcıda hatalı yorumlanmasına neden olur. Bu bozucu etkilerden kaynaklanan veri kaybı ve sinyal bozulmaları, iletişim sistemlerinin performansını olumsuz yönde etkilemektedir.

Daha kaliteli ve güvenilir bir iletişim kanalı oluşturmak için veri kaybının ve sinyal bozulmalarının azaltılması üzerine önemli çalışmalar yapılmaktadır. Bunlar arasında kanal modelleme yapılarak bu bozucu etkilerin analiz edilmesi ve azaltılması ön plandadır. Kanal modelleme teknikleri, bir sinyalin iletim süresince geçirdiği değişiklikleri ve bu değişikliklerin sinyal üzerindeki etkilerini incelemek için kullanılır. Kablosuz iletişim kanallarında, sinyaller yansıma, kırılma ve saçılma gibi fiziksel süreçler sonucunda farklı yollar üzerinden alıcıya ulaşır. Bu iletim sürecinde, çok yollu yayılım, yansıma ve gürültü gibi bozucu etkiler nedeniyle simgeler arası girişim (ISI) ortaya çıkar ve sinyalin net bir şekilde iletilmesi zorlaşır. Bu yüzden kanal modelleme yöntemlerini kullanmak, sinyal bozulmalarını anlamak ve bu bozulmalara karşı dengeleme önlemleri geliştirmek açısından kritik öneme sahiptir.

Bu yöntemler, haberleşme sistemlerinin performansını optimize etmek ve sinyal bozulmalarını azaltmak amacıyla geliştirilen denkleştirici algoritmalarla uyumlu olarak çalışmaktadır. Kanal denkleştirici sistemler, sinyalin geçiş yaptığı ortamın fiziksel özelliklerine uyum sağlayarak bozucu etkileri minimize eder. Ancak klasik denkleştirme yöntemleri, değişken ortam koşulları ve karmaşık kanal modelleri ile başa çıkmakta zorlanmaktadır. Bu noktada, metasezgisel algoritmalar, esneklikleri ve adaptasyon yetenekleri ile ön plana çıkar. Çalışma kapsamında kullanılan Parçacık Sürü Optimizasyonu (PSO) algoritması doğadan esinlenen güçlü bir metasezgisel optimizasyon yöntemidir ve çeşitli mühendislik problemlerinde çözüm aracı olarak başarıyla uygulanmaktadır. Özellikle haberleşme kanallarında, PSO algoritması kanal denkleştiricilerinin etkinliğini artırmak için etkili bir yöntem olarak kabul edilmektedir. PSO algoritmasının kullanılmasındaki amaç, çok yollu yayılım ve sinyal zayıflaması gibi bozucu etkilerin etkisini azaltmak ve sinyalin orijinal haline en yakın şekilde alıcıya ulaşmasını sağlamaktır. Bu algoritma doğadaki sürü davranışlarını taklit eden yapısı sayesinde, sinyal dengeleme problemlerinde güçlü ve esnek bir çözüm sunar.

Kablosuz iletişim sistemlerinde, sinyallerin alıcıya ulaşana kadar karşılaştığı bozucu etkilerin varlığı kanal modelleme yöntemlerinin önemini arttırmıştır. Burada, daha kaliteli ve güvenilir bir iletişim kanalı oluşturmak için veri kaybının ve sinyal bozulmalarının en az seviyede olması istenir. Kablosuz iletişim sistemlerinde kanal modellemesi ve metasezgisel algoritmaların kullanılmasına yönelik literatürde önemli çalışmalar yapılmıştır. Bunlar arasında [1]'de Farklı Evrim (DE) algoritması kullanılarak adaptif kanal denkleştirmesinde sinyal bozulmaları minimize edilmiştir. DE algoritması, çeşitli varyantlarla kanal modellerinde hızlı yakınsama ve Bit Hata Oranı (BER) azaltma performansıyla öne çıkmaktadır. Bu çalışmada, DE algoritmasının adaptif kanal denkleştirme problemlerinde iyi bir sonuç verdiği görülmüştür. Bir diğer çalışmada, adaptif kanal denkleştirme konusunda PSO algoritması geleneksel En Küçük

Kareler Yöntemi (LMS) algoritmasına göre daha hızlı yakınsama ve daha düşük hata oranı vermiştir. PSO algoritmasının, kanallardaki sinyaller arası girişimi azaltmada etkili bir yöntem olarak adaptif denkleştiriciler için uygun bir çözüm sunduğu belirtilmiştir [2]. [3]'te yapılan çalışmada ise PSO algoritmasıyla kanal denkleştirmede daha hızlı yakınsama ve düşük ortalama kare hata oranı elde edilmiştir. PSO algoritması, kanal modellerinde sinyal bozulmalarını azaltmada başarılı sonuçlar sunarak adaptif kanal denkleştiriciler için etkili bir çözüm olarak öne çıkmıştır.

[4]'te asenkron kooperatif iletişimlerde PSO ve LMS algoritmalarını birleştiren hibrit bir kanal denkleştirme yöntemi tasarlanmıştır. PSO algoritması kullanılarak kanal denkleştirmesi için geliştirilmiş bir yapay sinir ağı (ANN) modeli [5]'te tasarlanmıştır. [6]'da fiber optik iletişimde kanal bozulmalarını gidermek amacıyla PSO ile eğitilen bir silikon fotonik rezervuar bilişim sistemi önerilmiştir. Bu sistemle, düşük Bit Hata Oranı ve iyileştirilmiş sinyal performansı elde edilmiş, yüksek hızlı optik kanallarda kanal modelleme açısından etkin bir çözüm sunulmuştur. Kısa mesafe veri merkezi bağlantılarında bant genişliği sınırlı vericilerde PSO algoritması ile kontrol edilen bir optik denkleştirici [7]'de tasarlanmıştır. Bir diğer çalışmada PSO algoritması ve çeşitli uygulama alanları üzerine kapsamlı bir inceleme sunulmuş ve PSO algoritmasının yüksek kaliteli çözümler sunma kapasitesi vurgulanmıştır [8]. [9]'da ki çalışmada ise kanal denkleştirme performansını artırmak için metasezgisel bir yöntem olan Hibrit Aritmetik Balina Optimizasyon Algoritması (HAWOA) kullanılmıştır. Sonuçların hızlı ve etkili olduğu ve sinyal hata oranını azalttığı belirtilmiştir. İletişim sistemlerindeki adaptif denkleştirici katsayılarının optimizasyonunda Parçacık Sürü Optimizasyonu (PSO) algoritmalarının performansının incelenmesi üzerine çalışma [10]'da yapılmıştır.

Literatürde yapılan çalışmalar incelendiğinde PSO algoritmasının kablosuz haberleşme kanallarındaki denkleştirme performansı üzerine yeteri kadar çalışma yapılmadığı anlaşılmıştır. Bu çalışmada kanal denkleştirici katsayıları PSO algoritması kullanılarak optimize edilmesiyle haberleşme kanalları üzerindeki bozucu etkiler minimize edilmiştir. Bu sayede, iletişim kalitesi arttırılarak veri aktarımı daha güvenilir hale getirilmiştir.

Çalışmanın geri kalanı aşağıdaki gibi ilerlemektedir. 2. Bölümde haberleşme kanalıyla ilgili bilgiler verilmiş ve kullanılan algoritma açıklanmıştır. Sistemin performans analizi ve simülasyon sonuçları 3. Bölümde tartışılmaktadır. 4. Bölümde sonuçlara ver verilmiştir.

2. YÖNTEM

2.1. Haberleşme Kanalları

Haberleşme kanalları, veri iletimi sırasında sinyallerin geçtiği fiziksel ortam olarak tanımlanır. Bu kanallar kablolu (bakır kablo, fiber optik) ya da kablosuz (radyo frekansı, mikrodalga, uydu gibi) olabilir. Bunlar arasında yer alan telekomünikasyon iletişim kanalı, elektronik sinyalleri kullanarak mesafeler üzerinden bilgi iletmek için kullanılan özel bir iletişim kanal türüdür ve modern iletişim ağlarındaki cihaz ve sistemleri birbirine bağlamak için gereklidir. Bu kanal türüne örnek olarak kablosuz kanallar, uydu kanalları, hücresel ağlar,

internet kanalları verilebilir. Telekomünikasyon iletişim kanallarının kendine özgü avantajları ve sınırlamaları vardır. Bunlar mesafe, bant genişliği, maliyet ve uygulama gereksinimleri gibi faktörlerden etkilenmektedir.

2.2. Haberleşme Kanallarında Bozucu Etkiler

Özellikle kablosuz haberleşme kanallarında, sinyal yayılımı sırasında çeşitli bozucu etkiler mevcuttur. Bu etkiler arasında çok yollu yayılım, sinyal gücünün azalması (zayıflama), yansıma, kırılma ve saçılma gibi sorunlar bulunur. Örneğin çok yollu yayılım, sinyalin farklı yollar üzerinden alıcıya ulaşmasına neden olur. Bu farklı yollar, sinyalin yansıma, kırılma veya saçılma gibi fiziksel etkenlerle karşılaşmasından kaynaklanır. Alıcıya ulaşan bu farklı yol izleri, sinyalin aynı anda çakışmasına ve dolayısıyla simgeler arası girişime (ISI) yol açar [9]. Bununla birlikte sinyal, yayılma süresince enerjisinde azalma yaşar ve mesafeye bağlı olarak sinyal gücünde önemli kayıplar meydana gelir. Bu kayıplar, özellikle uzak mesafeli iletişimlerde sinyal-gürültü oranının (SNR) düşmesine neden olmaktadır. Zayıflama, kullanılan frekans bandına, verici ve alıcı arasındaki mesafeye ve ortam koşullarına bağlı olarak değişiklik gösterir. Bozucu etkilerden bir diğeri ise sinyalin alıcı tarafında yanlış yorumlanmasına yol açan gürültüdür. Gürültü iletim ortamında bulunan parazit ve diğer elektromanyetik dalgalar nedeniyle oluşur ve kanal üzerinde bozucu bir etkiye sahiptir. Bu bozucu etkiler, sinyalin alıcıya ulaştığında orijinal veriden sapmasına neden olur [10]. Bu sapmaları en aza indirmek için kanal denkleştirme yöntemleri kullanılmaktadır.

İletişim kanallarında sinyal bozulmalarının önlenmesi, veri iletişiminde güvenilirlik ve doğruluk sağlamak açısından kritik öneme sahiptir. Özellikle kablosuz haberleşme sistemlerinde değişen ortam koşulları, mesafe ve kanal üzerindeki engeller adaptif kanal denkleştirici sistemlerin gerekliliğini ortaya koymaktadır. Adaptif denkleştiriciler, kanal koşullarına uyum sağlayarak her bir kanal bozucu etkisini minimize etmeye çalışan sistemlerdir. Bu sistemler sinyalin gönderildiği ortamda meydana gelen dinamik değişikliklere uyum sağlayarak her bir veri aktarımında en iyi dengeleme performansı sunar. Özellikle çok yollu yayılım, darbe gürültüsü ve sinyal zayıflaması gibi problemlerin etkilerini minimize eden adaptif denkleştiriciler, kanalın frekans karakteristiklerine göre kendilerini otomatik olarak güncelleyebilmektedirler. Bu çalışma kapsamında adaptif kanal denkleştirme tekniklerinden Parçacık Sürü Optimizasyonu (PSO) algoritması kullanılmıştır.

2.3. Kanal Modellemesi

Kanal modellemesi, haberleşme sistemlerinin tasarımında sinyal bozulmalarını analiz etmek ve bu bozulmaların etkisini minimize edecek denkleştiricileri geliştirmek için kullanılmaktadır. Deterministik ve stokastik modeller olarak iki ana yaklaşıma sahiptir. Deterministik kablosuz kanal modelleri, iletişim ortamlarından hesaplanan kanal parametrelerine ve elektromanyetik dalgaların yayılma yasasına dayanır. Modelleme aşamasında kırınıma yaklaşım ve dağınık saçılma gibi iyileştirmeler kullanılır. Bu şekilde, ışın izleme teknikleri, tam iletişim ortamlarının bilgilerini kullanarak yansıma, kırınım, kırılma ve saçılmayı simüle edebilir. Dolayısıyla, kanal modelini elde etmek için hemen hemen her yayılma yolunun parametreleri teorik olarak türetilebilir [11]. Diğer bir yaklaşım türü olan

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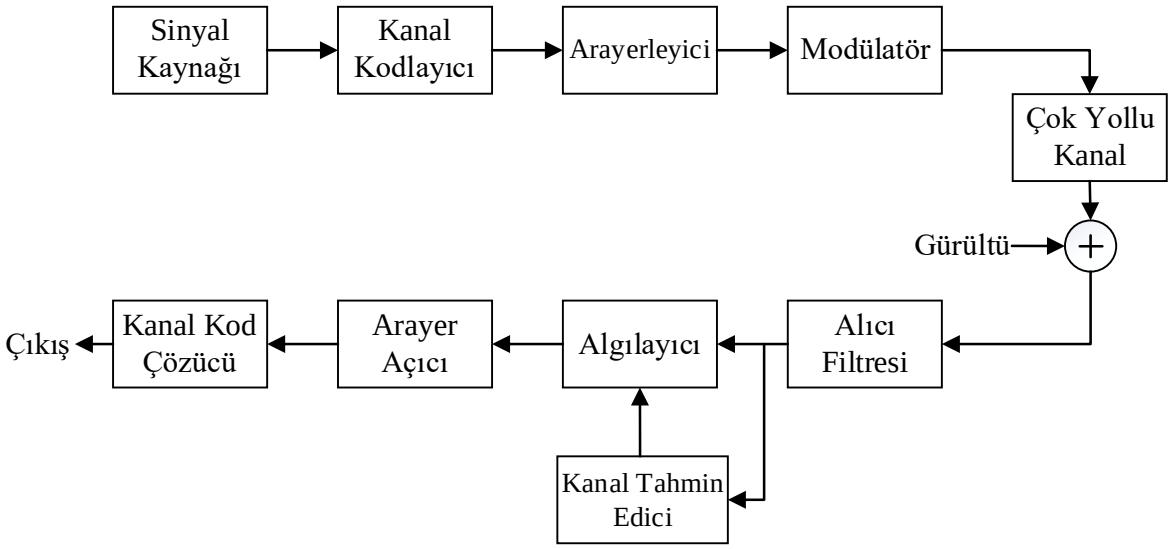
stokastik modeller, çevresel faktörler nedeniyle sinyalin rastgele bozulmasını ve çeşitli dağılımlar altında çok sayıda saçılmanın meydana gelmesini esas alır. Geometri tabanlı stokastik kanal modeli (GSCM), temsili bir stokastik kanal modelleme yöntemidir. GSCM, belirli bir dağılım altında birçok saçıcının bulunduğu bir ortamda elektromanyetik dalgaların yansıma, kırınım ve saçılmasının temel yasalarını kullanarak elde edilir.



Görsel 1. Çok Yollu Kanal Modeli ve Sinyal İşleme Süreci

Görsel 1'de çalışmada kullanılan çok yollu kanal modeli ve sinyal işleme süreci gösterilmektedir. Verilen görsel, sinyal kaynağından başlayan ve sinyalin modülasyon, kanal kodlama ve arayüzleme aşamalarından geçerek çok yollu bir kanalda bozuma uğramasını simüle etmektedir. Sistemin alıcı tarafında, bozulmuş sinyal kanal tahmin edici ve alıcı filtresi gibi birimlerden geçirilerek orijinal sinyale en yakın hale getirilir. Kanal tahmin edici, adaptif denkleştiricinin performansını artıran kritik bir bileşendir. Bu model, iletişim kanalında sinyal işleme sürecini ve bozucu etkilerin giderilmesini ele alır.

Kanal ölçüm süreci, geliştirme aşaması ve üretim aşaması olarak adlandırılan iki temel aşamadan oluşur. İlk aşamada, kanal sondaj yöntemleri ve ilgili modellerin performansları incelenir ve değerlendirilir. Bu aşama, sistem parametrelerinin ve veri toplama protokollerinin dikkatlice ayarlanmasını ve optimize edilmesini kapsamaktadır. İkinci aşama ise büyük miktarda ham ölçüm verisinin toplanmasına odaklanır. Elde edilen büyük hacimli veri, kanalın temel parametrelerini, bu parametrelerin dağılımını ve korelasyonlarını ortaya çıkarmak amacıyla kapsamlı bir şekilde analiz edilir. Son olarak kanal modelleri, kablosuz iletişim sistemlerinin tasarımı ve analizinde pratik gereksinimleri karşılayacak şekilde veya olasılık yoğunluk fonksiyonlarına dayalı olarak temsil edilir.

2.4. PSO Algoritması

Parçacık Sürü Optimizasyonu (PSO) algoritması, ilk olarak Kennedy ve Eberhart (1995) tarafından önerilmiş olup, kuşlar, balıklar ve diğer hayvan sürülerinin çevrelerine adapte olma, yiyecek kaynaklarını bulma ve avcılardan kaçma gibi davranışlarından esinlenerek geliştirilmiştir. PSO algoritmasının temel çalışma prensibi, çözüm arayışındaki parçacıkların hem kendi deneyimlerinden hem de sürünün kolektif hareketlerinden etkilenerek hareket etmesidir [12]. Bu algoritma, uygulaması kolay ve kısa sürede yüksek kaliteli çözümler sunan bir algoritmadır. Bu durum, algoritmanın birçok probleme hızlıca entegre edilmesine olanak tanır. PSO özellikle problem uzayı geniş olduğunda hızlı bir şekilde iyi çözümler bulabilme kapasitesine sahiptir ve bu durum problemi optimize etme sürecini hızlandırır. Bu algoritmayı uygularken kullanılan kısıtlamaları tanımlamak kolaydır ve az sayıda parametre ile bu işlem gerçekleştirilir. Bunun yanı sıra, PSO algoritması, yerel minimumda sıkışma riskini azaltarak global optimal çözümler bulma potansiyeline sahiptir. Bu sayede çoklu hedeflerin optimize edilmesi gereken durumlarda etkili bir şekilde çözüm bulunur.

PSO algoritmasında her bir parçacık, çözüm arayışında bireyleri temsil eder ve bir çözüm sunar. Burada, parçacık hareketinin hem kendi geçmiş deneyimlerinden hem de tüm sürünün kolektif hareketinden etkilendiği bir yapı mevcuttur [13]. Algoritma, rastgele üretilen belirli sayıda parçacıkla başlatılır ve bu parçacıklar güncellenerek en uygun çözüm değeri araştırılır. Parçacıkların her biri, kendi en iyi çözümünü ($personal\ best$, p_{best}) ve tüm parçacıkların en iyi çözümünü ($global\ best$, g_{best}) kullanarak güncellenir; bu değerler hafızada saklanır. PSO sürecinde öncelikle çözüm arayacak sürü ve gerekli parametreler belirlenir. Uygunluk fonksiyonu yardımıyla parçacıkların çözüme yakınlıkları ölçülür ve bu değerlere göre p_{best} ve g_{best} değerleri güncellenir. Ardından, değişim hızı fonksiyonu ile her parçacığın hareketi belirlenir ve yeni durumları ayarlanır. Uygunluk fonksiyonu ile çözüme ne kadar yaklaşıldığı kontrol edilir. Bu döngü, istenilen şartlara ulaşılıncaya kadar tekrarlanır [14].

PSO algoritması, başlatma fazı ve güncelleme aşaması olmak üzere iki farklı aşamada çalışır. İlk aşamada parçacıkların ilk pozisyonları belirlenir ve gerekli algoritma parametreleri tanımlanır. Bireyler olarak adlandırılan parçacıklar, çok boyutlu aramalarda yayılır. Her parçacık, optimize edilecek problem için uygun bir çözümü temsil eder. Problemin performans fonksiyonu, PSO algoritmasının uygunluk fonksiyonunu tanımlar. Parçacıkların hareketleri ise, hız güncelleme fonksiyonu aracılığıyla, hem parçacıkların kendi en iyi deneyimlerinden (bilişsel bileşen) hem de sürünün en iyi çözümünden (sosyal bileşen) etkilenerek belirlenir. Parçacık ve yinelemeden yinelemeye kadar bilgiler, p_{best} olarak adlandırılan en iyi çözümün parçacıkların belleğinde depolanmasını ve paylaşılmasını sağlar. Ayrıca, herhangi bir parçacık tarafından ziyaret edilen en iyi çözüm olan g_{best}, parçacıklar arası bilginin bir sonucu olarak saklanır. PSO algoritmasının her yinelemesinden sonra, uygunluk değeri açısından daha iyi veya daha baskın bir çözüm bulunduğunda, her parçacık için en iyi çözüm güncellenir [15]. Parçacık sürüsü, Denklem 1'e göre hızlarını değiştirerek arama uzayında evrimleşmektedir.

$$v_i^{k+1} = w_i v_i^k + c_1 rand \times \left(pbest_i - x_i^k\right) + c_2 rand \times \left(gbest - x_i^k\right) \quad (1)$$

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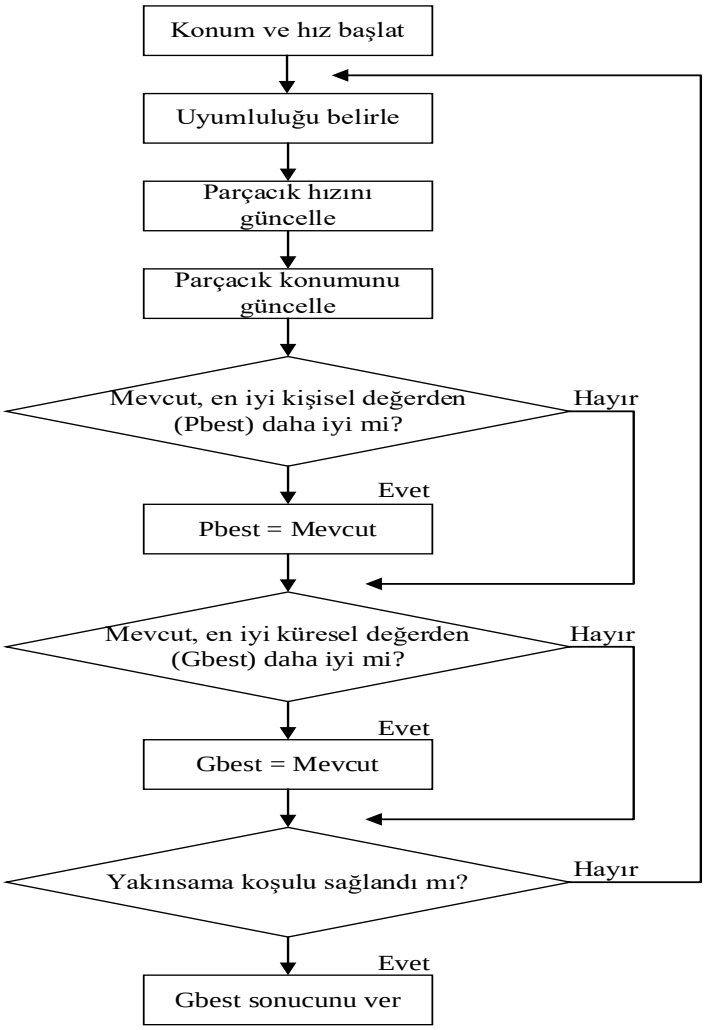
Burada, v_i^{k+1} i parçacığının k iterasyonundaki hızını, w_i eylemsizlik ağırlık faktörünü, $rand$ 0 ile 1 arasındaki rastgele bir sayıyı, c_1 ve c_2 ivme katsayılarını, $pbest_i$ mevcut parçacığın o ana kadar ulaştığı en iyi konumu, $gbest$ tüm bilgilendiriciler tarafından elde edilen küresel en iyi konumu ve x_i^k i parçacığının k iterasyonundaki konumunu göstermektedir. Her bir parçacığın yeni konumu Denklem 2 ile verilmektedir.

$$x_i^{k+1} = x_i^k + v_i^{k+1} \tag{2}$$

Parçacık i 'nin hızı için eylemsizlik ağırlık faktörü, eylemsizlik ağırlığı yaklaşımı ile Denklem 3'te tanımlanmıştır.

$$w_i = w_{max} - \frac{w_{max} - w_{min}}{iter_{max}} \times iter \tag{3}$$

Burada, $iter_{max}$ maksimum iterasyon sayısını ve $iter$ mevcut iterasyon sayısını temsil etmektedir. Ayrıca w_{max} ve w_{min} sırasıyla eylemsizlik ağırlık faktörünün üst ve alt sınırlarıdır.



Görsel 2. PSO Algoritmasının Akış Diyagramı

Görsel 2'de, PSO algoritmasının işlem adımları detaylandırılmıştır. İlk olarak, parçacıkların başlangıç konumları ve hızları rastgele bir şekilde belirlenir. Uyum fonksiyonu hesaplanarak her bir parçacığın performansı değerlendirilir ve parçacıkların hızları ve konumları güncellenir. Her bir parçacık, kendine özgü en iyi değeri (p_{best}) ve sürünün genel en iyi değerini (g_{best}) karşılaştırarak bu değerleri günceller. Yakınsama koşulu sağlanana kadar bu süreç tekrarlanır ve algoritma, g_{best} değerini optimize ederek en iyi çözümü belirler. Bu diyagram, PSO algoritmasının dinamik yapısını ve iteratif sürecini net bir şekilde göstermektedir.

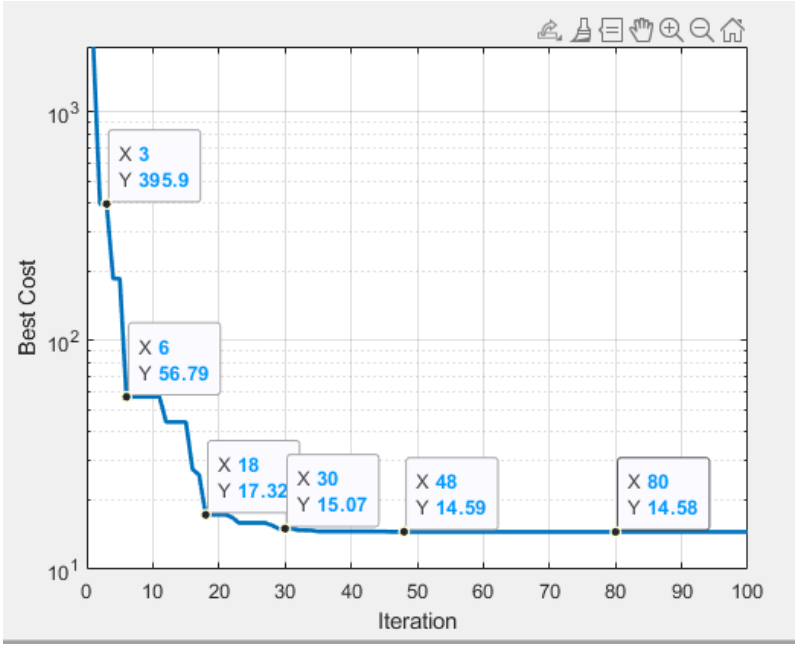
3. PERFORMANS ANALİZİ

Çok yollu iletişim kanallarında, gönderilen sinyallerin çeşitli bozucu etkiler nedeniyle alıcıda istenilen şekilde işlenememesi önemli bir sorundur. Bu çalışmada, kanalın bozucu etkilerini minimize etmek ve alıcıdaki sinyalin doğruluğunu artırmak amacıyla bir adaptif denkleştirici tasarımı yapılmıştır. Denkleştirici katsayılarının optimizasyonu için Parçacık Sürü Optimizasyonu (PSO) algoritması kullanılmıştır.

Kanal modeli, sinyalin çeşitli yollar üzerinden belirli zayıflama katsayıları ile birleşerek alıcıya ulaştığını varsaymaktadır. Örneğin, kanal katsayıları A, B ve C, sinyalin sırasıyla ilk, ikinci ve üçüncü yollar boyunca zayıflama oranlarını belirtmektedir. Bu model, gönderilen sinyalin A oranında zayıfladıktan sonra B katsayısıyla yansıyarak yeniden zayıflamasını ve üçüncü bir yansımada C katsayısıyla birleşerek alıcıya ulaşmasını simüle etmektedir. Denkleştirici, bu bozucu etkileri tersine çevirerek alıcıda orijinal sinyale en yakın sonucu elde etmeyi hedefler. Denkleştirici katsayılarının optimizasyonunda, rastgele sayılardan oluşan bir veri seti kullanılmıştır. Rastgele veri, çok yollu kanaldan ve adaptif denkleştiriciden geçirilmiştir. Gönderilen veri ile denkleştirici çıkışındaki veri arasındaki fark, ortalama karesel hata (MSE) fonksiyonu kullanılarak elde edilmiştir. PSO algoritmasıyla, her bir parçacık için bu işlemler tekrarlanır ve en düşük hata oranını sağlayan denkleştirici katsayıları optimize edilir. Bu süreç, deneme-yanılma yöntemiyle, en iyi çözümün bulunmasını sağlamıştır.

Yapılan çalışmada, bozulmuş sinyaller denkleştirici yardımıyla düzeltilmiş ve rastgele veri ile denkleştirici çıkışındaki sinyal arasındaki hata minimize edilmiştir. Burada PSO algoritmasının temel amacı, denkleştirici katsayılarını optimize etmek ve denkleştirici çıkışındaki sinyalin, gönderilen sinyale olabildiğince yaklaşmasını sağlamaktır. Bu sayede, alıcıdaki sinyallerin doğruluğu artırılmış ve iletişim kanalı nedeniyle ortaya çıkan bozucu etkiler iyi bir şekilde giderilmiştir.

Şekil 5'te denkleştiricinin optimizasyon sonucu elde ettiği katsayıların performansına ait grafik verilmiştir. Grafikte, hata miktarı ($Best_{cost}$) ve iterasyon sayısına bağlı olarak sonuçlar yer almaktadır. Her bir iterasyonda, 100 parçacık dağıtılmış ve bu parçacıkların taranmasıyla elde edilen en düşük hata değeri gösterilmiştir. Örneğin, 6. iterasyonda, 100 noktanın taranması sonucunda minimum hata değeri 129 olarak elde edilmiştir. Verilen grafik, PSO algoritmasının belirli iterasyonlarda hata değerini nasıl iyileştirdiğini açıkça göstermektedir. Kanal modellemesi ve PSO algoritmasının entegrasyonu, özellikle farklı zamanlarda yansıyan ve zayıflayan sinyallerin etkilerini azaltarak, denkleştirici performansının iyileştirilmesinde etkili bir çözüm sunmuştur. Elde edilen sonuçlar, önerilen yöntemin çok yollu kanallarda sinyal doğruluğunu artırmada başarılı olduğunu göstermiştir.



Görsel 3. PSO Algoritmasının İterasyonlara Göre Maliyet Fonksiyonu ($Best_{cost}$) Değişimi

4. SONUÇ

Yapılan çalışmada, çok yollu iletişim kanallarındaki bozucu etkileri azaltmak ve adaptif denkleştiricilerin performansını artırmak amacıyla Parçacık Sürü Optimizasyonu (PSO) algoritması kullanılmıştır. PSO algoritması, kanal denkleştirici katsayılarını optimize ederek, haberleşme sürecinde bozulan sinyallerin alıcıda orijinal verilere en yakın şekilde düzeltilmesini sağlamıştır. Önerilen yöntemin, çok yollu kanal modellemesiyle uyumlu bir şekilde sinyaller arası girişimi (ISI) minimize ettiği ve kanal bozulmalarını etkili bir şekilde azalttığı görülmüştür. Elde edilen sonuçlar, PSO algoritmasının düşük ortalama kare hata (MSE) değerleri ile hızlı ve doğru bir yakınsama sağladığını göstermektedir. Rastgele veri setleri kullanılarak yapılan testlerde, denkleştirici katsayılarının optimize edilmesiyle alıcıda elde edilen sinyalde önemli iyileşmeler gözlemlenmiştir. Önerilen yöntem, haberleşme kanallarında bozucu etkilerin baskın olduğu durumlarda güçlü bir çözüm sunmaktadır. İlerleyen çalışmalarda, farklı metasezgisel algoritmalarla PSO algoritmasının hibrit yapılarla birleştirilmesi veya gerçek zamanlı uygulamalarda denkleştirici performansının incelenmesi, yöntemin daha geniş bir alanda kullanımını mümkün kılabilir.

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MODELING OF STRAIN AGING EFFECTS IN AISI 304 AUSTENITIC STAINLESS STEEL WITH ARTIFICIAL NEURAL NETWORKS

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ABSTRACT

This study investigated the changes in the mechanical properties of AISI 304 austenitic stainless steel after static strain aging heat treatment to model these changes using artificial neural networks (ANN). In the experiments, pre-strains of 5%, 10%, and 15% were applied to the specimens, followed by annealing at temperatures of 200°C, 400°C, and 600°C for 30, 60, and 90 minutes. The experimental results indicated that the highest tensile strength (782 MPa) and yield strength (556 MPa) were achieved in specimens pre-strained by 15% and annealed at 200°C for 60 minutes. An ANN model was developed in the MATLAB environment and trained using the Levenberg-Marquardt algorithm to predict the relationship between process parameters (pre-strain rate, temperature, and time) and mechanical properties (tensile and yield strength). The model's predictions closely matched the experimental results, achieving an accuracy of R = 0.99. Without extensive experimental testing, this approach predicts material strength changes under various process parameters. The study demonstrates that artificial neural networks can effectively model the outcomes of heat treatment processes, offering a valuable tool for optimizing industrial processes.

Keywords: AISI 304, strain aging, artificial neural networks, Matlab

1. INTRODUCTION

AISI 304 austenitic stainless steel is widely used in industry. It is preferred due to its high corrosion resistance and machinability. In addition, due to its heat-resistant structure is used in various industrial applications requiring low and medium temperatures [1,2]. These applications are mainly in the aerospace and automotive industries, kitchen equipment, heat exchangers, and electrical devices [3].

Despite the favorable properties of AISI 304 materials, their limited ability to be hardened by heat treatment and their low strength limit their use in applications requiring strength [4]. Studies have determined that AISI 304 steel is annealed at low temperatures for a certain period after plastic deformation; applying a static strain aging process improves its mechanical properties [5–7]. After plastic deformation, the dislocations, whose density increases considerably in the material, interact with dissolved atoms such as carbon and nitrogen in austenitic steels under the influence of temperature, causing their movement to be restricted. This mechanism, called the Cottrell atmosphere, ensures the strengthening of the material [8].

Predicting the strength performance of AISI 304 steel subjected to plastic deformation by forming methods under conditions requiring a specific operating temperature without extensive experiments or by reducing the number of tests is very important for optimizing industrial processes. Artificial neural networks (ANN) are computational models used in machine learning inspired by the working principles of the human nervous system [9]. ANNs emulate the way nerve cells (neurons) in the human brain process information by communicating with each other [10]. In models consisting of various layers, the first layer is where data is input using the parameters measured during the experiments. The second layer is the hidden layer between the input and output of the algorithm where learning takes place. The last layer is the layer where the output data is obtained. ANN model is trained by performing mathematical operations on the given data. This process is also called the training or learning process. After this process, the ANN can now relate and evaluate the data [11,12]. Thus, ANN makes successful predictions about the results by learning and analysing various complex studies that require many tests with data inputs. It also saves time and cost.

Garg. et al. used various mathematical modeling methods to investigate the properties of AISI 304 austenitic stainless steel, which is widely used for cladding fuel rods in nuclear reactors. These methods include ANN support vector regression (SVR) and multiple genetic programming (MGGP) [13]. Gupta et al. used the ANN model to predict the yield stress of AISI 304 steel in the dynamic strain aging (DSA) regime. While the ANN models showed high matching with the experimental data, the Johnson Cook (JC), modified Zerilli-Armstrong (m-ZA), and altered Arrhenius (m-Arr) models could not effectively predict the yield stress in this regime [14]. Krishnamurthy et al. could accurately predict the material's behavior, especially at high temperatures and different deformation rates, thanks to the ANN model they developed for AISI 304 steel [15]. Mirzadeh and Najafizadeh modeled the effect of annealing temperature and time on transforming martensite to austenite in cold-worked AISI 304 stainless steel using ANN. This model can determine the appropriate annealing temperature and time [16]. Mandal et al. investigated the hot torsion behavior of AISI 304L stainless steel using ANN. This study evaluated the effects of temperature and deformation rate on yield stress, and the ANN model

could accurately predict the deformation behavior [17]. Although AISI 304 austenitic stainless steel has a wide range of applications in industry, studies on improving its mechanical properties and optimizing its strength performance using ANN are limited.

In this study, tensile test specimens obtained from AISI 304 austenitic stainless steel material supplied as sheet metal were pre-deformed at various rates, and the static strain aging process was applied under varying temperature and time parameters. The yield and tensile strengths of the treated specimens were determined by a tensile test and compared with those of the untreated specimens. In addition, deformation rate, time, and temperature values were used as input data in the ANN model created using the MATLAB program, and the model was trained with the experimental results obtained. Entering new variable values as input to the trained model aims to get results without experimentation and evaluate the performance of the ANN model.

2. MATERIAL AND METHOD

2.1. Chemical Analysis

Samples for chemical analysis were taken from the sheet metal to verify that the chemical composition of the purchased AISI 304 austenitic stainless steel conformed to known standard values. Chemical analysis was carried out using an Oxford brand optical emission spectrometer. The results confirmed that the chemical composition of the supplied material met the required standards. The values obtained are presented in Table 1.

Table 1. Standard and analyzed chemical compositions of AISI 304 steel

Material		Weight %						
		C	Mn	P	S	Si	Cr	Ni
AISI 304	Standard Composition	max. 0.08	max. 2.0	max. 0.045	max. 0.03	max. 0.75	18.0-20.0	8.0-10.5
	Analysis Results	0.0069	1.14	0.037	0.0095	0.423	18.249	8.012

2.2. Pre-Strain Process

Tensile tests were conducted to establish the untreated materials' reference yield strength and tensile strength values. To increase the number and density of dislocations within the material's microstructure, pre-strains of 5%, 10%, and 15% were applied at a rate of 10 mm/min using an INSTRON 5982 tensile testing machine with a capacity of 100 kN. The test specimens were prepared according to the ASTM E8 standard, and their dimensions and appearance are shown in Figure 1.

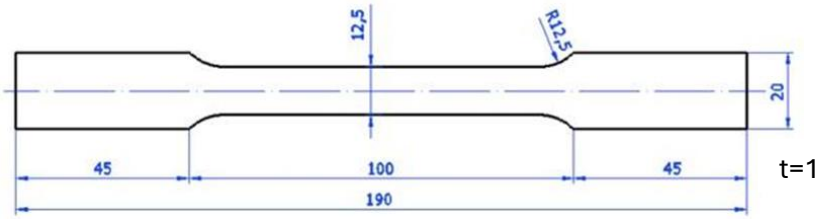

Figure 1. **Tensile test specimen dimensions**

2.3. Heat Treatments and

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To create a Cottrell atmosphere around the dislocations within the material's internal structure where the dislocation density had been increased by pre-straining, the specimens were annealed in separate groups at process temperatures of 200°C, 400°C, and 600°C for durations of 30, 60, and 90 minutes, considering the recrystallization temperature. To ensure accuracy and minimize errors, three samples were treated in the furnace for each combination of temperature and duration. Following the annealing process, tensile tests were performed at 10 mm/min speed using an INSTRON 5982 tensile testing machine with a capacity of 100 kN.

2.4. Artificial Neural Network Modeling

An artificial neural network (ANN) model was developed, trained, and tested using MATLAB to predict the tensile and yield strength values as output variables. The input variables for the model included pre-strain rate, temperature, and duration of the strain aging heat treatment applied to the samples. The structure of the ANN model is shown in Figure 2.

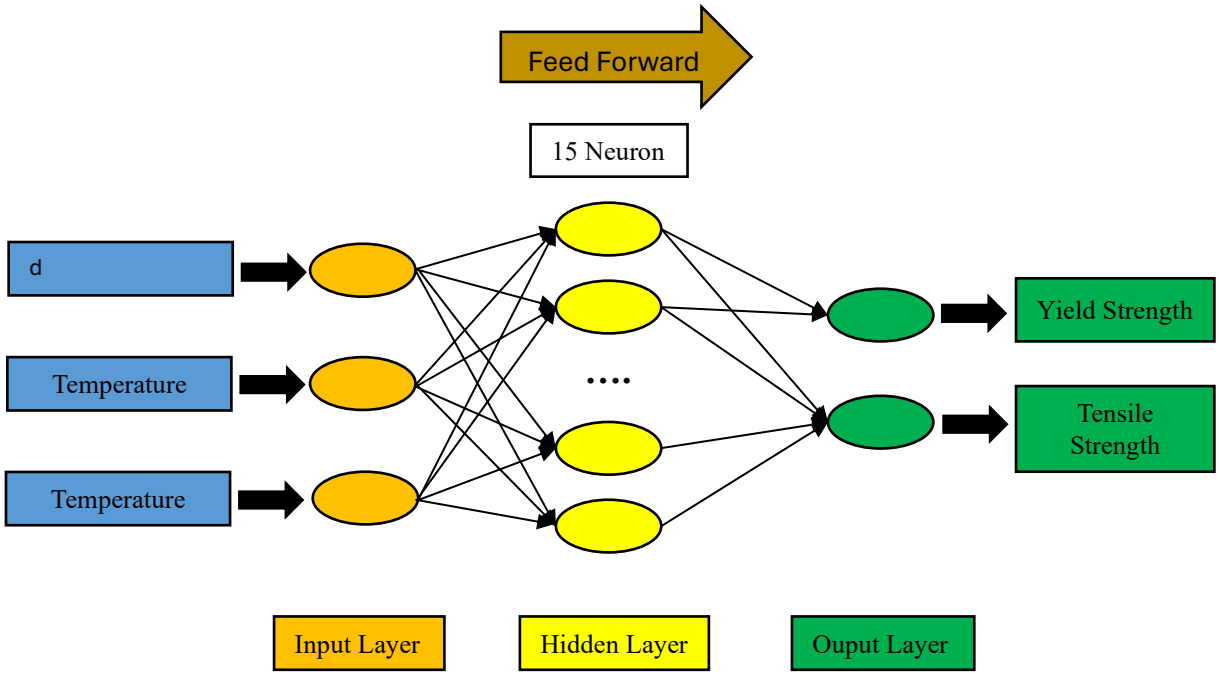

Figure 2. Artificial neural network model

Examining the structure of the neural network model given in Figure 2, it is seen that there is an input layer with three input neurons, a hidden layer with 15 neurons, and an output layer with two neurons. The algorithms used include random division of data (dividend), Levenberg-Marquardt training algorithm (trail), and Mean Square Error (MSE) performance measure.

3. RESULTS AND DISCUSSION

3.1. Pre-Strain Process and Tensile Test Results

To increase the number and density of dislocations in the material microstructure, the desired amount of deformation was achieved by applying 5%, 10%, and 15% pre-strain to the

specimens in the tensile test device. A comparative view of the test specimen used in the experimental studies is given in Figure 3.

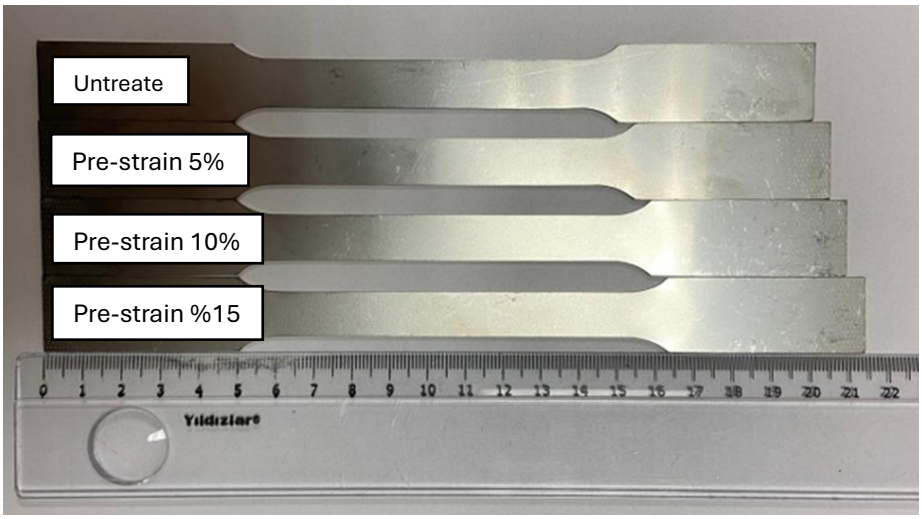

Figure 3. View of the test specimens after pre-strain

The yield strength and tensile strength values obtained from the tensile tests for specimens annealed at different temperatures and times are provided in Table 2. The average results of the three samples tested for each test condition were calculated, and standard deviation values were given. The yield strength of the untreated specimen was 196.6 MPa, and the tensile strength was 618.9 MPa. After the aging process was applied to the specimens, it was observed that the yield and tensile strength of the material improved for each test condition. The increase in the strength of AISI 304 austenitic stainless steel after static strain aging is related to the interaction of dislocations, whose number and density increase with pre-strain, with carbon atoms and the formation of Cottrell atmosphere. During static strain aging, diffusion of carbon atoms into dislocations occurs in the deformation-induced martensite and austenite phases. Carbon atoms collect around the dislocations due to diffusion and increase the strength of the material by interacting and making the movement of the dislocations difficult [7,18,19]. The highest strength value within the different changing test conditions was measured as 545.4 MPa for yield strength and 769.9 MPa for tensile strength of the specimens subjected to strain aging heat treatment at 200 °C for 60 min at 15% pre-strain rate.

Table 2. Tensile test experimental results

Deformation (mm)	Temperature (°C)	Time (min.)	Yield Strength (MPa)	Standard Deviation	Tensile Strength (MPa)	Standard Deviation
0	0	0	196.6	1.5	618.9	0.8
0.05	200	30	352.0	3.0	686.4	3.6
0.05	200	60	330.1	11.6	659.6	11.4
0.05	200	90	331.5	20.5	663.5	23.3
0.05	400	30	344.0	11.3	664.9	12.6
0.05	400	60	325.3	12.8	651.3	14.0
0.05	400	90	340.8	13.4	665.9	14.9
0.05	600	30	346.8	15.5	655.0	20.3
0.05	600	60	332.8	4.8	657.4	12.7

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0.05	600	90	328.1	8.7	656.9	18.5
0.1	200	90	435.1	12.5	694.5	13.6
0.1	400	60	434.4	13.7	690.7	18.3
0.1	400	90	435.3	12.1	687.9	12.3
0.1	600	90	424.5	10.0	685.5	10.3
0.15	200	60	545.4	11.5	769.9	12.6
0.15	200	90	533.6	14.9	752.1	13.6
0.15	400	90	546.2	11.6	755.9	11.9
0.15	600	60	517.4	9.7	747.5	10.5
0.15	600	90	505.4	22.8	754.7	24.1

3.1. Artificial Neural Network Training and Predictions

In Table 3, the predictions made by the artificial neural network trained to predict the tensile and yield strength values as output values using variables such as pre-strain amount, temperature, and time as input variables are shown in green. The predictions are close to the experimental results.

Table 3. Prediction results of the ANN after training

Deformation Value	Strain Aging Temperature	Strain Aging Time	Yield Strength (MPa)	Tensile Strength (MPa)	PREDICT Yield Strength	PREDICT Tensile Strength
0.05	200	30	349	682,7	330,9	669,9
0.05	200	30	355	689,9	330,1	666,4
0.05	200	60	343.8	674,9	330,1	666,4
0.05	200	60	331	656,1	330,1	666,4
0.05	200	60	315.4	647,7	329,3	662,9
0.05	200	90	360.2	696,4	329,3	662,9
0.05	200	90	313.6	646,8	329,3	662,9
0.05	200	90	320.5	647,1	332,7	663,6
0.05	400	30	359.7	682,7	332,7	663,6

A screenshot taken from the MATLAB interface showing the training process and performance of the neural network used in the study is given in Figure 4. The image includes the structure of the neural network, algorithms used, training progress, and performance measurements. The algorithms used include the randomization of the data (dividend), the Levenberg-Marquardt training algorithm (trail), and the Mean Square Error (MSE) performance measure.

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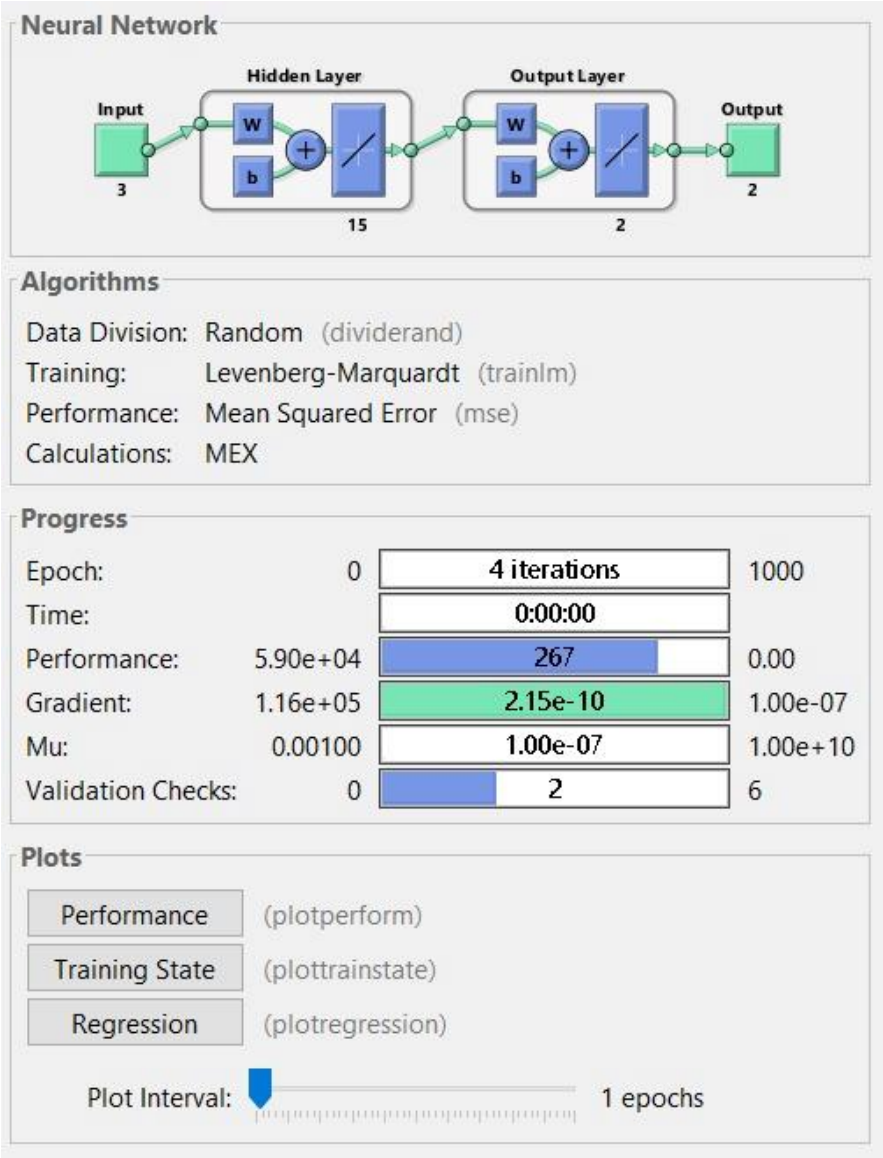

Figure 4. Neural network overview and performance status

The training progress section indicates that the neural network completed only four iterations, with training finishing rapidly (0:00:00). During this process, the initial performance value (Mean Square Error, MSE) dropped from 59,000 to 267. The initial gradient value also decreased significantly, from 116,000 to 2.15e-10, while the Marquardt parameter (Mu) decreased from an initial value of 0.001 to 1.00e-07. These results demonstrate that the model learned quickly, although the validation performance remained unchanged. The training process was halted after two validation checks despite an allowance for up to six failures, indicating that the early stopping mechanism effectively prevented overfitting.

An analysis of Figure 4 shows the training and validation performance graphs, the training state graph (depicting parameter changes during training), and the regression graph, which illustrates the relationship between actual and predicted values. The results confirm that while the model performed well during training, early stopping was triggered when no further improvement in validation performance was observed. Although the overall model performance and validation results were positive, further improvements could be made with more iterations

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and regularization techniques. Monitoring changes in validation performance over additional training epochs would be beneficial. These findings suggest regularization techniques, such as dropout or L2 regularization, could enhance the model's accuracy and generalization ability. Additionally, careful monitoring and adjustment of early stopping criteria during training is essential.

Figure 5 depicts the variation of MSE values for the training, validation, and test sets over the four training periods. The best validation performance was observed in period 2, with an MSE of 495.7891. During the first two periods, MSE values for training, validation, and test sets dropped rapidly, indicating efficient learning by the model. However, after period 2, validation and test MSE values stabilized and slightly increased, signaling to overfit. The continuous decrease in training MSE suggests that the model started to memorize the training data, thereby reducing its generalization performance. To improve the model's generalization, terminating the training process after period 2 using early stopping proved effective.

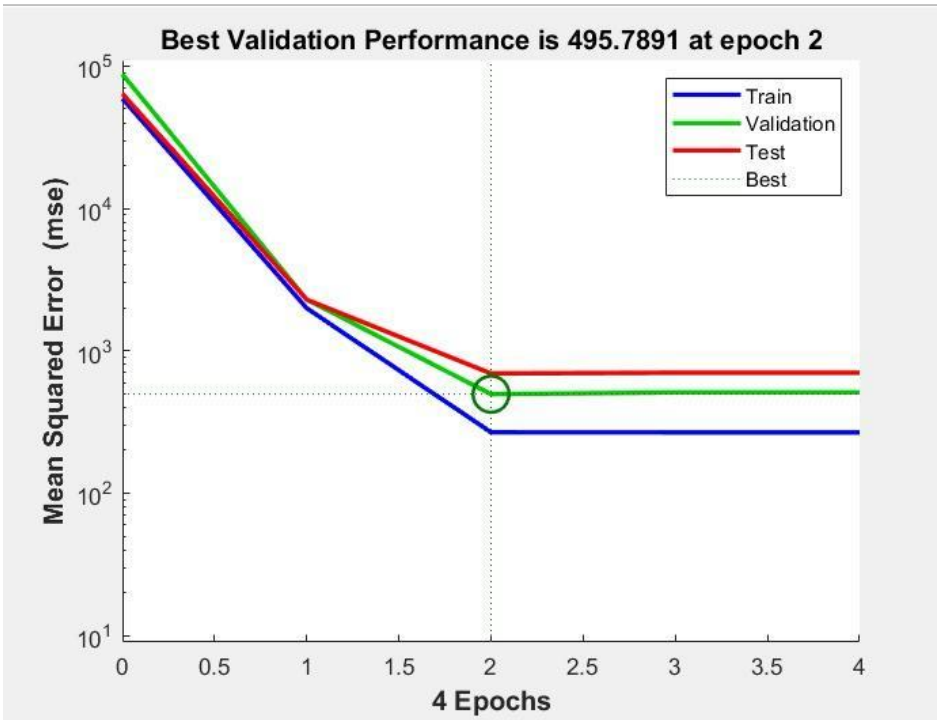

Figure 5. Performance graph of artificial neural network

Figure 6 contains regression graphs showing the neural network's performance in training, validation, testing, and overall data sets. Each graph shows the relationship between the model-predicted values (output) and target values (target). Performance metrics for training, validation, testing, and all data are presented in four sections in the graph.

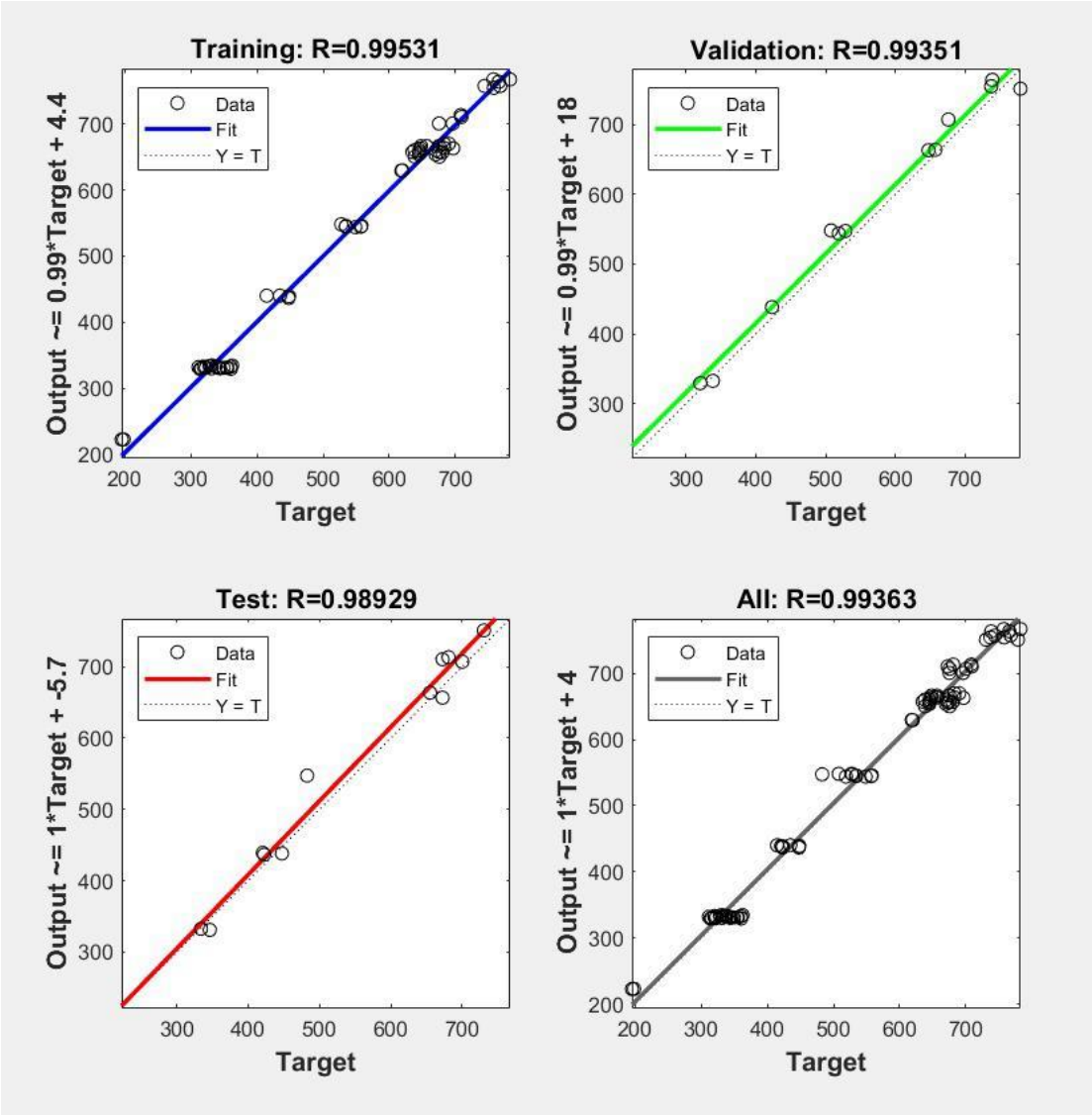

Figure 6. Regression graphs of artificial neural network

The blue line represents the relationship between the predicted and target values in the training data set. The R-value is specified as 0.99531. The R-value of the training plot is very close to 1, indicating that the model's predictions are highly correlated with the actual values. This means that the model performs quite well on the training data, and the accuracy of its predictions is high [20]. The green line shows the relationship between the predicted and target values in the validation dataset. The R-value is specified as 0.99351. An R-value close to 1 indicates that the model's predictions are very close to the target values and, therefore, the model works with high accuracy [21]. The R-value of 0.98929 in the test graph shown with the red line indicates that the model's predictions are highly correlated with the actual values [22]. The black line with an R-value of 0.99363 shows that the relationship between predicted and target values performs very well in all data sets.

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4. CONCLUSION

This study aims to investigate how the mechanical properties of AISI 304 austenitic stainless steel change after static stress aging heat treatment and to predict these changes with an artificial neural network (ANN) model. Different pre-strain ratios, temperatures, and treatment times were used in the experiments, and the ANN model successfully predicted the effect of these variables on the tensile and yield strengths of the material as a result of the following results;

- The yield strength of untreated AISI 304 austenitic stainless steel specimens was 196.6 MPa, and tensile strength was 618.9 MPa.
- The specimens given for 15% pre-strain and subjected to strain aging heat treatment at 200 °C for 60 min reached the highest strength values. The average yield strength was 545.4 MPa, and the tensile strength was 769.9 MPa.
- In the artificial neural network model, pre-stress amount, temperature, and time were used as input variable values. When the predictions made by the artificial neural network, which was trained to predict the tensile and yield strength values as output values, were examined, it was determined that it made predictions with an error margin of 5.2% for yield strength and 2.5% for tensile strength.
- The high R values obtained from the Training (R: 0.99531), Validation (R: 0.99531), and Test (R: 0.99351) data sets show that the model performs strongly and the predicted values are close to the actual values.
- The R-value of 0.99363, which indicates the overall performance in all data, shows that the model performs consistently and reliably in all data sets.

Acknowledgments

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A SIMULATIONAL COMPARISON OF EQUAL AND OPTIMUM POWER ALLOCATION CASES IN AN SDF COOPERATIVE TRANSMISSION SCENARIO FOR SMART VEHICLES

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ABSTRACT

One of the advantages of cooperative communication is that power can be allocated separately for the source and relay. Because the source power and relay power do not have to be equal. Increasing the total transmission power with equal allocation will bring the BER closer to zero. However, since the power cannot be increased infinitely, it is possible to minimize the BER at the receiver by allocating power unequally. In this study, a simulational comparison of equal and optimum power allocation cases is presented in the scenario of cooperative data transmission from a source/base station and a relay/traffic sign to a vehicle with constant speed using OTFS modulation and SDF protocol. According to this comparison, it is shown that optimum power allocation provides a better BER performance than equal power allocation.

Keywords : Equal power allocation, optimum power allocation OTFS; SDF; BER analysis; cooperative communications; smart vehicles; V2X

1. INTRODUCTION

Nowadays, the reliability and efficiency of wireless communication are seriously reduced due to time delay propagation as a result of deep fading due to reasons such as multipath, shadowing caused by surrounding buildings, vehicles, etc. . In addition, the fact that the user (or vehicle) is moving at a constant speed causes the disadvantageous situation called Doppler effect to be added in addition to the delay propagation in communication.

All the reasons mentioned above affect the Bit Error Rate (BER) performance, which is one of the basic metrics of digital communication performance. Bit Error Rate (BER) is the number of bit errors per unit time; where bit errors refer to the number of received bits in a data stream that have been changed due to noise, fading, interference, distortion, bit synchronization etc. errors over a communication channel. It is a very important metric used to evaluate the quality of digital communication [1].

Cooperative communication is a subject that has existed in wireless communication systems for years. By creating a diversity effect with cooperative communication, a serious decrease in BER performance can be achieved. There are various cooperative communication protocols and schemes in the literature. Selective Decode and Forward (SDF) scheme is one of them. In SDF, the source sends to the relay and destination in the first stage, and in the second stage, when the relay decodes correctly, it resends the data sent by the source [2].

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New modulation technique called OTFS (Orthogonal Time Frequency Space Modulation) is envisaged to be used in order to make V2X (Vehicle to Everything) communications more reliable and efficient. V2X, which stands for Vehicle to Everything, is a pioneering phenomenon for the communication system of smart vehicles, which paves the way to fully intelligent driving through high bandwidth, low latency, high reliability connections of information from sensors and other sources [3].

In cooperative communication systems, the source and relay or relays can transmit using equal power. Optimal power allocation between the source and relay or relays provides an advantage in order to minimize total power consumption. Thus, an energy efficient solution is obtained with the same BER performance with optimal power allocation [4].

In this paper, the communication of smart vehicle with the base stations is carried out by executing SDF protocol with the help of traffic sign used as a relay and using OTFS modulation in transmissions. In this study, the communication scenario of a fixed base station with an antenna above the roof level, a traffic sign used as a relay and a smart vehicle moving at a constant speed at the street level is considered as in [5] and [6]. In this scenario, approximately optimum allocated powers are used directly from [6] and a simulational comparison of equal and optimum power allocation cases in that scenario is performed. It is shown that optimum power allocation method presents better performance than equal power allocation method.

2. SYSTEM MODEL AND SDF PROTOCOL

In the system model, the transmission occurs in two phases as in SDF protocol [5] and [6]. The system model in [5] and [6] is taken as reference in exactly the same way and this model is presented in Figure 1 as in [5] and [6]. In the first phase, the base station/source emits the symbol and the symbol is received by both the smart vehicle/destination and the traffic sign/relay. In the second phase, if the symbol sent by the source in the first phase is correctly decoded in the traffic sign/relay, the traffic sign/relay retransmits the same symbol to the smart vehicle/destination [5], [6].

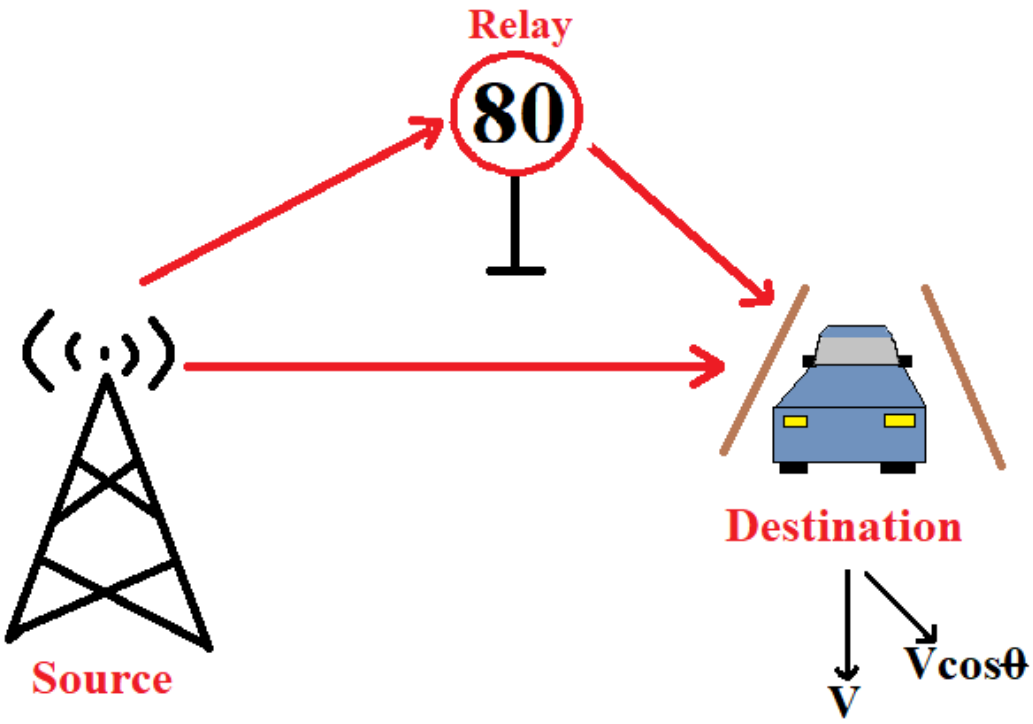

Figure 1. System model

The signal transmitted from the source and received at the destination in the delay-Doppler (DD) domain can be expressed in vector form with rectangular waveforms as follows:

$$\bar{y}_{s,d} = H^{rect}_{eff_{s,d}} \bar{x} + \bar{\tilde{n}}_{s,d} \tag{1}$$

where $H_{eff_{s,d}}$, $\bar{x}$ and $\bar{\tilde{n}}$ denote the effective channel matrix, the transmitted signal in the DD domain and added noise vector, respectively. Equation (1) can be stated as detailed as

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix}_{s,d} = \begin{bmatrix} h_1 & 0 & 0 & h_2 j \\ 0 & h_1 & h_2 & 0 \\ 0 & -h_2 j & h_1 & 0 \\ h_2 & 0 & 0 & h_1 \end{bmatrix}_{eff_{s,d}} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} \tilde{n}_1 \\ \tilde{n}_2 \\ \tilde{n}_3 \\ \tilde{n}_4 \end{bmatrix}_{s,d} \tag{2}$$

where h_1 and h_2 are the complex channel path attenuation factors, respectively.

In OTFS transmission, the number of subcarriers is expressed by M and the size of the time slots is expressed as N. The channel matrix has the size of MNxMN. Since M = 2 and N = 2 are taken in the scenario in this study, the channel matrix has the size of 4x4 and the symbol vector has the size of (2x2)x1.

The total instantaneous SNR for the transmission between source and destination is presented below:

$$SNR_{s,d_{total}} = \frac{P_s}{\sigma^2}\|h\|^2 = \frac{P_s}{\sigma^2}(|h_1|^2 + |h_2|^2) = SNR_s(|h_1|^2 + |h_2|^2) \quad (3)$$

where P_s is the power of the base station/source.

As in [5] and [6], the approximate average BER for the Rayleigh fading channel for source to destination transmission can be expressed by:

$$BER_{s,d} \approx \frac{1}{2SNR_s} \approx \frac{1}{2(\frac{P_s}{\sigma^2})} \quad (4)$$

The signal transmitted from the source and received at the relay in the DD domain can be expressed in vector form with rectangular waveforms as follows:

$$\bar{y}_{s,r} = H_{eff_{s,r}}^{rect}\bar{x} + \bar{\tilde{n}} \quad (5)$$

where $H_{eff_{s,r}}^{rect}$ denotes the effective channel matrix. Equation (5) can be stated as detailed as

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix}_{s,r} = \begin{bmatrix} h_3 & 0 & 0 & h_4 j \\ 0 & h_3 & h_4 & 0 \\ 0 & -h_4 j & h_3 & 0 \\ h_4 & 0 & 0 & h_3 \end{bmatrix}_{eff_{s,r}} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} \tilde{n}_1 \\ \tilde{n}_2 \\ \tilde{n}_3 \\ \tilde{n}_4 \end{bmatrix}_{s,r} \quad (6)$$

where h_3 and h_4 are the complex path attenuation factors, respectively.

The total instantaneous SNR for the transmission between source and relay is presented below:

$$SNR_{s,r_{total}} = \frac{P_s}{\sigma^2}\|h\|^2 = \frac{P_s}{\sigma^2}(|h_3|^2 + |h_4|^2) = SNR_s(|h_3|^2 + |h_4|^2) \quad (7)$$

As in [5] and [6], the approximate average BER for the Rayleigh fading channel for source to relay transmission can be expressed by:

$$BER_{s,r} \approx \frac{1}{2SNR_s} = \frac{1}{2(\frac{P_s}{\sigma^2})} \quad (8)$$

The signal transmitted from the relay and received at the destination in the DD domain can be expressed in vector form with rectangular waveforms as follows:

$$\bar{y}_{r,d} = H_{eff_{r,d}}^{rect}\bar{x} + \bar{\tilde{n}} \tag{9}$$

where $H_{eff_{r,d}}^{rect}$ denotes the effective channel matrix. Equation (9) can be stated as detailed as

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix}_{r,d} = \begin{bmatrix} 0 & h_6 & h_5 & 0 \\ h_6 & 0 & 0 & h_5 j \\ 0 & 0 & 0 & -h_6 \\ 0 & h_5 j & h_6 & 0 \end{bmatrix}_{eff_{r,d}} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} \tilde{n}_1 \\ \tilde{n}_2 \\ \tilde{n}_3 \\ \tilde{n}_4 \end{bmatrix}_{r,d} \tag{10}$$

where h_5 and h_6 are the complex path attenuation factors, respectively.

The total instantaneous SNR for the transmission between relay and destination is presented below:

$$SNR_{r,d_{total}} = \frac{P_r}{\sigma^2}\|h\|^2 = \frac{P_r}{\sigma^2}(|h_5|^2 + |h_6|^2) = SNR_r(|h_5|^2 + |h_6|^2) \tag{11}$$

where P_r is the power of the traffic sign/relay.

The approximate average BER is

$$BER_{r,d} \approx \frac{1}{2SNR_r} = \frac{1}{2(\frac{P_r}{\sigma^2})} \tag{12}$$

The combined single-input multiple-output (SIMO) model can be stated below in vector form as shown in [5] and [6], because the transmitted signal is the same in each transmission and the received signal is different.

$$\begin{bmatrix} \bar{y}_{s,d} \\ \bar{y}_{r,d} \end{bmatrix} = \begin{bmatrix} H_{eff_{s,d}}^{rect} \\ H_{eff_{r,d}}^{rect} \end{bmatrix} \bar{x} + \begin{bmatrix} \bar{\tilde{n}}_{s,d} \\ \bar{\tilde{n}}_{r,d} \end{bmatrix} \tag{13}$$

The approximate average BER expression assuming 1x2 SIMO communication can be used from [5] as in below.

$$BER_{conc} \approx \frac{3}{4SNR_s SNR_r} = \frac{3}{4(\frac{P_s}{\sigma^2})(\frac{P_r}{\sigma^2})} \tag{14}$$

3. A SIMULATIONAL COMPARISON OF EQUAL AND OPTIMUM POWER ALLOCATION CASES IN AN SDF COOPERATIVE TRANSMISSION SCENARIO

After getting each BERs as in [5] and [6], approximate average end-to-end BER at the destination is

$$Pr(e) \approx BER_{s,d}\, BER_{s,r} + BER_{conc} \tag{15}$$

$$Pr(e) = \frac{1}{2SNR_s} \times \frac{1}{2SNR_s} + \frac{3}{4SNR_s SNR_r} \tag{16}$$

Using the equations (4), (8), (12) and (14), approximate average end-to-end BER can be presented as follows:

$$Pr(e) = \frac{1}{2(\frac{P_s}{\sigma^2})} \times \frac{1}{2(\frac{P_s}{\sigma^2})} + \frac{3}{4(\frac{P_s}{\sigma^2})(\frac{P_r}{\sigma^2})} \tag{17}$$

The total power spent by the base station/source and traffic signal/relay can be stated as follows:

$$P_s + P_r = P = \alpha P + (1-\alpha)P \tag{18}$$

where α is the power ratio of total power for the source. Optimized power ratio values (α) have taken directly from [6] as in below

α_1 =0,5931 and α_2 =-0,8431

Positive root is used, then the approximate optimum power of the base station/source and the traffic sign/relay is stated below.

$$P_s = 0{,}5931P \tag{19}$$

$$P_r = (1 - 0{,}5931)P = 0{,}4069P \tag{20}$$

It should be emphasized that all the Equations in this paper are taken from the study [6].

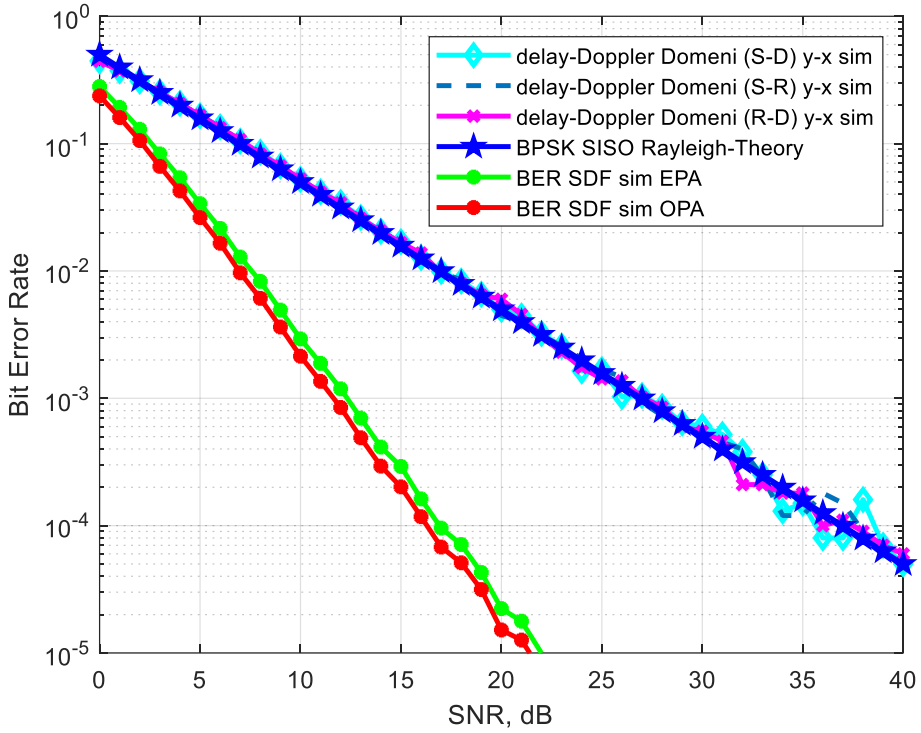

Figure 2. Comparison of EPA and OPA cases in SDF-OTFS scheme

It should be noted that non-cooperative transmissions have the same performance as the theoretical single-input single-output (SISO)-Rayleigh channel transmission with a single antenna at the transmitter and receiver, as seen in Figure 2. It is seen that when equal power is allocated to the base station and the traffic sign, a better SNR-BER performance is obtained compared to the SISO model. It is understood from the Figure 2 that the best SNR-BER performance is achieved when optimum power is allocated as in Equation (19) and (20) to the base station and the traffic sign.

4. CONCLUSIONS

In this paper, a simulational comparison of equal and optimum power allocation cases is presented in the scenario of cooperative transmission from a source/base station and a relay/traffic sign to a vehicle with constant speed using OTFS modulation and SDF protocol. According to this comparison, it is shown that optimum power allocation method provides a better SNR-BER performance than equal power allocation method.

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EV TİPİ TAMBURLU ÇAMAŞIR KURUTMA MAKİNELERİNDE MİKROPLASTİK FİLTRELEME SİSTEMİ

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ÖZET

Son yıllarda, sentetik giysilerin çamaşır makinelerinde yıkanması ve kurutma makinelerinde kurutulması sırasında ortaya çıkan mikroplastiklerin atık sulara karışması çevresel açıdan önemli bir tehdit olarak kabul edilmektedir. Özellikle bu kıyafetler yıkandığında salınan mikroplastikler, su kaynaklarına karışarak çevre kirliliğine yol açmaktadır. Mikroplastik kirliliğinin ciddi sonuçları göz önünde bulundurulduğunda, bu sorunu önlemek için çeşitli teknolojik çözümler geliştirilmeye başlanmıştır. Çalışmamızda, firmamız bünyesinde üretilen kurutma ve çamaşır makineleri kullanarak bu konuya yönelik bir araştırma gerçekleştirilmiştir. Temel amacımız, özel olarak tasarladığımız bir mikroplastik yakalama sisteminin etkinliğini test etmek ve bu sistemin kıyafet yıkama işlemleri sırasında atık suya mikroplastik salınımını ne ölçüde azalttığını incelemektir. Bu araştırmada, kurutma sırasında oluşan su ve bu yolla atık suya karışan mikroplastikler, DLS (Dinamik Işık Saçılımı) ve SEM (Taramalı Elektron Mikroskobu) gibi ileri teknoloji cihazlar kullanılarak analiz edilmiştir. DLS cihazı ile mikroplastiklerin boyut dağılımı ölçülmüş, SEM cihazı ile mikroplastiklerin yapısal özellikleri detaylı bir şekilde incelenmiştir. Analiz sonuçları, tasarladığımız mikroplastik yakalama sisteminin giysi yıkama sırasında atık suya salınan mikroplastik miktarını kayda değer ölçüde azalttığını göstermiştir. Bu bulgular, mikroplastik salınımını azaltmaya yönelik çözümlerin hem etkili hem de sürdürülebilir bir geleceğe katkı sağladığını ortaya koymaktadır. Mikroplastik yakalama sistemlerinin yaygın kullanımı, çevresel etkiyi azaltmada hem bireyler hem de sanayi için önemli bir adım olabilir. Teknolojinin daha da geliştirilmesi, ekosistemleri korumada büyük bir fark yaratabilir. Sonuç olarak, çalışmamız, mikroplastik kirliliğiyle mücadelede yenilikçi bir çözüm sunarak, bilimsel ve teknolojik ilerlemelerin çevre koruma açısından önemini vurgulamaktadır.

Anahtar Kelimeler: Mikroplastik, Çamaşır Kurutma Makinesi, Çevre Kirliliği

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MİCROPLASTİC FİLTRATİON SYSTEM İN DOMESTİC DRUM- TYPE CLOTHES DRYERS

Abstract

In recent years, the release of microplastics during the washing of synthetic garments in washing machines and their drying in tumble dryers has been recognized as a significant environmental threat. Microplastics released during the washing process can contaminate water sources, contributing to pollution. Given the serious consequences of microplastic pollution, various technological solutions have begun to be developed to address this issue. In our study, we conducted research using washing and drying machines manufactured by our company to investigate this matter. Our primary objective was to test the effectiveness of a specially designed microplastic capture system and to examine the extent to which it reduces microplastic discharge into wastewater during clothing wash cycles. During this investigation, microplastics released into wastewater during drying were analyzed using advanced technological instruments such as Dynamic Light Scattering (DLS) and Scanning Electron Microscopy (SEM). The DLS device measured the size distribution of microplastics, while the SEM provided detailed insights into their structural characteristics. The analysis results demonstrated that the microplastic capture system we designed significantly reduced the amount of microplastics released into wastewater during the washing process. These findings indicate that solutions aimed at reducing microplastic emissions are effective and contribute to a more sustainable future. The widespread use of microplastic capture systems can be a crucial step for both individuals and industries in mitigating environmental impact. Continued technological development in this area can make a significant difference in protecting ecosystems. In conclusion, our study highlights the importance of scientific and technological advancements in environmental conservation by presenting an innovative solution to combat microplastic pollution.

Keywords: Microplastics, Tumble Dryer, Environmental Pollution

1. GİRİŞ

Tekstiller, giyim, döşeme ve halı gibi çok çeşitli alanlarda kullanılmakta ve farklı amaçlara hizmet etmektedir. 2018 yılında, küresel tekstil elyafı üretimi 106 milyon tonu aşmış ve bu üretimin yaklaşık %63'ü polyester ve naylon gibi sentetik elyaflardan oluşmuştur. Geri kalan

üretim ise pamuk ve yün gibi doğal elyaflar ile suni ipek ve asetat gibi yarı sentetik veya rejenere elyaflardan oluşmaktadır. Önemli bir nokta, doğal ve yarı sentetik elyafların da renklendiriciler ve alev geciktiriciler gibi kimyasal işlemlerden ve iyileştirmelerden geçebildiğidir.
Mikrofiber terimi ise elyafın sentetik, yarı sentetik ya da doğal olmasından bağımsız olarak, genellikle 5mm'den daha kısa boyutlu elyafları tanımlamak için kullanılmaktadır [1].

Son araştırmalar, deniz ortamlarında tespit edilen mikrofiberlerin, mikroplastiklerin büyük bir bölümünün tekstil ürünlerinden, özellikle giysilerin yıkanması sırasında salındığını ortaya koymaktadır. Küresel ölçekte, okyanuslarda bulunan tüm birincil mikroplastiklerin yaklaşık %35'inin sentetik tekstil ürünlerinin yıkanmasıyla ilişkilendirildiği ve bu miktarın yılda 2 ila 13 milyon ton arasında olduğu tahmin edilmektedir. Bununla birlikte, doğal ve yarı sentetik elyafların salınımına yönelik araştırmaların sınırlı olması nedeniyle, bu tahminlerin önemli ölçüde eksik olabileceğini göz önünde bulundurmak önemlidir. Mikroplastiklerin, ev tipi çamaşır ve kurutma makinelerinde yıkama ve kurutma işlemi sırasında, kumaş üzerindeki mekanik baskılar sonucu salındığı bilinmektedir [2-3].

Tekstil ürünlerinin yaşam döngüsünde, özellikle çamaşır yıkama ve kurutma işlemleri sırasında tekstil mikrofiberlerinin (MF'ler) sürekli olarak su ortamına salındığı ve mikroplastik kirliliğine önemli katkıda bulunduğu bilinmektedir. MF'lerin salınımını ölçmek için çeşitli yöntemler önerilmiş olsa da, bu çalışmalar arasında doğrulukta yaşanan tutarsızlıklar ve farklı birimlerin kullanılması, doğrudan karşılaştırma yapılmasını zorlaştırmaktadır [4-5-6].

Bu çalışma ile kurutma makinelerimizde bulunan "Tank-in-Door" teknolojimize, tasarımımız olan mikroplastik filtresi ekleyerek bu alanda ve bu konuda sürdürülebilir, düşük maliyetli ve çevre dostu olunması odağımız olmuştur. Çalışmamız ile milyonlarca ton mikroplastiğin, mikrofiberlerin önüne geçilmesi hedeflenmiş ve yapılan çalışmalar ve analizler sonucunda mikroplastiklerin, sulara karışmasının önüne geçilebileceği ön görülmektedir.
Yapılan çalışma ile filtreleme sistemi sayesinde, kurutma makinelerinden çevreye salınan mikroplastik, mikrofiberlerin miktarında ciddi bir oranda azalmasına katkı sağlanması hedeflenmektedir.
Ev tipi kullanıma uygun, temizliği ve bakımı kolay filtreler mikroplastiklerin çevreye yayılmasını engelleyerek sürdürülebilir bir çözüm olanağı sunmaktadır.

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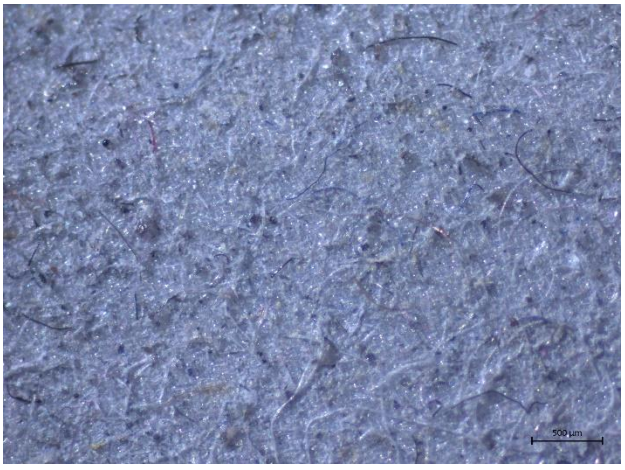
2. DENEYSEL ÇALIŞMALAR

2.1. Malzemeler

Yapmış olduğumuz çalışmada erlen, huni, kıskaç, vakum pompası, membran filtre (0.45 mikron – 47 mikron aralığında), büret standı, hortum, 60 litrelik bidon, hassas terazi ve 90mm çaplı petri kabı. Çalışma kapsamında, polyester, akrilik, pamuk ve elastan elyaf kompozisyonları not edilen çamaşırların ağırlıkları belirlenmiştir. Karışık olarak farklı çamaşırlar bulunmaktadır.

2.2. Numune Hazırlanması

Çamaşır ve kurutma makinelerimizden toplanan çevrim suları ve bu suların filtrasyonu sonucu ortaya çıkan filtrelerden oluşmaktadır. Filtreler farklı mikrometre yapılarındadır.
Makinelerden elde edilen sular ile DLS analizleri yapılmış ve daha sonrasında suların filtrasyonu sonucu ortaya çıkan filtreler SEM analizleri yapılmıştır.



Görsel 1. Filtrasyon Sonucu Elde Edilen Süzgeç Kağıdının Mikroskop Görüntüsü

3. BULGULAR

Çamaşır kurutma makinesinde mikroplastik filtreleme çalışmasında deneysel şartlarda testler yapılmıştır. Yapmış olduğumuz çalışmada elde etmiş olduğumuz atık sulardan DLS analizleri yapılmıştır.

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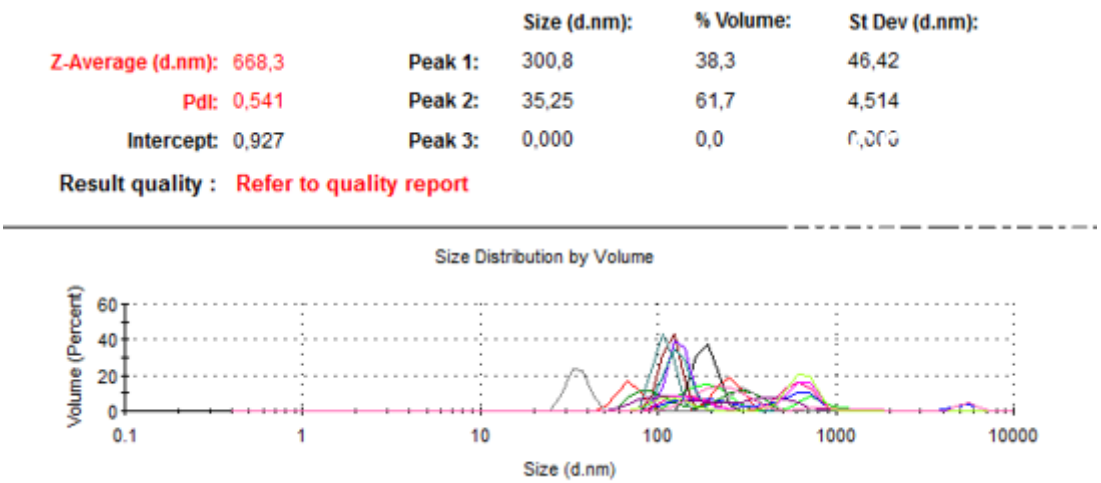
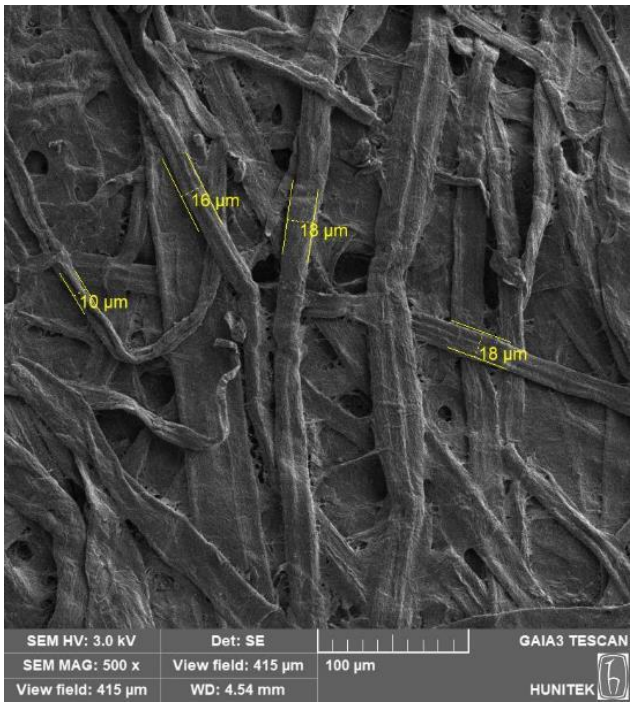


Görsel 2. Makineden Çıkan Atık Su DLS Sonucu

Görsel 2'de belirtilen DLS sonucuna göre 668.3 nm olarak hesaplanmış olup, PDI değeri 0.541 olarak verilmiştir. Pik 1'de 300.8nm'de %38.3 hacim oranına sahipken, Pik 2'de 35.25nm'de %61.7 hacim oranına sahip olmuştur.

Burada Pik 2'de daha küçük partiküllerin çoğunlukta olduğunu göstermiştir. Mikroplastiklerin farklı yıkama ve diğer mekanik işlemler sırasında suya karıştığını ve farklı partikül boyutlarının çözünme ve yayılma davranışlarının farklı olabileceğini göstermektedir.



Görsel 3. Filtrasyon Sonucu SEM Görüntüsü

Görsel 3'de taramalı elektron mikroskobu (SEM) görüntüsü, mikroplastik tekstil liflerinin bir yüzey üzerinde detaylı bir incelemesini göstermektedir. Görüntüde liflerin çapları mikrometre (µm) cinsinden ölçülmüş ve liflerin çaplarının 10 µm ile 8 µm arasında değiştiği görülmektedir. Bu, mikroplastiklerin oldukça ince olduğunu ve mikro düzeyde detaylı bir yapıya sahip olduğunu göstermektedir.

4. SONUÇLAR VE DEĞERLENDİRME

Bu çalışmada, çamaşır kurutma makinelerinde mikroplastik filtreleme sistemi tasarlanmış, testleri yapılmış ve incelenmiştir. Bu çalışmanın sonuçları, ev tipi çamaşır kurutma makinelerinde mikroplastik filtrasyon sistemlerinin uygulanabilirliğini ortaya koymuştur. Yapılan analizler ve testler, tasarlanan filtre sisteminin mikroplastik salınımını belirgin oranda azaltabileceğini göstermektedir. Bu, deniz ve tatlı su ekosistemlerinin korunmasında önemli bir adım olarak öne çıkmakta ve mikroplastik kaynaklı kirliliğin önüne geçme çabalarında umut verici bir çözüm sunmaktadır. Özellikle, filtreleme sisteminin uygun maliyetli ve sürdürülebilir tasarım özelliklerine sahip olması, gelecekte daha geniş çapta uygulanmasını kolaylaştıracaktır. Çalışmanın bulguları, mikroplastiklerin sucul yaşam üzerindeki tehditlerinin boyutlarını anlamaya ve azaltmaya yönelik çözümler geliştirilmesine önemli katkılar sağlamaktadır.

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Ayrıca, proje süresince elde edilen veriler, yeni teknolojilerin geliştirilmesi ve daha ileri düzeyde çalışmalar için önemli bir temel oluşturmaktadır.

Sonuç olarak, bu çalışma, mikroplastik kirliliğini azaltmada ev tipi çamaşır kurutma cihazların etkin kullanımı üzerine yapılan yenilikçi bir adımı temsil etmekte olup, çevre ve insan sağlığına yönelik uzun vadeli olumlu etkiler sağlayabilir. Projenin başarısı, gelecekteki araştırmalar için güçlü bir temel sunarken, daha geniş çapta uygulanabilir sürdürülebilir teknolojilerin geliştirilmesine de kapı aralamaktadır.

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Tİ ESASLI ALAŞIMLARDA ANTİBAKTERİYEL ÖZELLİKLERİN GELİŞTİRİLMESİ: AG İLAVESİNİN ROLÜ

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ÖZET

Ti esaslı alaşımlar üstün mekanik özellikleri ve mükemmel biyouyumlulukları nedeniyle biyomedikal uygulamalarda en çok tercih edilen malzemelerden biri haline gelmiştir. Ancak söz konusu malzemelerin antibakteriyel özellikleri yetersiz kalmaktadır. Bu durum yıkıcı komplikasyonlara neden olan bakteri kolonilerinin gelişmesine yol açabilmektedir. Dolayısıyla geliştirilmiş antibakteriyel özelliklere sahip Ti esaslı biyomalzemelere sürekli ihtiyaç duyulmaktadır. Bu noktada Ti esaslı alaşımların antibakteriyel özelliklerinin geliştirilmesinde yüzey işlemleri ve alaşım elementi ilavesi ilgi odağı olmaktadır. Diğer yandan yüzey işlemleri başarısızlıkla sonuçlandığında enfeksiyon riski artabilmektedir. Literatür çalışmaları incelendiğinde Ti esaslı alaşımlara Ag ilave edilerek antibakteriyel özelliklerin iyileştiği görülmektedir. Bu çalışmada Ag ilavesinin Ti alaşımlarının antibakteriyel ve mekanik özelliklere etkisi incelenmiş ve ilgili güncel çalışmalar tartışılmıştır.

Anahtar Kelimeler: Antibakteriyel Özellikler, Ti Esaslı Biyomalzemeler, Gümüş.

IMPROVEMENT OF ANTIBACTERIAL PROPERTIES IN Ti BASED ALLOYS: THE ROLE OF Ag ADDITION

ABSTRACT

Ti-based alloys have become one of the most preferred materials in biomedical applications due to their excellent mechanical properties and outstanding biocompatibility. However, these materials often lack sufficient antibacterial properties, which can lead to post-surgical infections due to the development of bacterial colonies, causing severe complications. This has created a demand for metallic alloys with inherent antibacterial properties. In response, there has been growing interest in enhancing the antibacterial properties of Ti-based alloys through surface treatments and the addition of alloying elements. Nevertheless, surface treatments can sometimes be ineffective, increasing the risk of infection. Consequently, developing inherently antibacterial metallic materials is a promising approach. Literature reviews indicate that the addition of Ag to Ti-based alloys improves antibacterial properties. This study examines the impact of Ag addition on the antibacterial and mechanical properties of Ti alloys, discussing recent findings and advancements in this area.

GİRİŞ

Son yıllarda Ti esaslı alaşımlar mükemmel korozyon direnci, biyouyumluluk ve üstün mekanik özellikleri nedeniyle ortopedik protezler, ortodonti ve eklem protezleri oluşturmak için yaygın olarak tercih edilmektedir [1]. Ancak eklem protezleri ameliyatından sonra belirli bir enfeksiyon oranı bulunmaktadır ve bu durum implantasyonun başarısız olmasına neden olabilmektedir [2]. Bununla birlikte her yıl Amerika Birleşik Devletleri'nde iki milyon hastane enfeksiyon vakasının yarısının implant enfeksiyonundan kaynaklandığı ve ortopedik implant cihaz enfeksiyonlarına neden olan başlıca bakterilerin Staphylococcus aureus (S. aureus) ve Staphylococcus epidermidis olduğu bildirilmiştir [3,4]. Dolayısıyla antibakteriyel özelliklere sahip implantların geliştirilmesi gerekmektedir. Bu noktada yüzey modifikasyon işlemleri umut verici olmaktadır [5]. Yüzey modifikasyon işlemleri iyon implantasyonu, püskürtme ve anodizasyon süreçleri gibi yöntemlerle antibakteriyel özellikleri iyileştirmektedir. Diğer yandan yüzey işlemlerinin başarısızlıkla sonuçlanması enfeksiyon riskini artırmakta ve implantın ömrünü azaltmaktadır [3]. Bu nedenle antibakteriyel özellikleri geliştirmek ve dolayısıyla enfeksiyon riskini azaltmak için Ti alaşımlarına Ag veya Cu gibi elementler eklenmektedir [6]. Etkili bir şekilde antibakteriyel oran (>%99) elde etmek için Ag elementi ilavesi en az %3, Cu elementi içeriği ise %5 olmalıdır [7]. Örnek bir çalışmada Liu J. ve ark. Ti-XCu (x = 2, 5, 10 ve 25 % ağ.) alaşımlarının faz yapısını ve mikroyapısını XRD ve SEM ile incelemiş ve Cu içeriğinin antibakteriyel özelliklere etkisini araştırmışlardır. Antibakteriyel testler sonucunda %5 veya daha yüksek Cu içeriğine sahip alaşımların güçlü antibakteriyel oranına sahip olduğu görülmüştür [8]. Yamanoğlu R. ve ark. Ti5Al2.5Fe alaşımına belirli oranlarda (ağ. %1, 3 ve 5 Cu) takviyesi yaparak alaşımın antibakteriyel özelliklerini ve sitotoksik özelliklerini incelemişlerdir. Yapılan Cu ilavesinin antibakteriyel özellikleri geliştirdiğini bildirmişlerdir [9]. Başka bir çalışmada Chen M. ve ark. Ag eklenmiş Ti alaşımlarının antibakteriyel özelliklerini incelemişlerdir. Ti ve Ag tozları belirli oranlarda karıştırılarak sıcak pres yöntemiyle sinterlenmiştir. XRD ve SEM ile faz yapısını ve mikroyapısını analiz etmişlerdir. Daha sonra alaşımın S. Aureus bakterisine karşı davranışını incelemek için antibakteriyel testler uygulamışlardır. Sonuç olarak %3 veya daha yüksek Ag içeriğine sahip alaşımın antibakteriyel özellik sağladığı görülmüştür [3]. Çalışma kapsamında Ti esaslı biyomalzemelerde yaşanan implant enfeksiyonu sorunu ele alınmıştır. Bu doğrultuda Ag ilavesinin Ti alaşımlarının antibakteriyel özelliklerine etkisi incelenmiştir.

Ti ESASLI ALAŞIMLARA Ag İLAVESİ

Son zamanlarda Ag içeren Ti alaşımları üzerine birçok çalışma yapılmıştır. Bununla birlikte Ag ilavesi Ti alaşımlarının hem mekanik hem de antibakteriyel özelliklerini iyileştirmektedir [1]. Literatür çalışmaları incelendiğinde Cu ve Zn elementlerinin eklenmesiyle de antibakteriyel özelliklerin geliştirildiği görülmüştür [3]. Ancak Ag ilavesi Cu ilavesine göre daha güçlü ve geniş spektrumlu antimikrobiyal etkilere sahiptir [4]. Ayrıca düşük bir Ag iyon konsantrasyonu güçlü antibakteriyel etki sağlamaktadır [10]. Örnek bir çalışmada Zheng Y. ve ark. Ti-Ni matris fazına Ag çökeltilerinin ilavesinin antibakteriyel özelliklere etkisini incelemişlerdir. Ti-Ni-Ag alaşımının mikroyapısı SEM ve TEM ile analiz edilmiştir. Ardından S. aureus, S. epidermidis ve P. gingivalis bakterilerini kullanarak in vitro antibakteriyel testi yapılmıştır.

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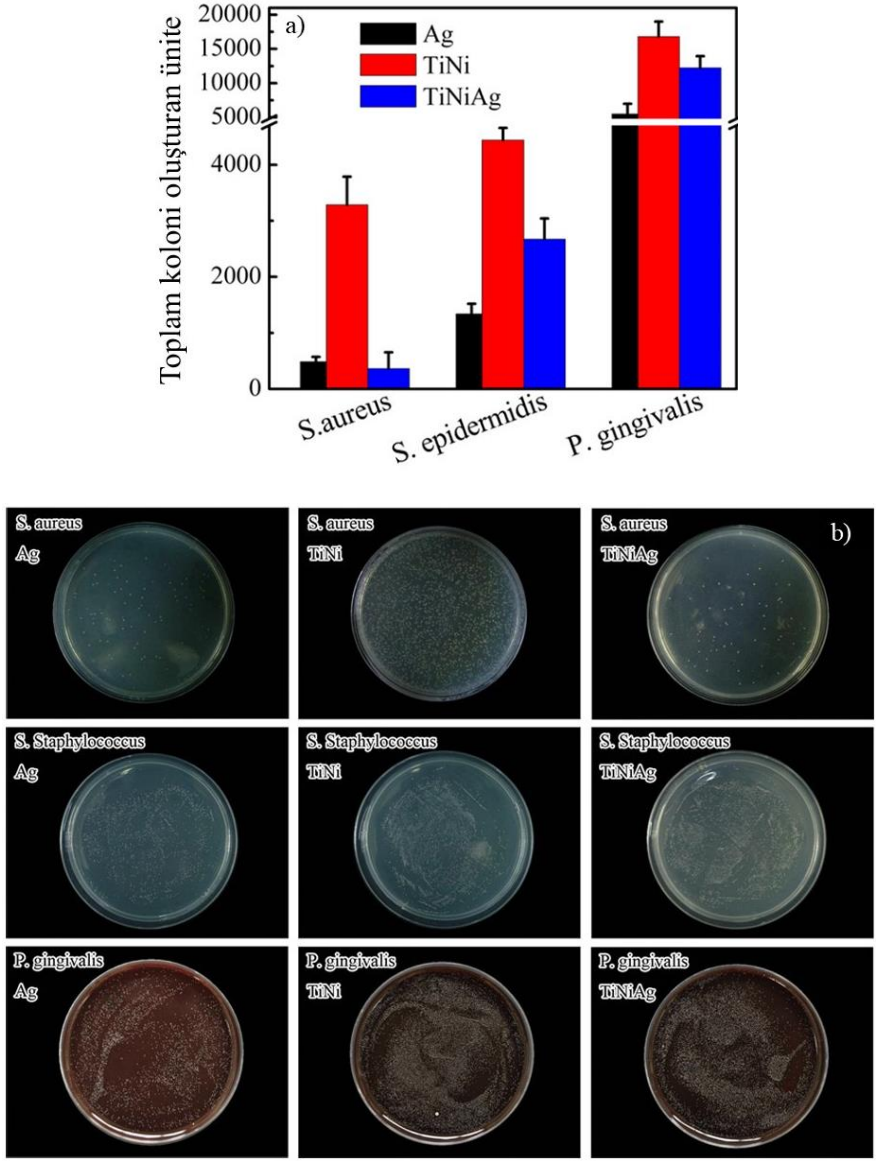
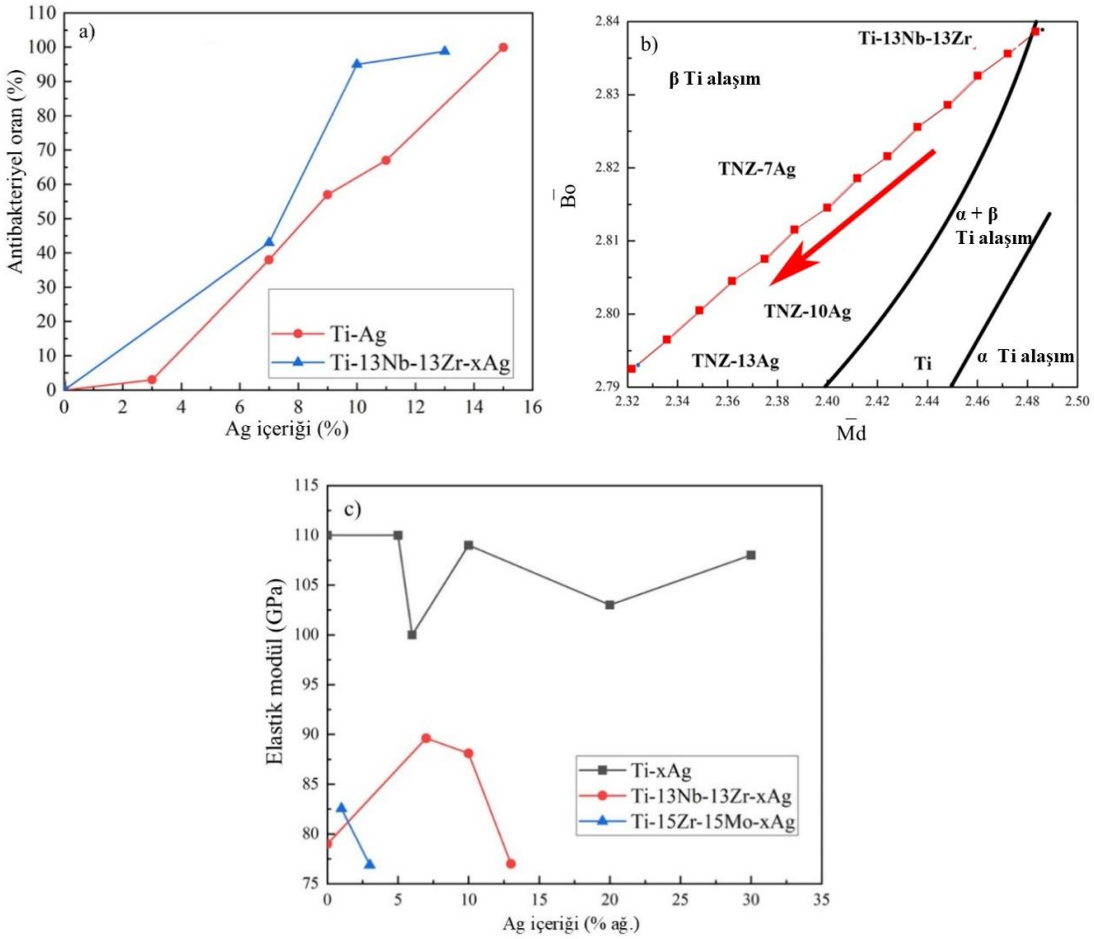
Şekil 1a'da farklı bakteri türlerine maruz bırakılan alaşımların yüzeylerine yapışan canlı bakterilerin sonuçları verilmiştir. Şekil 1b'de ise canlı yapışan bakterilerin makroskobik görüntüleri sunulmuştur.



Şekil 1. a) Saf Ag, Ti-Ni ve Ti-Ni-Ag alaşımlarının yüzeyi üzerindeki canlı yapışık bakterilerin oranları ve b) canlı yapışık bakterilerin makroskobik görüntüleri [11]

İn vitro bakteriyel çalışması incelendiğinde Ti-Ni-Ag alaşım yüzeyindeki bakteri (S. aureus, S. epidermidis ve P. gin givalis) sayısının Ti-Ni alaşımlı yüzeye göre önemli ölçüde azaldığını görülmüştür. Dolayısıyla antibakteriyel etkinin Ag çökeltilerinden salınan Ag iyonlarına bağlı olduğu sonucuna varılmıştır [11]. Başka bir çalışmada Cai D. ve ark. Ti-13Nb-13Zr-xAg alaşımlarına Ag ilavesinin mikroyapı, elastik modül ve antibakteriyel özelliklere etkilerini incelemişlerdir. Ek olarak β stabilizatör elementi olan Ag elementinin elastik modül üzerindeki etkisine de bakılmıştır. Ti-13Nb-13Zr-xAg (x=7,10) alaşımlarını vakumlu ark ergitme fırınında hazırlamışlar ve mikroyapısını SEM ile analiz etmişlerdir. Ardından S.aureus bakterisine karşı gösterdiği antibakteriyel etki değerlendirilmiştir. Şekil 2a'da Ag içeren Ti alaşımının

antibakteriyel oranları verilmiştir. Ag ilavesinin Ti_2Ag fazının çökelmesini sağladığı ve buna bağlı olarak antibakteriyel aktivite özelliklerini iyileştirdiği görülmüştür. Ayrıca Şekil 2b'de gösterilen (Md) değeri ve (Bo) değeri hesaplama yöntemine göre Ag elementinin ilavesi ile Ti-13Nb-13Zr-xAg alaşımı α + β faz yapısından β fazına geçmiştir [12]. Bo–Md diyagramı Ti esaslı alaşımlarda martenzit ve omega dönüşümlerinin sınırlarını belirlemek için kullanılmaktadır. Diyagramda Bo değeri Ti ile diğer metaller arasındaki kovalent bağın gücünü ölçerken Md değeri ise alaşımdaki metallerin d orbital enerji seviyesini göstermektedir [13]. Şekil 2c'de β fazının oluşumu ile elastik modüldeki azalma gösterilmiştir [12]. β fazı HMK yapıya sahiptir ve HCP yapıya sahip α fazına göre daha düşük bir elastik modül göstermektedir [14].



Şekil 2. Ag elementinin titanyum alaşımı fazları ve özellikleri üzerindeki etkisi (a) antibakteriyel oran (b) Bo/Md değerleri (c) Elastik modül [12]

Başka bir çalışmada Yamanoğlu R. ve ark. Ti-5Ag alaşımını toz metalürjik yöntemlerle üretmişler ve alaşımın antibakteriyel aktivite özelliklerini incelemişlerdir. Bu amaç için S. aureus ve E. coli bakterileri kullanılmış ve bakteriler MHA besiyerine tek koloni şeklinde ekilmiştir. Numunelere uygulanan antibakteriyel test sonuçları Tablo 1'de gösterilmiştir. Saf titanyuma yapılan Ag ilavesi E. coli ve S. aureus bakterileri açısından önemli değişikliklere yol açmıştır. E. coli ve S. aureus bakterileri için kontrol ekiminin ardından yüzeydeki koloni sayısının Ti5Ag numunesi için hızla azaldığı görülmektedir. Bu durum Ag ilavesi ile antibakteriyel özelliklerin geliştirildiği anlamına gelmektedir [15].

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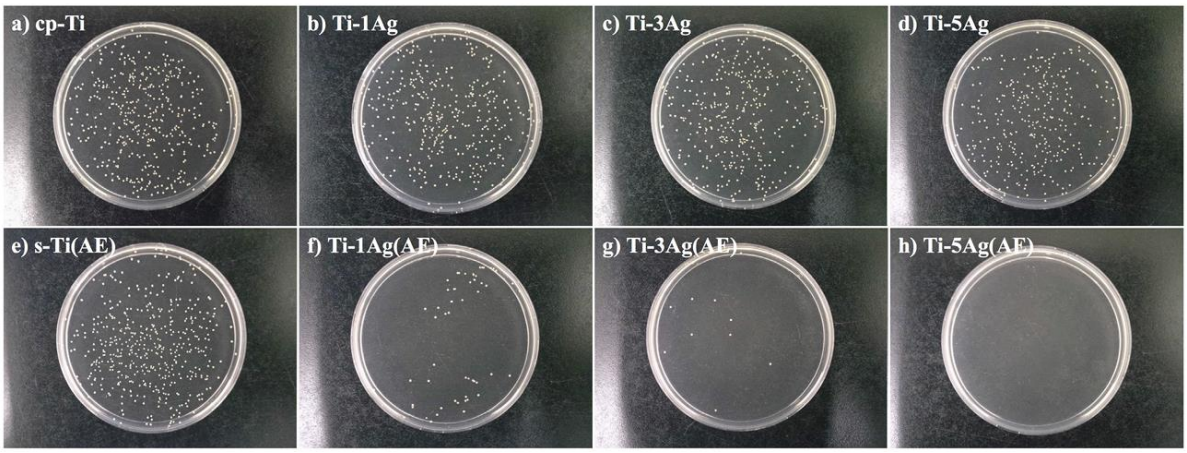
Tablo 1. Saf Ti ve Ti5Ag numunelerinin antibakteriyel özelliklerindeki değişim [15]

	E. Coli		S. Aureus	
Alaşım adı	Koloni sayısı			
Saf Ti	82	4.100	2	20
Ti5Ag	4	200	4	40
Kontrol ekimi	186	9.300	242	12.100

Diğer yandan literatür çalışmaları incelendiğinde Ag elementinin etkilerinin arttırmak için asit dağlama yönteminin kullanıldığı görülmüştür. Shi A. ve ark. Ag iyonu salınımını ve yüzeydeki Ti_2Ag hacim oranını değiştirmek için yüzeye asit dağlama işlemi uygulamışlardır. Sonuç olarak asit dağlama işlemi ile Ag iyon salınımı artmış ve yüzeyde daha fazla Ti_2Ag partikülü gözlemlenmiştir. Bununla birlikte antibakteriyel testler sonucu asit dağlama işleminin antibakteriyel aktiviteyi önemli ölçüde geliştirdiği sonucuna varılmıştır [16]. Örnek bir çalışmada Lei Z. ve ark. farklı Ag içeriklerine sahip Ti-Ag alaşımlarını kıvılcım plazma sinterleme (SPS) yöntemi ile hazırlamışlardır. Ag içeriği ağ. %0, 1, 3 ve 5 olan numuneler sırasıyla s-Ti, Ti-1Ag, Ti-3Ag ve Ti-5Ag olarak adlandırılmıştır. Daha sonra Ti-Ag alaşımlarının yüzeyini HF ve HNO_3 asit çözeltisi ile aşındırmışlardır ve yüzey işlemi öncesi (Ti-Ag) ve sonrası Ti-Ag (AE) numunelerinin yüzey özelliklerini, iyon salınımını ve antibakteriyel özelliklerini analiz etmişlerdir. Şekil 3'te PBS' de 30 gün boyunca bekletildikten sonra saf Ti, Ti-Ag, s-Ti (AE) ve Ti-Ag (AE) örnekleri üzerindeki S. aureus bakterileri gösterilmiştir.



Şekil 3. PBS içinde 30 gün bekletildikten sonra S. aureus bakterilerinin saf Ti ve Ti-Ag numunelerinin yüzey görüntüleri [17]

Saf-Ti, Ti-Ag ve s-Ti (AE) örneklerinde çok sayıda bakteri gözlenmiştir. Bununla birlikte asit dağlama işleminden sonra Ti-Ag (AE) numunelerinin yüzeylerinde yüksek Ag içeriğine sahip

mikropitler ve partiküller oluşmuş ve Ti-3Ag (AE) ve Ti-5Ag (AE) numuneleri yüksek oranda antibakteriyel özellikler göstermiştir [17].

SONUÇLAR

Ti esaslı alaşımların geliştirilmesi biyomedikal uygulamalar için önem taşımaktadır. Ancak söz konusu alaşımların antibakteriyel özellikleri yetersiz kaldığı için kullanım alanları biyomedikal uygulamalarda sınırlı kalmaktadır. Bu nedenle çalışma kapsamında antibakteriyel özellikleri iyileştirmek için Ag ilavesinin etkileri incelenmiştir. Literatür çalışmaları incelendiğinde Cu ve Zn gibi alaşım elementlerinin de antibakteriyel özellikleri arttırdığı görülmektedir. Diğer yandan düşük miktarda eklendiğinde (%3) güçlü antibakteriyel etkiler yarattığı için Ti esaslı alaşımlara Ag elementi yaygın olarak ilave edilmektedir. Çalışmalar doğrultusunda Ag elementinin etkilerini arttırmak için asit dağlama işleminin uygulandığı da görülmektedir. Ayrıca Ag ilavesi alaşımların mekanik özellikleri de değiştirmektedir. Ag elementi β stabilizatör elementi olduğu için alaşıma ilave edildiğinde elastik modül değerini düşürmektedir. Sonuç olarak Ag elementi Ti esaslı alaşımların antibakteriyel özelliklerini ve mekanik özelliklerini iyileştirmektedir.

TEŞEKKÜR

Bu çalışma Kocaeli Üniversitesi Bilimsel Araştırma Projeleri Birimi tarafından desteklenmiştir (Proje No: FKA-2024-3934).

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Tİ ALAŞIMLARINDA GERİLME KALKANI ETKİSİ: B -TİPİ ALAŞIMLAR VE ÜRETİM YÖNTEMLERİNİN KARŞILAŞTIRILMASI

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ÖZET

Günümüzde biyomedikal implantların performansını iyileştirmeyi hedefleyen araştırmalarda sürekli artış görülmektedir. Bu araştırmalar kapsamında metalik biyomalzemeler mükemmel biyolojik ve mekanik özellikleri nedeniyle diğer malzemelere göre oldukça fazla dikkat çekmektedir. Bununla birlikte bu malzemeler arasında düşük yoğunlukları, üstün korozyon dirençleri ve mükemmel biyouyumlulukları nedeniyle Ti alaşımları diğer alaşımlara göre önemli avantajlar sunmaktadır. Özellikle Ti6Al4V alaşımı dental ve ortopedik uygulamalarda sıklıkla tercih edilmektedir. Ancak sahip olduğu (110 GPa) elastik modül değeri diğer metalik biyomalzemelere göre düşük olsa da kemiğe göre oldukça yüksektir. Dolayısıyla bu durum kemik rezorpsiyonu gibi olumsuz etkilere yol açacak gerilme kalkanı etkisine neden olmaktadır. Bu nedenle düşük elastik modülleri ve yüksek mukavemetleri nedeniyle β tipi Ti alaşımları biyomedikal uygulamalarda ilgi odağı olmaktadır. Bu çalışmada β-stabilizatör elementlerin ve farklı üretim yöntemlerinin β tipi Ti alaşımlarının mekanik özelliklerine etkileri incelenmiştir.

Anahtar Kelimeler: Ti esaslı biyomalzemeler, Beta Ti, Gerilme kalkanı, Elastik modül.

THE EFFECT OF STRESS SHIELDING IN Ti ALLOYS: A COMPARISON OF β - TYPE ALLOYS AND PRODUCTION METHODS

ABSTRACT

There has been a continuous increase in research aimed at improving the performance of biomedical implants today. In this context, metallic biomaterials are attracting significant attention due to their excellent biological and mechanical properties compared to other materials. Among these materials, titanium alloys offer important advantages over other alloys due to their low densities, superior corrosion resistance, and excellent biocompatibility. In particular, the Ti6Al4V alloy is frequently preferred in dental and orthopedic applications. However, although its elastic modulus (110 GPa) is lower than that of other metallic biomaterials, it is still quite high compared to bone. Consequently, this situation leads to a stress shielding effect that can cause adverse effects such as bone resorption. Therefore, β-type titanium alloys are becoming the focus of interest in biomedical applications due to their low elastic moduli and high strengths. This study investigates the effects of β-stabilizing elements and different production methods on the mechanical properties of β-type Ti alloys.

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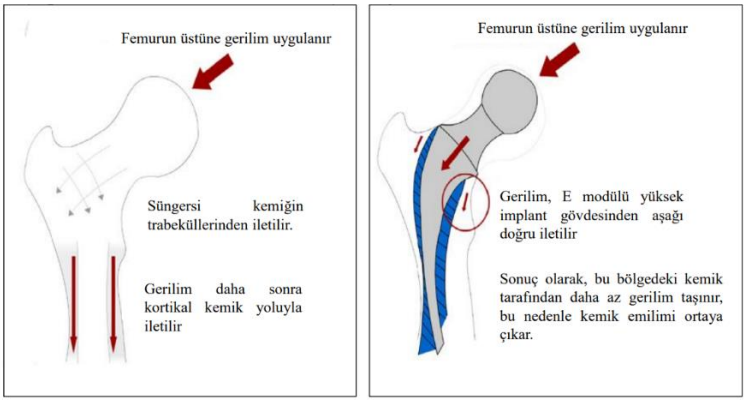
GİRİŞ

Son yıllarda tıp alanındaki ilerlemelerle birlikte farklı uygulamalar için çok sayıda yeni biyomalzeme geliştirilmiştir. Biyomalzemeler ortopedide, diş tedavisinde ve kardiyovasküler cihazlarda kullanılmaktadır. Söz konusu malzemelerin insan vücuduna herhangi bir zarar verici etki yaratmaması gerekmektedir [1]. Aynı zamanda biyomalzemelerden kemiğe yakın elastik modül, korozyon direnci ve biyouyumluluk beklenmektedir [2]. Günümüzde biyomalzemeler; polimerler, seramikler ve metalik malzemeler olarak üç ana gruba ayrılmaktadır. Polimer ve seramik esaslı malzemeler sırasıyla zayıf mukavemet ve kırılganlık gösterdiği için biyomedikal uygulamalarda kullanım alanları sınırlı kalmaktadır [3]. Bu noktada implant pazarının %70-80'ini oluşturan metalik malzemeler ilgi odağı olmaktadır [4]. Metalik biyomalzemeler titanyum alaşımları, kobalt-krom esaslı alaşımlar ve paslanmaz çelik olarak üç ana gruba ayrılmaktadır [5]. Titanyum alaşımları paslanmaz çeliklere ve kobalt krom esaslı alaşımlara göre yüksek spesifik mukavemet, üstün korozyon direnci, yüksek biyouyumluluk ve daha düşük elastik modül gibi avantajlar barındırmaktadır [6]. Titanyum alaşımlarından olan ve α+β faz yapısına sahip Ti6Al4V alaşımı ortopedik uygulamalar için yaygın olarak tercih edilmektedir [7]. Ancak Al iyonları kemik mineralizasyonunu engelleyerek yapısal eksikliklere yol açarken V hem sitotoksiktir hem de alerjik reaksiyonlara neden olabilmektedir [8]. Metalik implant malzemelerinin vücut içerisinde yarattığı sorunlar açısından dikkat edilmesi gereken diğer bir unsur da gerilme kalkanı etkisidir. Şekil 1'de gerilme kalkanı mekanizmasının şematik gösterimi verilmiştir.



Şekil 1. Gerilme kalkanı mekanizmasının şematik gösterimi [9]

Metalik biyomalzemeler söz konusu olduğunda implantlar ve kemik dokuları arasındaki elastik modül farkından dolayı gerilme kalkanı sorunu görülmektedir [5]. Gerilme kalkanı implant ve kemik arasında gerilimin homojen olmayan bir şekilde aktarılmasının bir sonucudur [10]. Bu durum zaman içinde implant gevşemesiyle birlikte kemiğin kırılmasına yol açar. Dolayısıyla implant elastik modül değerinin kemiğe göre oldukça yakın olması beklenmektedir [9]. Özellikle yük taşıyıcı uygulamalarda kullanılan metalik implant malzemeleri incelendiğinde en yaygın titanyum alaşımı olan Ti6Al4V'nin (110 GPa) elastik modül değeri Co-Cr alaşımları ve 316L paslanmaz çeliklere (sırasıyla 210 ve 180 GPa) göre çok daha düşüktür [10,11]. Şekil 2'de metalik biyomalzemelerin elastik modül değerleri verilmiştir.

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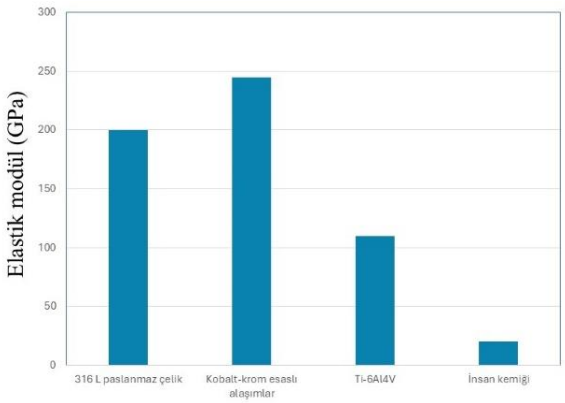


Şekil 2. Metalik biyomalzemelerin elastik modül değerleri [12]

Ti6Al4V alaşımı diğer metalik biyomalzemelere göre daha düşük elastik modüle sahip olmasına rağmen kemik yapısına (20 GPa) göre oldukça yüksek bir elastik modül değerine sahiptir [13]. İdeal bir metalik biyomalzemeden kemik rezorpsiyonunu önlemek için kemiğe yakın elastik modül beklenmektedir [14]. Bu noktada mükemmel biyouyumluluk ve düşük elastik modül gibi üstün özellikler gösteren β tipi Ti alaşımları ilgi odağı olmaktadır [2]. Çalışmamızda metalik biyomalzemelerde karşılaşılan gerilme kalkanı sorunu ele alınmıştır. Ayrıca β tipi Ti alaşımlarının özellikleri ve üretim yöntemlerinin mekanik özelliklere ve mikroyapıya etkileri incelenmiştir.

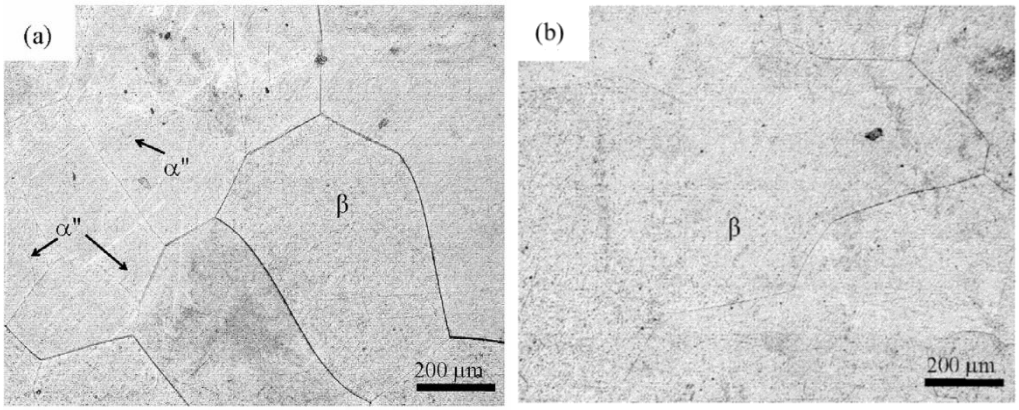
β -TİPİ TİTANYUM ALAŞIMLARI

Ti alaşımlarının yapısı mikroyapıdaki faz bileşenlerine göre α, α + β ve β tipi Ti alaşımları olarak sınıflandırılmaktadır [15]. α tipi Ti alaşımları yüksek korozyon direnci ancak düşük mukavemete sahipken α + β tipi çift fazlı Ti alaşımları daha yüksek mukavemet, tokluk ve yorulma direnci gibi üstün özellikler göstermektedir [16]. Tablo 1'de farklı Ti alaşımlarının faz yapılarına göre değişen elastik modül değerleri verilmiştir.

Tablo 1. Ti alaşımlarının faz yapılarına göre değişen elastik modül değerleri [17]

Alaşım	Faz yapısı	Elastik modül (GPa)
Saf Ti	α	105
T-i6Al-4V	α+β	110-114
Ti-6Al-7Nb	α+β	105
Ti-5Al-2.5Fe	α+β	110
Ti-23Nb-0.7Ta-2Zr	β	55
Ti-24Nb-0.5N	β	43
Ti-36Nb-2Ta-3Zr-0.3O	β	32
Ti-13Nb13Zr	β	79
Ti-15Mo-2.8Nb-3Al	β	82
Kortikal kemik yapısı	-	30-70

Tablo 1 incelendiğinde α + β tipi Ti alaşımları olması gereken elastik modül değerinden oldukça fazla olduğu görülmektedir [16]. Bu noktada daha düşük elastik modül değerine sahip gerilme kalkanı sorununu önleyen ve protezlerin ömrünü uzatabilen β tipi Ti alaşımları ilgi odağı olmaktadır [18]. Bununla birlikte Nb, Ta, Zr, Mo ve Hf gibi elementleri β faz alanını genişletmektedir. Ayrıca alaşım elementlerine ve miktarına göre β fazının dengesi ayarlanabilmekte ve buna bağlı olarak mukavemet, tokluk ve yorulma direnci gibi özellikler geliştirilmektedir [3,19]. Literatür çalışmaları incelendiğinde yeni Ti-Nb-Ta-Zr, Ti-Nb-Ta-Sn, Ti-Nb-Zr-Sn, Ti-Nb-Mo-Sn, Ti-Nb-Sn ve Ti-Nb-Zr alaşımları gibi β -tipi Ti alaşımları geliştirilmiştir [16]. Örnek bir çalışmada Li P. ve ark. beş farklı bileşime sahip β -tipi Ti alaşımlarının mikroyapısını ve mekanik özelliklerini incelemişlerdir. Tungsten ark ergitme ile argon atmosferinde alaşımlar hazırlanmıştır. Ardından alaşımların mikroyapısı XRD ve optik mikroskop ile incelenmiştir. Şekil 3'te Ti74Nb26 ve Ti66Mo8Nb26 alaşımlarının optik mikroskop görüntüleri verilmiştir.



Şekil 3. a) Ti74Nb26 ve b) Ti66Mo8Nb26 alaşımlarının optik mikroskop görüntüleri [20]

Görüntüler incelendiğinde Ti74Nb26 alaşımının mikroyapısı β fazından ve β fazının iç kısmında yer alan α" martenzit fazından oluşmaktadır. Bununla birlikte Ti66Mo8Nb26 alaşımının mikroyapısı β fazından oluşmaktadır. Dolayısıyla Mo ilavesi α" martenzit fazının geçişini engellemekte ve Ti-Mo-Nb alaşımlarının β fazını stabilize etmektedir. Optik mikroskop görüntülerinin ardından alaşımların Nano-indentasyon testi ile elastik modül değerleri ölçülmüştür. Tablo 2'de beş farklı alaşımın elastik modül değerleri verilmiştir.

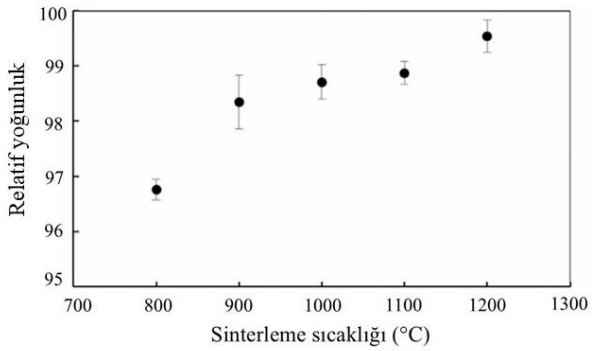
Tablo 2. Beş farklı alaşımın elastik modül değerleri [20]

Alaşım	E (GPa)
Ti74Nb26	75.1
Ti72Mo2Nb26	67.0
Ti70Mo4Nb26	63.6
Ti68Mo6Nb26	55.7
Ti66Mo8Nb26	54.5

Sonuç olarak Ti66Mo8Nb26 alaşımının indirgenmiş elastik modülü (E) 54.5GPa'dır ve bu değer insan kemiğine (10-30 GPa) oldukça yakındır. Ayrıca çok bileşenli Ti alaşımlarında molibden eşdeğeri (Mo_{eq}) β fazının kararlılığını belirlemektedir. Mo_{eq} değeri ne kadar büyükse β fazı o kadar kararlıdır. Aynı zamanda Mo ilavesi sadece Ti-Mo-Nb alaşımlarının β fazını

stabilize etmekle kalmaz mukavemetini de arttırır [20]. Başka bir çalışmada Karre R. ve ark. β-fazının oluşum enerjisini azaltmak ve elastik modülünü düşürmek amacıyla Ti-25Nb alaşım kompozisyonuna Zr eklemişlerdir. Ek olarak Ti–Nb ve Ti–Nb–Zr alaşımlarının elastik modülü ve biyouyumluluk özelliklerini incelemişlerdir. Alaşımların elastik modül değerlerini kristal yapısına bağlı olarak farklı yönlerde ölçmüşlerdir. Ayrıca Ti–Nb alaşımının β fazının kararlılığı Nb yüzdesine bağlı olarak değerlendirilmiş ve Nb içeriğinin artışı ile β fazının daha kararlı hale geldiği tespit edilmiştir. Bununla birlikte Ti–Nb alaşımında %22 veya daha yüksek Nb içeriği β fazı için optimum konsantrasyon olarak belirlenmiştir. Ek olarak Ti–Nb–Zr alaşımında Zr katkısı ile β fazının kararlılığı artmıştır. Sonuç olarak Ti-25Nb alaşım kompozisyonu yaklaşık 80 GPa ortalama elastik modülü değeri göstermiştir. Ti25Nb6.25Zr alaşımının ise yaklaşık 50 GPa ile en düşük elastik modül değerine sahip olduğu tespit edilmiştir [21].

Diğer yandan implantların elastik modüllerini azaltmak ve gerilme kalkanı etkisini engellemek için gözenekli β Ti alaşımlarına ihtiyaç duyulmaktadır. Bu noktada gözenekli β Ti alaşımları hazırlamak için toz metalurjisi ve eklemeli imalat yöntemleri yaygın olarak kullanılmaktadır. Toz metalurjisi gözenekli yapılara sahip metalik parçaları kolaylıkla üretebilmektedir. Kıvılcım plazma sinterleme (SPS) yöntemi gözenekli Ti ve Ti alaşımları üretmek için yaygın olarak kullanılmaktadır [22]. Örnek bir çalışmada Hussein M. ve ark. β tipi Ti-20Nb-13Zr alaşımını SPS yöntemi ile hazırlamışlardır. XRD ve TEM ile alaşımın mikroyapısı analiz edilmiş. Vickers sertliği (HV) ile mekanik özellikleri incelenmiştir. Bununla birlikte alaşımın yoğunluk değerleri ölçülmüştür (Şekil 4).



Şekil 4. Ti-20Nb-13Zr alaşımının yoğunluk değerleri [23]

Sonuç olarak 1200 °C'de SPS sonrasında tam yoğunluğa sahip bir yapı ve 1200°C'nin altındaki sıcaklıklarda gözenekli bir yapı elde edildiği görülmüştür. Diğer yandan eklemeli imalat yöntemlerinden olan seçici lazer ergitme (SLM) ve elektron ışını ergitme (EBM) yüksek performanslı metalik parçaların üretilmesinde ilgi odağı olmaktadır [23]. Örnek bir çalışmada Ummethala R. ve ark. Ti–35Nb–7Zr–5Ta (TNZT) alaşımını SLM kullanarak hazırlamışlardır. TNZT tozunu gaz atomizasyonuyla üretmişlerdir. Tozlar 20-150 µm boyut aralığında olup küresel şekilli partiküllerden oluşmaktadır. Şekil 5'te TNZT tozlarının SEM görüntüleri verilmiştir.

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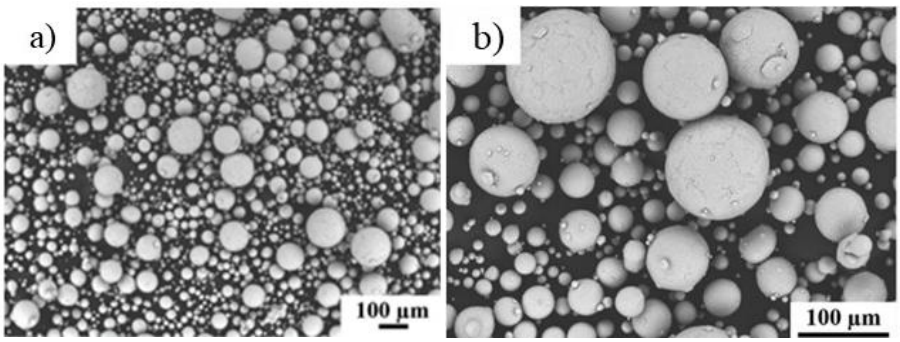

Şekil 5. Küresel morfolojiyi ve dendritik yapıyı gösteren (a) düşük ve (b) yüksek büyütmelerde SEM görüntüleri [24]

Ardından alaşımın faz yapısını XRD ile incelemişler ve sonuç olarak β fazını gözlemlemişlerdir. Alaşımın mekanik özelliklerini değerlendirmek için elastik modül değerini ölçmüşler ve çekme testi uygulamışlardır. Sonuç olarak SLM yöntemiyle üretilen TNZT alaşımının 631 MPa mukavemete ve 81 GPa düşük elastik modüle sahip olduğu görülmüştür. Düşük elastik modüle ve yüksek mukavemete sahip bir alaşım geliştirerek implantlarda yaygın olarak görülen gerilme kalkanı etkisini azaltmaya katkı vermişlerdir [24].

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SONUÇLAR

Biyomedikal implantlarda sıkça karşılaşılan gerilme kalkanı etkisinin azaltılması amacıyla Ti alaşımları araştırılmıştır. β tipi Ti alaşımları diğer alaşımlara göre düşük elastik modül ve yüksek mukavemet gibi üstün özellikler göstermektedir. Bu nedenle çalışma kapsamında β-stabilizatör elementleri incelenmiş ve mekanik özelliklere etkileri değerlendirilmiştir. Bununla birlikte β tipi Ti alaşımlarının üretiminde kullanılan yöntemlerin alaşıma etkileri incelenmiştir. Çalışma kapsamında Mo, Nb ve Zr gibi β-stabilizatör elementlerinin ilavesinin elastik modül değerlerinin düşürülmesinde kritik bir rol oynadığı görülmektedir. SPS ve SLM yöntemiyle üretilen Ti alaşımlarında gözenekli yapılar oluşturulabildiği ve böylece elastik modül değerlerinin daha fazla azaltılabildiği gözlemlenmiştir. Sonuç olarak biyomedikal implantlarda kullanılmak için geliştirilen β tipi Ti alaşımlarının gerilme kalkanı etkisini azalttıkları ve implant ömrünü uzatma potansiyeline sahip oldukları görülmüştür.

TEŞEKKÜR

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ARK ERGİTME YÖNTEMİ İLE İMALATIN AL-17Sİ VE AL-17Sİ-0,2Tİ ALAŞIMLARININ İÇYAPI VE MEKANİK ÖZELLİKLERİNE ETKİLERİNİN İNCELENMESİ

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ÖZET

Bu çalışmada ark ergitme yöntemiyle imal edilen Al-17Si ve Al-17Si-0,2Ti hafif alaşımlarının yapısal ve mekanik özellikleri araştırılarak indüksiyonla ergitilip kokil kalıba döküm yöntemi ile üretilen aynı alaşımlardan elde edilen veriler ile karşılaştırıldı. Söz konusu alaşımların içyapıları, sertlikleri, akma ve çekme dayanımları ile süneklikleri incelendi. İçyapı araştırmaları uygun yöntemler ile zımparalandıktan sonra parlatılan numunelerin optik mikroskopta incelenmesi suretiyle gerçekleştirildi. Alaşımların sertliği Brinell ölçüm yöntemiyle belirlendi. Akma ve çekme dayanımları ile kopma uzaması değerleri talaşlı imalat yöntemi ile hazırlanan uygun boyutlardaki numuneler üzerinde gerçekleştirilen çekme deneyleri ile belirlendi. Alaşımların içyapılarının α-Al dendiritleri, ötektik alüminyum (Al)-silisyum (Si), primer silisyum parçacıkları ve β fazından oluştuğu gözlendi. Ark ergitme yönteminin ve %0,2Ti ilavesinin α dendiritleri ve ötektik silisyum parçacıklarının boyutlarının önemli ölçüde incelmesine yol açtığı görüldü. Ark ergitme yöntemi ile imalatın Al-17Si ve Al-17Si-0,2Ti alaşımının sertlik ve dayanım değerlerini artırdığı belirlendi. İncelenen alaşımlar içerisinde en yüksek sertlik, akma ve çekme dayanımı değerleri ark ergitme yöntemi ile üretilen Al-17Si-0,2Ti alaşımından elde edildi. Üretim yönteminin alaşımların sertlik ve mukavemet değerlerinde yol açtığı artış içyapılarındaki değişime dayandırılarak irdelendi.

Anahtar Kelimeler : Al-Si alaşımları, İçyapı, Sertlik, Mekanik özellikler

1. GİRİŞ

Al-Si alaşımları otomotiv, uzay, havacılık, savunma, nükleer, medikal ve elektrik sanayi dallarında sahip oldukları hafiflik, düşük termal genleşme katsayısı, yüksek korozyon direnci ve yeterli mukavemet özelliklerinin yanı sıra düşük hammadde ve üretim maliyeti sergilemeleri nedeniyle yoğun olarak kullanılmaktadır (Alemdağ & Beder, 2019; Nikanorov et al., 2005). Al-Si alaşımları içerisinde uygulamada önemli bir konuma sahip Al-17Si esaslı alaşımlar ilgili faz diyagramına göre ötektik üstü olarak sınıflandırılmakta olup, otomotiv sanayiinde özellikle motor blokları, piston ve külbütör kapağı gibi yüksek sertlik ve aşınma direnci gerektiren parçaların tasarım ve imalatında tercih edilmektedir (Dwivedi, 2006; Miller et al., 2000). Bununla birlikte, son yıllarda Al-17Si alaşımlarının uygulama alanları genişletmek, performanslarını ve kullanım ömürlerini artırmak amacıyla bu alaşımlar üzerinde farklı çalışma grupları veya araştırmacılar tarafından yoğun çalışmalar yürütülmüştür (Çalış & Hekimoğlu, 2022; Hekimoğlu et al., 2020). Bu araştırma ve geliştirme çalışmalarında Al-17Si alaşımlarının yapısal ve mekanik özelliklerinin farklı yöntemler ile iyileştirilebileceği ortaya koyulmuştur (Çalış & Hekimoğlu, 2022; Hekimoğlu et al., 2020). Bu yöntemler arasında içyapılarındaki primer ve ötektik silisyum parçacıklarının modifikasyonu, bir başka deyişle morfolojilerinin değiştirilmesi ve boyutlarının küçültülmesi önemli bir yer tutmaktadır (Çalış & Hekimoğlu, 2022; Hekimoğlu et al., 2019). Farklı alaşım elementi ilaveleri, ısıl işlem uygulamaları ve üretim yöntemleri söz konusu alaşımların sertlik, akma dayanımı, çekme dayanımı, yorulma dayanımı ve/veya korozyon dirençlerini artıran diğer yöntemler arasında gelmektedir (Alemdag et al., 2021; Hekimoğlu et al., 2020; Moustafa et al., 2003). Al-Si alaşımlarının içyapısındaki primer ve ötektik silisyum parçacıklarının modifikasyonu genellikle bu alaşımlara dökümleri sırasında düşük oranlarda sodyum, kalsiyum, stronsiyum, titanyum, bor gibi tane inceltici element ilavesi yaparak gerçekleştirilmektedir (Çalış & Hekimoğlu, 2022; Ho & Cantor, 1995; Saheb et al., 2001). Son zamanlarda yapılan bir çalışmada Al-Si alaşımlarına yüksek oranlarda çinko ilavesinin de bu alaşımlarda silisyum parçacıklarının modifikasyonuna neden olduğu ve mukavemet değerlerinde önemli bir artışa yol açtığı ortaya koyulmuştur (Hekimoğlu et al., 2024). Al-Si alaşımlarına uygun alaşım elementi katılması durumunda katı çözelti sertleşmesi, ikincil faz çökelmesi ve/veya dispersiyon sertleşmesi gibi mekanizmalar ortaya çıkarak bu alaşımların sertlik ve dayanım değerlerinde önemli oranda artış elde edilebilmektedir (Hekimoğlu et al., 2020). Al-Si alaşımlarının sertlik, dayanım ve/veya süneklik özelliklerini iyileştiren ısıl işlemlerin başında ise T5, T6 ve T7 ısıl işlemleri gelmektedir (Beroual et al., 2019; Li et al., 2004; Moustafa et al., 2003). Söz konusu alaşımlara uygulanacak en uygun ısıl işlem geliştirilmesi istenen malzeme özelliği ve kimyasal bileşime bağlı olarak belirlenmektedir. Son zamanlarda yapılan bazı çalışmalarda Al-Si alaşımlarına titanyum ilavesi yaparak ve/veya bu alaşımları vakum altından ark ergitme yöntemi ile üreterek önemli oranda sertlik ve mukavemet artışı elde edilebileceği ortaya koyulmuştur (Hacıosmanoğlu & Hekimoğlu, 2019; Hekimoğlu & Çalış, 2021). Bu çalışmalar farklı oranlarda silisyum içeren Al-Si alaşımlarında ve farklı alaşım elementleri içeren Al-17Si esaslı alaşımlar üzerinde yapılmıştır(Hekimoğlu & Çalış, 2021; Samuel et al., 2014). İndüksiyon ocağında ergitme ve kokil kalıba döküm yöntemiyle üretilen ikili Al-17Si alaşımına titanyum katkılarının etkisinin incelendiği bir çalışmada %0,2 titanyum katkısının bu alaşımın sertlik ve dayanım değerlerini artırdığı ortaya koyulmuştur (Hacıosmanoğlu & Hekimoğlu, 2019). Ancak ikili Al-17Si ve üçlü Al-17Si-0,2Ti alaşımlarının yapısal ve mekanik özelliklerine ark ergitme yönteminin etkisini inceleyen bir çalışma henüz yapılmamıştır. Bu nedenle bu çalışmada ark ergitme yönteminin ikili Al-17Si ve üçlü Al-17Si-

0,2Ti alaşımlarının yapısal ve mekanik özelliklerine etkisinin incelenmesi ve elde edilen sonuçların indüksiyon ocağında ergitilip kokil kalıba dökülerek üretilen aynı alaşımların söz konusu özellikleri ile karşılaştırılması amaçlanmıştır.

2. DENEYSEL ÇALIŞMALAR

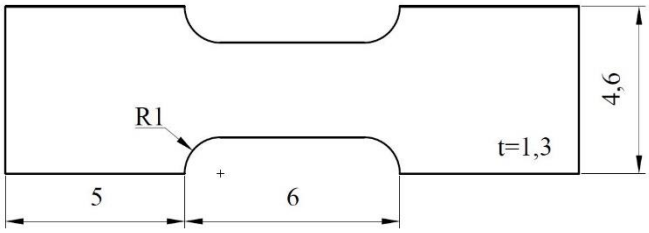
Bu çalışmada nominal kimyasal bileşimleri Tablo 1'de verilen Al-17Si ve Al-17Si-0,2Ti hafif alaşımları ark ergitme yöntemiyle imal edildi. Alaşımların imalatında kullanılan ark ergitme fırınının fotoğrafı Şekil 1'de yer almaktadır. Alaşımların üretiminde ağırlıkça istenilen oranları sağlayacak şekilde piyasadan temin edilen %99,8 saflıkta alüminyum ve silisyum ile Al-10Ti master alaşım külçeleri kullanıldı. Bu külçelerden gerekli miktarlarda parçalar alınarak vakum altında ve argon gazı ortamında elektrik arkı ile ergitilip katılaştırıldı. Ergitme ve katılaştırma sırasında alaşımların homojenliğinin sağlanması için her bir alaşım külçesi üçer kez ergitilerek katılaştırıldı.

Çizelge 1. Üretilen alaşımların nominal kimyasal bileşimleri.

Alaşım	Ağırlıkça element oranı (%)		
	Alüminyum	Silisyum	Titanyum
Al-17Si	Kalan	7	-
Al-17Si-0,2Ti	Kalan	7	0,2

Görsel 1. Alaşımların üretiminde kullanılan ark ergitme ocağının görüntüsü

Üretilen alaşımların içyapıları ışık mikroskobunda incelendi. Mikroskobik incelemelerden önce alaşım külçelerinden uygun şekilde alınan numuneler standart metalografik yöntemler ile zımparalandı ve parlatıldı. Parlatılan numuneler dağlama yapılmadan incelendi ve görüntülendi. Alaşımların sertlikleri Brinell ölçüm yöntemi ile belirlendi. Söz konusu ölçümler 62,5 kg×f yük ve 2,5 mm çapında bilye kullanılarak gerçekleştirildi. Ölçümler üretilen her alaşım için en az on kez yapıldı ve elde edilen değerlerin ortalaması alınarak alaşımların ortalama sertlik değerleri belirlendi. Çekme deneyleri Şekil 3'de boyutları verilen numuneler üzerinde 10-3 s-1'lik deformasyon hızında gerçekleştirildi. Her bir alaşım için 6 adet çekme deneyi yapıldı ve akma dayanımı, çekme dayanımı ve kopma uzaması değerleri bu deneylerden elde edilen sonuçların ortalaması alınarak hesaplandı. Ark ergitme yöntemiyle üretilen Al-17Si ve Al-17Si-0,2Ti alaşımlarının yapısal ve mekanik deneylerinden elde edilen bulgular bu alaşımların indüksiyon ocağında ergitilip kokil kalıba dökülerek üretildiği daha önceki bir çalışmada (Hacıosmanoğlu & Hekimoğlu, 2019) sunulmuş olan veriler ile karşılaştırıldı.



Görsel 2. Üretilen alaşımların çekme deneylerinde kullanılan numunelerin teknik resmi (Birimler mm'dir)

3. SONUÇLAR VE DEĞERLENDİRME

İncelenen Al-17Si ve Al-17Si-0,2Ti alaşımlarının içyapıları Şekil 3-6 'de verilen optik mikroskop fotoğraflarında da görüleceği üzere α-alüminyum dendiritleri, demir, alüminyum ve silisyum içeren β fazı, ötektik dönüşüm ile oluşan Al-Si karışımı ve primer silisyum parçacıklarından oluşmaktadır. Al-17Si alaşımlarında bu içyapının oluşumu ikili Al-Si faz diyagramına göre daha önceki çalışmalarda açıklanmıştı (Hacıosmanoğlu & Hekimoğlu, 2019; Hekimoğlu et al., 2020). Şöyle ki, bu faz diyagramına göre ötektiküstü Al-Si alaşımlarının katılaşması sırasında önce primer silisyum parçacıkları oluşmaktadır. Katılaşma devam ettikçe sıvı metaldeki silisyum oranı ötektik bileşime yaklaşmaktadır. Sıvı metaldeki silisyum oranı ötektik noktadaki değerine, sıcaklık değeri de ötektik noktanın sıcaklık değerine düştüğünde katılaşma ötektik dönüşümle meydana gelmekte ve bu dönüşüm ile ötektik Al-Si fazı oluşmaktadır. Alaşımların içyapısındaki alüminyumca zengin α-dendiritlerinin denge dışı soğuma nedeniyle oluştuğu düşünülmektedir. Al-17Si alaşımına % 0,2 oranında titanyum katılması iç yapısındaki α-Al dendiritleri ve ötektik silisyum parçacıklarının küçülmesine yol açmış olup elde edilen bulgular literatür ile uyumludur (Hacıosmanoğlu & Hekimoğlu, 2019) (Şekil 4 ve 6). Titanyumun alüminyum esaslı alaşımların yapısında bulunan α-Al dendiritlerinin morfolojisinde neden olduğu küçülme literatürdeki benzer çalışmalarda çözünürlük teorisine dayandırılarak açıklanmıştır (Hacıosmanoğlu & Hekimoğlu, 2019; Hekimoğlu & Çalış, 2020).

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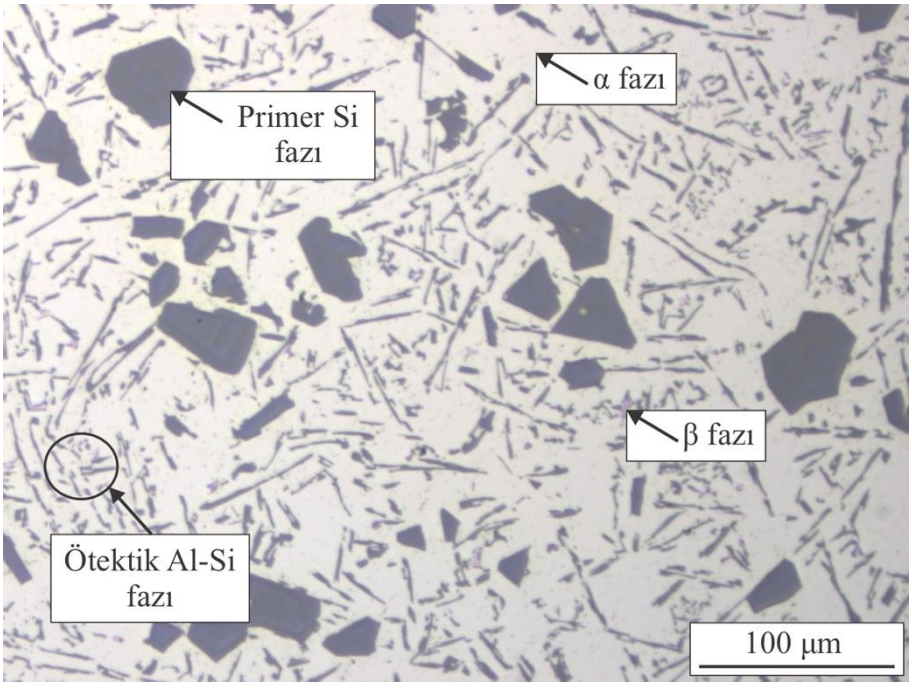
Söz konusu teoriye göre bir fazın içerisinde başka bir elementin çözünmesi bu fazın büyümesini kısıtlamaktadır ve içyapı daha ince taneli olmaktadır (Hacıosmanoğlu & Hekimoğlu, 2019; Hekimoğlu & Çalış, 2020). Al-17Si-0,2Ti alaşımının içyapı incelemelerinde Al-17Si alaşımının içyapısında bulunanlardan farklı bir fazın gözlenememesi nedeniyle ilave edilen titanyumun içyapıda tamamen çözündüğü ve çözünürlük teorisiyle uyumlu olarak α-Al dendiritlerinin büyümesini engellediği söylenebilir. Ötektik silisyum parçacıklarındaki incelme ise titanyum ilavesi nedeniyle ötektik dönüşüm sırasında açığa çıkan ısının artmasından, ötektik dönüşümün daha yüksek silisyum oranında ve daha düşük sıcaklık değerinde gerçekleşmesinden kaynaklanmış olabilir (Hacıosmanoğlu & Hekimoğlu, 2019; Zhang et al., 2006). Zira alaşım elementi ilavelerinin Al-Si alaşımlarındaki ötektik noktayı ötelediği yönünde çalışmalar yer almaktadır (Çalış & Hekimoğlu, 2022; Hacıosmanoğlu & Hekimoğlu, 2019).

Ark ergitme fırını kullanılarak üretilen alaşımların içyapısındaki α-Al dendiritlerinin ve silisyum parçacıklarının indüksiyonla ergitme yöntemiyle üretilen alaşımlara göre daha ince olduğu gözlendi, Şekil 3-6. Bu durumun ark ergitme yöntemindeki soğuma/katılaşma hızının daha yüksek olmasından kaynaklandığı düşünülmektedir. Bilindiği üzere katılaşma sırasında soğuma hızının yüksek olması içyapının daha ince taneli olmasına yol açmaktadır (Hekimoğlu & Çalış, 2021).



Görsel 3. İndüksiyon ocağında ergitme yoluyla üretilen Al-17Si alaşımının içyapısını gösteren fotoğraf

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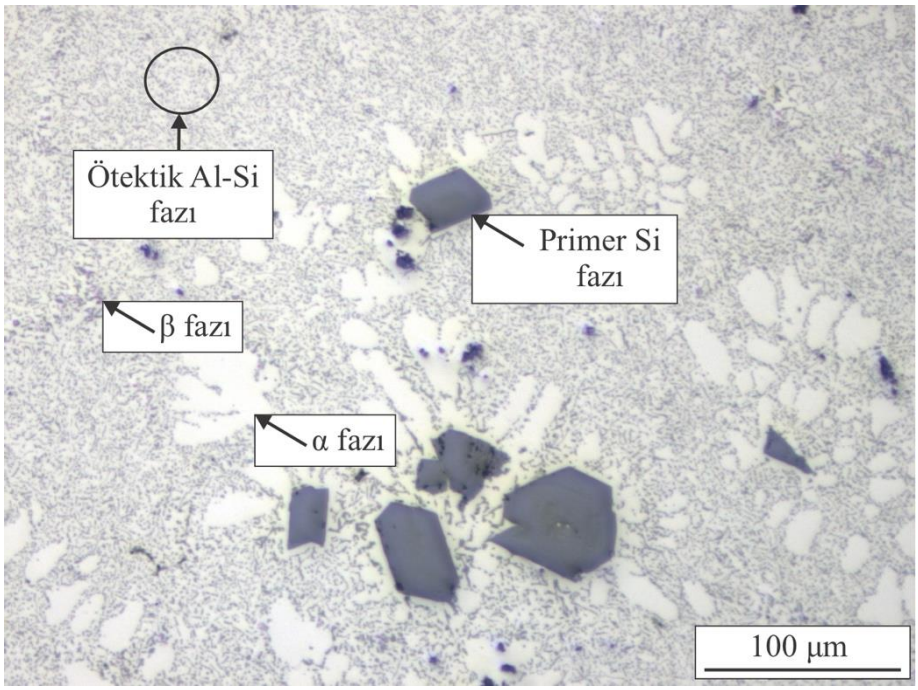
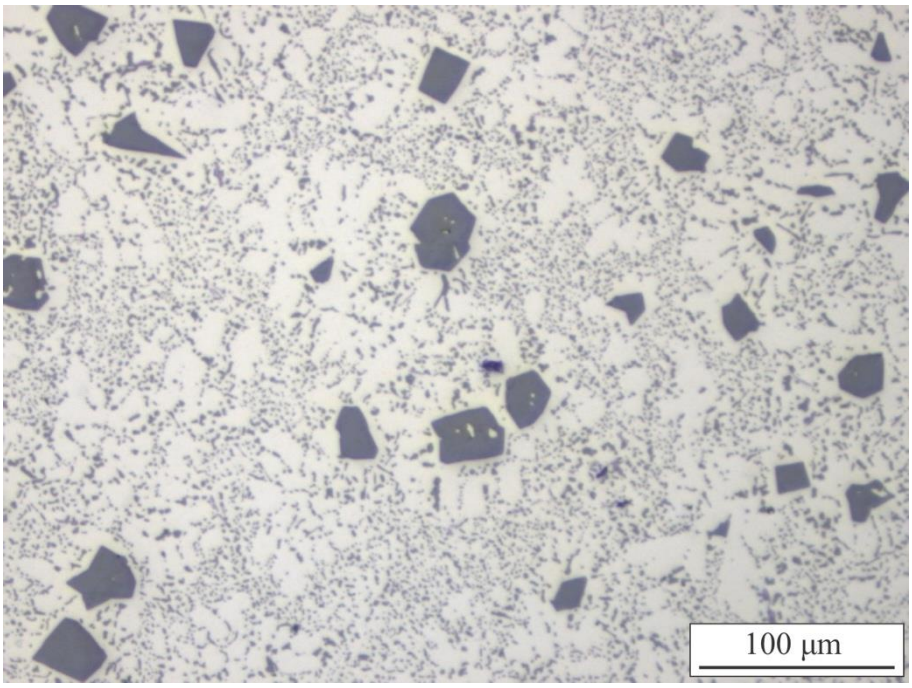


Görsel 4. İndüksiyon ocağında ergitme yoluyla üretilen Al-17Si-0,2Ti alaşımının içyapısını gösteren fotoğraf



Görsel 5. Ark ergitme yöntemiyle üretilen Al-17Si alaşımının içyapısını gösteren fotoğraf

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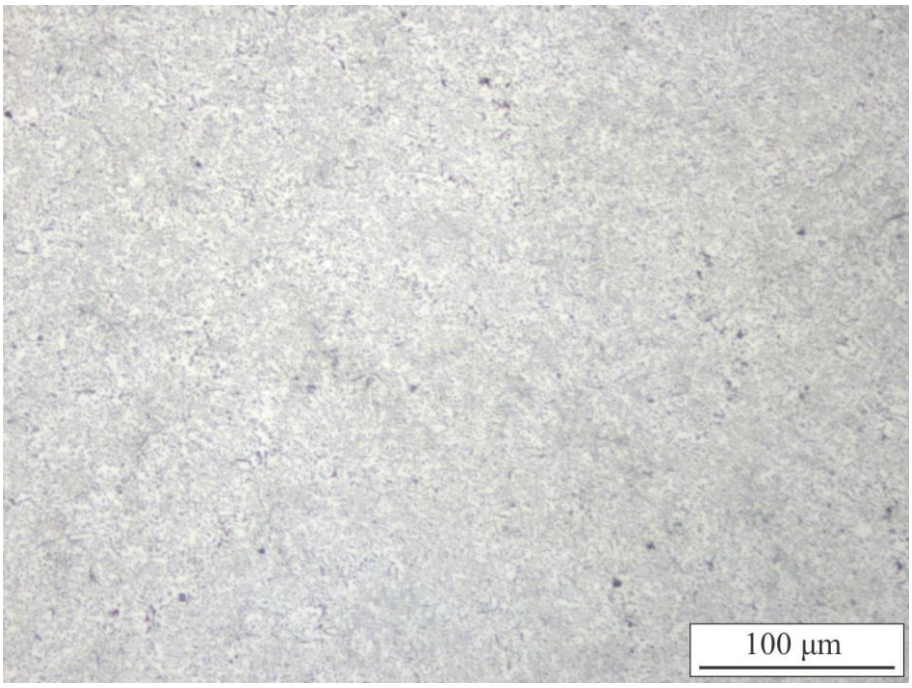
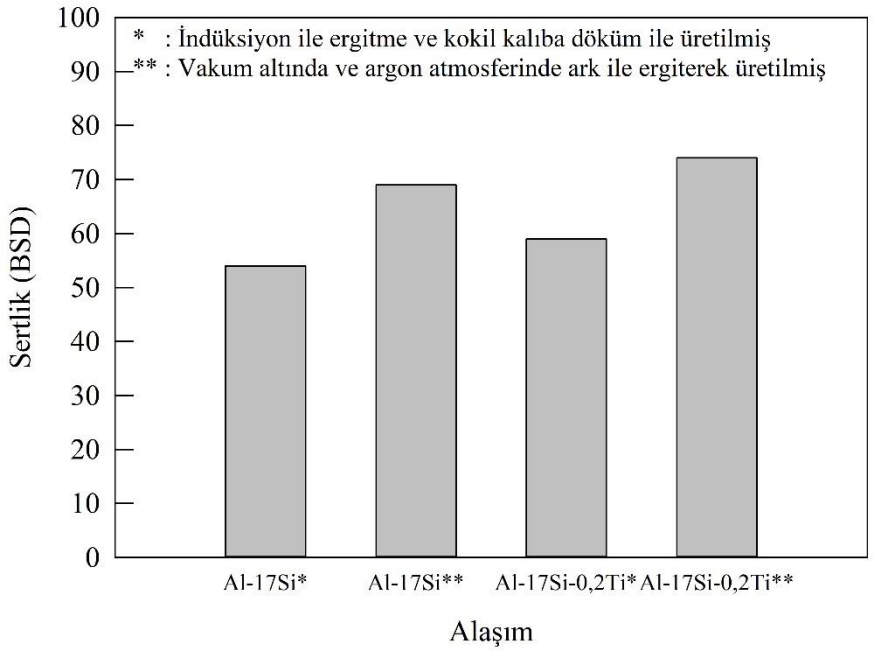


Görsel 6. Ark ergitme yöntemiyle üretilen Al-17Si-0,2Ti alaşımının içyapısını gösteren fotoğraf

İncelenen alaşımlarının sertlik, akma dayanımı, çekme dayanımı ve kopma uzaması değerleri Tablo 2'de, bu değerlerin incelenen alaşımlara göre karşılaştırmalı olarak yer aldığı çubuk diyagramlar ise Şekil 7-10'da verilmiştir. Bu tablo ve diyagramlarda indüksiyonla üretilen Al-17Si alaşımına yapılan %0,2 titanyum katkısının ve ark ergitme yönteminin bu alaşımın sertlik ve dayanım değerlerini artırdığı görülmektedir, Tablo 2. Titanyumun Al-17Si alaşımının sertlik ve dayanım değerlerinde yol açtığı artış; içyapıda çözünmesi nedeniyle katı çözelti sertleşmesi, α-dendiritlerinin ve silisyum parçacıklarının küçülmesi nedeniyle tane incelmesi ve silisyum parçacıklarının daha ince ve çok sayıda dağılması nedeniyle ortaya oluşabilecek dispersiyon sertleşmesi mekanizmalarının biri veya birden fazlasının etkisine dayandırılarak açıklanmaktadır (Çalış & Hekimoğlu, 2022; Hacıosmanoğlu & Hekimoğlu, 2019). Literatürde Al-Si alaşımlarında dendritlerin ve silisyum parçacıklarının küçülmesinin bu tür sertleştirme mekanizmaları sayesinde sertlik ve dayanım değerlerini artırdığına dair detaylı çalışmalar mevcuttur (Çalış & Hekimoğlu, 2022; Hacıosmanoğlu & Hekimoğlu, 2019; Hekimoğlu et al., 2019). Vakum altında argon atmosferinde ark ergitme ocağında üretilen ikili alaşımların mukavemetlerinde gözlenen artışında tane incelmesi ve dispersiyon sertleşmesi mekanizmaları, titanyum içeren üçlü alaşımlarda ise bu mekanizmalara ek olarak katı çözelti sertleşmesi mekanizmasının etkisinden kaynaklandığı düşünülmektedir (Çalış & Hekimoğlu, 2022; Hacıosmanoğlu & Hekimoğlu, 2019; Hekimoğlu et al., 2019).

Çizelge 2. İncelenen alaşımlarının sertlik, akma ve çekme dayanımı değerleri.

Alaşım	Sertlik (BSD)	Akma dayanımı (MPa)	Çekme dayanımı (MPa)	Kopma uzaması (%)
Al-17Si*	54 [IMSMATEC 2019]	92 [IMSMATEC 2019]	126 [IMSMATEC 2019]	2,1 [IMSMATEC 2019]
Al-17Si**	69	118	200	8,5
Al-17Si-0,2Ti*	59 [IMSMATEC 2019]	98 [IMSMATEC 2019]	129 [IMSMATEC 2019]	1,4 [IMSMATEC 2019]
Al-17Si-0,2Ti**	74	143	235	8,3



Görsel 7. İncelenen alaşımların sertlik değerlerini gösteren grafik

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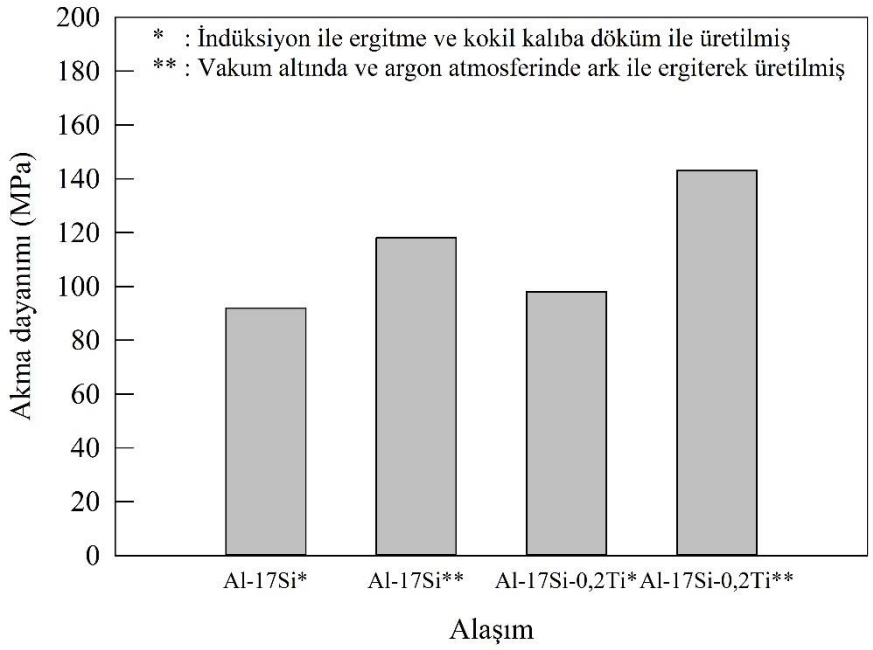
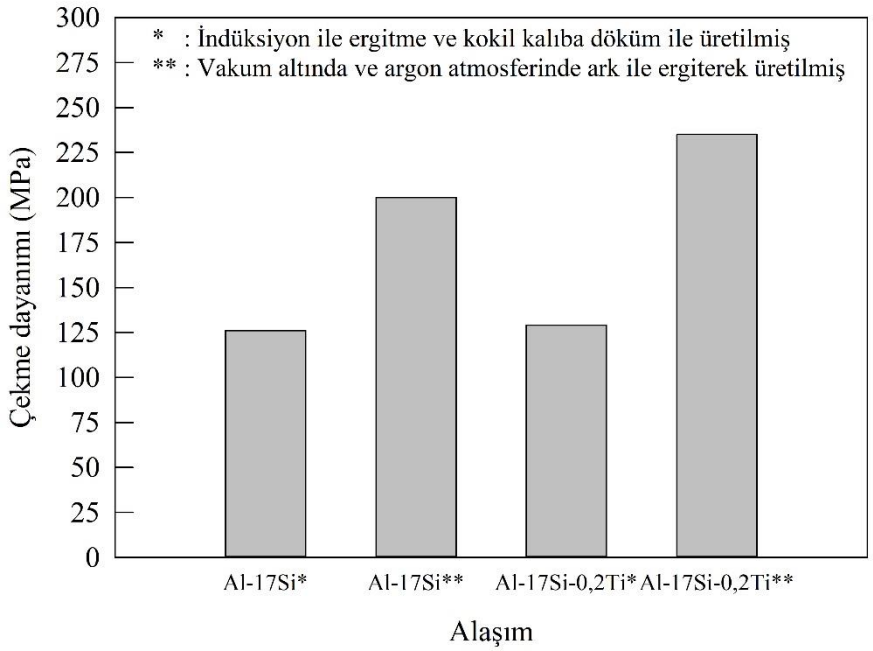


Görsel 8. İncelenen alaşımların akma dayanımı değerlerini gösteren grafik



Görsel 9. İncelenen alaşımların çekme dayanımı değerlerini gösteren grafik

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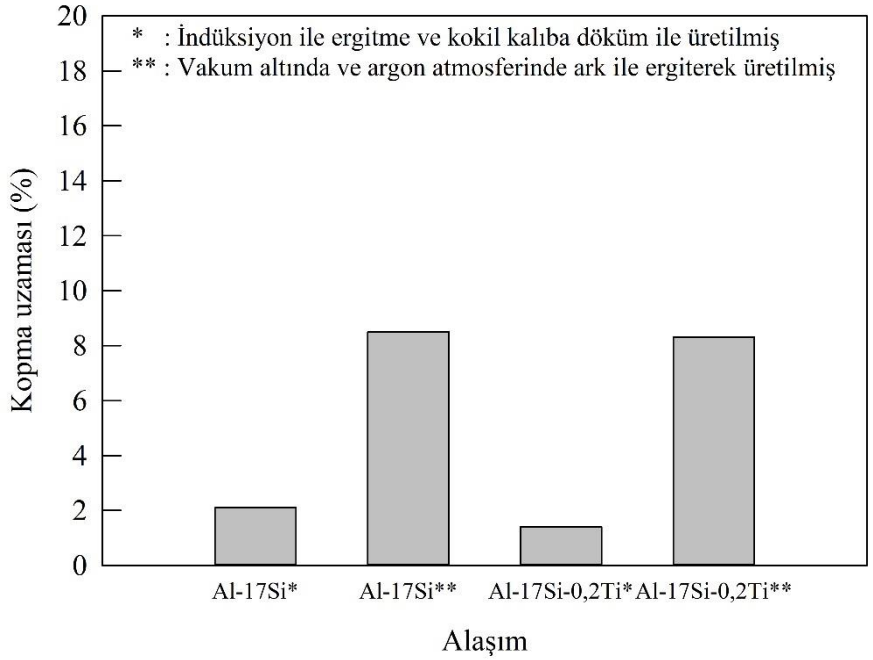

Görsel 10. İncelenen alaşımların kopma uzaması değerlerini gösteren grafik

4. GENEL DEĞERLENDİRME VE SONUÇLAR

I. Al-17Si ve Al-17Si-0,2Ti alaşımlarının içyapıları α-Al dendiritleri, ötektik dönüşüm ile oluşan alüminyum (Al)-silisyum (Si) faz bölgesi, primer silisyum parçacıkları ve β fazından oluşur.

II. Ark ergitme yöntemi Al-17Si ve Al-17Si-0,2Ti alaşımlarının içyapısındaki α dendiritleri ve ötektik silisyum parçacıklarının incelmesine yol açmaktadır.

III. Vakum altında argon gazı atmosferinde ark ergitme yöntemi ile üretilen Al-17Si ve Al-17Si-0,2Ti alaşımları indüksiyonla ergitme yöntemi ile üretilenlere göre daha yüksek sertlik, akma dayanımı, çekme dayanımı ve kopma uzaması sergilemektedir.

Teşekkür

Bu çalışma Recep Tayyip Erdoğan Üniversitesi Bilimsel Araştırma Projeleri Koordinatörlüğü tarafından desteklenmiştir. Proje Numarası: FKG-2016-578.

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SÜRÜNME GERİLMESİNİN ENJEKSİYONLA KALIPLANAN POLİPROPİLEN BLOK KOPOLİMER MALZEDE SÜRÜNME HIZINA ETKİSİ

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ÖZET

Polipropilen blok kopolimer (PPB) malzemesi, yüksek sürünme dayanımı ve çevresel yüklemelere karşı çatlak direnciyle bilinmektedir. Bu çalışmada, PPB malzemede sürünme gerilmesinin sürünme hızına olan etkisi incelenmiştir. Ayrıca, sürünme gerilmesinin sürünme ömrü üzerindeki olası etkilerini de yansıttığı tespit edilmiştir.

Çalışma kapsamında plastik enjeksiyon yöntemiyle üretilen PPB numunelere; 0.0003 1/s genleme hızında, farklı sürünme gerilmesi değerlerinde (8, 11, 16 ve 18 MPa) ve 1800 s sürünme süreli testler uygulanmıştır. Ek olarak, aynı genleme hızında çekme testiyle PPB malzemenin kalıcı şekil değişimi olmadan depo edebileceği şekil değiştirme enerjisi hesaplanmıştır.

Deney sonuçları, sürünme gerilmesinin yükselme, birincil ve ikincil sürünme bölgelerinde bölgesel genleme ve sürelerde artışa yol açtığını göstermiştir. Tüm bölgelerde sürünme gerilmesinin artması, bölgesel genlemeyi ve buna bağlı olarak sürünme hızını artırmaktadır. Bundan başka, yüksek sürünme gerilmesi altında malzeme ömrünü kısalttığı belirlenmiştir.

Sonuç olarak, gerilme değeri lineer artsa da genleme oranının geometrik olarak arttığı belirlenmiştir.

Anahtar Kelimeler: Polipropilen Blok Kopolimer, Sürünme Gerilmesi, Sürünme Hızı

THE EFFECT OF CREEP STRESS ON THE CREEP RATE OF INJECTION MOULDED POLYPROPYLENE BLOCK COPOLYMER MATERIAL

ABSTRACT

Polypropylene block copolymer (PPB) material is known for its high creep resistance and crack resistance under environmental loading. In this study, the effect of creep stress on the creep rate of PPB material was examined. It was also determined that creep stress reflects its potential effects on creep lifespan.

Within the scope of the study, PPB samples produced by plastic injection molding were subjected to creep tests at a strain rate of 0.0003 1/s, at different creep stress levels (8, 11, 16, and 18 MPa), and for a duration of 1800 seconds. In addition, a tensile test at the same strain rate was performed to calculate the deformation energy that PPB material is able to wtih stand without undergoing permanent deformation.

The experimental results showed that creep stress leads to increase in regional strain and time in the initial, primary, and secondary creep regions. In all regions, an increase in creep stress corresponded to an increase in regional strain and, consequently, in creep rate. Furthermore, it was found that higher creep stress shortens the material's lifespan.

As a result, it was determined that although the stress value increases linearly, the strain ratio geometrically increases.

Keywords: Polypropylene Block Copolymer, Creep Stress, Creep Rate

1.GİRİŞ

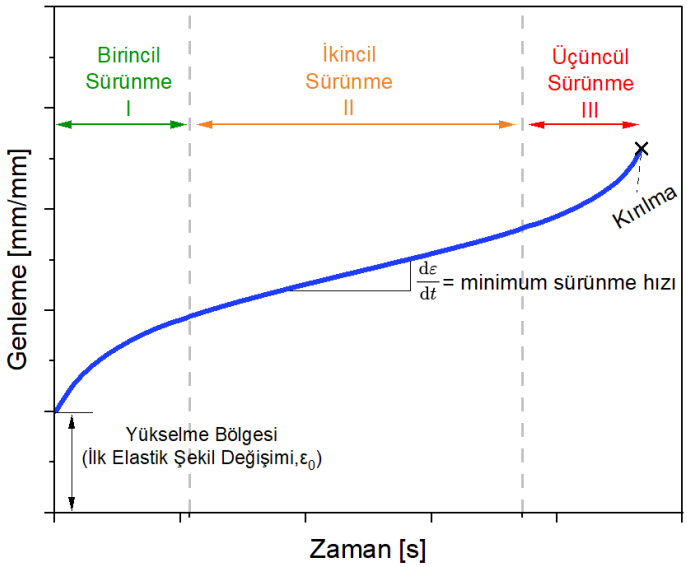
Poliolefin grubu termoplastiklerinden biri olan polipropilen (PP), iyi mekanik özellikleri, iyi işlenebilirlik kabiliyeti ve çok uygun bir fiyat/verim oranına sahip olmasının sağladığı avantajlardan dolayı öne çıkan polimerler arasındadır. Bu özelliklerinden dolayı birçok sektörde kullanılmaktadır [1]. PP, homopolimer (PPH veya Tip 1), blok kopolimer (PPB veya Tip 2) [2] ve random kopolimer (PPR veya Tip 3) olarak piyasaya sürülmektedir. PPB, darbe dayanımı ve eğilme direnciyle diğer PP türlerinden ayrışmaktadır [3].

2010 yılında Haddad'ın yapmış olduğu çalışmasında, Avrupa'da PPB malzemeden üretilen oluklu su drenajı ve atık su tahliye borularında büyük başarı elde edildiğini bildirmiştir. Bu başarının temelinde ise yüksek sürünme dayanımı ve çevresel yüklemelere karşı çatlak oluşumu direncinin yer aldığını açıklamıştır [4]. PPB'nin küresel ölçekte tercih edilen bir malzeme olarak öne çıkaran faktörlerden bir tanesinin sürünme dayanımı olması hem ilgi uyandırmaktadır hem de PPB malzemesinin sürünme davranışını araştırılmaya değer bir konu haline getirmektedir.

Sürünme testinde; belirli bir süre, sıcaklık ve sabit bir yük altında numuneye yükleme yapılmaktadır. Bu test ile numunenin boyutsal kararlılığını sağlama yeteneği incelenmektedir

[5]. Bir diğer ifade ile sürünme direncini incelemektedir. Polimer esaslı plastik malzeme için tipik bir sürünme testi cevabı Görsel 1'de verilmiştir [6, 7].

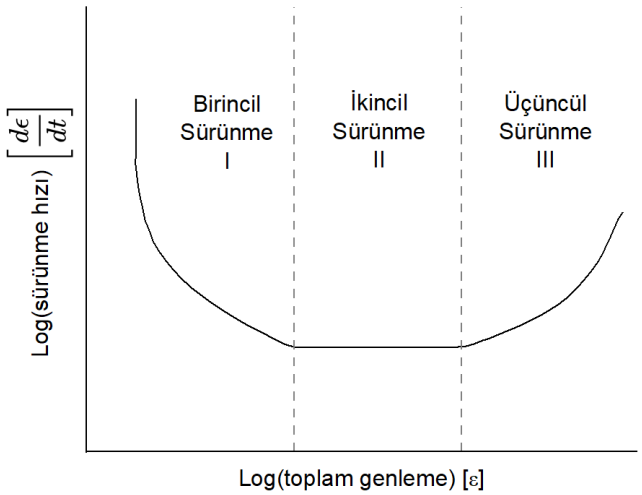
Görsel 1'de, sürünme yüklemesine maruz kalan polimer esaslı plastiklerin zamana, yüklemeye ve sıcaklığa bağlı farklı davranış bölgelerine ayrıldığı görülmektedir. [6, 7].



Görsel 1. Polimer esaslı plastik malzemeler için tipik sürünme testi cevabı [6, 7]

Testte belirlenen gerilme değerine ani yükleme yapılmaktadır; bu durum, plastik malzemenin ilk elastik genleme değerine hızla ulaşmasını sağlamaktadır. Malzeme, stabil bir sürünme eğimi kazanana kadar birincil sürünme bölgesinde düşen bir hızla şekil değiştirmeye devam etmektedir. İkincil sürünme bölgesinde, sabit bir sürünme hızıyla şekil değiştirme sürmektedir. Üçüncül sürünme bölgesinde ise malzeme, tamamen hasarlanana kadar artan bir sürünme hızıyla plastik şekil değiştirmektedir ve kırılmaktadır [6, 7].

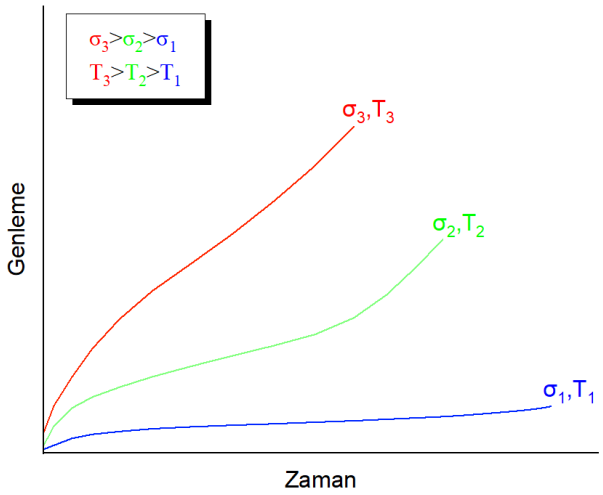
Görsel 2'de sürünme hızı – zaman değerlerinin logaritmik eksendeki hali verilmiştir [6, 7].



Görsel 2. Polimer esaslı plastik malzemelerdeki sürünme hızının değişimi [6, 7]

Birincil sürünme bölgesinde sürünme hızının azaldığı, ikincil sürünme bölgesinde minimum sürünme hızında devam ettiği ve üçüncül sürünme bölgesinde de sürünme hızının artarak sürünme cevap karakteristiğinin sonlandığı görülmektedir.

Görsel 3'de artan gerilme ve/veya sıcaklığın sürünme davranışına etkisi grafiksel olarak şematize edilerek gösterilmiştir [8, 9]. Sıcaklığın ve/veya sürünme gerilmesinin arttırılması sürünme hızına etki ederek artmasına etki etmektedir. Bu şekilde, daha düşük sürünme gerilmesi ve/veya sıcaklıkta yapılan testlerin, sıcaklık ve/veya sürünme gerilmesi değerleri artırılarak daha kısa sürede tamamlanması sağlanabilmektedir.



Görsel 3. Artan sürünme gerilmesinin ve/veya sıcaklığının sürünme davranışına genel etkisi [8, 9]

Bu kapsamda, çalışmanın amacı PPB malzemeden imal edilmiş çekme numunelerinin aynı ortam koşullarında, 0.003 1/s genleme hızında ve birbirinden 4 farklı sabit (8, 11,16 ve 18 MPa) sürünme gerilmesi değerlerinde kısa süreli sürünme davranışlarının incelenmesidir.

2.MATERYAL VE YÖNTEM

2.1.Materyal

Bu çalışmada, üretici firma tarafından basınçsız boru sistemleri için tavsiye edilen Polipropilen BorECO^{TM} BEC5015 (Borealis AG) ticari isimli polipropilen blok kopolimer (PPB) hammaddesi kullanılmıştır. PPB hammaddesinin önemli fiziksel ve mekaniksel özellikleri üreticinin ürün spesifikasyonlarına göre Çizelge 1'de verilmiştir [10], [11]

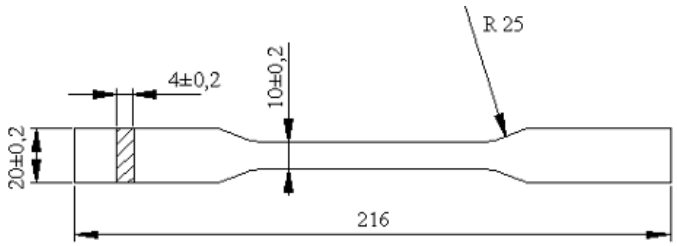
Çizelge 1. PPB malzemenin ürün spesifikasyonları [10], [11]

Özellik	Test Metodu	Test Koşulu	Birim Sistemi	Özellik Değeri
Çekme Akma Gerilmesi	ISO 527-2	50 mm/dak	MPa	30
Çekme Akma Genlemesi	ISO 527-2	50 mm/dak	%	10
Çekme Modülü	ISO 527	1 mm/dak	MPa	1500
Charpy Çentik Darbe Dayanımına	ISO 179/1eU	+ 23 °C	kJ/m^2	70
Kütlesel Akış Hızı (MFR)	ISO 1133	230°C / 2.16 kg	g/10 dak	0.3

Yoğunluk	ISO1183		g/cm^3	0.9

2.2. Çok Amaçlı Deney Parçası Hazırlama

Saf PPB hammaddelerini toplam uzunluğu 216 mm ve boyutları TS EN ISO 527-2 standardında belirtilen tip 1A (ve/veya TS EN ISO 3167'de tip A) çok amaçlı deney parçalarına kalıplamak için vida çapı (D) 46 mm ve vida oranı (L/D) 20 olan bir enjeksiyon kalıplama makinesi (Haitian Plastics Machinery HTF 90W) kullanılmıştır. Çok amaçlı deney parçasının teknik ölçüleri şematize edilerek Görsel 4'de gösterilişitir [11].



Görsel 4. Çok amaçlı deney parçası ölçüleri [11]

Saf PPB hammaddelerin enjeksiyon kalıplama işlemi, 1450 bar enjeksiyon basıncı, 650 bar tutma basıncı, 60 s tutma süresi, 225ºC/220ºC/220ºC/215ºC bir kovan bölgesi sıcaklıkları (besleme bölgesinden meme bölgesine doğru), 225°C eriyik sıcaklığı ve 30°C kalıp soğutma sıcaklığı gibi sabit enjeksiyon parametreleriyle TS EN ISO 294-1'e göre gerçekleştirilmiştir. Ayrıca, her çok amaçlı deney parçası için kalıp sıcaklığını belirtilen sıcaklıkta sabit tutmak için sıcaklık kontrol üniteli yüksek hassasiyetli proses soğutucu (Frigel Microgel Duo) kullanılmıştır. Bundan başka, tip A çok amaçlı deney parçaları, ISO 294-1'e göre bir T-dağıtıcı ve iki kavite (oyuk) ile S235JR çeliğinden (malzeme numarası 1.0038) yapılmış bir A tipi ISO kalıbına doğrudan doğruya enjeksiyon kalıplama ile üretilmiştir.

2.3. Yöntem

Tip A çok amaçlı deney parçalarının sürünme testleri (için) 10 kN kapasiteli çekme/basma test cihazı (Shimadzu AG-X) ve bilgisayar destekli Trapezium-X yazılımı kullanılmıştır.

Çok amaçlı deney parçaları, deney parçalarının enjeksiyon girişi bölgesinin sabit çene tarafından tutulacak ve/veya kelepçelenecek şekilde ana uzunlamasına eksenleri boyunca çekme test makinesinin çenelerine yerleştirilmiştir. Böylece, sürünme testi sırasında uygulanan sürünme (çekme) gerilmesi yönünün, deney parçalarının enjeksiyon kalıbının doldurma yönü ile aynı yönde (doğrultuda) olması sağlanmıştır. Bu şekilde deney numuneleri üzerindeki çekme gerilmesinin, ISO 13586'da L-T yönü olarak belirtilen numunenin ana uzunlamasına ekseninin (veya kalıp doldurma) yönüne paralel olması sağlanmıştır.

Sürünme testleri TS EN ISO 899-1'e uygun olarak 22°C ± 1°C sıcaklık ve %50 ± %10 nemli ortam koşulları altında 0.003 1/s genleme hızında, 4 farklı sabit (8, 11,16 ve 18 MPa) sürünme gerilmesi değerlerinde ve belirlenen sabit sürünme gerilmesi değerinde 1800 s sürünme süresinde gerçekleştirilmiştir.

Ayrıca her ortalama deneysel değer için en az 3 deney parçası kullanılmış ve ortalama deneysel değer, ilgili deneysel verilerin Chauvenet kriterine [12] göre istatistiksel olarak değerlendirilmesiyle belirlenmiştir.

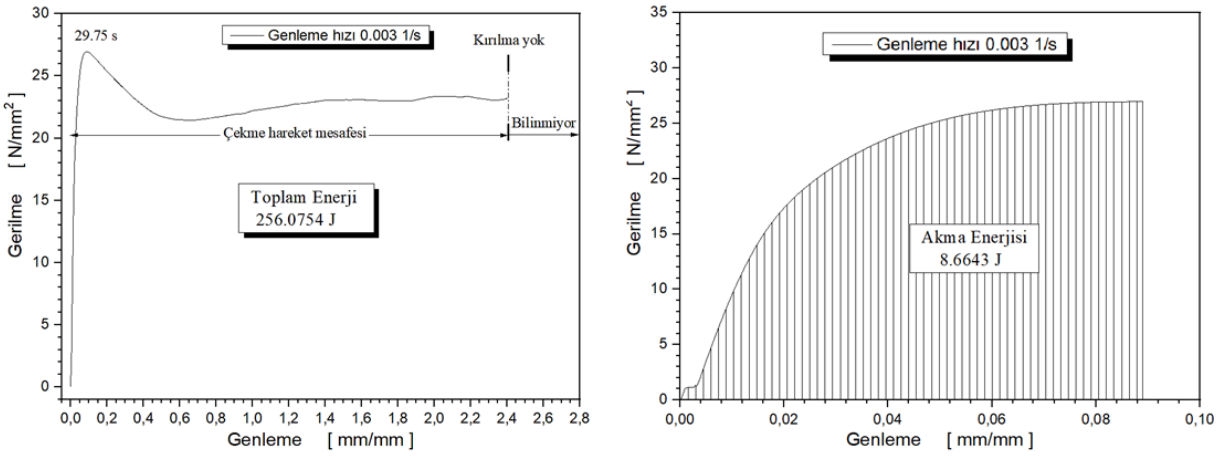
3.BULGULAR VE TARTIŞMA

PP-B malzemeye sabit 0.003 1/s genleme hızında çekme testi uygulanmıştır. Çekme cihazının maksimum çene açıklık mesafesine kadar teste devam edilmiştir ve kopma ile karşılaşılmamıştır. Testin sonucunda elde edilen veri işlenerek şekil değişimi enerji miktarları hesaplanmıştır.

Akma noktasına kadar elastik şekil değişimi enerjisini depo edebilmesi ve serbest bırakabilme kapasitesi, malzemenin rezilyans modülünün bir ölçütü olmaktadır [13]. Akma şekil değişimi enerjisi malzemenin kalıcı şekil değişimi olmaksızın depo edebildiği ve eski haline dönerken serbest bırakabildiği enerji olarak ifade edilebilmektedir.

Görsel 5.a.'da PPB malzemeye uygulanan sabit 0.003 1/s genleme hızındaki çekme testi sonucunda elde edilen gerilme – genleme grafiği verilmiştir. Eğri altındaki kalan alan hesap edilerek numune üzerine yüklenen şekil değişimi enerjisi hesap edilmiştir. Çekme cihazının maksimum çene açıklığı mesafesine kadar malzemenin yüklenmesinden dolayı malzemedeki şekil değişim enerji miktarı ise 256.0754 joule olarak hesaplanmıştır.

Görsel 5.b.'de de çekme testinin akma noktasına kadar olan gerilme – genleme grafiği verilmiştir. Ayrıca buradaki eğri altındaki kalan alanın hesaplaması sonucunda PPB malzemenin akma enerjisi değeri tespit edilmiştir. Çekme testi ile akma noktasına kadar malzemenin depo edebildiği enerji miktarı 8.6643 Joule olarak hesaplanmıştır.



a. b.

Görsel 5. a. 0.003 1/s genleme hızında PPB malzemenin gerilme – genleme grafiği **b.** Akma noktasına kadar olan gerilme-genleme grafiği

PPB malzemeden imal edilmiş çekme numunelerinin aynı ortam koşullarında ve birbirinden 4 farklı sabit (8, 11,16 ve 18 MPa) sürünme gerilmesi değerlerinde 1800 s sürünme süresinde teste tabi tutulmuştur. Görsel 6'da görüleceği üzere test süresince önceden belirlenen sürünme gerilmesi değerlerinde sabit yükler numunelere uygulanmıştır.

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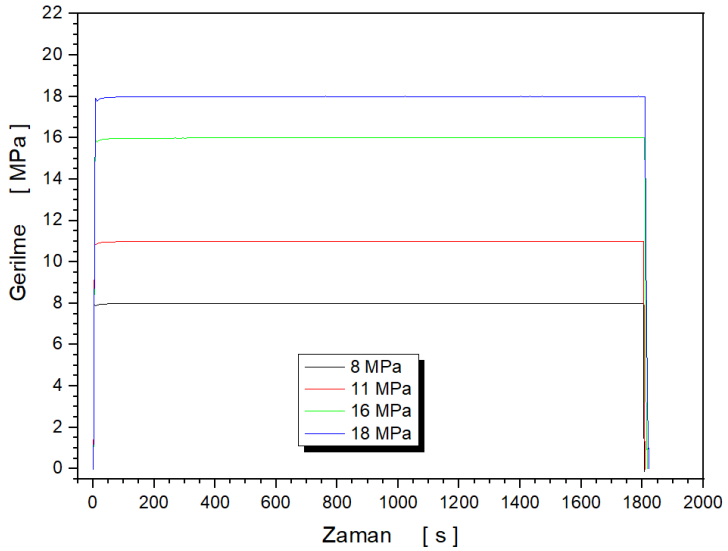
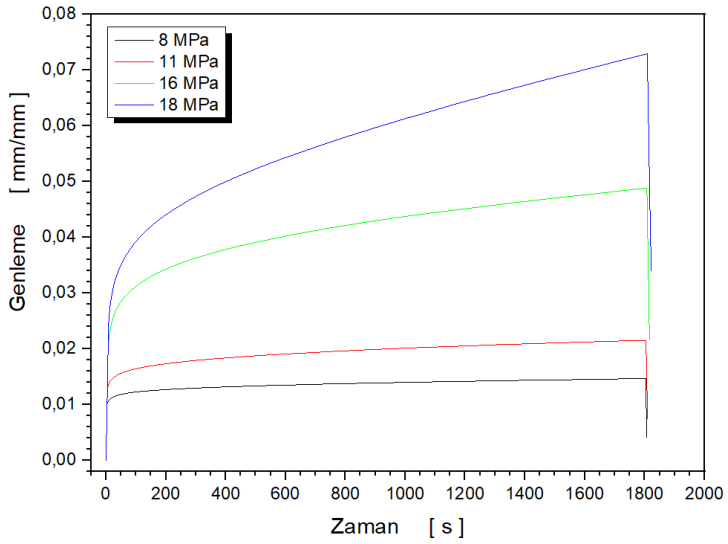


Görsel 6. 0.003 1/s genleme hızında PPB malzemeye uygulanan farklı sabit gerilme (8, 11, 16 18 MPa) değerlerindeki sürünme testlerinin gerilme – zaman grafikleri

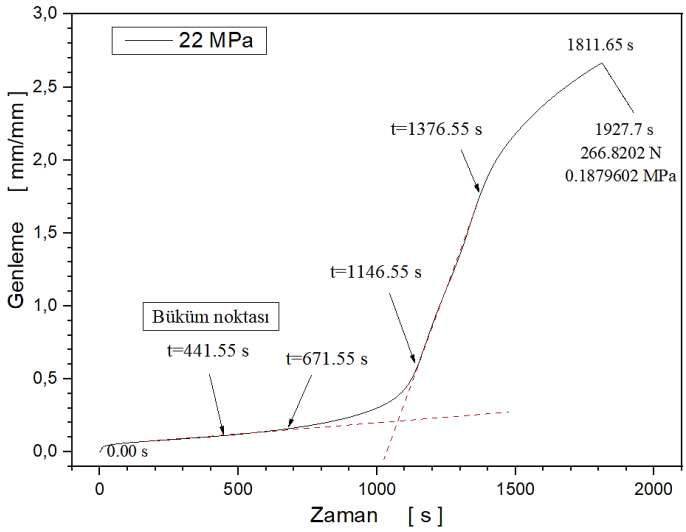
Görsel 7'de 0.003 1/s genleme hızında PPB numunelerine uygulanan farklı sabit gerilme (8, 11, 16 18 MPa) değerlerindeki sürünme testi cevaplarının genleme – zaman grafikleri verilmiştir. Gerilme seviyesi arttıkça stabil bölgenin (ikincil sürünme bölgesinin) eğimi artmaktadır, bir diğer ifade ile minimum sürünme hızı artmaktadır. Bu durum literatürle de uyumlu olmaktadır.



Görsel 7. 0.003 1/s genleme hızında PPB malzemeye uygulanan farklı sabit gerilme (8, 11, 16 18 MPa) değerlerindeki sürünme testlerinin genleme – zaman grafikleri

Belirlenen sürünme gerilmesi seviyesine erişene kadar geçen sürede oluşan genleme ise yükselme genlemesi (ilk elastik şekil değişimi) olmaktadır. Görsel 1'de de bu yükselme bölgesi tanımlanmıştır. Görsel 7'de de her sürünme gerilmesi seviyesinde ilk elastik şekil değişimi bölgesi görülebileceği gibi sürünme gerilmesi arttıkça yükselme bölgesindeki genleme ve geçen süre artmaktadır.

Görsel 8'de ise 0.003 1/s genleme hızında PPB numunesine 1800 s sürünme süresince uygulanan 22 MPa sabit sürünme gerilmesi testi sonucundaki genleme – zaman grafiği verilmiştir.

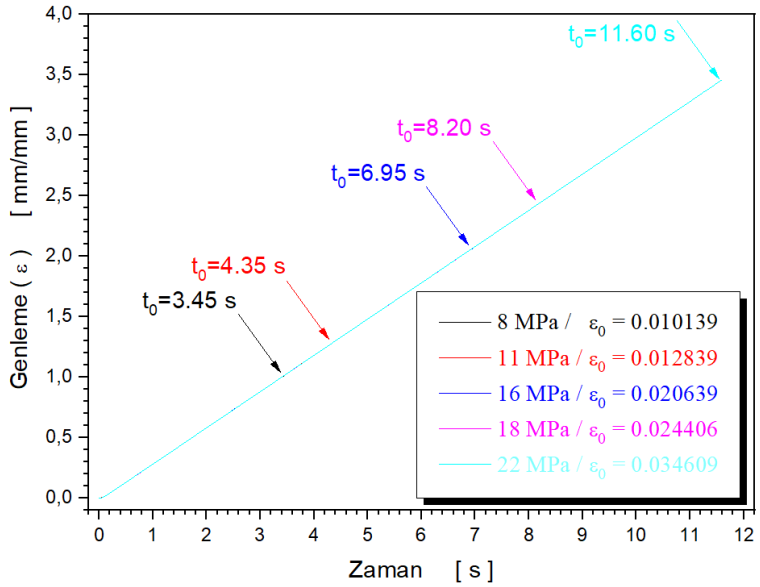


Görsel 8. 0.003 1/s genleme hızında PPB numunesine uygulanan 22 MPa gerilme değerlerindeki sürünme testinin genleme – zaman grafiği

Polimer esaslı plastik malzemelerde görülen tüm sürünme bölgeleri (kırılma veya kopma) hariç Görsel 8'de de görülmektedir. Sabit 22 MPa sürünme gerilmesi ve 1800 s sürünme süresi ile uygulanan testte, PPB malzeme için üçüncül bölge oluşmuştur. Üçüncül sürünme bölgesinde, sürünme hızı arttığı gibi ani olarak hasar görülmüştür. Bir numunede üçüncül sürünme bölgesinin oluşması; malzemenin kalıcı şekil değişimine (plastik şekil değişimine) uğradığı anlamına gelmektedir. Bu nedenle 22 MPa sürünme gerilmesinde ve 1800 s sürünme süresindeki sürünme testi çalışma kapsamına alınmamıştır.

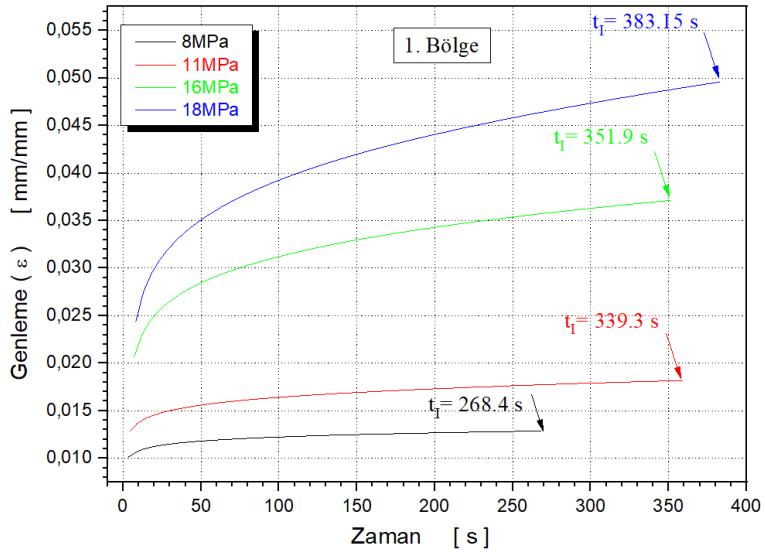
PPB numunelerine uygulanan 0.003 1/s genleme hızında ve farklı sabit gerilme (8, 11, 16 18 MPa) değerlerindeki sürünme testi cevaplarının yükselme bölgesi için Görsel 9'da, birincil sürünme bölgesi için Görsel 10'da ve ikincil sürünme bölgesi için Görsel 11'de genleme – zaman grafikleri verilmiştir.

Görsel 9 incelendiğinde, belirlenen sürünme gerilmesi değerlerinin sabit değerlerine ulaştıkları zamanı, t_0 yükselme süreleri göstermektedir. Ayrıca, sürünme gerilme değeri arttırıldıkça, geçen yükselme süresi (t_0) ile beraber ilk elastik şekil değişim (genleme) miktarının da (ε_o) artmakta olduğu görülmektedir. Bundan başka, sürünme gerilmesi değerinin 8 MPa 'dan 11 MPa'a, 16 MPa'a ve 18 MPa'a yani sırasıyla yaklaşık yüzde 137.5, 200 ve 225 artarken yükselme genlemesinin aynı sırayla yaklaşık yüzde 126.6, 203.6 ve 240.7 arttığı belirlenmiştir. Buradan, t_0 yükselme süreleri ve diğer bir ifadeyle sürünme gerilmesi değerlerinin artış oranı ne kadar artarsa yükselme genleme değerlerinin artış oranlarının daha çok arttığı tespit edilmiştir.



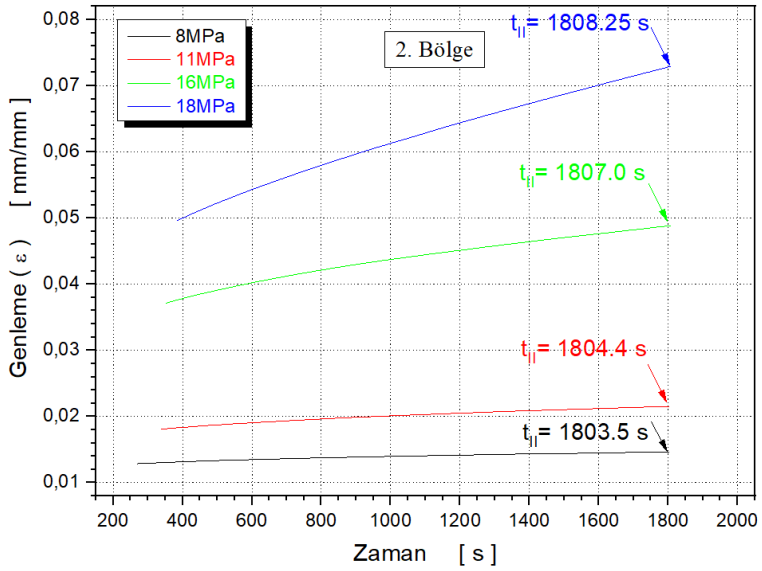
Görsel 9. PPB malzemesinin yükselme bölgesi için 0.003 1/s genleme hızında ve farklı sabit (8, 11, 16 18 MPa) gerilmelerdeki genleme – zaman grafikleri

Görsel 10 incelendiğinde, belirlenen sabit sürünme gerilmesi değerlerinde, t_1 birincil sürünme (geçici sürünme) sürelerini göstermektedir. Ayrıca, sabit sürünme gerilme değeri arttıkça, geçen birincil sürünme süresi (t_1) ile beraber birincil elastik şekil değişim (genleme) miktarının da (ε_1) artmakta olduğu görülmektedir. Bundan başka, birincil sürünme bölgesinde sabit sürünme gerilmesi değerinin 8 MPa 'dan 11 MPa'a, 16 MPa'a ve 18 MPa'a yani sırasıyla yaklaşık yüzde 137.5, 200 ve 225 artarken birincil sürünme genlemesinin aynı sırayla yaklaşık yüzde 141,3, 288,5 ve 385,2 arttığı belirlenmiştir. Buradan, t_1 birincil sürünme süreleri ve diğer bir ifadeyle sürünme gerilmesi değerlerinin artış oranı ne kadar artarsa birincil sürünme genleme değerlerinin artış oranlarının daha aşırı arttığı tespit edilmiştir.



Görsel 10. PPB malzemesinin birincil sürünme bölgesi için 0.003 1/s genleme hızında ve farklı sabit (8, 11, 16 18 MPa) gerilmelerdeki genleme – zaman grafikleri

Görsel 11 incelendiğinde, belirlenen sabit sürünme gerilmesi değerlerinde, t_2 ikincil sürünme (kararlı sürünme) sürelerini göstermektedir. Ayrıca, sabit sürünme gerilme değeri arttıkça, geçen ikincil sürünme süresi (t_2) ile beraber ikincil elastik şekil değişim (genleme) miktarının da (ε_2) artmakta olduğu görülmektedir. Bundan başka, ikincil sürünme bölgesinde sabit sürünme gerilmesi değerinin 8 MPa 'dan 11 MPa'a, 16 MPa'a ve 18 MPa'a yani sırasıyla yaklaşık yüzde 137.5, 200 ve 225 artarken birincil sürünme genlemesinin aynı sırayla yaklaşık yüzde 146,8, 333.2 ve 497,5 arttığı belirlenmiştir. Buradan, sabit t_2 ikincil sürünme sürelerinde sürünme gerilmesi değerlerinin artış oranı ne kadar artarsa ikincil sürünme genleme değerlerinin artış oranlarının çok daha aşırı arttığı tespit edilmiştir.



Görsel 11. PPB malzemesinin ikincil sürünme bölgesi için 0.003 1/s genleme hızında ve farklı sabit (8, 11, 16 18 MPa) gerilmelerdeki genleme – zaman grafikleri

SONUÇLAR

0.003 1/s genleme hızında, farklı sabit (8, 11, 16 18 MPa) sürünme gerilmesi değerlerinde , 1800 s sürünme süresinde PPB saf malzememin sürünme davranışı bu çalışma kapsamında incelenmiştir ve aşağıdaki sonuçlar elde edilmiştir.

1. Yükselme bölgesi için sabit sürünme gerilmesi değerinin 8 MPa 'dan 11 MPa'a, 16 MPa'a ve 18 MPa'a yani sırasıyla yaklaşık yüzde 137.5, 200 ve 225 artarken yükselme genlemesinin aynı sırayla yaklaşık yüzde 126.6, 203.6 ve 240.7 arttığı belirlenmiştir.
2. Birincil sürünme bölgesi için sabit sürünme gerilmesi değerinin 8 MPa 'dan 11 MPa'a, 16 MPa'a ve 18 MPa'a yani sırasıyla yaklaşık yüzde 137.5, 200 ve 225 artarken birincil sürünme genlemesinin aynı sırayla yaklaşık yüzde 141,3, 288,5 ve 385,2 arttığı belirlenmiştir.
3. İkincil sürünme bölgesinde sabit sürünme gerilmesi değerinin 8 MPa 'dan 11 MPa'a, 16 MPa'a ve 18 MPa'a yani sırasıyla yaklaşık yüzde 137.5, 200 ve 225 artarken birincil sürünme genlemesinin aynı sırayla yaklaşık yüzde 146,8, 333.2 ve 497,5 arttığı

belirlenmiştir. Aynı zamanda, ikincil sürünme sürelerinin sabit kaldığı tespit edilmiştir. Bu durum sürünme hızının arttığını göstermektedir.

4. Yükselme, birincil sürünme ve ikincil sürünme bölgelerinde sabit sürünme gerilmesi değeri arttırıldığında incelenen bölgenin sürünme genlemesi değerleri artmaktadır.
5. Sürünme bölgelerindeki veriler incelendiğinde, her bir bölgedeki sabit sürünme gerilmesi artışı, bir sonraki bölgedeki genleme artış oranının daha yüksek olduğunu göstermektedir. Yani, başlangıç, birincil ve ikincil sürünme bölgelerinde, sabit sürünme gerilmesi belirli oranlarda arttıkça, buna karşılık gelen genleme artış oranları her bir bölgede kademeli olarak yükselme eğilimi göstermektedir. Bu durum, gerilme artışının sürünme genlemesi üzerindeki etkisinin, bölgeler ilerledikçe daha belirgin hale geldiğini ifade etmektedir.
6. Gerilme değeri lineer olarak artış gösterse de genleme oranının geometrik artış gösterdiği belirlenmiştir.
7. Sürünme genlemesi değerinin geometrik artmasından dolayı sürünme hızı değeri de geometrik artmaktadır.

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THE EFFECT OF FANCY YARN TYPES ON THE STRENGTH OF KNITTED FABRICS

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ABSTRACT

Fabric designers have realized that yarn defects can create a surface effect and that the effects resulting from these defects give fabrics a different appearance, leading to the commercial production of such yarn. These yarns, defined as fancy yarns, have some intentionally planned irregularities in color and/or structure and enable the design and production of various and innovative products with visually striking features due to these effects. However, these yarn irregularities not only enhance the visual aspects of the fabric but also affect the physical properties of both the yarns and the fabrics produced from these yarns. Having sufficient strength is one of the most important parameters in terms of the performance of textile products. In this study, the strength properties of fancy yarns produced in different types and using different raw materials and the fabrics obtained from these yarns were investigated. In the study, four types of fancy yarns—bouclé, loop, knot, and slub—were produced using three different raw materials: 100% PAC, 100% wool, and a blend of 50% PAC and 50% wool. Fabrics were then knitted in a plain weave structure using the same production parameters. The bursting strength properties of the fabrics were compared based on the type of fancy yarn and the raw materials used. The findings showed a significant effect of yarn type on fabric strength at a 95% confidence interval. Fabrics knitted from 100% PAC yarns exhibited higher bursting strength values, whereas those made from 100% wool yarns had lower bursting strength values. When the effect of yarn types on fabric strength was evaluated, it was determined that fabrics knitted from slub yarns had the highest bursting strength values whereas fabrics from bouclé yarns had the lowest.

Key Words: Fancy yarn, bouclé yarn, knot yarn, slub yarn, loop yarn, knitted fabric strength.

FANTAZİ İPLİK TÜRÜNÜN ÖRME KUMAŞ MUKAVEMETİNE ETKİSİ

ÖZET

Kumaş tasarımcılarının iplik kusurlarının bir yüzey efekti oluşturabileceğini ve bu hatalardan kaynaklanan efektlerin kumaşlara farklı bir görünüm kazandırdığını fark etmeleri, bu tarz ipliklerin ticari olarak üretilmelerine yol açmıştır. Fantazi iplikler olarak tanımlanan bu iplikler, renk ve/veya yapı açısından bazı planlı düzensizliklere sahiptirler ve içerdikleri efektlerle görsel özelliği ön planda olan, çeşitli ve yenilikçi ürünlerin tasarlanıp üretilebilmesine imkân sağlamaktadır. Ancak bu iplik düzensizlikleri, kumaş yüzeyinde oluşturdukları görsel etkilerin yanı sıra ipliklerin ve dolayısıyla bu ipliklerden üretilen kumaşların fiziksel özelliklerinde farklılaşmaya neden olmaktadır. Yeterli mukavemete sahip olmak tekstil ürünlerinin kullanım performansı açısından en önemli parametrelerden birisidir. Bu çalışmada farklı tiplerde ve farklı hammaddeler kullanılarak üretilen fantazi ipliklerin ve bu ipliklerden elde edilen kumaşların mukavemet özellikleri incelenmiştir. Çalışmada Nm 12 numarada %100 PAC, %100 Yün ve %50 PAC- %50 Yün olmak üzere üç farklı hammaddeden bukleli, halkalı, düğümlü ve balıklı dört tip fantazi iplik üretilmiştir. Bu ipliklerden aynı üretim parametreleri kullanılarak düz örgü yapısında kumaşlar örülmüştür. Elde edilen kumaşların patlama mukavemet özellikleri fantazi iplik ve hammadde türüne göre kıyaslamalı olarak incelenmiştir. İplik tipinin kumaş mukavemeti üzerine etkisi %95 güven aralığında anlamlı bulunmuştur. Hammadde açısından incelendiğinde %100 PAC ipliklerden örülen kumaşlardan yüksek, %100 yün kumaşlardan ise düşük patlama mukavemeti değerleri elde edilmiştir. İplik tiplerinin kumaş mukavemetine etkisi değerlendirildiğinde balıklı ipliklerden örülen kumaşların en yüksek, bukleli ipliklerden örülen kumaşların ise en düşük patlama mukavemeti değerlerine sahip olduğu tespit edilmiştir.

Anahtar Kelimeler: Fantazi iplik, bukleli iplik, düğümlü iplik, balıklı iplik, halkalı iplik, örme kumaş mukavemeti

1. INTRODUCTION

Fancy yarns are formed by intentionally producing irregularities in the structure of flat yarns. These unique characteristics capture the attention of textile and fashion designers, as they can use the resulting surface effects as a design element. Using fancy yarns also allows the economical production of original designs with aesthetic and high decorative appeal. The use of fancy yarns in clothing and home textile design has increased in recent years However, these irregularities not only enhance the visual appeal of the fabric but also lead to variations in the physical properties of the yarn and the resulting fabrics. Sufficient strength is one of the most important parameters of the usage performance of textile products.

Fancy yarn is generally made up of three components: the “main” yarn, the “effect” material, and a “binder” that holds the structure together [1]. The most significant factor influencing the strength of fancy yarns is the strength of the main yarn. Effect material, on the other hand, is more related to the aesthetic properties of the yarn [2]. (Figure 1).

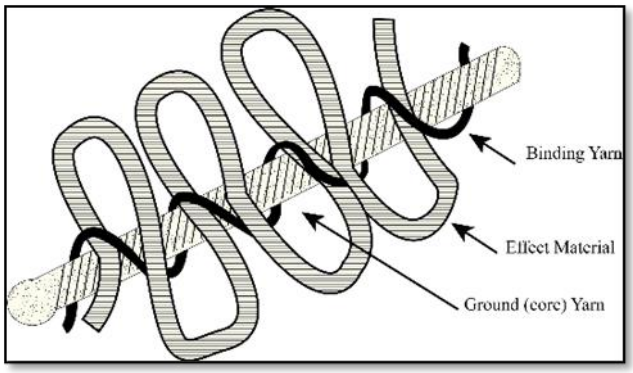

Figure 1. The basic structure of fancy yarns

In the production of fancy yarns, various processes such as spinning, twisting, texturing, knitting and dyeing processes are used to obtain different effects. By using fancy yarns, the surface properties of fabrics can be changed, and softness and permeability properties can be improved. The applications for fancy yarns are extensive, as their aesthetic and decorative qualities make them preferred in woven and knitted fabrics. Their use has become widespread in areas such as outerwear, upholstery, knitting and decoration [3-5]. According to the market analysis published by Stratview Research in 2023, the fancy yarn market, valued at $ 5.1 billion in 2023, is projected to grow to $6.73 billion by 2028, with a compound annual growth rate (CAGR) of 5.7% [6].

2. PREVIOUS STUDIES

There are some studies in the literature examining the effects of yarn production parameters on the fabric properties produced with these yarns in various fancy yarns. This section presents the results of studies focusing on different strength properties and raw materials. In the study conducted by Özdemir and Kalaoğlu (2001) on fabrics produced with flat knitting machines, it was determined that the abrasion resistance of cotton fabrics was higher than viscose, lyocell and acrylic fabrics [7]. The studies researched by Kalaoğlu and Demir (2001) [8], Özdemir and Çeven (2004) [9] and Ülkü and Örtlek (2004) [10] revealed that the raw material was effective on the abrasion resistance of chenille yarns. In the study using viscose, cotton, and acrylic yarns, the highest abrasion resistance was observed in cotton, while the lowest was noted in fabrics made from viscose yarns. Additionally, the results from studies conducted by Kalaoğlu and Özdemir (2002) [11] and Özdemir and Çeven (2006) [12] on the abrasion properties of fabrics made from wool and wool-blended chenille yarns showed that the abrasion resistance of 100% wool fabrics was lower than that of wool-polyester blended fabrics.

Nergis and Candan (2003) showed the most important parameter affecting the bursting strength of plain knitted fabrics knitted from chenille yarns was the component yarn properties. [13]. In a study conducted by Nergis (2006) on knitted fabrics made from elastane chenille yarn, it was found that the abrasion resistance of viscose fabrics was lower than that of cotton fabrics.

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However, there was no observed correlation between the bursting resistance of the fabrics and the presence of elastane in the chenille yarn [14].

Research by Nergis and Candan (2007) demonstrated that the feed rate, twist direction and twist amount of bouclé yarns influenced the loop density, fabric thickness and abrasion behavior of the knitted fabrics produced from these yarns [15]. Turay et al. (2009) examined the properties of fabrics knitted from 100% wool and 100% acrylic bouclé yarns and indicated that acrylic fabrics exhibited higher bursting strength values [16,17]. Kumpikaite et al. (2007) analyzed the abrasion and air permeability properties of woven fabrics made from loop, slub, and spiral yarns, concluding that the type of raw material used and the knitting pattern significantly affected abrasion test results [18].

Atef et al. (2018) investigated the effects of blend ratios and the knitted fabric structure of polyester/cotton blended slub fabrics on various fabric parameters. Their findings revealed that the bursting strength of 1x1 rib fabrics was higher than that of plain knitted and 3x1 rib fabrics. Additionally, they found that the bursting strength of fabrics made with yarns containing a higher percentage of polyester was superior to that of fabrics made with yarns that had a higher cotton content [19].

The decorative features of fancy yarns not only enhance the aesthetic appeal of the fabrics but also influence strength properties, which are critical for the mechanical performance and usage performance of these yarns and therefore resulting the fabrics. This study focused on the impact of yarn type and raw material on the bursting strength of plain knitted fabrics made from fancy yarns. For this purpose, four types of fancy yarns were used: boucle, loop, knot, and slub, along with three different raw materials: 100% PAC, 100% wool, and a blend of 50% PAC and 50% wool. The bursting strength properties of the resulting fabrics were compared based on the type of fancy yarn and raw material used.

3. MATERIALS AND METHODS

In the study, yarns with Nm 12 count were produced using 100% wool, a blend of 50% PAC- 50% wool and 100% PAC raw materials. To investigate the effect of different fancy yarn types on bursting strength, four types of yarn: bouclé, loop, knot, and slub yarn were selected.

Yarns containing thicker regions at certain intervals along the length of the yarn are known as slub yarn. Bouclé yarn is a compound yarn containing a twisted core combined with an effect yarn (or roving) in a way that creates wavy protrusions on its surface. The effect yarn forms small loops by twisting in the opposite direction at a higher speed than the core and binding yarn [19-20]. Knot yarn consists of knots that are formed by the yarn material at either regular or irregular intervals along its length. Loop yarn consists of a main yarn with an overfed effect yarn wrapped around it in a way that creates circular protrusions [2]. Visuals of the yarns used in the study are shown in Figure 2. The properties of the yarns are summarized in the table below (Table 1).

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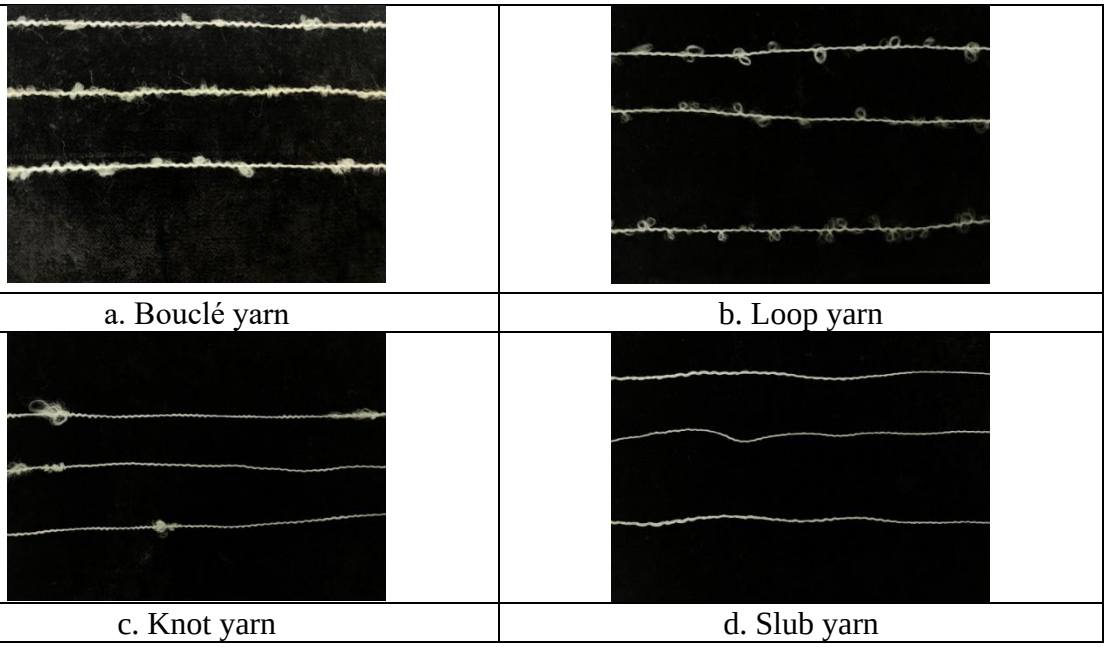

a. Bouclé yarn | b. Loop yarn

c. Knot yarn | d. Slub yarn

Figure 2. Yarn types used in the study

Table 1. Properties of the yarns used in the study

Yarn Type	Material
Bouclé yarn	%100 Wool
	%50 Wool/%50 PAC
	%100 PAC
Loop yarn	%100 Wool
	%50 Wool/%50 PAC
	%100 PAC
Knot yarn	%100 Wool
	%50 Wool/%50 PAC
	%100 PAC
Slub yarn	%100 Wool
	%50 Wool/%50 PAC
	%100 PAC

Plain knitted fabrics were produced using the SHIMA SEIKI brand NSSC122 model, E7 knitting machine. These fabrics were conditioned and tested under standard atmospheric conditions of 20±2°C temperature, 65±4% relative humidity. The strength tests of the yarns were carried out according to the TS EN ISO 2062 standard. Fabric weights were determined according to the TS 251 standard. The bursting strength tests applied to the fabrics were carried out using the TRUBURST 4 Bursting Strength Measuring Device in accordance with the TS EN ISO 13938-2 standards.

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Figure 3. TRUBURST 4 Bursting strength measuring device

4. RESULTS AND DISCUSSIONS

As a result of the experimental study, the strength results of the yarns are given in Figure 4, and the fabric weight and bursting strength test results are shown in Figures 5 and 6, respectively.

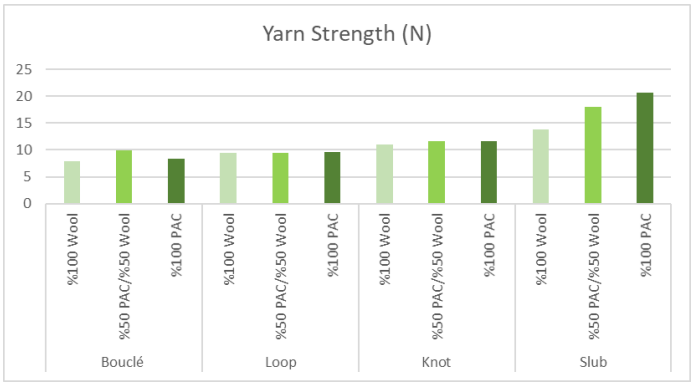

Figure 4. Strength values of fancy yarns

When the results of the breaking strength values of the yarns were examined (Figure 4), it was found that yarns made from 100% wool exhibited the lowest breaking strength, while the highest breaking strength was determined in yarns produced from 100% PAC fibers. Among the various fancy yarn types, slub yarns displayed greater strength due to the presence of thicker areas. In contrast, the loops on the surface of bouclé yarns resulted in decreased strength.

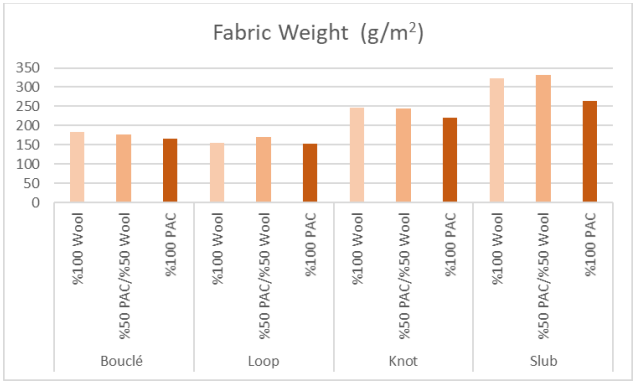

Figure 5. Fabric weights of knitted fabrics from fancy yarns

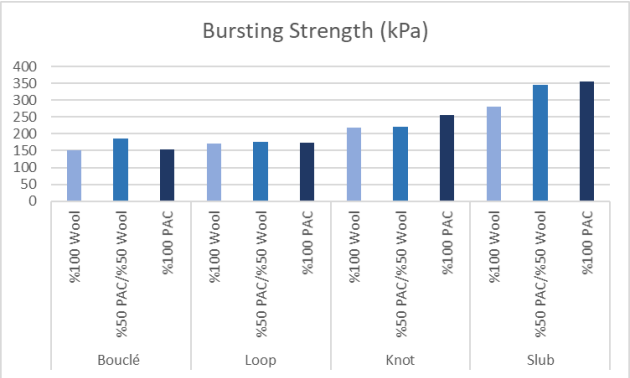

Figure 6. Bursting strength values of fabrics knitted from fancy yarns

As can be seen in Figure 6, fabrics produced from slub yarns exhibit higher bursting strength compared to other types of fabrics, whereas the strength values of fabrics from bouclé yarns are notably low. The high fabric weight values of fabrics knitted from slub yarns and the strength values of the yarns used in the production of these fabrics positively affect the bursting strength of the fabrics. Furthermore, the bursting strength values of the fabrics correspond well with the breaking strengths of the yarns from which they are made.

When evaluating raw materials, it is observed that fabrics produced from acrylic yarns, specifically knotted and slub yarn types, exhibit high strength values. Conversely, the fabrics obtained from blended yarns in bouclé yarns have higher strength values than the others.

The study also investigated whether the type of fancy yarn and the raw material used have a statistically significant effect on the bursting strength of the fabrics. For this purpose, ANOVA was carried out and multiple Post-Hoc comparison tests (Tukey's) were applied to examine whether there was a difference between the mean values of the groups. The results of the statistical analyses are presented in Tables 2 and 3.

Table 2. ANOVA analysis results

Parameter	**p- values**
Fancy Yarn Type	0,000*
Material	0,376

Table 3. Tukey's Post-Hoc comparison test results according to yarn type

Fancy Yarn Type	**Subset**		
Bouclé,	1		
Loop	1		
Knot		2	
Slub			3

Statistical analysis indicates that the effect of fancy yarn type on fabric bursting strength is significant at 95% confidence interval. The effect of the raw materials used in the study was not found to be significant.

5. CONCLUSION

The mechanical properties of fancy yarns play a crucial role in achieving original designs cost-effectively and are also significant for end users. In this study, the bursting strength

properties of fancy yarns, which have been increasingly used in recent years due to their decorative and aesthetic properties, were examined in terms of yarn type and raw material used.

For this purpose, 100% wool, a blend of 50%wool/%50PAC and 100% PAC fibers were selected as raw materials, and four different fancy yarns (Nm12), including bouclé, loop, knot and slub, were produced with these materials. The bursting strengths of plain knitted fabrics produced from these yarns were compared and statistical analyses were performed.

When the bursting strength results of the fabrics were examined, it was determined that knitted fabrics made from 100% PAC slub yarn exhibited the highest bursting strength, while those made from 100% wool bouclé yarn had the lowest.

The effect of the fancy yarn type on bursting strength was found to be significant at the 95% confidence interval. No significant difference was observed among the selected raw materials in the study. Overall, the strongest bursting strength values were found for fabrics produced from slub yarns, which possess greater yarn strength and weight. This suggests that the strength properties of the yarn need to be improved to achieve the desired strength levels in fabric production using fancy yarns.

6. ACKNOWLEDGEMENTS

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SEPARATION EFFICIENCY OF C_{18} STATIONARY PHASE FOR THE CO–ELUTED PEAKS OF TOCOPHEROLS: OPTIMIZATION AND MODELLING WITH CHEMOMETRICS

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ABSTRACT

This study aims to optimize the separation performance of reversed phase (C_{18} stationary phase)–high performance liquid chromatography (HPLC) method for co-eluted tocopherol (T) isomers (*δ–T, γ–T, β–T* and *α–T*) by central composite design (CCD). The impact of three experimental factors (*flow rate, temperature* and *%B in mobile phase composition*) on 5 level (*–1.68, –1, 0, +1, +1.68*) were determined. The results of CCD were evaluated by Design Expert–12 software according to response surface methodology (RSM). The effect of selected experimental parameters on the separation of β–/γ–T and α–T isomers were evaluated based on four different response value (R_s, α, N_{ort} and k_{ort}). Optimum performance was founded at a flow rate of 0.37 mL.min^{-1}, a temperature of 13.69°C, and %B content (*methyl tert–butyl ether: methanol: water, 80:18:2, v/v/v*) in the mobile phase of 38.04%.

Keywords: Tocopherol, Reverse–phase HPLC, Optimization, Chemometrics

1. INTRODUCTION

Tocopherols are important compounds naturally found in many foods and are the most widely used among naturally occurring antioxidants. Tocopherols, which are monophenolic and lipophilic compounds widely distributed in plant tissues, have been recorded to exhibit significant physiological activities since their discovery. There are four different tocopherols that are highly effective in reducing the risk of cardiovascular diseases, some types of cancer, and many chronic diseases, and most of them are found in different edible oils [1, 2]. Tocopherols contain a chroman ring and are classified as α-, β-, γ-, and δ- according to the number and position of methyl groups in their structures. The antioxidant activities of tocopherols vary depending on their chemical structures and concentrations. Tocopherols, which have the widest range of use among natural antioxidants, are clear, viscous, yellowish, almost odorless oils in pure form and can give crystalline derivatives such as succinate and palmitate. In general, the antioxidant activities of tocopherols decrease in the order δ- > γ- > β- > α-T [3, 4]. The tocopherol that is most commonly found in nature as a vitamin and has the greatest biological activity is α-tocopherol. Tocopherols are taken in from outside with food together with lipids as fat-soluble vitamins. α-tocopherol is easily absorbed from the small intestine, most probably transported to the liver in chylomicrons and from there to peripheral tissues in lipoproteins [5, 6]. Mitochondrial phospholipids, endoplasmic reticulum and plasma membrane have specific affinity for α-tocopherol. The antioxidant activity of tocopherol is

effective even at high oxygen concentrations where many antioxidant defense elements are inadequate. Erythrocytes and alveolar membranes are the most important examples that explain this situation. Tocopherol bioactive components, which are quite effective in reducing the negative effects of many chronic diseases and cancer types and in their treatment; the isomeric structures defined as α-, β-, γ- and δ-tocopherol have been proven by many studies to have different antioxidative, anti-cancer, immunomodulatory, nephroprotective, hepatoprotective and anti-inflammatory activity properties [7, 8]. In addition, it has been determined that these components have many important functions such as preserving the quality of foods, extending shelf life, improving color, preserving nutritional value and improving structure.

The separation and determination of the amounts of tocopherol bioactive isomers with different activity properties by accurate and highly precise analytical methods are of great importance. It is seen that there are many analytical methods in the literature for the separation and determination of α-, β-, γ- and δ- isomer structures. In liquid chromatography technique, which is the most widely used method among these methods; normal-phase chromatography (NP-HPLC) and reversed-phase chromatography (RP-HPLC) methods are applied. When the applications of both techniques are compared, it is seen that NP-HPLC technique is a more effective method in the separation of all isomers. In the RP-HPLC technique; it is seen that especially the separation of β- and γ- isomers cannot be achieved and these two important isomeric structures are eluted together. Partial improvements have been achieved in the application of new generation reversed-phase stationary phase packing materials such as monolithic, polyvinyl alcohol, solid-core pentafluorophenyl (PFP) and long-chain alkyl-bonded C18 silica columns in HPLC technique [9].

With the present study, the separation performance of reversed phase (C_{18} stationary phase)–HPLC method was optimized for co-eluted tocopherol (T) isomers (*δ–T, γ–T, β–T* and *α–T*). The impact of three experimental factors (*flow rate*, *temperature* and *%B in mobile phase composition*) on 5 level (*–1.68, –1, 0, +1, +1.68*) were determined by CCD. The results of CCD were evaluated by Design Expert–12 software according to RSM. The effect of selected experimental parameters on the separation of β–/γ–T and α–T isomers were evaluated based on $R_{s,}$ α, N_{ort} and k_{ort} response values.

2. EXPERIMENTAL RESEARCH

2.1. Chemicals and standards

Chemicals were chromatographic and spectroscopic purity and supplied by VWR International (Poole, UK), Sigma-Aldrich (St. Louis, USA) and Merck (Darmstadt, DEU). High purity standards of α-, β-, γ- and δ-tocopherol (T) isomers were supplied by Sigma-Aldrich. Stock standard solutions were prepared in hexane as 0.1 µg μL^{-1}. Injections were made in the range of 5-50 µL from the prepared stock solutions and analyses were carried out for standard materials. All solutions were kept in an ultrasonic bath for approximately 30 min before analysis to ensure that the solutions were prepared appropriately.

2.2. Optimization and validation of RP–HPLC/FLD method with chemometrics

An Agilent 1200 Series HPLC system equipped with fluorescence detector (HPLC/FLD) were used in the experimental studies (Agilent Scientific Instruments, Santa Clara, California, US). Optimization studies of the RP-HPLC/FLD method experimental parameters with CCD and RSM were carried out using standard substances belonging to the mixture of tocopherol isomers [2]. In order to optimize the experimental parameters; 5 level/3 factor CCD application was carried out. In the experimental design, the effects of 3 important experimental factors (*flow rate, temperature and %B in mobile phase composition*) were investigated for 5 different level values (*-1.68, -1, 0, +1, +1.68*). The data of CCD were evaluated with 3D-surface graphs drawn using the Design Expert–12 software and the optimum parameters were decided. The method parameters of the method are given in **Table 2.1**; the parameters in the experimental design study are given in **Table 2.2**.

Table 2.1 Method parameters of RP–HPLC/FLD by using C_{18} column

Injection	5 µL		
Column	Waters Nova-Pak C18 column (300 × 3.9 mm; 4.0 µm)		
Mobile phase		**% A**	**% B**
A (*methanol: water, 99:1, v/v*) B (*tert-metilbutileter: methanol: water, 80:18:2, v/v/v*)	0–20.5 min	100%	0%
	20.5–25 min	100–70%	0–30%
	25–36 min	70%	30%
	36–46 min	70–45%	30– 55% B
	46–48 min	45–20%	55–80% B
	48–51 min	20%	80% B
	51–53 min	20–100%	80–0% B
	53–63 min	100%	0% B
Detector	FLD, λex 296 nm, λem 330 nm		

Table 2.2 CCD runs for the optimization studies of RP–HPLC/FLD by using C_{18} column

		levels					**runs**	
factors (variables)		**–1.68**	**–1**	**0**	**+1**	**+1.68**	*Factorial points*	8
flow rate (mL.min^{-1})	X_1	0.164	0.3	0.5	0.7	0.836	*Axial points*	6
column temperature (°C)	X_2	1.6	5	10	15	18.4	*Center points*	9
B content in mobile phase (%)	X_3	6.48	16	30	44	53.52	**Total**	**23**

† B: methyl tert–butyl ether: methanol: water, 80:18:2, v/v/v

Run	**Flow rate (mL.min^{-1})** X_1	**Column temperature (°C)** X_2	**B content in mobile phase (%)** X_3
1	**–1**	**–1**	**–1**
	0.3	5	16
2	**1**	**–1**	**–1**
	0.7	5	16
3	**–1**	**1**	**–1**
	0.3	15	16
4	**1**	**1**	**–1**

	0.7	15	16
5	**–1** 0.3	**–1** 5	**1** 44
6	**1** 0.7	**–1** 5	**1** 44
7	**–1** 0.3	**1** 15	**1** 44
8	**1** 0.7	**1** 15	**1** 44
9	**0** 0.5	**0** 10	**0** 30
10	**–1.68** 0.164	**0** 10	**0** 30
11	**1.68** 0.836	**0** 10	**0** 30
12	**0** 0.5	**–1.68** 1.6	**0** 30
13	**0** 0.5	**1.68** 18.4	**0** 30
14	**0** 0.5	**0** 10	**–1.68** 6.48
15	**0** 0.5	**0** 10	**1.68** 53.52
16	**0** 0.5	**0** 10	**0** 30
17	**0** 0.5	**0** 10	**0** 30
18	**0** 0.5	**0** 10	**0** 30
19	**0** 0.5	**0** 10	**0** 30
20	**0** 0.5	**0** 10	**0** 30
21	**0** 0.5	**0** 10	**0** 30
22	**0** 0.5	**0** 10	**0** 30
23	**0** 0.5	**0** 10	**0** 30

3. RESULTS AND DISCUSSION

3.1. Optimization and validation of RP–HPLC/FLD method with chemometrics

The experimental parameters reported by [2] were modified and optimized in accordance with our pre-experiments by HPLC system. Next, a CCD experimental design set was created with 3 important experimental factors (X_i) and 5 different levels. In the CCD studies, the concentration and other experimental parameters were kept constant and the analyses were carried out (**Tables 2.1** and **2.2**). The CCD study including 23 experiments (runs) was successfully completed and their results were given in **Table 3.1**. Next, the 'value' that will be the response values (R_s, α, N_{ort} and k_{ort}) on the system was created from these experiments. In

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the study, four different response values for the separation between β–/γ–T and α–T isomers were evaluated (**Table 3.1**). With the help of the matrix created between the code values and response values of the independent variables; the coefficient values of the equations (β0, β1, β2, ... etc.) were obtained by Design Expert–12 software. By the coefficient values into the equations, "y response values" were obtained [$y = \beta_0 + \beta_1.X_1 + \beta_2.X_2 + \beta_3.X_3 + \beta_{11}.X_1^2 + \beta_{22}.X_2^2 + \beta_{33}.X_3^2 + \beta_{12}.X_1.X_2 + \beta_{13}.X_1.X_3 + \beta_{23}.X_2.X_3 + \beta_{123}.X_1.X_2.X_3$]. The theoretically obtained "y response values" were compared with the experimental response values (**Figure 3.1**). As could be seen from the normal distribution graphs in **Figure 3.1**, the flow rate (X_1, mL/min), column temperature (X_2, °C), and the amount of B solvent in the mobile phase (X_3, %) values are all important in their degree of effect on the obtained separation quality. The obtained equations were processed in the Design Expert–12 software and three-dimensional (3D) surface graphs were created. The 3D-surface graphs, in which Rs, N, k', and α values were taken as the response values, are given in **Figures 3.2–3.4**. There are three different axes in 3D-surface graphs; the first and second axes represent the mobile phase flow rate, temperature or mobile phase composition values, and the third axis represents the response value. The 3D-surface graphs with high red intensity offer a more accurate approach in terms of deciding on the optimum experimental parameters. In addition, this situation was validated and interpreted with the ANOVA test (**Table 3.2**). It is seen that the ANOVA test data are quite compatible with the data obtained in the normal distribution graph. The $F_{variance}$ values greater than the $F_{critical}$ value in ANOVA represent that the parameters whose effect degrees are considered significant in chromatography separation. These data, in which only the model and residual values were tested as the source value, proved the suitability of the model with the $F_{variance}$ value obtained greater than the $F_{critical}$ value.

Table 3.1 Results of the CCC experiments for tocopherol analysis performed by RP-HPLC/FLD by using C_{18} column

	Central composite design (CCD) matrix with 5 levels and 3 factors													
							Response–1 Rs for β–/γ–T and δ–T		Response–2 α for β–/γ–T and δ–T		Response–3 N_{ort} for β–/γ–T and δ–T		Response–4 k_{ort} for β–/γ–T and δ–T	
Run	flow rate ($mL.min^{-1}$)		temperature (°C)		%B in MP. (%)		Experimental	Predicted	Experimental	Predicted	Experimental	Predicted	Experimental	Predicted
1	–1	(0.3)	–1	(5)	–1	(16)	0.92	0.94	1.01	0.97	212056.42	208000.00	3.78	3.39
2	1	(0.7)	–1	(5)	–1	(16)	2.32	2.44	1.04	1.06	196693.18	183200.00	0.96	0.94
3	–1	(0.3)	1	(15)	–1	(16)	1.06	1.05	1.02	0.99	195962.35	188400.00	1.32	1.28
4	1	(0.7)	1	(15)	–1	(16)	2.30	2.50	1.05	1.08	176551.64	163600.00	0.94	0.94
5	–1	(0.3)	–1	(5)	1	(44)	2.37	2.22	1.12	1.11	36981.23	38392.05	0.80	1.32
6	1	(0.7)	–1	(5)	1	(44)	2.00	2.06	1.26	1.19	35825.90	31860.22	0.26	0.39
7	–1	(0.3)	1	(15)	1	(44)	2.29	2.23	1.13	1.12	37526.89	39406.77	0.73	0.39
8	1	(0.7)	1	(15)	1	(44)	1.99	2.03	1.28	1.21	40334.24	32832.54	0.22	0.69
9	0	(0.5)	0	(10)	0	(30)	2.47	2.53	1.08	1.02	78482.70	83981.00	0.94	1.68
10	–1.68	(0.164)	0	(10)	0	(30)	1.35	1.49	1.03	1.17	84571.12	57644.93	1.49	0.26
11	1.68	(0.836)	0	(10)	0	(30)	2.81	2.58	1.18	1.08	40684.63	94901.07	0.59	2.62
12	0	(0.5)	–1.68	(1.6)	0	(30)	2.59	2.58	1.05	1.11	88539.62	79211.82	2.99	1.10
13	0	(0.5)	1.68	(18.4)	0	(30)	2.72	2.65	1.10	0.98	69203.11	296000.00	0.86	1.44
14	0	(0.5)	0	(10)	–1.68	(6.48)	1.09	0.91	1.02	1.21	278908.29	43456.22	1.16	–0.15
15	0	(0.5)	0	(10)	1.68	(53.52)	1.51	1.60	1.16	1.09	44174.87	84387.37	0.26	1.40
16	0	(0.5)	0	(10)	0	(30)	2.51	2.53	1.07	1.09	90296.92	84387.37	0.97	0.94
17	0	(0.5)	0	(10)	0	(30)	2.50	2.53	1.08	1.09	84007.19	84387.37	0.94	0.94
18	0	(0.5)	0	(10)	0	(30)	2.50	2.53	1.08	1.09	82557.89	84387.37	0.94	0.94
19	0	(0.5)	0	(10)	0	(30)	2.55	2.53	1.08	1.09	85387.27	84387.37	0.94	0.94
20	0	(0.5)	0	(10)	0	(30)	2.55	2.53	1.08	1.09	85391.93	84387.37	0.94	0.94
21	0	(0.5)	0	(10)	0	(30)	2.55	2.53	1.08	1.09	85389.60	84387.37	0.94	0.94

22	0	(0.5)	0	(10)	0	(30)	2.55	2.53	1.08	0.97	85394.26	84387.37	0.94	0.94
23	0	(0.5)	0	(10)	0	(30)	2.55	2.53	1.08	1.06	85387.27	84387.37	0.94	0.52

† %t B: methyl tert–butyl ether: methanol: water, 80:18:2, v/v/v

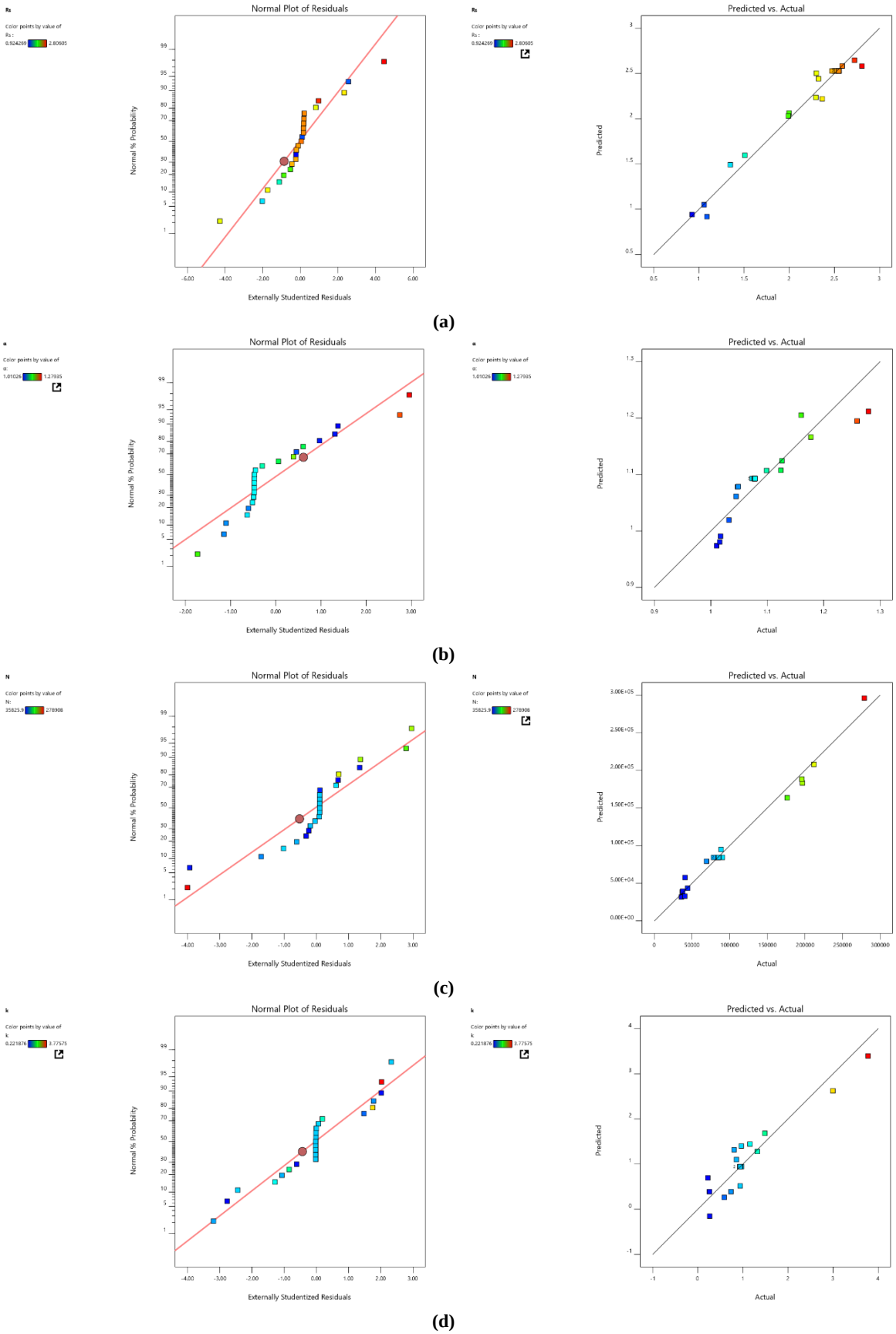
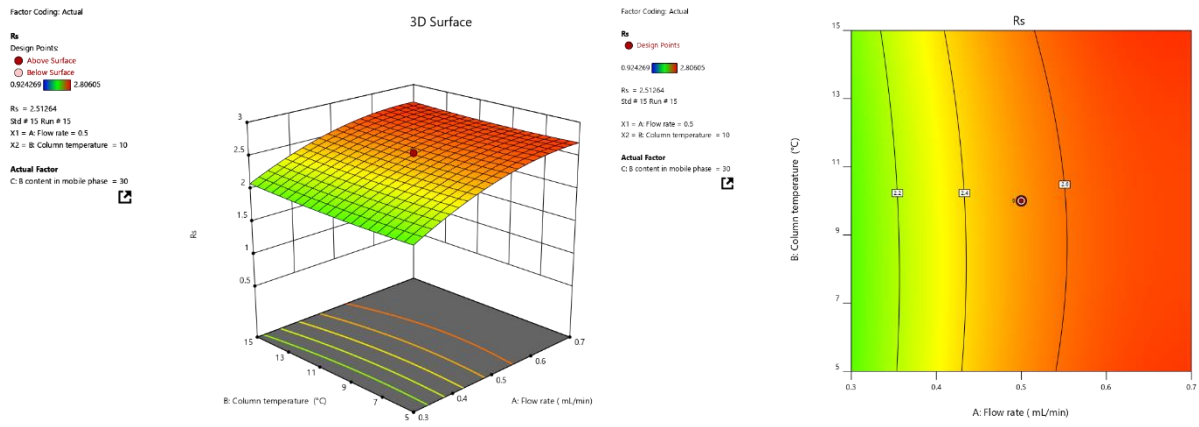
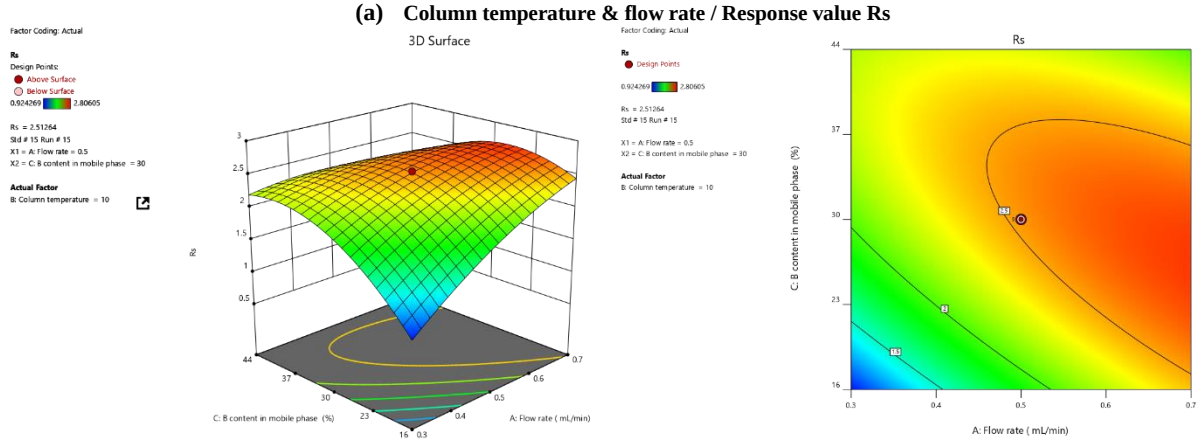


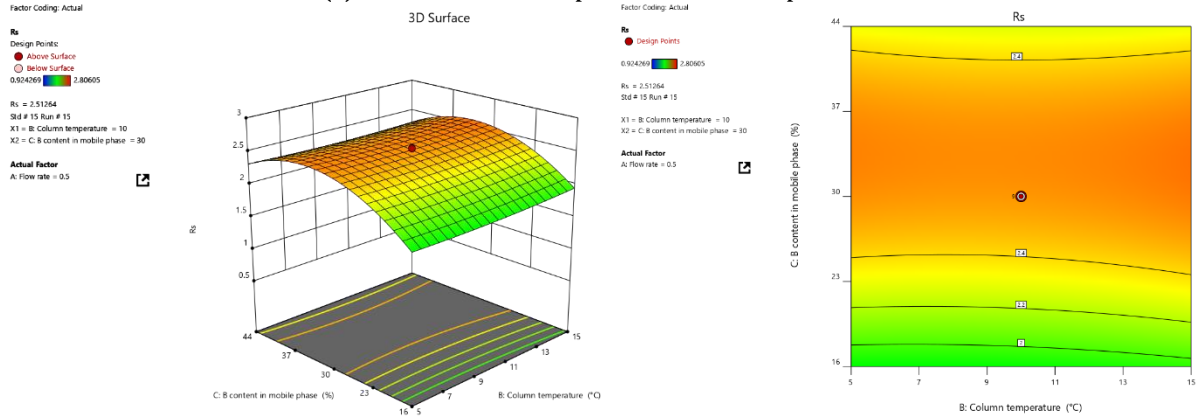
Figure 3.1 Normal distribution graphs and comparison of the data obtained from experimental design study with the theoretical data



(a) Column temperature & flow rate / Response value Rs

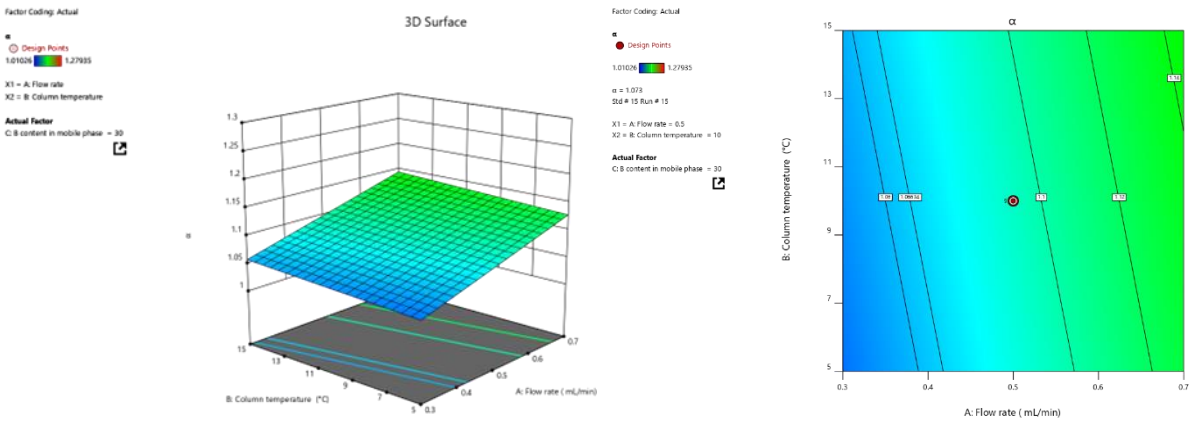


(b) %B content in mobile phase & flow rate / Response value Rs

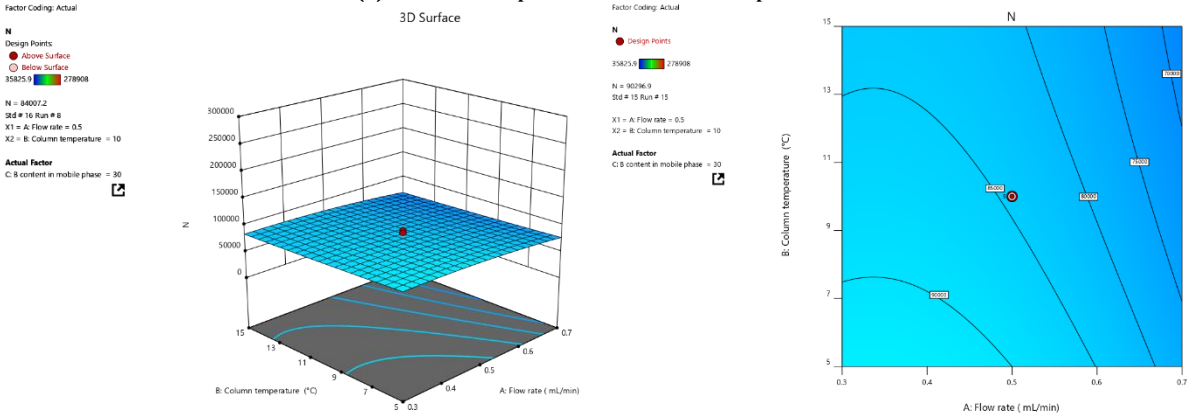


(c) Column temperature & %B content in mobile phase / Response value Rs

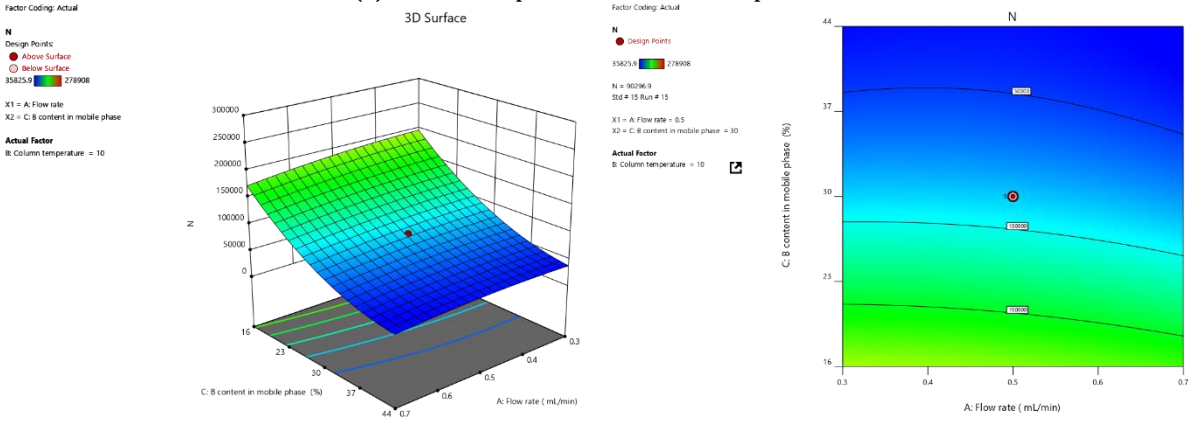
Figure 3.2 3-D surface plot graphs obtained as a result of the CCD study / Response value Rs



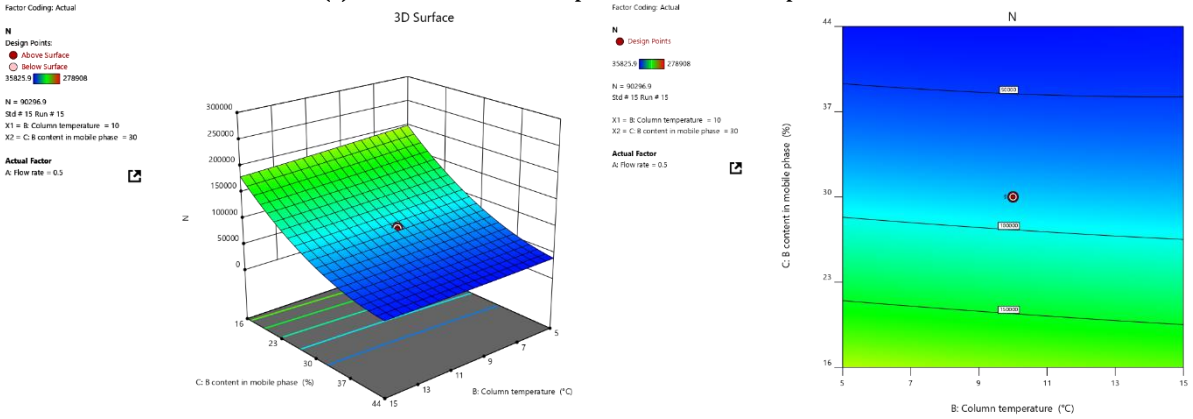
(a) Column temperature & flow rate / Response value α



(b) Column temperature & flow rate / Response value N

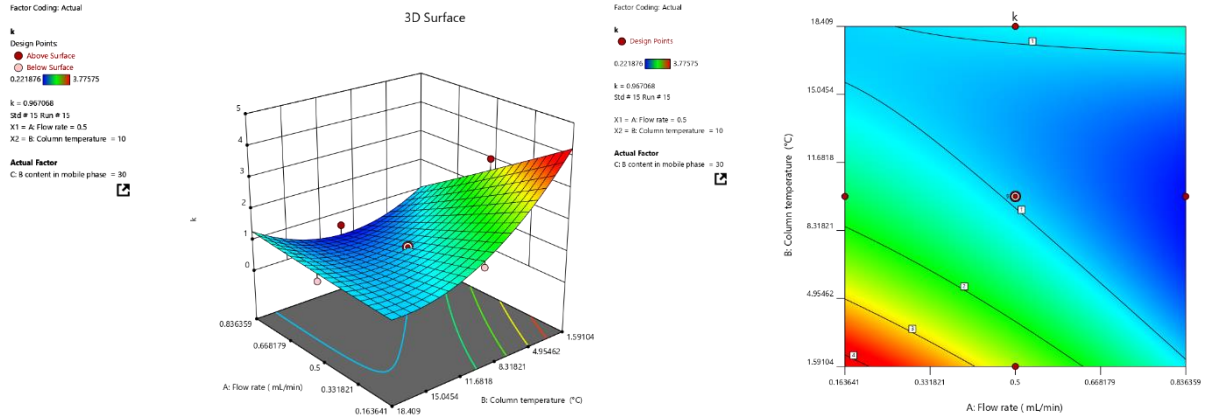


(c) %B content in mobile phase & flow rate / Response value N

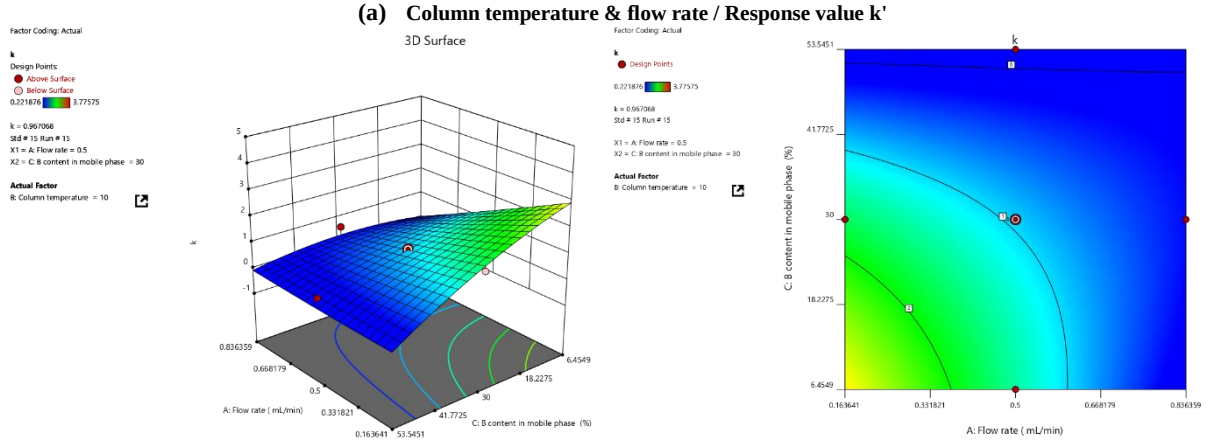


(d) Column temperature & %B content in mobile phase / Response value N

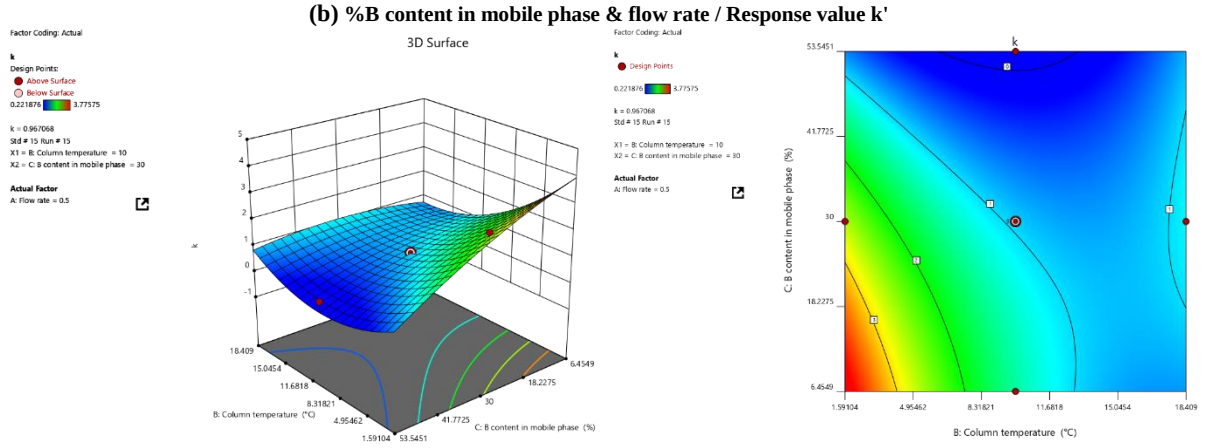
Figure 3.3 3-D surface plot graphs obtained as a result of the CCD study / Response value N/ α



(a) Column temperature & flow rate / Response value k'



(b) %B content in mobile phase & flow rate / Response value k'



(b) Column temperature & %B content in mobile phase / Response value k'

Figure 3.4 3-D surface plot graphs obtained as a result of the CCD study / Response value k'

Table 3.2 Results of the CCD model ANOVA test for RP-HPLC/FLD method optimization

ANOVA for Quadratic model **Response 1: Rs **

Response 1: Rs [*y= 2.52735 + 0.323856 * A + 0.018989 * B + 0.201438 * C + -0.0117715 * AB + -0.414344 * AC + -0.023405 * BC + -0.173511 * A^2 + 0.0307481 * B^2 + -0.448939 * C^2*]

Source	Sum of Squares	df	Mean Square	F-value	p-value

Model	7.05	9	0.7837	49.27	< 0.0001	**significant**
A-Flow rate	1.43	1	1.43	90.05	< 0.0001	
B-Column temperature	0.0049	1	0.0049	0.3096	0.5874	
C-B content in mobile phase	0.5542	1	0.5542	34.84	< 0.0001	
AB	0.0011	1	0.0011	0.0697	0.7959	
AC	1.37	1	1.37	86.35	< 0.0001	
BC	0.0044	1	0.0044	0.2755	0.6085	
A^2	0.4784	1	0.4784	30.07	0.0001	
B^2	0.0150	1	0.0150	0.9445	0.3489	
C^2	3.20	1	3.20	201.33	< 0.0001	
Residual	0.2068	13	0.0159			
Lack of Fit	0.1995	5	0.0399	44.02	< 0.0001	**significant**
Pure Error	0.0073	8	0.0009			
Cor Total	7.26	22				

Factor coding is **Coded**.
Sum of squares is **Type III - Partial**
The **Model F-value** of 49.27 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.
P-values less than 0.0500 indicate model terms are significant. In this case A, C, AC, A^2, C^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.
The **Lack of Fit F-value** of 44.02 implies the Lack of Fit is significant. There is only a 0.01% chance that a Lack of Fit F-value this large could occur due to noise. Significant lack of fit is bad -- we want the model to fit.

ANOVA for Linear model **Response 2: α**

Response 2: α [*y= 1.0928 + 0.0437304 * A + 0.00847984 * B + 0.0667912 * C*]

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.0880	3	0.0293	29.42	< 0.0001	**significant**
A-Flow rate	0.0261	1	0.0261	26.19	< 0.0001	
B-Column temperature	0.0010	1	0.0010	0.9846	0.3335	
C-B content in mobile phase	0.0609	1	0.0609	61.08	< 0.0001	
Residual	0.0190	19	0.0010			
Lack of Fit	0.0189	11	0.0017	633.03	< 0.0001	**significant**
Pure Error	0.0000	8	2.718E-06			
Cor Total	0.1070	22				

Factor coding is **Coded**.
Sum of squares is **Type III - Partial**
The **Model F-value** of 29.42 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.
P-values less than 0.0500 indicate model terms are significant. In this case A, C are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.
The **Lack of Fit F-value** of 633.03 implies the Lack of Fit is significant. There is only a 0.01% chance that a Lack of Fit F-value this large could occur due to noise. Significant lack of fit is bad -- we want the model to fit.

ANOVA for Quadratic model **Response 3: N**

Response 3: N [y= 84387.4 + -7829.76 * A + -4664.44 * B + -75080.9 * C + -10.5997 * AB + 4553.25 * AC + 5161.2 * BC + -4799.28 * A^2 + 943.661 * B^2 + 30172 * C^2]

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	9.337E+10	9	1.037E+10	103.65	< 0.0001	**significant**
A-Flow rate	8.372E+08	1	8.372E+08	8.36	0.0126	
B-Column temperature	2.971E+08	1	2.971E+08	2.97	0.1086	

C-B content in mobile phase	7.699E+10	1	7.699E+10	769.14	< 0.0001	
AB	898.82	1	898.82	8.980E-06	0.9977	
AC	1.659E+08	1	1.659E+08	1.66	0.2205	
BC	2.131E+08	1	2.131E+08	2.13	0.1683	
A^2	3.660E+08	1	3.660E+08	3.66	0.0781	
B^2	1.415E+07	1	1.415E+07	0.1414	0.7130	
C^2	1.446E+10	1	1.446E+10	144.51	< 0.0001	
Residual	1.301E+09	13	1.001E+08			
Lack of Fit	1.224E+09	5	2.448E+08	25.29	0.0001	**significant**
Pure Error	7.743E+07	8	9.679E+06			
Cor Total	9.467E+10	22				

Factor coding is **Coded**.
Sum of squares is **Type III - Partial**
The **Model F-value** of 103.65 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.
P-values less than 0.0500 indicate model terms are significant. In this case A, C, C^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.
The **Lack of Fit F-value** of 25.29 implies the Lack of Fit is significant. There is only a 0.01% chance that a Lack of Fit F-value this large could occur due to noise. Significant lack of fit is bad -- we want the model to fit.

ANOVA for Quadratic model **Response 4: k**

Response 4: k [y= 0.943623 + -0.422152 * A + -0.452861 * B + -0.474647 * C + 0.307832 * AB + 0.266648 * AC + 0.297227 * BC + 0.0101078 * A^2 + 0.324255 * B^2 + -0.105445 * C^2]

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	12.20	9	1.36	10.16	0.0001	**significant**
A-Flow rate	2.43	1	2.43	18.24	0.0009	
B-Column temperature	2.80	1	2.80	20.99	0.0005	
C-B content in mobile phase	3.08	1	3.08	23.05	0.0003	
AB	0.7581	1	0.7581	5.68	0.0331	
AC	0.5688	1	0.5688	4.26	0.0595	
BC	0.7067	1	0.7067	5.30	0.0386	
A^2	0.0016	1	0.0016	0.0122	0.9139	
B^2	1.67	1	1.67	12.52	0.0036	
C^2	0.1767	1	0.1767	1.32	0.2706	
Residual	1.73	13	0.1335			
Lack of Fit	1.73	5	0.3468	3486.85	< 0.0001	**significant**
Pure Error	0.0008	8	0.0001			
Cor Total	13.94	22				

Factor coding is **Coded**.
Sum of squares is **Type III - Partial**
The **Model F-value** of 10.16 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.
P-values less than 0.0500 indicate model terms are significant. In this case A, B, C, AB, BC, B^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.
The **Lack of Fit F-value** of 3486.85 implies the Lack of Fit is significant. There is only a 0.01% chance that a Lack of Fit F-value this large could occur due to noise. Significant lack of fit is bad -- we want the model to fit.

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As a result, the experimental design model proposed for the optimization of RP-HPLC/FLD method parameters shows a suitable approach for the separation performance of tocopherols (**Figure 3.5**).

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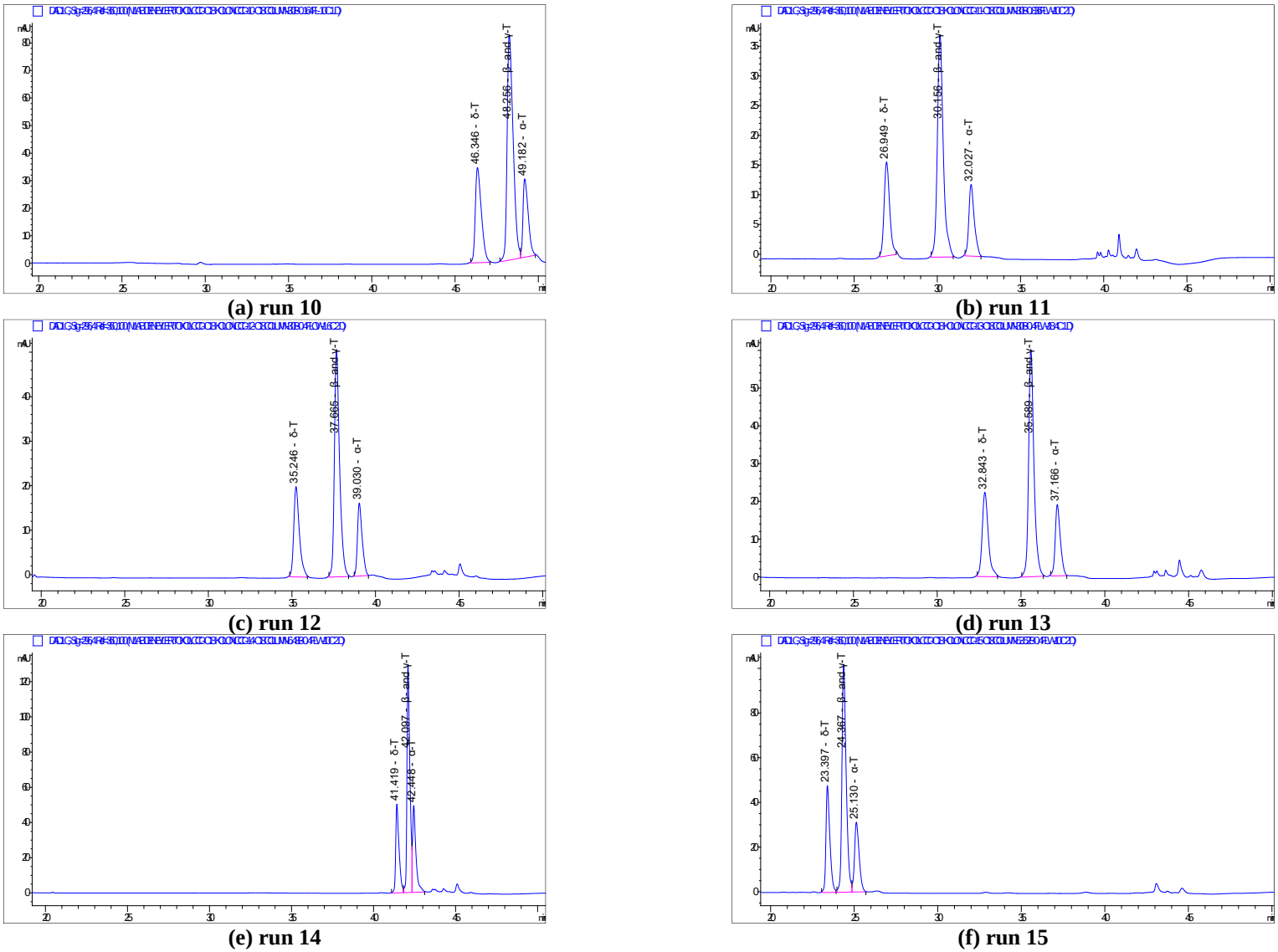

(a) run 10 **(b) run 11**

(c) run 12 **(d) run 13**

(e) run 14 **(f) run 15**

Figure 3.5 Chromatograms the CCC experiments for tocopherol analysis performed by RP-HPLC/FLD by using C_{18} column

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A STUDY OF THE GENERALIZED ABSOLUTE VALUE DISTANCE FUNCTION AND ITS GEOMETRIC PROPERTIES

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ABSTRACT

This study presents some fundamental geometric properties in the resulting non-Euclidean plane by focusing on the generalized absolute value distance function. The concept of the generalized absolute value distance introduces a family of distance functions in the analytical plane by including traditional metrics. Defined by two parameters, a and b, this metric unifies several well-known distances, such as the taxicab, maximum, and Chinese Checkers distances, depending on the values assigned to these constants. This defined distance influences the geometric sets determined by the distance function and their shapes.

Firstly, the relationship between the generalized absolute value distance and Euclidean distance is given through a series of properties, including conditions under which they maintain proportionality across collinear points. This makes the generalized absolute value distance a valuable tool for various applications in non-Euclidean geometries. Then, the minimum distance sets are examined. It has been investigated how the given points being on the same coordinate axis, on the horizontal line, on the vertical line, on the gradual line, on the steep line affect the minimum distance set. Additionally, the concept of the circle is mentioned in the generalized absolute value plane. Also, the distance between a point and a line is determined by the minimal generalized absolute value distance between the point and each point on the line. Finally, the midsets in the generalized absolute value plane are defined, and results obtained from analysis under different conditions are presented along with examples.

Anahtar Kelimeler: Generalized absolute value distance, minimum distance set, midset

1. INTRODUCTION

A family of metrics introduced by Minkowski in the late 1800s offered fresh perspectives on the study of plane geometry. The Minkowski distance, also known as the p-norm, is a generalization in which the type of metric depends on the value of p: the maximum metric for

$p = \infty$, the taxicab metric for $p = 1$, and Euclidean metric for $p = 2$. Non-Euclidean metrics that are applied in practical settings have been the subject of much research in recent years, [1-4, 6-7].

The generalized absolute value distance, d_g, was defined by Kaya et al. [8] and has been studied further in various works [5, 8]. This distance function is an extension of some well-known non-Euclidean distances, defining distances between points based on two parameters, *a* and *b*, rather than a single, fixed metric. When both *a* and *b* are set to 1, this distance function corresponds to the familiar taxicab (or Manhattan) distance. However, by varying these parameters, a range of different distance functions emerges, including the maximum distance and the Chinese Checkers distance, depending on their specific values. This approach allows for infinitely many distance measurements and provides a means of analyzing distances in the plane equipped with this distance, making it useful for various geometrical analyses and applications in non-Euclidean geometries.

This study presents some fundamental geometric properties in the resulting non-Euclidean plane by focusing on the generalized absolute value distance function. First, the relationship between the generalized absolute value distance and Euclidean distance is given through a series of properties. Next, the minimum distance sets are examined. Additionally, the concept of the circle is mentioned in the generalized absolute value plane. Also, the distance between a point and a line is determined by the minimal generalized absolute value distance between the point and each point on the line. Finally, the midsets in the generalized absolute value plane are defined, and results obtained from analyses under different conditions are presented, with examples provided.

2. THE GENERALIZED ABSOLUTE VALUE DISTANCE and ITS PROPERTIES

Definition 2.1. Let $X = (x_1, x_2)$ and $Y = (y_1, y_2)$ be any two points in the analytical plane. The generalized absolute value distance between the points X and Y, denoted as $d_g(X,Y)$, is defined as:

$$d_g(X,Y) = a\max\{|x_1 - y_1|, |x_2 - y_2|\} + b\min\{|x_1 - y_1|, |x_2 - y_2|\}$$

where $a \geq b \geq 0, a \neq 0,\ a,\ b \in \mathbf{R}$, [8].

As indicated by the definition, each pair of non-zero real numbers *a* and *b* defines a distance function, resulting in a family of distance functions.

In the above definition, when *a=b=1*, the distance d_g is equal to the taxicab distance d_T When *a=b*, d_g is simply *a* times the taxicab distance d_T. When *a=1* and *b=0*, d_g corresponds to the maximum distance d_M. When *a=1*, b=$\sqrt{2}-1$, d_g is equal to the Chinese Checkers distance d_C. Thus, it is evident that there are infinitely many different distance functions depending on

the values of *a* and *b*. In this study, unless otherwise stated, we assume that the values of *a* and *b* are predetermined and constant.

The following theorem provides the relationship between the Euclidean distance and the generalized absolute value distance in the analytical plane.

Theorem 2.2. Let *X* and *Y* be any two points in the analytical plane. If the slope of the line passing through the points *X* and *Y* is *m*, then the generalized absolute value distance between *X* and *Y* is given by:

$$d_g(\mathrm{X},\mathrm{Y}) = \rho(m).d_E(\mathrm{X},\mathrm{Y})$$

where

$$\rho(m) = \begin{cases} \dfrac{a+b|m|}{\sqrt{1+m^2}}, & |m| \le 1 \\ \dfrac{a|m|+b}{\sqrt{1+m^2}}, & |m| \ge 1, \end{cases}$$

[8].

Example 2.3. In the the generalized absolute value plane where *a=3* and b=2 the distance between the points $X=(1,2)$ and $Y=(-2,0)$ is found as:
$d_g(X,Y) = 3\max\{3,2\} + 2\min\{3,2\} = 13$.

Since the slope of the line passing through the points *X* and *Y* is $m=\frac{2}{3}$, $\rho\left(\frac{2}{3}\right)=\sqrt{13}$ and $d_g(\mathrm{X},\mathrm{Y}) = \sqrt{13}.d_E(\mathrm{X},\mathrm{Y})$.

In the the generalized absolute value plane where *a=2* and b=1 the distance between these points is $d_g(X,Y)=8$. And, since $\rho\left(\frac{2}{3}\right)=\frac{8}{\sqrt{13}}$, $d_g(\mathrm{X},\mathrm{Y}) = \frac{8}{\sqrt{13}}.d_E(\mathrm{X},\mathrm{Y})$.

The above theorem states that the generalized absolute value distance d_g along any line is a positive constant multiple of the Euclidean distance along the same line. The following results can be derived from this theorem.

Corollary 2.4. Let A_1, A_2, and A_3 be three collinear points in the analytical plane. Then, $d_E(A_1,A_2) = d_E(A_2,A_3) \Leftrightarrow d_g(A_1,A_2) = d_g(A_2,A_3)$, [8].

Example 2.5. Consider the three collinear points $A_1=(0,0)$, $A_2=(1,2)$ and $A_3=(2,4)$ in the the generalized absolute value plane where *a=3* and b=2. The slope of the line passing through

the points $A_i, i=1,2,3$ is $m=2$, $\rho(2)=\frac{8}{\sqrt{5}}$ and $d_E(A_1,A_2)=d_E(A_2,A_3)=\sqrt{5}$.

$d_g(A_1,A_2)=\frac{8}{\sqrt{5}}d_E(A_1,A_2)=\frac{8}{\sqrt{5}}d_E(A_2,A_3)=d_g(A_2,A_3)$.

Corollary 2.6. Let A_1, A_2, and A_3 be three collinear points in the analytical plane. Then, $\frac{d_g(A_1,A_3)}{d_g(A_2,A_3)}=\frac{d_E(A_1,A_3)}{d_E(A_2,A_3)}$.

That is, the ratio of the Euclidean lengths of these points along a line is equal to the ratio of their lengths d_g.

Example 2.7. Consider the three collinear points $A_1=(0,0)$, $A_2=(1,3)$ and $A_3=(\frac{4}{3},4)$ in the the generalized absolute value plane where $a=\frac{1}{2}$ and b=$\frac{1}{3}$. $d_E(A_1,A_3)=\frac{4}{3}\sqrt{10}$ and $d_E(A_2,A_3)=\frac{1}{3}\sqrt{10}$; $d_g(A_1,A_3)=\frac{22}{9}$ and $d_g(A_2,A_3)=\frac{11}{18}$. From here, it is immediately seen that $\frac{d_g(A_1,A_3)}{d_g(A_2,A_3)}=\frac{d_E(A_1,A_3)}{d_E(A_2,A_3)}=4$.

Definition 2.8: Consider the line *l* with the slope *m* in the generalized absolute value plane. If $|m|>1$, *l* is called a steep line; if $|m|<1$, *l* is called a gradual line; and if $|m|=1$, *l* is called a separator line. If the line *l* is parallel to the *x*-axis, it is referred to as a horizontal line, and similarly, if it is parallel to the *y*-axis, it is referred to as a vertical line.

In the generalized absolute value plane, every translation is an isometry. Since the reflections in the line $y=mx$ passing through the origin where $m\in\{0,\pm1,\infty\}$ for $\frac{b}{a}\neq0$, $m\in\{0,\pm1,\pm(\sqrt{2}-1),\pm(\sqrt{2}+1),\infty\}$ for $\frac{b}{a}=0$ preserve the distance d_g, they are isometries in the generalized absolute value plane. The rotations R_θ about the origin where $\theta\in\{0,\frac{\pi}{2},\pi,\frac{3\pi}{2}\}$ for $\frac{b}{a}\neq0$, $\theta\in\{0,\frac{\pi}{4},\frac{\pi}{2},\frac{3\pi}{4},\pi,\frac{5\pi}{4},\frac{3\pi}{2},\frac{7\pi}{4}\}$ for $\frac{b}{a}=0$ preserve the generalized absolute value, [8].

Definition 2.9 Let A_1 and A_2 be any two points in the analytical plane. The minimum distance set of the points A_1 and A_2 is defined as

$$\{X\,|\,d_g(A_1,X)+d_g(X,A_2)=d_g(A_1,A_2)\}$$

and is denoted by A_1A_2 .

The minimum distance set of the points A_1 and A_2 varies depending on their positions.

If the points lie on the same coordinate axes, the same horizontal or vertical line, or the same separator line, the minimum distance set is the line segment connecting these points.

If the points A_1 and A_2 are on the same gradual line, the minimum distance set is the region bounded by the horizontal lines and the separator lines passing through the points A_1 and A_2 (which have the same sign as the slope of A_1A_2), forming a parallelogram.

Similarly, if the points lie on the same steep line, the minimum distance set is the region bounded by the vertical lines and the separator lines passing through each of these points (having the same sign as the slope of the line connecting the points) , forming a parallelogram.

Example 2.10. Consider the points $A_1=(1,1)$ and $A_2=(3,1)$ in the the generalized absolute value plane where $a=\frac{1}{2}$ and b=$\frac{1}{4}$. The points A_1 and A_2 are on the horizontal line $y=1$. The minimum distance set is the set of the points satisfying the equation $\left(\frac{1}{2}\max\{|x-1|,|y-1|\}+\frac{1}{4}\min\{|x-1|,|y-1|\}\right)+\left(\frac{1}{2}\max\{|x-3|,|y-1|\}+\frac{1}{4}\min\{|x-3|,|y-1|\}\right)=1$. Upon examining this equation, it is found that the set is the line segment $y=1,1\le x\le 3$, Fig. 1.

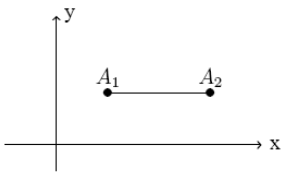

Figure 1

Example 2.11. Consider the points $A_1=(0,0)$ and $A_2=(2,1)$ in the the generalized absolute value plane where $a=\frac{1}{2}$ and b=$\frac{1}{4}$. The points A_1 and A_2 are on the gradual line $y=\frac{1}{2}x$. The minimum distance set is the set of the points satisfying the equation $\left(\frac{1}{2}\max\{|x|,|y|\}+\frac{1}{4}\min\{|x|,|y|\}\right)+\left(\frac{1}{2}\max\{|x-2|,|y-1|\}+\frac{1}{4}\min\{|x-2|,|y-1|\}\right)=1$. When all cases of the equation are examined, it is observed that the set is a parallelogram formed by the region $|x|>|y|$, $|x-2|>|y-1|$, $0\le x<2$, $0\le y<1$ and the line segments $y=x, 0\le y\le 1$; $y=x-1, 0\le y\le 1$, Fig. 2.

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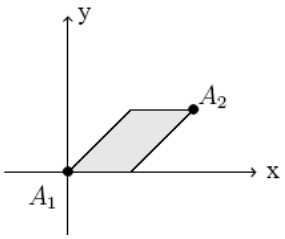

Figure 2

In generalized absolute value plane, a circle is still defined as the set of all points that are the same generalized absolute value distance (the radius) from a point (the center), but because of the generalized absolute value formula, the figure of circle becomes a octagon rather than a smooth curve. The points on the generalized absolute value circle with the center $\mathrm{M} = (m_1, m_2)$ and the radius r satisfy the equation:

$$a\,max\{|x-\mathrm{m}_1|,|\mathrm{y}-\mathrm{m}_2|\}+b\,min\{|x-\mathrm{m}_1|,|\mathrm{y}-\mathrm{m}_2|\}=r\,.$$

The generalized absolute value circle has eight vertices at points that are on the horizontal, the vertical lines and the separator lines passing through the center. These vertices are $(m_1+\frac{r}{a},m_2)$, $(m_1+\frac{r}{a+b},m_2+\frac{r}{a+b})$, $(m_1,m_2+\frac{r}{a})$, $(m_1-\frac{r}{a+b},m_2+\frac{r}{a+b})$, $(m_1-\frac{r}{a},m_2)$, $(m_1-\frac{r}{a+b},m_2-\frac{r}{a+b})$, $(m_1,m_2-\frac{r}{a})$ and $(m_1+\frac{r}{a+b},m_2-\frac{r}{a+b})$. Thus, it is made up of the line segments connecting these vertices, forming a octagon.

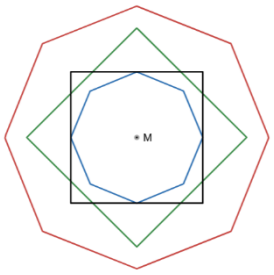

Fig. 3 The generalized absolute value circles

The figure above shows the generalized absolute value circles. The red circle in the generalized absolute value plane where $a=\frac{1}{2}, b=\frac{1}{5}$, the green circle in the generalized absolute value plane where $a=b=\frac{3}{5}$, the blue circle in the generalized absolute value plane (the Chinese Checker plane) where $a=1, b=\sqrt{2}-1$, and the black circle in the generalized absolute value plane (the maximum plane) where $a=1, b=0$. All circles have the center at $M=(0,0)$ and the radius $r=\frac{15}{2}$.

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Consider the point *A* and the line *l* in the generalized absolute value plane. The generalized absolute value distance d_g from the point *A* to the line *l* is equal to the minimum of the generalized absolute value distances between the point *A* and every point on the line *l*. Therefore,

$$d_g(A,l) = \min_{x \in l} d_g(A,l)$$

To find the generalized absolute value distance from the point *A* to the line *l*, circles centered at the point *A* are drawn in the generalized absolute value plane. When the line *l* is tangent to the circle with the radius *r*, the generalized absolute value from the point *A* to the line *l* is equal to *r*. Let *m* be the slope of the line *l*. d_g from the point *A* to the line *l* based on the values of *m* is as follows:

1) If $|m| \geq \frac{a}{b}$, $d_g(A,l)$ is the distance between the point *A* and the intersection point of the horizontal line passing through *A* and the line *l*.

2) If $|m| \leq \frac{b}{a}$, $d_g(A,l)$ is the distance between the point *A* and the intersection point of the vertical line passing through *A* and the line *l*.

3) If $\frac{b}{a} \leq |m| \leq \frac{a}{b}$, $d_g(A,l)$ is the distance between the point *A* and the intersection point of the separator line passing through *A* and the line *l*.

Theorem 2.12. In the generalized absolute value plane, the generalized absolute value distance d_g from point $A = (x_0, y_0)$ to the line *l* given by the equation $a_1x + a_2y + a_3 = 0$ is

$$d_g(A,l) = \begin{cases} \dfrac{a|a_1x_0 + a_2y_0 + a_3|}{|a_2|} & , |m| \leq \dfrac{b}{a} \\ \dfrac{(a+b)|a_1x_0 + a_2y_0 + a_3|}{|a_1 + sgn(-m)a_2|} & , \dfrac{b}{a} \leq |m| \leq \dfrac{a}{b} \\ \dfrac{a|a_1x_0 + a_2y_0 + a_3|}{|a_1|} & , |m| \geq \dfrac{a}{b} \end{cases}$$

where *m* is the slope of the line *l*.

Example 2.13. Consider the line l_1 with the equation $x + 2y + 1 = 0$ and the points $A = (1,1)$ in the the generalized absolute value plane where *a=3* and b=2. Since the slope of *l* is $-\frac{1}{2}$ and the

absolute of the slope is less than $\frac{2}{3}$, it is obtained $d_g(A,l_1)=\frac{3|1+2.1+1|}{|2|}=6$. Let us consider the line l_2 with the equation $x+y+1=0$. Since l_2 is a separator line, the absolute value of its slope is between $\frac{2}{3}$ and $\frac{3}{2}$. It is immediately seen that $d_g(A,l_2)=\frac{5|1+1+1|}{|2|}=\frac{15}{2}$.

In the generalized absolute value plane, the locus of points equidistant from the points A_1 and A_2 with respect to the distance d_g is called *the generalized absolute value midset* of A_1 and A_2. This set is defined as:

$$\left\{X\in R_G^2 \,|\, d_G(A_1,X)=d_G(X,A_2)\right\}.$$

The generalized absolute value midsets are classified according to the positions of the points A_1 and A_2.

1) If the points A_1 and A_2 are on the same coordinate axis, a same horizontal line or a same vertical line and a separator line, then the generalized absolute value midsets is the line passing through the midpoint of these points and perpendicular to the line A_1A_2.

2) If the points A_1 and A_2 are on a gradual or a steep line, then the generalized absolute value midsets is the union of two rays and five line segments such that four line segments are parallel in pairs.

3) If the points A_1 and A_2 are on a line with a slope of $\pm\frac{a}{b}$ or $\pm\frac{b}{a}$, the generalized absolute value midset is the union of two regions and five line segments.

In the following examples, the generalized absolute value midsets of two points given on the same coordinate axis, the same separator line, the same gradual line and the same gradual line with the slope $\frac{b}{a}$ are examined.

Example 2.14. Consider the points $A_1=(0,0)$ and $A_2=(3,0)$ in the the generalized absolute value plane where $a=\frac{1}{3}$ and $b=\frac{1}{4}$. The points A_1 and A_2 are on x-axis. The generalized absolute value midsets is the set of the points satisfying the equation $\left(\frac{1}{3}\max\{|x|,|y|\}+\frac{1}{4}\min\{|x|,|y|\}\right)=\left(\frac{1}{3}\max\{|x-3|,|y|\}+\frac{1}{4}\min\{|x-3|,|y|\}\right)$.

When all cases of the equation are examined, it is obtained that the line segment $x=\frac{3}{2}, -\frac{3}{2}<y<\frac{3}{2}$, the rays $x=\frac{3}{2}, y\geq\frac{3}{2}$ and $x=\frac{3}{2}, y\leq-\frac{3}{2}$. The midset formed by the union of these is the line $x=\frac{3}{2}$, Fig. 4.

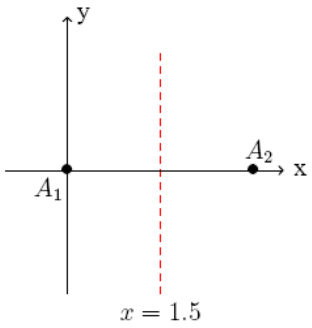

Figure 4

Example 2.15. Consider the points $A_1=(0,0)$ and $A_2=(3,3)$ in the the generalized absolute value plane where $a=\frac{1}{3}$ and $b=\frac{1}{4}$. The points A_1 and A_2 are on the separator line $y=x$. The generalized absolute value midsets is the set of the points satisfying the equation $\left(\frac{1}{3}\max\{|x|,|y|\}+\frac{1}{4}\min\{|x|,|y|\}\right)=\left(\frac{1}{3}\max\{|x-3|,|y-3|\}+\frac{1}{4}\min\{|x-3|,|y-3|\}\right)$.
When all cases of the equation are examined, it is obtained that the midset is the separator line $x+y=3$ passing through the midpoint of the points A_1 and A_2, Fig. 5.

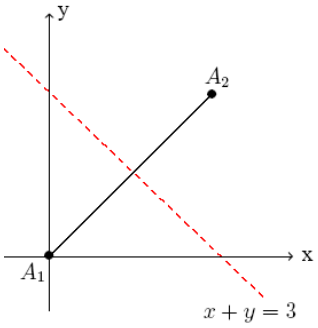

Figure 5

Example 2.16. Consider the points $A_1=(0,0)$ and $A_2=(4,2)$ in the the generalized absolute value plane where $a=\frac{1}{3}$ and $b=\frac{1}{4}$. The points A_1 and A_2 are on the gradual line $y=\frac{1}{2}x$. The generalized absolute value midsets is the set of the points satisfying the equation $\left(\frac{1}{3}\max\{|x|,|y|\}+\frac{1}{4}\min\{|x|,|y|\}\right)=\left(\frac{1}{3}\max\{|x-4|,|y-2|\}+\frac{1}{4}\min\{|x-4|,|y-2|\}\right)$.

As a result of analyzing the equation, it is obtained that the midset is union of the line segments $d_i, i=1,2,3,4,5$ and the rays $r_j, j=1,2$ where $d_1: 4x+3y=11, \frac{3}{7} \le y \le \frac{11}{7}$; $d_2: 7x+y=20, -\frac{10}{3} \le y \le 0$; $d_3: x+y=\frac{20}{7}, 0 \le y \le \frac{3}{7}$; $d_4: x+y=\frac{22}{7}, \frac{11}{7} \le y \le 2$; $d_5: 7x+y=10, 2 \le y \le \frac{16}{3}$; $r_1: x=\frac{10}{3}, y \le -\frac{10}{3}$ and $r_2: x=\frac{2}{3}, y \ge \frac{16}{3}$. It is seen that the line segments d_3 and d_4 lie on the separator lines and are parallel. Also, the line segments d_2 and d_5 are parallel. And, the slope of the line segment d_1 is $-\frac{a}{b}=-\frac{4}{3}$. Furthermore, the rays r_1 and r_2 are parallel to y-axis, Fig. 6.

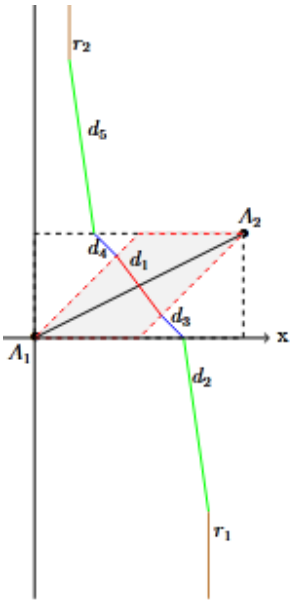

Figure 6

Example 2.17. Consider the points $A_1=(0,0)$ and $A_2=(4,3)$ in the the generalized absolute value plane where $a=\frac{1}{3}$ and b=$\frac{1}{4}$. The points A_1 and A_2 are on the gradual line $y=\frac{3}{4}x$. The generalized absolute value midsets is the set of the points satisfying the equation $\left(\frac{1}{3}\max\{|x|,|y|\}+\frac{1}{4}\min\{|x|,|y|\}\right)=\left(\frac{1}{3}\max\{|x-4|,|y-3|\}+\frac{1}{4}\min\{|x-4|,|y-3|\}\right)$.

After examining the equation, it is obtained that the midset is union of the line segments $d_i, i=1,2,3,4,5$ and the regions $r_j, j=1,2$ where $d_1: 4x+3y=\frac{25}{2}, \frac{17}{14} \le y \le \frac{25}{14}$; $d_2: 7x+y=24, -4 \le y \le 0$; $d_3: x+y=\frac{24}{7}, 0 \le y \le \frac{17}{14}$; $d_4: x+y=\frac{25}{7}, \frac{25}{14} \le y \le 3$; $d_5: 7x+y=7, 3 \le y \le 7$; $r_1: x \ge 4, y \le -x$ and $r_2: x \le 0, y \ge -x+7$. It is seen that the line segments d_3 and d_4 lie on the separator lines and are parallel. Also, the line segments d_2 and

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d_5 are parallel. And, the slope of the line segment d_1 is $-\frac{a}{b}=-\frac{4}{3}$. Furthermore, the rays r_1 and r_2 are parallel to y-axis, Fig. 7.

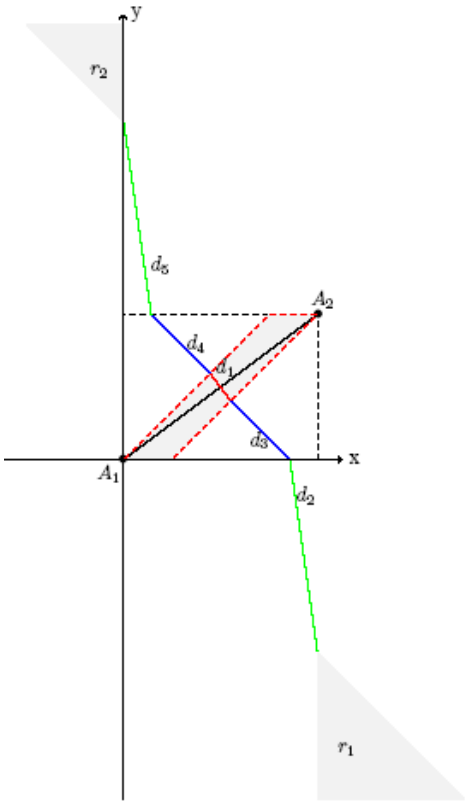

Figure 7

For the generalized absolute value midset of two points on the same steep line and the steep line with the slope $\frac{a}{b}$, similar results in Examples 2.15 and 2.16 are obtained.

3. CONCLUSION

As a result, this study expands some classical distance concepts by highlighting the geometric variations provided by the generalized absolute value distance function that includes different parameter values. The study is an analysis method especially for non-Euclidean planes; it covers basic geometric properties such as distance between points, distance of a point to a line, minimum distance sets, circle, and median set concepts. We think that the generalized absolute valued distance function will contribute to theoretical and applied geometric studies by providing examples of these properties.,

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ON THE ROLE OF CARTESIAN GROUP IN THE STRUCTURE AND EXISTENCE OF SUBPLANES OF PROJECTIVE PLANE OF ORDER 25

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ABSTRACT

In this study, we consider the projective plane, which is coordinatized by elements of the smallest Cartesian group. Depending on the choice of a regular quadrangle, it is shown that, in some cases, there does not exist a projective subplane of order 3, whereas a projective subplane of order 5 is found to exist. This analysis provides new insights into the structural properties of projective planes and their subplanes, contributing to a deeper understanding of finite geometries.

Key Words: Cartesian group, Projective plane, Subplanes
Ams Subject Classification: 51E20, 51E30

1 Introduction

Algebraic structures refer to mathematical objects that have specific operations defined on them, such as Cartesian group, ring, field, and vector space. A projective plane is a geometric concept that arises from geometry, which deals with properties that are invariant under projective transformations.

To obtain a projective plane from algebraic structures, we can use ideas from algebraic geometry and projective geometry.

By combining these algebraic and geometric concepts, many scientists can construct and study projective planes, which have applications in fields like computer graphics, geometric modelling, and projective geometry itself.

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Different coordinate systems can be used based on the algebraic structures involved.

By using these concepts, one can establish a coordinate system for points and lines in a projective plane based on the given algebraic structures.

There are projective planes of the same order from different algebraic structures that are not isomorphic to each other.

The k-arcs, Fano planes, Baer subplanes in the projective planes of orders 9 and 25, and the embedding of these projective planes into projective spaces have been extensively discussed in previous studies [3–7].

In [9], there are subplanes of order 3 in the Hughes plane of order 25 .

Some 2nd, 3rd and 5th order subplanes of Cartesian group plane of order 25 were examined in [1] and [2]. In this study, some new configurations with or without subplanes have been obtained.

2 Preliminaries

The following definitions establish the foundational concepts of projective planes, subplanes, Cartesian groups, and their interactions within finite geometrical structures.

Definition 1 If N and D are two sets whose elements are points and lines, respectively, and if $\circ \subset N \times D$ and the triple $(N, D, \circ)$ satisfies the following conditions, this geometric structure is

called a projective plane P.

P1) $\exists_1 l \in D \ni X \circ l and Y \circ l for \forall X, Y \in N, X \neq Y.$

P2) $\exists X \in N \ni X \circ l_1 and X \circ l_2 for \forall l_1, l_2 \in D, l_1 \neq l_2.$

P3) There exist four points, no three of which are collinear.

Definition 2 Let P be a projective plane of order n and S be a set with two special elements denoted 0 and 1 and cardinality $n \geq 2$. Let's assume the vertices of the regular quadrangle

are O, E, U, V. The points, lines and the incidence relation on P using the set S are determined respectively as follows:

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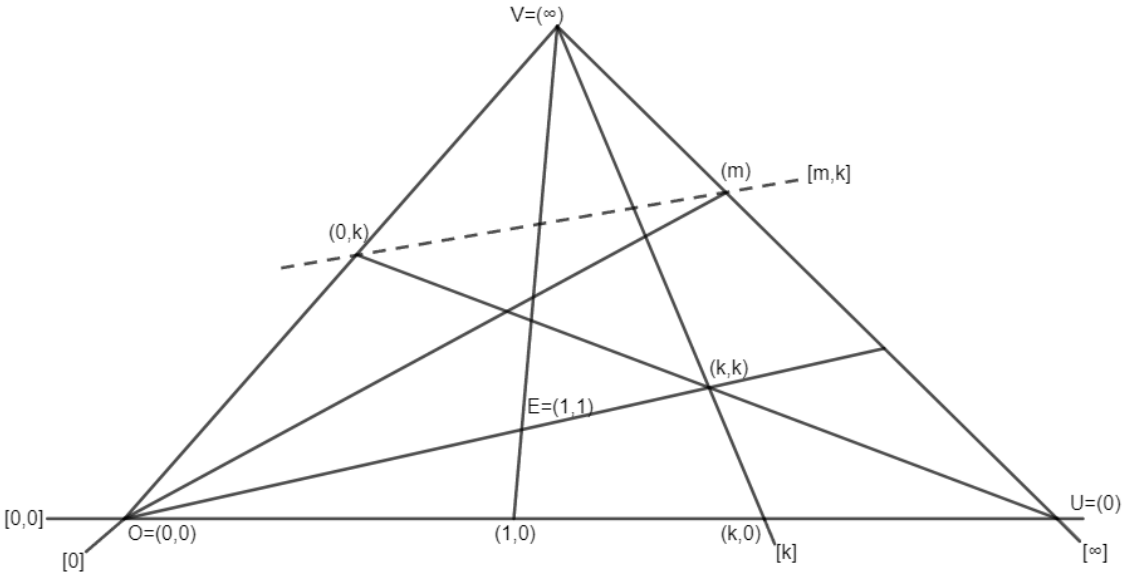

Figure 1

and

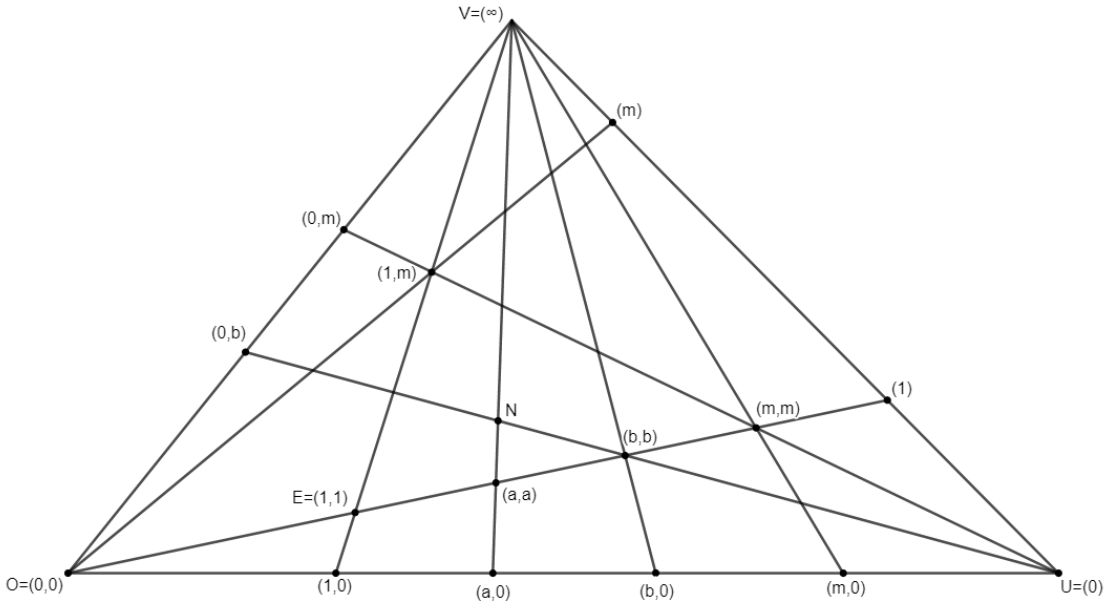

Figure 2

Definition 3 (See 1,2) Let $(F_5, +, \cdot)$ be Galois field. Let

$$S = F_5 \times F_5 = \{(a,b) \ : \ a,b \in F_5\}$$

and consider the addition and multiplication on S given by

$$(a,b) \oplus (c,d) = (a+b, c+d)$$

and.

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22	00	12	24	31	43	22	40	03	14	34	44	23	30	13	01	11	04	42	20	32	33	21	41	02	10
23	00	42	34	21	13	23	31	11	02	40	41	04	12	30	22	14	33	20	43	01	32	10	03	44	24
24	00	32	14	41	23	24	13	40	33	01	43	11	21	02	30	12	20	03	34	44	31	04	22	10	42
30	00	03	01	04	02	30	33	31	34	32	10	13	11	14	12	40	43	41	44	42	20	23	21	24	22
31	00	23	41	14	32	31	42	10	22	04	12	44	34	03	20	43	30	02	21	11	24	01	33	40	13
32	00	13	21	34	42	32	24	44	03	10	14	01	43	20	33	41	22	30	12	04	23	40	02	11	31
33	00	43	31	24	12	33	10	02	41	21	11	32	20	42	04	44	01	13	30	23	22	34	14	03	40
34	00	33	11	44	22	34	01	23	10	43	13	20	02	31	41	42	14	24	03	30	21	12	40	32	04
40	00	04	03	02	01	40	44	43	42	41	30	34	33	32	31	20	24	23	22	21	10	14	13	12	11
41	00	11	22	33	44	41	03	13	31	20	32	12	01	40	21	23	34	10	04	43	14	30	24	42	02
42	00	31	12	43	24	42	32	01	20	11	34	40	14	22	02	21	03	33	41	10	13	44	30	04	23
43	00	21	42	13	34	43	14	20	04	33	31	03	23	11	40	24	10	44	32	02	12	22	01	30	41
44	00	41	32	23	14	44	20	34	12	02	33	24	40	04	13	22	42	01	10	31	11	03	43	21	30

Table 1

The system $(S, \oplus, \otimes)$ is a proper Cartesian group.

We consider the geometrical structure of the projective plane which is constructed on the known the smallest cartesian group.

A finite projective plane of order n has $n^2 + n + 1$ points and $n^2 + n + 1$ lines. We shall be interested in the projective plane $P_2S = PG(2,25)$ over the smallest Cartesian Group of order 25. The 651 points of P_2S are the elements of the set

$$\{(x, y) \ : \ x, y \in S\} \cup \{(m) \ : \ m \in S\} \cup \{(\infty)\}$$

The points of the form *(x, y)* are called affine points and the points of the form *(m)* and the unique point (∞) are called ideal points. The 651 lines of P_2S are defined to be set of points satisfying one of the three conditions:

$$[m, k] = \{(x, y) \in S^2 \ : \ y = m \otimes x \oplus k, \quad m, k \in S\} \cup \{(m), \quad m \in S\}$$
$$[\lambda] = \{(x, y) \in S^2 : x = \lambda\} \cup \{(\infty)\}$$
$$[\infty] = \{(m), \quad m \in S\} \cup \{(\infty)\}$$

The 625 lines of P_2S having form $y = m \otimes x \oplus k$ and 25 lines of P_2S having of the form $x = \lambda$ are called the affine lines and the unique line $[\infty]$ of P_2S is called the ideal line. The

system of points, lines and incidence relation given above defines a projective plane of order 25, which is the smallest Cartesian group plane.

1 On the subplanes of P_2S

In this section, the text explores conditions under which a regular quadrangle within a projective plane either determines or fails to determine Fano subplanes and projective subplanes of order 3. It presents several lemmas and theorems that describe the geometric configurations and collineations involved, leading to proofs about the impossibility of certain subplanes forming under given parameters.

Let's assume the vertices of the regular quadrangle are *O, I, X, P*. If the diagonal points *E, F, G* of this regular quadrangle *O, I, X, P* are not collinear, then this quadrangle does not determine a Fano subplane.

1.1 Subplanes of order 2 of P_2S

The following lemmas are taken from [1].

Let $O = (00,00),\ I = (10,10),\ X = (00)$ and $P = (00, cd)$ be regular quadrangle in P_2S.

Lemma 4 *If* $P = (00, cd)$ *with* $d \neq 0$ *then the completion of each a regular quadrangle O, I, X, P determines a Fano subplane of* P_2S.

Lemma 5 *If* $P = (00, cd)$ *with* $c \neq 0,1$ *and* $d = 0$, *then the completion of the regular quadrangle O, I, X, P doesn't determine a Fano subplane of* P_2S.

Lemma 6 *If* $Y = (\infty)$, *then the regular quadrangle O, I, X, Y doesn't determine a Fano configuration of* P_2S.

1.2 Subplanes of order 3 of P_2S

Theorem 7 Let $O = (00,00),\ I = (10,10),\ X = (00)$ and $P = (00, cd)$ *with* $c \in \{2,3,4\}$ *and* $d \in F_5\{0,1,2,3,4\}$ *be a regular quadrangle in* P_2S. *The configurations obtained from completing the regular quadrangles O, I, X, P of* P_2S *do not form the projective subplanes of order 3 of* P_2S.

Proof. In [1], it is known that if $O = (00,00),\ I = (10,10),\ X = (00)$ and $P = (00, cd)$ with $c \in \{2,3,4\}$ and $d = 0$, then the regular quadrangles *O, I, X, P* doesn't a projective subplanes of order 3.

Also, for each $t \in S$ we can define collineations f_t of P_2Sas follows:

$$f_t: (x,y) \longrightarrow (x, y \oplus t), (t \in S) \qquad f_t: [m,k] \longrightarrow [m, k \oplus t]$$
$$(m) \longrightarrow (m) \qquad [\lambda] \longrightarrow [\lambda]$$
$$(\infty) \longrightarrow (\infty) \qquad [\infty] \longrightarrow [\infty].$$

One can see that the images of the regular quadrangle *O, I, X, P* under the these collinations $f_t,\ t \in S$ do not determine a projective subplanes of order 3.

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Theorem 8 Let $O = (00,00)$, $I = (10,10)$, $X = (00)$ and $P = (01, cd)$ *with* $c \in \{2,3,4\}$ *and* $d \in F_5\{0,1,2,3,4\}$, *(mod 5) be a regular quadrangle in* P_2S. *The configurations obtained from completing the regular quadrangle O, I, X, P of* P_2S *do not from the projective subplanes of order 3 of* P_2S.

Proof. To obtain a subplane of order 3 of P_2S, we must choose a regular quadrangle that does not form a subplane of order 2.
While investigating the subplanes of order 3 of P_2S, all the regular quadrangles were chosen to meet the following conditions.

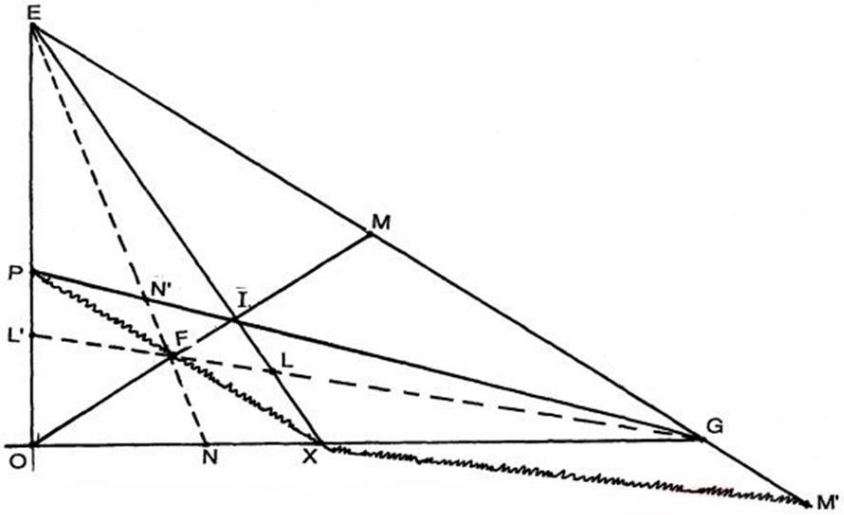

Figure 3: The points of projective plane of order 3

In this proof, we choose two configurations that do not form the 3rd order subplane of P. Other cases are easily illustrated by similar calculations.

Case 1 : Let $O = (00,00)$, $I = (10,10)$, $X = (00)$, and $P = (01,20)$ be four points, any three of which are not collinear in P_2S.The opposite sides of this regular quadrangle are $OP = [04,00]$, $OX = [00,00]$, $OI = [10,00]$, $PX = [00,00]$, $IX = [00,10]$ and the diagonal points are $OP \wedge IX = (03,10) = E$, $OI \wedge PX = (20,00) = F$ and $PI \wedge OX = (34,00) = G$.

If other lines and points in the configuration are calculated, these lines and points $EF = [04,00]$, $EF \wedge OX = (24,00) = N$, $EF \wedge PI = (44,22) = N'$, $FG \wedge IX = (23,10) = L$, $FG \wedge OP = (04) = L'$, $EG \wedge OI = (04,04) = M$, and $PX \wedge EG = (30,20) = M'$ are obtained.

As a result of these calculations, thirteen points were obtained. However, for this geometric structure to be a subplane of order 3, there must be four points on each line. For example, there should be two more points on the line $PM = [32,12]$. However, there are no other points on this line from $L \circ PM$. $L \circ PM \Leftrightarrow (1,0) \neq (3,2) \otimes (2,3) \oplus (1,2)$ and $N \circ PM$. $N \circ PM \Leftrightarrow (0,0) \neq (3,2) \otimes (2,4) \oplus (1,2)$. Therefore, the completion of this regular quadrangle is not a subplane of order 3 of P_2S.

Case 2 : Let $O = (00,00)$, $I = (10,10)$, $X = (00)$, and $P = (01,21)$ be four points, any three of which are not collinear in P_2S. The opposite sides and intersection points are obtained as follows. $OP = [43,00]$, $OP \wedge IX = (31,10) = E$, $OP = [43,00]$ and $OP \wedge IX = (31,10) = E$, $PX \wedge OI = (21,21) = F$ and $PI \wedge OX = (24,00) = G$. It is easily seen that these points *E*, *F* and *G* are not collinear. The lines that have diagonal points two by two are $EF = [34,01]$, $EG = [31,30]$ and $FG = [21,41]$. Other points on these lines are calculated as $EF \wedge OX = (44,00) = N$, $EF \wedge PI = (41,13) = N'$, $FG \wedge IX = (23,10) = L$, $FG \wedge OP = (42,01) = L'$, $M = (32,32)$ and $M' = (02,21)$. Thus, thirteen points were obtained. In order for this geometric structure to be a subplane of order 3, there must be thirteen lines and four points on each line. First, if the line passing through points *P* and *M* is calculated, the coordinates of line $PM = [03,11]$. The other two points on the line *PM* must be the points *N* and *L*. However, when the necessary calculations are made, it is seen that both point *N* and point *L* are not on the line *PM* .So this configuration does not form subplane of order 3 of P_2S.

Similarly, in other cases, it is observed that a subplane of order 3 does not occur.

1.3 Subplanes of order 5 of P_2S

The section discusses the formation of subplanes of order 5 within a projective plane, specifically focusing on the Baer subplane. The following theorem and proof outline how a regular quadrangle in a Cartesian group plane leads to the configuration of a Baer subplane, detailing its geometric properties and structure.

The following theorem is taken from [1]. It is clear that for the Baer subplane of order $n = m^2$.

Theorem 9 *Let $O = (00,00)$, $I = (10,10)$, $X = (00)$ and $Y = (\infty)$ be a regular quadrangle in P_2S. The configuration obtained from completing the regular quadrangle of P_2S determines a Baer subplane of P_2S.*

Proof. The Baer subplane of the Cartesian group plane of order 25 is of a projective subplane of order 5. It is well known that this Baer subplane must have 31 points and 31 lines. If one makes the necessary calculations, one can obtain the points set and the lines set of this plane as the following sets.

The points set and lines set are the following respectively:

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((0,0),(0,0)) , ((0,0),(1,0)) , ((0,0),(2,0)) , ((0,0),(3,0)) , ((0,0),(4,0)) , ((0,0))
((1,0),(0,0)) , ((1,0),(1,0)) , ((1,0),((2,0)) , ((1,0),(3,0)) , ((1,0),(4,0)) , ((1,0))
((2,0),(0,0)) , ((2,0),(1,0)) , ((2,0),(2,0)) , ((2,0),(3,0)) , ((2,0),(4,0)) , ((2,0))
((3,0),(0,0)) , ((3,0),(1,0)) , ((3,0),(2,0)) , ((3,0),(3,0)) , ((3,0),(4,0)) , ((3,0))
((4,0),(0,0)) , ((4,0),(1,0)) , ((4,0),(2,0)) , ((4,0),(3,0)) , ((4,0),(4,0)) , ((4,0))
(∞)

[(0,0),(0,0)] , [(0,0),(1,0)] , [(0,0),(2,0)] , [(0,0),(3,0)] , [(0,0),(4,0)] , [(0,0)]
[(1,0),(0,0)] , [(1,0),(1,0)] , [(1,0),(2,0)] , [(1,0),(3,0)] , [(1,0),(4,0)] , [(1,0)]
[(2,0),(0,0)] , [(2,0),(1,0)] , [(2,0),(2,0)] , [(2,0),(3,0)] , [(2,0),(4,0)] , [(2,0)]
[(3,0),(0,0)] , [(3,0),(1,0)] , [(3,0),(2,0)] , [(3,0),(3,0)] , [(3,0),(4,0)] , [(3,0)]
[(4,0),(0,0)] , [(4,0),(1,0)] , [(4,0),(2,0)] , [(4,0),(3,0)] , [(4,0),(4,0)] , [(4,0)]
[(∞)]

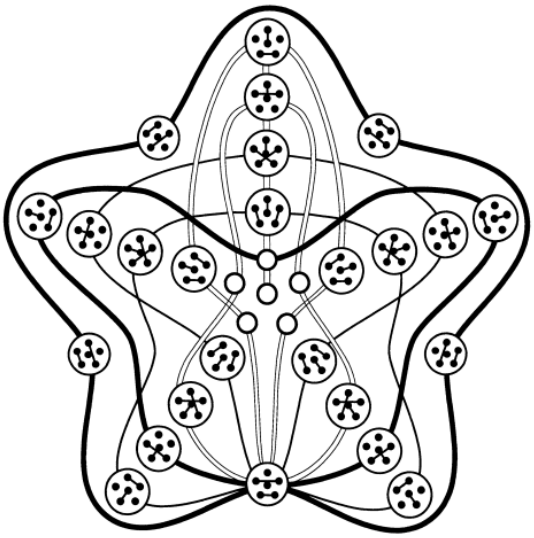

Figure 4: Projective plane of order 5

Conclusion

In this study, we have examined the intricate relationship between projective planes and their subplanes, particularly focusing on configurations derived from the Cartesian group. Our findings reveal that the existence of projective subplanes is highly contingent on the chosen regular quadrangle and its associated algebraic structures. Notably, while we identified the absence of projective subplanes of order 3 in certain configurations, the presence of subplanes of order 5 underscores the rich diversity within finite geometries.

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ON THE 3-NETS IN THE PROJECİVE PLANE P_2S OF ORDER 25

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ABSTRACT

A projective plane is a geometric structure defined by a set of points and a set of lines, and it satisfies the following axioms:

1. Any two distinct points from the points set lie on exactly one line from the line set.
2. Any two distinct lines from the line set intersect at exactly one point from the points set.
3. There exist at least four points in the points set such that no three are collinear, meaning they do not all lie on the same line from the line set.

Finite projective planes, particularly those derived from finite fields, are a fundamental structure in finite geometry and combinatorial mathematics. These planes exhibit rich algebraic and geometric properties, making them an important subject of study. One of the intriguing features of finite projective planes is the presence of 3-nets, which provide a powerful geometric tool for understanding the interplay between points and lines within these planes.

A projective plane obtained from a field is called a field projective plane, often denoted as PG(2,K), where K is a field.

A 3-net in a projective plane obtained from a field is a pair (A, X) where A is a finite set of lines of projective plane partitioned into 3 subsets $A = A_1 \cup A_2 \cup A_3$ and X is a finite set of points of projective plane subject to the following conditions:

1- Any two lines from distinct families are concurrent with exactly one line from each component.
2- 2-For every point $x \in X$ and every i (i $\in \{1, 2, 3\}$) there exists a unique line $\ell \in$ Ai passing through the point x.

In this paper, we provide some examples of 3-nets in a projective plane of order 25, where the underlying algebraic structure is a smallest Cartesian group.

1. INTRODUCTION

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The projective plane is a geometric concept in which every pair of lines intersects at exactly one point, even if the lines are parallel in Euclidean geometry. It is a two-dimensional projective space where each line extends infinitely and every two lines meet at a unique point, including at infinity. In a projective plane, properties such as parallelism do not exist as they do in Euclidean geometry, which makes it useful for understanding perspective and transformations in geometry.

Studies on the embeddings of projective planes explore how these geometric structures can be represented within higher-dimensional projective spaces [4,6].

Arcs in projective planes are studied for their properties in determining configurations of points with specific geometric and combinatorial characteristics in [2,3,5,6,7].

The study of finite projective planes and their geometric properties has been a central topic in combinatorial mathematics and finite geometry. One important within this is the Cartesian group plane, named after the mathematician Panella. This plane is constructed through specific algebraic method and possess unique properties that make them a key area of interest in the study of finite geometry.

Understanding the Cartesian group plane and its connection to 3-nets opens up various pathways for exploring both theoretical and applied aspects of finite geometries.

This study provides valuable insights into the properties of projective planes, as well as their significance in modern mathematical research.

Definition 1 *(See 8)* A system $(S, \oplus, \otimes)$ is called a Cartesian group if and only if the following conditions are satisfied:

1. $(S, \oplus)$ is a group.
2. For each of the equations $a \otimes x = b$ and $x \otimes a = b$, there exists a unique solution for all elements, where 0 denotes the additive identity.
3. There exists an element $e \in S$ such that $e \otimes x = x \otimes e = x$ for all $x \in S$..
4. For all $x \in S$, $0 \otimes x = x \otimes 0 = 0$ must hold.
5. Given $a, b, c, d \in S$ such that $a \neq c$, there exists a unique $x \in S$ such that $a \otimes x \otimes b = c \otimes x \otimes d$.
6. Given $a, b, c, d \in S$ such that $a \neq c$, there exists a unique pair $(x, y) \in S^2$ such that $x \otimes a \oplus y = b$ and $x \otimes c \oplus y = d$.

Definition 2 (See 8) Let $(F_5, +, \cdot)$ be the field of integers modulo 5. Let

$$S = F_5 \times F_5 = \{(a, b) : a, b \in F_5\}$$

and consider the addition and multiplication on S given by

$$(a, b) \oplus (c, d) = (a + b, c + d)$$

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and

$$(a,b)\otimes(c,d)=\begin{cases}(ac,ad), & \text{If } b=0\\ (ac-(a^2-2)db^{-1},bc-ad), & \text{If } b\neq 0\end{cases}.$$

According to this operation, the multiplication is given in the table below.

⊗	00	01	02	03	04	10	11	12	13	14	20	21	22	23	24	30	31	32	33	34	40	41	42	43
00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
01	00	30	10	40	20	01	21	14	44	31	02	33	42	12	23	03	32	43	13	22	04	24	11	41
02	00	40	30	20	10	02	43	22	32	13	04	14	31	21	44	01	11	34	24	41	03	42	23	33
03	00	10	20	30	40	03	12	33	23	42	01	41	24	34	11	04	44	21	31	14	02	13	32	22
04	00	20	40	10	30	04	34	41	11	24	03	22	13	43	32	02	23	12	42	33	01	31	44	14
10	00	01	02	03	04	10	11	12	13	14	20	21	22	23	24	30	31	32	33	34	40	41	42	43
11	00	14	23	32	41	11	30	21	43	03	22	31	10	01	42	33	13	04	40	24	44	02	12	34
12	00	34	13	42	21	12	41	30	01	22	24	02	32	44	10	31	40	11	23	03	43	33	04	20
13	00	24	43	12	31	13	23	04	30	44	21	10	41	33	03	34	02	22	14	40	42	11	20	01
14	00	44	33	22	11	14	02	42	24	30	23	43	04	10	34	32	21	40	01	12	41	20	31	13
20	00	02	04	01	03	20	22	24	21	23	40	42	44	41	43	10	12	14	11	13	30	32	34	31
21	00	22	44	11	33	21	04	32	40	12	42	30	03	24	14	13	41	31	02	20	34	43	10	23
22	00	12	24	31	43	22	40	03	14	34	44	23	30	13	01	11	04	42	20	32	33	21	41	02
23	00	42	34	21	13	23	31	11	02	40	41	04	12	30	22	14	33	20	43	01	32	10	03	44
24	00	32	14	41	23	24	13	40	33	01	43	11	21	02	30	12	20	03	34	44	31	04	22	10
30	00	03	01	04	02	30	33	31	34	32	10	13	11	14	12	40	43	41	44	42	20	23	21	24
31	00	23	41	14	32	31	42	10	22	04	12	44	34	03	20	43	30	02	21	11	24	01	33	40
32	00	13	21	34	42	32	24	44	03	10	14	01	43	20	33	41	22	30	12	04	23	40	02	11
33	00	43	31	24	12	33	10	02	41	21	11	32	20	42	04	44	01	13	30	23	22	34	14	03
34	00	33	11	44	22	34	01	23	10	43	13	20	02	31	41	42	14	24	03	30	21	12	40	32
40	00	04	03	02	01	40	44	43	42	41	30	34	33	32	31	20	24	23	22	21	10	14	13	12
41	00	11	22	33	44	41	03	13	31	20	32	12	01	40	21	23	34	10	04	43	14	30	24	42
42	00	31	12	43	24	42	32	01	20	11	34	40	14	22	02	21	03	33	41	10	13	44	30	04
43	00	21	42	13	34	43	14	20	04	33	31	03	23	11	40	24	10	44	32	02	12	22	01	30
44	00	41	32	23	14	44	20	34	12	02	33	24	40	04	13	22	42	01	10	31	11	03	43	21

According to the addition and multiplication operations above, $(S,\oplus,\otimes)$. is a Cartesian group.

2. THE PLANE P_2S

A finite projective plane of order q has some interesting properties. Here's a concise overview:

There are q^2+q+1 points and the same number of lines in the projective plane of order q.

Each line contains $q+1$ points.

Each point lies on $q+1$ lines.

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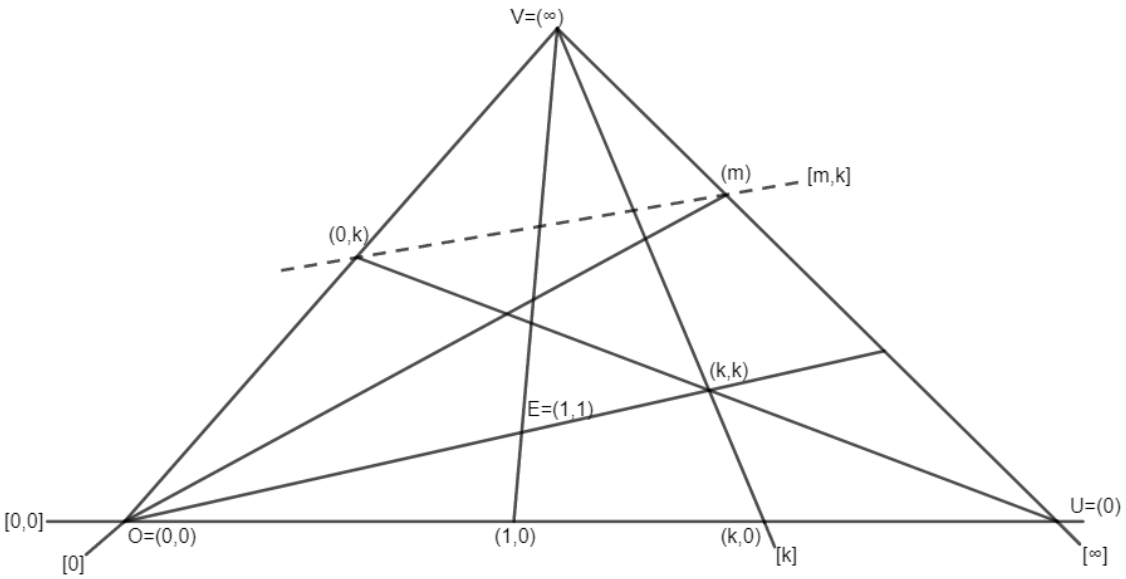
Let $(S,\oplus,\otimes)$. be a Cartesian group. It is given in [1] that the geometric structure defined below with the elements of *S* as points and lines is a projective plane of order 25, denoted by P_2S .

In this type of geometry, the set of points and lines are denoted by

Let's assume the vertices of the regular quadrangle are *O, E, U, V*. The points, lines and the incidence relation on *P* using the set *S* are determined respectively as follows:

$$\{(x,y): x,y \in S\} \cup \{(m): m \in S\} \cup \{(\infty): \infty \notin S\}.$$



and $\{[\boldsymbol{m},\boldsymbol{k}]: \boldsymbol{m},\boldsymbol{k} \in \boldsymbol{S}\} \cup \{[\boldsymbol{a}]: \boldsymbol{a} \in \boldsymbol{S}\} \cup \{[\infty]: \infty \notin \boldsymbol{S}\}$.

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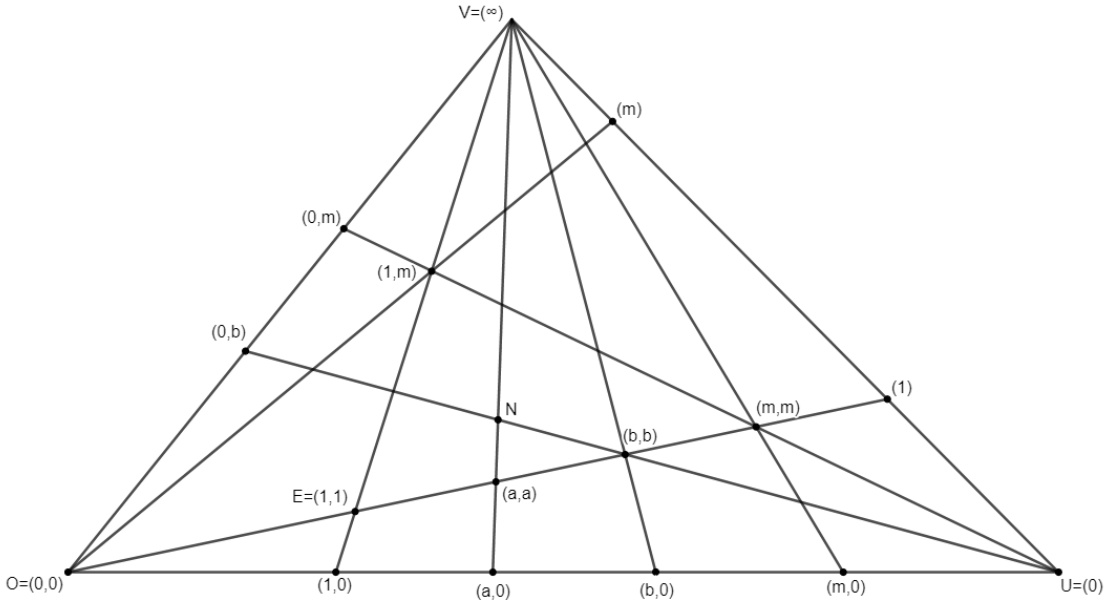

The 625 lines of P_2S having form $\mathrm{y} = \mathrm{m} \otimes \mathrm{x} \oplus \mathrm{k}$ and 25 lines of P_2S having of the form $\mathrm{x} = \mathrm{a}$ are called the affine lines and the unique line [∞] of P_2S is called the ideal line. The system of points, lines and incidence relation given above defines a projective plane of order 25, which is the smallest Cartesian group plane. P_2S.

3. Investigating 3-Nets in the Plane P_2S

In a finite projective plane, 3-nets provide insight into the arrangement of lines and points, as well as the symmetries of the plane. These structures are particularly significant in the study of finite geometries, offering a geometric interpretation of certain algebraic systems.

Definition 4 *(See9,10)* A *projective plane obtained from a field* is called *a field-derived projective plane,* often denoted as *PG*(2,*K*), where *K* is a field.

A 3-net in a projective plane obtained from a field is a pair (A, X) where A is a finite set of lines of projective plane partitioned into 3 subsets $\mathrm{A} = A_1 \cup A_2 \cup A_3$ and X is a finite set of points of projective plane subject to the following conditions:

1-for every $i \neq j$ and every $\ell \in A$i , $\ell' \in A$j , we have $\ell \cap \ell' \in X$
2-for every point $x \in X$ and every i ($i \in \{1, 2, 3\}$) there exists a unique line $\ell \in A$i passing through x, [].

In this section, we provide examples of 3-nets in a projective plane P_2S of order 25, where the underlying algebraic structure is a Cartesian group.

Theorem 5 Let $X_1 = (00,00), X_2 = (10,10), X_3 = (00)$ and $X_4 = (00,\mathrm{cd})$ with $c \neq 0,1 \mathrm{and}\ \mathrm{d} = 0$, be a regular quadrangle in P_2S. (A, X) in $P_2S$is a 3-net where

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$X = \{X_1, X_2, X_3, X_4\}$ is the set of points and
$A = \{l_1 = X_1X_4, l_2 = X_1X_3, l_3 = X_1X_2, l_4 = X_2X_3, l_5 = X_2X_4, l_6 = X_3X_4\}$ is the set of lines.

Proof. Since c and d are elements of F_5 and $c \neq 0,1 \text{and } d = 0$, we need to prove the proof in three steps.

Case 1 If X is the set of points and A is the set of lines given below, then (A, X) is a 3-net in P_2S.

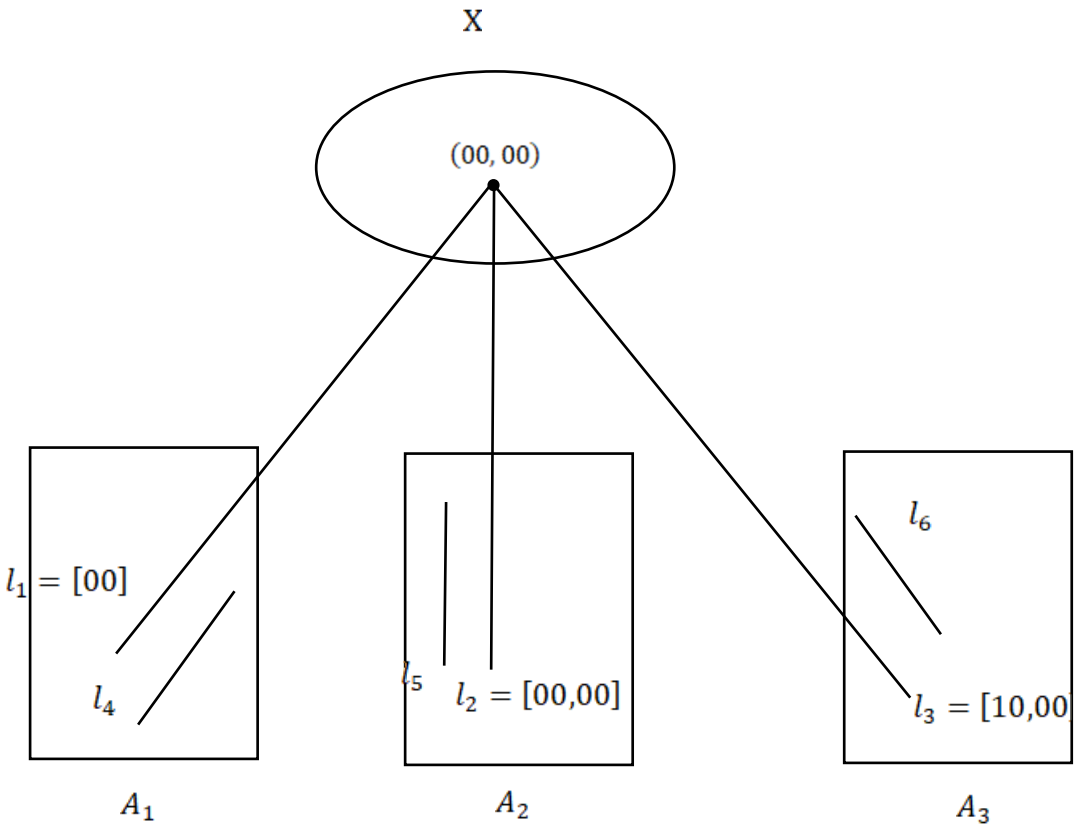
$X = \{(00,00), (10,10), (00), (00,20)\}$and

$A = A_1 \cup A_2 \cup A_3 = \{l_1, l_4\} \cup \{l_2, l_5\} \cup \{l_3, l_6\}$

$$= \{[00], [00, 10)]\} \cup \{[00, 00], [40, 20]\} \cup \{[10, 00], [00, 20]\}.$$

The set of lines A is divided into three subsets, with 2 lines in each. Moreover, from any point selected from the set of points X, only one line passes through each of the subsets Ai, whose unions are the set of lines A. Since this geometric structure is finite, the following configurations for each point can be easily obtained.

If the selected point is **(00,00),** the set of three lines passing through this point is obtained as follows:



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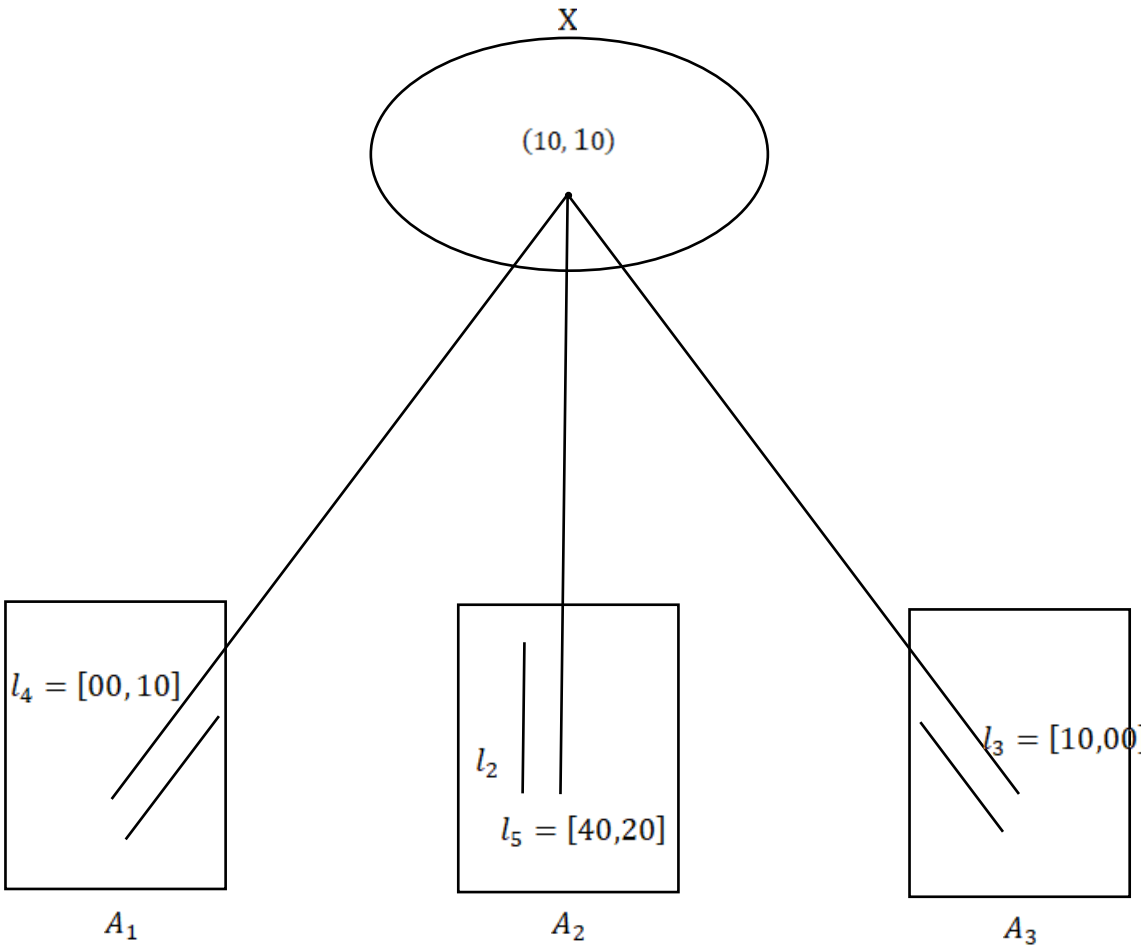
If the selected point is **(10,10),** the set of three lines passing through this point is obtained as follows:



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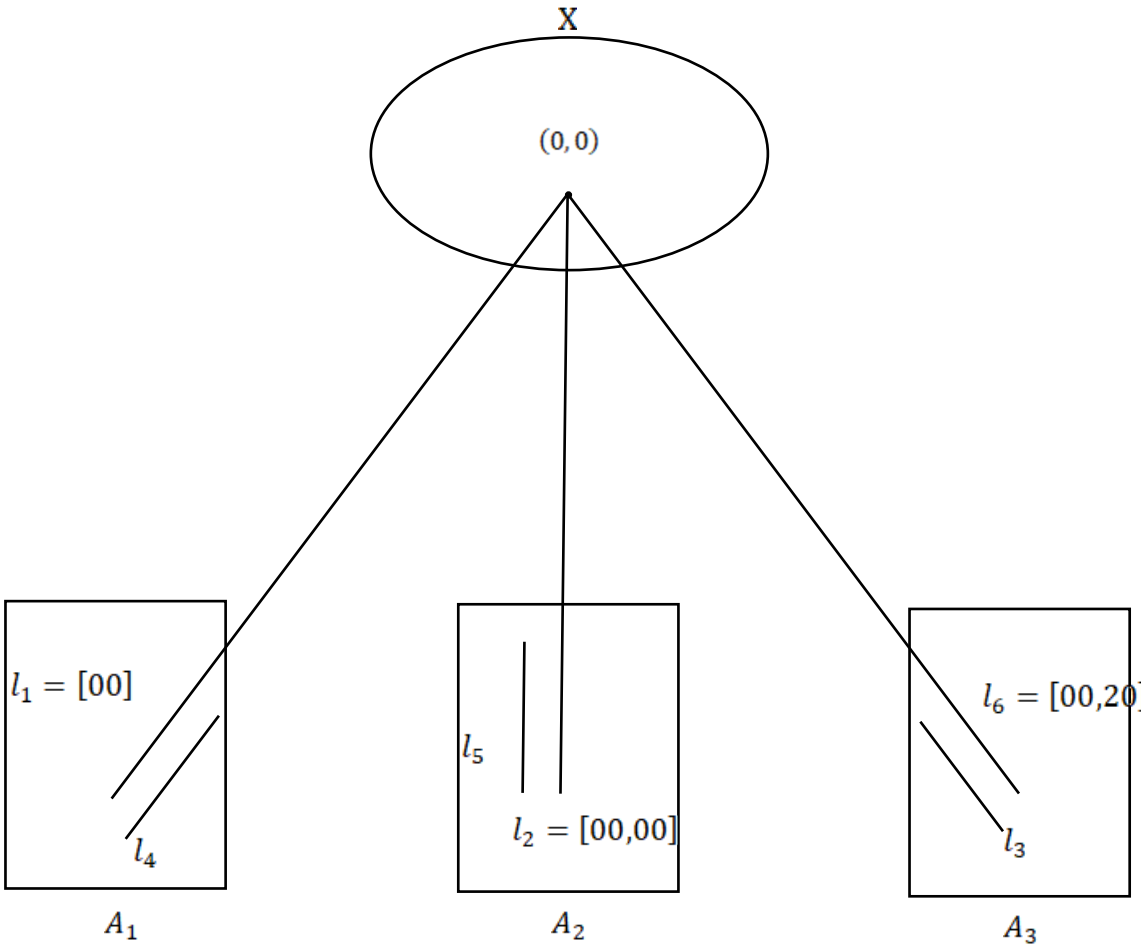
If the selected point is (0,0), the set of three lines passing through this point is obtained as follows:



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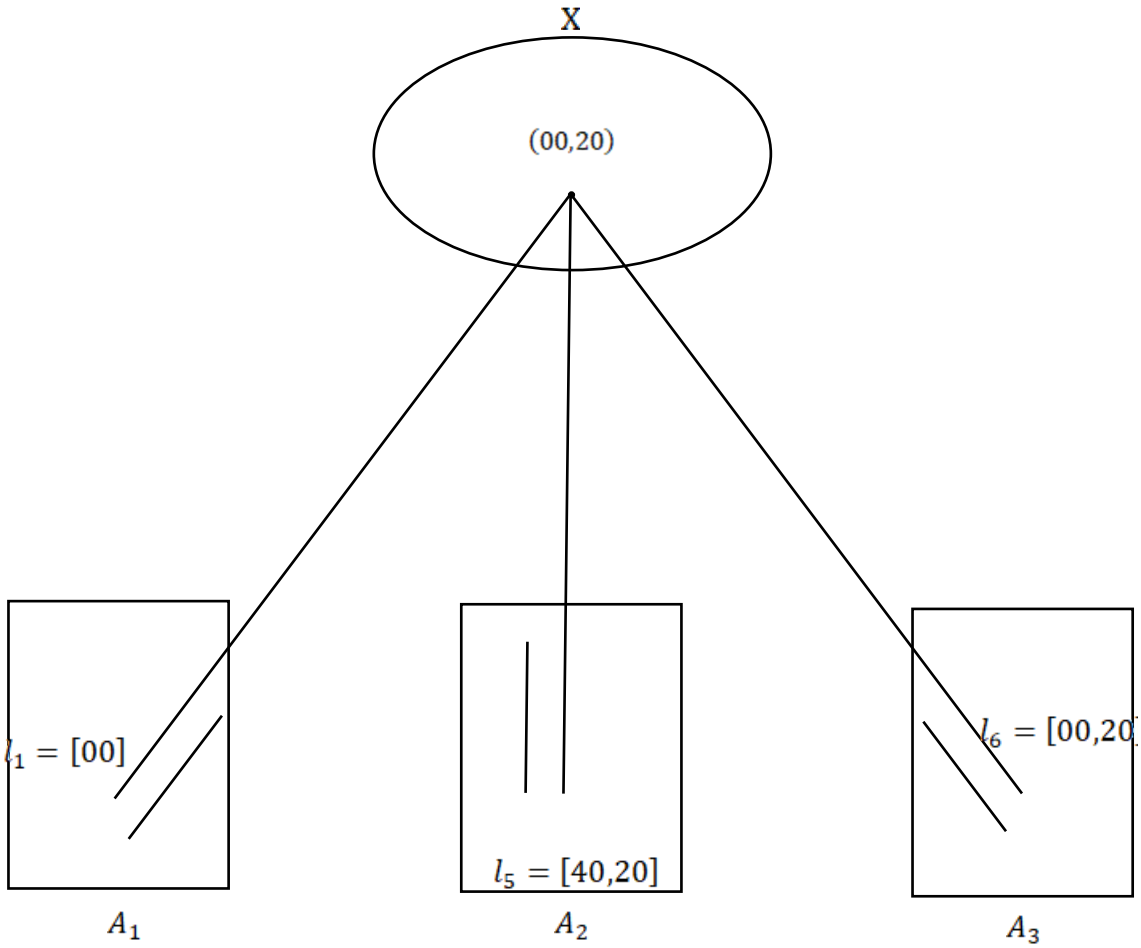
And if the selected point is (00, 20), the set of three lines passing through this point is obtained as follows:



Therefore, the selected (*A, X*) structure within P_2S is 3-net of 2-order.

Case 2 If *X* is the set of points and *A* is the set of lines given below, then (*A*, *X*) is a 3-net in P_2S .

$X = \{(00,00),\ (10,10),\ (00),\ (00,30)\}$

$A = A_1 \cup A_2 \cup A_3 = \{l_1, l_4\} \cup \{l_2, l_5\} \cup \{l_3, l_6\}$

$= \{[00],\ [00, 10)]\} \cup \{[00, 00],\ [30, 30]\} \cup \{[10, 00],\ [00, 30]\}$

If the selected point is (00,00), the set of three lines passing through this point is obtained as follows:

The lines passing through the point $(00,00)$ are l_1, l_2 and l_3.

The lines passing through the point $(10,10)$ are l_3, l_4 and l_5.

The lines passing through the point (00) are l_2, l_4 and l_6 and

The lines passing through the point $(00,30)$ are l_1, l_5 and l_6

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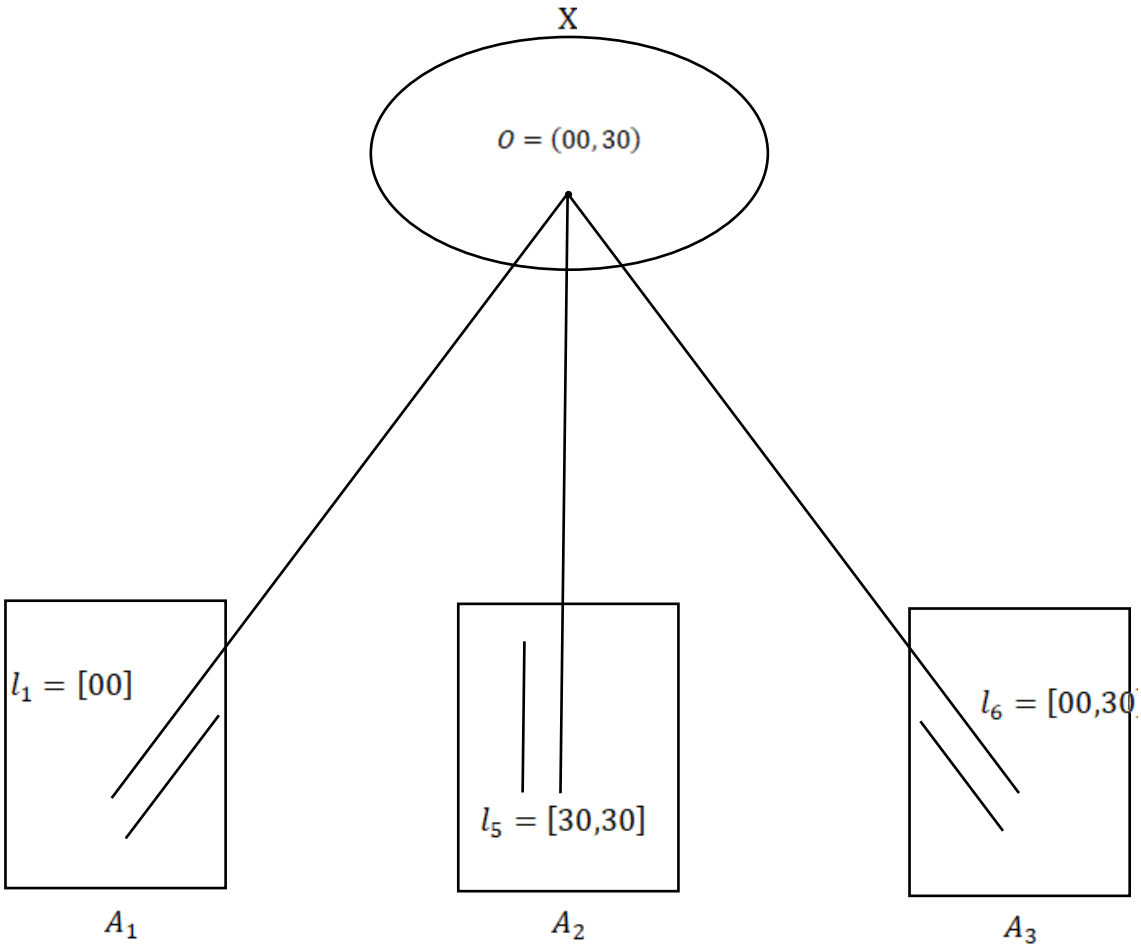

Case 3 If X is the set of points and A is the set of lines given below, then (A, X) is a 3-net in P_2S .

$\mathbf{X} = \{(00,00),\ (10,10),\ (00),\ (00,40)\}$

$A = A_1 \cup A_2 \cup A_3 = \{l_1, l_4\} \cup \{l_2, l_5\} \cup \{l_3, l_6\}$

$= \{[00],[00,10)]\} \cup \{[00,00],[20,40]\} \cup \{[10,00],[00,40]\}$

The lines passing through the point $(00,00)$ are l_1, l_2 and l_3.

The lines passing through the point $(10,10)$ are l_3, l_4 and l_5.

The lines passing through the point (00) are l_2, l_4 and l_6 and

The lines passing through the point $(00,30)$ are l_1, l_5 and l_6

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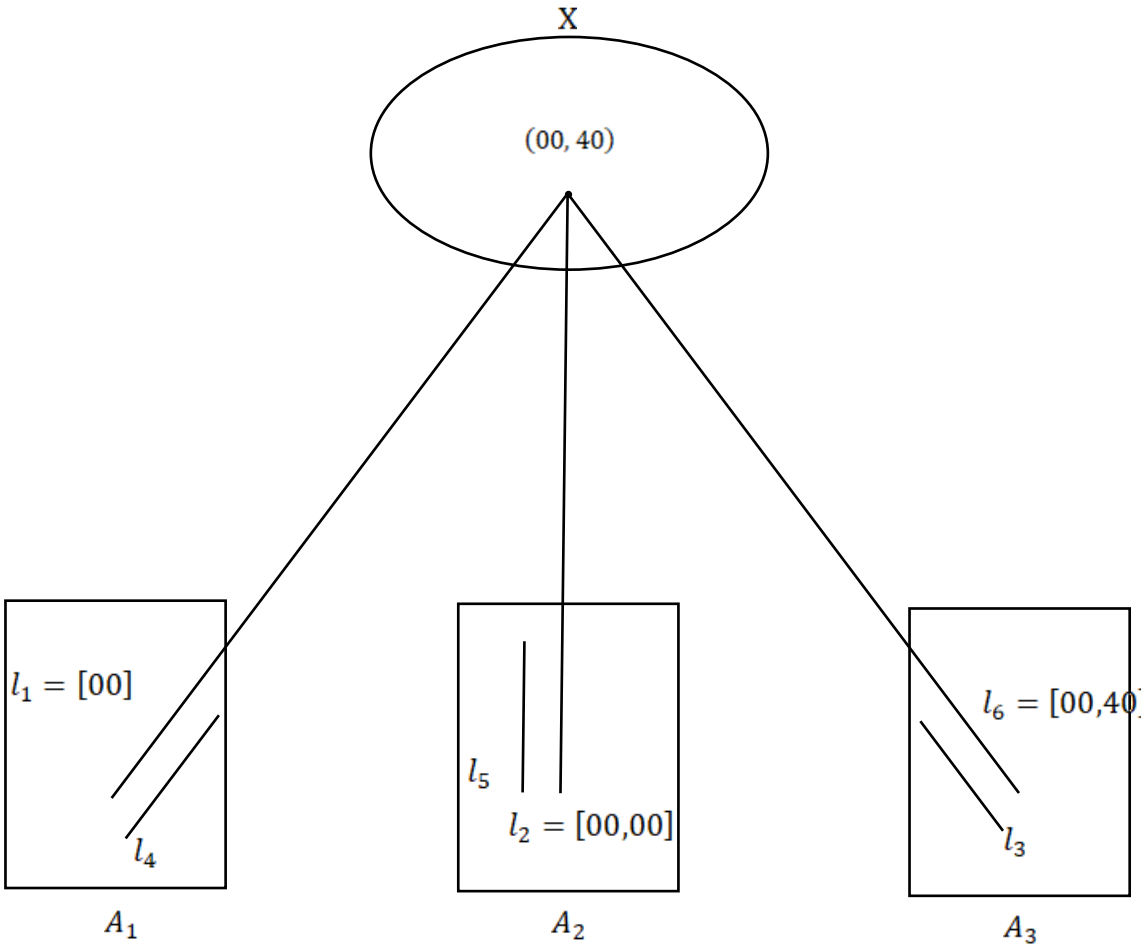

Conclusion

In this paper, we explored the concept of 3-nets within the context of finite projective planes, focusing specifically on a projective plane of order 25 obtained from a Cartesian group structure. By analyzing the geometric and algebraic properties of this plane, we provided examples of 3-nets and demonstrated their utility in understanding the relationship between points and lines in finite geometry.

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A NOTE ON THE CHINESE CHECKERS HYPERSPHERES

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ABSTRACT

The Chinese Checkers distance between the given points $P = (P_1, P_2)$ and $Q = (Q_1, Q_2)$ is defined as $d_C(P,Q) = max\{|P_1 - Q_1|, |P_2 - Q_2|\} + (\sqrt{2} - 1)\, min\{|P_1 - Q_1|, |P_2 - Q_2|\}$.

The geometric location of points in the Chinese Checker plane that are at a fixed Chinese Checker distance from a fixed point is called a Chinese Checker circle. The Chinese Checker sphere is defined as the geometric location of all points $P = (P_1, P_2, P_3)$ equidistant from a given point, called the centre, in a three-dimensional space.

In this study, we have examined the structural properties of Chinese Checker hyperspheres by exploring the relationships between their vertices, edges, and faces within different dimensions.

Chart 1. The properties of circle, sphere and hyper-sphere in Chinese Checkers are as follows:

Number of dimensions	Number of vertices	Number of edges at any vertex	Total number of edges
2	8	2	8
3	10	9	45
4	12	11	66

Utilizing the Chinese Checker distance, we derived formulations for the Chinese Checker circle, sphere and hypersphere highlighting the distinct geometry that emerges from this metric.These structures, particularly the C_3-sphere and C_4-hypersphere, present unique non-Euclidean characteristics, such as deltoidal icositetrahedral and polyhedral configurations with 24 faces. Furthermore, the dimensional cross-sections within these hyperspheres offer a novel perspective on symmetry and distance in non-Euclidean spaces, which may contribute valuable insights into mathematical applications involving alternative distance metrics.

Keywords Chinese Checker distance, Chinese Checker space, C-sphere.

1. INTRODUCTION AND PRELIMINARIES

After Krause introduced taxicab geometry [8], Kaya and her colleagues contributed considerable work on this subject to the literature in [1-4, 6,10]. For the game known as Chinese Checkers, Krause thought that the distance between two points on the game plane should be improved. The Chinese checkers distance between the given points $A = (P_1, P_2)$ and $B = (Q_1, Q_2)$ is defined as

$$d_C = \max\{|P_1 - Q_1|, |P_2 - Q_2|\} + (\sqrt{2} - 1) \min\{|P_1 - Q_1|, |P_2 - Q_2|\}$$

Bayar and Ekmekçi gave the definition and properties of trigonometric functions in the Chinese checkers plane in [5]. Some recent work using Chinese Checkers and maximum distance function can be seen in [5-7, 11].

Mertens [9] also made a study on taxicab hyperspheres.

In this study, we are working on hyperspheres obtained by using the Chinese checker distance in the plane and in space. Now we will recall the Chinese checker circle, the Chinese checker sphere and the Chinese checkers hypersphere and give some of their properties.

2. CHINESE CHECKER CIRCLE, CHINESE CHECKERS SPHERES AND CHINESE CHECKERS HYPER-SPHERES

2.1. CHINESE CHECKERS CIRCLE

A circle can be defined as the geometric location of all points $P = (P_1, P_2)$ equidistant from a certain point called the centre. The geometric place of points in the Chinese Checker plane at a fixed Chinese Checker distance from a fixed point is called the Chinese Checker circle. The fixed point is the centre of the Chinese Checker circle and the fixed Chinese Checker distance gives the radius of the circle.

The Chinese Checker circle with center M=(m_1, m_2) and radius r is represented by the following set

$$C = \{P = (P_1, P_2): d_c(M, P) = r\}$$

That is, this set *C* is a Chinese Checker circle of radius *r* centred *M*

$C = \{(P_1, P_2) : \max\{|P_1 - m_1|, |P_2 - m_2|\} + \sqrt{2} - 1 \min\{|P_1 - m_1|, |P_2 - m_2|\} = r\}$ forms.

The figure of Chinese Checker circle with M(0,0) and radius r is as follows

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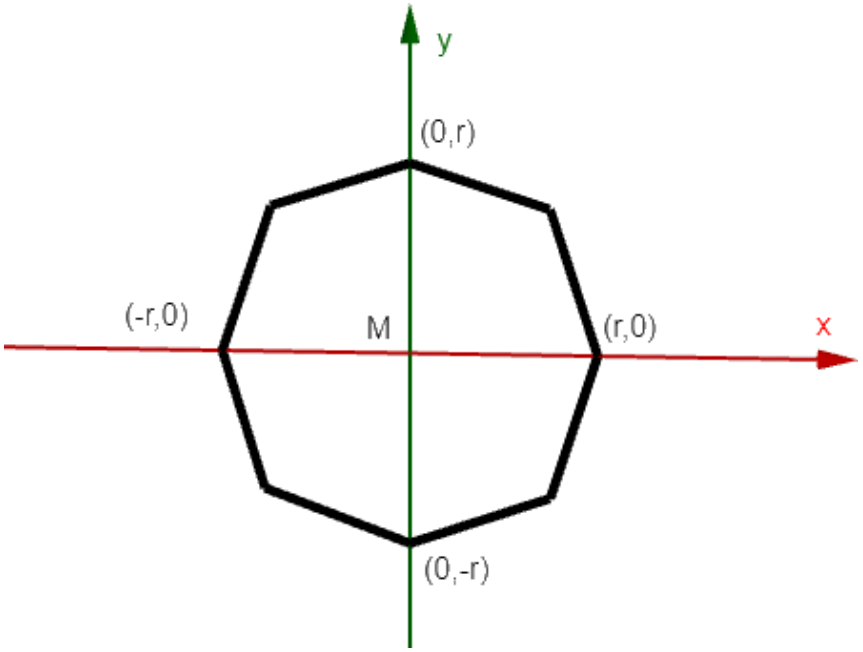

Figure 1. Circle $C = \{(P_1, P_2) : \max\{|P_1|, |P_2|\} + \sqrt{2} - 1 \min\{|P_1|, |P_2|\} = r\}$

A circle can be represented by two vertices on each of the two axes and four vertices taken between the x-y axes. These vertices are located at (±r,0) and (0,±r) on the axes respectively. Each vertex is connected to other vertices. These relations connecting the eight corner points form the edges (discretes) of the Chinese Checker circle.

When the number of corners is eight and the number of sides drawn from each corner is multiplied by two, 8 * 2 = 16. Since each side is counted twice, dividing by two gives 16 / 2 = 8. This shows how many sides the Chinese Checker circle has.

2.2 CHINESE CHECKERS SPHERES

The CC-metric is defined in accordance with the following distance function.

$$d_C(A,B) = d_L(A,B) + (\sqrt{2} - 1)\, d_S(A,B)$$

where

$$d_L(A,B) = \max\{|x_1 - x_2|, |y_1 - y_2|, |z_1 - z_2|\}$$

and

$$d_S(A,B) = \min\{|x_1 - x_2| + |y_1 - y_2|, |x_1 - x_2| + |z_1 - z_2|, |y_1 - y_2| + |z_1 - z_2|\}$$

where $A = (x_1, y_1, z_1)$, $B = (x_2, y_2, z_2)$. In accordance with the definition of d_C – dictance, the shortest path between points A and B can be expressed as the union of three line segments.

Proposition The Chinese Checkers sphere can be defined as a deltoidal icositetrahedron.

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Proff A Chinese checkers sphere, defined as a ball with centre 0 and radius r, in R_c^3 is the set of points (x, y, z) in 3-dimensional space that satisfy the equation

$$\max\{|x|, |y|, |z|\} + (\sqrt{2} - 1)\min\{|x|+|y|, |x|+|z|, |y|+|z|\} = r$$

which is a polyhedra which has 24-faces with vertices.

The Chinese Checkers sphere can be defined as a deltoidal icositetrahedron. A Chinese Checkers sphere (ball) with center 0 and radius r in R_c^3 is the set of points (x, y, z) in the 3-dimensional space satisfying the equation $\max\{|x|, |y|, |z|\} + (\sqrt{2} - 1)\min\{|x|+|y|, |x|+|z|, |y|+|z|\} = r$ which is a polyhedra which has 24-faces with vertices.

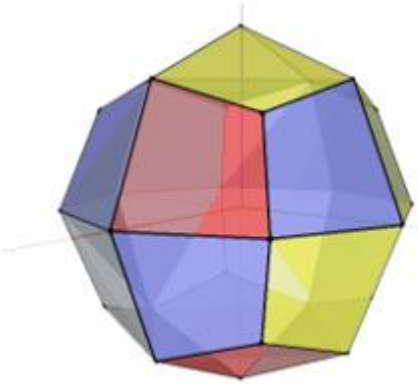

Figure 2(a)

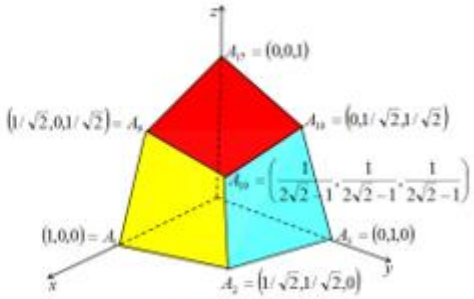

Figure 2(b)

Figure 2(a) and Figure 2(b) show the graph of the CC-sphere and graph of the unit CC-sphere in the first octant, respectively.

CC-unit sphere has 24 deltoidal faces each of which is the part of plane having one of the following equations.

We give a Chinese Checker sphere C_3 as the set of all points, $P = (P_x, P_y, P_z)$ in a three-dimensional space at the same distance from a given point called the central point. As before, the radius is the distance between any point on the Chinese Checker sphere's surface and its centre. It is important to note that the Chinese Checker circle is no longer perceived as a perfect sphere in the conventional sense. Therefore, it is not unexpected that the C_3-sphere would not be spherical. The C_3-sphere has been found to possess eight triangular faces, which collectively form an Euclidean octahedron.

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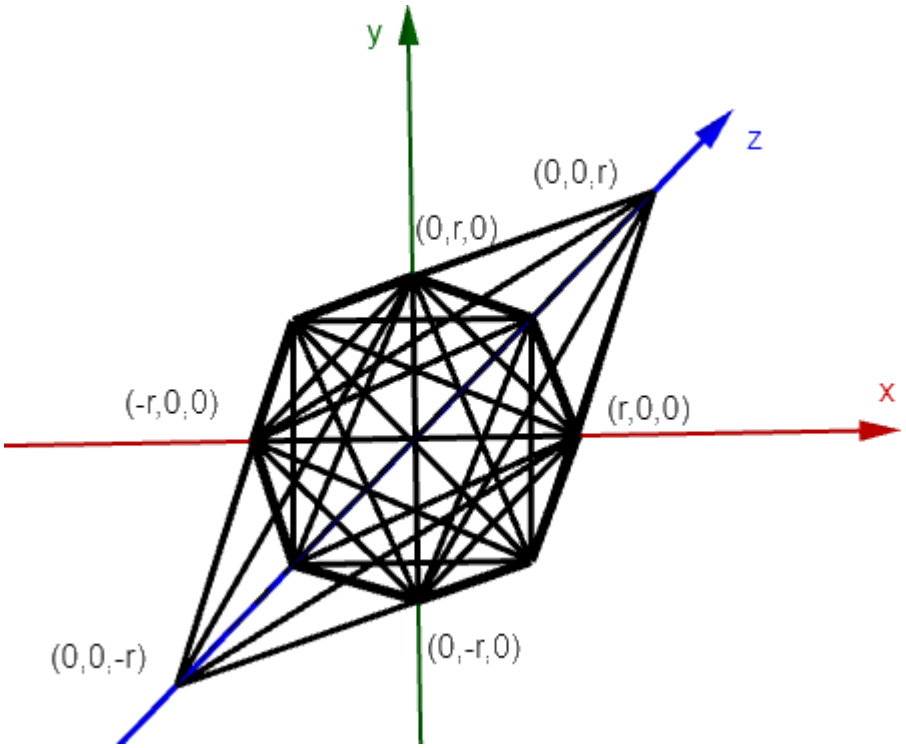

Figure 2. A C_3-sphere with radius r and centre at (0,0,0)

The spherical shape of the surface of a Chinese Checker sphere can be represented by two vertices on each of the three axes and four points between the x-y axes. These vertices are located on the axes at the points (±r, 0, 0,), (0, ±r, 0), (0, 0, ±r) respectively. Given that each vertex is connected to the other vertices, it follows that there are nine line segments at any given vertex. These line segments represent the edges of the sphere, and multiplying the number of vertices, ten, by the number of edges of the Chinese Checker sphere, nine, gives 90. The number of sides on the Chinese Checker sphere can be determined by dividing the sum by two, since each side is counted twice. This gives 45, which represents the number of sides on the Chinese Checker sphere.

2.3. CHINESE CHECKERS HYPER-SPHERES

A Chinese Checker hypersphere C_4 may be defined as the set of all points P, where each of the coordinates P_x, P_y, P_z and P_w is equidistant from a given point designated as the C_4 −sphere's centre. Once more, the radius may be defined as the distance between the centre and any point on the surface of the Chinese Checker hypersphere.

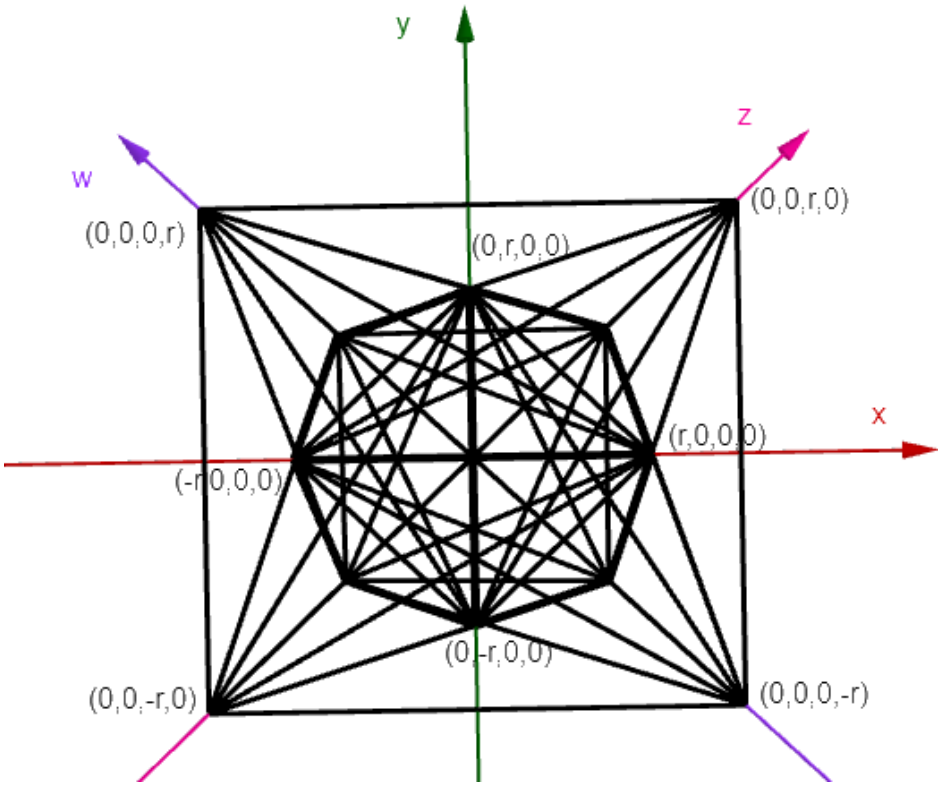

Figure 3. C_4 – hypersphere with center at (0,0,0,0) and radius = r

As with the circle and the sphere, the hypersphere is defined by two vertices on each axis at the points (±r,0,0,0), (0,±r,0,0), (0,0,±r,0), (0,0,0,±r) and four vertices taken between the x-y axes. Figure 3 shows that any vertex has eleven edges coming out of it. This is one less than the number of vertices. When the number of vertices is twelve and the number of edges drawn from each vertex is multiplied by eleven, 12 * 11 = 132. Since each edge is counted twice, dividing by two gives the result 132 / 2 = 66. This shows how many sides the hypersphere has.
It is necessary to ascertain whether the drawing in Figure 3 represents a hyper-sphere. We will now consider the varices cross-sections of the hyper sphere that are related to the coordinate axes.

For the remainder of this paper, it is assumed that the centre is located at the origin, the radius is equal to one, and P is represented by the vector P = (P_x , P_y, P_z, P_w).

2.3.1. C_2 – CROSS-SECTION OF THE CHİNESE CHECKER HYPER-SPHERE

If the centre of the hypersphere is located at the point M = (0,0,0,0) and the point P = (P_x , P_y, P_z, P_w) lies on the x-y section of the hypersphere C_4,
max $\{|P_x|, |P_y|\} + \sqrt{2} - 1$ min $\{|P_x|, |P_y|\}$ =1 and $P_z = P_w = 0$
d_C (P , M) = max $\{|P_x|, |P_y|\} + \sqrt{2} - 1$ min $\{|P_x|, |P_y|\}$ =1
$P_z = P_w = 0$ when max $\{|P_x|, |P_y|\} + \sqrt{2} - 1$ min $\{|P_x|, |P_y|\}$ =1 and point P lies in the x-y plane of the hypersphere.
When $P_z = P_w = 0$, we look at the two-dimensional cross section of the hypersphere.

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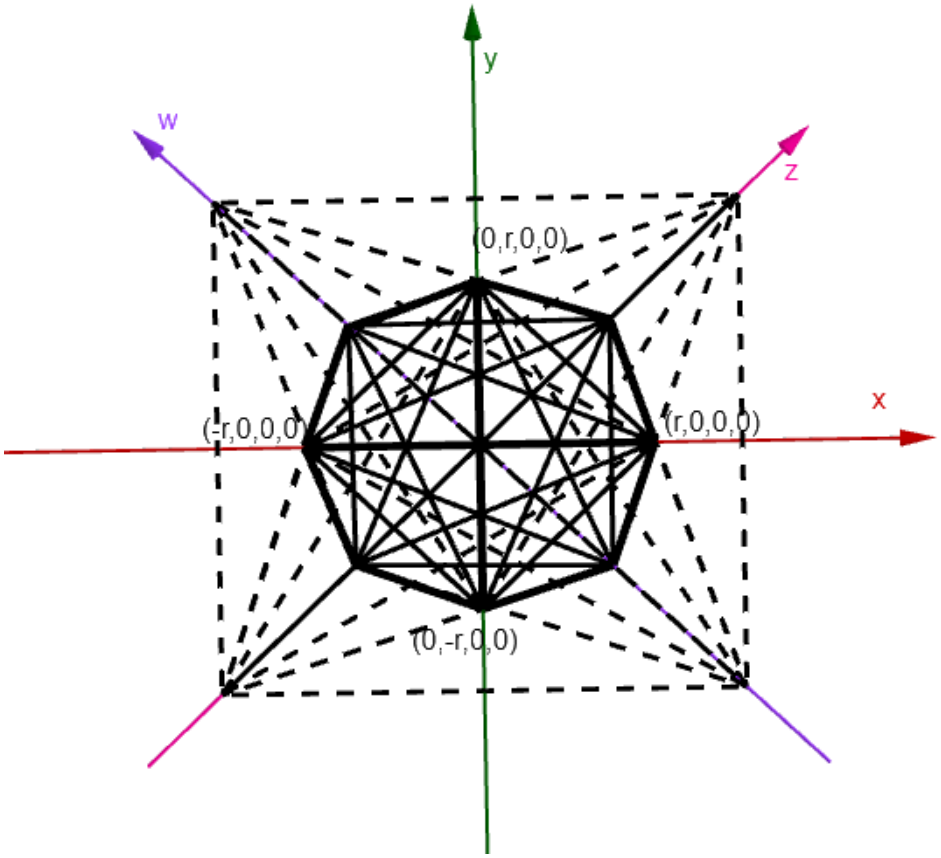

Figure 4. The two-dimensional cross-section in the x-y plane of the C_4-hyper- sphere centred at the origin is depicted.

Please note that Figure 4 depicts one of six possible circles in the hypersphere with respect to the coordinate axes. You can locate five additional two-dimensional cross-sections of the hypersphere related to the coordinate axis.

2.3.2. C_3 – CROSS-SECTION OF THE HYPER-SPHERE

If the centre of the hypersphere is located at the point M = (0,0,0,0) and the point P = (P_x , P_y, P_z, P_w) lies on the x-y-z section of the C_4 hypersphere,

max $\{|P_x|, |P_y|, |P_z|\} + \sqrt{2} - 1$ min $\{|P_x|, |P_y|, |P_z|\} = 1$ and $P_w = 0$

d_C (P , M) = max $\{|P_x|, |P_y|, |P_z|\} + \sqrt{2} - 1$ min $\{|P_x|, |P_y|, |P_z|\} = 1$

$P_w = 0$ when max $\{|P_x|, |P_y, |P_z|\} + \sqrt{2} - 1$ min $\{|P_x|, |P_y|P_z|\} = 1$ and point P lies in the x-y-z plane of the hypersphere.

Note that Figure 5 shows 1 or 4 possible spherical sections or hyperspheres related to the coordinate axes. Can you find the other three spherical cross-sections that relate to the coordinate axes?

Let us look again at the hypersphere, now that we have looked at the two- and three-dimensional cross-sections. It is essential to recall that the cross-sections under consideration originate from

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the origin and are related to the coordinate axes. It is possible to say that p cannot lie on the two or three dimensional surface but must lie in hyperspace if none of P_x, P_y, P_z, P_w is 0.

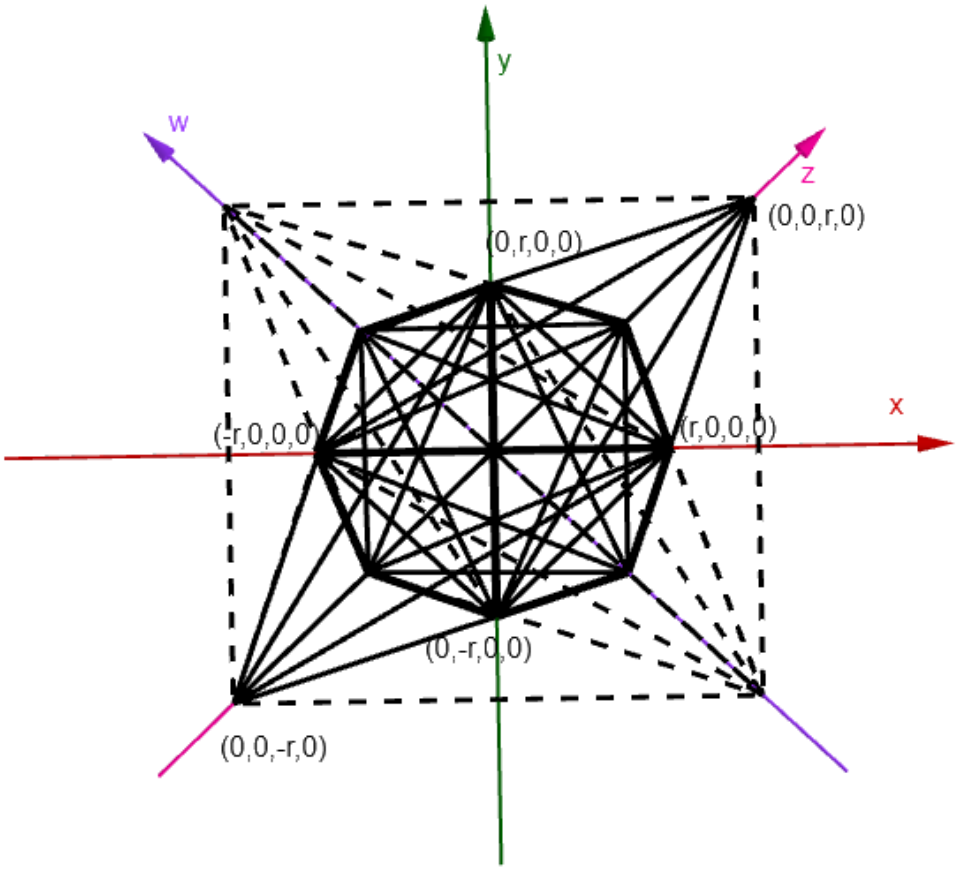

Figure 5. The three-dimensional cross-section of the hyper-sphere, C_4, centred at the origin is presented.

3. CONCLUSION

In this study, we have examined the structural properties of Chinese Checker hyperspheres by exploring the relationships between their vertices, edges, and faces within different dimensions. Utilizing the Chinese Checker distance, we derived formulations for the Chinese Checker circle, sphere, and hypersphere, highlighting the distinct geometry that emerges from this metric. These structures, particularly the C_3-sphere and C_4-hypersphere, present unique non-Euclidean characteristics, such as deltoidal icositetrahedral and polyhedral configurations with 24 faces. Furthermore, the dimensional cross-sections within these hyperspheres offer a novel perspective on symmetry and distance in non-Euclidean spaces, which may contribute valuable insights into mathematical applications involving alternative distance metrics. Future work may focus on extending these findings to other multidimensional spaces or integrating additional geometric functions to expand on the properties of the Chinese Checker spaces and the maximum spaces.

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SEPSİS RİSKİNİN METABOLOMİK ANALİZ İLE ERKEN TESPİTİ

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ÖZET

Amaç: Sepsise bağlı küresel mortalite, yoğun bakım ünitelerinde kabul edilemeyecek kadar yüksek olmaya devam ediyor. Septik hastalarda hayatta kalma ve ölüm arasındaki çeşitli moleküler süreçlerin belirlenmesi daha iyi tedaviye yardımcı olabilir. Sepsisin doğru prognostik değerlendirmesi esasen karşılanmamış bir ihtiyaçtır. Bu çalışmanın amacı gelişmiş makine öğrenimi tekniği aracılığıyla metabolomik profillemeyi kullanarak sepsis riskinin erken tespiti için öngörücü bir model geliştirmektir.

Yöntem: Çalışmada sepsis tanısı alan hastalardan ve sağlıklı kontrollerden alınan kan örneklerinden elde edilen metabolomik veriler kullanıldı. Bu profillere göre sepsis riskini sınıflandırmak için AdaBoost algoritması kullanıldı. AdaBoost modelinin performansı, doğruluk, duyarlılık, F1-skor, negatif tahmin değeri, pozitif tahmin değeri ve seçicilik ölçütleri kullanılarak değerlendirildi.

Bulgular: AdaBoost modeli, sepsis tahmininde 0.900 doğruluk, 0.867 duyarlılık, 0.867 F1-skor, 0.920 negatif tahmin değeri, 0.867 pozitif tahmin değeri ve 0.920 seçicilik ile sağlam bir performans sergiledi. Bu sonuçlar, modelin sağlıklı ve risk altındaki hastalar arasında etkili bir şekilde ayrım yapma konusunda yüksek kapasitesi olduğunu göstermektedir.

Sonuç: Sonuç olarak, bu çalışmanın sepsisin erken teşhisinde klinisyenlere önemli ölçüde destek sağlayacağı düşünülmektedir.

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Anahtar Kelimeler: Sepsis, erken teşhis, metabolomik, AdaBoost.

1. GİRİŞ

Sepsisten kaynaklanan mortalitenin yüksek oranları, terapötik hedefleri temsil edebilecek yeni hastalık biyobelirteçlerinin araştırılmasını zorunlu kılmaktadır. Metabolik değişiklikler sepsiste yeterince araştırılmamış bir patofizyolojik ekseni temsil etmektedir. Dolaşımdaki yüzlerce metabolitin profilinin çıkarılması potansiyel yeni terapötik hedeflerin araştırılmasının yanı sıra klinik risk tahminine yönelik veriye dayalı sistem biyolojisi yaklaşımları için olanaklar sağlamıştır (1, 2).

Yoğun bakım araştırmalarında metabolomiklerin uygulanması son yıllarda artmış olsa da, bu tür yüksek boyutlu verilere yönelik optimal istatistiksel analitik yaklaşımlar, özellikle de hasta sayısı arasında büyük bir dengesizlik olduğunda belirsizliğini koruyor. Lojistik regresyon gibi geleneksel istatistiksel yöntemler, yüksek derecede iç korelasyona (metabolom dahil), eksikliğe, alt sınıf heterojenliğine ve metabolitler ile sonuçlar arasındaki dengesizliğe sahip verilere uygulandığında önemli sınırlamalara sahip olabilir; bunlar yüksek boyutlu insan biyolojik araştırmalarında sık karşılaşılan zorluklardır. Kritik kohortlardaki veriler, yapay zekanın bir alt kümesi olan makine öğrenimini (ML) kullanan analitik yaklaşımlar, bu zorlukların bazılarının üstesinden gelebilir. Bu tür yaklaşımlar yakın zamanda klinik tahmin modelleri oluşturmaya odaklanarak metabolomik verilere başarıyla uygulanmıştır.

Bu çalışmada, ML sınıflandırma algoritmalarından biri olan AdaBoost yardımıyla, kantitatif 1H-NMR teknolojisini kullanarak elde edilen metabolomik profil verilerine dayalı olarak sepsisli hastaları ayırt edebilen bir modelin geliştirilmesi amaçlandı (3).

2. MATERYAL VE YÖNTEM

Veri Seti

Bu çalışmada 25 sepsis hastası ve 14 kontrol olmak üzere toplam 39 olgu değerlendirildi. Kantitatif 1H-NMR teknolojisi kullanılarak sepsisin tespitinde mOCR'nin izole edilmiş trombosit metabolitleri incelendi. Çalışmaya acil servise (AS) başvuran sepsis ve sepsis dışı kontrol hastaları dahil edildi. Acil serviste her katılımcıdan tek seferde trombosit örnekleri alındı. Kontrol grubu cinsiyet ve yaş açısından sepsis kohortuyla eşleştirildi.

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Makine Öğrenmesi Yaklaşımı

İlk olarak kayıp değer problemini gidermek için random forest tabanlı atama yöntemi kullanıldı. Daha sonra makine öğrenmesi sınıflandırma algoritmalarından biri olan AdaBoost modeli oluşturuldu. AdaBoost karar ağacı sınıflandırıcısı son yıllarda en yaygın kullanılan makine öğrenmesi tekniklerinden biridir. Terminal olmayan düğümlerin nitelik testlerini gösterdiği ve terminal düğümlerin karar sonuçlarını sunduğu basit bir yapıyı temsil eden sınıflandırma ağaçları oluşturmak için ağaç benzeri bir hiyerarşiye dayanan bir yöntemdir (3).

Modelin doğrulaması için beş katlı çapraz geçerlik yöntemi kullanıldı. K-katlı çapraz doğrulama, öğrenme algoritmalarını değerlendirmek ve karşılaştırmak için kullanılan istatistiksel bir yöntemdir; k-katlı çapraz doğrulamada, veriler ilk önce her biri diğerlerine eşit veya eşit olmaya çok yakın bir boyuta sahip olan k katlara bölünür (4). Bunu takiben, her yinelemede, verinin farklı bir katı doğrulama için tutulacak ve geri kalan k katı öğrenme için kullanılacak şekilde gerçekleştirilir. Modelin performansı doğruluk, duyarlılık, F1-skor, negatif tahmin değeri, pozitif tahmin değeri ve seçiçilik metrikleri ile değerlendirilmiştir.

Doğruluk: Doğruluk, bir sınıflandırma modelinin doğru sınıflandırma oranını ifade eder. Doğruluk puanı, doğru tahmin edilen örneklerin toplam örnek sayısına oranı olarak hesaplanır. Ancak sınıfların dengesiz olması veya yanlış sınıflandırma maliyetleri durumunda doğruluk puanı tek başına yetersiz olabilir ve diğer ölçütlerle birlikte değerlendirilmelidir.

Duyarlılık: Geri çağırma puanı, gerçek pozitiflerden (Gerçek Pozitif) kaçının doğru tahmin edildiğini ifade eder. Geri çağırma puanı, yanlış negatif sayısının (Yanlış Negatif) toplam gerçek pozitif sayısına (Doğru Pozitif + Yanlış Negatif) oranı olarak hesaplanır. Geri çağırma puanı ne kadar yüksek olursa, model gerçek pozitifleri o kadar iyi yakalar.

F1 skor: F1 skoru, kesinlik ve hatırlama puanlarının harmonik ortalaması alınarak hesaplanır. Kesinlik ve hatırlama puanları arasındaki dengeyi sağladığı için harmonik ortalamaya tercih edilir. F1 puanı ne kadar yüksek olursa, model hem yüksek hassasiyet hem de yüksek duyarlılık ile o kadar yüksek sınıflandırma yapar.

Negatif Tahmin Değeri: Bir sınıflandırma modelinin negatif olarak tahminlediği durumların gerçekten negatif olduğunu ne ölçüde doğru tahmin ettiğini ifade eden bir performans ölçütüdür. Bu ölçüt, modelin tüm negatif tahminler içerisinde doğru olarak tahmin edilen negatif vakaların oranını belirtir.

Pozitif Tahmin Değeri: Modelin pozitif olarak tahmin ettiği durumların gerçekten pozitif olduğunu ne ölçüde doğru tahmin ettiğini gösteren bir metriktir. Bu değer, modelin yapmış olduğu pozitif tahminler arasından, doğru olarak saptanan pozitif vakaların yüzdesini yansıtır.

Seçicilik: Bir sınıflandırma modelinin gerçek negatif durumları ne kadar doğru bir şekilde negatif olarak sınıflandırdığını gösteren bir ölçüttür. Bu ölçüt, modelin tüm gerçek negatif vakaları doğru bir şekilde negatif olarak ayırt etme yeteneğini değerlendirir. Seçicilik, modelin negatif sınıfı ne derece başarılı bir şekilde tanıyabildiğini anlamak için kullanılır.

4. BULGULAR

Bu çalışmada, metabolomik biyobelirteçler kullanılarak sepsis tahmini için AdaBoost modeli 5 katlı çapraz geçerlik yaklaşımına dayalı olarak oluşturulmuştur (5). Model, %90 doğruluk oranı ile sağlam bir performans göstermiştir. Duyarlılık ve F1-skoru değerleri %86.7 olarak hesaplanmıştır, ve bu sonuçlarda modelin pozitif sepsis vakalarını doğru bir şekilde tanımlamada yüksek bir performansa sahip olduğunu ifade etmektedir. Negatif tahmin değeri %92 iken, pozitif tahmin değeri %86.7 olarak bulunmuştur. Bu değerler, modelin pozitif (sepsis) ve negatif (sağlıklı kontrol) sınıfları doğru tahmin etme yeteneğinin oldukça yüksek olduğunu göstermektedir.

Tablo 1. AdaBoost modelinin Sepsis tahminine ilişkin performans ölçütleri sonuçları

Metrik	Değer
Doğruluk	0.900
Duyarlılık	0.867
F1-skor	0.867
Negatif tahmin değeri	0.920
Pozitif tahmin değeri	0.867
Seçicilik	0.920

Sepsisin metabolomik biyobelirteçlerinin önemlilik dağılımını gösteren grafik Şekil 1'de sunulmaktadır. Grafikte, metabolitlerin önemlilik değerlerine göre sıralanmaktadır. Şekil 1'e göre, Offosfoetanolamin, karnitin ve glutamat metabolitleri en yüksek önemlilik değerlerine sahip olup sepsisinin en önemli biyobelirteç günleri olarak belirlenmiştir.

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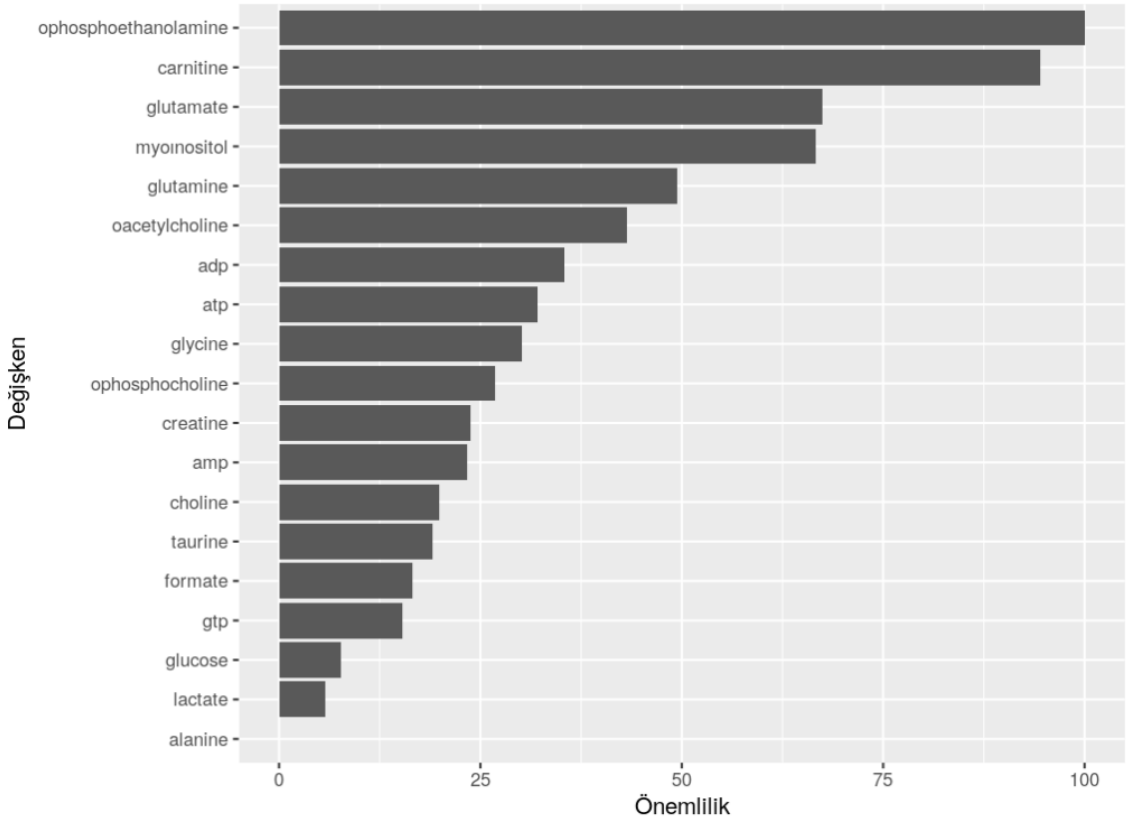

Şekil 1. Sepsisin metabolomik biyobelirteçlerinin önemlilik grafiği

5. SONUÇLAR

Sepsisin tanı ve tedavisindeki temel zorluk patogenezinin tam olarak belli olmamasıdır (6). Sepsis ile ilgili önceki çalışmalar esas olarak genomik ve transkriptomik üzerine odaklanmıştır. Sepsis tanısına yönelik spesifik klinik göstergelerin bulunmaması nedeniyle bu hastalığın ölüm oranı çok yüksektir. Sepsis meydana geldiğinde vücudun hipermetabolik bir durumda olduğu ve üç ana besin maddesi olan şeker, protein ve lipitlerin hepsinin vücutta yapısal değişikliklere uğradığı ve tek bir biyobelirtecin hastalığın teşhisi ve değerlendirilmesi için ideal olmadığı gösterilmiştir (7). Bu çalışmada metabolomik biyobelirteçler kullanılarak sepsis başarılı bir şekilde tahmin edildi. Bu metabolitler terapötik hedeflerin taranması ve sepsisin hedefe yönelik tedavisi için faydalı olabilir (1). Ek olarak AdaBoost modeli sepsis tahmininde etkili bir performans sergiler ve klinik uygulamalarda potansiyel olarak kullanılabilir (2, 8).

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CONSTRUCTION OF MACHINE LEARNING-BASED PREDICTION MODEL FOR PREDICTING VOICE CHANGES ASSOCIATED WITH PARKINSON'S DISEASE

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ABSTRACT

Objective: The objective of this study was to use machine learning (ML) techniques to categorize and predict voice changes related to Parkinson's disease (PD).

Method: The study uses a dataset of audio recordings from individuals with and without Parkinson's disease (PD). This dataset consists of 31 individuals, 23 of whom have Parkinson's disease. Each column is a specific sound measure and each row consists of 195 voice recordings of these individuals. The dataset was obtained from 23 individuals with PD and 184 rows by using the autocoder method, which is one of the data dimensionality reduction methods. 5-fold cross validation based on ML method was used using 20 variables found significant by applying variable selection with the Least Absolute Shrinkage and Selection Operator (LASSO) regression method to the dimensionally reduced dataset. The Extreme Gradient Boosting (XGBoost) model was evaluated for PD classification using various performance measures such as accuracy, balanced accuracy, sensitivity, specificity, positive predictive value, negative predictive value, and F1-score.

Results: The accuracy, balanced accuracy, sensitivity, specificity, positive predictive value, negative predictive value, and F1-score obtained from the XGBoost algorithm were calculated as 0.923, 0.965, 0.993, 0.698, 0.914, 0.968, and 0.952 respectively.

Conclusion: The XGBoost model achieved a correct classification rate of 92.3% on the biomedical voice measurement dataset for PD. This high accuracy indicates that voice recordings are a valuable and non-invasive diagnostic tool for PD, underscoring their clinical significance.

Keywords: Parkinson disease, voice measure, machine learning, XGBoost

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1. INTRODUCTION

Parkinson's disease (PD), the second-fastest-growing neurological disorder globally after Alzheimer's disease, primarily affects middle-aged and older adults, with an estimated 12 million affected by 2040 due to the aging global population (1). Both genetic and environmental variables have a role in the intricate and poorly understood pathophysiology of PD. The disease's primary symptom is the progressive death of dopaminergic neurons in the brain's basement membrane region, which causes the recognizable motor signs and symptoms. But it's difficult to diagnose these symptoms early because they usually don't show up until after severe damage has taken place. Developing successful treatment plans and enhancing patient outcomes depend on early identification of PD. More precise and timely diagnosis may be possible thanks to recent developments in biomarker research, neuroimaging, and ML methods for clinical and biological data analysis (2).

PD suffers from a range of motor and non-motor impairments, including problems with walking, sleeping, and speaking. Recent evidence suggests that speech changes may occur up to a decade before the cardinal motor symptoms of PD become apparent. Consequently, assessing these speech changes may be effective in facilitating early diagnosis. Typically, PD diagnosis relies heavily on empirical assessment of visible symptoms, highlighting the need for methods to identify prodromal PD indicators. This opens up interesting opportunities for ML-assisted pre-diagnosis in telehealth (3). Including cutting-edge technologies in diagnostic methods should greatly improve early diagnosis, given the high prevalence of these speech disorders. For example, machine learning-equipped remote monitoring systems can identify small changes suggestive of PD in voice data long before other symptoms manifest. Furthermore, sensor-based technologies have the ability to continuously monitor speech and motor skills, giving important information for early intervention tactics (4).

Patients with vocal issues are greatly affected, and acoustic equipment can test voice function objectively. Disorders of the sustained vowels cause a variety of symptoms, such as breathiness and virtually periodic vibrations to extremely complex, aperiodic patterns. These disorganized noises have been shown to exhibit significant nonlinear and non-Gaussian random properties through modeling and research utilizing surrogate data (5). This study aims to construct an ML model that can reliably diagnose PD by successfully predicting PH based on a speech recording dataset.

2. MATERIAL AND METHOD

The dataset of voice characteristics of PD patients was obtained from the open access website https://www.kaggle.com/datasets/jainaru/parkinson-disease-detection. It consisted of 195 samples, including 147 (75.4%) with PD and 48 (24.6%) without PD. The Lasso regression variable selection method was applied to the PD voice recording dataset. After variable selection, 182 samples were obtained, including 139 (76.4%) with PD and 43 (23.6%) without PD, and the XGBoost algorithm was used for correct classification.

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2.1.XGBoost algorithm

XGBoost has been applied recently in a number of fields, including credit scoring and energy healthcare (6). boosting model is incorporated into the algorithm known as XGBoost, which was created (7). The goal function uses normalization to speed up learning, prevent overfitting, and lower model complexity. Most notably, XGBoost is an ensemble model that outperforms stand-alone methods in prediction. It is created by effectively applying decision trees to create a cohesive model (8).

3. RESULTS

The performance metrics of the XGBoost model in the test set are given in Table 1. The values of accuracy, balanced accuracy, sensitivity, specificity, positive predictive value, negative predictive value and F1-score obtained from the XGBoost algorithm are 0.923, 0.965, 0.993, 0.698, 0.914, and 0.968 respectively.

Table 1. Performance Metrics for XGBoost Model

Metrics	Value
Accuracy	0.923
Sensitivity	0.965
Specificity	0.993
PPV	0.698
NPV	0.914
F1-Score	0.968

PPV: Positive predictive value; NPV: Negative predictive value

4. DISCUSSION

PD currently has no known cure, and available therapies can be quite expensive. Currently, early detection of the illness lowers expenses while also improving treatment outcomes. One approach that shows promise for early detection is voice analysis. Voice abnormalities can be observed prior to the onset of Parkinson's disease motor symptoms, such as tremor and slowness of movement. The likelihood of an early diagnosis rises as a result. ML technologies improve the results of voice analysis. These methods involve comparing patient voice recordings with healthy individual voice recordings. ML algorithms use speech distortions (such as tremor, softness, monotony) to determine the likelihood of Parkinson's disease (9).

Voice recording data from biomedical voice measurement of PD can be used in clinical decision support systems built by ML algorithms for early and effective detection. Therefore, voice measurements of 182 patients with and without PD, mean vocal fundamental frequency variables such as maximum and minimum vocal fundamental frequency, and various measures of variation in fundamental frequency, were analyzed. The prediction performance of the ML model for accurate classification is realized. Therefore, the LASSO variable selection method

was used first. Then, the prediction model was created with the XGBoost algorithm and evaluated with comprehensive performance criteria. The accuracy, balanced accuracy, sensitivity, specificity, positive predictive value, negative predictive value, and F1-score values. criteria obtained from the XGBoost algorithm were calculated as 0.923, 0.965, 0.993, 0.698, 0.914, 0.968 and 0.952, respectively. The developed model may help clinicians by shortening the clinical decision-making process and treatment initiation in patients with PD.

5. CONCLUSION

As a result, the proposed ML model approach can be used for rapid preliminary diagnosis in individuals with PD in the voice recording dataset to accurately diagnose PD. Therefore, the proposed XGBoost algorithm can also be used for prediction of other diseases.

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DEEPDENT OTOMATİK ÖNGÖRÜ YÖNTEMİNİN AYLIK TUFE ÖNGÖRÜSÜ İÇİN PERFORMANSININ ARAŞTIRILMASI

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ÖZET

Derin yapay sinir ağları öngörü probleminin çözümünde sıklıkla kullanılmaktadır. Fiyat endekslerinin tahmininde makine öğrenmesi yöntemlerinin başarılı sonuçlar üretmesi, derin yapay sinir ağlarının da bu alanda öngörü performansı üzerinde merak uyandırmaktadır. Bu çalışmada aylık tüketici fiyat endeksi zaman serisinin derin yapay sinir ağı olan DeepDenT'e dayalı otomatik öngörü yönteminin performansı klasik zaman serisi yöntemleri ile karşılaştırılmıştır.

Anahtar Kelimeler: Derin Öğrenme, Yapay Sinir Ağı, Tüketici Fiyat Endeksi, Öngörü

1. GİRİŞ

Tüketici fiyat endeksi öngörüsü, öngörü yöntemlerinin kullanıldığı bir alandır. Bu alanda birçok çalışma yapılmaktadır. Köse ve ark. (2000) VAR modellerini, Domaç (2003) AR1MA modellerini, Kızılkaya (2007) yapay sinir ağları ve ARIMA modellerini, Erilli ve ark. (2010) ileri ve geri beslemeli yapay sinir ağlarının bir melez yaklaşımını, Liliana (2012) YSA modelini kullanmıştır.

Zaman serisi öngörü probleminde son yıllarda derin öğrenme yöntemlerinin popüler olduğu görülmektedir. En popüler derin geri beslemeli sinir ağı Hochreiter ve Schmidhuber (1997) tarafından önerilen uzun kısa süreli hafızalı (LSTM) yapay sinir ağlarıdır. Zhang vd. (2017) kısa vadeli yük tahmini için, Kong vd. (2017) kısa vadeli konut yük tahmini için, Elsaid

vd. (2018) türbin motoru titreşimini tahmin etmek için, Chung ve Shin (2018) borsa tahmini için ve Yuan vd. (2018) aylık akış tahmini için LSTM yapay sinir ağlarını kullanmışlardır. LSTM yapay sinir ağından farklı bir mantık ile çalışan derin bir yapay sinir ağı DEEPDENT Egrioglu ve Bas (2024) çalışmasında önerilmiştir. DEEPDENT derin yapay sinir ağı yine aynı çalışmada önerilen dentritik hücre yapısına dayalı olarak çalışmaktadır. Bu çalışmada Tüketici fiyat endeksi (TUFE) öngörüsü için DEEPDENT yapay sinir ağı için oluşturulan otomatik öngörü yönteminin performansı araştırılmıştır.

Çalışmanın ikinci bölümünde DEEPDENT için oluşturulan otomatik öngörü yöntemi tanıtılmıştır. Üçüncü bölümde TUFE öngörüsü için yöntemin uygulanmasından elde edilen sonuçlar sunulmuştur. Son bölümde ise elde edilen sonuçlar tartışılmıştır.

2. DEEPDENT İÇİN OTOMATİK ÖNGÖRÜ YÖNTEMİ

DEEPDENT yapay sinir ağının öngörü problemi için otomatikleştirilmesi, uygulamacılar tarafından daha sık tercih edilir olmasını sağlamaktadır. Kişisel kararlar yerine objektif kararlara bağlı öngörü elde edilebilmesi de diğer bir avantajdır. Otomatik DEEPDENT algoritmasının adımları aşağıda sunulmuştur.

Algoritma 1. DEEPDENTE dayalı otomatik öngörü yöntemi algoritması

Adım 1. Yöntemin aşağıda verilen hiper parametre ve hiper parametrelerin alabileceği en düşük ve en yüksek değerler belirlenir.

- Minimum ve Maksimum Gizli Tabaka Sayısı
- Her bir hücredeki Minimum ve Maksimum Dendritik hücre sayısı m_{min} ve m_{max}
- Minimum ve maksimum zaman adımlarının sayısı: h_{min} ve h_{max}
- Rastgele başlangıç ağırlıkları için tekrar sayısı: n_{repeat}
- Eğitim, geçerlilik ve test kümesi için öğrenme örnekleri sayıları: n_{train}, n_{val} ve n_{test}
- Zaman serisinin periyodu: s
- Bootstrap tekrar sayısı: n_{bst}
- Öngörü sayısı: n_f

Adım 2. Zaman serisi eğitim geçerlilik ve test kümesi olarak aşağıdaki gibi üç kümeye ayrılır. Orijinal zaman serisi X_t toplam n gözlemden oluşmaktadır.

$$X_t = \{x_1, x_2, \dots, x_n\} \tag{1}$$

Zaman serisinin eğitim verisi ilk n_{train} gözlemden oluşan X_t^{train} zaman serisidir. Burada $n_{train} < n$ olmaktadır.

$$X_t^{train} = \{x_1, x_2, \dots, x_n\} \tag{2}$$

Zaman serisinin geçerlilik kümesi $n_{train} + n_{val} < n$ olmak üzere blok yapıda olarak aşağıda verilen gözlemlerden seçilir.

$$X_t^{val} = \{x_{n_{train}+1}, x_{n_{train}+2+}, \dots, x_{n_{train}+n_{val}}\} \tag{3}$$

Son olarak zaman serisinin test kümesi $n_{train} + n_{val} + n_{test} = n$ olmak üzere blok yapıda olarak aşağıda verilen gözlemlerden seçilir.

$$X_t^{test} = \{x_{n_{train}+n_{val}+1}, x_{n_{train}+n_{val}+2+}, \dots, x_n\} \tag{4}$$

Adım 3. Zaman serisi durağanlaştırılır. Durağanlaştırma işlemi için ilk adımda mevsimsellik sınaması gerçekleştirilir. Zaman serisindeki mevsimselliğin belirlenmesinde Eşitlik (5) ile verilen koşul kontrol edilir.

$$|ACF_m| > 1.645\sqrt{\frac{1+2(ACF_1+\sum_{i=2}^{m-1} ACF_i^2)}{n}} \tag{5}$$

Eşitlik (5) sağlanıyor ise zaman serisinin mevsimsellik içerdiği kabul edilerek Eşitlik (6) ile $D = 1$ alarak mevsimsel fark alma işlemi uygulanır. Aksi halde $D = 0$ olduğundan herhangi bir işlem uygulanmaz.

$$z_t = (1 - B^s)^D x_t \tag{6}$$

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İkinci adımda mevsimsel açıdan durağanlaştırıldığı kabul edilen seriye "Augmented Dickey Fuller" testi uygulanarak zaman serisinde birim kök varlığı araştırılır. Eğer zaman serisi birim kök içeriyor ise $d = 1$ alınarak Eşitlik (7) ile fark alma işlemi uygulanır. Aksi halde $d = 0$ alınarak fark alma işlemi uygulanmaz.

$$w_t = (1 - B)^d z_t \tag{7}$$

Adım 4. Zaman serisi için kısmi otokorelasyon katsayıları $r_{kk}, k = 1,2, \dots, nlag$ ve güven aralıkları hesabı için kısmi otokorelasyon katsayılarının varyansları hesaplanır.

$$r_k = \frac{\frac{1}{n_{trn}-k}\sum_{t=k+1}^{n_{trn}}(x_t-\bar{x})(x_{t-k}-\bar{x})}{\frac{1}{n_{trn}}\sum_{t=1}^{n_{trn}}(x_t-\bar{x})^2} \tag{8}$$

$$r_{kk} = \frac{r_k-\sum_{j=1}^{k-1} r_{k-1,j} r_{k-j}}{1-\sum_{j=1}^{k-1} r_{k-1,j} r_j} \tag{9}$$

$$V(r_{kk}) = \frac{1}{n_{trn}} \tag{10}$$

$\pm 2\sqrt{V(r_{kk})}$ sınırları dışında kalan kısmi otokorelasyon katsayılarına karşılık gelen gecikmeler belirlenir. Bu gecikmeler $LagK$ kümesinin elemanlarını oluşturur. $LagK$ kümesinin üyelik fonksiyonu $k = 1,2, \dots, nlag$ olmak üzere Eşitlik (11) ile verilmiştir.

$$\mu_{LagK}(k) = \begin{cases} 1, & Eğer\ \ r_{kk} > 2\sqrt{V(r_{kk})}\ veya\ r_{kk} < -2\sqrt{V(r_{kk})} \\ 0, & d.d. \end{cases} \tag{11}$$

Adım 5. Tüm mümkün hiper parametre değerleri için Adım 5.1 ve 5.2 uygulanarak geçerlilik ve test kümesi performansları hesaplanır. Mümkün hiper parametre setleri $q \in [q_{min}, q_{max}]$, $m \in [m_{min}, m_{max}]$, $h \in [h_{min}, h_{max}]$ kümelerinden alınan elemanların farklı kombinasyonları olmak üzere toplam $(q_{max} - q_{min} + 1) \times (m_{max} - m_{min} + 1) \times (h_{max} - h_{min} + 1)$ tane olmaktadır.

Adım 5.1. Rastgele başlangıç ağırlıklarının kümesi n_{repeat} kez rastgele olarak oluşturulur.

Adım 5.2. Her bir rastgele başlangıç ağırlığı seti için Adım 5.2.1 ve Adım 5.2.3, n_{repeat} kez uygulanır.

Adım 5.2.1. Mevcut hiper parametre seti (m, q, h) ve girdi olarak $LagK$ kümesine göre oluşturulan gecikmeli değişkenler veya Adım 5.2.3 ile "DEEPDENT" yapay sinir ağına Algoritma 3 uygulanarak model geçerliliği ve girdilerin anlamlılıkları test edilir.

Adım 5.2.2. Model geçerli değil ise $LagK = \{1\}$ alınarak geçerlilik ve test kümesi performansları hesaplanır ve Adım 5.3'e geçilir. Eğer model geçerli ise Adım 5.2.3'e geçilir.

Adım 5.2.3. Modeldeki her bir girdinin anlamlılığı test edilir. Eğer modeldeki tüm girdiler anlamlı ise geçerlilik ve test kümesi performansları hesaplanır ve Adım 5.3'e geçilir. Eğer bazı girdiler anlamsız ise modeldeki anlamsız girdiler çıkarılarak anlamlı girdiler ile Adım 5.2.1'e dönülür.

Adım 5.3. Farklı rastgele başlangıç ağırlık setleri için elde edilen geçerlilik kümesi sonuçlarından en iyisi seçilir.

Adım 6. Farklı hiper parametre setlerine göre hesaplanan geçerlilik performanslarından en iyi performansa sahip hiper parametre seti seçilir.

Adım 7. Seçilen hiper parametre seti için test performansı kontrol edilerek, eğitilmiş modelden n_f adet öngörü hesaplanır ve algoritma sonlandırılır.

3. UYGULAMA

Uygulamada Türkiye İstatistik Kurumu verilerinde elde edilen 2003 yılını baz alan aylık tüketici fiyat endeksi zaman serisi kullanılmıştır. Zaman serisi toplamda 151 aylık gözlem

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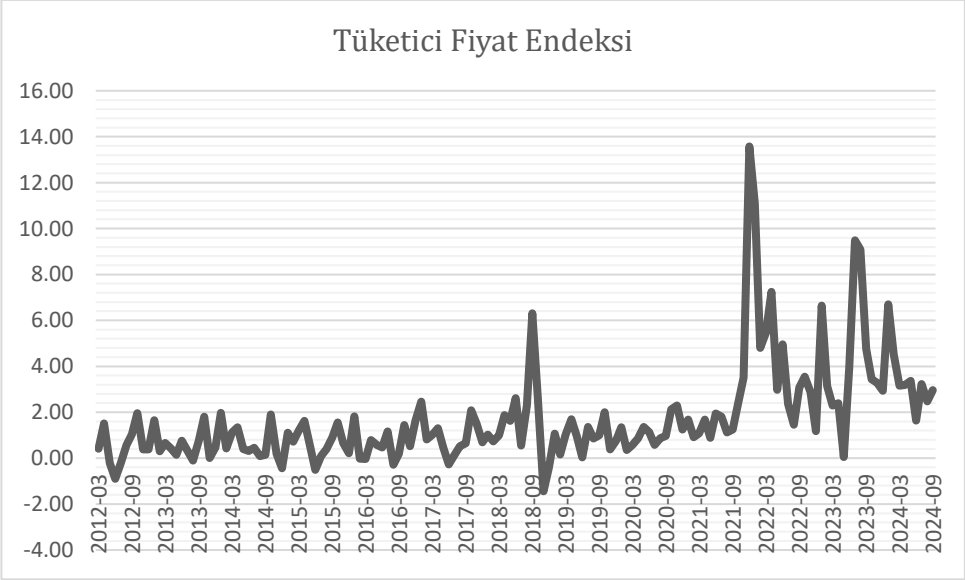
değeri içermektedir. Görsel 1'de 2012 yılının 3. Ayı ile 2024 yılının 9. Ayı arasında gözlemlenen uygulamada kullanılan tüketici fiyat endeksi zaman serisi verilmiştir.

Zaman serisinin otomatik DEEPDENT ile çözümünde yöntemin parametreleri aşağıdaki alınmıştır.

- Minimum ve Maksimum Gizli Tabaka Sayısı $q_{min} = 1$ ve $q_{max} = 2$
- Her bir hücredeki Minimum ve Maksimum Dendritik hücre sayısı $m_{min} = 1$ ve $m_{max} = 2$
- Minimum ve maksimum zaman adımlarının sayısı: $h_{min} = 1$ ve $h_{max} = 2$
- Rastgele başlangıç ağırlıkları için tekrar sayısı: $n_{repeat} = 5$
- Eğitim, geçerlilik ve test kümesi için öğrenme örnekleri sayıları: $n_{val} = 12$ ve $n_{test} = 12$
- Zaman serisinin periyodu: $s = 12$
- Bootstrap tekrar sayısı: $n_{bst} = 1000$
- Öngörü sayısı: $n_f = 12$



Görsel 1. Tüketici Fiyat Endeksi Zaman Serisi Grafiği

Elde edilen sonuçlar ise aşağıda verilmiştir. Modeldeki hiper parametre tahminleri Çizelge 1'de verilmiştir.

Çizelge 1. Hiper Parametre Tahminleri

Zaman Adımı (h)	Gizli Tabaka Sayısı (q)	Dendrite Sayısı (m)	En iyi Gecikme Sayısı
2	1	1	2

Test verisi için hesaplanan hatat ölçütleri Çizelge 2'de verilmiştir. Görüldüğü gibi test verisindeki performans yöntemin bir adım öngörü performansını yansıtmaktadır. Yöntemin test kümesindeki performansının Naive yöntemden daha kötü olduğu görülmüştür. Yöntemin öngörü performansının istatistiklerde kötü görünmesinin nedeni verinin test kümesinde bulunan aykırı değerler olduğu düşünülebilir.

Çizelge 2. Test Verisi İçin Hata Ölçütleri

RMSE	MAPE	SMAPE	MASE	REIMAE
3,102	148,4282	37,51727	1,556229	2,609431

Otomatik DEEPDENT yönteminin 12 ay için öngörü değerler ise Çizelge 3'de verilmiştir.

Çizelge 3. 12 aylık Öngörü Değerleri

Tarih	**2024/10**	**2024/11**	**2024/12**	**2025/1**	**2025/2**	**2025/3**
Öngörüler	3,61	3,35	2,98	6,89	4,78	3,41
Tarih	**2025/4**	**2025/5**	**2025/6**	**2025/7**	**2025/8**	**2025/9**
Öngörüler	3,43	3,62	1,89	3,48	2,73	3,22

Elde edilen öngörülere göre 12 aylık enflasyonun % 43 olarak tahmin edildiği görülmektedir.

4. SONUÇLAR VE TARTIŞMA

Bu çalışmada aylık tüketici fiyat endeksi zaman serisi otomatik dentritik derin yapay sinir ağı ile çözümlenerek, yöntemin performansı araştırılmıştır. Test verisinde yöntemin bir adım öngörü performansının Naive metoda göre daha kötü olduğu görülmüştür. Ancak bu durumun test verisinde yer alan aykırı değerler nedeniyle olduğu anlaşılmaktadır. Naive yöntem aykırı değerden nispeten daha az etkilenmektedir. Yöntemin verdiği 12 aylık öngörülerin incelenmesi durumunda aykırı değer etkisini içermeyen öngörüler olduğu görülmektedir. Çalışma sonucunda gelecek 12 ay için yıllık enflasyonun uygulanan politikalarda bir değişiklik olmaması durumunda % 43 civarında olacağı tahmin edilmiştir.

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KLASİK VE BOOTSTRAP HİPOTEZ TESTLERİNİN PERFORMANSLARININ AUTODEEPDENT İÇİN KARŞILAŞTIRILMASI

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ÖZET

Zaman serileri için otomatik öngörü elde edilmesi, araştırmacıların öznel kararlar verme gerekliliğini ortadan kaldırmaktadır. Bu nedenle literatürde otomatik öngörü yöntemlerine olan ilgi gün geçtikçe artmaktadır. Bu çalışmada derin dentritik geri beslemeli yapay sinir ağına ve bootstrap girdi anlamlılık testlerine dayalı bir otomatik öngörü yöntemi ortaya koyularak, yöntemin performansı klasik girdi anlamlılık testlerine dayalı algoritma ile karşılaştırılmıştır. Uygulamada M4 yarışmasında verilen zaman serileri kullanılmıştır.

Anahtar Kelimeler: Derin Öğrenme, Yapay Sinir Ağı, Girdi anlamlılık Testleri, M4 Yarışması.

1. GİRİŞ

Öngörü sorunsalı literatürde üzerin yoğun olarak çalışılan ve alternatif çözümlerin sunulduğu bir araştırma alanıdır. Son yıllarda öngörü probleminin çözümünde, derin yapay sinir ağları tercih edilen bir yöntem olmuştur. Uzun kısa dönem hafıza (LSTM), evrişimsel sinir ağı (CNN), geçitli geri beslemeli ağ (GRU) literatürde en sık kullanılan yöntemlerdir. Bu tür yapay sinir ağları farklı amaçlar ile öngörü probleminde kullanılabilmektedir. [2] çalışmasında borsa öngörüsü için kullanılan LSTM, GRU ve CNN gibi derin öğrenme yöntemlerinin detaylı bir literatür gözden geçirmesi sunulmuştur. [8] çalışmasında karbon fiyatı öngörüsü için derin öğrenme yöntemleri uygulanmıştır. [9] çalışmasında LSTM ağının farklı bir kullanımı, Covid 19 vakalarının öngörüsü için gerçekleştirilmiştir. [6] çalışmasında iki yönlü GRU modeli ile

CNN-LSTM ağını kullanarak elektrik yükü öngörüsü için hibrit bir yöntem önermişlerdir. [10] çalışmasında güç yükü öngörüsü için derin öğrenme ve makine öğrenmesini de içeren yöntemleri sentezleyerek melez öngörü modeli ortaya koymuşlardır. [7] çalışmasında kısa dönem yük öngörüsüne odaklanılmış ve hiper parametre optimizasyonu ile bir GRU modeli önerilmiştir. [11] çalışmasında karbon emisyonu ticari fiyatlarının öngörüsü üzerine odaklanılmıştır ve iki yönlü GRU yöntemine dayalı bir yöntem önerilmiştir. [1] çalışmasında rüzgâr gücü öngörüsü için destek vektör makinası, k en yakın komşu algoritması, aşırı gardyent boosting algoritması ve rastgele orman yöntemlerinin performansı araştırılmıştır. Literatürde iyi bilinen LSTM, GRU gibi ağlar yanı sıra, DEEPDENT derin geri beslemeli yapay sinir ağı [5] çalışmasında önerilmiştir. DEEPDENT yapay sinir ağı öngörü problemine uygulamada klasik hipotez testlerine dayalı olarak girdi anlamlılık testi [3] çalışmasında ortaya koyulmuştur. Bu çalışmada [3] çalışmasında önerilen girdi anlamlılık testi, bootstrap hipotez testi kullanılarak modifiye edilmiş ve verinin dağılımına bakılmaksızın uygulanabilen bir girdi anlamlılık testi geliştirilmiştir. Geliştirilen bu testin performansı M4 verileri üzerinde klasik hipotez testi ile karşılaştırılmıştır.

Çalışmanın ikinci bölümünde DEEPDENT yapay sinir ağı kısaca tanıtılmıştır. Üçüncü bölümde bootstrap hipotez testine dayalı girdi anlamlılık testi algoritması verilmiştir. Dördüncü bölümde M4 verileri üzerin yapılan uygulamanın sonuçları sunulmuştur. Son bölümde elde edilen sonuçlar tartışılmıştır.

2. DEEPDENT DERİN YAPAY SİNİR AĞI

DEEPDENT yapay sinir ağı [5] çalışmasında ortaya koyulmuştur. Görsel 1'de DEEPDENT derin yapay sinir ağının mimarisi verilmiştir. DEEPDENT mimarsinde ağın çıktıları aşağıdaki eşitlikler ile hesaplanmaktadır.

Modeldeki her bir gizli tabakadaki parametreler bir parametre vektöründe aşağıdaki gibi verilebilir.

$$\Theta^j = \left[W_x{}^j, \theta_x^j, W_h{}^j, \theta_h^j, k_{soma}^j, \theta_{soma}^j, k^j\right), j = 1,2, \dots, q \quad (1)$$

Birinci gizli tabakadaki hücrelerin çıktıları aşağıdaki formül ile hesaplanır.

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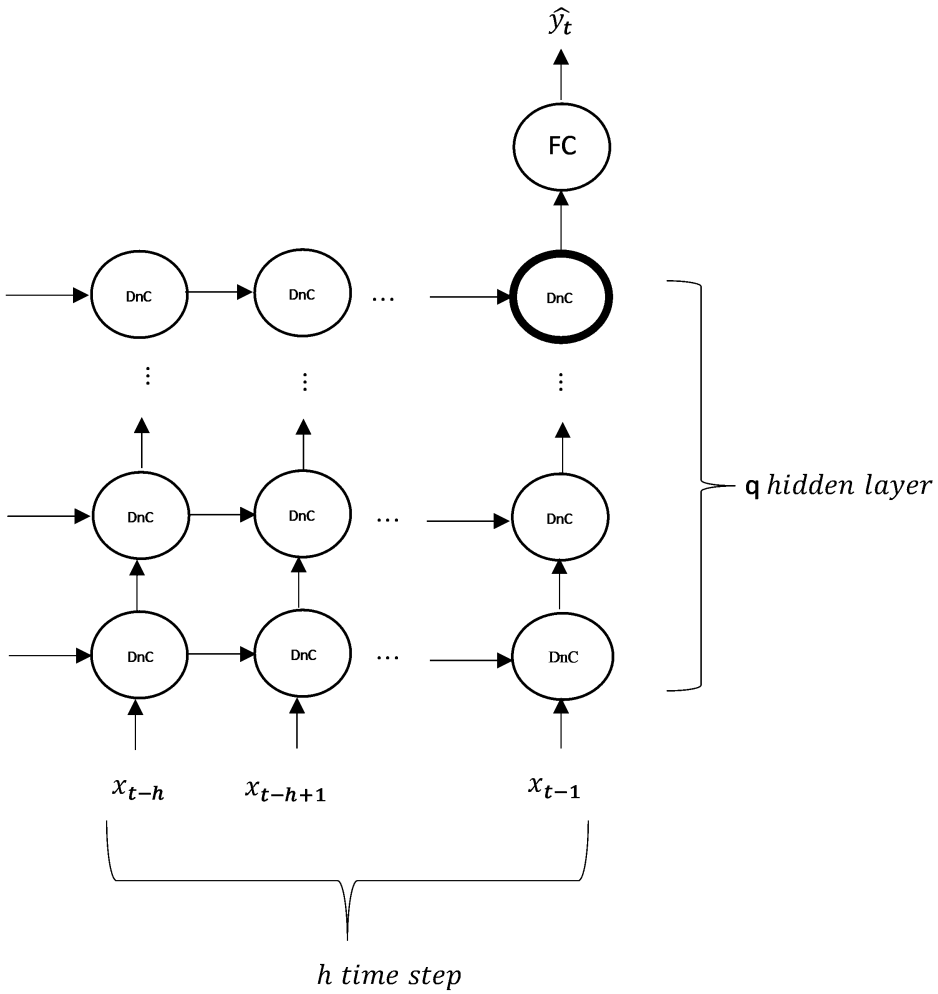
$$h_{t-k}^{1} = f(h_{t-k-1}^{1}, x_{t-k}, \Theta^{1}), k = 1,2,\dots,h \quad (2)$$

Birinci gizli tabakadan sonraki gizli tabakalarda hücreleri çıktıları ise Eşitlik (3) ile hesaplanır.

$$h_{t-k}^{j} = f\left(h_{t-k-1}^{j}, h_{t-k}^{j-1}, \Theta^{j}\right), k = 1,2,\dots,h, j = 2,\dots,q \quad (3)$$

DEEPDENT yapay sinir ağının çıktısı eşitlik (4) ile hesaplanmaktadır.

$$\hat{y}_t = \sigma\left(W_{FC} h_{t-1}^{q} + b_{FC}\right) \quad (4)$$



Görsel 1. DEEPDENT Derin yapay sinir ağı mimarisi

DEEPDENT yapay sinir ağının eğitimi için [5] çalışmasında diferansiyel gelişim algoritması ve [4] çalışmasında ise parçacık sürü optimizasyonuna dayalı bir yöntem önerilmiştir.

3. DEEPDENT İÇİN BOOTSTRAP GİRDİ ANLAMLILIK TESTLERİ

DEEPDENT yapay sinir ağının otomatik öngörü yöntemi haline getirilmesi için girdi anlamlılık testlerine ihtiyaç duyulmaktadır. Egrioglu ve Bas (2024) çalışmasında önerilen girdi anlamlılık testi F dağılımına dayalı olup, regresyon modelindeki hataların dağılımının normalliği varsayımına ihtiyaç duymaktadır. Çoğunlukla varsayım ihlallerinden dolayı F dağılımının kullanımı hatalı olabilmektedir. Bu nedenle bu çalışmada Bootstrap F testine dayalı bir yaklaşım ortaya koyulmuştur. Yöntemin algoritması aşağıda sunulmuştur.

Algoritma. DEEPDENT için Bootstrap Model Yeterliliği ve Girdi Anlamlılık Testleri

Adım 1. DEEPDENT diferansiyel gelişim algoritması kullanılarak eğitilir.

Adım 2. Diğer girdilerin ortalamaları sabitken her bir girdi için eğitilmiş DEEPDENT 'in çıktıları hesaplanır. Eğitilmiş DEEPDENT'den Eşitlik (5) ile öngörü fonksiyonu elde edilir.

$$\hat{x}_t = g\left(x_{t-1}, \dots, x_{t-p} \; ; \; \widehat{W}, \; \hat{B}\right) \tag{5}$$

Öğrenme örneklerinin sayısı nts olsun. Her bir girdi için çıktılar $\hat{Y}_j^{(k)}$, $j = 1,2,\dots,nts, k = 1,2,\dots,p$ şeklinde gösterilir ve aşağıdaki formül ile hesaplanır. Herhangi bir girdi için çıktılar hesaplanırken, diğer girdiler aritmetik ortalamalarında sabitlenir.

$$\hat{Y}_j^{(k)} = g\left(x_{t-1} = mean(x_{t-1}), \dots, x_{t-k-1} = mean(x_{t-k-1}), x_{t-k}, x_{t-k+1} = mean(x_{t-k+1}), \dots, x_{t-p} = mean(x_{t-p})\right) \tag{6}$$

Adım 3. Çoklu doğrusal regresyon analizi uygulanır. Regresyon analizinde, ağın hedef değerleri bağımlı değişken gözlemleri, $\hat{Y}_j^{(k)}$ çıktıları ise bağımsız değişken gözlemleri olarak kullanılır. Çoklu regresyon analizi için denklem Eşitlik (7) ile verilmiştir:

$$x_t = \beta_0 + \sum_{k=1}^{p} \beta_k \hat{Y}^{(k)} + \varepsilon_t \tag{7}$$

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Bu modelden tahmin edilen $\widehat{\beta_k}$ değerlerinin mutlak değerleri her bir girdinin önem skoru olarak yorumlanır.

Adım 4. Model yeterliliğini test etmek için kısmi F-testleri uygulayın. Test için hipotez aşağıda verilmiştir.

$$H_0: \beta_1 = \beta_2 = \cdots = \beta_k = 0$$
$$H_1: \exists \beta_k \neq 0,\ k = 1,2, \ldots, p$$

Test istatistikleri aşağıdaki formüller ile hesaplanır. K bir matristir ve elemanları test ipotezlerine göre belirlenir. X matrisi bağımsız değişkenler matrisidir ve ith satırı Eşitlik (8) ile verilmiştir:

$$X_i = \left[1\ \hat{Y}^{(1)}\ \hat{Y}^{(2)} \ldots \hat{Y}^{(p)}\right];\ i = 1,2, \ldots, nts \tag{8}$$

σ, model (7) için standart sapma tahminini temsil eder ve aşağıdaki formülle hesaplanır.

$$\hat{\sigma}^2 = \frac{Y'\left[I - X(X'X)^{-1}X_I\right]^{-1}Y}{nts - p - 1} \tag{9}$$

Test istatistikleri aşağıdaki gibi hesaplanır:

$$F = \frac{(K\beta)'\left[K(X'X)^{-1}K_I\right]^{-1}(K\beta)}{p\hat{\sigma}^2} \tag{10}$$

Karar aşaması için kritik değer $Fbootstrap$ bootstrap yaklaşım ile elde edilir. Bunun için (7)'de verilen model için oluşturulan öğrenme örneklerinden yerine koyma koşulu ile bootstrap örneklem çekilerek Eşitlik (10) da verilen F değeri her bir bootstrap örneklemi için hesaplanır. Böylece F değerlerinin bir bootstrap örneklemi oluşur. Bu örneklem üzerinden yüzdelikler hesaplanarak kritik değer $Fbootstrap$ elde edilir. Anlamlılık değeri $P(Fbootstrap > F_{value})$ olasılığıdır.

Adım 5. Eğer $P(Fbootstrap > F_{value}) < \alpha$ ise DEEPDENT modeli yeterlidir ve girdi anlamlılık testleri için Adım 6'ya geçilir. Aksi halde model yetersizdir sonucuna ulaşılır ve algoritma durdurulur.

Adım 6. Tüm girdiler aşağıdaki hipotezler ile test edilir.

$H_0: \beta_k = 0$

$H_1: \beta_k \neq 0$

Adım 7. Test istatistiği aşağıdaki formül ile hesaplanır. K hipoteze göre hesaplanan bir matristir.

Test istatistiği yine (10)'dur. Kritik değer $Fbootstrap'ın$ hesabı için Adım 4'deki yöntem uygulanır. Anlamlılık değeri $P(Fbootstrap > F_{value})$ olasılığı ile hesaplanır.

Adım 8. Eğer $P(Fbootstrap > F_{value}) < \alpha$ ise ilgili girdi anlamlı aksi halde anlamsızdır.

Adım 9. Adım 6-8 tüm girdiler için tekrar edilir.

4. UYGULAMA

Uygulamada M4 yarışmasında kullanılan saatlik zaman serilerinin ilk 100 tanesi kullanılmıştır. Hem klasik hemde bootstrap hipotez testlerine dayalı olarak model seçilerek öngörüler hesaplanmıştır. Karşılaştırmada yarışmanın kazana yöntemi, benchmark yöntemler ve klaik hipotezt testi ile boostrap hipotez testine dayalı DEEPDENT yöntemleri, SMAPE ve MASE ölçütlerinin 100 veri için medyanları kullanılarak karşılaştırılmıştır.

Çizelge 1. M4 yarışmasındaki saatlik zaman serilerinin çözümlenmesinde elde edilen sonuçlar

Yöntem	Medyan (SMAPE)	Medyan (MASE)
ARIMA	7,5048	1,2718
Com	5,9667	1,1948
Damped	5,3378	1,1075
ETS	5,6935	1,1981
Holt	13,6426	2,1852
MLP	10,2267	1,7159

Naive	6,0655	1,2317
Naive2	6,0655	1,2317
RNN	11,0844	1,7144
SES	6,1696	1,2820
sNaive	6,0655	1,2317
Teta	6,5219	1,3034
Yarışmanın Kazanan Yöntemi	6,6429	1,121
Klasik Hipotez Testine Dayalı DEEPDENT	1,4489	0,9788
Bootstrap Hipotez Testine Dayalı DEEPDENT	1,3629	0,9620

Elde edilen sonuçlar Çizelge 1'de verilmiştir. Çizelge 1 incelendiğinde Bootstrap hipotez testine dayalı yöntemin klasik hipotez testine göre saatlik veriler için çok daha başarılı öngörü sonuçları ürettiği görülmektedir.

5. SONUÇLAR VE TARTIŞMA

Bu çalışmada DEEPDENT derin geri beslemeli yapay sinir ağında model geçerlilik ve girdi anlamlılık testleri için bootstrap hipotez testi yöntemi önerilmiştir. Önerilen yöntem sayesinde zaman serilerinin girdilerinin otomatik seçimi gerçekleştirilebilmektedir. Ayrıca önerilen yöntem hipotez testlerinin uygulanmasında gereken normallik, sabit varyans gibi varsayımlara ve dolayısıyla testlerin uygulanmasında kullanılan F dağılımı varsayımına ihtiyaç duymama avantajına sahiptir. Uygulamada saatlik veriler için bootsrap hipotez testine dayalı olarak seçilen öngörü modellerinin performanslarının klasik hipotez testlerine göre seçilen modellerden daha başarılı olduğu görülmektedir.

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BULANIK REGRESYON FONKSİYONLARI YAKLAŞIMLARININ BORSA ÖNGÖRÜSÜ ÜZERİNDEN KARŞILAŞTIRILMASI

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ÖZET

Zaman serisi öngörü probleminin çözümünde bir alternatif olarak bulanık regresyon fonksiyonları yaklaşımları tercih edilebilmektedir. Bulanık regresyon fonksiyonları yaklaşımları öğrenme örneklerinin kümelenmesi sayesinde elde edilen üyeliklerin yeni açıklayıcı değişkenler olarak kullanıldığı bir kombine model yaklaşımı sunmaktadır. Son zamanlarda klasik bulanık küme kullanılarak önerilen bulanık regresyon fonksiyonları yaklaşımları, sezgisel ve resim bulanık kümeler içinde uygulanabilir hale getirilerek yeni öngörü yöntemleri ortaya koyulmuştur. Bu çalışmada bulanık regresyon fonksiyonları, sezgisel bulanık regresyon fonksiyonları ve resim bulanık regresyon fonksiyonları öngörü yöntemleri, İngiliz sterlini ve dolar paritesi zaman serisi kullanılarak öngörü performansı açısından karşılaştırılmıştır.

Anahtar Kelimeler: Bulanık Küme, Sezgisel Bulanık Küme, Resim Bulanık Küme, Bulanık Regresyon Fonksiyonları, Öngörü

1. GİRİŞ

Günümüzde veriyi işleyip anlamlı sonuçlar elde etmek, geleceği planlamak ve doğru öngörüler yapmak önem taşımaktadır. Son yıllarda tahmin problemleri çözümünde çeşitli yöntemler kullanılmaktadır. Bulanık çıkarım sistemleri de bu yöntemlerden biridir. Bulanık çıkarım sistemleri eldeki girdi ve çıktı veri setleri için oluşturulan bulanık kümelere dayanarak çalışmaktadır. Bulanık çıkarım sistemlerinin karar alma süreci yapısında "eğer-ise" adı verilen bir kural tabanı bulunmaktadır ve kuralların belirlenmesi uzman görüşü gerektirmektedir. Bu durumda kuralları belirlemek çok kolay olmamaktadır. Bu nedenle kural tabanına ve uzman görüşüne ihtiyaç olmayan bulanık regresyon fonksiyonları yaklaşımları önerilmiştir. Bulanık regresyon fonksiyonları (BRF) yaklaşımı, zaman serisi tahmin problemlerinin çözümü için başarılı sonuçlar üretebilen ve bulanık küme mantığına dayanan bir bulanık çıkarım sistemidir. Her bulanık kümeye karşılık gelen bulanık bir fonksiyon bulunmaktadır. İlk olarak Turksen (2008) tarafından önerilen BRF yaklaşımının sistem girdileri Bezdek ve ark. (1984) tarafından önerilen bulanık c-ortalamalar yöntemi (FCM) ile bulanıklaştırılmaktadır. Bulanık kümelerden elde edilen üyelikler model oluştururken kullanılmaktadır. BRF yaklaşımın genişletilmiş hali olan ve Bas ve ark. (2021) tarafından önerilen sezgisel bulanık regresyon fonksiyonları (SBRF) yaklaşımı, BRF yaklaşımından farklı olarak üyelik olma değerleri dışında üyelik olmama değerlerini de modele girdi olarak eklemektedir. SBRF'deki üyelik ve üyelik olmama değerleri Chaira (2011) tarafından önerilen sezgisel bulanık c-ortalamalar yöntemi (IFCM) ile elde edilmektedir. BRF yaklaşımının en genelleştirilmiş hali olan ve Bas ve ark (2020) tarafından önerilen resim bulanık regresyon fonksiyonları (RBRF) yaklaşımı ise girdi olarak pozitif, negatif ve nötr üyelik değerlerini modele ekleyerek, Thong ve Son (2016) tarafından önerilen resim bulanık c-ortalamalar yöntemi (PFCM) algoritmasını kullanarak modeli tahmin etmektedir.

Konu ile ilgili yapılan çalışmalar incelendiğinde bulanık kavramı ilk olarak, Zadeh (1965) tarafından ortaya konulmuştur. Literatürdeki en iyi bilinen ve en sık kullanılan bulanık çıkarım sistemi Jang (1993) tarafından önerilen uyarlamalı ağ tabanlı bulanık çıkarım sistemi (ANFIS) olmasına rağmen, Mamdani - Assilian (1975) ve Takagi - Sugeno (1985) tarafından önerilen bulanık çıkarım sistemleri de literatürde oldukça önemli bir yer sahiptir. Literatüre bakıldığında BRF yaklaşımı ile ilgili çalışmaların sıklıkla kullanıldığı görülmektedir. Beyhan ve Alci (2010) ve Aladag ve ark. (2014) çalışmalarında tahmin problemleri için bulanık fonksiyon yaklaşımlarını kullanmışlardır. Aladag ve ark. (2016) sistemin gecikmeli değişkenlerinin parçacık sürüsü optimizasyonu ile belirlendiği bir BRF yaklaşımı önermiştir. Dalar ve Egrioglu (2018) çalışmasında bootstrap yöntemlerini kullanan yeni regresyon fonksiyonları yaklaşımını önermişlerdir. Bas ve ark. (2019) çalışmasında ortaya çıkabilen çoklu doğrusalık sorununa çözüm için yeni bir bulanık tahmin yöntemi önermiştir. Demirhan ve Baser

(2024) çalışmasında gayrimenkul fiyat tahmini için hiyerarşik bulanık regresyon fonksiyonları adlı yeni bir bulanık regresyon fonksiyonları yaklaşımı önermiştir.

SBRF yaklaşımı öngörü probleminde sıklıkla kullanılmaktadır. Kizilaslan ve ark. (2020) çalışmasında ridge regresyonu ile ilgili zaman serisi tahmini için yeni bir sezgici bulanık regresyon fonksiyonları yaklaşımı önermiştir. Cagcag Yolcu ve ark. (2020) çalışmasında tereddüt derecesine dayanan ve yine zaman serisi tahmini için bu yaklaşımı önermiştir. Tak ve ark (2021) çalışmasında tahmin amaçlı meta bulanık fonksiyonlar yaklaşımını önermiştir. Egrioglu ve Bas (2023) çalışmasında ise aykırı değerlerden etkilenmeyen sağlam sezgisel bulanık regresyon fonksiyonları geliştirerek zaman serisi tahminlerinde doğruluğu artırmak için yeni bir sezgisel bulanık regresyon yaklaşımı önermiştir.

Ayrıca literatür de RBRF yaklaşım ile yapılan çalışmalar da bulunmaktadır. Cuong (2014) ve Son ve ark. (2017) çalışmalarında kontrol teorisi için bir resim bulanık çıkarım sistemi önermiştir. Egrioglu ve ark. (2020) çalışmasında meteorolojik veriler ile yüksek dereceli tek değişkenli bulanık zaman serisi tahmin modellerindeki doğruluğu artırarak daha iyi sonuçlar elde etmek için yeni bir resimsel bulanık zaman serisi tahmin yöntemi önermiştir. He ve Wang (2023) çalışmasında enerji analizi için duygu analizi ile resim bulanık kümelerini kullanmışlardır. Haktanır ve Kahraman (2023) çalışmasında mevcut ekipman ve yeni ekipman karşılaştırılmış ve bu karar sürecinde resim bulanık kümeler kullanılmıştır. Kumar ve Tyagi (2023) çalışmasında resim bulanık kümeleri çok kriterli karar verme için kullanmışlardır. Bas ve ark. (2024) çalışmasında aykırı değer varlığında kullanılabilecek bir resim bulanık regresyon fonksiyonu yaklaşımı önerilmiştir.

Literatür incelendiğinde BRF, SBRF ve RBRF yaklaşımları farklı konular için tahmin, sınıflandırma, öngörü, karar verme, desen tanıma vb. problemlerinin çözümünde kullanıldığı gözlemlenmiştir. Ayrıca bu yöntemlerin uygulama alanları incelendiğinde ise özellikle ekonomi ve finans, tıp ve sağlık, mühendislik ve üretim, enerji ve yenilebilir enerji sistemleri, meteoroloji ve hidroloji vb. alanlarda kullanıldığı gözlemlenmiştir.

Bu çalışmada BRF, SBRF ve RBRF yöntemleri 2022 ve 2023 yıllarına ait İngiliz sterlini ve dolar (GBP/USD) paritesi zaman serileri kullanılarak öngörü performansı açısından karşılaştırılmıştır.

Çalışmanın diğer bölümleri takipteki gibidir. Çalışmanın ikinci bölümde bulanık regresyon fonksiyonu yaklaşımı, üçüncü bölümde sezgisel bulanık regresyon fonksiyonu yaklaşımı, dördüncü bölümde resim bulanık regresyon fonksiyonu yaklaşımı yöntemleri adım adım açıklanmıştır. Beşinci bölümde

çalışmada kullanılan GBP/USD zaman serileri incelenmiş ve yöntemler karşılaştırılarak analizler gerçekleştirilmiştir. Son bölümde ise elde edilen bulgulara göre sonuç ve önerilere ulaşılmıştır.

2. BULANIK REGRESYON FONKSİYONLARI

Turksen (2008) tarafından önerilen BRF yaklaşımında, Bezdek ve ark. (1984) tarafından önerilen FCM ile elde edilen her bir bulanık küme için regresyon yöntemiyle bir fonksiyon oluşturulur ve sistemin çıktısı, üyeliklerin ağırlıklar olduğu ağırlıklı bulanık fonksiyon tahminlerinin çıktısından elde edilir. Yöntemin algoritması Algoritma 1 ile adım adım verilmiştir.

Algoritma 1. Tip-1 BRF yaklaşımının algoritması

Adım 1. Eğitim (n) ve test kümesi $(ntest)$ olmak üzere veri seti ikiye ayrılır ve araştırmacı tarafından gecikme sayısı (p) belirlenir.

Adım 2. Sistemin girdileri eğitim kümesinin gecikmeli değişkenlerinden ve bu girdilere karşılık gelen çıktılarla Eşitlik (1) ile bir D matrisi oluşturulur.

$$D = \begin{bmatrix} x_1 & x_2 & \cdots & x_p & x_{p+1} \\ x_2 & x_3 & \cdots & x_{p+1} & x_{p+2} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{n-p} & x_{n-p+1} & \cdots & x_{n-1} & x_n \end{bmatrix} \quad (1)$$

Adım 3. Oluşturulan D matrisi, belirlenen bulanık küme sayısından (c) hareketle FCM ile kümelenir. Böylelikle üyelik değerleri $(u_{ik},\ i = 1,2,\cdots,c\ ; k = 1,2,\cdots,n)$ elde edilir.

Adım 4. Çıktıya karşılık gelen bileşenin D matrisinden çıkarılması ile küme merkezleri indirgenerek yeniden üyelik değerleri elde edilir.

Adım 5. Alfa kesmesi (α) değerine göre normalleştirilmiş üyelik değerleri (μ) Eşitlik (2-3) ile elde edilir.

$$\gamma_{ik} = \begin{cases} u_{ik} & u_{ik} > \alpha \\ 0 & u_{ik} \leq \alpha \end{cases} \quad (2)$$

$$\mu_{ik} = \gamma_{ik} / \sum_{i=1}^{c} \gamma_{ik} \quad (3)$$

Adım 6. Eğitim kümesi için üyelik değerleri ve gecikmeli değişkenlerden oluşan girdiler X matrisinde toplanır ve $i.$ bulanık fonksiyonu $Y^{(i)} = X^{(i)}\beta^{(i)} + \varepsilon^{(i)}\ ;\ i = 1,2,\ldots c$ çok değişkenli regresyon modeli olarak tahmin edilerek elde edilir. Eşitlik (4-5) ile verilen X matrisi ve Y vektörü oluşturulur. X matrisi için Celikyılmaz ve Turksen (2009) üyelik değerlerinin üstel

ve logaritmik bazı dönüşümlerinin ilave edilmesinin yöntem performansını arttırabileceğini önerdiği için ilgili matriste bu dönüşümlere yer verilmiştir.

$$X^{(i)} = \begin{bmatrix} 1 & \mu_{i1} & {\mu_{i1}}^2 & exp\,(\mu_{i1}) & ln(\frac{(1-\mu_{i1})}{\mu_{i1}}) & x_1 & x_2 & \cdots & x_p \\ 1 & \mu_{i2} & {\mu_{i2}}^2 & exp\,(\mu_{i2}) & ln(\frac{(1-\mu_{i2})}{\mu_{i2}}) & x_2 & x_3 & \cdots & x_{p+1} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & \mu_{in} & {\mu_{in}}^2 & exp\,(\mu_{in}) & ln(\frac{(1-\mu_{in})}{\mu_{in}}) & x_{n-p} & x_{n-p+1} & \cdots & x_{n-1} \end{bmatrix} \quad (4)$$

$$Y^{(i)} = \begin{bmatrix} x_{p+1} \\ x_{p+2} \\ \vdots \\ x_n \end{bmatrix} \quad (5)$$

Adım 7. Eğitim kümesinde her bir bulanık küme için bulanık regresyon fonksiyonları, Eşitlik (6-7) ile tahmin edilir.

$$\hat{\beta}^{(i)} = (X^{(i)'}X^{(i)})^{-1}X^{(i)'}Y^{(i)} \quad (6)$$

$$\hat{Y}^{(i)} = X^{(i)}\hat{\beta}^{(i)}\,;\; i = 1,2,\ldots c \quad (7)$$

Adım 8. Elde edilen çıktılar ilgili üyelik değerleri ile ağırlıklandırılarak eğitim kümesine ait nihai tahmin değerleri $(\hat{Y}_k)$ Eşitlik (8) ile elde edilir.

$$\hat{Y}_k = \frac{\sum_{i=1}^{c}\hat{Y}^{(i)}\mu_{ik}}{\sum_{i=1}^{c}\mu_{ik}}\,, i = 1,2,\ldots,c,\;\; k = 1,2,\ldots,n \quad (8)$$

Adım 9. $X^{(i)}$ matrisi ve $Y^{(i)}$ vektörü test kümesi için yeniden oluşturulur. Test kümesinin $X^{(i)}$ matrisi üyelik değerleri eğitim kümesinde elde edilen küme merkezleri kullanılarak elde edilir ve her bir bulanık regresyon fonksiyonlarının test kümesi için tahmin değerleri yeniden oluşturulan $X^{(i)}$ matrisi ve $Y^{(i)}$ vektörü üzerinden hesaplanır.

3. SEZGİSEL BULANIK REGRESYON FONKSİYONLARI

Bas ve ark. (2021) tarafından önerilen SBRF yönteminde ise sistemin girdileri Chaira (2011) tarafından önerilen sezgici bulanık kümeleme yöntemi ile elde edilen üyelik değerleri, üyelik olmama değerleri ve zaman serisinin gecikmeli değişkenleridir. Yöntemin algoritması Algoritma 2 ile adım adım verilmiştir.

Algoritma 2. SBRF yaklaşımının algoritması

Adım 1. Sezgici bulanık küme sayısı (c), alfa kesme değeri (α) gecikme sayısı (p), eğitim kümesi uzunluğu (n) ve test kümesi uzunluğu $(ntest)$ belirlenir.

Adım 2. Sistemin girdileri eğitim kümesinin gecikmeli değişkenlerinden ve bu girdilere karşılık gelen çıktılarla bir D matrisi oluşturulur.

Adım 3. Oluşturulan D matrisi, belirlenen sezgici bulanık küme sayısından (c) hareketle IFCM ile kümelenir. Böylelikle sezgisel üyelik değerleri $(u_{ik},\ i = 1,2,\cdots,c\ ; k = 1,2,\cdots,n)$ ve üyelik olmama değerleri $(\nu_{ik}, i = 1,2,\cdots,c;\ k = 1,2,\cdots,n)$ elde edilir.

Adım 4. Çıktıya karşılık gelen bileşenin D matrisinden çıkarılması ile küme merkezleri indirgenerek yeniden sezgisel üyelik ve üyelik olmama değerleri elde edilir.

Adım 5. Alfa kesmesi (α) değerine göre normalleştirilmiş sezgisel üyelik değerleri (μ) ve normalleştirilmiş sezgisel üyelik olmama değerleri (φ) Eşitlik (9-12) ile elde edilir.

$$\gamma_{ik} = \begin{cases} u_{ik} & u_{ik} > \alpha \\ 0 & u_{ik} \leq \alpha \end{cases} \tag{9}$$

$$\mu_{ik} = \gamma_{ik} / \sum_{i=1}^{c} \gamma_{ik} \tag{10}$$

$$\eta_{ik} = \begin{cases} \nu_{ik} & \nu_{ik} > \alpha \\ 0 & \nu_{ik} \leq \alpha \end{cases} \tag{11}$$

$$\varphi_{ik} = \eta_{ik} / \sum_{i=1}^{c} \eta_{ik} \tag{12}$$

Adım 6. Eğitim kümesi için sezgisel üyelik ve üyelik olmama değerlerinin yanı sıra bu değerlerin üstel ve çeşitli logaritmik dönüşümleri gibi bazı dönüşümleri ve gecikmeli değişkenlerden oluşan girdiler X matrisinde toplanır ve $i.$ sezgisel bulanık fonksiyonu $Y^{(i)} = X^{(i)}\beta^{(i)} + \varepsilon^{(i)}\ ;\ i = 1,2,\ldots c$ çok değişkenli regresyon modeli olarak tahmin edilerek elde edilir. Eşitlik (13-14) ile verilen X matrisi ve Y vektörü oluşturulur.

$$X^{(i)} = \begin{bmatrix} 1 & \mu_{i1} & {\mu_{i1}}^2 & exp\,(\mu_{i1}) & \varphi_{i1} & {\varphi_{i1}}^2 & exp\,(\varphi_{i1}) & x_1 & x_2 & \cdots & x_p \\ 1 & \mu_{i2} & {\mu_{i2}}^2 & exp\,(\mu_{i2}) & \varphi_{i2} & {\varphi_{i2}}^2 & exp\,(\varphi_{i2}) & x_2 & x_3 & \cdots & x_{p+1} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & \mu_{in} & {\mu_{in}}^2 & exp\,(\mu_{in}) & \varphi_{in} & {\varphi_{in}}^2 & exp\,(\varphi_{in}) & x_{n-p} & x_{n-p+1} & \cdots & x_{n-1} \end{bmatrix} \tag{13}$$

$$Y^{(i)} = \begin{bmatrix} x_{p+1} \\ x_{p+2} \\ \vdots \\ x_n \end{bmatrix} \tag{14}$$

Adım 7. Eğitim kümesinde her bir sezgisel bulanık küme için sezgisel bulanık regresyon fonksiyonları, Eşitlik (15-16) ile tahmin edilir.

$$\hat{\beta}^{(i)} = (X^{(i)'}X^{(i)})^{-1}X^{(i)'}Y^{(i)} \quad (15)$$

$$\hat{Y}^{(i)} = X^{(i)}\hat{\beta}^{(i)}\ ;\ i\ =\ 1,2,\dots c \quad (16)$$

Adım 8. Elde edilen çıktılar ilgili sezgisel üyelik değerleri $(\hat{Y}_k{}^{\mu})$ ve üyelik olmama değerleri $\hat{Y}_k{}^{\varphi}$ile orantılı olarak Eşitlik (17-18) ile ayrı ayrı elde edilir. Eğitim kümesine ait nihai tahmin değerleri $\left(\hat{Y}_{eğitim}\right)$ Eşitlik (19) ile elde edilir.

$$\hat{Y}_k{}^{\mu} = \frac{\sum_{i=1}^{c}\hat{Y}^{(i)}\mu_{ik}}{\sum_{i=1}^{c}\mu_{ik}}\ ,i = 1,2,\dots,c,\ \ k = 1,2,\dots,n \quad (17)$$

$$\hat{Y}_k{}^{\varphi} = \frac{\sum_{i=1}^{c}\hat{Y}^{(i)}\varphi_{ik}}{\sum_{i=1}^{c}\varphi_{ik}}\ ,i = 1,2,\dots,c,\ \ k = 1,2,\dots,n \quad (18)$$

$$\hat{Y}_{eğitim} = \left(\hat{Y}_k{}^{\mu} * (1 - beta)\right) + \left(\hat{Y}_k{}^{\varphi} * beta\right) \quad (19)$$

Eşitlik (19)'da beta araştırmacı tarafından belirlenen 0 ile 1 aralığında değere sahip bir parametredir.

Adım 9. $X^{(i)}$ matrisi ve $Y^{(i)}$ vektörü test kümesi için yeniden oluşturulur. Test kümesinin $X^{(i)}$ matrisi sezgisel üyelik değerleri eğitim kümesinde elde edilen küme merkezleri kullanılarak elde edilir ve her bir sezgisel bulanık regresyon fonksiyonlarının test kümesi için tahmin değerleri yeniden oluşturulan $X^{(i)}$ matrisi ve $Y^{(i)}$ vektörü üzerinden hesaplanır.

4. RESİM BULANIK REGRESYON FONKSİYONLARI

BRF yaklaşımına göre daha fazla bilgi bulunan ve Bas ve ark. (2020) tarafından önerilen genetik algoritmaya dayalı RBRF yaklaşımında resim bulanık kümelerden elde edilen pozitif, nötral ve negatif üyelik değerleri bulunmaktadır. Bir tür öngörü kombinasyonu yöntemi olarakta düşünülmektedir. Yönteme ait algoritma Algoritma 3 ile adım adım verilmiştir.

Algoritma 3. RBRF yaklaşımının algoritması

Adım 1. Resim bulanık küme sayısı (c), alfa kesme değeri (α) gecikme sayısı (p), eğitim kümesi uzunluğu (n) ve test kümesi uzunluğu $(ntest)$ belirlenir.

Adım 2. Sistemin girdileri eğitim kümesinin gecikmeli değişkenlerinden ve bu girdilere karşılık gelen çıktılarla bir D matrisi oluşturulur.

Adım 3. Oluşturulan D matrisi, belirlenen sezgici bulanık küme sayısından (c) hareketle PFCM ile kümelenir. Pozitif üyelik değerleri $(\mu_A(x))$, nötral üyelik değerleri $(\eta_A(x))$ ve negatif üyelik değerleri $(\nu_A(x))$ elde edilir.

Adım 4. Pozitif, nötral ve negatif üyelik değerleri (α) değerine göre düzeltilir. $\mu_A(x) < \alpha$ ise $\mu_A(x)$ =0, $\eta_A(x) < \alpha$ ise $\eta_A(x)$ =0, $\nu_A(x) < \alpha$ ise $\nu_A(x)$ =0 olarak elde edilir.

Alfa kesmesi değeri işlemine göre düzenlenen pozitif, nötral ve negatif üyelik değerleri sırası ile μ_{ik}, η_{ik} ve ν_{ik} sırasıyla i. resim bulanık kümenin ve k. eğitim örneği için düzenlenmiş üyelik değerlerini göstermektedir.

Adım 5. Eğitim kümesi için pozitif (μ_{ik}), nötral (η_{ik}) ve negatif (ν_{ik})üyelik değerlerinin yanı sıra bu değerlerin üstel ve çeşitli logaritmik dönüşümleri gibi bazı dönüşümleri ve gecikmeli değişkenlerden oluşan girdiler X matrisinde toplanır ve i. resim bulanık fonksiyonu $Y^{(i)} = X^{(i)}\beta^{(i)} + \varepsilon^{(i)}$; $i = 1, 2, \dots c$ çok değişkenli regresyon modeli olarak tahmin edilerek elde edilir. Eşitlik (20-21) ile verilen X matrisi ve Y vektörü oluşturulur.

$$X^{(i)} = \begin{bmatrix} 1 & \mu_{i1} & {\mu_{i1}}^2 & \exp(\mu_{i1})^2 & \eta_{i1} & {\eta_{i1}}^2 & \exp(\eta_{i1})^2 & \nu_{i1} & {\nu_{i1}}^2 & \exp(\nu_{i1})^2 & x_1 & x_2 & \cdots & x_p \\ 1 & \mu_{i2} & {\mu_{i2}}^2 & \exp(\mu_{i2})^2 & \eta_{i2} & {\eta_{i2}}^2 & \exp(\eta_{i2})^2 & \nu_{i2} & {\nu_{i2}}^2 & \exp(\nu_{i2})^2 & x_2 & x_3 & \cdots & x_{p+1} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & \mu_{in} & {\mu_{in}}^2 & \exp(\mu_{in})^2 & \eta_{in} & {\eta_{in}}^2 & \exp(\eta_{in})^2 & \nu_{in} & {\nu_{in}}^2 & \exp(\nu_{i2})^2 & x_{n-p} & x_{n-p+1} & \cdots & x_{n-1} \end{bmatrix} \quad (20)$$

$$Y^{(i)} = \begin{bmatrix} x_{p+1} \\ x_{p+2} \\ \vdots \\ x_n \end{bmatrix} \quad (21)$$

Adım 7. Eğitim kümesinde her bir resim bulanık küme için resim bulanık regresyon fonksiyonları, Eşitlik (22-23) ile tahmin edilir.

$$\hat{\beta}^{(i)} = (X^{(i)'} W_f X^{(i)})^{-1} X^{(i)'} W_f Y^{(i)} \quad (22)$$

$$\hat{Y}^{(i)} = X^{(i)}\hat{\beta}^{(i)} \; ; \; i = 1, 2, \dots c \quad (23)$$

Adım 8. Elde edilen çıktılar ilgili pozitif üyelik değerleri $(\hat{Y}_k{}^{\mu})$ ve nötral üyelik değerleri $(\widehat{Y_k}^{\eta})$ ve negatif üyelik değerleri $(\hat{Y}_k{}^{\nu})$ orantılı olarak Eşitlik (24-26) ile ayrı ayrı elde edilir.

$$\hat{Y}_k{}^{\mu} = \frac{\sum_{i=1}^{c} \hat{Y}^{(i)} \mu_{ik}}{\sum_{i=1}^{c} \mu_{ik}} \; , i = 1,2, \dots, c, \; k = 1,2, \dots, n \quad (24)$$

$$\hat{Y}_k{}^{\eta} = \frac{\sum_{i=1}^{c} \hat{Y}^{(i)} \eta_{ik}}{\sum_{i=1}^{c} \eta_{ik}} \; , i = 1,2, \dots, c, \; k = 1,2, \dots, n \quad (25)$$

$$\hat{Y}_k^{\nu} = \frac{\sum_{i=1}^{c} \hat{Y}^{(i)} \nu_{ik}}{\sum_{i=1}^{c} \nu_{ik}}, i = 1,2,\ldots,c,\ k = 1,2,\ldots,n \quad (26)$$

Adım 9. Her bir üyelik derecesi için en uygun ağırlıklar elde edilir. Ağırlıklar Eşitlik (27) ile belirtildiği gibi Eşitlik (24-26) ile elde edilen tahminlerin ağırlıklı toplamından oluşmaktadır. Optimum ağırlıkları belirlemek için ise Eşitlik (28) ile verilen kısıtlı optimizasyon problemini çözümlemek gerekmektedir. Bu çalışmada genetik algoritma yöntemi, optimizasyon çözümü için kullanılmıştır.

$$\hat{Y}_k^{\text{RBRF}} = w_1 \hat{Y}_k^{\mu} + w_2 \hat{Y}_k^{\eta} + w_3 \hat{Y}_k^{\nu} \quad (27)$$

$$\min_{w1,w2,w3} = \sum_{i=1}^{n} (\hat{Y}_k^{\text{RBRF}} - Y_k)^2 \quad (28)$$

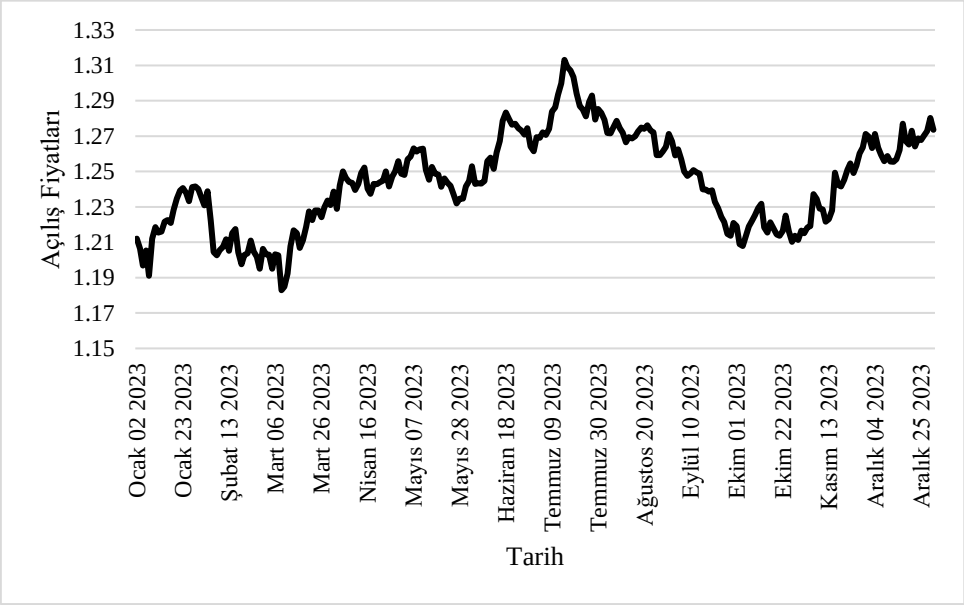
Kısıtlar: $\sum_{i=1}^{n} w_i = 1; 0 \leq w_i \leq 1, i = 1,2,3$

Adım 9. $X^{(i)}$ matrisi ve $Y^{(i)}$ vektörü test kümesi için yeniden oluşturulur. Test kümesinin $X^{(i)}$ matrisi resim üyelik değerleri eğitim kümesinde elde edilen küme merkezleri kullanılarak elde edilir ve her bir resim bulanık regresyon fonksiyonlarının test kümesi için tahmin değerleri yeniden oluşturulan $X^{(i)}$ matrisi ve $Y^{(i)}$ vektörü üzerinden hesaplanır.

5. UYGULAMA

Bu çalışmada BRF, SBRF ve RBRF yöntemlerinin öngörü performansı 2022 ve 2023 yıllarında günlük olarak elde edilen GBP/USD paritesi açılış fiyatlarına ait zaman serileri üzerinden karşılaştırılmıştır. 2022 ve 2023 yılları için elde edilen GBP/USD paritesi zaman serisi grafikleri sırası ile Görsel 1 ve Görsel 2 ile verilmiştir.

Görsel 1. 2022 Yılı GBP/USD Paritesi Zaman Serisi Grafiği



Görsel 2. 2023 Yılı GBP/USD Paritesi Zaman Serisi Grafiği

Her bir GBP/USD paritesi zaman serisi, eğitim, geçerlilik ve test kümesi olmak üzere üç kümeye ayrılmıştır. Ayırma işlemi sırasıyla eğitim, geçerlilik ve test kümesi olarak blok yapıda yapılmıştır. Geçerlilik ve test kümesinin uzunluğu 30 olarak alınmıştır. BRF, SBRF ve RBRF yöntemlerinin performans karşılaştırmasında Eşitlik (29) ile verilen hata kareler ortalaması karekök (HKOK) kriteri kullanılmıştır.

$$HKOK = \sqrt{\frac{\sum_{t=1}^{ntest}(X_t - \hat{X}_t)^2}{ntest}} \quad (29)$$

Bununla birlikte her bir BRF, SBRF ve RBRF yöntemi ile analiz edilen GBP/USD paritesi zaman serilerinde girdi sayısı bir ile beş arasında birer arttırılarak ve küme sayıları da üç ile on arasında birer arttırılarak farklı girdi ve küme sayıları ile analizler gerçekleştirilmiş ve her bir yöntem için optimal parametreler geçerlilik kümesi üzerinden belirlenmiştir. Her bir GBP/USD paritesi zaman serinin analizi için toplamda kırk farklı deneme gerçekleştirilmiş ve en düşük HKOK değerine sahip parametreler her bir yöntem için elde edilmiştir. Daha sonra ise bu optimal parametreler ile her bir BRF, SBRF ve RBRF yöntemi on kez tekrar çalıştırılmış ve on farklı HKOK değeri elde edilmiştir. Son olarak ise elde edilen bu on farklı HKOK değeri kullanılarak her bir GBP/USD paritesi zaman serisi test kümesi üzerinden ortalama, medyan, standart sapma, minimum ve maksimum istatistikleri hesaplanmıştır.

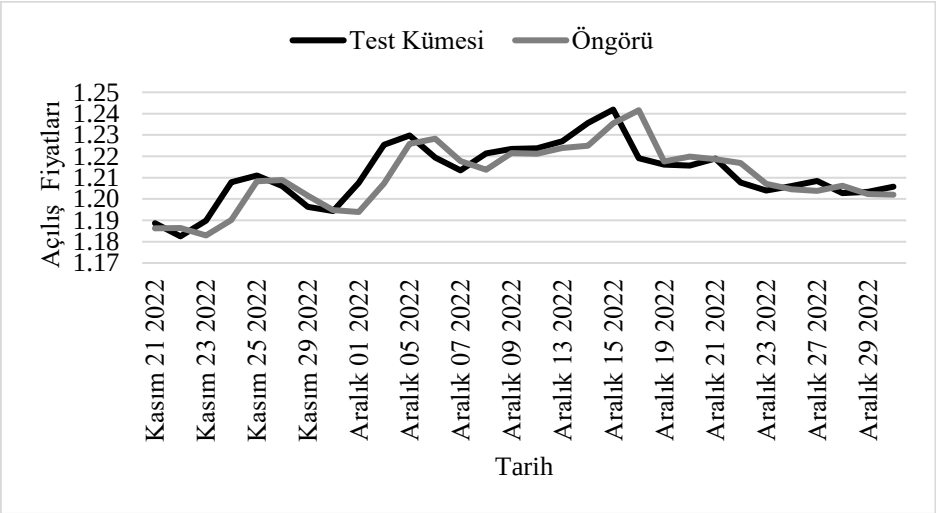
2022 yılına ait GBP/USD paritesi zaman serisinin test kümesinin BRF, SBRF ve RBRF yöntemleri ile analizinden elde edilen HKOK değerlerine ait istatistikler ve her bir yöntemden elde edilen optimal parametreler Çizelge 1 ile verilmiştir.

Çizelge 1. 2022 Yılına Ait GBP/USD Paritesi Zaman Serisinin Test Kümesi İçin Tüm Yöntemlerden Elde Edilen HKOK Değerlerine Ait Çeşitli İstatistikler

Yöntemler	Ortalama	Standart Sapma	Minimum	Maksimum	c	p
BRF	0.0082	0.0001	0.0081	0.0084	6	1
SBRF	0.0090	0.0004	0.0087	0.0099	3	4
RBRF	0.0085	0.0006	0.0080	0.0098	6	1

Çizelge 1 ile verilen analiz sonuçlarına göre, 2022 yılına ait GBP/USD paritesi zaman serisinin analizinde ortalama, standart sapma ve maksimum istatistiklerine göre en başarılı yöntemin BRF yöntemi olduğu görülmektedir. En başarılı yöntem olarak görülen BRF yöntemi minimum istatistiği sonucuna göre ise ikinci sırada yer almaktadır.

2022 yılına ait GBP/USD paritesi zaman serisinin analizi için en başarılı yöntem olarak belirlenen BRF yöntemi ile elde edilen öngörüler ile 2022 yılına ait GBP/USD paritesi zaman serisinin test kümesine ait gözlemlerin birlikte grafiği Görsel 3 ile verilmiştir.



Görsel 3. BRF Yöntemi İle Elde Edilen Öngörüler İle 2022 Yılına Ait GBP/USD Paritesi Zaman Serisinin Test Kümesine Ait Gözlemlerin Birlikte Grafiği

Görsel 3 ile verilen grafikten, BRF yönteminden elde edilen öngörülerin 2022 yılına ait GBP/USD paritesi zaman serisinin test kümesine ait gözlemler ile oldukça uyumlu olduğu söylenebilir.

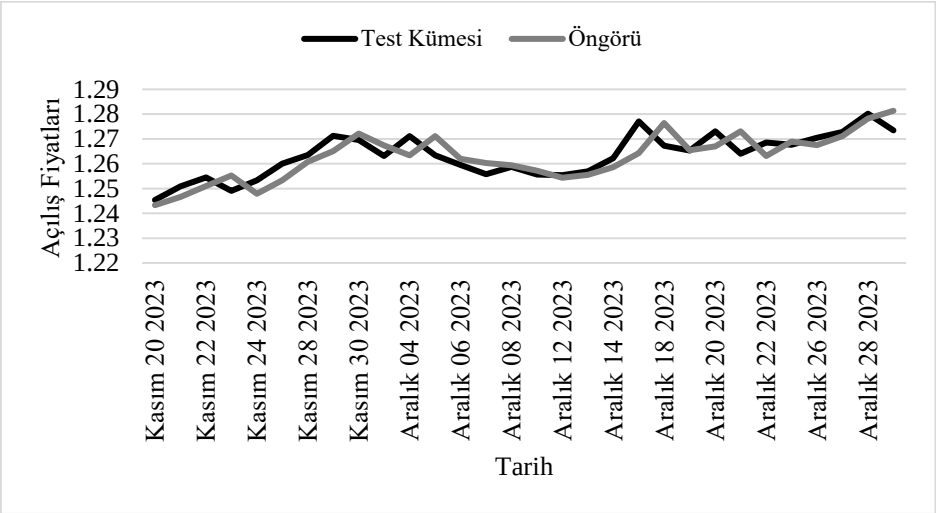
2023 yılına ait GBP/USD paritesi zaman serisinin test kümesinin BRF, SBRF ve RBRF yöntemleri ile analizinden elde edilen HKOK değerlerine ait istatistikler ve her bir yöntemden elde edilen optimal parametreler Çizelge 2 ile verilmiştir.

Çizelge 2. 2023 Yılına Ait GBP/USD Paritesi Zaman Serisinin Test Kümesi İçin Tüm Yöntemlerden Elde Edilen HKOK Değerlerine Ait Çeşitli İstatistikler

Yöntemler	Ortalama	Standart Sapma	Minimum	Maksimum	c	p
BRF	0.0059	0.0002	0.0055	0.0061	10	1
SBRF	0.0057	0.0000	0.0057	0.0058	7	2
RBRF	0.0056	0.0001	0.0053	0.0058	4	2

Çizelge 2 ile verilen analiz sonuçlarına göre, 2023 yılına ait GBP/USD paritesi zaman serisinin analizinde ortalama, minimum ve maksimum istatistiklerine göre en başarılı yöntemin RBRF yöntemi olduğu görülmektedir. En başarılı yöntem olarak görülen RBRF yöntemi standart sapma istatistiği sonucuna göre ise ikinci sırada yer almaktadır.

2023 yılına ait GBP/USD paritesi zaman serisinin analizi için en başarılı yöntem olarak belirlenen RBRF yöntemi ile elde edilen öngörüler ile 2023 yılına ait GBP/USD paritesi zaman serisinin test kümesine ait gözlemlerin birlikte grafiği Görsel 4 ile verilmiştir.



Görsel 4. RBRF Yöntemi İle Elde Edilen Öngörüler İle 2023 Yılına Ait GBP/USD Paritesi Zaman Serisinin Test Kümesine Ait Gözlemlerin Birlikte Grafiği

Görsel 4 ile verilen grafikten, RBRF yönteminden elde edilen öngörülerin 2023 yılına ait GBP/USD paritesi zaman serisinin test kümesine ait gözlemler ile oldukça uyumlu olduğu söylenebilir.

6. SONUÇ VE TARTIŞMA

Klasik bulanık çıkarım sistemleri yöntemleri, uzman bilgisine ihtiyaç duyması, kural tabanlı sistemlere dayanması ve bu kuralların belirlenmesinin zor olması gibi problemlere sahip olması nedeni ile son yıllarda yerini uzman bilgisine ve kural tabanına ihtiyaç duymayan bulanık regresyon fonksiyonları türlerine bırakmıştır. Bu çalışmada BRF, SBRF ve RBRF yöntemlerinin analiz performansı farklı yıllara ait GBP/USD paritesi zaman serisi üzerinden değerlendirilmiştir. İlgili yöntemlerin veriye dayalı yöntemler olması sebebi ile de farklı regresyon fonksiyonu yaklaşımları farklı zaman serilerinde daha başarılı öngörü sonuçları üretmiştir. 2022 yılına ait GBP/USD paritesi zaman serisinin analizinde en başarılı öngörü yöntem, BRF yöntemi iken, 2023 yılına ait GBP/USD paritesi zaman serisinin analizinde en başarılı öngörü yöntemi RBRF yöntemi olarak belirlenmiştir. İleri çalışmalarda zaman serisinde aykırı değer/değerler bulunduğu dahi kullanılabilecek dayanıklı BRF, SBRF ve RBRF yöntemleri kullanılabilir.

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REVIEW OF SCIENTIFIC PUBLICATIONS MADE IN 11 LEADING COUNTRIES IN THE FIELD OF RENEWABLE ENERGY

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Abstract

It is critical to meet energy needs with sustainable and environmentally friendly resources in combating environmental problems such as global warming and climate change. The environmental damage caused by fossil fuels and their limited reserves have increased the interest in renewable energy sources. Renewable energy sources include various options such as solar, wind, hydroelectric, biomass and geothermal energy. Each of these sources has low carbon emissions during energy production and contributes to environmental sustainability.

The Organization for Economic Co-operation and Development, or OECD for short, was created as part of the system of Western organizations created after World War II. OECD is an organization where 38 countries with democratic structures and market economies work together to solve economic, social and management problems and benefit from the opportunities of this process. The "Convention on the Organization for Economic Co-operation and Development", signed in Paris on 14 December 1960, constitutes the founding agreement of the OECD. In accordance with the principles included in the founding purposes of the OECD, scientific publications are shared, as in every field, and these are recorded in a common database. One of these is the work done in the field of renewable energy resources.

Turkey is among the leading states in the world in renewable energy investments, and according to the International Renewable Energy Agency's 2023 statistics, Turkey ranks 11th in the installed capacity ranking. It also ranks 5th in Europe. In this study, scientific publications in the field of renewable energy were examined along with investments and technological developments in this field. For this purpose, the development of scientific publications in the field of renewable energy made by the countries in the top 11 in the world ranking from the OECD database between 2013 and 2022 was examined, and Turkey's ranking among these countries was evaluated on a yearly basis. In the study, annual development rankings were integrated with the Borda Count method and turned into a single ranking.

Keywords: OECD, Renewable Energy, Borda Count Method.

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YENİLENEBİLİR ENERJİ ALANINDA ÖNDE GELEN 11 ÜLKEDE YAPILAN BİLİMSEL YAYINLARIN İNCELENMESİ

ÖZET

Küresel ısınma ve iklim değişikliği gibi çevre sorunlarıyla mücadelede enerji ihtiyacının sürdürülebilir ve çevre dostu kaynaklarla karşılanması kritik öneme sahiptir. Fosil yakıtların çevreye verdikleri zararlar ve sınırlı rezerve sahip olmaları, yenilenebilir enerji kaynaklarına olan ilgiyi artırmıştır. Yenilenebilir enerji kaynakları arasında güneş, rüzgar, hidroelektrik, biyokütle ve jeotermal enerji gibi çeşitli seçenekler yer almaktadır. Bu kaynakların her biri enerji üretimi sırasında düşük karbon emisyonuna sahiptir ve çevresel sürdürülebilirliğe katkı sağlamaktadır.

Ekonomik İşbirliği ve Kalkınma Örgütü veya kısaca OECD, İkinci Dünya Savaşından sonra oluşturulan Batı kuruluşları sisteminin bir parçası olarak ihdas edilmiştir. OECD, demokratik yapılara ve piyasa ekonomisine sahip 38 ülkenin ekonomik, sosyal ve yönetim sorunlarını çözmek ve bu sürecin fırsatlarından faydalanmak üzere müştereken çalıştıkları bir örgüttür. 14 Aralık 1960 yılında Paris'te imzalanan "Convention on the Organisation for Economic Co-operation and Development", OECD'nin kurucu anlaşmasını teşkil etmektedir. OECD içerisinde kuruluş amaçlarının içerisinde yer alan ilkeleri gereği her alanda olduğu gibi bilimsel yayınlar açısından da paylaşımlar yapılmakta, bunlar ortak veri tabanında kaydedilmektedir. Bunlardan birisi de yenilenebilir enerji kaynakları alanında yapılan çalışmalardır.

Türkiye de yenilenebilir enerji yatırımlarında dünya da önde gelen devletler içerisinde olup, Uluslararası Yenilenebilir Enerji Ajansı, 2023 yılı istatistiklerine göre Türkiye, kurulu güç sıralamasında 11'inci sıradadır. Ayrıca Avrupa'da 5'nci sırada yer almaktadır. Bu çalışmada da bu alandaki yatırım ve teknolojik gelişmelerle birlikte yenilenebilir enerji alanında yapılan bilimsel yayınlar incelenmiştir. Bu amaçla 2013-2022 yılları arasında OECD veri bankasından Dünya sıralamasında ilk 11'de yer alan ülkelerin yapılan yenilenebilir enerji alanındaki bilimsel yayınların gelişimi incelenmiş, Türkiye'nin bu ülkeler arasındaki sıralaması yıl bazında değerlendirilmiştir. Çalışmada yıllık gelişim sıralamaları Borda Sayım yöntemi ile bütünleştirilip tek sıralama haline getirilmiştir.

Anahtar Kelimeler: OECD, Yenilenebilir Enerji, Borda Sayım Yöntemi.

INTRODUCTION

Energy is the most important need in every moment of human life and in every activity. Ensuring adequate energy levels and using this energy in the most efficient way has become the most important social duty. Compared to the past, the rapid increase in the world population, the increase in quantity and diversity of human needs, and especially technological developments have now begun to reveal the problem of "not being enough" in the field of energy. In addition to the inadequacy, the environment has also begun to be negatively affected

by the use of high amounts of energy. In order to eliminate this insufficiency and environmental problems, human beings have realized the limitations of natural resources that they have used carelessly until now and have started to search for alternative energy sources (Erdinç and Aydınbaş, 2020).

Of course, as in every field, energy competition has begun between countries in this field, and this competition has intensified especially in the energy field in the last century. Energy, which became the indicator and building block of civilization, development, economic power and modernity after the Industrial Revolution, also shaped the country's policies. Therefore, energy has become the most determining factor in diplomacy, law and especially geopolitical relations between countries (Çolak, 2013:14). Countries have come together with many organizations to cooperate in many fields, especially in energy, and have tried to develop in cooperation. One of these organizations is OECD.

OECD (Organisation for Economic Co-operation and Development) is an organization of countries that come together to support economic development, increase welfare and ensure global economic stability. Founded in 1961, OECD today operates as an important platform in the field of global economic development and social policies with 38 member countries. Member countries include countries that have a strong place in the world economy, such as the USA, Canada, Germany, France, Japan, Australia, Turkey and South Korea.

OECD countries share knowledge and experience to find solutions to common economic and social problems, promote sustainable growth and improve quality of life. The OECD helps implement economic policies effectively through data sharing, research and analysis between countries. For example, it aims to disseminate best practices by making comparisons between member countries on issues such as education, health, environment, employment and income inequality.

In this study, Turkey's scientific studies on the same subject, which has an important place in the world's renewable energy production, were examined. The development of renewable energy scientific publications in Turkey, which ranks 11th in the world in renewable energy installed capacity according to 2023 data, among OECD countries, was examined.

1. Renewable Energy Concepts

Resources that produce energy by various methods as economic value are described as energy resources. These resources are called chemical, nuclear, mechanical, thermal, geothermal, hydraulic, solar, wind and electrical energy. At the same time, these types of energy are converted into each other using different technologies. Energy resources are generally classified according to their use and conversion. Renewable and non-renewable depending on their use; According to transformation, they are divided into primary and secondary sources (Aykırı, 2017).

As a result of meeting the energy demand, two basic concepts have emerged: renewable energy resources and non-renewable energy resources. In the literature, both concepts are defined

almost the same way. It is a type of energy that can exist continuously and maintain its continuity through natural processes (Australian Renewable Energy Agency, 2016). In addition, renewable energy source is defined as "an energy source that can remain the same for the next use within nature's own cycle" (Yılmaz et al., 2018: 527). In another definition, renewable energy; It is also described as energy produced from sources that are constantly found in nature such as wind, water and sun (Spurgeon and Flood, 2010:43). Although many definitions have been made in this context, these definitions mean the same thing. According to these definitions, the most basic feature of renewable energy is that it can renew itself naturally and do not disappear. Non-renewable energy is; They are defined as "energy resources that cannot be replaced or replaced in a short time due to their occurrence and formation processes" (Kara et al., 2006: 120). Resources that exist naturally in nature, such as solar, wind, biomass, geothermal and wave energy, are included in the renewable energy class. Coal, oil and natural gas, also known as fossil fuels, and nuclear energy are non-renewable energy types.

To briefly look at the definition of renewable energy resource types, solar energy is the natural resource that provides the most direct and maximum benefit in terms of producing energy. Converting a very small amount of the sun's rays reaching the earth into energy will be able to meet a large part of the energy amount of the world and therefore humanity (Çıtak and Pala, 2017: 84-85). China, USA, Germany, Japan and Italy, respectively, benefit from this easiest and most economical type of energy; It is among the top 5 (World Bank, 2015). In Turkey, according to the May 2024 Installed Power Report data, Turkey's total renewable energy installed power is 58 462 MW, according to the end of May 2024 evaluations, 12 425 MW of this power, in other words 21% of the installed power, is solar energy. was provided from power plants (TC Ministry of Energy and Natural Resources, 2024).

Wind energy is the energy produced by using air currents occurring in nature. This energy also meets the energy needs of humanity in many areas, including electricity production. Although wind energy as a resource can be obtained anywhere in the world, in order to benefit from it, the wind must blow with a certain continuity and intensity. In this way, maximum energy production can be achieved at minimum cost thanks to wind turbines installed in the most suitable region. In wind energy, countries such as Germany, Spain and Denmark have made significant investments and have become a model for other countries (Çıtak and Pala, 2017: 84). Türkiye is among the top 10 countries in the world in terms of wind energy investments. In 2019, there was an increase in wind energy capacity of 686 MW in Turkey, and in 2020, the increase amount doubled compared to the previous year with 1224 MW. As of 2020, total wind capacity in Turkey has increased to 9280 MW (GWEC, 2021).

Similarly, another common type of renewable energy is energy obtained from hydropower. It is also possible to diversify the energy obtained from water power such as hydraulic, wave-tidal and ocean (heat) energy. The most important issue in benefiting from this energy is the creation of the necessary technological infrastructure. Hydraulic energy is mostly used in the field of electricity production, and electricity production with hydroelectric power plants accounts for approximately 23% of the total electricity production in the world. Since Türkiye has high flow rate rivers, it ranks first in the world in terms of hydroelectric energy resources. When we look

at the world in general, China, Brazil, Canada, USA, Venezuela, Japan, Sweden, France and Italy are the leading countries in hydroelectric energy.

2. World Countries and Türkiye in Clean Energy

The most important factor to benefit from renewable energy resources is geographical location. Therefore, the renewable energy potential of each country differs from each other. In addition, the technological infrastructure of the country significantly affects the rate of energy utilization. Türkiye, on the other hand, has made major investments in every renewable energy resource it has in the last decade, and has shown a rapid increase in the rate of renewable energy use among the world countries. In 2020, European countries invested approximately 42.8 billion Euros in wind energy. Türkiye was among the top five countries investing in this field in 2020. The total investment in renewable energy in Turkey has reached 66 billion dollars as of 2021, and electricity production among these investments has reached 53.15%. Among renewable energy, wind and solar energy ranked first, respectively (TRTHABER, 2021). Similarly, Turkey ranked 7th in the list of "Countries Attracting the Most Foreign Investment in Renewable Energy", which includes 20 countries, with 19 direct foreign investment projects in the field of renewable energy (AA, 2020).

METHOD

In the research, the Borda Census procedure was used, which allows decision makers to make a single ranking by combining the rankings. The data of the research were obtained from the OECD database. In the research, data from the top 11 countries in the world ranking of renewable energy installed capacity between 2013 and 2022 were used. Data are bilateral international cooperation intensity, normalized to full counts. The indicator of the intensity of bilateral collaboration between two economies is calculated by dividing the number of scientific publications by authors with affiliations in both economies (complete counts) by the square root of the product of the publications of both economies (complete counts). Therefore this indicator is normalized for broadcast output.

BOARD COUNT METHOD

There are many studies in the literature where ranking is done using MCDM methods. Borda Counting method offers decision makers the opportunity to make a single ranking by combining rankings calculated with two or more techniques. This method is based on the scoring logic of assigning a decreasing value such as m-1 to the first of the m alternatives of the class considered in the search, m-2 to the second, and the last alternative receives the value 0. The steps to be followed in the Borda Counting procedure are as follows (Akyüz and Aka, 2017).

Step 1: Determining the Borda Score

For each alternative, Borda value is calculated via Equation (1).

$$b_i = \sum_{k=1}^{n}(M - r_{ik}) \quad (1)$$

r_{ik} : k. under criterion i. order of alternative.

M: Total number of alternatives.

The Borda value is obtained by summing the values assigned for the alternatives in the entire class. Here, the ranking is made starting from the alternative with the highest value.

FINDINGS AND CONCLUSION

According to IRENA 2024 data, the installed capacity of the leading countries in renewable energy investment in the world and Turkey is given in Table 1.

Table 1. World Countries (Top 11) Renewable Energy Installed Power (MW)

CAP (MW)	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
China	414651	479103	541016	620856	695463	758870	896412	1.017.852	1.156.126	1.453.701
USA	180970	196009	216174	230714	245595	263821	293527	326733	354314	385205
Brazil	106445	112646	121378	128425	136613	144658	150685	161483	176709	194085
Germany	71892	78582	90414	105258	118227	128475	134774	147390	163213	175934
India	90325	97851	104436	112514	118905	125068	131686	139077	149143	166939
Japan	55520	66905	75563	83598	90723	98685	107935	115170	122922	128782
Canada	89773	95973	97881	99131	100743	101328	101812	103808	106359	108718
Spain	46850	47708	47798	47948	48283	54601	57313	62011	73818	80136
France	40733	43024	45059	48036	50687	53544	55847	59700	64692	67916
Italy	49526	50417	51195	52128	53161	54373	55493	56856	59479	65157
Türkiye	27940	31516	34446	38746	42230	44389	49195	53175	55946	58462

According to IRENA 2024 data, the ranking of the installed capacities of the leading countries in the world's renewable energy investment and Turkey by years is given in Table 2.

Table 2. World Countries (Top 11) Renewable Energy Installed Power Ranking (MW)

CAP (MW)	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
China	1	1	1	1	1	1	1	1	1	1
USA	2	2	2	2	2	2	2	2	2	2
Brazil	3	3	3	3	3	3	3	3	3	3
Germany	6	6	6	5	5	4	4	4	4	4
India	4	4	4	4	4	5	5	5	5	5
Japan	7	7	7	7	7	7	6	6	6	6
Canada	5	5	5	6	6	6	7	7	7	7
Spain	9	9	9	10	10	8	8	8	8	8
France	10	10	10	9	9	10	9	9	9	9
Italy	8	8	8	8	8	9	10	10	10	10

Türkiye	11	11	11	11	11	11	11	11	11	11

When Table 2 is examined, Turkey's renewable energy installed capacity ranking in all years is 11.

Table 3. Results obtained by Borda Counting method (RES Installed Power)

Country	Borda Scor	Final Rank
China	10	1
USA	20	2
Brazil	30	3
Germany	48	5
India	45	4
Japan	66	7
Canada	61	6
Spain	87	8
France	94	10
Italy	89	9
Türkiye	110	11

According to Table 3, when the rankings between 201-2023 are combined with the Borda method, Turkey's ranking is 11.

Table 4 shows the number of scientific studies carried out by Turkey and these 11 countries in the field of renewable energy.

Table 4. World Countries (Top 11) Renewable Energy Field Scientific Studies

	2014	2015	2016	2017	2018	2019	2020	2021	2022
Kanada	320,57	297,88	349,24	497,49	550,87	377,02	420,73	445,60	429,02
Fransa	295,88	224,36	247,59	285,12	313,30	268,22	282,21	327,16	298,31
Almanya	416,82	447,83	478,52	568,30	635,85	608,28	735,90	751,67	675,39
İtalya	299,54	502,30	453,94	533,59	515,61	526,09	663,64	701,87	613,55
Japonya	369,93	336,11	317,86	421,60	404,00	381,60	380,11	394,57	425,60
İspanya	330,71	399,94	445,56	469,91	514,58	550,20	660,35	645,24	516,10
Türkiye	158,28	194,30	240,33	249,67	301,57	342,68	376,73	398,29	640,33
ABD	1839,59	1616,22	1989,05	2188,06	2271,71	1848,74	1965,85	2029,13	1828,19
Brezilya	183,51	215,31	219,76	329,63	344,40	405,81	433,64	496,67	458,27
Çin	2318,54	2620,42	2903,68	3672,42	4735,67	5819,17	6774,58	7512,03	10048,06
Hindistan	839,44	799,80	389,94	1347,85	1517,90	1432,24	1710,96	2041,13	3445,69

Çizelge 5'te 11 ülkenin yenilenebilir enerji alanında yaptığı bilimsel çalışmalara göre sıralaması verilmiştir.

Çizelge 5. Dünya Ülkeleri (İlk 11) Yenilenebilir Enerji Alanı Bilimsel Çalışmalar Sıralaması

	2014	2015	2016	2017	2018	2019	2020	2021	2022
Canada	7	8	7	6	5	9	8	8	9

France	9	9	9	10	10	11	11	11	11
Germany	4	5	3	4	4	4	4	4	4
Italy	8	4	4	5	6	6	5	5	6
Japan	5	7	8	8	8	8	9	10	10
Spain	6	6	5	7	7	5	6	6	7
Türkiye	11	11	10	11	11	10	10	9	5
USA	2	2	2	2	2	2	2	3	3
Brazil	10	10	11	9	9	7	7	7	8
Chinese	1	1	1	1	1	1	1	1	1
India	3	3	6	3	3	3	3	2	2

When Table 5 is examined, Turkey's ranking of scientific studies in the field of renewable energy along with these 11 countries has changed from year to year. When Table 5 is examined, Türkiye ranked 11th in 2013 in terms of studies carried out in the field of renewable energy publications, and ranked 5th in 2022. Between 2013 and 2022, studies in the field of renewable energy have shown a significant increase. The United States ranked first in all years. Although its renewable energy production capacity is ranked 11th in the world, especially in 2022, its scientific publication ranking in the same field is 5th. The results obtained by the Borda Counting method are given in Table 6.

Table 6. Results obtained by Borda Counting method

Country	Borda Scor	Final Ranking
Canada	67	7
France	91	11
Germany	36	4
Italy	49	5
Japan	73	8
Spain	55	6
Türkiye	88	10
USA	20	2
Brazil	78	9
Chinese	9	1
India	28	3

Table 6 shows the joint integration of all rankings between 2013 and 2022 according to the Bordra counting method. Accordingly, the integrated ranking of renewable energy scientific studies conducted in Turkey is 10th among OECD countries. Turkey's ranking for 2022 is 11. Therefore, the fluctuation over the years has caused the ranking average to fall further behind. Among OECD countries, Turkey's giving more importance to scientific studies in the field of renewable energy will both increase its ranking and increase the qualitative quality of the studies.

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REVIEW OF MULTIDISCIPLINARY SCIENTIFIC PUBLICATIONS IN OECD COUNTRIES

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ÖZET

Yazının icat edilmesiyle bilginin üretilmesi mümkün olmuş, kayıt altına alınan bilgi nesilden nesile aktarılır hale gelmiştir. Kayda geçirilen bu bilgilerin paylaşılması diğer araştırmacılar tarafından temel olarak alınmış ve üzerine konularak yeni bilgiler elde edilmiştir. Günümüzde bilimsel araştırma sonucu elde edilen birikimler yazılı ya da online ortamlarda olarak tüm dünyaya duyurulmaktadır. Özellikle bilimsel dergi sayısının artması, alanına özgü kongrelerin dünya genelinde yapılıyor olması bilim insanlarının bilimsel iletişimini oldukça geliştirmiştir.

Günümüzde kalkınmanın temelini bilimsel bilgi oluşturmaktadır. Bilimsel bilginin en önemli özelliği elde edilirken bilimsel ilkelere dikkat edilmesidir. Elde edilen bilgiler, sonuçlar kitap, dergi, bildiri, makale gibi formlarla bilim dünyasına yayınlanır ve kazandırılır. Bir ülkede bilimin gelişimini gösteren en önemli etmenlerden birisi de bilimsel alanda yapılan çalışmalardır. Türkiye'de de her geçen gün bilim sayısı artmakta, bu yayınların niceliksel ve niteliksel özellikleri de tartışılır hale gelmiştir. Bilimsel yayınların niteliği bir ülkedeki araştırmaların sağlıklı bir şekilde yapılıp yapılmadığının somut göstergelerindendir.

Günümüzde yapılan araştırmalarda disiplinler arası yapılan çalışmaların sayısı da artmaktadır. Multidisipliner olarak adlandırılan bu çalışmaların sayısı bilimin gelişmesini gösteren en önemli etmenlerdendir. Bir çalışmanın niteliğini arttıran en önemli göstergelerinden birisi de uluslararası düzeyde kabul edilebilirliğidir.

Ülkeler ekonomik sosyal ve birçok alanda kıyaslandığı gibi bilimsel çalışmaların sayısı açısından da sınıflandırılmaktadır. Bu çalışmada da OECD ülkelerine ait multidisipliner alanında yapılmış çalışmalar incelenmiştir. 2013-2022 yılları arasında yapılan multidisipliner çalışmaların sayıları kıyaslanmış, yıllara göre Türkiye'de yapılan multidisipliner çalışmalarının gelişimi incelenmiştir. Çalışmada, yıllara göre çalışmaların sıralaması Borda Sayım prosedürü ile bütünleştirilmiş, Türkiye'nin hem sıralamadaki yeri hem de gelişim süreci incelenmiştir.

Anahtar Kelimeler: OECD, Multidisipliner Yayın, Borda Sayım.

OECD ÜLKELERİNDE MULTİDİSİPLİNER BİLİMSEL YAYINLARIN İNCELENMESİ

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Abstract

With the invention of writing, it became possible to produce information, and recorded information became transferable from generation to generation. Sharing this recorded information was taken as a basis by other researchers and new information was obtained by building on it. Today, the knowledge gained as a result of scientific research is announced to the whole world in written or online media. Especially the increase in the number of scientific journals and the fact that field-specific congresses are held around the world have greatly improved the scientific communication of scientists.

Today, scientific knowledge forms the basis of development. The most important feature of scientific knowledge is to pay attention to scientific principles while obtaining it. The information and results obtained are published and brought to the scientific world in forms such as books, journals, papers and articles. One of the most important factors that show the development of science in a country is the studies carried out in the scientific field. In Turkey, the number of scientific studies is increasing day by day, and the quantitative and qualitative characteristics of these publications have become debatable. The quality of scientific publications is a concrete indicator of whether research in a country is carried out in a healthy way.

In today's research, the number of interdisciplinary studies is also increasing. The number of these studies, called multidisciplinary, is one of the most important factors that show the development of science. One of the most important indicators that increase the quality of a study is its acceptability at the international level.

Countries are classified in terms of the number of scientific studies as well as comparisons in economic, social and many areas. In this study, studies conducted in the multidisciplinary field of OECD countries were examined. The numbers of multidisciplinary studies conducted between 2013 and 2022 were compared, and the development of multidisciplinary studies conducted in Turkey was examined over the years. In the study, the ranking of studies by year was integrated with the Borda Census procedure, and both Turkey's place in the ranking and its development process were examined.

Keywords: OECD, Multidisciplinary Publication, Borda Count.

GİRİŞ

Öğretim konusu olan veya olabilecek bilgilerin bütünü bilim dalı olarak ifade edilen disiplin kavramı çağın gelişimine göre farklı şekillerde nitelendirilmiştir. Günümüzde ise her disiplin kendine özgü kavramlar oluşturmuş ve diğer disiplinlerle de ilişkilerini geliştirmiştir. Bilim tarihi incelendiğinde ise ilk bilim insanları bütüncül olarak olaylara yaklaşmışlardır. Hatta aldıkları eğitiminde bütüncül bir anlayışla verildiği görülmektedir (Jacobs, 1989; Yıldırım, 1996). Örneğin İbn-i Sina felsefe eğitimi almasının yanı sıra farklı alanlarda ve disiplinlerde de (matematik, hukuk, tıp, edebiyat gibi) kendini geliştirdiği görülmektedir. Bunun sonucu olarak da ilk bilim insanları hayatta bir problemle karşılaştıklarında, sahip oldukları bütüncül anlayışa paralel olarak bütüncül bir çözüm üretmişlerdir (İnci ve Kaya, 2022). Ancak günümüzde bilim dallarının çeşitlenmesi ve bilimin genişlemesi ile birlikte birden fazla alanda uzmanlaşmak yerine bir disiplin alanında uzmanlaşmak tercih edilir hale gelmiştir. Buna rağmen bir olaya

veya bir soruna bir tek disiplin açısından değil farklı disiplinler açısından bakmak daha elverişlidir.

Farklı bilim dallarından, disiplinlerden gelen bilgileri, yöntemleri, bakış açılarını bir araya getirerek ortak bir çalışma yapmaya multidisipliner alanda çalışmak denir. Multidisipliner yaklaşım, bir çalışmada birden fazla alan bilgisi gerektiren araştırmalarda çoğunlukla kullanılır. Bu yaklaşımda her disiplin kendi uzmanlık alanına odaklanır, diğer alanlardan gelen bilgiyi ve yöntemi kendi uzmanlık alanına adapte ederek kullanır. Örneğin, tıbbi bir araştırmada biyologlar, psikologlar, mühendisler, sosyologlar ve istatistikçiler bir arada çalışabilir. Ya da sosyal bir araştırmada muhasebeciler, pazarlamacılar, istatistikçiler hatta mühendisler bilgi birikimlerini kullanabilirler. Dolayısıyla bir konu hakkında o konuya hitap eden birden fazla disiplin bir araya gelerek o konuya farklı bakış açıları ve çözümler sunabilir. Dolayısıyla multidisipliner çalışmada daha kapsamlı bir çözüm bulunmuş olur. Özellikle çok karmaşık ve çok boyutlu problemlerin çözümünde multidisipliner yaklaşım daha kapsamlı sonuçlar verecektir. Günümüz bilim dünyasında da hem sorunların altında yatan nedenler birçok disipline hitap ettiğinden, hem de bilimin birçok alt bilimlere ayrılmasından dolayı birçok araştırmacı kendi disiplinin yanında farklı disiplinlerle çalışma ihtiyacı duymaktadır. Bu çalışmada da OECD ülkelerine ait multidisipliner alanında yapılmış çalışmalar incelenmiştir. 2013-2022 yılları arasında yapılan multidisipliner çalışmaların sayıları kıyaslanmış, yıllara göre Türkiye'de yapılan multidisipliner çalışmalarının gelişimi incelenmiştir. Çalışmada yıllara göre sıralamalar Borda Sayım prosedürü ile bütünleştirilmiş, Türkiye'nin hem sıralamadaki yeri hem de gelişim süreci incelenmiştir.

OECD (Ekonomik Kalkınma ve İşbirliği Örgütü) ülkeleri, ekonomik kalkınmayı desteklemek, refahı artırmak ve küresel ekonomik istikrarı sağlamak amacıyla bir araya gelen ülkelerin oluşturduğu bir örgüttür. 1961 yılında kurulan OECD, günümüzde 38 üye ülkeyle küresel ekonomik gelişim ve sosyal politikalar alanında önemli bir platform olarak faaliyet göstermektedir. Üye ülkeler arasında ABD, Kanada, Almanya, Fransa, Japonya, Avustralya, Türkiye ve Güney Kore gibi dünya ekonomisinde güçlü bir yer edinmiş ülkeler bulunmaktadır.

OECD ülkeleri, ortak ekonomik ve sosyal sorunlara çözüm üretmek, sürdürülebilir büyümeyi teşvik etmek ve yaşam kalitesini artırmak için bilgi ve tecrübe paylaşımında bulunurlar. OECD, ülkeler arasındaki veri paylaşımı, araştırmalar ve analizler yoluyla ekonomik politikaların etkili bir şekilde uygulanmasına yardımcı olur. Örneğin, eğitim, sağlık, çevre, istihdam ve gelir eşitsizliği gibi konularda üye ülkeler arasında karşılaştırmalar yaparak en iyi uygulamaları yaygınlaştırmayı amaçlar.

YÖNTEM

Araştırmada sıralamaları birleştirerek karar vericilere tek bir sıralama yapma imkânı sunan Borda Sayım prosedürü kullanılmıştır. Araştırmanın verileri OECD veri tabanından elde edilmiştir. Araştırmada 2013-2022 yılları arasında OECD ülkelerinde multidisipliner alanında yapılan çalışmaların sayısı kullanılmıştır.

BORDA SAYIM YÖNTEMİ

Literatürde ÇKKV yöntemleri kullanılarak sıralamanın yapıldığı çok sayıda çalışma bulunmaktadır. Borda Sayım yöntemi, iki ya da daha fazla sayıda teknikle hesaplanan

sıralamaları birleştirerek karar vericilere tek bir sıralama yapma imkânı sunmaktadır. Bu yöntem, aramada ele alınan sınıfın m alternatiften birincisine $m-1$, ikincisine $m-2$ gibi azalan bir değer atayarak son alternatif 0 değerini alacak şekilde puanlama mantığına dayanmaktadır. Borda Sayım prosedüründe izlenecek adımlar şu şekildedir (Akyüz ve Aka, 2017).

Adım 1: Borda Skorunun Belirlenmesi

Her bir alternatif için Eşitlik (1) vasıtasıyla Borda değeri hesaplanır.

$$b_i = \sum_{k=1}^{n}(M - r_{ik}) \quad (1)$$

r_{ik} : k. kriter altındaki i. alternatifin sırası

M: Toplam alternatif sayısı

Borda değeri, tüm sınıftaki alternatifler için atanan değerlerin toplanması ile elde edilir. Burada en yüksek değere sahip olan alternatiften başlayarak sıralama yapılır.

BULGULAR VE SONUÇ

Araştırmada kullanılan verileri OECD veri tabanından elde edilmiş olup Çizelge 1'de verilmiştir.

Çizelge 1. OECD Ülkeleri 2013-2022 Multidisipliner Çalışma Yüzdeleri

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Avustralya	271,12	235,97	214,27	187,98	165,96	156,38	66,95	125,83	94,40	111,87
Avusturya	47,42	55,18	56,40	45,40	47,15	33,22	22,95	27,27	29,22	31,67
Belçika	77,34	66,80	68,56	58,74	48,33	52,48	30,81	28,90	32,51	42,02
Kanada	249,40	231,03	200,23	173,33	154,20	143,62	69,15	106,11	98,63	134,18
Şili	14,13	20,83	19,45	18,13	23,12	23,05	13,02	19,64	26,04	24,29
Kolombiya	16,80	32,91	18,38	15,91	13,02	14,31	17,27	20,36	22,61	30,89
Kosta Rika	0,61	1,80	0,95	0,81	1,41	1,88	2,07	2,70	0,90	2,36
Çekya	25,71	29,74	36,55	31,27	34,46	25,83	15,99	21,46	24,95	30,50
Danimarka	67,98	67,78	60,56	54,81	49,99	45,48	18,39	34,36	24,13	35,54
Estonya	7,86	6,97	8,42	4,52	4,53	1,97	3,37	3,99	2,24	3,51
Finlandiya	37,35	33,09	30,92	27,67	28,17	19,84	11,94	13,73	11,17	20,35
Fransa	174,65	147,82	152,79	124,82	141,28	115,43	89,70	92,64	103,20	136,81
Almanya	417,61	427,18	424,88	362,24	337,59	297,27	168,96	209,36	236,81	339,06
Yunanistan	17,39	9,95	16,30	8,29	11,58	9,56	7,65	6,94	7,96	9,49
Macaristan	17,03	18,55	13,83	14,04	17,56	22,48	13,93	19,70	22,17	29,66
İzlanda	2,01	2,09	3,13	2,29	2,06	1,74	0,74	2,21	1,05	2,33
İrlanda	21,70	15,55	17,76	16,13	13,32	11,80	9,01	14,87	13,43	15,33
İsrail	43,74	34,83	33,79	29,56	28,33	26,47	20,94	27,16	27,77	41,44
İtalya	193,53	191,11	194,72	148,18	168,30	110,74	111,71	98,47	130,46	174,38
Japonya	348,41	355,30	369,80	305,09	313,65	273,30	173,76	248,48	258,69	333,45
Kore	85,21	96,33	288,11	231,27	155,21	134,23	95,45	113,06	118,71	158,70
Litvanya	1,01	7,01	3,98	2,42	7,49	3,78	1,70	1,85	1,57	5,15
Lüksemburg	1,89	3,01	3,26	2,78	1,98	1,53	1,10	2,25	1,05	3,19
Meksika	33,67	31,16	40,32	33,29	37,22	38,83	28,10	34,10	30,95	41,61
Hollanda	171,29	155,76	155,43	125,41	121,77	104,56	44,46	61,98	51,99	74,22

Yeni Zelanda	30,88	22,16	29,26	17,90	42,90	16,80	11,15	15,99	21,99	20,07
Norveç	42,37	49,18	44,06	37,02	46,47	35,02	12,57	29,92	18,00	25,61
Polonya	33,07	65,49	83,87	63,49	76,71	65,76	30,95	53,14	59,06	74,61
Portekiz	25,24	22,13	21,27	13,52	14,53	16,82	15,55	21,20	27,54	24,80
Slovak Cumhuriyeti	4,73	1,92	3,93	1,81	4,98	2,71	6,54	3,28	5,67	4,85
Slovenya	8,44	9,06	10,42	8,33	6,97	9,19	4,80	9,39	5,97	5,94
İspanya	136,58	141,67	148,39	137,27	131,58	156,80	98,35	107,57	123,16	132,07
İsveç	81,58	79,22	77,11	71,53	60,53	55,00	30,08	42,14	39,14	62,72
İsviçre	94,37	80,47	87,63	77,33	85,23	85,21	59,81	53,94	70,42	89,82
Türkiye	48,45	36,65	39,45	60,20	37,63	31,84	43,74	54,68	64,60	87,15
Birleşik Krallık	462,66	388,84	392,86	343,43	302,47	282,18	183,42	222,00	191,39	280,00
ABD	1758,87	1614,14	1509,07	1249,46	1183,83	1055,85	587,55	831,29	728,90	995,38

Çizelge 2'de Ülkelerin aynı yıllar içerisindeki sıralaması gösterilmiştir.

Çizelge 2. Ülkelerin 2013-2022 Yılları Arasındaki Multidisipliner Yayın Sıralaması

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Avustralya	5	5	6	6	6	6	10	5	10	10
Avusturya	17	17	17	18	17	19	18	20	18	20
Belçika	14	15	15	16	16	15	15	19	16	16
Kanada	6	6	7	7	8	7	9	8	9	8
Şili	30	27	26	24	25	23	25	26	21	26
Kolombiya	29	22	27	27	29	28	21	24	24	21
Kosta Rika	37	37	37	37	37	35	34	34	37	36
Çekya	24	24	21	21	22	22	22	22	22	22
Danimarka	15	14	16	17	15	16	20	16	23	19
Estonya	32	33	32	32	34	34	33	32	33	34
Finlandiya	20	21	23	23	24	25	27	29	29	27
Fransa	8	9	10	11	9	9	8	10	8	7
Almanya	3	2	2	2	2	2	4	4	3	2
Yunanistan	27	30	29	31	30	30	30	31	30	30
Macaristan	28	28	30	28	26	24	24	25	25	23
İzlanda	34	35	36	35	35	36	37	36	36	37
İrlanda	26	29	28	26	28	29	29	28	28	29
İsrail	18	20	22	22	23	21	19	21	19	18
İtalya	7	7	8	8	5	10	5	9	5	5
Japonya	4	4	4	4	3	4	3	2	2	3
Kore	12	11	5	5	7	8	7	6	7	6
Litvanya	36	32	33	34	31	32	35	37	34	32
Lüksemburg	35	34	35	33	36	37	36	35	35	35
Meksika	21	23	19	20	21	17	17	17	17	17
Hollanda	9	8	9	10	11	11	12	11	14	14
Yeni Zelanda	23	25	24	25	19	27	28	27	26	28
Norveç	19	18	18	19	18	18	26	18	27	24
Polonya	22	16	13	14	13	13	14	14	13	13
Portekiz	25	26	25	29	27	26	23	23	20	25
Slovak Cumhuriyeti	33	36	34	36	33	33	31	33	32	33
Slovenya	31	31	31	30	32	31	32	30	31	31
İspanya	10	10	11	9	10	5	6	7	6	9
İsveç	13	13	14	13	14	14	16	15	15	15
İsviçre	11	12	12	12	12	12	11	13	11	11
Türkiye	16	19	20	15	20	20	13	12	12	12
Birleşik Krallık	2	3	3	3	4	3	2	3	4	4
ABD	1	1	1	1	1	1	1	1	1	1

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Çizelge 2 incelendiğinde Türkiye multidisiplener alanında yapılan çalışmalar açısından 2013 yılında 16. Sırada yer alırken, 2022 yılında 12.sırada yer almıştır. 2013-2022 yılları arasında sıralaması değişkenlik göstermiştir. United States ise bütün yıllarda ilk sırada yer almıştır. Borda Sayım yöntemi ile elde edilen sonuçlar Çizelge 3'te verilmiştir.

Çizelge 3. Borda Sayım Yöntemi İle Elde Edilen Sonuçlar

Ülkeler	Borda Skoru	Nihai Sıralama
Avustralya	69	5
Avusturya	181	18
Belçika	157	15
Kanada	75	8
Şili	253	27
Kolombiya	252	25
Kosta Rika	361	37
Çekya	222	22
Danimarka	171	17
Estonya	329	32
Finlandiya	248	23
Fransa	89	10
Almanya	26	2
Yunanistan	298	30
Macaristan	261	28
İzlanda	357	36
İrlanda	280	29
İsrail	203	20
İtalya	69	5
Japonya	33	4
Kore	74	7
Litvanya	336	34
Lüksemburg	351	35
Meksika	189	19
Hollanda	109	11
Yeni Zelanda	252	25
Norveç	205	21
Polonya	145	14
Portekiz	249	24
Slovak Cumhuriyeti	334	33
Slovenya	310	31
İspanya	83	9
İsveç	142	13
İsviçre	117	12
Türkiye	159	16
Birleşik Krallık	31	3
Amerika Birleşik Devletleri	10	1

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ÖZET

İnsanoğlu ağrı ve acıdan uzak bir yaşam sürdürmesi için yapılan bütün müdahaleler bakım olarak tanımlanabilir. Bakımla özdeşleşmiş olan hemşirelik mesleğindeki bakımda ise bireyi tanımak, bakım gereksinimlerini tanımlamak; bireyin sorunları ile etkin baş edebilir ve gereksinimlerini karşılayabilir hale gelmesine ek olarak topluma ve hastaya bilgi vermek ve bakımını sağlamak amaçlanmaktadır. Hemşire bu hizmeti sunarken bireyin duygu, düşünce ve gereksinimlerine yönelik, içten sevgi ve şefkat vererek, destek sağlayarak, bireye uygun bir bakım planlamalıdır. Şefkat içinde merhameti barındıran bir boyuttur. Hemşirelik bakım planlarına merhamet duygusunu katmak hem hemşireleri daha fazla motive eder, hem de hastaları cesaretlendirir. Bu da hemşirelik bakımının kalitesini artırır. Ayrıca merhametli bakım, bakım verilen bireyin yaşadığı biyopsiko-sosyal zorlukların farkına vararak anlamayı ve bakım verilen bireyin gereksinimlerini karşılamayı da içermektedir. Hasta ve ailenin bakıma dahil edilmesi de merhametli bakımın en önemli unsurlarından olduğu unutulmamalıdır. Merhametli bakımla birlikte bireyler kendi sağlığına yönelik verilen kararlara aktif katılım sağlayabilecektir. Ancak hemşirelik bakım süreci açısından oldukça önem arzeden merhamet duygusunun hemşireler açısından merhamet yorgunluğu gibi bazı istenmedik durumların ortaya çıkmasına neden olduğu bilinmektedir. Diğer tükenmişlik şekillerinden farklı olan merhamet yorgunluğu, hastalardan kaynaklı duygusal, ruhsal, fiziksel ve sosyal bir tükenmenin bakım hizmeti sunan sağlık profesyonellerinde görülen şeklidir. Bu durumun oluşması için empatik yetenek, endişe ve acı çeken bireylere istekli ve direkt maruziyet gereklidir. Merhamet yorgunluğunun pek çok biyo-psikososyal olumsuzluklara neden olmaktadır. Bu olumsuzluklardan etkilenmemek için bireylerin farkındalık düzeylerini artırma, kişisel düzenleme, amaçlar doğrultusunda yaşama, kendini doğrulama, sosyal destek ağları ile kısa sürede iyileşme, bütüncül ve kişisel bir özbakım disiplini geliştirme, psikolojik sağlamlığı destekleme hedefleyen uygulamalar yapılmalıdır.

Anahtar Kelimeler: Bakım, Hemşirelik, Merhamet

ABSTRACT

Human interventions aimed at ensuring a life free from pain and suffering can be classified as care. In nursing, which is closely associated with care, the goals are to understand the individual, identify their care needs, effectively address their issues, meet their needs, and provide information and care to both the community and the patient. Nurses must develop a care plan tailored to the individual, offering genuine love, compassion, and support in response to the person’s emotions, thoughts, and needs. Compassion encompasses mercy and is an integral part of nursing care plans. Including compassion in care not only motivates nurses but also encourages patients, thus improving the quality of care. Furthermore, compassionate care

involves recognizing and understanding the biopsychosocial challenges faced by individuals and addressing their needs. Involving patients and their families in the care process is also a crucial element of compassionate care. However, it is known that compassion, while crucial, can lead to undesired situations such as compassion fatigue among nurses. Unlike other forms of burnout, compassion fatigue is a form of emotional, mental, physical, and social exhaustion seen in healthcare professionals due to their exposure to patients' suffering. This condition requires empathetic skills, concern, and a willingness to engage directly with suffering individuals. Compassion fatigue leads to various bio-psychosocial negative impacts, which can be mitigated through awareness, personal regulation, living according to goals, self-affirmation, social support, quick recovery strategies, holistic and personal self-care practices, and psychological resilience support.

Keywords: Care, Nursing, Compassion

GİRİŞ

İnsanların yaşamını sürdürmesi, toplumsal varlığını koruması ve devam ettirebilmesi, gelişebilmesi ve işlevsel kalabilmesi için, temel biyolojik ihtiyaçlarını karşılamalarına, asli becerilerini geliştirme ve sürdürmelerine, bunun yanında mümkün olduğu kadar acıdan uzak bir yaşam sürebilmelerine yardımcı olmak amacıyla yapılan her türlü şey bakım olarak tanımlanmaktadır (Engster, 2006). Bakım insanoğlunun büyüme ve gelişmesini sağlayan esas unsurdur ve herkes için yaşam boyu devamlılık gerektiren bir gereksinimdir. İnsanoğlu için varolmanın yolu bakımdan geçmektedir (Özkan, 2014). Hemşirelik ve bakım kavramlarının bütünün birer parçaları gibi işlev gördüğü, hemşireliğin temel fonksiyonu ve özünün bakım olduğu vurgulanmıştır (Öner ve ark., 2011; Ay, 2015; Toru, 2020). Hemşirelik bakımının temel amacı; sağlığın korunmasında ve hastalıkların tedavisinde karşılıklı güvene dayalı bir iletişim ve etkileşim içinde hizmet verilen bireyi tanımak, bakım gereksinimlerini tanımlamak; bireyin sorunları ile etkin baş edebilir ve gereksinimlerini karşılayabilir hale gelmesine ek olarak topluma ve hastaya bilgi vermek ve bakımını sağlamaktır (Toru, 2020; Tutuk ve ark., 2002). Nitelikli bakım, hemşireliğin özüdür ve tüm insanlar için ortak bir değerdir (Engster, 2006; Tutuk ve ark., 2002). Bu bağlamda, hemşireler tarafından kaliteli bir bakım sunulabilmesi için, bu konuda gerekli bilgi ve becerinin olması, bakımın insani ve ahlaki yönü konusunda duyarlılığın olması, mesleki yeterliliğin devamlı geliştirmesi ve meslek ahlakına uygunluğun sağlanması gerekmektedir (Dinç, 2009). Hemşire bu hizmeti sunarken bireyin duygu, düşünce ve gereksinimlerine yönelik, içten sevgi ve şefkat vererek, destek sağlayarak, bireye uygun bakım planlamalıdır (Toru, 2020). Nitekim bakım planlanırken şefkat, yeterlilik, güven, vicdan ve söz vermek gibi boyutları göz önünde bulundurmak gerekmektedir (Göçmen, 2014). Bu kavramlardan şefkat içinde merhameti barındıran bir boyuttur. Merhamet duygusu bireyler için motivasyonel bir güçtür. Nitekim insanların hastalıklarından dolayı çektiği acı, sağlık profesyonellerinde merhamet duygusu uyandırmakta ve bu duyguyu hisseden sağlık profesyoneli hastanın sağlığına kavuşması için çaba sarf ederek harekete geçmektedir (Çapan, 2019). Bu bağlamda merhamet duygusu, hemşirenin hasta hakkında daha iyi bilgi edinmesini, daha iyi sonuçlar alınacak bakımlar planlanmasını sağlayarak hemşirelik bakım kalitesini artırabilir. Hemşirelik bakım planlarına merhamet duygusunu katmak hem hemşireleri daha fazla motive eder, hem de hastaları cesaretlendirir (Kolay, 2019).

Merhamete dayalı düşünme, bakım verilen bireye saygı ve samimiyet iyi bir hemşirenin temel özelliklerindedir. Hemşirelikte merhamet ve empati beraber kullanılan beceriler olmasının yanında hemşirelerin hissettiği merhamet duygusu sadece hastaların içinde bulundukları zorlayıcı durum için empati becerisinin sergilenmesi ile sınırlı değildir. Bu becerilerin kullanımının hemşirelik bakımına yansıması da beklenmektedir. Bu bağlamda merhametli bakım, bakım verilen bireyin yaşadığı biyopsiko-sosyal zorlukların farkına vararak anlamayı ve bakım verilen bireyin gereksinimlerini karşılamayı da içermektedir (Pehlivan ve Güner, 2020). Çünkü hastalanmak, hastalığa bağlı olarak ortaya çıkan biyolojik, psikolojik ve sosyal problemlere ek olarak korku, gerginlik, endişe ve zayıflık duygularının da hissedilmesine neden olmaktadır. Özellikle bilinç problemleri, psikolojik hastalığı, fiziksel kısıtlılığın bulunan, bitkin ve zayıf durumdaki yaşlılar ve çocuklar gibi savunmasız ve çok kolay örselenebilir grupta olan hastalar hemşirelere bağımlı ve bakıma muhtaçtırlar (Dinç, 2010). Bu tür durumlarda sağlık profesyonellerinin merhamet duygusuna sahip olmaları daha iyi bakım eylemine geçebilmelerini sağlamaktadır (Dalgalı ve Gürses, 2018). İyi bakım eyleminde hemşireler hasta ve aileleri bakıma dahil etmeyi önemsemelidir. Çünkü hasta ve aileleri bakıma dahil etme merhametli bakımın da en önemli unsurlarından biridir (Dinç, 2010). Merhametli bakımla birlikte, bakım gereksinimi olan bireyler kendi bakımlarına katılma şansı bulacak ve sadece hemşirelik bakımının pasif alıcıları değil kendi sağlığına yönelik verilen kararlara aktif katılım sağlayabileceği belirtilmiştir (Sharp ve ark., 2016). Bir diğer unsur ise hemşirenin hastanın sıkıntısını anlayarak merhametle onu hafifletmek için harekete geçmek olmalıdır. Yani hemşire hastaların ve ailelerin gereksinimlerini belirleyebilmeli ve uygun yaklaşımda bulunabilme becerisini artırmalıdır (Pehlivan ve Güner, 2020). Bunun yolu yine merhamet duygusundan geçmektedir. Merhamet duygusunun, hemşirelerin hastalarla kurduğu ilişki ve iletişim üzerine de olumlu etkilerinin olduğu bildirilmektedir (Pehlivan ve Güner, 2020; Yılmaz ve Üstün, 2018). Bu etkinin oluşmasını sağlayan empati ve etkili iletişimin merhametli bakımın içinde yer alması hasta sonuçları üzerine olumlu etkilerin şekillenmesini sağlamaktadır (Pehlivan ve Güner, 2020).

Hemşirelik bakım süreci açısından oldukça önem arzeden merhamet duygusunun hemşireler açısından bazı istenmedik durumların ortaya çıkmasına neden olduğu bilinmektedir. Hemşirelerin yaptığı iş yardım etme, merhamet ve evrensel değerleri barındırmaktadır. Bundan dolayı kişilerarası iletişim becerileri ve empati kurma becerisi temel hemşirelik rollerindendir. Bu temel hemşirelik rollerinden empati doğru kullanıldığında bakım kalitesini artırırken yanlış empatik yaklaşım ve daha fazla yardım etme istekliliği hemşirelerin daha fazla strese maruz kalmasına sebebiyet vermektedir. Hemşirenin stresi kontrol edememesi ile birlikte stres kronikleşme eğilimi göstererek merhamet yorgunluğuna dönüşebilmektedir (Sabo, 2016). Empati bakım verici ve bakıma ihtiyaç duyan arasındaki bağın kurulmasını sağlayan en önemli unsurlardan bir tanesi olmasının yanında profesyonel sınırlar aşıldığında bunaltı ve aşırı yüklenme gibi zarar verici etkilerinin ortaya çıkabileceği ifade edilmektedir (Yılmaz ve Üstün, 2018). Ayrıca bir tür tükenmişlik hali olan merhamet yorgunluğu, bakım vericilerde hastalara bakım sonucu oluşan yıpranmışlık ve stres bozukluğuna bağlı olarak da ortaya çıkmaktadır. Diğer tükenmişlik şekillerinden farklı olan merhamet yorgunluğu, hastalardan kaynaklı duygusal, ruhsal, fiziksel ve sosyal bir tükenmenin bakım hizmeti sunan sağlık profesyonellerinde görülen şeklidir. Bu durumun oluşması için empatik yetenek, endişe ve acı

çeken bireylere istekli ve direkt maruziyet gereklidir. Bu doğrudan maruz kalma yoluyla hastaların acı çekme hallerini duygusal olarak yaşayan sağlık profesyonelinde empatik stres ortaya çıkmaktadır. Hastanın davranışlarından köken alan, duygusal enerjinin kalıntısı olan, bir hastanın acısını hafifletmek için devam eden eylem talebi olarak nitelendirilmesinin yanında empatik stresle birlikte görülen merhamet stresinde geri çekilme ya da yaşantısal kaçınma koruyucu bir faktör olabilir. Bu stresin oluşmasına izin verilmesi halinde hizmeti sağlayan kişi merhamet yorgunluğu ile karşı karşıyadır (Şeremet ve Ekinci, 2021). Bununla birlikte hastaların acılarına, ağrılarına ve travmatik deneyimlerine hemşirelerde terapötik etkileşim, hastanın durumunun içselleştirilmesi, aşırı ve hatalı empatik tepki verme kısır döngüsü içerisinde kendini suçlama, boşuna uğraşma ve kararsızlık/güçsüzlük duygularına ortaya çıkmaktadır. Bu durum hemşirenin merhamet yorgunluğuna sürüklenmesine neden olmaktadır. Ayrıca bu süreci hızlandıran bir faktörde hemşire hasta arasındaki duygusal bulaşmadır. Bu bağlamda sürekli ve uzun süre hastaların acı çektiğini görmek, onları gözlemlemek, onlara hizmet vermek, hemşirelerde olumsuz deneyimlere, bilişsel şemada değişime ve travmatik anılara sebebiyet vermektedir. Hemşire için kırılım bu noktadır, yani artık merhamet yorgunluğunun gelişmektedir. Buna ek olarak fonksiyonel baş etme becerileri kullanılamadığı ya da destek alınamadığında merhamet yorgunluğunda artık son aşamaya girilmiş ve kronikleşmeye başlamıştır. Bu aşamayla birlikte fiziksel, bilişsel, duygusal, davranışsal, spiritüel ve sosyal olumsuzluklarda gözlenmeye başlanmaktadır. Bu belirtilerin ortaya çıkması ile birlikte birey yaşamsal ihtiyaçlarını ertelemeye ve ihmal etmeye doğru sürüklenmektedir (Yılmaz ve Üstün, 2018). Bu sürüklenmeye belirli bazı hastalar ile çalışmanın korkma veya onlardan kaçma, hastalara veya ailelere karşı empati hissetme yeteneği azalma, sık sık izin kullanma, yapılan işten doyum sağlayamama, keyif ve neşe yoksunluğu gibi işle ilgili belirtiler eşlik edebilir. Ayrıca huzursuzluk, sinirlilik, aşırı kaygı, öfke ve kızgınlık, bağımlılık yapıcı maddelere yönelim, depresif belirtilerin varlığı, bellek sorunları gibi duygusal belirtilerde ortaya çıkabilmektedir. Baş ağrısı, ishal, kabızlık gibi sindirim sorunları, uyku problemleri gibi fiziksel belirtilerinde varlığı söz konusudur (Şeremet ve Ekinci, 2021).

Hem hemşirelerin bireysel sağlıkları açısından, hem de hasta bakım kalitesi ve sunulan sağlık hizmetleri açısından pek çok olumsuz etkiye sahip merhamet yorgunluğunun önlenmesi oldukça önem arzetmektedir. Literatürde merhamet yorgunluğunun önlenmesine yönelik çok sayıda uygulamadan bahsedilmektedir. Bu uygulamalardan bazıları bireysel öz-bakım programları, destek grupları veya süpervizyon sağlama ve psiko-eğitimsel müdahaleler/psikoterapiler gibi uygulamalar olduğu bildirilmektedir (Kırçı ve Kızıler, 2021). Bireylerin baş etme becerilerinin geliştirilmesi, stres ve acıların üstesinden gelmelerini sağlanmak amacıyla kullanılan farkındalık temelli uygulamalara ek olarak egzersiz, sosyal aktiviteler, yoga, meditasyon, reiki gibi bireysel baş etme stratejilerini kullanmasının merhamet yorgunluğunu engelleyici etkiye sahip olduğu bildirilmektedir (Boellinghaus ve ark., 2014; Hesselgrave, 2014; Solomon, 2014). Bu uygulamalarda bireylerin farkındalık düzeylerini artırma, kişisel düzenleme, amaçlar doğrultusunda yaşama, kendini doğrulama, sosyal destek ağları ile kısa sürede iyileşme, bütüncül ve kişisel bir özbakım disiplini geliştirme, psikolojik sağlamlığı destekleme hedeflenmektedir (Kırçı ve Kızıler, 2021).

SONUÇ

Merhamet yorgunluğunun en çok geliştiği grup olan hemşireler hastalarla en fazla zaman geçiren sağlık profesyonelleridir. Bu uzun zamandan, bakım ilişkisinden ve empatiden köken alan merhamet yorgunluğu, ağır duygusal yükün fazla olduğu çalışma ortamında empatik becerilerini doğru kullanamayan, profesyonel sınırlarını doğru belirleyemeyen ve fonksiyonel baş etme becerilerine sahip olmayan hemşirelerde ortaya çıkma olasılığı daha fazladır (Yılmaz ve Üstün, 2018; Kırçı ve Kızıler, 2021). Bu durumdan bakım sağlayıcıların yaşam kalitesi, bakım davranışları ve sunulan sağlık hizmetleri olumsuz etkilenmektedir (Yılmaz ve Üstün, 2018; Kırçı ve Kızıler, 2021). Bundan dolayı merhamet yorgunluğuna gereken önemin verilmesi önem arz etmektedir. Merhamet yorgunluğunu azaltmak ve bakım kalitesini yükseltmek için hemşirelere uygun bir iş-yaşam dengesi sağlayarak öz-bakımlarını geliştirecek imkânlar sunulması, hemşirelerin bireysel hedeflerinin farkında olunması, akran desteklerinin sağlanması veya profesyonel mesleki desteklerin verildiği ideal çalışma ortamlarının geliştirilmesi ve psiko-eğitim programlarına katılımın sağlanması önerilebilir (Yılmaz ve Üstün, 2018; Kırçı ve Kızıler, 2021; Şirin ve Yurttaş, 2015).

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ERGENLİK VE TEKNOLOJİK BAĞIMLILIKLAR

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ÖZET

Teknolojideki hızlı ilerlemeler teknolojik cihazların yaygın halde kullanımına neden olmuştur. İnternet kullanımın artması ile birlikte diğer sosyal medya ağ kullanımının da arttığı bilinmektedir. Teknoloji kullanımındaki bu çeşitlilik ve artış kullanıcı açısından pek çok yarar sağladığı gibi psikolojik ve fizyolojik pek çok olumsuzluğa da neden olmaktadır. Bu olumsuzlukların temel nedeni olarak görülen teknoloji bağımlılığı ise, teknoloji ve internetin bilinçli olmayan, kontrolsüz bir şekilde kullanımına bağlı olarak ortaya çıkan davranışsal bağımlılıklar olarak tanımlanmaktadır. Davranışsal bağımlılıkların temelinde enerjiyi boşaltma, kendini ifade etme ya da bir gruba ait olma ve sosyalleşme olmak üç temel ihtiyaç yatmakta ve ergenlerde görülme sıklığı artmaktadır. Ergenlerdeki bu durumun sıklığı ise biyo-psikososyal değişimlere ek olarak heyecan arama davranışının baskınlığı ve duyguları anlamlandırmaktaki zorlanmalar olduğu bildirilmektedir. Teknoloji bağımlılığının belirtileri, bireyin teknolojik cihazlara aşırı bağımlı hale gelmesi ve bu bağımlılığın günlük yaşamını olumsuz etkilemeye başlaması ile birlikte ortaya çıkmaktadır. Teknoloji bağımlılığı olan bireyler günün büyük bir kısmını teknolojik cihazlarla geçirmekte ve bu cihazlara sürekli olarak bağlı kalmaktadır. Bu bağlanma belirli bir süreden sonra ihtiyaç halini almakta ve birey bu ihtiyacı kontrol edemez hale gelmektedir. Ayrıca teknolojik cihazlara ulaşamadığı zamanlarda kendini huzursuz, eksik ve endişeli hissetmektedir. Bu durum, sosyal izolasyona ve gerçek hayattaki ilişkilerin zayıflamasına neden olmaktadır. Bu durumun altında nöroanatomik/nörobiyolojik değişiklikler, genetik etkenler ve psikososyal pek çok faktörün yer aldığı bildirilmektedir. Teknoloji bağımlılıklarının tedavisinde genel olarak hem farmakoterapi hem de psikoterapi yöntemleri önerilmektedir.

Anahtar Kelimeler: Ergenlik, Teknoloji, Bağımlılık

ABSTRACT

Rapid advancements in technology have led to the widespread use of technological devices. Alongside the increased use of the internet, there has been a rise in the use of other social media networks. While this diversity and increase in technology use offer many benefits, they also lead to several psychological and physiological drawbacks. One primary issue is technology addiction, which is characterized by behavioral dependencies resulting from uncontrolled and unconscious use of technology and the internet. The root causes of these behavioral dependencies often include the need to release energy, self-expression, group belonging, and socialization, and their prevalence is increasing among adolescents. This rise in adolescents is attributed to bio-psychosocial changes, a tendency for thrill-seeking behavior, and difficulties in understanding emotions. Symptoms of technology addiction emerge when an individual

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becomes excessively dependent on technological devices, negatively impacting their daily life. People with technology addiction spend a large portion of their day engaged with these devices and feel a continuous need to stay connected. This dependency eventually becomes uncontrollable and leads to feelings of restlessness, inadequacy, and anxiety when access to these devices is unavailable. Such conditions can result in social isolation and weakened real-life relationships. Underlying this situation are neuroanatomical/neurobiological changes, genetic factors, and various psychosocial elements. Treatment for technology addiction generally involves both pharmacotherapy and psychotherapy approaches.

Keywords: Adolescence, Technology, Addiction

GİRİŞ

Teknoloji çağı olarak nitelendirilen 21. yüzyılda yaşanan hızlı ilerlemeler teknolojinin yaygınlaşmasına ve giderek günlük yaşantımızın vazgeçilmez bir parçası haline gelmesine sağlamıştır (Bulut, 2019). Nitekim günlük yaşantımızda ve işlerimizde akıllı telefon, tablet veya dizüstü bilgisayarlar yaygın olarak kullanılmaktadır (Kumar ve Manhas, 2021). Türkiye İstatistik Kurumu (TÜİK, 2023), verilerine göre internete erişim imkanı olan hane oranının %95,5 olduğu bilinmektedir. Ayrıca 2023 yılı itibariyle bireysel olarak Türkiye'de internet kullanım oranı %83.4, akıllı telefon kullanım oranı %95.4 ve sosyal medya kullanım oranı %73.1 olduğu bildirilmektedir. Ek olarak hem teknolojik cihaz çeşitliliğinin hem de teknolojik cihazlarla geçirilen süreninde giderek arttığı ifade edilmektedir (Türkiye Dijital, 2023). Teknoloji kullanımındaki bu çeşitlilik ve artış kullanıcı açısından pek çok yarar sağladığı gibi olumsuz etkileri de içerisinde barındırmaktadır (Balcıoğlu ve Türk, 2021; Hekim ve ark., 2019). Bu durum insanların büyük çoğunluğunda psikolojik ve fizyolojik birçok olumsuz etki yaratmıştır (Kumar ve Manhas, 2021). Teknoloji ile birlikte bireyleri etkileyen olumsuzluklardan biri de teknoloji bağımlılığıdır. Bireyin herhangi bir madde kullanımını ya da davranışı kontrol edememesi, zamanının büyük çoğunluğunu madde/davranış için harcaması, madde/davranıştan kurtulma çabalarına bağlı olarak ortaya çıkan yoksunluk durumunda depresif davranışlar sergilemesi durumu bağımlılık olarak tanımlanmaktadır (Muslu ve Gökçay, 2019).

Oyun oynama bozukluğu, sosyal medyanın ve akıllı telefonun aşırı kullanımı gibi bağımlılık yapıcı alt davranışlarla kendini gösteren teknoloji bağımlılığı ise, teknoloji ve internetin bilinçli olmayan, kontrolsüz bir şekilde kullanımına bağlı olarak ortaya çıkan davranışsal bağımlılıklar olarak tanımlanmaktadır (YEŞİLAY, 2024). Davranışsal bağımlılıkların temelinde enerjiyi boşaltma, kendini ifade etme ya da bir gruba ait olma ve sosyalleşme olmak üç temel ihtiyaç yatmaktadır. Bu temel ihtiyaçların karşılanma baskısı oldukça fazla olan ergenlerde davranışsal bağımlılıkların görülme olasılığı diğer gruplara göre daha yüksektir. Bu durum ergenlerdeki biyo-psikososyal değişimlere ek olarak heyecan arama davranışının baskınlığı ve duygularını anlamlandırmakta zorlanmalarından kaynaklandığı bilinmektedir (YEŞİLAY, 2021). Bu bağlamda ergenlerin karşılaşma riskinin yüksek olduğu önemli ruh sağlığı sorunlarından bir tanesi de teknoloji bağımlılığıdır. Davranışsal bağımlılıkların altında yatan üç temel ihtiyaç doğrultusunda günümüzde başkalarıyla etkileşim imkânı veren, sosyalleşme, sosyal kabul edilebilirlik ve ait olma duygusu sağlayan yeni

teknolojik iletişim yöntemlerine ergenler tarafından ilgi duyulmaktadır (Zboralskisz ve ark., 2009). Nitekim 2022 yılı Türkiye İstatistik Kurumu (TÜİK, 2022) verilerine göre Türkiye nüfusunun % 15,2'si gençlerden oluştuğu, % 16-24 yaş arası ergenlerde internet kullanım oranının %96.9 olduğu ve bu oranın giderek arttığı görülmektedir. İnternet kullanımı ile teknoloji kullanımı arasındaki paralellik bağımlılık sürecinde de gözlenmektedir (KKÜ, 2024). Teknoloji kullanımının özellikle gençler arasında hızla artması bu grubun yaşam biçimlerinin de yeniden şekillenmesine neden olmakla birlikte duygusal dalgalanmaların ve kimlik bunalımının yaşanması, arkadaşlığın ve sosyal çevrenin önem kazanması gibi etkenler teknoloji kullanımını cazip hale getirmektedir. Bu etkenlerle başlayan aşırı teknoloji kullanımı bireyleri pek çok yaşamsal alanda olumsuz bir şekilde etkilemekte ve sorunlu bir durum haline gelerek ergenleri teknolojik bağımlılıklara karşı daha hassas hale getirebilmektedir (Ektiricioğlu ve ark., 2020). Bu bağlamda ergenlerde teknoloji bağımlılığının belirti, neden, sonuç ve bu soruna yönelik alınacak önlemler oldukça önem arz etmektedir.

TEKNOLOJİ BAĞIMLILIĞININ BELİRTİLERİ

Teknoloji bağımlılığının belirtileri, bireyin teknolojik cihazlara aşırı bağımlı hale gelmesi ve bu bağımlılığın günlük yaşamını olumsuz etkilemeye başlaması ile birlikte ortaya çıkmaktadır. Teknoloji bağımlılığı olan bireyler günün büyük bir kısmını teknolojik cihazlarla geçirmekte ve bu cihazlara sürekli olarak bağlı kalmaktadır. Bu bağlanma belirli bir süreden sonra ihtiyaç halini almakta ve birey bu ihtiyacı kontrol edemez hale gelmektedir. Ayrıca teknolojik cihazlara ulaşamadığı zamanlarda kendini huzursuz, eksik ve endişeli hissetmektedir. Bu durum, sosyal izolasyona ve gerçek hayattaki ilişkilerin zayıflamasına neden olmaktadır. Bireyin teknoloji dünyasında daha fazla zaman geçirmesiyle birlikte gerçek yaşamdaki sosyal ilişkileri aksayabilmekte veya ihmal edilmektedir. Bu sosyal ilişkilerde bozulmaya ek olarak bireylerde teknoloji kullanımına karşı tolerans gelişmesi sebebiyle daha fazla teknoloji kullanımına yönelmektedir. Başlangıçta tatmin edici olan bir miktar teknoloji kullanımı zamanla yetersiz hale gelmekte ve daha fazla kullanım görülmektedir. Teknoloji kullanımının iş, okul veya kişisel sorunlara neden olduğunu gören bireyde, kurtulma ya da uzak durma çabalarına bağlı olarak yoksunluk belirtileri ortaya çıkmaktadır. Bu belirtiler arasında huzursuzluk, irritabilite, anksiyete, konsantrasyon bozukluğu ve depresif duygulanım gibi duygusal sorunlar yer almaktadır. Ayrıca hem bu duygusal sorunlara bağlı hem de gece geç saatlere kadar teknoloji kullanımı, kişinin uyku düzenini bozmaktadır. Sürekli ekran karşısında olmak, melatonin üretimini engelleyerek uykusuzluğa yol açtığı da bilinmektedir (Gökçearslan ve Durakoğlu, 2014; Kuss ve ark., 2014). Teknoloji bağımlılığı ve belirtiler arasında bir kısır döngünün olduğu söylenebilir. Ayrıca teknoloji bağımlılığında ortaya çıkan belirtiler bireyden bireye farklı şekil ve derecelerde görülebilmektedir. Bu bağlamda teknoloji bağımlılığının şiddeti ve etkileri, bireylerin teknoloji kullanım alışkanlıklarına ve yaşam koşullarına bağlı olarak değişiklik göstermektedir. Ancak, bu değişiklikle birlikte, teknoloji kullanımı aşırı olan bireylerde belirtilerden birkaçının sürekli bulunması durumunda, teknoloji bağımlılığından şüphelenmek gerekir ve destek almak için uzmana başvurmak faydalı olabileceği unutulmamalıdır (Gökçearslan ve Durakoğlu, 2014).

TEKNOLOJİ BAĞIMLILIĞININ NEDENLERİ

Teknoloji bağımlılığının temelinde, nöroanatomik/nörobiyolojik değişiklikler, genetik etkenler ve psikososyal faktörlerin yer aldığı bildirilmektedir. Madde ile ilişkili bağımlılıklarda olduğu gibi teknolojik bağımlılıklarda azalmış korteks hacim/kontrolü (dorsolateral prefrontal korteks, orbito frontal korteks, serebellum ve singulat korteks gibi), yürütücü işlevlerde bozulma, artmış impulsivite ve dopaminerjik ödül sistemine ilişkin değişikliklerin ortaklaşan özellikler olduğunu göstermektedir (Kuss ve ark., 2014). Ayrıca ergenlerdeki internet gibi teknoloji bağımlılıklarında sol anterior ve posterior singulat korteks, sol lingual gyrus ve sol insuladaki gri madde yoğunluğunda, dorsolateral prefrontal korteks ve orbito frontal korteks, serebellum ve singulat kortekstekı gri madde hacminde azalmanın olduğu bildirilmektedir. Bu noröanatomik alanlara ek olarak parahipokampal gyrus, internal ve eksternal kapsül, bilateral frontal lob-beyaz cehver yapıları gibi beynin pek çok bölgesindeki beyaz cehverde yapısal değişiklikler olduğu saptanmıştır. Bu nöroanotomik değişikliklerin teknolojik bağımlılıkların süre ve şiddeti ile yakından ilişkili olduğu ve ergenlerdeki karar vermedeki bozulmanın, davranışsal ve duygusal problemlerin, tekrarlı davranış geliştirmenin ve gecikmiş öğrenmenin nedeni olabileceği ifade edilmektedir (Yektaş ve Yüncü, 2021). Ergenlerdeki internet bağımlılığının bazı nöroanotomik alanlardaki (striatal bölge, orbitofrontal bölge,gb.) dopamin reseptör ve taşıyıcısının ekspresyon düzeylerindeki ve glikoz metabolizmasındaki anormalliklerle de ilişkili olduğu bildirilmektedir (Kim ve ark., 2011; ,Tian ve ark., 2014). Dopamin, serotonin ve nikotinik asetil kolinin alt varyans ve reseptörlerindeki anormalliklerinde ergenlerdeki teknoloji bağımlılıkları ile ilişkili olduğu ifade edilmektedir. Ayrıca erkek ve genç yaşta olma, internetin oyun, kumar, alışveriş sosyalleşme gibi özel amaçlarla kullanılması, düşük benlik saygısı, depresyon, dikkat eksikliği ve hiperaktivite bozukluğu (DEHB), madde kullanımı ve ruhsal hastalıkların varlığı gibi pek çok psikososyal faktörde teknoloji bağımlılıkları için risk faktörleri arasında yer aldığı bildirilmektedir (Yektaş ve Yüncü, 2021).

TEKNOLOJİ BAĞIMLILIĞINDA TEDAVİ YAKLAŞIMLARI

Teknoloji bağımlılıklarının tedavisinde genel olarak hem farmakoterapi hem de psikoterapi yöntemleri önerilmektedir. Farmakolojik tedavilerde antidepresanlar, duygudurum düzenleyicileri, antidepresanlar ve duygudurum düzenleyici kombinasyonları, anksiyolitikler ve naltrekson kullanılmaktadır. Teknoloji bağımlılıkları diğer ruhsal hastalıkları komorbid gelişebileceği için mutlaka altta yatan ruhsal hastalığın tanı ve tedavisi dikkate alınmalıdır (Arısoy, 2009; Bozkurt ve ark., 2016; Koral ve Alptekin, 2023). Eğer herhangi bir ruhsal hastalık yoksa teknoloji bağımlılığının impulsif – egosintonik doğası gereği dürtü kontrol bozukluğuna daha yakın olduğuna dikkat edilerek farmakoterapi Seçici Serotonin Geri Alım İnhibitörleri (SSRI) ve duygudurum düzenleyiciler ile başlaması gerektiği bildirilmiştir (Bozkurt ve ark., 2016). Alkol-madde bağımlılığı tedavisinde kullanılan bir opiyat antagonisti olan naltrekson, pornografi ve sanal sex gibi teknolojik bağımlılıklarda fayda sağladığı ifade edilmektedir. Teknoloji bağımlılıklarının tedavisinde kullanılan bir diğer yöntemde psikoterapidir. Bu yöntem hem farmakoterapiye ek olarak hem de farmakoterapiden bağımsız olarak kullanılabilmektedir (Arısoy, 2009; Bozkurt ve ark., 2016). Bilişsel-davranışçı psikoterapötik yöntemlere göre teknoloji bağımlılıklarında bazı olumsuz bilişlerin rolünün olduğu ve bu bağımlılıkların bireyin yaşamında başarısız olduğu alanları telafi etmeye yönelik

bir davranış örüntüsü olarak ortaya çıktığı savunulmaktadır. Bu bilgi doğrultusunda internetin ya da teknolojinin aşırı kullanımının ödüllendirici bir davranış olarak görülebileceğini ve öğrenme mekanizmaları aracılığıyla bazı olumsuz duygularla (korku, huzursuzluk, hayal kırıklığı) başetmeyi sağlayan yetersiz bir yöntem olduğu bildirilmiştir (Bozkurt ve ark., 2016). Bu noktadan hareketle Davis'in önerdiği bilişsel-davranışçı tedavi protokolü Tablo 1'de verilmiştir (Davis, 2001).

Tablo 1: Bilişsel-Davranışçı Tedavi Protokolü

1. Kişinin internetten uzak kalıp kalamadığının tespiti
2. Bilgisayarın yerinin değiştirilmesi ve diğer insanların bulunduğu yere nakli
3. Diğer insanlar ile beraber internete bağlanması
4. İnternete bağlanma zamanını değiştirmesi
5. İnternet defteri oluşturması
6. Persona kullanımına son vermesi
7. Arkadaşlarından ve yakınlarından internet ile ilgili problemleri olduğunu saklamaması
8. Spor aktivitelerine katılması
9. İnternet tatillerinin verilmesi
10. Otomatik düşüncelerin ele alınması
11. Gevşeme egzersizleri
12. İnternete bağlanma sırasında hissedilenlerin not edilmesi
13. Yeni sosyal becerilerin kazandırılması

İnternet bağımlılığı özelinde teknoloji bağımlılıklarının tamamının tedavisinde kullanılabilecek bilişsel-davranışçı teknikleri: internet kullanımını tam zıt saatlere kaydırmak, dış durdurucular (external stoppers) kullanmak, internet kullanımıyla ilgili hedefler belirlemek, özellikle belli bir işlevden uzak durmaya çalışmak, hatırlatıcı kartlar kullanmak, internet yerine yapmak istediklerini not edebileceği kişisel bir defter kullanmak, bir destek grubuna girmek ve aile terapisi şeklinde özetlemek mümkündür (Arısoy, 2009).

İnternet kullanımını tam zıt saatlere kaydırmak, dış durdurucular (external stoppers) kullanmak ve internet kullanımıyla ilgili hedefler belirlemek aslında basit zaman ayarlama teknikleridir. Bu zaman ayarlama tekniklerinin yetersiz kaldığı durumlarda daha sıkı ve sert uygulamaların kullanılması gereklidir. Bu tip durumlarda tedavinin hedefi, bireyin güçlenmesi ve destek sistemlerini aktif etmesi ile uygun baş etme becerilerini geliştirerek internet ya da teknolojiden uzak durma yeteneğinin artırılması olmalıdır. Fakat bu durumun özellikle tedavinin ilk zamanlarında oldukça zor olacağı unutulmamalıdır. Uzun süre teknolojiyi hayatının merkezine koyan ve büyük bir zevk alan bireyin kayıp yaşaması ve teknoloji kullanımına özlem duyması oldukça doğal bir durumdur (Arısoy, 2009).

Teknolojik bağımlılıkların psiko-sosyal tedavisinde ailenin tedavi sürecine dahil edilmesi oldukça elzemdir. Teknolojik bağımlılıkların tedavinde aile desteği olmadan başarı elde etmek güç hale gelmektedir (Koral ve Alptekin, 2023). Diğer bağımlılıklarda olduğu gibi, aileyle yapılacak terapilerde de Tablo 2'deki süreçte adım adım ilerlenmelidir:

Tablo 2: Aileyle yapılacak terapilerde izlenecek süreç (Mutlu, 2013).

• Mesleki ilişkiyi başlatmak ve aile ile işbirliği yapmak, • Ailenin problemlerle baş etme ve çözme kapasitesini artırmak, • Aileyi süreç, tedavi hakkında bilgilendirmek ve ailenin bu tedaviye katılımını sağlamak, • Aile üyeleri arasında, çözülemeyen iletişimin yerine sorunları giderici iletişim oluşmasına yardımcı olmak, • Aile içindeki bireylerin kendi hayatlarıyla ilgili görev ve sorumluluklarını üstlenmelerine, bağımlı bireylerin sorumluluklarını almalarına yardımcı olmak, •Bağımlı bireylerin problemli internet kullanımını besleyen diğer aile bireylerinin ilişkilerinin sağlıklı ilişkiye çevrilmesine yardımcı olmak, • Gerekli olduğunda aileyi, toplumsal hizmet ve kaynaklardan faydalandırmak

Teknoloji bağımlılıklarının tedavisindeki bir diğer seçenekte grup terapileridir. Bu seçenek sayesinde bağımlığı olan ergen yaşamındaki yetersizlik duygusunu yenebilmek adına sosyal beceriler kazanmaya yönelmektedir. Yeni sosyal becerilerin kazanılması için bu tip ortamlar pekçok imkân sunmaktadır. Grup çalışmalarına dâhil olan ergenler bilişsel, duygusal ve davranışsal durumlarla başa çıkabilme becerilerini de artırmaktadır (Koral ve Alptekin, 2023).

SONUÇ

Teknolojik araçların yaşamımızı kolaylaştırması, eğlendirmesi, merak duygusunu canlı tutması, boş zamanları değerlendirirken vakit geçirilen etkinlik olması özellikle ergenleri teknoloji ile içli dışlı yapmaktadır. Bu durum ergenlerin teknoloji ve teknolojik cihazlarla ile daha uzun süre boyunca zaman geçirmesine neden olmakta hatta bağımlılık boyutuna ulaşmaktadır. Bütün bağımlılıklarda (madde, alkol, kumar vb.) olduğu gibi teknoloji bağımlılığında da sosyal, ekonomik, kültürel ve fiziksel birtakım olumsuz sonuçların ortaya çıkma olasılığı bulunmaktadır. Teknolojik cihaz çeşitliliğinin artması ile birlikte özellikle ergenlerde teknolojik bağımlılığın yaygınlığının da arttığı söylenebilir. Teknoloji kullanımından uzak durmak mümkün olmadığı gibi kontrollü bir şekilde kullanılması durumunda bireylere bilişsel, duygusal ve sosyal açıdan pek çok olumlu katkılar sağlamaktadır. Bu olumlu etkiler, kontrolsüz kullanımla birlikte uyku, beslenme, iskelet, kas, göz rahatsızlığı, obezite gibi birçok olumsuz sonuca evrilebilmektedir. Dünyanın tamamında olduğu gibi ülkemizde de teknoloji kullanımı ve bağımlılığı genç nüfus arasında gün geçtikçe artış göstermektedir (Koral ve Alptekin, 2023).

Özellikle ergenlerin sosyal medya, internet oyun oynama gibi teknoloji kullanımları giderek artış göstermekte ve bu artış ile birlikte ergenlerin bir kısmı bağımlılık seviyesine kadar ulaşmaktadır. Bu gruptaki teknolojik bağımlılıkların tedavisinde ilk yapılması gereken, çocukların ve ergenlerin bağımlı olmasını engellemek ve bağımlılığı önlemektir. Önleme, tedaviden daha pratik ve güçlü bir yoldur (Koral ve Alptekin, 2023). Ayrıca ergenlerin bu konuda doğru karar vermeleri ve sağlıklı bir ilişki kurmaları için teknoloji bağımlılığına neden olabilecek faktörlerin belirlenmesi ve gerekli önlemlerin alınması gerekmektedir. Bu bağlamda ergenlere enerjilerini uygun bir şekilde boşaltabilecekleri, kendi yeteneklerini gösterebilecekleri ve ifade edebilecekleri ortama ek olarak, akranlarıyla sosyalleşebilecekleri zemin ve imkânların sağlanması da gerekmektedir (Dinç, 2015).

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DONDURMA YAPIMINDA SÜT YAĞINA VE SÜT PROTEİNİNE ALTERNATİF BİTKİSEL KAYNAKLARIN KULLANIMI

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ÖZET

Veganlık, et, süt ürünleri, bal, yumurta ve diğer ürünler de dahil olmak üzere tüm hayvansal ürünlerin tüketiminden kaçınan bir diyet ve yaşam tarzı seçimidir. Fonksiyonel gıdalar ve bazı biyoaktif gıda bileşenlerinin sağlıklı yaşama faydalı tesirleri, herkesin ilgisini çekmektedir. Dondurma, birçok yapısal bileşeni olan karmaşık bir gıdadır. Dondurma, sütlü buz ve sorbe gibi ürünler, donduruularak elde edilen sütlü tatlılar içerisinde en fazla sevilerek tüketilen gıdalardan birisidir. Gıda formülasyonuna katılan doymuş yağ, kalp hastalığı riskiyle ilgili olduğundan, Dünya Sağlık Örgütü, doymuş yağ alımının günlük enerji alımının %10'undan fazla olmayacak şekilde sınırlandırılmasını önermektedir. Dondurma formülasyonunda süt yağını azaltmak ve bitkisel yağlar kullanmak isteyen dondurma üreticileri bu amaçla hurma çekirdeği yağı, hurma yağı veya hindistancevizi yağı gibi doğal olarak doymuş yağlardan yararlanmaktadır. Bitkisel yağlarda, çerezlerde ve tohumlarda bulunan omega-6 yağ asitleri, yeterli ve sağlıklı beslenmenin önemli bir parçasıdır. Oleojelatörler, sıvı yağları, yağ asidi bileşimlerini değiştirmeden katı hale getirir, dolayısıyla oleojel formundaki sıvı yağlar, dondurma formülasyonunda doymuş yağı azaltmak için kullanılabilir. Dondurma formülasyonlarında sıvı yağların oleogelatör yardımıyla kullanılması dondurmaya hem yüksek düzeyde çoklu doymamış yağ asitleri ilavesi hem de yüksek düzeyde esansiyel yağ asitlerinin katılmasını sağlayacaktır. Bitkisel kaynaklı proteinler, dondurma formülasyonlarında süt proteinlerinin yerine kullanılabilmektedir. Soya proteini katılan dondurmalarda viskozite ve sertliğin arttığı belirlenmiştir. Soya bazlı dondurmaların düz bir dokuya sahip olmaları yanında, erime direncinin yüksek olduğu tesbit edilmiş ancak bu dondurmalarda az miktarda kireç ve çok hafif miktarda fasulye tadı belirlenmiştir. Bezelye proteini izolatları fonksiyonel ve besin değeri açısından süt ürünlerine benzerlik göstermektedir. İnülin, bağırsak mikrobiyotası için fermente edilebilir bir gıda olarak prebiyotik görevi görebilen bir diyet lifidir; mineral emilimini iyileştirerek ve bağışıklık fonksiyonlarını uyararak, irritabl bağırsak hastalıkları ve kabızlık riskini azaltarak insan üzerinde yararlı bir etkiye sahiptir. Dondurma örneklerine *Spiriluna platensis* tozunun ilavesi protein içeriğinde önemli artışlar sağlar.

Anahtar kelimeler: Dondurma, vegan beslenme, bitkisel yağ, bitkisel protein, inülin, soya, bezelye, *Spiriluna*

USE OF ALTERNATIVE VEGETABLE SOURCES TO MILK FAT AND MILK PROTEIN IN ICE CREAM MAKING

SUMMARY

Veganism is a diet and lifestyle choice that avoids the consumption of all animal products, including meat, dairy, honey, eggs and other products. Functional foods and the positive impact of some bioactive food ingredients on human health are attract the attention of consumers. Although many of the foods included in daily nutrition are rich in natural essential compounds, the market for foods enriched with nutraceutical ingredients that improve health quality is constantly growing.Ice cream is a complex food with many structural components. Products such as ice cream, milk ice and sorbet are among the most consumed foods in the frozen milk dessert category. Because saturated fat incorporated into food formulation is related to the risk of heart disease, the World Health Organization recommends limiting saturated fat intake to no more than 10% of daily energy intake. Ice cream producers who want to reduce milk fat and use vegetable oils in their ice cream formulation can use naturally saturated fats such as palm kernel oil, palm oil or coconut oil for this purpose. Omega-6 fatty acids, found in vegetable oils, nuts and seeds, form a beneficial part of a healthy diet. Oleogelators turn oils into solids without changing their fatty acid composition, so oils in oleogel form can be used to reduce saturated fat in ice cream formulation. The use of oleogels in ice cream formulations will ensure the addition of high levels of polyunsaturated fatty acids and high levels of essential fatty acids to the ice cream. Vegetable-derived proteins can be used instead of milk proteins in ice cream formulations. It was determined that viscosity and hardness increased in ice cream samples due to the addition of soy protein isolate, and a darker color was obtained compared to the control sample. It has been stated that soy-based ice creams have a smooth texture and high melting resistance, but these samples have a slightly chalky and/or slightly bean taste. The use of pea protein isolate may be an alternative to dairy products in terms of its functional and nutritional properties. Inulin is a dietary fiber that can act as a prebiotic as a fermentable food for the gut microbiota; It has a beneficial effect on humans by improving mineral absorption and stimulating immune functions, reducing the risk of irritable bowel diseases and constipation. The addition of *Spiriluna platensis* powder to ice cream samples provides significant increases in protein content.

Key words: Ice cream, vegan nutrition, vegetable oil, vegetable protein, inulin, soy, peas, *Spiriluna*

1.Giriş

Veganlık, et, süt ürünleri, bal, yumurta ve diğer ürünler de dahil olmak üzere tüm hayvansal ürünlerin tüketiminden vazgeçen bir beslenme şeklini içerir.Veganlığın uygulanmasının ana sebebi sağlıklı bir beslenme arayışıdır (Dyett vd., 2013). Dondurma, süt ve ürünlerinin içerisine emülgatör, stabilizatör, tatlandırıcı (sakkaroz, glikoz vb.), renk, aroma ve çeşni maddeleri katılarak elde edilen miksin, dondurulması ile elde edilen bir süt ürünüdür. Dondurma, gıda ve süt teknolojisi alanında en hızlı büyüyen ve gün geçtikçe de ekonomik olarak pazar payı artan sektörlerden biridir. Dondurma, dünyanın her yerinde birçok insanın severek tükettiği, yağ açısından zengin, lezzetli bir gıdadır. Dondurma yüksek oranda süt yağı (yaklaşık %9) içerdiğinden, bu dondurmayı tüketen kişiler belirli düzeyde doymuş yağ asitleri ve kolesterol de almaktadır. Orta yağlı, az yağlı ve yağsız dondurma üretimi, doymuş yağ alımının daha düşük olması nedeniyle obezite ve kardiyovasküler hastalık riskini azaltır. Ancak, yağın azaltılması, dondurmanın yapısı üzerinde olumsuz bir etkiye sahiptir. Çünkü yağ, dondurma miksinin önemli bir bileşenidir ve dondurmanın yapısını önemli düzeyde etkiler.

Dünya Sağlık Örgütü, doymuş yağ alımının günlük enerji alımının %10'undan fazla olmayacak şekilde sınırlandırılmasını önermektedir (Frederick vd.,2010). Oleojel oluşturarak sıvı yenilebilir yağların dondurma yapımında kullanılması , doymuş yağların kullanımını azaltmanın bir yolu olarak büyük ilgi uyandırmıştır(Zetzl vd.,2012).Oleojelatörler,sıvı yağları, yağ asidi bileşimlerini değiştirmeden katı hale getirir, dolayısıyla oleojel formundaki sıvı yağlar, dondurma formülasyonunda doymuş yağı azaltmak için kullanılabilir (Co ve Marangoni,2012). Bal mumu (BM), kandelilla mumu (KM), karnauba mumu (KM) ve pirinç kepeği mumu (PKM) gibi gıda sınıfı mumların oleojelatörler olarak kristalleştirme özellikleri dondurmanın yapısında önemli bir rol oynayabilir. Bunların arasında pirinç kepeği mumu, yapılan çalışmalarda iyi sonuç veren mumlardan birisidir (Dassanayake vd. 2012). Ancak oleojelatörlerin türleri ve oleojellerin gıdalara uygulanma alanları hala oldukça sınırlıdır. Balmumu oleojelasyonu da dondurma üretimine fayda sağlayabilir (Cove Marangoni,2012). Dondurma formülasyonlarında sıvı yağların oleogelatör yardımıyla kullanılması dondurmaya hem yüksek düzeyde çoklu doymamış yağ asitleri ilavesi hem de yüksek düzeyde esansiyel yağ asitlerinin katılmasını sağlayacaktır.

2.Dondurmanın Bitkisel Yağ ve Protein Kaynakları İle Zenginleştirilmesi

2.1.Dondurmaya Süt Yağı Yerine Bitkisel Yağ Katılması

Rrieskorn vd. (2016), ABD'de kardiyovasküler hastalık oranının arttış olduğunu bildirmişler ve diyette doymuş yağın azaltılması yanı sıra diyet lifi oranındaki artışın bu hastalıkla mücadelede yardımcı olabileceğini tespit etmişlerdir. Dondurma üretiminde krem şanti yerine Hindistan cevizi sütü kullanmışlar fakat her iki örneğe de yağ içeriğini azaltarak besinsel değeri arttırmak için pancar küspesi ilave etmişlerdir. Yapılan analizlerin sonucunda ahududu ve pancar dondurması örneğinin, hindistan cevizi sütü ilaveli dondurma örneğine göre daha az yağlı, daha az asidik, vizkozitesi düşük ve sertliğinin düşük olduğunu, düşük yağlı ahududu ve pancar dondurmasının sağlıklı yaşam için iyi bir alternatif olabileceğini tespit etmişlerdir..Bekiroğlu vd.(2022) yaptığı çalışmada dondurma üretiminde kurutulmuş ve taze olmak üzere iki tür ceviz sütü kullanmışlardır. Ceviz sütünün dondurma üretiminde

kullanılması, dondurma örneklerinin fizikokimyasal özelliklerini fazla miktarde etkileyerek cevizin yüksek yağ içeriğine sahip olması nedeniyle dondurma örneklerinin yağ muhtevası artmıştır. Ayrıca, ceviz sütü kullanılması, dondurma örneklerinin hacim artışını olumlu yönde etkileyerek değiştirmiştir. Dondurma üretiminde ceviz sütünün kullanılması dondurma örneklerinin parlaklık değerini düşürse de reolojik özelliklerini iyileştirmiştir. Tüm dondurma örneklerinde L-limonen ana uçucu bileşik olarak belirlenmiş ve ceviz sütü kullanımının farklı uçucu bileşikler oluşturduğu tespit edilmiştir. Son olarak duyusal değerlendirme parametrelerine göre ceviz sütü kullanılarak üretilen dondurma örnekleri panelistler tarafından kontrole göre benzer yakın puanlar almış olup, bu çalışma ceviz sütünün dondurma üretiminde kullanılabileceğini göstermiştir.

Güven vd.(2018) dondurma miks örneklerine süt yağı, fındık yağı ve zeytinyağını %12 yağ olacak şekilde ilave etmişler ve duyusal analiz sonuçlarından %50 fındık yağı-%50 zeytinyağı karışımı ilave edilen dondurmalar en yüksek renk ve görünüm puanları aldığı tespit edilmiştir. Öte yandan en yüksek dondurma tekstür puanları %50 süt yağı-%50 fındık yağı ilave edilen örneklerde belirlenmiştir. Toplam kalite kriterinde %50 süt yağı-%50 zeytinyağı ilave edilen dondurmalar panelistlerce daha çok tercih edilmiştir. Özdemir (2023) yaptığı çalışmada, dondurma üretiminde yağ kaynağı olarak süt yağı yerine balmumu oleojellerinin ve salep yerine stabilizatör olarak konjak sakızının olası kullanım olanaklarını araştırmıştır. Süt yağı içeren dondurma numunelerinin hacim artışı oranının oleojel içeren numunelere göre daha yüksek olduğunu belirlenmiştir. Araştırıcı oleojel içeren örneklerin doymamış yağ asitleri (C18:1, C18:2 ve C18:3) oranının süt yağı içeren örneklere göre anlamlı derecede yüksek ($p<0.01$) olduğunu tespit etmiştir. Ancak süt yağı yerine oleojel ilave edilen örneklerde alifatik yağ asitlerinden bütirik ve kaproik asitlerin eksik olduğu tespit edilmiştir. Mikroskobik görünüm açısından oleojelli dondurma örneklerinde su ve yağ parçacıkları homojen olarak dağılmazken, süt yağı ilaveli dondurma örneklerinde tamamen homojen olarak dağılmıştır.

2.2. Dondurmaya Bitkisel Kaynaklı Protein Katılması

Bezelye proteini izolatının kullanımı (protein içeriğinin %80'inden fazlası), fonksiyonel ve besleyici özellikleri nedeniyle süt ürünleri alternatiflerinin geliştirilmesinde uygun fiyatlı ve sürdürülebilir metotlardan biridir (Lu vd., 2020). Bezelye esas olarak %65 – 80 oranında globulin proteinlerinden, %10 – 20 oranında albümin proteinlerinden ve yüksek miktarda lisinden oluşur (Güler-Akin vd.,2021). Bezelye proteinleri (çoğu zaman bezelye proteini hidrolizatları ve spesifik peptid fraksiyonları) antioksidan, antihipertansif, antiinflamatuar, kolesterol düşürücü ve bağırsak bakteri aktivitelerini artırıcı özelliklere sahiptir (Liu ve Wu, 2019). Ayrıca köpürme, emülsifiye etme, yağ tutma kapasitesi, su tutma kapasitesi, çözünürlük ve gıda tekstürü gibi fonksiyonel özellikler, bitki bazlı süt ürünleri alternatiflerinin üretiminde bezelye proteini izolatlarının diğer önemli özellikleridir (Güler-Akin vd., 2021; Liu ve Wu, 2019).

Igutti vd. (2011), dondurmanın bileşimini oluşturan süt, yağ, stabilizatör ve emülgatör yerine; yeşil hindistan cevizi küspesi, kakao tozu, sükroz, su, karagenan, guar ve hidrojene bitkisel yağ katılması ile yeni bir formülasyonda dondurma üretimi gerçekleştirmişlerdir. Araştırıcılar, yeşil hindistan cevizinin, laktoz veya süt proteinleri içeren ürünleri tüketemeyen insanlara yönelik iyi bir alternatif olacağını ve dondurma formülasyonuna yeşil Hindistan cevizi

küspesi katılmasının, az yağlı dondurma üretimine önemli olumlu katkılar yapacağını bildirmişlerdir.

Aboulfazli vd. (2016), inek sütüne alternatif olarak bitkisel süt (soya ve hindistan cevizi sütü) içeren dondurma örnekleri üretmiş ve bu dondurmalara *Lactobacillus acidophilus* (LA-5) ve *Bifidobacterium bifidum* (BB-12)ile inoküle etmişlerdir. Bitkisel sütten yapılan dondurma örneklerinde pH değerinin, inek sütünden yapılanlara göre daha hızlı düştüğünü belirlemişlerdir. Soya veya hindistancevizi sütü ile yapılan dondurmaların probiyotik bakteri sayısının, inek sütü ile yapılan dondurmalardan daha yüksek olduğunu belirlemişlerdir. *Spiriluna platensis'in* protein içeriği %55 ila %70 ve % 67,18 ila %72,85 arasındaydı. Dondurma örneklerinin protein içeriğinde *Spiriluna platensis* tozunun ilavesinden önce ve sonra önemli artışlar bulunmuştur. *S.platensis* ilave edilmemiş dondurma örneklerinde%3,23 olan protein oranı, %0,6 kurutulmuş *S.platensis* yosunu ilavesinden sonra protein içeriğinin %3,48'e ve %1,2 ilavesinde de %3,54' yükseldiği tespit edilmiştir. Buna karşılık dondurma örneklerine kurutulmuş *S.platensis* yosunu ilavesi örneklerin yağ ve şeker oranını azaltmıştır (Agustini vd.,2016). Yoğurtların protein değerlerinde bakıldığında ise *Spirulina* eklenmiş yoğurtlarda kontrol yoğurduna kıyasla daha yüksek bulunmuştur. Bu durumun, *Spirulina'nın* yüksek protein değerleri protein içeriğinden kaynaklandığı düşünülmektedir(Aydemir ve Öner,2020). Kapsüllü ve kapsülsüz *Spirulina* ilavesi dondurma örneklerinde protein miktarında önemli bir artışa ($p<0.05$) neden olmuştur(Tiepo vd.,2021).

3.SONUÇ VE ÖNERİLER

Doymuş yağ, kalp hastalığı riskiyle ilgili olduğundan, Dünya Sağlık Örgütü, doymuş yağ alımının günlük enerji alımının %10'undan fazla olmayacak şekilde sınırlandırılmasını önermektedir. Dondurma, yarı donmuş bir çözelti içinde dağılmış yağ kürecikleri, hava kabarcıkları ve buz kristallerinden oluşan karmaşık, çok fazlı bir gıdadır. Dondurma, yapısal ve yapısal olarak önemli bir rol oynayan yaklaşık %12 yağ içerir. Öte yandan tüketiciler az yağlı gıdaları tüketmeye ilgi göstermektedir. Günümüzde az yağlı dondurmalarda dokusal ve duyusal kusurları azaltabilen birçok yağ ikame maddesi kullanılmaktadır. Yağ ikame maddeleri bileşimlerine göre üç gruba ayrılır. Bunlar lipit, protein ve karbonhidrat bazlıdır. Dondurmada kullanılan en yaygın yağ ikame maddeleri arasında inülin, maltodekstrin, polidekstroz, süt proteinleri, soya proteinleri, diyet lifleri ve nişastalardır. Dondurma yüksek oranda süt yağı içerdiğinden, bu dondurmayı tüketen kişiler belirli düzeyde doymuş yağ asitleri ve kolesterol de almaktadır. Süt yağı yerine mum ve bitkisel yağlarla üretilen oleojel katılan örneklerde çoklu doymamış yağ asitleri oranı yüksek bulunurken, alifatik yağ asitlerinden bütirik ve kaproik asitlerin eksik olduğu tespit edilmiştir. Süte %50 oranına kadar soya sütü ilavesinin dondurmanın lezzet, doku, renk ve genel kabul edilebilirliğini önemli derecede etkilemediği belirlenmiştir. Süt tozu yerine bezelye proteini izolatının eklenmesinin dondurmanın fiziksel ve dokusal özelliklerini iyileştirdiğini, ancak yüksek miktarda bezelye proteini izolatının eklenmesinin duyusal özellikleri olumsuz etkilediğini ve vegan tipi dondurma üretimi için uygun olmadığı sonucuna varılmıştır. Dondurma örneklerinin protein içeriğinde *Spiriluna platensis* tozunun ilavesi önemli artışlar sağlanmıştır.

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Doymuş yağların ve trans yağların yerini bitkisel yağların alabilmesi için dondurmanın yapısını koruyacak şekilde katılaştırılması gerekmektedir. Oleojelasyon işlemi sıvı yağları, yağ asidi bileşimlerini değiştirmeden katı hale getirir. Gelecek vaad eden bir çalışma alanı oluşturmaktadır. Bitkisel yağların dondurmada duyusal özelliklerini bozmadan kullanılabilmesini sağlamak için 'Oleojelasyon' gibi yöntemler üzerinde daha fazla çalışmalar yapılmalıdır.

Hurma yağı, hindistan cevizi yağı gibi doğal olarak doymuş bitkisel yağlardan yararlanmak yeterli olabilir ancak bitki tohumlarından ve çerezlerden faydalanmak dondurmaya fonksiyonellik katar. Bitki tohumlarının fitokimyasal açıdan zengin yağlarının kullanılması besin değerini yükselttiği gibi fonksiyonel içeriğine de katkı sağlar. Yeni gıda trendlerine de cevap verebilmektedir.

Dondurmada bitki bazlı süt çeşitlerinin kullanımı, dondurma içeriğindeki hem yağa hem de proteine katkı sağlayacaktır. Ceviz sütü, Hindistan cevizi sütü gibi ürünler dondurmaya hem yağ olarak hem protein olarak katkı sağlar. Hammadde açısından hem maliyeti düşürebilmek hem de kaliteyi korumak mümkün olabilmektedir.

Soya proteini, bezelye proteini vb. bitkisel proteinlerin kullanımı dondurmada fiziksel ve tekstürel özellikleri iyileştirdiği gözlemlenmiştir. Ayrıca soya sütü ve / veya PASPİ + inülin içeren dondurmaların laktoz intoleransı veya laktoz duyarlılığı olan kişiler için uygun olabileceğini bildirmişlerdir.

Bitkilerin ve tohumlarının yağları ve bitkisel kaynaklı proteinlerin dondurmaya katkısı antioksidan, antihipertansif, anti inflamatuar, kolesterol düşürücü ve bağırsak bakteri aktivitelerini artırıcı özelliklere olumlu etki yapmaktadır. Dondurmada bulunan doymuş yağlara alternatif bir çözüm olarak bitkisel yağların kullanımı kardiyovasküler problemleri azaltabileceği gibi, antidiyabetik, antimikrobiyal, antioksidan aktivite sağlayarak sağlımıza katkıda bulunabilir.

Fitokimyasallar açısından zengin yağların kullanımı farmasötik ve nutrasötik açıdan fayda sağlar. Bitkisel kaynakların kullanımı sürdürülebilirlik ve maliyet açısından büyük bir yenilik olması yanında yüksek lif ve yüksek oranda çoklu doymamış yağ asidi, protein ve vitamin içeriğine sahip besin içeriğini de zenginleştirmektedir. Kullanılan bitki ve tohumlarının müsilajları emülsifiye edici, köpürtücü, koyulaştırıcı, stabilize edici ve jelleştirici özelliklere sahip olduğu saptanmıştır.

Bitkisel kaynaklı proteinler, son yıllarda artan süt ve süt ürünleri alerjileri, laktoz intoleransı olan kişiler için çözüm sunar.

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