ICoN-FAC 2025

INTERNATIONAL CONGRESS ON NUTRITION, FOOD, AGRICULTURE AND CLIMATE

August 21-22, 2025 / Istanbul Arel University, Istanbul, Türkiye

EDITOR

PROF. DR. OSMAN ERKMEN

ISBN: 979-8-89695-170-4

INTERNATIONAL CONGRESS ON NUTRITION, FOOD, AGRICULTURE AND CLIMATE

Scientific Approaches for Sustainable Living

August 21-22, 2025

Istanbul Arel University, İstanbul, Türkiye

20.09.2025

Liberty Publishing House

Water Street Corridor New York, NY 10038

www.libertyacademicbooks.com

+1 (314) 597-0372

adopted by Mariam Rasulan

PROCEEDINGS BOOK

ISBN: 979-8-89695-170-4

CONGRESS ID

CONGRESS TITLE

INTERNATIONAL CONGRESS ON NUTRITION, FOOD, AGRICULTURE AND CLIMATE

Scientific Approaches for Sustainable Living

DATE AND PLACE

August 21-22, 2025

Istanbul Arel University, İstanbul, Türkiye

ORGANIZATION

ISTANBUL AREL UNIVERSITY

IKSAD INSTITUTE

EDITORS

Prof. Dr. Osman ERKMEN

COORDINATOR

Samet KUŞKIRAN

PARTICIPANTS COUNTRY (14 countries)

TÜRKİYE, MOROCCO, KOSOVO, IRAQ, PAKISTAN, NIGERIA, MONTENEGRO, NORTH MACEDONIA, LITHUANIA, BANGLADESH, ALGERIA, UZBEKISTAN, GERMANY, USA

Total Accepted Article: 71

Total Rejected Papers: 18

Accepted Article (Türkiye): 30

Accepted Article (Other Countries): 41

ISBN: 979-8-89695-170-4

ICoN-FAC 2025

INTERNATIONAL CONGRESS ON NUTRITION, FOOD, AGRICULTURE AND CLIMATE

Scientific Approaches for Sustainable Living

August 21-22, 2025 / Istanbul Arel University, Istanbul, Türkiye
In collaboration with the Department of Nutrition and Dietetics and IKSAD Institute
Online and In Person

İSTANBUL AREL ÜNİVERSİTESİ

IKSAD INSTITUTE
Institute of Economic Development and Social Research

20.09.2025

REF: Akademik Teşvik

İlgili makama;

2. Uluslararası Başkent Bilimsel Araştırmalar Kongresi, 16-18 Ocak 2023 tarihleri arasında Baku, Havana, Küba'da 13 farklı ülkenin (Türkiye 22 bildiri- Diğer ülkeler 25 bildiri) akademisyen/araştırmacılarının katılımıyla gerçekleşmiştir

Kongre 16 Ocak 2020 Akademik Teşvik Ödeneği Yönetmeliğine getirilen "Tebliğlerin sunulduğu yurt içinde veya yurt dışındaki etkinliğin uluslararası olarak nitelendirilebilmesi için Türkiye dışında en az beş farklı ülkeden sözlü tebliğ sunan konuşmacının katılım sağlaması ve tebliğlerin yarıdan fazlasının Türkiye dışından katılımcılar tarafından sunulması esastır." değişikliğine uygun düzenlenmiştir.

Bilgilerinize arz edilir,

Saygılarımla

Prof. Dr. Osman ERKMEN
Istanbul Arel University
HEAD OF CONGRESS

E-mail: **contact@iksad.co.uk**
Web Page: **www.iksad.co.uk/iconfac**

Evrak Tarih ve Sayısı: 12.05.2025-745937

T.C.
İSTANBUL AREL ÜNİVERSİTESİ REKTÖRLÜĞÜ

2025 AİLE YILI

Sayı : E-69396709-051-745937 12.05.2025
Konu : CoN-FAC 2025 Kongresi Düzenleme İzni

DAĞITIM YERLERİNE

İlgi : 07.05.2025 tarihli, 32911891-051-E.745528 sayılı yazınız.

İlgide kayıtlı yazıya istinaden, Üniversitemiz Beslenme ve Diyetetik Bölüm Başkanlığının ekli yazısına istinaden; İstanbul Arel Üniversitesi Sağlık Bilimleri Fakültesi Cevizlibağ Yerleşkesi'nde, Beslenme ve Diyetetik Bölümü ile İKSAD iş birliğinde, 21-22 Ağustos 2025 tarihlerinde hem online hem de yüz yüze olarak gerçekleştirilecek olan "International Congress on Nutrition, Food, Agriculture and Climate: Scientific Approaches for Sustainable Living (ICoN-FAC 2025)" başlıklı kongrenin düzenlenmesi, Kongre Başkanı ile Kongre Düzenleme Kurulu üyelerinin anılan tarihlerde görevli-izinli sayılmaları Rektörlüğümüzce uygun görülmüştür.

Bilgilerini ve gereğini rica ederim.

Prof. Dr. Ersin GÖSE
Rektör V.

Ek:International Congress on Nutrition, Food, Agriculture and Climate_ Scientific Approaches for Sustainable Livin (10 Sayfa)

Dağıtım:
Sağlık Bilimleri Fakültesi Dekanlığına
Yök İlişkileri ve Yazı İşleri Ofisine
İnsan Kaynakları Müdürlüğüne
Öğrenci İşleri Ofisine

Mevcut Elektronik İmzalar
Prof. Dr. ERSİN GÖSE (Rektör V.) 12.05.2025 08:04
Bu belge, güvenli elektronik imza ile imzalanmıştır.

Adres: Türkoba Mahallesi Erguvan Sokak No:26 / K 34537 Tepekent - Büyükçekmece/İstanbul
Telefon:0 (850) 850 27 35 Faks0 (212) 860 04 81
Kep Adresi: areluniv@hs01.kep.tr
Bilgi için: Nazan ÖZMEN
Unvan: Yazı İşleri Kıdemli Uzmanı
Tel No: 08508502735

T.C.
İSTANBUL AREL ÜNİVERSİTESİ REKTÖRLÜĞÜ
Sağlık Bilimleri Fakültesi Dekanlığı
Beslenme ve Diyetetik Bölüm Başkanlığı

2025 AİLE YILI

Sayı : E-13362403-100-745124 06.05.2025
Konu : Kongre İzni Hk. (International Congress on Nutrition, Food, Agriculture and Climate: Scientific Approaches for Sustainable Living (ICoN-FAC 2025)

SAĞLIK BİLİMLERİ FAKÜLTESİ DEKANLIĞINA

İstanbul Arel Üniversitesi Sağlık Bilimleri Fakültesi Cevizlibağ Yerleşkesinde Beslenme ve Diyetetik Bölümü ve İKSAD işbirliği ile 21-22 Ağustos 2025 tarihlerinde Online ve Yüzyüze "International Congress on Nutrition, Food, Agriculture and Climate: Scientific Approaches for Sustainable Living (ICoN-FAC 2025)" kongresini düzenleyeceğiz.

Kongreyi düzenleyebilmemiz için gerekli iznin verilmesi ve kongreyi düzenleyecek Kongre Başkanı ve ve Kongre Düzenleme Kurulun üyelerinin onaylanması hususunda gereğini saygılarımla arz ederim.

Prof. Dr. Osman ERKMEN
Bölüm Başkanı

Ek:
1- Dilekçe-ICoN-FAC 2025 (2 Sayfa)
2- ICoN-FAC 2025 (2 Sayfa)
3- İKSAD Hakkında (1) (5 Sayfa)

Mevcut Elektronik İmzalar
Prof. Dr. ERSİN GÖSE (Rektör V.) 12.05.2025 08:04
Bu belge, güvenli elektronik imza ile imzalanmıştır.

Kongre Düzenleme Kurulu

Prof. Dr. Osman ERKMEN
Assist. Prof. Dr. Dilek Özçelik ERSÜ - İstanbul Arel University
Assist. Prof. Dr. İlkay Turhan KARA - İstanbul Arel University
Assist. Prof. Dr. Semih ŞAHİN - İstanbul Arel University
Inst. Çınar ERGİNBAŞ - İstanbul Arel University
Res. Assist. Zekiye YILDIZ - İstanbul Arel University
Res. Assist. Emine KARACA - İstanbul Arel University

SCIENTIFIC COMMITTEE
Bilimsel Komite

Prof. Dr. Faruk BOZOĞLU - Konya Chamber of Commerce Karatay University
Prof. Dr. Hasan YETİM - İstanbul Sabahattin Zaim University
Prof. Dr. Haydar ÖZPINAR - İstanbul Aydın UniversityProf. Dr. Bashir Ali K. SALEHAl -
Assoc. Prof. Dr. Ali ÖZKAN - Gaziantep University
Assoc. Prof. Dr. Müge ARSLAN - Üsükar University
Assoc. Prof. Dr. Özlem Persil ÖZKAN - Bandırma Onyedı Eylül University
Assoc. Prof. Dr. Hüseyin BOZ- Atatürk University
Assist. Prof. Dr. Bora EKİNCİ - Muğla Sıtkı Koçman University
Assist. Prof. Dr. Funda Esin FAKILI - Sanko University
Assist. Prof. Dr. Halime UĞUR - Medeniyet Üniversity
Assist. Prof. Dr. İrem KORKMAZ - Marmara University
Assist. Prof. Dr. Nihal Zekiye ERDEM - İstanbul Medipol University
Assist. Prof. Dr. Özlem YALÇINÇIRAY - İstanbul Arel University
Assist. Prof. Dr. Zeki ÖZDEMİR - İstanbul Arel University
Assist. Prof. Dr. Zeynep Begüm KALYONCU ATASOY- Yıldırım Beyazıt University
Jabal Al-Gharbi University
Prof. Dr. Muhammad FAISAL - Director, Ministry of Human Rights Commission, Pakistan
Prof. Dr. Natalia LATYGINA - Ukraine Shevchenka University
Prof. Dr. Shaukat Aref Mohammed Al ATROUSHİ - Zakho University
Assoc. Prof. Dr. Ahmet Salih SÖNMEZDAĞ - Muğla Sıtkı Koçman University
Assoc. Prof. Dr. Muntazir MEHDI - Pakistan Fiml
Assoc. Prof. Dr. Natalija ATANASOVA - Sts Cyril and Methodius University
Assoc. Prof. Dr. Sehrana KASIMI - Azerbaijan Academy of Sciences
Assist. Prof. Dr. Aisha DASTHİ - Tebriz University
Dr. Samson A. OYEYINKA - Johannesburg University
Dr. Violla MAKHZON - Islamic University of Lebanon

HONORARY PRESIDENT

Prof. Dr. Ersin GÖSE

Rector of the Istanbul Arel University

CONGRESS PRESIDENT

Prof. Dr. Osman ERKMEN

Istanbul Arel University

MEMBERS OF THE ORGANIZING COMMITTEE

Assist. Prof. Dr. Dilek Özçelik ERSÜ
İstanbul Arel University

Assist. Prof. Dr. İlkay Turhan KARA
İstanbul Arel University

Assist. Prof. Dr. Semih ŞAHİN
İstanbul Arel University

Inst. Çınar ERGİNBAŞ
İstanbul Arel University

Res. Assist. Zekiye YILDIZ
İstanbul Arel University

Res. Assist. Emine KARACA
İstanbul Arel University

SCIENTIFIC AND ADVISORY BOARD

Assoc. Prof. Dr. Müge ARSLAN
Üsükar University

Assoc. Prof. Dr. Özlem Persil ÖZKAN
Bandırma Onyedı Eylül University

Assoc. Prof. Dr. Hüseyin BOZ
Atatürk University

Assoc. Prof. Dr. Ahmet Salih SÖNMEZDAĞ
Muğla Sıtkı Koçman University

Assist. Prof. Dr. Bora EKİNCİ
Muğla Sıtkı Koçman University

Assist. Prof. Dr. Çağla PINARLI
İstanbul Gedik University

Assist. Prof. Dr. Derya Dursun SAYDAM
İstanbul Yeni Yüzyıl University

Assist. Prof. Dr. Funda Esin FAKILI
Sanko University

Assist. Prof. Dr. Halime UĞUR
Medeniyet University

PHOTO GALLERY

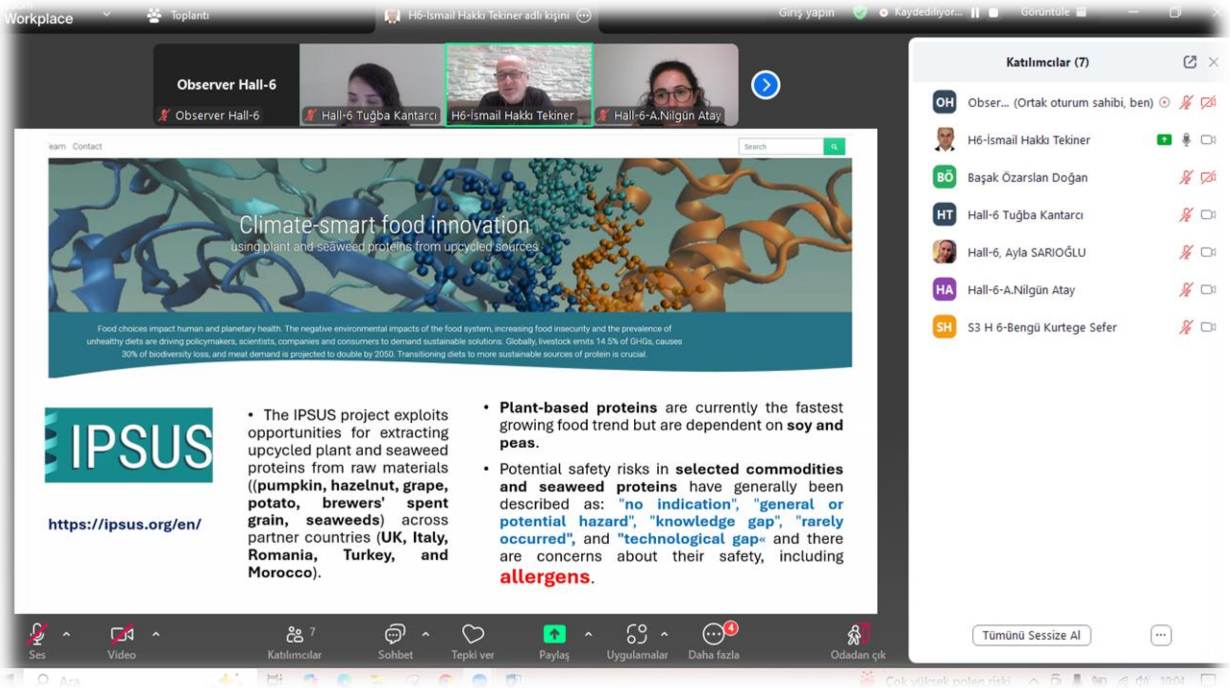
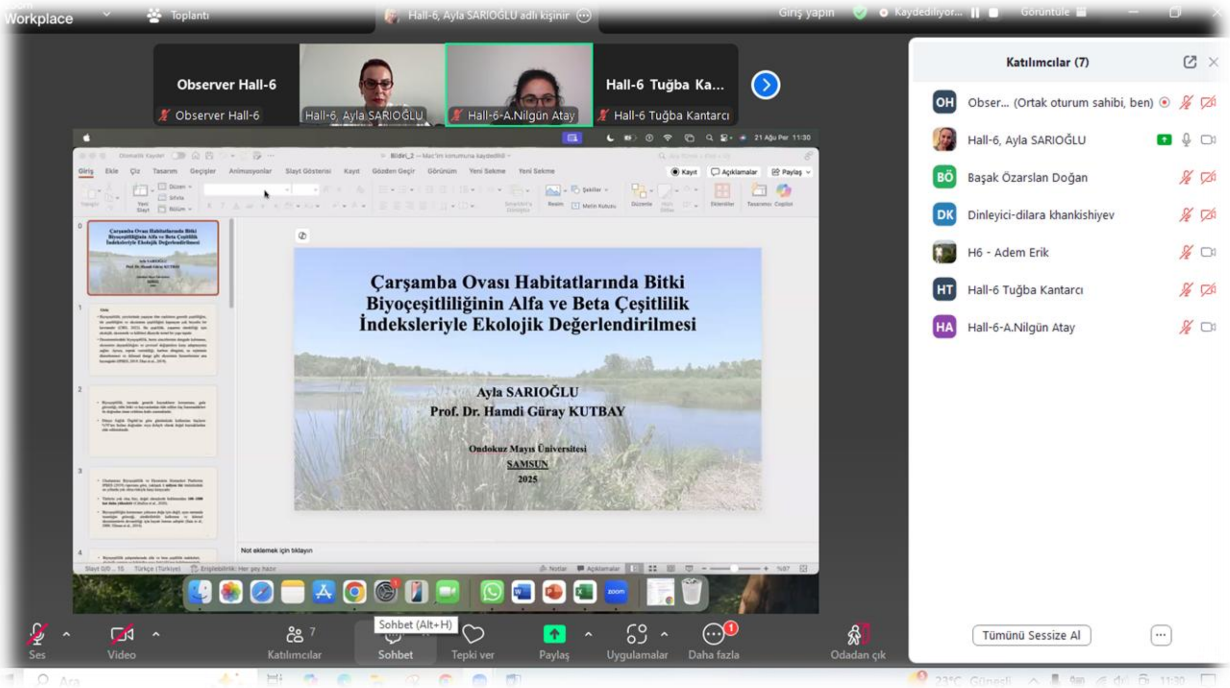


PHOTO GALLERY



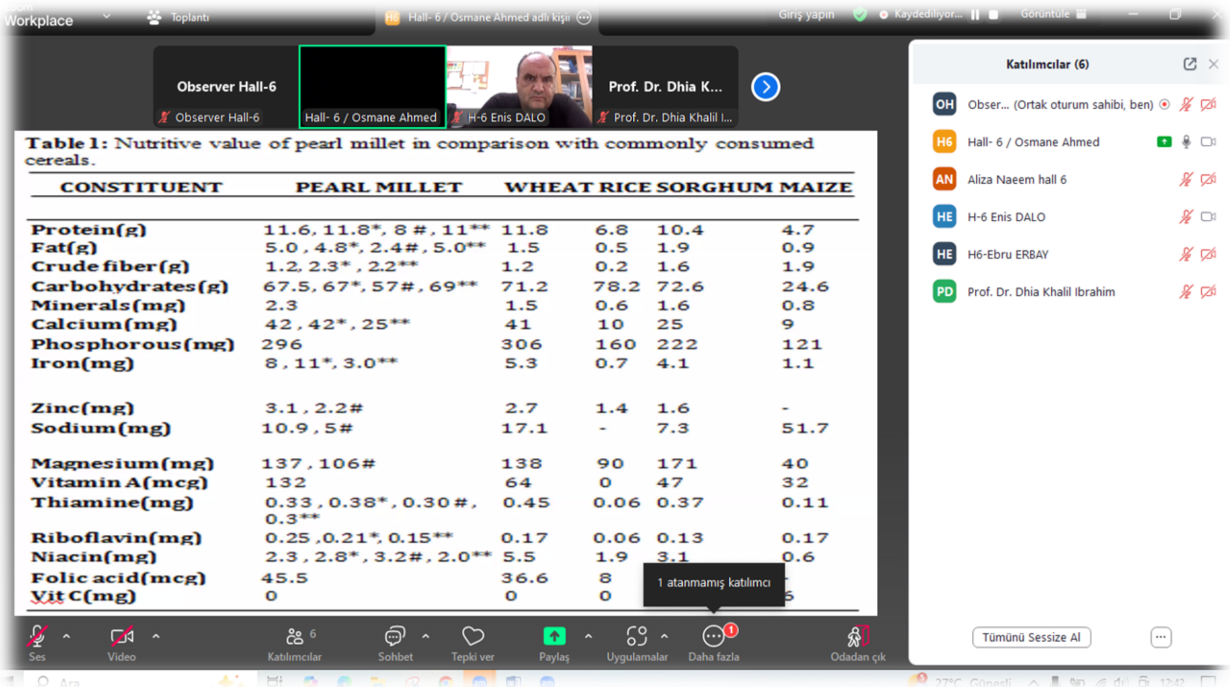
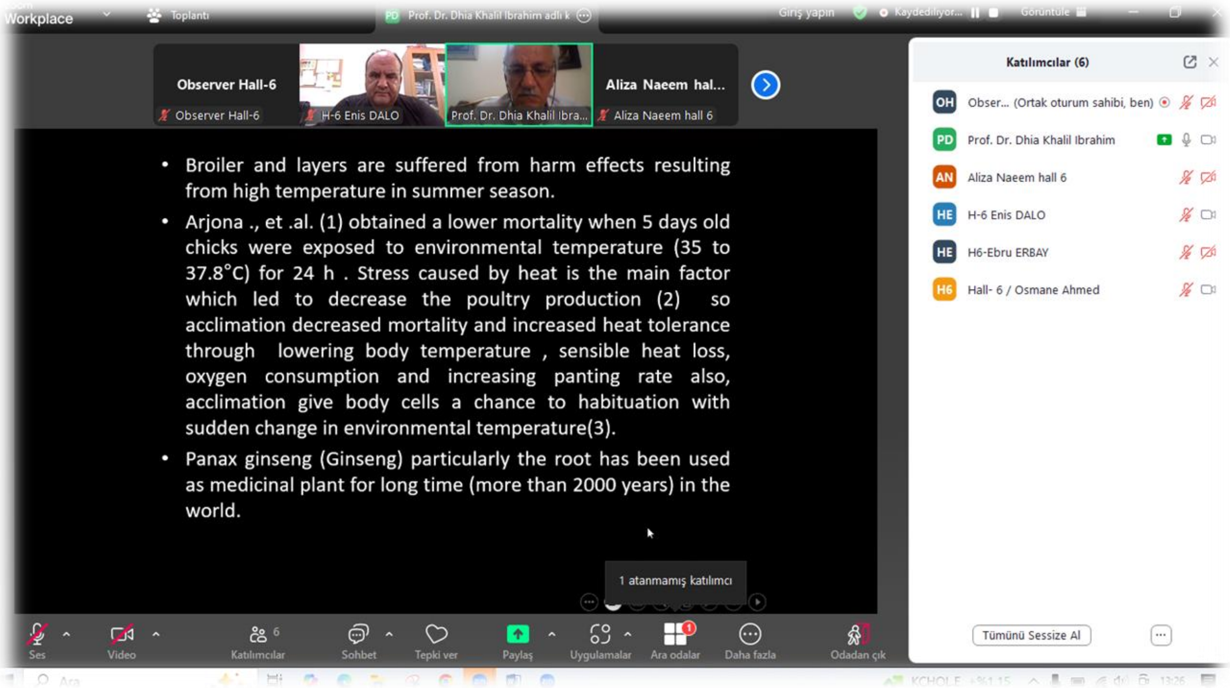


Table 1: Nutritive value of pearl millet in comparison with commonly consumed cereals.

CONSTITUENT	PEARL MILLET	WHEAT	RICE	SORGHUM	MAIZE
Protein(g)	11.6, 11.8*, 8 #, 11**	11.8	6.8	10.4	4.7
Fat(g)	5.0 , 4.8*, 2.4#, 5.0**	1.5	0.5	1.9	0.9
Crude fiber(g)	1.2, 2.3* , 2.2**	1.2	0.2	1.6	1.9
Carbohydrates(g)	67.5, 67*, 57#, 69**	71.2	78.2	72.6	24.6
Minerals(mg)	2.3	1.5	0.6	1.6	0.8
Calcium(mg)	42 , 42*, 25**	41	10	25	9
Phosphorous(mg)	296	306	160	222	121
Iron(mg)	8 , 11*, 3.0**	5.3	0.7	4.1	1.1
Zinc(mg)	3.1 , 2.2#	2.7	1.4	1.6	-
Sodium(mg)	10.9 , 5#	17.1	-	7.3	51.7
Magnesium(mg)	137 , 106#	138	90	171	40
Vitamin A(mcg)	132	64	0	47	32
Thiamine(mg)	0.33 , 0.38*, 0.30 #, 0.3**	0.45	0.06	0.37	0.11
Riboflavin(mg)	0.25 ,0.21*, 0.15**	0.17	0.06	0.13	0.17
Niacin(mg)	2.3 , 2.8*, 3.2#, 2.0**	5.5	1.9	3.1	0.6
Folic acid(mcg)	45.5	36.6	8	[illegible]	[illegible]
Vit C(mg)	0	0	0	[illegible]	[illegible]

PHOTO GALLERY



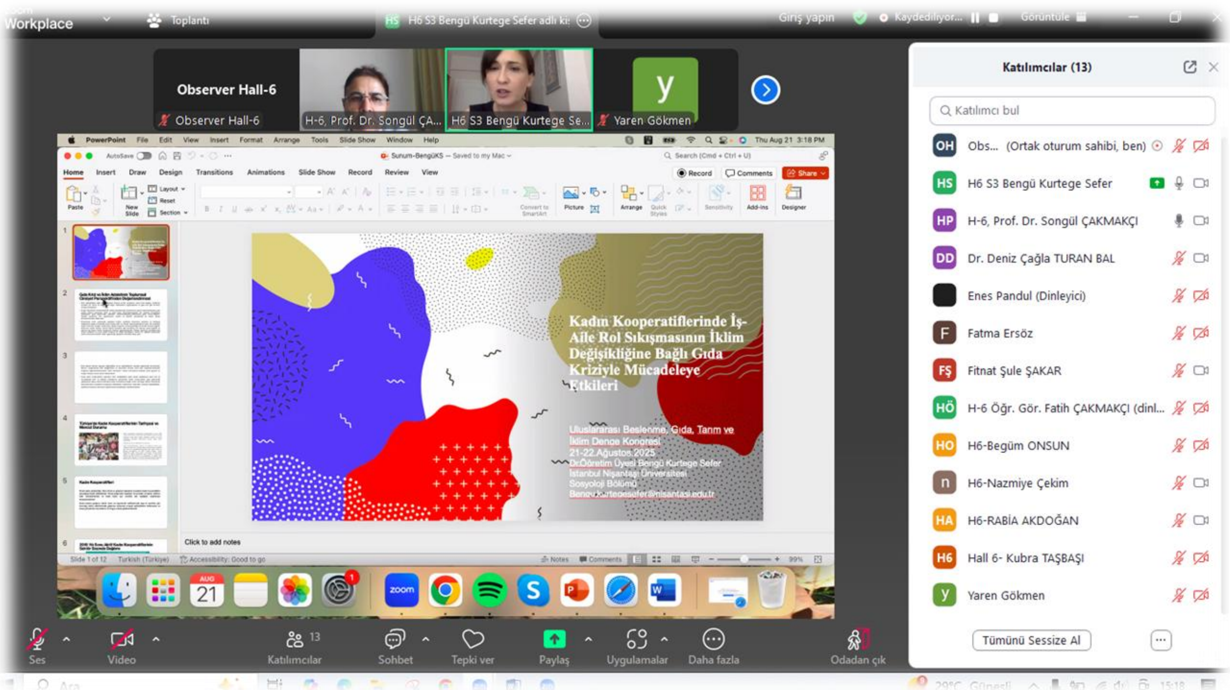
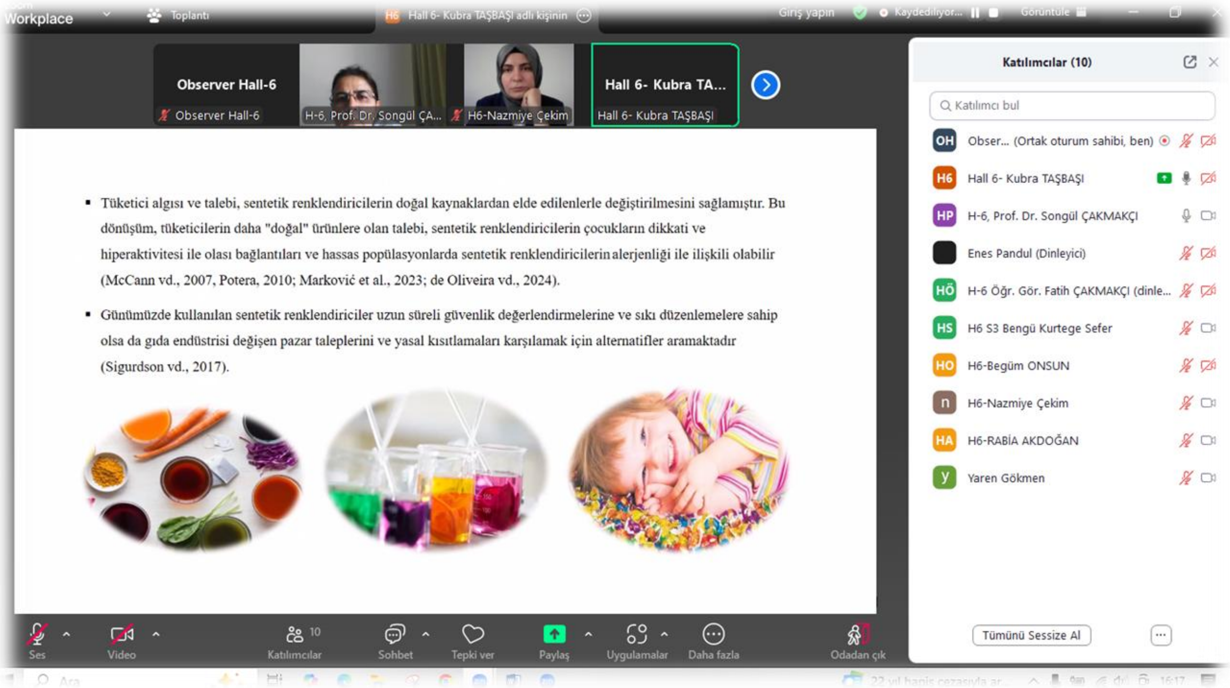


PHOTO GALLERY

PHOTO GALLERY



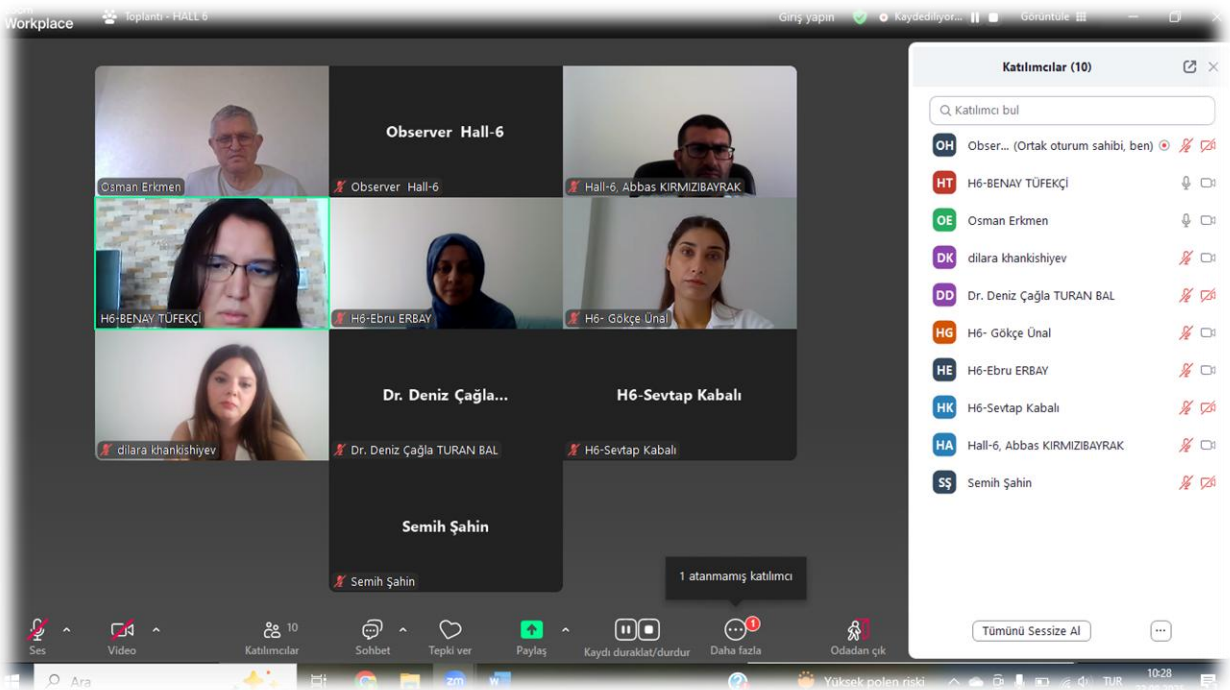


PHOTO GALLERY

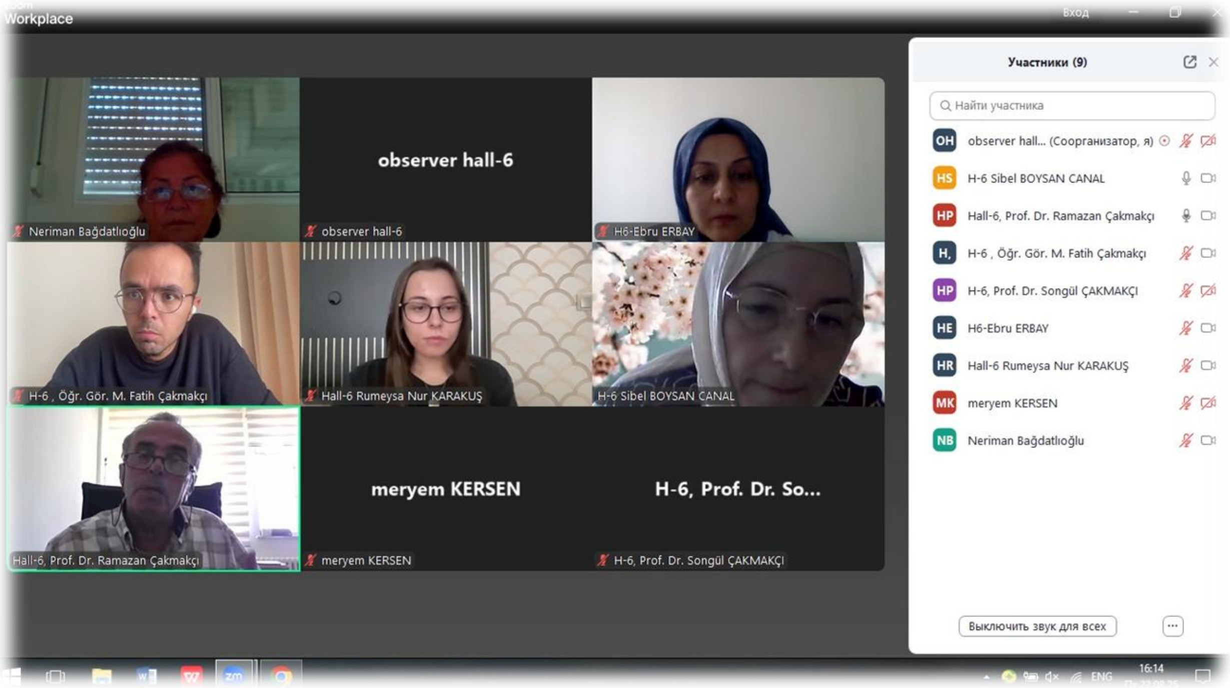


PHOTO GALLERY

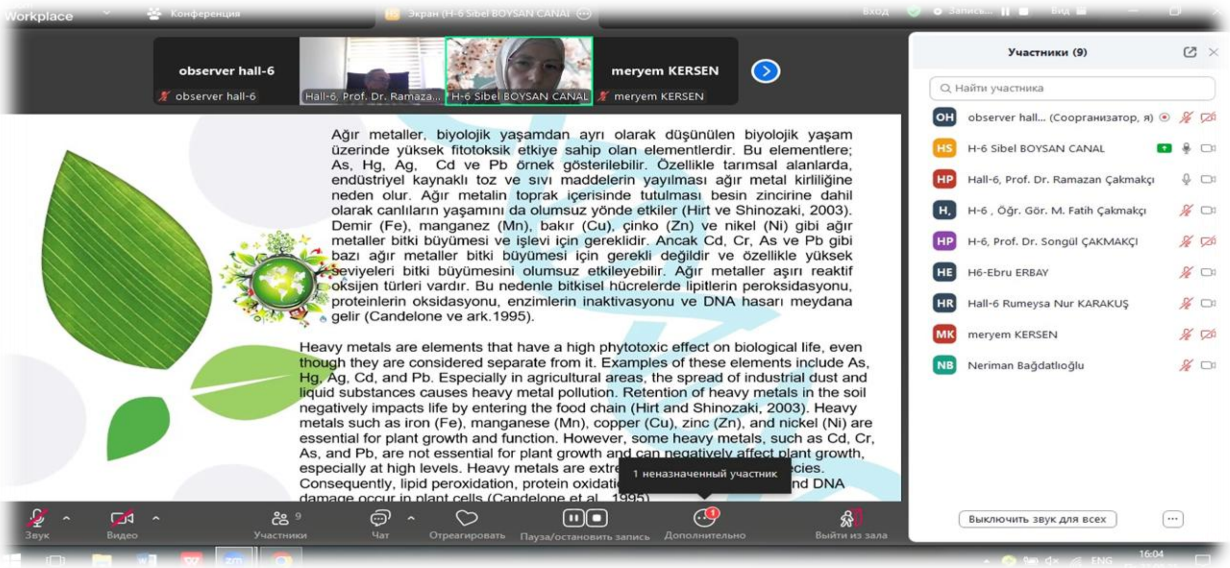


PHOTO GALLERY

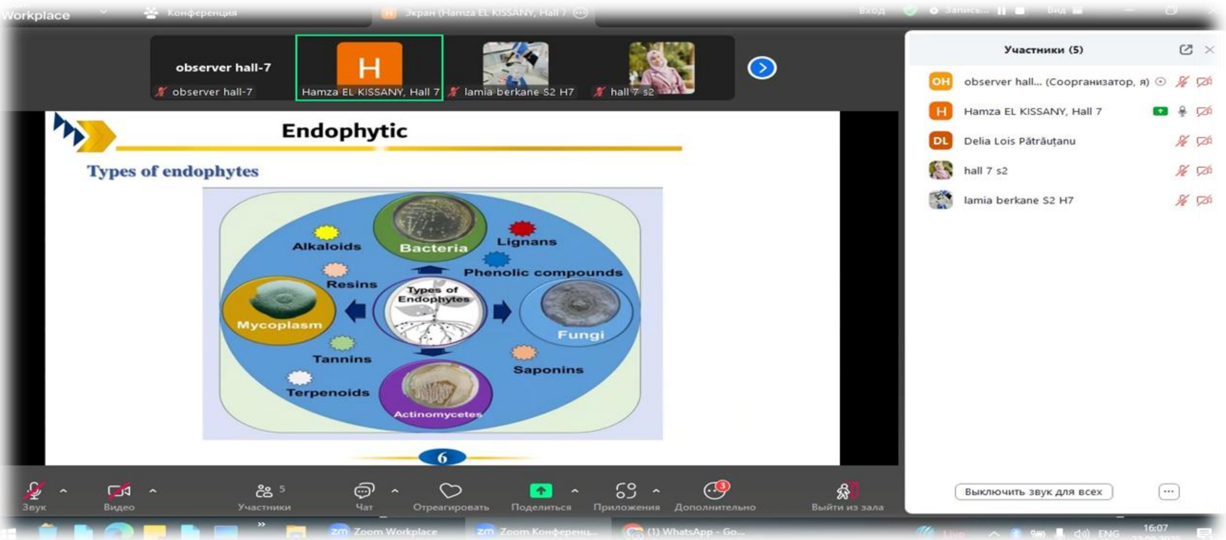
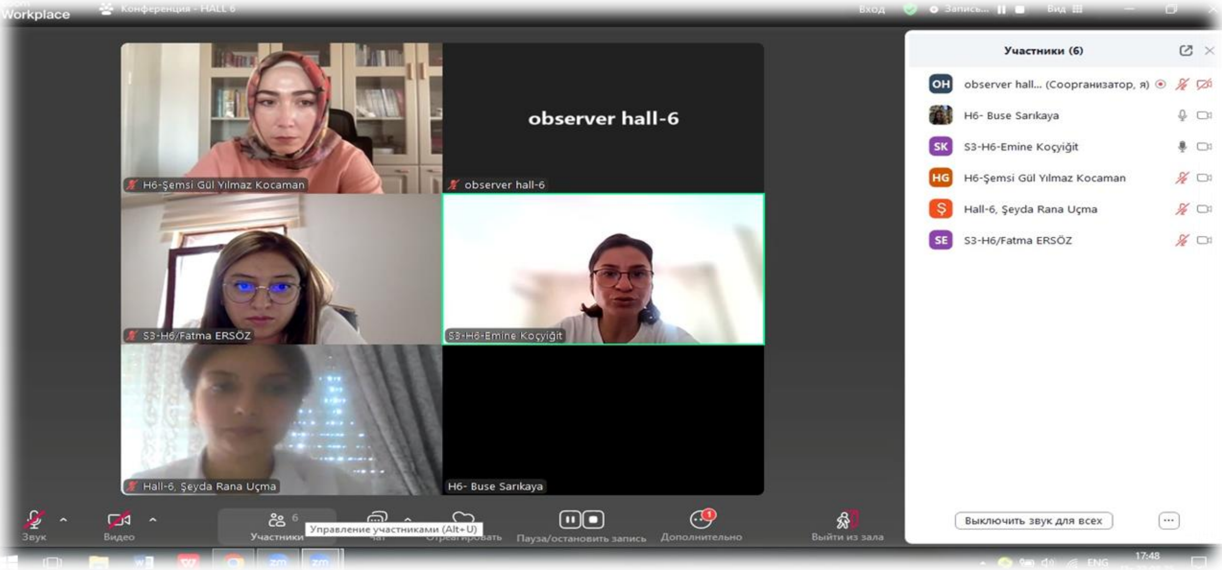
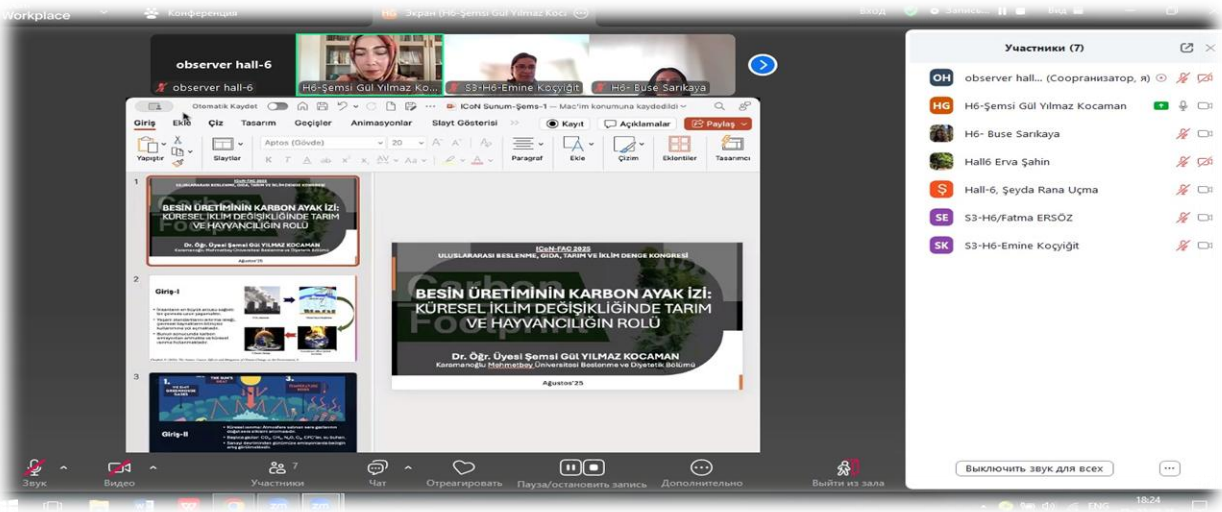
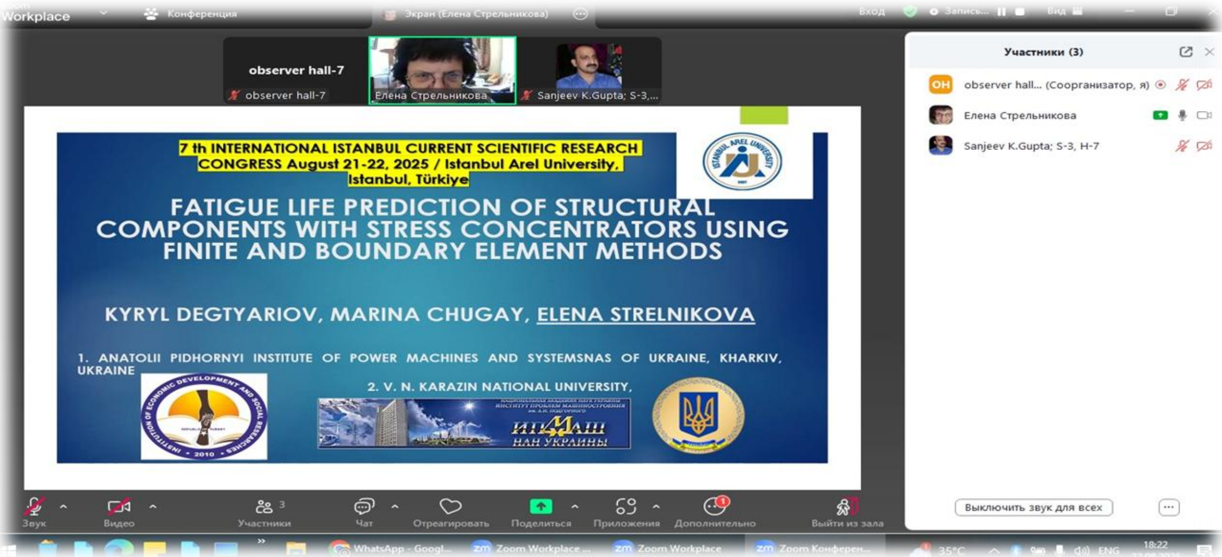


PHOTO GALLERY







ICoN-FAC 2025
INTERNATIONAL CONGRESS ON NUTRITION, FOOD, AGRICULTURE AND CLIMATE
Scientific Approaches for Sustainable Living

AUGUST 21-22, 2025 / ISTANBUL AREL UNIVERSITY
ISTANBUL, TÜRKİYE

CONFERENCE PROGRAM

Zoom Meeting ID: 844 6001 0824
Zoom Passcode: 123123

https://us02web.zoom.us/j/84460010824?pwd=JTcCJHcvf3VxDyxf1G9AjFb87CnVwc.1

Participant Countries (14): TÜRKİYE, MOROCCO, KOSOVO, IRAQ, PAKISTAN, NIGERIA, MONTENEGRO, NORTH MACEDONIA, LITHUANIA, BANGLADESH, ALGERIA, UZBEKISTAN, GERMANY, USA

IMPORTANT, PLEASE READ CAREFULLY

- ✓ To be able to attend a meeting online, login via **https://zoom.us/join** site, enter ID "Meeting ID or Personal Link Name" and solidify the session.
- ✓ The Zoom application is free and no need to create an account.
- ✓ The Zoom application can be used without registration.
- ✓ The application works on tablets, phones and PCs.
- ✓ The participant must be connected to the session 15 minutes before the presentation time.
- ✓ All congress participants can connect live and listen to all sessions.
- ✓ Moderator is responsible for the presentation and scientific discussion (question-answer) section of the session.

Points to Take into Consideration - TECHNICAL INFORMATION

- ✓ Make sure your computer has a microphone and is working.
- ✓ You should be able to use screen sharing feature in Zoom.
- ✓ **Attendance certificates will be sent to you as pdf at the end of the congress.**

Requests such as change of place and time will not be taken into consideration in the congress program.

Before you login to Zoom please indicate your name_surname and HALL number,
exp. Hall-1, Merve KIDIRYUZ

21.08.2025 / Session-1/Hall-6
Ankara Local Time: 10:00 – 12:00
Meeting ID: 844 6001 0824 / Passcode: 123123
Moderator: Assoc. Prof. Dr. Ayşe Nilgün ATAY

Title	Author(s)	Affiliation
IN SILICO COMPUTATIONAL ASSESSMENT OF ALLERGENICITY AND TOXICITY OF EMERGING PLANT AND SEAWEED PROTEINS	Assoc. Prof. Dr. Mehmet ÖZBİL Dr. İsmail Hakkı TEKİNER Exp. Sinem Nur AÇIKGÖZ Prof. Dr. Pınar OBAKAN YERLİKAYA Assist. Prof. Dr. Leila MEHDIZADEHTAPEH	Gebze Technical University TÜRKİYE Indpendent Researcher İstanbul TÜRKİYE Gebze Technical University TÜRKİYE İstanbul Medeniyet University TÜRKİYE Recep Tayyip Erdoğan University TÜRKİYE
SOIL HEALTH ASSESSMENTS FOR FRUIT CROPS	Assoc. Prof. Dr. Ayşe Nilgün ATAY	Burdur Mehmet Akif Ersoy University TÜRKİYE
EVALUATION OF AI-GENERATED DIET PLANS ACROSS DIVERSE CLIENT PROFILES: A MULTI-CRITERIA DECISION-MAKING APPROACH	Assist. Prof. Dr. Adem ERİK Sakhi Mohammad HAMIDY Hilal KARAMANCIOĞLU Büşra Nur KÜÇÜK KIRTIKLI	Tarsus University TÜRKİYE İstanbul Arel University TÜRKİYE Tarsus University TÜRKİYE Toros University TÜRKİYE
STRUCTURAL TRANSFORMATION FOR SUSTAINABILITY: GROWTH, AGRICULTURE, AND ENERGY POLICIES	Assoc. Prof. Dr. Başak ÖZARSLAN DOĞAN Assist. Prof. Dr. Burcu SAVAŞ ÇELİK Assist. Prof. Dr. Tuğba KANTARCI	İstanbul Gelişim University TÜRKİYE
STRATEGIC APPROACHES TO THE ECOLOGICAL SIGNIFICANCE AND CONSERVATION OF PLANT BIODIVERSITY IN ÇARŞAMBA PLAIN HABITATS	Ayla SARIOĞLU Hamdi Güray KUTBAY	Ondokuz Mayıs University TÜRKİYE
ECOLOGICAL ASSESSMENT OF PLANT BIODIVERSITY IN ÇARŞAMBA PLAIN HABITATS USING ALPHA AND BETA DIVERSITY INDICES	Ayla SARIOĞLU Hamdi Güray KUTBAY	Ondokuz Mayıs University TÜRKİYE

All participants must join the conference 10 minutes before the session time.
Every presentation should last not longer than 10-12 minutes.
Kindly keep your cameras on till the end of the session.

21.08.2025 / Session-2/Hall-6
Ankara Local Time: 12:30 – 14:30
Meeting ID: 844 6001 0824 / Passcode: 123123
Moderator: Aamir Jalal Al Mosawi

Title	Author(s)	Affiliation
ASSESSING MAIZE AGRONOMIC AND PHYSIOLOGICAL BENEFITS IN SEMI-ARID REGIONS: IMPACTS OF TRICKLING FILTER-TREATED WASTEWATER IRRIGATION	Ahmed Osmane Khadija Zidan Moustapha Belmouden	Agadir University MOROCCO Cadi Ayyad University MOROCCO
HEALTH AND FUNCTIONAL IMPLICATIONS OF SORGHUM IRRIGATED WITH TRICKLING FILTER-TREATED WASTEWATER IN SEMI-ARID NORTH AFRICA	Ahmed Osmane Khadija Zidan Moustapha Belmouden	Agadir University MOROCCO Cadi Ayyad University MOROCCO
THE IMPACT OF SESAME SEEDS ON THE GROWTH PERFORMANCE AND TOTAL PROTEIN CONTENT OF MEALWORMS (TENEBRIO MOLITOR)	Hazbije Sahiti Arbnore Morina Enis Dalo	Prishtina University KOSOVO
EFFECT OF EARLY ACCLIMATIZATION AND GINSENG (PANAX GINSENG) EXTRACT ALONE AND WITH VITAMINS AND MINERALS SUPPLEMENTATION TO DRINKING WATER ON SOME PRODUCTIVE TRAITS OF BROILER CHICKENS	Nadia AL-Muslimawi Dhia Ibrahim	Baghdad University IRAQ
CHARACTERIZATION OF VOLATILE PROFILES IN CHERRY FRUITS USING ELECTRONIC NOSE (ENOSE) AND HSSPMEGCMS	Aliza Naeem Bushra Niaz Farhan Saeed Muhammad Afzaal Muhammad Bilal Hussain Marwa Waheed	Government College University PAKISTAN Riphah International University PAKISTAN
A NEW DIETARY THERAPY FOR CHRONIC RENAL FAILURE: INTESTINAL DIALYSIS TECHNOLOGY	Aamir Jalal Al Mosawi	Baghdad Medical City and the Iraqi Ministry of Health IRAQ
IN SILICO DRUG-LIKENESS/ADME-T STUDIES AND MOLECULAR DOCKING OF COMPOUNDS FROM TEPHROSIA BRACTEOLATA LEAVES AGAINST SOME ARGETS OF DIABETIC COMPLICATIONS	Emmanuel Iyiola Precious Idakwoji Endaline Madu Hannah Nsude Micheal Adeyeye Racheal Chinweuba Aanuoluwa Iyiola Okpanachi Oyibo Josiah Aderinto	Ilorin University NIGERIA Nigeria University NIGERIA Renaissance University NIGERIA Salem University NIGERIA Federal University of Technology NIGERIA Prince Abubakar Audu University NIGERIA Federal University of Agriculture NIGERIA

All participants must join the conference 10 minutes before the session time.
Every presentation should last not longer than 10-12 minutes.
Kindly keep your cameras on till the end of the session.

21.08.2025 / Session-3/Hall-6
Ankara Local Time: 15:00 – 17:00
Meeting ID: 844 6001 0824 / Passcode: 123123
Moderator: Prof. Dr. Songül ÇAKMAKÇI

Title	Author(s)	Affiliation
THE IMPACT OF REDUCTION OF FOOD WASTE ON SUSTAINABLE AGRICULTURE AND CLIMATE RESILIENCE	Assist. Prof. Dr. Fitnat Şule ŞAKAR Yaren GÖKMEN YAZ	Haliç University TÜRKİYE İstanbul Okan University TÜRKİYE
THE EFFECTS OF WORK-FAMILY CONFLICT IN WOMEN'S COOPERATIVES ON FIGHTING CLIMATE CHANGE-INDUCED FOOD CRISIS	Assist. Prof. Dr. Bengü KURTEGE SEFER	İstanbul Nişantaşı University TÜRKİYE
THE ROLE OF HEALTH MANAGEMENT IN COMBATING CLIMATE CHANGE: AN INTEGRATED APPROACH	Dr. Rabia AKDOĞAN	University of Health Sciences TÜRKİYE
THE RELATIONSHIP BETWEEN ULTRA-PROCESSED FOOD CONSUMPTION AND SUSTAINABLE NUTRITION PATTERNS WITH OBESITY IN WOMEN	Begüm ONSUN Assist. Prof. Dr. Sümeyra SEVİM	Ankara Medipol University TÜRKİYE
FOOD ADDITIVES USED IN BREAKFAST CEREALS: TECHNOLOGICAL FUNCTIONS, HEALTH EFFECTS AND RECOMMENDATIONS	Nazmiye ÇEKİM Prof. Dr. Songül ÇAKMAKÇI	Atatürk University TÜRKİYE
COLORANTS: EFFECTS OF SYNTHETIC COLORANTS USED IN CANDIES ON CHILDREN'S HEALTH	Kübra TAŞBAŞI Prof. Dr. Songül ÇAKMAKÇI	Atatürk University TÜRKİYE

All participants must join the conference 10 minutes before the session time.
Every presentation should last not longer than 10-12 minutes.
Kindly keep your cameras on till the end of the session.

22.08.2025 / Session-1/Hall-6
Ankara Local Time: 10:00 – 12:00
Meeting ID: 844 6001 0824 / Passcode: 123123
Moderator: Prof. Dr. Osman ERKMEN

Title	Author(s)	Affiliation
A GENERAL OVERVIEW OF THE IMPACT OF GLOBAL CLIMATE CHANGE ON APRICOT	Abbas KIRMIZIBAYRAK	Turgut Özal University TÜRKİYE
MICROBIOTA-TARGETED APPROACHES IN PARKINSON'S DISEASE PATIENTS: THE ROLE OF PROBIOTICS, PREBIOTICS, AND KETOGENIC DIET	Benay TÜFEKÇİ Gülsüm TÜFEKÇİ Prof. Dr. Osman ERKMEN	İstanbul Nişantaşı University TÜRKİYE İstanbul Arel University TÜRKİYE
A SUSTAINABLE FUTURE WITH ALTERNATIVE FOODS: A NEW NUTRITION PARADIGM FOR HEALTHY GENERATIONS	Dilara ŞAHAN KHANKISHIYEV Assist. Prof. Dr. Semih ŞAHİN Prof. Dr. Osman ERKMEN	İstanbul Arel University TÜRKİYE
URBANIZATION AND FOOD SECURITY: DEVELOPING SUSTAINABLE FOOD SYSTEMS IN ISTANBUL	Assist. Prof. Dr. Sema KONYALI Res. Assist. Dr. Deniz Çağla TURAN BAL Dr. Osman İNAN	Tekirdağ Namık Kemal University TÜRKİYE Tekirdağ Namık Kemal University TÜRKİYE Independent Researcher TÜRKİYE
IMPACT OF SUSTAINABLE NUTRITION EDUCATION ON SUSTAINABLE EATING BEHAVIORS AND SUSTAINABLE FOOD CHOICE MOTIVES	Res. Assist. Dr. Gökçe ÜNAL Lect. Sevtap KABALI	Ondokuz Mayıs University TÜRKİYE

All participants must join the conference 10 minutes before the session time.
Every presentation should last not longer than 10-12 minutes.
Kindly keep your cameras on till the end of the session.

22.08.2025 / Session-1/Hall-7
Ankara Local Time: 10:00 – 12:00

Meeting ID: 844 6001 0824 / Passcode: 123123

Moderator: Dr. Zineb Mahi

Title	Author(s)	Affiliation
FROM WILD TO CULTIVATED: DOMESTICATION BOOSTS ESSENTIAL OIL QUALITY AND ANTIMICROBIAL POWER IN MOROCCAN THYMUS	Aabdousse Jamal Boulli Abdelali Wahid Nadya Oussif Ilis Salim Nora	Sulatn Moulay Slimane University MOROCCO
POSTHARVEST QUALITY COMPARISON OF TWO COMMERCIAL STRAWBERRY VARIETIES: PHYSICO-CHEMICAL AND SENSORY PERSPECTIVES	Sana El Moutaouakil Youssef El Madhi Fathalah Elwahab Mohammed Ouhssine	Ibn Tofail University MOROCCO
AGRICULTURAL MARKETS IN INDIA: EMERGING TRENDS AND CHALLENGES	Arijmand Shahid Tramboo Dr. Omar Fayaz Khan Dr. Kusumakar Gautam Dr. Ubair Nisar	Institute of Business & Policy Research INDIA
ENDOPHYTES AS AN ALTERNATIVE IN MANY FIELDS	Hicham EL-BOUKHARY Hamza ELKISSANY Adil LAAZIZ Abdelouahed HAJJAJI	Sultan Moulay Slimane University MOROCCO Sidi Mohamed Ben Abdellah University MOROCCO
PROSPECTIVE STUDY ON THE CONSUMPTION OF FOOD SUPPLEMENTS AMONG ATHLETES IN ALGERIA	Dr. Zineb Mahi	Mohamed Boudiaf University of Science and Technology ALGERIA
POTENTIAL SOURCE OF PLANT BIOMASS FOR BIOFUEL PRODUCTION	Dr. Zineb Mahi Bouhameur Mansour	Mohamed Boudiaf University of Science and Technology ALGERIA
INNOVATIVE DIRECTIONS AND PROSPECTS OF MICROBIOLOGICAL BİOTECHNOLOGY IN ENSURING FOOD SECURITY IN AGRICULTURE	Shirinboyeva Dilrabo Komilovna Kutliyeva Guzal Dzhumaniyozovna Daminov Asadullo Suvonovich	Samarkand State University UZBEKISTAN

All participants must join the conference 10 minutes before the session time.
Every presentation should last not longer than 10-12 minutes.
Kindly keep your cameras on till the end of the session.

22.08.2025 / Session-2/Hall-6
Ankara Local Time: 12:30 – 14:30
Meeting ID: 844 6001 0824 / Passcode: 123123
Moderator: Prof. Dr. Ramazan ÇAKMAKÇI

Title	Author(s)	Affiliation
PATHWAYS TO SUSTAINABLE FOOD PRODUCTION: CLIMATE-SMART AND RESILIENT AGRI-FOOD SYSTEMS OF THE FUTURE	Prof. Dr. Ramazan ÇAKMAKÇI Lect. Muhammet Fatih ÇAKMAKÇI	Çanakkale Onsekiz Mart University TÜRKİYE Mudanya University TÜRKİYE
AGRICULTURE-BASED CIRCULAR BIOECONOMY FOR SUSTAINABLE PRODUCTION, FOOD SECURITY, AND RESOURCE AND ENVIRONMENTAL PROTECTION	Prof. Dr. Ramazan ÇAKMAKÇI Prof. Dr Songül ÇAKMAKÇI	Çanakkale Onsekiz Mart University TÜRKİYE Atatürk University TÜRKİYE
ANALYSIS OF MEAT PRODUCTS SOLD IN KAYSERI PROVINCE FOR ADULTERATION USING MOLECULAR AND HISTOLOGICAL METHODS	MSc. Rumeysa Nur KARAKUŞ Prof. Dr. Nurhan ERTAŞ ONMAZ Prof. Dr. Emel ALAN	Erciyes University TÜRKİYE
THE FUNCTIONAL CONTRIBUTION OF PLANT–MICROORGANISM SYMBIOSES TO HEAVY METAL TOLERANCE AND PHYTOREMEDIATION PERFORMANCE	Dr. Sibel BOYSAN CANAL	Van Yüzüncü Yıl University TÜRKİYE
THE LEVEL OF KNOWLEDGE AND AWARENESS IN SOCIETY REGARDING FOOD DRUG INTERACTIONS: THE CASE OF ERZURUM	Meryem KERSEN Engin ŞAHİN Fatma CEBECİ AYDIN	Bayburt University TÜRKİYE
THE EVALUATION OF PRICKLY PEAR (Opuntia ficus-indica) IN FUNCTIONAL FRUIT LEATHER PRODUCTION	Ebru ERBAY Prof. Dr. Neriman BAĞDATLIOĞLU	Manisa Celal Bayar University TÜRKİYE

All participants must join the conference 10 minutes before the session time.
Every presentation should last not longer than 10-12 minutes.
Kindly keep your cameras on till the end of the session.

22.08.2025 / Session-2/Hall-7
Ankara Local Time: 12:30 – 14:30
Meeting ID: 844 6001 0824 / Passcode: 123123
Moderator: Dr. Roxana Gheorghita

Title	Author(s)	Affiliation
ENHANCEMENT OF BIOACTIVE COMPOUND SYNTHESIS IN AROMATIC AND MEDICINAL PLANTS BY ENDOPHYTIC MICROORGANISMS: A REVIEW	Hamza EL KISSANY Hicham EL-BOUKHARY Hicham EL KISSANI Adil LAAZIZ Abdelouahed HAJJAJI	Sultan Moulay Slimane University MOROCCO Sidi Mohamed Ben Abdellah University MOROCCO
ISOLATION AND IDENTIFICATION OF MOST PREDOMINANTFUNGI RESPONSIBLE FOR THE SPOILAGE OF TOMATO	Haruna Karamba Zainab Umar Zandam	Hussaini Adamu Federal Polytechnic NIGERIA
PHYTOCHEMISTRY AND HEALTH-PROMOTING POTENTIAL OF MORINGA OLEIFERA	Lamia Berkane Ghania Ahmed Mohammed Sadok Derki Chikha Maria Manel Azzi	El Oued University ALGERIA Heinrich-Heine University GERMANY El Oued University ALGERIA
OPTIMIZING SWEET POTATO PRODUCTIVITY THROUGH PRECISION PROPAGATION BY VINE CUTTING POSITION AND VARIETY SYNGERY IN TROPICAL NIGERIA	Solomon Oluwaseyi ADEWUYI Uchenna Noble UKWU Nathaniel DAUDA Ayomide Benjamin OLUGBADE Vivian Ogechi OSADEBE Patience Amaka ISHIEZE Chinenye Blessing ARUAH Adebisola Benedicta FADOJU	Nigeria University NIGERIA Fairfax University USA Obafemi Awolowo Teaching hospital Complex NIGERIA
THE EFFECTS OF KONJAC PASTA CONSUMPTION ON APPETITE AND ENERGY INTAKE	Anamaria Andronachi Dr. Roxana Gheorghita	Stefan cel Mare University ROMANIA
THE IMPACT OF EXCESSIVE SCREEN TIME ON EATING HABITS	Delia-Lois Pătrăuțanu Dr. Roxana Gheorghita	Stefan cel Mare University ROMANIA

All participants must join the conference 10 minutes before the session time.
Every presentation should last not longer than 10-12 minutes.
Kindly keep your cameras on till the end of the session.

22.08.2025 / Session-3/Hall-4
Ankara Local Time: 15:00 – 17:00
Meeting ID: 844 6001 0824 / Passcode: 123123
Moderator: Milos Rabrenovic

Title	Author(s)	Affiliation
ADDRESSING NIGERIA'S ECONOMIC CHALLENGES: THE NEED FOR AGRICULTURAL ENTREPRENEURSHIP LITERACY IN THE NIGERIAN TETIARY EDUCATIONAL INSTITUTIONS	Agwu, Ani Ekwe Onuoha, Ikedieze Arisa	Federal Polytechnic NIGERIA
EFFECTS OF METHANOL SEED EXTRACT OF ACACIA NILOTICA ON INDOMETHACIN-INDUCED ULCER IN WISTAR RATS	Nwamaka Maureen Odu Saudat Bisola Bello Mary Uchenna Ogunsanya	Federal University of Technology NIGERIA
FLAVORS AND RHYTHMS: THE SYNERGY OF GASTRONOMY, CULINARY ARTS, AND DANCE IN THE SPIRIT OF INTERCULTURAL COLLABORATION	Milos Rabrenovic Monika Stojanova	Montenegro Dance Sport Federation MONTENEGRO Association for Scientific-research, Educational and Cultural Activities "Open Science" NORTH MACEDONIA
IMPROVING TOMATO TOLERANCE TO INDUSTRIAL WASTEWATER THROUGH FOLIAR IRON-LYSINE CHELATE SUPPLEMENTATION	Naila Hadayat Ayesha Ramzan Syed Mohsan Raza Shah	Education University PAKISTAN
LIVESTOCK AND DAIRY DEVELOPMENT UNDER BUHARINOMICS: A REVIEW OF POLICY GAPS AND PROSPECTS	Sadiq, M.S Singh, I.P Ahmad, M.M Sani, B.S	Department of Agricultural Economics and Agribusiness NIGERIA Department of Agricultural Economics NIGERIA Department of Agricultural Economics and Extension NIGERIA Department of Agricultural Economics and Agribusiness NIGERIA
STUDY ANALYSIS OF THE SPREADING PROCESS OF ORGANIC GRANULAR FERTILIZERS TO SUSTAINABLE ENVIRONMENT	Eglė Jotautienė Raimonda Zinkevičienė	Vytautas Magnus University LITHUANIAN
RISK ASSESSMENT ON DISEASE TRANSMISSION AND STUDIES IDENTIFYING BACTERIA THROUGH CONTAMINATION ON BANGLADESH CURRENCY INCLUDING ESCHERICHIA COLI, KLEBSIELLA SPP., SALMONELLA SPP., SHIGELLA SPP., STAPHYLOCOCCUS AUREUS	Selim Ali	Rajshahi University BANGLADESH

All participants must join the conference 10 minutes before the session time.
Every presentation should last not longer than 10-12 minutes.
Kindly keep your cameras on till the end of the session.

22.08.2025 / Session-3/Hall-5
Ankara Local Time: 15:00 – 17:00
Meeting ID: 844 6001 0824 / Passcode: 123123
Moderator: Ana-Lucia Blendea

Title	Author(s)	Affiliation
EDUCATIONAL STRATEGIES AND CLASSROOM ENVIRONMENTS FOR STUDENTS WITH ASPERGER'S SYNDROME: A MULTISENSORY APPROACH	Ana-Lucia Blendea Alin Ciobica Ioan Gotca Daniela DIMITRIU	University of Medicine and Pharmacy ROMANIA Alexandru Ioan Cuza University ROMANIA Romanian Academy of Science ROMANIA Socola Psychiatry Institute ROMANIA
TOXICOLOGICAL AND BIOLOGICAL CHARACTERIZATION OF THE VENOMS OF THE MOST DANGEROUS VIPER SPECIES IN MOROCCO	Noureddine HAMMANI Khawla AMMOUCH1 Nihal MESMOUDI Prof. Abdellah MOUSTAGHFIR Ennaji HANANE Samir IBENMOUSSA Dr. Naoual OUKKACHE	Hassan II University MOROCCO Mohammed V University MOROCCO Hassan II University MOROCCO Pasteur Institute MOROCCO
ANALGESIC EFFECTS OF AQUEOUS LEAF EXTRACT OF MERCURIALIS ANNUA IN MICE	Abdeljalil ELMAHDAOUİ Lansine DİAKİTÉ Azız AUHMAN Zahra SOKAR	Cadi Ayyad University MOROCCO
MOLECULAR DOCKING STUDIES OF 3-DIAZO-1-METHYL-1,3-DIHYDRO-INDOL-2-ONE FROM ANOGEISSUS LEIOCARPUS LEAVES AGAINST SOME INFLAMMATORY MEDIATORS	Iyiola Aanuoluwa Temitayo Precious Idakwoji Emmanuel Iyiola Hannah Nsude Micheal Adeyeye Racheal Chinweuba	Federal University of Technology NIGERIA Nigeria University NIGERIA Ilorin University NIGERIA Salem University NIGERIA Federal Polytechnic NIGERIA Prince Abubakar Audu University NIGERIA
KNOWLEDGE, LIFESTYLE HABITS, AND THE ROLE OF NUTRITIONAL ELEMENTS IN TYPE 2 DIABETES MANAGEMENT: A CROSS-SECTIONAL STUDY AMONG IRAQI PATIENTS	Ali Hussein Mustafa AL-Obaidi Majd Ahmed Jumaah Omar Salih Hassan	Tikrit University IRAQ
EFFECT OF DIFFERENT CONCENTRATION OF NEEM OIL ON INSECT PESTS OF OKRA (ABELMOSCHUS ESCULENTUS L. MOENCH) IN MINNA, NIGER STATE	Oyewale, R. O. Afolabi, H. O. Babawo, S. J. Ibrahim, H. M. Olaniyi, R. M.	Federal University of Technology NIGERIA
GREEN SYNTHESIS OF NANOPARTICLES USING MEDICINAL PLANTS	S.Harinisri M.Farhat Yassir V.Hariharan Mrs.E.Elavarasi	Bharath Institute Of Higher Education And Research INDIA

All participants must join the conference 10 minutes before the session time.
Every presentation should last not longer than 10-12 minutes.
Kindly keep your cameras on till the end of the session.

22.08.2025 / Session-3/Hall-6

Ankara Local Time: 15:00 – 17:00

Meeting ID: 844 6001 0824 / Passcode: 123123

Moderator: Assist. Prof. Dr Emine KOCYİĞİT

Title	Author(s)	Affiliation
INTERMITTENT FASTING IN TYPE 2 DIABETES MANAGEMENT: GLYCEMIC CONTROL, FEASIBILITY, AND PERSONALIZATION	Assist. Prof. Dr. Tevfik KOÇAK Assist. Prof. Dr. Buse SARIKAYA Assist. Prof. Dr. Mehmet Arif İÇER	Gümüşhane University TÜRKİYE Amasya University TÜRKİYE
RELATIONSHIP BETWEEN CAFFEINE CONSUMPTION AND BODY COMPOSITION IN FEMALE NUTRITION AND DIETETICS STUDENTS AGED 18–25	Assist. Prof. Dr. Buse SARIKAYA Burak TÖNGÜŞ Gökdeniz YÜCEL Melike Ebrar ÜNAL Assist. Prof. Dr. Mehmet Arif İÇER	Amasya University TÜRKİYE
STUDY OF THE ANTIOXIDANT ACTIVITY AND PHENOLIC COMPOUNDS OF ORANGES PROCESSED USING DIFFERENT DRYING METHODS	Assist. Prof. Dr Yağmur DEMİREL ÖZBEK Assoc. Prof. Dr. Özlem SARAL Assist. Prof. Dr Emine KOCYİĞİT	Recep Tayyip Erdoğan University TÜRKİYE Ordu University TÜRKİYE
CARBON FOOTPRINT OF FOOD PRODUCTION: THE ROLE OF AGRICULTURE AND LIVESTOCK IN GLOBAL CLIMATE CHANGE	Assist. Prof. Dr. Şemsi Gül YILMAZ KOCAMAN	Karamanoğlu Mehmetbey University TÜRKİYE
THERAPEUTIC POTENTIAL OF COENZYME Q 10 IN METABOLIC SYNDROME: A NUTRACEUTICAL APPROACH TO OXIDATIVE STRESS, INSULIN RESISTANCE, AND INFLAMMATION	Assist. Prof. Dr. Şemsi Gül YILMAZ KOCAMAN	Karamanoğlu Mehmetbey University TÜRKİYE
WASTE MANAGEMENT IN TERMS OF SUSTAINABILITY OF TURKISH CUISINE	Şeyda Rana UÇMA Eren BALCI Erva ŞAHİN Neslihan BAĞLAR Prof. Dr. Nurten ÇEKAL	Pamukkale University TÜRKİYE
A REVIEW ON THE EVALUATION OF DIFFERENT ANIMAL MANURE AND WHEY IN BIOGAS PRODUCTION	Assist. Prof. Dr. Fatma ERSÖZ	Ardahan University TÜRKİYE

All participants must join the conference 10 minutes before the session time.
Every presentation should last not longer than 10-12 minutes.
Kindly keep your cameras on till the end of the session.

22.08.2025 / Session-3/Hall-7
Ankara Local Time: 15:00 – 17:00
Meeting ID: 844 6001 0824 / Passcode: 123123
Moderator: Sanjeev Kumar Gupta

Title	Author(s)	Affiliation
ETHNO-MEDICINAL PLANTS USED BY NOMADIC TRIBES IN JASROTA WILDLIFE SANCTUARY OF DISTRICT KATHUA, JAMMU AND KASHMIR, INDIA	Sanjeev Kumar Gupta Nikita Devi	Degree College INDIA
ISOLATION OF SAHARAN ACTINOBACTERIA FOR BIOLOGICAL CONTROL AGAINST PHYTOPATHOGENS: TOWARDS SUSTAINABLE AGRICULTURE	Fedwa BEGHDADI El-Hadj DRICHE	Hassiba Benbouali University ALGERIA
PLANT-BASED FUNCTIONAL FOODS: A PATH TO BETTER NUTRITION AND HEALTH	Marwa Waheed Muhammad Bilal Hussain Azha Fatima Farhan Saeed Muhammad Afzaal	Government College University PAKISTAN Riphah International University PAKISTAN
IN VITRO ANTIOXIDANT AND ANTIBACTERIAL ACTIVITY OF TWIGS EXTRACTS OF JUNIPERUS OXYCEDRUS SUBSP OXYCEDRUS FROM MOROCCO	Neg Imane Bouda Saıd Zaggoumı Hasna Mardoume Ibtıssam Haddıouı Abdelmajıd	Sultan Moulay Slimane University MOROCCO
COMPARATIVE ANALYSIS OF METHANOL EXTRACTS FROM JUNIPERUS OXYCEDRUS ACROSS ELEVEN MOROCCAN POPULATIONS	Neg Imane Bouda Saıd Zaggoumı Hasna Mardoume Ibtıssam Haddıouı Abdelmajıd	Sultan Moulay Slimane University MOROCCO
DIGITAL TRANSFORMATION IN AGRICULTURE: IOT AND MACHINE LEARNING FOR SMART CROP MONITORING IN MOROCCO'S GHARB PLAIN	Fathalah Elwahab Mohamed Sedki Chetto Abdelaziz Sana El Moutaouakil Najiba Brhadda Rabea Ziri	Ibn Toufail University MOROCCO Regional Center of Agricultural Research of Kenitra MOROCCO Ibn Toufail University MOROCCO
VALUE-ADDED NANOCELLULOSE VALORIZED FROM FRUIT PEEL WASTE FOR POTENTIAL DERMAL WOUND HEALING AND TISSUE REGENERATIVE APPLICATIONS	R. Thiruchelvi Dr. P. Saravanan Dr. M. Chamundeeswari	St. Joseph's College of Engineering INDIA

All participants must join the conference 10 minutes before the session time.
Every presentation should last not longer than 10-12 minutes.
Kindly keep your cameras on till the end of the session.

CONTENTS

GREEN SYNTHESIS OF NANOPARTICLES USING MEDICINAL PLANTS

S.Harinisri

M.Farhat yassir

V.Hariharan

Mrs. E.Elavarasi

Bharath Institute Of Higher Education And Research, Chennai, India

Abstract

Nanoparticles are gaining attention for their applications in drug delivery, diagnostics, and antimicrobial activity. Green synthesis of nanoparticles using medicinal plant extracts is an eco-friendly and cost-effective approach compared to traditional chemical methods.

Plants contain various phytochemicals such as flavonoids, alkaloids, and tannins that act as reducing and stabilizing agents in the nanoparticle synthesis process. This method avoids the use of toxic chemicals and high energy consumption, making it sustainable.

Examples include the synthesis of silver nanoparticles using neem, tulsi, or aloe vera extracts. These green nanoparticles have shown antimicrobial, anticancer, and antioxidant properties. They can be used in topical formulations, wound healing agents, and targeted drug delivery systems.

Despite their potential, challenges include standardizing the synthesis process and ensuring stability and reproducibility. Further research is required to understand the exact mechanisms and scale-up for industrial production.

PHYTOCHEMISTRY AND HEALTH-PROMOTING POTENTIAL OF MORINGA OLEIFERA

Lamia Berkane

Department of Molecular and cellular biology, faculty of biology, university of El Oued, Algeria,

ORCID: 0009-0001-9986-6685

Ghania Ahmed

Department of Molecular and cellular biology, faculty of biology, university of El Oued, Algeria,

Mohammed Sadok Derki

Faculty of Medicine, Heinrich-Heine university Düsseldorf, Germany

Chikha Maria

Department of Molecular and cellular biology, faculty of biology, university of El Oued, Algeria,

Manel Azzi

Department of Molecular and Cellular Biology, Faculty of Biology, University of El Oued, Algeria

ORCID: 0009-0001-9986-6685

Abstract

Moringa oleifera, widely recognized as the "miracle tree" or "drumstick tree," stands out as one of the most nutrient-rich plant species. This remarkable plant, native to the Indian subcontinent, has been an integral part of traditional medicinal systems for centuries due to its exceptional nutritional profile and healing potential. Almost every part of the plant—including the leaves, seeds, pods, roots, and flowers—contains a diverse array of bioactive constituents, such as flavonoids, alkaloids, essential vitamins, minerals, and amino acids, making it a valuable resource for both dietary and therapeutic uses. In recent years, *Moringa oleifera* has gained renewed scientific interest as a promising botanical in the fields of nutrition, medicine, and public health. Due to its broad spectrum of biological activities, it has emerged as a strong candidate in the development of novel pharmaceuticals and functional foods. The various phytochemicals found in *Moringa* offer a range of therapeutic benefits, including antioxidant, anti-inflammatory, antimicrobial (against bacteria and fungi), and anticancer properties. This review highlights multiple extraction methods, explores pharmacological effects, and discusses its potential applications in modern clinical and nutritional practices.

Keywords: Moringa oleifera, therapeutic potential, bioactive phytochemicals, health-promoting effects, nutritional applications.

THE EFFECTS OF KONJAC PASTA CONSUMPTION ON APPETITE AND ENERGY INTAKE

Anamaria Andronachi

Faculty of Medicine and Biological Science, Stefan cel Mare University of Suceava, Romania

Dr. Roxana Gheorghita

Faculty of Medicine and Biological Science, Stefan cel Mare University of Suceava, Romania

ABSTRACT

This study explores the impact of konjac pasta consumption on appetite and energy intake, aiming to evaluate the potential of this functional food in body weight management. Konjac pasta, rich in glucomannan a soluble fiber with significant physiological effects may enhance satiety and reduce subsequent caloric intake. The study combines a theoretical review of current scientific literature with experimental data assessing changes in appetite and dietary intake following the consumption of konjac pasta. It discusses the nutritional composition, mechanisms through which glucomannan affects digestion and appetite regulation, and the implications of regular consumption within a balanced diet. The results suggest that incorporating konjac pasta into daily meals can be an effective strategy for reducing energy intake without compromising overall satiety, making it a useful alternative in nutritional plans focused on weight maintenance or reduction. Healthy participants were recruited via invitations distributed on the campus of Ștefan cel Mare University of Suceava. Interested individuals underwent on-site screening to verify compliance with the initial inclusion criteria: age between 18 and 65 years, and a body mass index (BMI) ranging from 18 to 39 kg/m². Participants (n=10) completed satiety questionnaires using 100 mm visual analogue scales (VAS) to evaluate four subjective measures of satiety: desire to eat, hunger, fullness, and prospective food consumption. Baseline satiety was assessed prior to preload administration (0 min), followed by repeated measurements taken after the first bite of the test sample at 15-minute intervals, up to 90 minutes post-ingestion. Test conditions that have been evaluated were: (i) Cooked pasta noodles without KGM gel noodles (control), (ii) Partial replacement of cooked pasta noodles with KGM gel noodles (50-KGM), (iii) Complete replacement of cooked pasta noodles with KGM gel noodles (100-KGM) – Slim Pasta (spaghetti) konjac. Body weight was measured using a digital scale (Tanita), and height was measured with a wall-mounted stadiometer. The results indicate that konjac pasta consumption led to a greater reduction in appetite and energy intake compared to regular pasta. The mixed pasta (1:1 konjac and regular) produced intermediate effects, suggesting a dose-dependent response.

STRUCTURAL TRANSFORMATION FOR SUSTAINABILITY: GROWTH, AGRICULTURE, AND ENERGY POLICIES

SÜRDÜRÜLEBİLİRLİK İÇİN YAPISAL DÖNÜŞÜM: BÜYÜME, TARIM VE ENERJİ POLİTİKALARI

Başak ÖZARSLAN DOĞAN

İstanbul Gelişim Üniversitesi, Sürdürülebilir Çevre ve Toplum Uygulamaları ve Araştırma Merkezi, İktisadi, İdari ve Sosyal Bilimler Fakültesi, Uluslararası Ticaret ve İşletmecilik Bölümü, İstanbul, Turkey

ORCID ID: https://orcid.org/0000-0002-5126-7077

Burcu SAVAŞ ÇELİK

İstanbul Gelişim Üniversitesi, İktisadi, İdari ve Sosyal Bilimler Fakültesi, Uluslararası Ticaret ve İşletmecilik Bölümü, İstanbul, Turkey

ORCID ID: https://orcid.org/0000-0002-3896-5858

Tuğba KANTARCI

İstanbul Gelişim Üniversitesi, İktisadi, İdari ve Sosyal Bilimler Fakültesi, Ekonomi ve Finans Bölümü, İstanbul, Turkey

ORCID ID: https://orcid.org/0000-0002-2257-430X

ABSTRACT

The increase in carbon emissions, which is considered one of the most important causes of climate change, is critical to ensuring the economic, social, and environmental sustainability of countries. In particular, the widespread use of fossil fuels, the increase in fossil fuel-dependent industrial activities, the increase in chemical fertilizer use, deforestation, the use of low energy efficiency technological products, increased consumption, the formation of long supply chains, and insufficient demand for renewable energy sources increase countries' production and income, but at the same time, these factors also cause an increase in carbon emissions.

While the literature examines the effects of the industrial, agricultural, and energy sectors on carbon emissions, it is observed that the effects of fertilizer consumption, organic farming, agricultural productivity, and renewable energy consumption on carbon emissions are overlooked. Therefore, this study aims to fill an important gap in the literature.

Countries are using economic models that increase resource efficiency in order to achieve environmental sustainability goals and combat the global climate crisis. In this context, it is crucial to identify factors that reduce carbon emissions. In this study, the effects of GDP, renewable energy consumption, and fertilizer consumption on carbon emissions in Turkey between 1991 and 2020 were tested using the ARDL bounds test approach. According to the analysis results, GDP, fertilizer consumption, and renewable energy consumption have a significant effect on carbon emissions in the long term. A one-unit change in GDP and fertilizer consumption increases carbon emissions, while a one-unit change in renewable energy consumption reduces carbon emissions. In the short term, GDP, fertilizer consumption, and renewable energy consumption have a significant effect on carbon emissions at the 1% level. In the short term, a one-unit change in GDP and fertilizer consumption increases carbon emissions, while a one-unit change in renewable energy consumption reduces carbon emissions. Accordingly, the fact that increases in production and income and fertilizer consumption cause carbon emissions to increase indicates that Turkey still needs more structural changes at the policy level to achieve sustainable growth. In conclusion, a multi-dimensional approach to reducing carbon emissions must be adopted, fertilizer use and GDP must be channeled into more efficient areas, and the transition to renewable energy use must be accelerated.

Key Words: Carbon emissions, Economic growth, Fertilizer use, Türkiye, ARDL

Özet

İklim değişikliğinin en önemli nedenlerinden birisi olarak gösterilen karbon emisyonlarındaki artış ülkelerin ekonomik, sosyal ve çevresel sürdürülebilirliğinin sağlanması açısından kritik öneme sahiptir. Özellikle fosil yakıtların yaygın bir biçimde kullanılması, fosil yakıta bağlı sanayi faaliyetlerinin artış göstermesi, kimyasal gübre kullanımının artması, ormansızlaşma, enerji verimliliği düşük teknolojik ürünlerin kullanımı, tüketimin artması, uzun tedarik zincirlerinin oluşması ve yenilebilir enerji kaynaklarına olan talebin yetersiz olması ülkelerin üretim ve gelirini artırırken söz konusu faktörler aynı zamanda karbon emisyonlarının da artmasına neden olmaktadır.

Literatürde sanayi, tarım ve enerji sektörlerinin karbon emisyonları üzerindeki etkileri araştırılırken gübre tüketimi, organik tarım, tarımsal verimlilik ve yenilenebilir enerji tüketimlerinin de karbon emisyonları üzerindeki etkilerinin göz ardı edildiği görülmektedir. Bu nedenle bu çalışma önemli bir literatür açığını doldurmayı hedeflemektedir.

Ülkeler çevresel sürdürülebilirlik hedeflerine ulaşmak ve küresel iklim kriziyle mücadele etmek amacıyla kaynak verimliliğini artırıcı ekonomik modelleri kullanmaktadırlar. Bu bağlamda karbon emisyonlarını azaltıcı unsurları tespit etmek oldukça önemlidir. Çalışmada 1991 – 2020 dönemleri arasında Türkiye'de gerçekleşen karbon emisyonları üzerinde GSYİH, yenilenebilir enerji tüketiminin ve gübre tüketiminin etkisi ARDL sınır testi yaklaşımı kullanılarak test edilmiştir. Analiz sonucuna göre uzun dönemde GSYİH, gübre tüketimi ve yenilenebilir enerji tüketiminin karbon emisyonları üzerinde anlamlı etkisi bulunmaktadır. GSYİH'de ve gübre tüketiminde meydana gelen bir birimlik değişim karbon emisyonlarını artırırken yenilenebilir enerji tüketiminde meydana gelen bir birimlik değişim ise karbon emisyonlarını azaltmaktadır. Kısa dönemde GSYİH, gübre tüketimi ve yenilenebilir enerji tüketiminden karbon emisyonları üzerinde %1 düzeyinde anlamlı etkisi olduğu görülmektedir. Kısa dönemde GSYİH ve gübre tüketiminde meydana gelen bir birimlik değişim karbon emisyonlarını artırırken yenilenebilir enerji tüketiminde meydana gelen bir birimlik değişim karbon emisyonlarını azaltmaktadır. Buna göre üretim ve gelirde meydana gelen artışların ve gübre tüketiminin karbon emisyonlarını artmasına neden olması Türkiye'nin halen daha sürdürülebilir büyümeye yönelik politika düzeyinde daha fazla yapılandırmaya ihtiyaç duyduğunu göstermektedir. Sonuç olarak, karbon emisyonlarının azaltılması için çok boyutlu yaklaşımların benimsenmesi, gübre kullanımının ve GSYİH'nin daha verimli alanlara kanalize edilmesi ve yenilenebilir enerji kullanımına geçişin hızlandırılması gerekmektedir.

Anahtar Kelimeler: Karbon Emisyonları, Ekonomik Büyüme, Gübre Kullanımı, Türkiye, ARDL

THE IMPACT OF SESAME SEEDS ON THE GROWTH PERFORMANCE AND TOTAL PROTEIN CONTENT OF MEALWORMS (*Tenebrio molitor*)

Hazbije Sahiti

University of Prishtina, Faculty of Mathematics and Natural Science, Department of Biology

Arbnore Morina

University of Prishtina, Faculty of Mathematics and Natural Science, Department of Biology

Enis Dalo

University of Prishtina, Faculty of Mathematics and Natural Science, Department of Biology

Abstract

The worm of the *Tenebrio molitor* mealybug belonging to the Tenebronidae family feeds on different types of food, including plastic. It is a very fast decomposer which is easy to cultivate and has quantity high nutritional values including proteins, fats, amino acids and minerals. It has a wide industrial use as a biological cleaner of nature, but due to the high concentration of proteins found in its body it also has a nutritional role. The objective of the research was to evaluate the impact of sesame seeds and sesame oil on the amount of total proteins in mealworms (*Tenebrio molitor*). In the research, 40 worms of the flour *Tenebrio molitor* were used. The average weight of these individuals were 0.13 gr and total weight 5.21 gr. The worms used in this experiment were cultured with different food grounds (flour, sesame seeds and sesame oil). Cultivation was done in a period of 12-14 weeks. With sesame oil, cultivation failed. After the cultivation of worms, cultured samples with different types of food are brought to laboratories where at the beginning were sacrificed by freezing and then weighed. After obtaining the homogenate of incubated worms the protein concentration was measured with spectrophotometric method of Lowry. Based on the results in conclusion that the concentration of total proteins in the mealworm homogenate cultured with flour was smaller than in the homogenate cultivated with sesame seeds. In the weight, the results were the opposite, where weight was greater in worms cultured with flour than in those cultured with sesame.

Key words: mealworms, flour, sesame, total proteins.

THE ROLE OF HEALTH MANAGEMENT IN COMBATING CLIMATE CHANGE: AN INTEGRATED APPROACH

İKLİM DEĞİŞİKLİĞİ İLE MÜCADELEDE SAĞLIK YÖNETİMİNİN ROLÜ: ENTEGRE BİR YAKLAŞIM

Dr. Rabia AKDOĞAN

University of Health Sciences

ABSTRACT

Problem of the Study: Climate change is a global crisis that directly affects public health. Paradoxically, the healthcare sector, which is expected to play a leading role in combating this crisis, is also responsible for a significant portion of greenhouse gas emissions. Effectively forecasting the health risks associated with climate change, planning against these risks, and developing mitigation strategies require a multi-sectoral and multi-level governance approach at both local and international levels. Although the literature on the relationship between climate change and health has expanded rapidly in recent years, studies focusing on managerial aspects such as interprofessional collaboration in healthcare services, the development of decision-support tools, and economic evaluations remain limited.

Purpose of the Study: Health management is a comprehensive field that not only ensures the organization of services but also involves the protection of public health and the management of social and economic impacts. In this context, it is essential for health management to take on a proactive role in the fight against climate change. The aim of this study is to highlight the critical role of health management within the context of climate change and health, emphasizing sustainability and an integrated approach.

Method: This study evaluates the role of health management in combating climate change within the framework of multi-sectoral and multi-level governance. Accordingly, an interdisciplinary literature review focusing on the themes of climate change, health, and management has been conducted.

Results and Recommendations: Health managers, through an integrated approach, play a key role in ensuring sustainability and reducing climate-related risks by: - Providing strategic leadership and aligning health policies with climate change objectives, -Developing risk assessment and early warning systems, -Allocating resources and establishing climate-resilient infrastructures, -Promoting education and awareness-raising initiatives. To effectively reduce climate-related health risks, collaboration must be established between public health professionals, environmental scientists, meteorologists, information and technology experts, urban planners, disaster management professionals, and the health sector. This holistic approach will contribute to overcoming climate change skepticism and to building a more sustainable environment and society.

Keywords: Climate change, Health management, Sustainability, Public health, Integration.

ÖZET

Çalışmanın Problemi: İklim değişikliği, halk sağlığını doğrudan etkileyen küresel bir kriz niteliğindedir. Paradoksal bir şekilde, bu krizle mücadelede öncü rol oynaması beklenen sağlık hizmetleri, sera gazı emisyonlarının önemli bir kısmından sorumludur. İklim değişikliğinin sağlık üzerindeki risklerini etkili biçimde öngörmek, bu risklere karşı planlama yapmak ve mücadele stratejileri geliştirebilmek için yerel ve uluslararası düzeyde çok sektörlü ve çok düzeyli bir yönetişim anlayışı gereklidir. Son yıllarda iklim değişikliği ve sağlık ilişkisine dair literatür hızla genişlemiş olsa da sağlık hizmetlerinde meslekler arası etkileşimin önemi, karar destek araçlarının geliştirilmesi ve ekonomik değerlendirmeler gibi yönetimsel alanlara yönelik çalışmalar sınırlı kalmıştır.

Çalışmanın Amacı: Sağlık yönetimi yalnızca hizmetlerin organizasyonunu sağlamakla sınırlı olmayan, aynı zamanda halk sağlığının korunması ile sosyal ve ekonomik etkilerin yönetimini içeren bütüncül bir alandır. Bu bağlamda, iklim değişikliğiyle mücadelede sağlık yönetiminin proaktif bir rol üstlenmesi zorunludur. Çalışmanın amacı, sağlık yönetiminin iklim değişikliği ve sağlık ilişkisi bağlamındaki kritik rolünü sürdürülebilirlik ekseninde ve entegre bir yaklaşımla ortaya koymaktır.

Yöntem: Bu çalışma, sağlık yönetiminin iklim değişikliğiyle mücadeledeki rolünü çok sektörlü ve çok düzeyli yönetişim anlayışı çerçevesinde değerlendirmektedir. Bu kapsamda, iklim değişikliği, sağlık ve yönetim temalarına odaklanan disiplinlerarası bir literatür taraması gerçekleştirilmiştir.

Sonuç ve Öneriler: Sağlık yöneticileri, sürdürülebilirliği sağlama ve iklimle ilişkili riskleri azaltma sürecinde entegre bir yaklaşımla: **-**Stratejik liderlik ve sağlık politikalarının iklim değişikliğiyle uyumlu hâle getirilmesi, -Risk değerlendirme ve erken uyarı sistemlerinin geliştirilmesi, **-**Kaynak tahsisi ve iklim dirençli altyapıların kurulması, **-**Eğitim ve farkındalık faaliyetlerinin yaygınlaştırılmasıdır. İklim değişikliğine bağlı sağlık risklerinin azaltılabilmesi için halk sağlığı uzmanları, çevre bilimciler, meteorologlar, bilişim ve teknoloji uzmanları, şehir plancıları ve afet yönetimi profesyonelleri ile sağlık sektörü arasında etkin iş birliği sağlanmalıdır. Bu bütüncül yaklaşım, iklim değişikliği konusundaki şüpheciliğin aşılmasına ve daha sürdürülebilir bir çevre ve toplum yapısının inşasına katkı sağlayacaktır**.**

Anahtar Kelimeler: İklim değişikliği, Sağlık yönetimi, Sürdürebilirlik, Halk sağlığı, Entegrasyon.

FLAVORS AND RHYTHMS: THE SYNERGY OF GASTRONOMY, CULINARY ARTS, AND DANCE IN THE SPIRIT OF INTERCULTURAL COLLABORATION

Milos Rabrenovic

Montenegro Dance Sport Federation, Montenegro

Monika Stojanova

Association for Scientific-research, Educational and Cultural Activities “Open Science”, North Macedonia

Abstract

In today’s interconnected world, gastronomy and dance are emerging as dynamic tools for fostering cultural dialogue, artistic collaboration, and community building. This review paper aims to explore how the fusion of culinary arts and dance can serve as a powerful framework for intercultural exchange. By examining existing case studies, interdisciplinary initiatives, and creative practices from different cultural contexts, the paper investigates how taste and movement – two deeply embodied and sensorial experiences – can be integrated into collaborative platforms that celebrate diversity while promoting mutual understanding.

The objective of this paper is to analyze how cultural narratives are expressed and exchanged through food preparation, shared meals, and traditional or contemporary dance performances. Through examples of festivals, culinary-dance residencies, and interactive workshops involving chefs, dancers, and artists from diverse ethnic and national backgrounds, the paper highlights the potential of these collaborations to act as cultural bridges. These encounters not only foster inclusivity and empathy, but also inspire new hybrid forms of artistic expression that transcend traditional boundaries.

By synthesizing theoretical insights with real-world applications, the paper proposes practical models for using gastronomy and dance as educational, touristic, and artistic tools. Ultimately, this interdisciplinary exploration argues that the combination of flavors and rhythms offers a unique and underutilized medium for intercultural communication, creativity, and sustainable cultural development.

Keywords: Intercultural collaboration, culinary arts, gastronomy, dance, cultural exchange.

WASTE MANAGEMENT IN TERMS OF SUSTAINABILITY OF TURKISH CUISINE

Şeyda Rana UÇMA
Pamukkale Üniversitesi, Sosyal Bilimler Enstitüsü
ORCID: 0009-0000-0840-047X

Eren BALCI
Pamukkale Üniversitesi, Sosyal Bilimler Enstitüsü
ORCID: 0009-0000-2784-4711

Erva ŞAHİN
Pamukkale Üniversitesi, Sosyal Bilimler Enstitüsü
ORCID: 0009-0008-6148-7605

Neslihan BAĞLAR
Pamukkale Üniversitesi, Sosyal Bilimler Enstitüsü
ORCID: 0009-0002-8094-4417

Prof. Dr. Nurten ÇEKAL
Pamukkale Üniversitesi, Turizm Fakültesi
ORCID: 0000-0002-7596-9129

ABSTRACT

Introduction and Purpose: Increasing production and consumption activities all over the world have led to problems such as environmental pollution, decrease in natural resources and deterioration of ecological balance, and this situation has begun to pose a risk in transferring resources to future generations. For this reason, it was necessary to take precautions in this regard, and the careful and most economical use of existing resources has gained importance all over the world. Eating and drinking activities have become one of the most essential needs since the existence of human beings. While food was previously only a physical need, it has become a culture as a result of changes in people's lifestyles. In this sense, Turkish Culinary Culture is one of our intangible cultural heritages that was formed under the influence of many factors throughout history. In recent years, rapid population growth has necessitated an increase in food production. Every day, operations such as food preparation, cooking and storage occur in both food and beverage establishments and other kitchens, and these processes also cause the formation of many residues. As resources decrease, it will not be possible to maintain current food and beverage recipes with the same quality and same products in the future. In this context, this study focuses on the recycling of wastes generated during food and beverage preparation in Turkish cuisine into food and beverages, thus aiming to prevent waste and contribute to the sustainability of Turkish cuisine.

Materials and Methods: In the research, archive document scanning technique, one of the qualitative research methods, was used, scientific publications and websites related to the subject were scanned, and the literature was created in the light of the data obtained. In the study, the wastes that occur in kitchens from all food groups were revealed and suggestions were made on how to evaluate these wastes.

Results: Food and beverage residues in the kitchen cause economic losses, which negatively affects not only the economy but also nature and society. In this study, recipe suggestions were made that will contribute to the utilization of waste from all food groups in Turkish cuisine in order to minimize food losses.

Discussion and Conclusion: In the kitchen, residues may form during the preparation and cooking of food and beverages from food groups such as meat, milk, vegetables and fruits, and grains, and even food that is not consumed after cooking is thrown away. There are precautions that need to be taken to prevent this waste and ensure sustainability. The most important of these measures is the reuse of leftover food and beverages by turning them into food and beverages.

Key Words: Türk Mutfağı, Sürdürülebilirlik, Atık yönetimi, Yiyecek artıkları

ETHNO-MEDICINAL PLANTS USED BY NOMADIC TRIBES IN JASROTA WILDLIFE SANCTUARY OF DISTRICT KATHUA, JAMMU AND KASHMIR, INDIA

Sanjeev Kumar Gupta

Head, Department of Botany, Govt. Degree College Kathua, Jammu and Kashmir, India- 184101

https://orcid.org/0000-0002-8252-8225

Nikita Devi

Department of Sociology, University of Jammu, Jammu and Kashmir, India- 180006

Abstract

The district Kathua of Jammu and Kashmir is geographically situated in the north-western Himalayan region of India. It is mostly a mountainous region inhabited by people of different races, religions and cultures including some nomadic tribes. The area of study lies in the foothills of mighty Himalayas popularly known as the Siwalik Hills. The climate of the region is moderate sub-tropical type which supports rich floral diversity. The plant diversity plays a significant role in the lives of people inhabiting the vast expanse of wildlife sanctuary. The nomadic tribes are primarily dependent on their own traditional knowledge of medicinal plants in order to get rid of health related disorders. The aim of study is to explore the medicinal plant wealth of the region particularly used by the nomadic tribes of gujjar and bakerwal. The research work was performed through field study and data generation from nomadic communities. A total of 84 respondents were surveyed to garner data. The exploratory research work reveals the use of 62 medicinal plant species belonging to 23 families of angiosperms. The plant species like *Ajuga integrifolia* Buch.-Ham. ex D.Don., *Artemisia nilagirica* Pamp., *Centella asiatica* (L.) Urb., *Curcuma longa* L., *Mentha spicata* L., *Mentha longifolia* L., *Phyllanthus emblica* L., *Terminalia bellirica* (Gaertn) Roxb., *Tinospora sinensis* (Lour.) Merr. and *Vitex negundo* L. are the most commonly used ethno-medicinal plants. *Ajuga integrifolia* Buch.-Ham. ex D.Don. is found to cure some chronic skin ailments. A popularly known ethnomedicinal herb *Centella asiatica* (L.) is becoming rare due to its overexploitation and need to be conserved.

Keywords: nomadic tribe, formulations, extinction, conservation.

VALUE-ADDED NANOCELLULOSE VALORIZED FROM FRUIT PEEL WASTE FOR POTENTIAL DERMAL WOUND HEALING AND TISSUE REGENERATIVE APPLICATIONS

R. Thiruchelvi
Research Scholar, Biotechnology, St. Joseph's College of Engineering, Chennai, India.
ORCID NO: 0000-0001-5532-8597

Dr. P. Saravanan
Head & Associate Professor, Chemistry, St. Joseph's College of Engineering, Chennai, India.

Dr. M. Chamundeeswari
Associate Professor, Biotechnology, St. Joseph's College of Engineering, Chennai, India.

Abstract

Purpose: Postharvest fruit and vegetable waste is a rich source of cellulose, carbohydrates, flavors, colorants, minerals, and antioxidants. Discarded fruit peels, in particular, have been extensively studied for cellulose isolation. As the primary structural polysaccharide in plant cell walls, cellulose is a naturally abundant and renewable polymer, continuously replenished through photosynthesis and readily available in horticultural waste.

Methods: This review provides a comprehensive assessment of cellulose extraction and characterization using various analytical techniques. Additionally, it explores the potential pharmaceutical applications of cellulosic biomass derived from different sources.

Results: Fruit peels consist mainly of pectin, cellulose, hemicellulose, and trace lignin. Studies confirm their high cellulose content, making them a promising source of polysaccharides due to their abundance of sucrose, glucose, and fructose. Nano-crystalline cellulose has been successfully extracted from biomass and waste-derived cellulosic materials. The review discusses cellulose valorization from fruit peels, its medical applications, and its role in drug delivery systems, alongside methods of isolation, characterization, biocompatibility, and biodegradability. Innovative technologies must integrate with renewable resources to develop next-generation sustainable materials.

Conclusion: Cellulosic biomass holds significant potential in biomedical applications, including drug delivery, wound healing, and tissue engineering scaffolds. Furthermore, cellulose-based biomaterials show promise in 3D bioprinting for prototyping tissues and organs. These insights may inspire further research into advanced biomedical and industrial applications.

Lay Summary: Fruit processing and post-harvest waste pose global challenges in waste management, environmental pollution, and public health. However, this waste also serves as a valuable source of bioproducts and renewable energy. Over the past two decades, researchers have explored methods to repurpose biomass waste into high-value bioproducts. This review examines cellulosic biomass, focusing on nanocellulose production from various waste sources and its potential applications in dermatology and beyond. Cellulose, the most abundant biodegradable polymer in nature, is widely used across industries. Recent advancements highlight the potential of post-harvest fruit and vegetable waste as a sustainable resource for cellulosic biorefineries and food-sector innovations.

Keywords: Cellulose, Fruit peel waste, Biomedical applications, Nanocrystalline cellulose, Drug delivery, Biodegradability

COMPARATIVE ANALYSIS OF METHANOL EXTRACTS FROM *JUNIPERUS OXYCEDRUS* ACROSS ELEVEN MOROCCAN POPULATIONS

Neg Imane

Bouda Said

Zaggoumi Hasna

Mardoume Ibtissam

Haddioui Abdelmajid

Laboratory of Agro-industrial and Medical Biotechnologies, Faculty of Sciences and Techniques, Sultan Moulay Slimane University, Beni Mellal, Morocco

Abstract

Juniperus oxycedrus subsp *oxycedrus* is a versatile medicinal plant with well-documented antimicrobial, antioxidant, anti-inflammatory, antidiabetic, and dermatological benefits. Its essential oil (cade oil) and extracts are used in both traditional and modern medicine, particularly for skin conditions, digestive disorders, and as a natural detoxifier. Ongoing research continues to validate and expand its therapeutic applications. The aim of this study is to investigate the total phenolic, flavonoid contents and condensed tannins, the in vitro antioxidant activity. The eleven extracts were prepared from the twigs of the plant using maceration extraction for methanolic extracts. The antioxidant capacity of twigs extracts was measured through DPPH, ABTS. The total phenolic and flavonoid content were determined by the Folin Ciocalteu and aluminum chloride methods respectively.

ANOVA results indicated statistically significant differences ($p < 0.05$) in bioactive compound levels and antioxidant activity among the studied populations. Population Azilal demonstrated the highest concentrations of polyphenols (22.13 ± 0.032 mg GAE/g dw) and tannins (0.184 ± 0.042 mg CE/g dw) along with the strongest antioxidant activity, as evidenced by DPPH (IC_{50} = 0.072 ± 0.032 mg/mL) and ABTS (IC_{50} = 0.160 ± 0.059 mg/mL) assays. While he Ouaouizeghet population exhibited the highest total flavonoid content (3.399±0.008) RE/g. In contrast, Population Chefchaouen recorded the lowest values for these parameters: polyphenols (5.912 ± 0.005 mg GAE/g dw), flavonoids (0.723 mg RE/g dw; standard deviation not reported), tannins (0.051 mg CE/g dw), and antioxidant activity (DPPH IC_{50} = 0.301 ± 0.05 mg/mL; ABTS IC_{50} = 0.289 ± 0.071 mg/mL).

Keywords: antioxidant activity, population, methanolic extracts, polyphenol, flavonoid, tannin.

IN VITRO ANTIOXIDANT AND ANTIBACTERIAL ACTIVITY OF TWIGS EXTRACTS OF *JUNIPERUS OXYCEDRUS* SUBSP *OXYCEDRUS* FROM MOROCCO

Neg Imane

Bouda Said

Zaggoumi Hasna

Mardoume Ibtissam

Haddioui Abdelmajid

Laboratory of Agro-industrial and Medical Biotechnologies, Faculty of Sciences and Techniques, Sultan Moulay Slimane University, Beni Mellal, Morocco

Abstract

The genus *Juniperus (*Family Cupressaceae) includes various aromatic and medicinal species that are largely used as valuable ingredient for food, cosmetics and pharmaceutical industries. Among these Juniperus species, *J. oxycedrus L*, *J. communis L*, *J. phoenicea L* and *J. thurifera L* are of great economic importance due to their richness in essential oils and extract, that are traditionally exploited in Mediterranean regions to treat various infectious diseases. The present work aimed to compare, for the first time, the antimicrobial potency of *Juniperus oxycedrus* twigs extracts against some pathogenic microorganisms. Antimicrobial activity was investigated against Gram-positive bacteria (*Bacillus subtilis* (OP861484), *Staphylococcus Aureus* (ATTCC25923)), Gram-negative bacteria (*E. coli* (ATCC25922) and *Pseudomonas Aeruginosa* (ATCC9721)) Using methods like agar well diffusion and broth microdilution, the minimum inhibitory concentrations (MIC) and minimum bactericidal concentrations (MBC) were determined. The antioxidant activity was determined by the radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) and radical-scavenging assay (ABTS). *Juniperus oxycedrus* subsp. *oxycedrus* extracts showed moderate to good inhibitory activity against Gram-positive bacteria and Gram-negative bacteria. While all tested populations of *Juniperus oxycedrus* L. subsp. *oxycedrus* twigs exhibited significantly high antioxidant capacity, the highest and lowest of free radical scavenging activity (DPPH and ABTS tests) of *Juniperus oxycedrus* L. subsp. *oxycedrus* twigs extracts were detected in Azilal population and Chefchaouen population (0.072± 0.032 mg/ml, 0.301±0.05 mg/ml and 0.160 ± 0.059mg/ml ,0.289 ±0.071 mg/ml, respectively). This work confirms that the *Juniperus oxycedrus subsp oxycedrus* extract was shown to contain a remarkable amount of different secondary metabolites, thus confirming their involvement in several biological activities.

Keywords: *Juniperus oxycedrus* subsp *oxycedrus*, methanolic extract, antioxidant activity, antimicrobial activity.

IMPROVING TOMATO TOLERANCE TO INDUSTRIAL WASTEWATER THROUGH FOLIAR IRON-LYSINE CHELATE SUPPLEMENTATION

Naila Hadayat

Department of Botany, Division of Science and Technology, University of Education, Lahore, Pakistan

Ayesha Ramzan

Department of Botany, Division of Science and Technology, University of Education, Lahore, Pakistan

Syed Mohsan Raza Shah

Department of Botany, Division of Science and Technology, University of Education, Lahore, Pakistan

ABSTRACT

Due to freshwater scarcity, textile industry wastewater—often containing hazardous chemicals and heavy metals—is commonly used for irrigation, posing risks to crop health and food safety. This study evaluated the potential of foliar-applied iron-lysine (Fe-lys) chelate to mitigate the adverse effects of textile wastewater on tomato growth. A pot experiment was conducted using eighteen treatments: six levels of textile wastewater (0, 20, 40, 60, 80, and 100%) and two concentrations of Fe-lys (10 and 20 mg/L), applied individually and in combination, following a completely randomized design with three replicates each. Results showed that increasing wastewater concentrations significantly reduced growth (shoot/root length, biomass, number of leaves), biochemical attributes (photosynthetic pigments, soluble proteins, sugars), and yield (fruit number and weight), while increasing oxidative stress markers (H_2O_2, MDA), antioxidant enzyme activity (SOD, CAT, POD), ascorbic acid, and heavy metal accumulation (Cd, Cr). Foliar application of Fe-lys, alone and in combination with wastewater, improved all measured growth, physiological, and yield parameters, and reduced oxidative damage and metal uptake. These findings highlight the potential of Fe-lys chelate in alleviating wastewater-induced stress in tomato, though further research is warranted to assess its long-term effects on soil health, crop quality, and integration with other nutrient management strategies.

Keywords: Tomato, Textile wastewater, Heavy metals, Oxidative stress, Antioxidant enzymes, Phytotoxicity mitigation

DIGITAL TRANSFORMATION IN AGRICULTURE: IOT AND MACHINE LEARNING FOR SMART CROP MONITORING IN MOROCCO'S GHARB PLAIN

Fathalah Elwahab

University Ibn Toufail, Faculty of Sciences, Laboratory of Plant, Animal, and Agro- Industry Productions, B.P. 242, 14000Kenitra, Morocco

Mohamed Sedki

Regional Center of Agricultural Research of Kenitra, B.P. 257, 14000 Kenitra, Morocco

Chetto Abdelaziz

Regional Center of Agricultural Research of Kenitra, B.P. 257, 14000 Kenitra, Morocco

Sana El Moutaouakil

Laboratory of Natural Resources and Sustainable Development, Department of Biology, Faculty of Sciences, Ibn Tofail University, BP 133, Kenitra 14000, Morocco

NajibaBrhadda

University Ibn Toufail, Faculty of Sciences, Laboratory of Plant, Animal, and Agro- Industry Productions, B.P. 242, 14000Kenitra, Morocco

Rabea Ziri

University Ibn Toufail, Faculty of Sciences, Laboratory of Plant, Animal, and Agro- Industry Productions, B.P. 242, 14000Kenitra, Morocco

Abstract

The increasing challenges posed by climate change, water scarcity, and the need for sustainable food production have accelerated the adoption of digital technologies in agriculture. This study explores the integration of Internet of Things (IoT) devices and Machine Learning (ML) algorithms for real-time crop monitoring and decision-making in the context of precision agriculture. Focusing on the Gharb Plain, one of Morocco's most productive agricultural regions, the research presents a case study demonstrating how digital tools can enhance crop health monitoring, irrigation management, and yield prediction.

A smart monitoring system was deployed using soil moisture sensors, temperature and humidity sensors, and wireless communication protocols (LoRaWAN) to collect field data continuously. This data was processed using edge-computing techniques and analyzed through supervised ML models to detect anomalies, optimize irrigation scheduling, and predict crop performance.

The results show that the IoT-ML integrated system significantly improves resource use efficiency, reduces manual monitoring efforts, and enables timely agricultural interventions. This approach not only supports sustainable agricultural practices but also provides a scalable model for other regions facing similar agro-climatic challenges.

This work highlights the potential of digital transformation in empowering Moroccan farmers through data-driven agriculture and contributes to national efforts toward climate-resilient farming systems.

Keywords: Internet of Things (IoT); Machine Learning (ML); Precision Agriculture; Smart monitoring; Crop Monitoring, Gharb Plain; Morocco

ENDOPHYTES AS AN ALTERNATIVE IN MANY FIELDS

Hicham EL-BOUKHARY

Biotechnology and Sustainable Development of Natural Resources Unit, Polydisciplinary Faculty of Beni Mellal, Sultan Moulay Slimane University, Beni Mellal, Morocco.

Hamza ELKISSANY

Laboratory of Biotechnology, Environment, Agri-food and Health, Faculty of Sciences Dhar El Mahraz, Sidi Mohamed Ben Abdellah University, Fez, Morocco.

Adil LAAZIZ

Laboratory of Biotechnology, Environment, Agri-food and Health, Faculty of Sciences Dhar El Mahraz, Sidi Mohamed Ben Abdellah University, Fez, Morocco.

Abdelouahed HAJJAJI

Biotechnology and Sustainable Development of Natural Resources Unit, Polydisciplinary Faculty of Beni Mellal, Sultan Moulay Slimane University, Beni Mellal, Morocco.

Abstract

Endophytes—microorganisms that live symbiotically within plant tissues—are gaining significant attention as sustainable alternatives in multiple domains. Their ability to produce bioactive metabolites has positioned them as promising agents in pharmaceuticals, where they exhibit antimicrobial, antioxidant, anticancer, and anti-inflammatory properties. In agriculture, endophytes contribute to plant growth promotion, stress tolerance, and biological control, reducing reliance on chemical fertilizers and pesticides. Additionally, they show potential in bioremediation, food preservation, and enzyme production for industrial applications. The adaptability and diverse metabolic capabilities of endophytes make them powerful tools for addressing global challenges, including climate change, food security, and antimicrobial resistance. Exploring and harnessing endophyte diversity offers a novel path toward eco-friendly and economically viable solutions across biotechnology, agriculture, medicine, and environmental sciences.

Keywords: Endophytes, bioactive compounds, sustainable agriculture, pharmaceuticals, biocontrol, plant-microbe interaction.

RISK ASSESSMENT ON DISEASE TRANSMISSION AND STUDIES IDENTIFYING BACTERIA THROUGH CONTAMINATION ON BANGLADESH CURRENCY INCLUDING *ESCHERICHIA COLI, KLEBSIELLA* SPP., *SALMONELLA* SPP., *SHIGELLA* SPP., *STAPHYLOCOCCUS AUREUS*

MD. SELIM ALI

University of Rajshahi, Faculty of Agriculture, Department of Microbiology, Bangladesh,

ORCID: 0009-0000-3560-8938

ABSTRACT

In Bangladesh, handling of paper currency notes could transmit bacteria. Paper currency notes in Bangladesh serve as a potential reservoir and transmission vehicle of pathogenic bacteria. Recent studies about the prevalence, bacterial diversity, and public health risks due to contaminated Bangladeshi currencies are reviewed here. Notes of various denominations and some from occupational sources were analysed. This revealed a contamination rate of about 90%, with more than one bacterium being present. Most prevalent were *Escherichia coli*, *Klebsiella* spp., *Salmonella* spp, *Shigella* spp, and *Staphylococcus aureus*. Lower denomination notes and those obtained from the informal sector, such as hawkers, fishmongers, vegetable sellers and food vendors, exhibited significantly higher levels of contamination. The results of antibiotic resistance tests showed that a lot of the tested isolates were resistant to common antibiotics like ampicillin and penicillin. I have conducted a number of biological tests, such as culture-based testing, staining and microscopy tests, biochemical tests, and tests for antibiotic sensitivity. Studies show that dirty money can carry diseases. However, the risk gets worse in places where hygiene and sanitation aren't up to the mark. Bangladesh must have better hand washing, increasing awareness, and decontaminating the currency in order to reduce the transmission of microbes. This summary brings together important results and consequences for public health from research work on bacterial contamination and risk of transmitting pathogens on Bangladeshi currency.

Keyword: Disease Transmission, Escherichia coli, Biological tests, Pathogens

EFFECT OF DIFFERENT CONCENTRATION OF NEEM OIL ON INSECT PESTS OF OKRA (*ABELMOSCHUS ESCULENTUS* L. MOENCH) IN MINNA, NIGER STATE

Oyewale, R. O.

Department of Crop Production, Federal University of Technology, Minna, Niger State, Nigeria

Afolabi, H. O.

Department of Crop Production, Federal University of Technology, Minna, Niger State, Nigeria

Babawo, S. J.

Standard Organization of Nigeria

Ibrahim, H. M.

Department OF Horticulture, Federal University of Technology, Minna, Niger State, Nigeria

Olaniyi, R. M.

Department of Crop Production, Federal University of Technology, Minna, Niger State, Nigeria

ABSTRACT

The research was conducted to evaluate the effect of neem oil on the management of insect pests of okra, in the Teaching and research Farm of the Department of Crop Production, Federal University of Technology Minna, Niger State. Different concentrations of Neem oil; 75 ml, 50 ml, 25 ml and 0 ml were used to control the infestation of insect pests for four weeks on Clemson Spineless okra variety. Data on plant height, stem diameter, leaf length, pest population, number of flowers, number of fruits and fruit weight were subjected to analysis of variance (ANOVA) the means were separated using least significance difference (LSD). The result indicated that neem oil at 75 ml showed the highest level of effectiveness in the plant yield and morphological performance while 50 ml performed better on pest population hence the results of this study suggests that neem oil can be used as an alternative to chemical pesticides for managing insect pests of okra inMinna

Keywords: Neem oil, okra, insect pests, Treatment

STUDY OF THE ANTIOXIDANT ACTIVITY AND PHENOLIC COMPOUNDS OF ORANGES PROCESSED USING DIFFERENT DRYING METHODS

Yağmur DEMIREL OZBEK
Recep Tayyip Erdoğan University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Rize, Turkey
ORCID ID: https://orcid.org/0000-0003-3877-3183

Özlem SARAL
Recep Tayyip Erdoğan University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Rize, Turkey
ORCID ID: https://orcid.org/0000-0002-5283-7000

Emine KOCYIGIT
Ordu University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Ordu, Turkey
ORCID ID: https://orcid.org/0000-0002-9459-9557

ABSTRACT

Introduction and Purpose: An orange, which belongs to the citrus family, is a fruit with a distinctive taste and aroma. Rich in phenolics, oranges are consumed both fresh and dried. Drying aims to extend the shelf life of oranges by removing water to prevent spoilage. The objective of this study is to investigate the effect of four different drying methods applied to orange slices on total phenolic content (TPC), antioxidant activity, and phenolic compound content.

Materials and Methods: This study compares four different drying methods applied to oranges: shade-drying, sun-drying, airfryer-drying (40 °C) and oven-drying (80 °C). TPC content of the dried samples was determined using the Folin-Ciocalteu method, while antioxidant activity was assessed using ferric reducing antioxidant power. The phenolic compound content of the samples was analysed using HPLC.

Results: When the total phenolic compound content of the samples was examined, the highest TPC content was found in the samples dried in the shade and sun (1.891±0.02 and 1.670±0.04 mg GAE/g, respectively); the lowest TPC content was found in oven-dried samples (0.515±0.19 mg GAE/g). Similarly, the antioxidant activities of the samples were found to be, in order, shade-drying=sun-drying>airfryer-drying>oven-drying ($p<0.05$). When the phenolic compound content was examined, gallic acid (6.88, 2.56, 8.23 and 2.05 µg/ml, respectively), epicatechin (47.19, 46.19, 34.81 and 45.29 µg/ml, respectively), quercetin (5.42, 9.75, 6.16 and 7.19 µg/ml), and kaempferol (5.44, 5.69, 8.64 and 3.26 µg/ml, respectively) were detected.

Discussion and Conclusion: It has been determined that an increase in the heat applied during drying reduces the TPC content and antioxidant activity. Exposure to heat during thermal processing may have caused a significant decrease in TPC content and antioxidant activity by disrupting the structure of phenolic compounds. As a result, it was concluded that the most suitable drying methods for oranges in terms of antioxidant activity and phenolic compounds are those with the least heat exposure.

Key Words: Drying, Orange, Antioxidant Activity, Phenolic Compounds

IN SILICO COMPUTATIONAL ASSESSMENT OF ALLERGENICITY AND TOXICITY OF EMERGING PLANT AND SEAWEED PROTEINS

Mehmet ÖZBİL

Gebze Technical University, Biotechnology Institute, Kocaeli, Türkiye

ORCID ID: https://orcid.org/0000-0002-1465-7674

İsmail Hakkı TEKİNER

Indpendent Researcher, Istanbul, Türkiye

ORCID ID: https://orcid.org/0000-0002-7248-2446

Sinem Nur AÇIKGÖZ

Gebze Technical University, Biotechnology Institute, Kocaeli, Türkiye

ORCID ID: https://orcid.org/0009-0006-3256-7388

Pınar OBAKAN YERLİKAYA

Istanbul Medeniyet University, Faculty of Engineering and Natural Sciences, Molecular Biology and Genetics Department, Istanbul, Türkiye

ORCID ID: https://orcid.org/0000-0001-7058-955X

Leila MEHDIZADEHTAPEH

Recep Tayyip Erdoğan University, Faculty of Health Sciences, Nutrition and Dietetics Department, Rize, Türkiye

ORCID ID: https://orcid.org/0000-0001-8759-5016

ABSTRACT

Introduction and Purpose: The IPSUS project aims to assess the food safety risks of the emerging plant-based protein sources for developing meat and dairy analogues. The current work aimed to examine *in silico* computational assessment of allergenicity and toxicity risks of brewers' spent grain, grapes, hazelnut, potato, pumpkin, and seaweed in line with the key objectives of the EU 2015 NFR and European Food Safety Authority (EFSA).

Materials and Methods: The bioinformatical and computational approach utilizing various types of analysis and programs was planned to decrease the workload of *in vivo* animal experiments. A total of 24 allergens in the brewers' spent grain, grapes, hazelnuts, potatoes, pumpkins, and seaweed were retrieved from the WHO/IUIS Allergen Nomenclature Sub-Committee Database. Among these, 19 were initially subjected to molecular docking simulations in the Hdock server to determine their chemical affinity scores with IgE, an antibody responsible for allergenic immune response. Subsequently, the ToxinPred server was used to calculate the toxicity of proteins at three different threshold values, followed by the Expasy Peptide Cutter server to determine the pepsin and trypsin cut points. Toxicity was then estimated using ABCPred to predict possible IgE epitopes. The accuracy and sensitivity of this method were tested by calculating the confusion matrix, accuracy, precision, recall and F1 score.

Results: *In silico* analyses for allergenicity revealed that *Cuc ma* 4 in pumpkin was the best IgE-binder with a binding score of -327.4, whereas *Cor a* 8 in hazelnut was the worst IgE-binder, with a binding score of -160.5. However, combined with sequence-based allergenicity prediction performed with the ALgPred server, all proteins revealed low to high allergenicity. *In silico* toxicity prediction of the proteins, performed in the ToxinPred server, indicated that the most probable toxic proteins were *Cuc ma 5* in pumpkin, *Cor a 8* in hazelnuts, *Hor v 15* in barley, and *Vit v 1* in grapes. We concluded that computational allergenicity and toxicity predictions with many tools and techniques needed to be tested with *in vivo* and *in vitro* experimental data to prove their acceptance in food safety risk assessments of alternative protein-rich plants and seaweed for novel food and ingredient applications.

Key Words: *In silico*; Food Safety; Allergenicity; Toxicity; Plant Protein; Seaweed Protein

Acknowledgements:

1. The IPSUS "Climate smart food innovation using plant and seaweed proteins from upcycled sources" project is supported by ERA-Nets SUSFOOD2 and FOSC.
2. This work is supported by TÜBİTAK 1071-Support Programme for Increasing Capacity to Benefit from International Research Funds and Participation in International R&D Cooperation [Grant number: 122N018].

SOIL HEALTH ASSESSMENTS FOR FRUIT CROPS

Ayşe Nilgün ATAY

Burdur Mehmet Akif Ersoy University, Food Agriculture and Livestock School, Department of Crop and Livestock Production, Horticulture Program, Burdur, Türkiye

ORCID ID: https://orcid.org/0000-0002-7557-360X

ABSTRACT

Introduction and Purpose: There remain significant knowledge gaps regarding the relationship between soil health, productivity, and environmental outcomes in the fruit sector. Addressing these gaps is critical to ensuring the long-term sustainability of fruit production. This study aims to highlight the current soil health challenges in orchards across Türkiye and to suggest pathways for improvement.

Materials and Methods: This study was based on long-term field observations and expert evaluations from different regions of Turkey. Key soil constraints and widely recommended management practices were identified, synthesized, and assessed in relation to fruit production systems.

Results: The most common soil-related issues faced by Turkish fruit growers include low organic matter content, high pH, nutrient imbalances, compaction, soil-borne pests and pathogens, erosion, salinity, excess sodium, and declining soil biodiversity. Traditional agricultural practices and the impacts of climate change further exacerbate these challenges. The degradation caused by poor soil health in orchards is becoming increasingly severe and can no longer be overlooked. Managing soil health is one of the most effective strategies to improve both the sustainability of orchards and broader environmental outcomes. Practices such as crop rotation, cover cropping, reduced or no tillage, mowing, mulching, nutrient management, and integrated pest management have been widely adopted to enhance soil health globally. These core practices form the foundation of soil health management systems. However, it's important to recognize that not all practices are suitable for all crops or regions. Some growers may benefit from a single approach, while others may need to implement multiple strategies to achieve the desired outcomes. **Discussion and Conclusion:** Soil health is a vital component of a successful orchard system. By focusing on soil biology and the physical as well as chemical properties of soil, fruit growers can build more resilient and productive orchard ecosystems. A comprehensive understanding of soil health enables more informed management decisions.

Key Words: Mediterranean Orchards; Soil Constraints; Sustainability; Soil Management; Tree Fruit Production

EVALUATION OF AI-GENERATED DIET PLANS ACROSS DIVERSE CLIENT PROFILES: A MULTI-CRITERIA DECISION-MAKING APPROACH

Adem ERİK

Tarsus University, Faculty of Engineering, Department of Industrial Engineering, Mersin, Türkiye

ORCID ID: https://orcid.org/0000-0001-6840-0586

Sakhi Mohammad HAMIDY

İstanbul Arel University, Faculty of Engineering, Department of Industrial Engineering, Istanbul, Türkiye

ORCID ID: https://orcid.org/0000-0002-7389-7352

Hilal KARAMANCIOĞLU

Tarsus University, Faculty of Engineering, Department of Industrial Engineering, Mersin, Türkiye

ORCID ID: https://orcid.org/0005-0009-2020-8698

Büşra Nur KÜÇÜK KIRTIKLI

Toros University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Mersin, Türkiye

ORCID ID: https://orcid.org/0009-0008-2262-059X

ABSTRACT

Introduction and Purpose: The rapid development of artificial intelligence (AI) has introduced new possibilities in health sciences, particularly in the field of nutrition. Among these advancements, AI-generated diet plans are emerging as a practical tool for personalized nutrition support. The present study aims to evaluate diet plans generated by various AI tools for individuals with differing health profiles through a structured multi-criteria decision-making (MCDM) framework.

Materials and Methods: A total of six realistic client profiles were constructed using anonymized clinical data provided by a registered dietitian. Each profile included detailed information on medical history, dietary habits, and lifestyle. For each scenario, standardized prompts were used to generate diet plans from AI platforms such as ChatGPT, Gemini, and DeepSeek. The diet plans were assessed based on a set of main and sub-criteria including nutritional adequacy, personalization, feasibility, ethical compliance, reproducibility, and linguistic clarity. Two MCDM methods—LBWA-COPRAS and PROMETHEE—were employed to perform a comparative analysis of the AI tools and their outputs.

Results: The results showed varying levels of effectiveness among AI tools. Some platforms demonstrated stronger alignment with expert dietitian expectations, while others fell short in personalization or reproducibility. The evaluation revealed that client profile characteristics significantly influenced output quality, and that identical prompts could yield diverse outputs across different AI tools and times of generation.

Discussion and Conclusion: This study highlights the potential of AI tools as supportive systems in dietary planning, but also points out current limitations in consistency and medical reliability. It emphasizes the need for oversight by qualified professionals and further refinement of AI-generated recommendations to meet ethical and practical standards in healthcare services.

Key Words: Nutrition; Artificial Intelligence Tools; Multi-Criteria Decision Making; Diet Plan; Client Profile

FROM WILD TO CULTIVATED: DOMESTICATION BOOSTS ESSENTIAL OIL QUALITY AND ANTIMICROBIAL POWER IN MOROCCAN THYMUS

Aabdousse Jamal
Higher School of Technology Fkih Ben Salah, Sultan Moulay Slimane University, Tighnari District, National Route N° 11 from Casablanca, Fkih Ben Salah, PB. 336, Morocco

Boulli Abdelali
Environmental, Ecological and Agro-industrial Engineering Laboratory, Department of Life Sciences, Faculty of Sciences and Techniques, Sulatn Moulay Slimane University Beni Mellal, BP 523, 23000 Beni Mellal, Morocco. ORCID: 0000-0002-9385-3429

Wahid Nadya
Environmental, Ecological and Agro-industrial Engineering Laboratory, Department of Life Sciences, Faculty of Sciences and Techniques, Sulatn Moulay Slimane University Beni Mellal, BP 523, 23000 Beni Mellal, Morocco. ORCID: 0000-0002-9385-3429

Oussif Ilis
Environmental, Ecological and Agro-industrial Engineering Laboratory, Department of Life Sciences, Faculty of Sciences and Techniques, Sulatn Moulay Slimane University Beni Mellal, BP 523, 23000 Beni Mellal, Morocco. ORCID: 0000-0002-9385-3429

Salim Nora
Environmental, Ecological and Agro-industrial Engineering Laboratory, Department of Life Sciences, Faculty of Sciences and Techniques, Sulatn Moulay Slimane University Beni Mellal, BP 523, 23000 Beni Mellal, Morocco. ORCID: 0000-0002-9385-3429

Abstract

Thymus is an aromatic and medicinal plant with remarkable endemism in North Africa and the Iberian Peninsula. This includes *Thymus maroccanus* Ball, a subspecies endemic to Morocco, and *Thymus zygis* L. subsp. *gracilis*, which is endemic to both Morocco and the Iberian Peninsula. The plant has been highly valued for generations due to its wide range of uses particularly in traditional medicine, as a flavoring agent in food, and for its essential oils with antiseptic and disinfectant properties. However, its popularity has led to intensive harvesting, making the species increasingly vulnerable.

In order to overcome the imbalance between the demand and supply of this species particularly regarding its essential oils, we conducted a study on the impact of domestication on its quantitative, qualitative, and biological properties. The qualitative analysis of the plant's essential oils using gas chromatography coupled with mass spectrometry (GC-MS) revealed a high content of bioactive compounds, including Carvacrol (1.69–66.77%), Thymol (0.48–34.92%), o-Cymene (5.44–24.98%), and γ-Terpinene (8.66–19.21%). Furthermore, aromatogram assays indicated that the essential oils extracted from cultivated *Thymus* species exhibited stronger antibacterial activity than those from wild populations. These findings demonstrate that domestication significantly influences the yield and chemical composition of *Thymus* essential oils, as well as enhances their antibacterial efficacy against certain pathogenic bacteria.

Key words: *Thymus*, Domestication, essential oil, yield, chemical composition, antibacterial activity, Morocco.

ANALGESIC EFFECTS OF AQUEOUS LEAF EXTRACT OF MERCURIALIS ANNUA IN MICE

Abdeljalil ELMAHDAOUİ
University Cadi Ayyad, Faculty of Sciences, Semlalia, Department of Biology, Marrakech, Morocco

Lansine DİAKİTÉ
University Cadi Ayyad, Faculty of Sciences, Semlalia, Department of Biology, Marrakech, Morocco

Azız AUHMAN
University Cadi Ayyad, Faculty of Sciences, Semlalia, Department of Chemestry, Marrakech, Morocco
Laboratory of Pharmacology, Neurobiology, Anthropology and Environment, Department of Biology, Faculty of Sciences, Semlalia, University Cadi Ayyad, 40000 Marrakech, Morocco.

Zahra SOKAR
University Cadi Ayyad, Faculty of Sciences, Semlalia, Department of Biology, Marrakech, Morocco

ABSTRACT

Pain is devastating conditions that characterize several diseases. Corticosteroids, non-steroidal anti-inflammatory drugs and opioids are widely used to manage the symptoms associated with pain. Notwithstanding their success, these agents are unaffordable and cause many undesirable side-effects. As a result, the search for alternative and complementary treatments is justified. Medicinal and aromatic plants have been widely used to treat a variety of illnesses. *Mercurialis* species are used in Moroccan and European ethnomedicine to treat conditions associated with inflammation, such as purulent wounds, eczema, abscesses and lung diseases, but also as a laxative and to treat menstrual disorders. In addition, there is insufficient scientific data on toxicity of Moroccan *Mercurialis anuua* used by herbalists and practitioners. In this context, the acute oral toxicity of the aqueous extract of *Mercurialis anuua* in Swiss mice was assessed in accordance with OECDE guidelines. Analgesic activity was examined using the hot plate and acetic acid-induced writhing test in mice. The results indicated that the extract examined had LD 50 values > 5000 mg/kg and was thus assessed as non-toxic according to OECD document 425. The results of the hot plate test showed that the various doses studied, and particularly at 800 mg/kg, caused a significant increase in latency time similar to Morphine (10 mg/kg) compared with the control. On the other hand, the extract at dose of 400 and 800 mg/kg and mg/kg showed significant inhibition of number of writhes induced by acetic acid and comparable to that shown by the reference drug (acetylsalicylic acid). As a result, the aqueous leaf extract of *Mercuriallis annua* possess analgesic in Swiss albino mice. It therefore has the potential to offer safe analgesic and anti-inflammatory compounds. Further studies to isolate, elucidate and characterize the bioactive components responsible for these activities are recommended.

Keywords: *Pain; Acute toxicity; Mercuriallis annua; Hot plate test*

ADDRESSING NIGERIA'S ECONOMIC CHALLENGES: THE NEED FOR AGRICULTURAL ENTREPRENEURSHIP LITERACY IN THE NIGERIAN TETIARY EDUCATIONAL INSTITUTIONS

Agwu, Ani Ekwe

Department of Animal Health and Production Technology, Federal Polytechnic Ngodo-Isuochi, Abia state, Nigeria.

Onuoha, Ikedieze Arisa

Department of Business Administration and Management, Federal Polytechnic Ngodo-Isuochi, Abia state, Nigeria.

ABSTRACT

Nigeria, a country heavily reliant on oil and gas for its economic survival, faces significant socio-economic challenges, more importantly, as global oil prices remain volatile, and the continual dwindling in oil and gas income. This economic vulnerability underscores the urgent need for diversification, with agriculture adjudged as a critical sector capable of driving national economic growth and food sustainability. As the world scrambles to achieve food security, and with millions in Nigeria currently battling hunger and chronic poverty, agricultural entrepreneurship offers an enduring platform for achieving sustainable agricultural practices, food security, employment creation, and improved living standards, hence the need for government to rejig her policies to achieve food sustainability through craft and vocational agricultural literacy programmes. This paper, therefore, argues that the introduction of agricultural entrepreneurship as a special and compulsory general course in the Nigerian Universities, Polytechnics, and Colleges of Education will help to cultivate the zeal for agripreneurship amongst our teaming youths, provide needed skills required for improved agricultural practices, brood innovation, attain food security, and check unemployment. Data were sourced from secondary sources in order to discover the place of agricultural entrepreneurship in addressing Nigeria’s socio-economic challenges. Empirical evidences were also used to ascertain the effect of agripreneurship on food security, poverty alleviation, and employment generation. Findings reveal that introducing agricultural entrepreneurship as a compulsory general course in the Nigerian tertiary institutions will positively affect overall economic growth and food security. It is recommended that embedding agricultural entrepreneurship study into the broader curriculum will assist tertiary institutions contribute significantly to addressing Nigeria's food and economic challenges.

Keywords**: Agricultural Literacy**, Agricultural Entrepreneurship, Agripreneurship, Economic Diversification**,** and Food Security.

AGRICULTURAL MARKETS IN INDIA: EMERGING TRENDS AND CHALLENGES

Arijmand Shahid Tramboo

Research Scholar, Institute of Business & Policy Research, SKUAST-K, India.

Dr. Omar Fayaz Khan

Assistant Professor, Institute of Business & Policy Research, SKUAST-K, India.

Dr. Kusumakar Gautam

Assistant Professor, Institute of Business & Policy Research, SKUAST-K, India.

Dr. Ubair Nisar

Assistant Professor, Institute of Business & Policy Research, SKUAST-K, India.

Abstract. Agriculture, a cornerstone of human civilization, has undergone profound changes throughout history, shaping economies, societies, and the environment. In addition to its essential role in nourishing the world's population, agriculture has been instrumental in driving the economic development of countries. While global demand for agricultural products is rising rapidly, agricultural supply is struggling to meet this increasing demand. The study of agricultural market trends is essential for understanding how shifts in demand, technology, and environmental factors are influencing food production and distribution, so that sustainable food systems. The study focuses on key agricultural market trends, with a special emphasis on India, including the rising demand for organic and sustainably produced products, the adoption of advanced technologies, and the drive for more efficient supply chains to uphold the four pillars of food security: availability, accessibility, utilization, and stability. However, these trends are accompanied by several challenges. The study also examines major obstacles such as climate change, the high costs of new technologies, and the complexities introduced by trade policies, market fluctuations, and land-use changes. By analysing these trends and challenges, the study aims to contribute to strategies that ensure food security and economic stability in the agricultural sector.

Keywords: Agriculture, Market, Trends & Challenges

MICROBIOTA-TARGETED APPROACHES IN PARKINSON'S DISEASE PATIENTS: THE ROLE OF PROBIOTICS, PREBIOTICS, AND KETOGENIC DIET

PARKINSON HASTALARINDA MIKROBIYOTA-HEDEFLI YAKLAŞIMLAR: PROBIYOTIKLER, PREBIYOTIKLER VE KETOJENIK DIYETIN ROLÜ

Benay TÜFEKÇİ

İstanbul Nişantaşı University Biotechnology Department Istanbul, Turkey

ORCID ID: https://orcid.org/0009-0009-2377-7342

Gülsüm TÜFEKÇİ

İstanbul Arel University, Faculty of Health Science, Department of Nutrition and Dietetics, Istanbul, Türkiye

ORCID ID: https://orcid.org/0000-0001-6188-3642

Osman ERKMEN

İstanbul Arel University, Faculty of Health Science, Department of Nutrition and Dietetics, Istanbul, Türkiye

ORCID ID: https://orcid.org/0000-0001-9113-9638

ABSTRACT

Introduction and Purpose: Parkinson's disease is a progressive neurodegenerative disorder characterized by the abnormal accumulation of alpha-synuclein in the substantia nigra of the basal ganglia, leading to the loss of dopaminergic neurons. Motor symptoms of Parkinson's disease include tremors, muscle rigidity, bradykinesia (slowness of movement), and postural instability. Non-motor symptoms of the disease also frequently include sensory disturbances, sleep problems, gastrointestinal (GI) dysfunction, and autonomic nervous system disorders. Gastrointestinal symptoms such as constipation, nausea, and vomiting are reported in approximately 80% of patients with Parkinson's disease. Parkinson's disease is a complex neurodegenerative disease that is not limited to motor symptoms but affects multiple systems, particularly the gastrointestinal system. In recent years, a growing number of studies have indicated that the gut microbiota may play a crucial role in the pathogenesis, severity of symptoms, and progression of Parkinson's disease. Mechanistic explanations based on the microbiota-brain axis highlight the importance not only of neurological but also of systemic aspects of the disease. In this context, the report addresses the relationship between Parkinson's disease and gut microbiota, the potential of probiotic- and prebiotic-based intervention strategies, and sustainable nutritional models in disease management with a holistic approach. The report aims to evaluate the effects of microbiota-based interventions on both clinical symptoms and public health and environmental sustainability.

Discussion and Conclusion: In recent years, the gut microbiota has been considered an important factor in the pathogenesis of neurological diseases. Microbiota acts through multiple mechanisms, including metabolite production, hormone synthesis, modulation of the immune system, and communication with the central nervous system. Intestinal microflora can regulate the brain-gut axis through immunological, neuroendocrine, and neural pathways. Lipopolysaccharides and proinflammatory cytokines (such as TNF-α, IL-1β, IL-6, and IL-17) produced by pathogenic bacteria that may be present in the microbiota cause local and systemic inflammation. Gut dysbiosis is characterized by bacterial overgrowth and increased intestinal permeability; this can lead to neuroinflammation in the central nervous system due to overactivation of the innate immune system. Furthermore, bacterial proteins can cross-react with human antigens in the immune system and trigger autoimmune responses. Numerous neurotransmitters, such as γ-aminobutyric acid, serotonin, dopamine, and short-chain fatty acids, are produced by gut bacteria. These neurochemical compounds play an important role in the bidirectional communication between the microbiota and the nervous system. Alpha-synucleinopathies lead to impaired communication between neurons in the central nervous system, and the accumulation of these proteins as phosphorylated, insoluble fibrils may be considered the fundamental pathology of neurodegenerative disorders such as Parkinson's disease. Changes in the intestinal microbiota disrupt intestinal barrier function, increasing epithelial permeability, which may contribute to gastrointestinal inflammation and, consequently, alpha-synuclein accumulation via glial cells and enteric neurons. Probiotics are defined as live or inactive microorganisms or biological components that contribute to the regulation of the intestinal microbiota. They have been shown to be effective in alleviating GI symptoms such as constipation, abdominal pain, and bloating seen in Parkinson's disease patients. Prebiotics are dietary fibers that reach the colon undigested and promote the growth of beneficial bacteria. The most commonly used prebiotic sources include soybeans, raw oats, whole wheat, barley, and oligosaccharides. Prebiotics may contribute to enhancing immune function in patients with Parkinson's disease. Consumption of probiotic strains and fermented dairy products containing prebiotic fiber has been reported to be particularly effective in reducing constipation symptoms. Additionally, some studies have reported that oligosaccharides have positive effects on both motor and non-motor symptoms and increase the activity of dopamine transporters in the striatum. The ketogenic diet, used in Parkinson's disease patients, is a high-fat, adequate-protein, and low-carbohydrate eating pattern. This diet encourages the production of ketone bodies (ketogenesis) by limiting glucose utilization, a state defined as nutritional ketosis. The ketogenic diet has been shown to have positive effects on brain function, energy metabolism, and the suppression of neuroinflammation. Microbiota-based nutritional approaches not only contribute to the alleviation of motor and gastrointestinal symptoms associated with Parkinson's disease but also facilitate the development of long-term, sustainable health strategies. The use of plant-based prebiotic fibers and traditional fermented foods, in particular, helps balance the gut microbiota and encourages the use of local, natural resources with a low carbon footprint. These approaches, through their potential to reduce medication use, contribute to both reducing individual healthcare costs and supporting the sustainability of healthcare systems. Furthermore, the adoption of natural dietary patterns, along with the support of ecosystem-friendly production methods, paves the way for the development of an environmentally harmonious lifestyle across society. In this respect, microbiota-focused nutritional interventions can offer a holistic approach that serves both biological and environmental sustainability, particularly in the context of Parkinson's disease.

Keywords: Parkinson hastalığı; Microbiota; Probiotics; Prebiotics; Ketogenic diet

Giriş ve Amaç: Parkinson hastalığı, bazal gangliyonlar içinde substantia nigra bölgesinde anormal alfa-sinüklein birikimi ve buna bağlı olarak dopaminerjik nöronların kaybı ile karakterize edilen progresif bir nörodejeneratif hastalıktır. Parkinson hastalığının motor semptomları arasında titreme, kas sertliği, bradikinezi (hareket yavaşlığı) ve postüral instabilite (duruş bozukluğu) yer almaktadır. Ayrıca, hastalığın motor olmayan semptomları arasında duyusal bozukluklar, uyku problemleri, gastrointestinal (GI) disfonksiyon ve otonom sinir sistemi bozuklukları da sık görülmektedir.

Parkinson hastalarının yaklaşık %80'inde kabızlık, bulantı ve kusma gibi gastrointestinal belirtilmiştir. Parkinson hastalığının yalnızca motor belirtilerle sınırlı kalmayan, gastrointestinal sistem başta olmak üzere çoklu sistemleri etkileyen kompleks bir nörodejeneratif hastalıktır. Son yıllarda giderek artan sayıda çalışma, bağırsak mikrobiyotasının Parkinson hastalığının patogenezi, semptomların şiddeti ve hastalığın ilerleyişi üzerinde belirleyici rol oynayabileceğini göstermektedir. Mikrobiyota-beyin ekseni üzerinden yürütülen mekanistik açıklamalar, hastalığın yalnızca nörolojik değil, sistemik yönlerinın da önemini belirtmektedir. Bu bağlamda, bildiride Parkinson hastalığı ile bağırsak mikrobiyotası arasındaki ilişki, probiyotik ve prebiyotik temelli müdahale stratejileri ve sürdürülebilir beslenme modellerinin hastalık yönetimindeki potansiyeli bütüncül bir yaklaşımla ele alınmıştır. Bildiride, mikrobiyota temelli müdahalelerin hem klinik semptomlar hem de toplum sağlığı ve çevresel sürdürülebilirlik üzerindeki etkilerini değerlendirilmesi amaçlanmıştır.

Tartışma ve Sonuç: Bağırsak mikrobiyotası, son yıllarda nörolojik hastalıkların patogenezinde önemli bir faktör olarak değerlendirilmiştir. Mikrobiyota, metabolit üretimi, hormon sentezi, bağışıklık sisteminin modülasyonu ve merkezi sinir sistemi ile iletişim gibi birçok mekanizma yoluyla etkili olur. Bağırsak mikroflorası, immünolojik, nöroendokrin ve nöral yollar aracılığıyla beyin-bağırsak aksını düzenleyebilmektedir. Mikrobiyotada yer alabilecek patojenik bakterilerin ürettiği lipopolisakkaritler ve proenflamatuar sitokinler (TNF-α, IL-1β, IL-6 ve IL-17 gibi), lokal ve sistemik enflamasyona neden olmaktadır. Bağırsak disbiyozisi, aşırı bakteri çoğalması ve artmış bağırsak geçirgenliği ile karakterizedir; bu durum doğuştan gelen bağışıklık sisteminin aşırı aktivasyonu sonucunda merkezi sinir sisteminde nöroenflamasyona yol açabilir Ayrıca, bakteriyel proteinler, bağışıklık sisteminde insan antijenleriyle çapraz reaksiyonlara girerek otoimmün yanıtları tetikleyebilir. Bağırsak bakterileri tarafından γ-aminobütirik asit, serotonin, dopamin ve kısa zincirli yağ asitleri gibi birçok nörotransmiter üretilir. Bu nörokimyasal bileşikler, mikrobiyotanın sinir sistemi ile çift yönlü iletişiminde önemli rol oynar. Alfa-sinükleinopatiler, merkezi sinir sisteminde nöronlar arası iletişimin bozulmasına yol açmakta ve bu proteinlerin fosforile olmuş, çözünmeyen fibriller halinde birikimi, Parkinson hastalığı gibi nörodejeneratif bozuklukların temel patolojisi olarak belirtilebilir. Bağırsak mikrobiyotasındaki değişiklikler, bağırsak bariyer fonksiyonunu bozarak epitel geçirgenliğini artırmakta, bu da glial hücreler ve enterik nöronlar aracılığıyla gastrointestinal enflamasyona ve dolayısıyla alfa-sinüklein birikimine katkı sağlayabilir. Probiyotikler, bağırsak mikrobiyotasının düzenlenmesine katkı sağlayan, canlı veya inaktif mikroorganizmalar ya da biyolojik bileşenler olarak tanımlanır. Parkinson hastalarında görülen kabızlık, karın ağrısı ve abdominal distansiyon gibi GI semptomların hafifletilmesinde etkili oldukları belirtilmiştir. Prebiyotikler, sindirilmeden kalın bağırsağa ulaşan ve faydalı bakterilerin gelişimini teşvik eden diyet lifleridir. En sık kullanılan prebiyotik kaynaklar arasında soya fasulyesi, çiğ yulaf, tam buğday, arpa ve oligosakkaritler bulunmaktadır. Prebiyotiklerin, Parkinson hastalarında bağışıklık fonksiyonlarının iyileştirilmesine katkı sağlayabilmektedir. Probiyotik suşlar ve prebiyotik lif içeren fermente süt ürünlerinin tüketimi, özellikle kabızlık semptomlarının azaltılmasında etkili olduğu belirtilmiştir. Ayrıca, yapılan bazı çalışmalarda oligosakkaritlerin, hem motor hem de motor olmayan semptomlar üzerinde olumlu etkileri olduğu ve striatumda dopamin taşıyıcılarının aktivitesini artırdığı rapor edilmiştir. Parkinson hastalarında uygulanan ketojenik diyet, yüksek yağ, yeterli protein ve düşük karbonhidrat içeren bir beslenme modelidir. Bu diyet, glikoz kullanımını sınırlandırarak keton cisimcikleri üretimini (ketogenez) teşvik eder ve bu durum nutrisyonel ketozis olarak tanımlanır. Ketojenik diyetin, beyin fonksiyonları, enerji metabolizması ve nöroenflamasyonun baskılanması üzerinde olumlu etkiler sağladığı belirtilmiştir.

Mikrobiyota temelli beslenme yaklaşımları, yalnızca Parkinson hastalığının motor ve gastrointestinal semptomlarının hafifletilmesine katkı sağlamakla kalmaz, aynı zamanda uzun vadede sürdürülebilir sağlık stratejilerinin geliştirilmesine de olanak tanır. Özellikle bitkisel kökenli prebiyotik liflerin ve geleneksel fermente gıdaların kullanımı, hem bağırsak mikrobiyotasının

dengelenmesine yardımcı olur hem de çevresel açıdan düşük karbon ayak izine sahip yerel ve doğal kaynakların kullanımını teşvik eder. Bu yaklaşımlar, ilaç kullanımını azaltma potansiyeli sayesinde, hem bireysel sağlık harcamalarının azaltılmasına hem de sağlık sistemlerinde sürdürülebilirliğin desteklenmesine katkı sunar. Ayrıca, doğal beslenme modellerinin benimsenmesi, ekosistem dostu üretim biçimlerinin desteklenmesiyle birlikte toplum genelinde çevreyle uyumlu bir yaşam biçiminin gelişmesine de zemin hazırlar. Bu yönüyle mikrobiyota odaklı beslenme müdahaleleri, Parkinson hastalığı özelinde hem biyolojik hem de çevresel sürdürülebilirliğe hizmet eden bütüncül bir yaklaşım sunabilir.

Anahtar kelimeler: Parkinson hastalığı; Mikrobiyota; Probiyotikler; Prebiyotikler; Ketojenik diyeti

A SUSTAINABLE FUTURE WITH ALTERNATIVE FOODS: A NEW NUTRITION PARADIGM FOR HEALTHY GENERATIONS

ALTERNATİF GIDALARLA SÜRDÜRÜLEBİLİR GELECEK: SAĞLIKLI NESİLLER İÇİN YENİ BESLENME PARADİGMASI

Dilara ŞAHAN KHANKISHIYEV

İstanbul Arel University, Faculty of Health Science, Department of Nutrition and Dietetics, Istanbul, Türkiye

ORCID ID: 0000-0002-4484-8287

Semih ŞAHİN

İstanbul Arel University, Faculty of Health Science, Department of Nutrition and Dietetics, Istanbul, Türkiye

ORCID ID: https://orcid.org/0000-0001-5665-5629

Osman ERKMEN

İstanbul Arel University, Faculty of Health Science, Department of Nutrition and Dietetics, Istanbul, Türkiye

ORCID ID: https://orcid.org/0000-0001-9113-9638

ABSTRACT

Introduction and Purpose: In today's world, a growing population, rapid urbanization, and intensive industrial activities are depleting natural resources and causing environmental degradation, posing irreversible threats to both ecosystems and human health. Sustainable nutrition, environmentally friendly food production, and consumption also aim to raise healthy future generations. The environmental impacts of current food production systems, which are directly related to high carbon emissions and excessive water and land use, are increasingly driving the need for alternative food sources. The large environmental footprint of animal production, in particular, highlights the importance of plant-based, low-impact protein sources. Alternative foods are important for both their production processes, which support sustainability, and their nutritional properties. Therefore, raising public awareness of these alternatives and increasing their acceptability are crucial. This research evaluates the nutritional content, environmental impact, and sustainable nutrition potential of alternative foods, including plant-based proteins, laboratory-grown meat and dairy products, edible insects, algae, and fermented foods, based on current scientific data. Additionally, an analysis of findings regarding the social acceptability of these foods and a discussion of their ethical dimensions are included.

Results: The findings suggest that alternative foods have a lower carbon footprint and require less water consumption than conventional animal products. Furthermore, some of these products, with their high protein, essential amino acid, vitamin, and mineral content, will provide significant nutritional support for the development of healthy generations. The widespread adoption of alternative foods can contribute not only to improving individual health but also to ensuring environmental sustainability.

Discussion and Conclusion: Today, the development of sustainable food systems has become a crucial part of both environmental imperatives and societal health goals. Numerous studies have demonstrated that alternative foods (especially plant-based proteins, cultured meat, algae, and edible insects) offer advantages over conventional animal products in terms of both environmental impacts and nutritional value. It has been reported that cultured meat production can reduce greenhouse gas emissions by up to 78% and water use by up to 82% compared to conventional red meat. Edible insects contain high levels of protein, iron, and zinc per gram and have been reported to contribute to environmental sustainability through their low greenhouse gas emissions and reduced land use. Microalgae are notable for their short production time, CO_2 absorption capacity, and richness in functional components. They are considered an alternative source, particularly for omega-3 fatty acids, carotenoids, and polysaccharides. Plant-based meat alternatives, introduced to the market by US-based companies Beyond Meat and Impossible Foods, have been favored not only by vegetarians and vegans but also by environmentally concerned consumers. Plant-based meat sales in the US have increased by 27% annually, with 80% of this growth attributed to consumers who continue to consume both animal products and plant-based alternatives. The Netherlands is one of the leading countries in Europe in alternative food production and consumption. One of the first global prototypes for cultured meat production was developed in 2013 through projects supported by Wageningen University. In the Netherlands, the target is to shift the proportion of animal and plant-based protein consumption to 40% animal and 60% plant-based by 2030. Sweden, on the other hand, supports dietary patterns aligned with the "Eat Lancet" guidelines, which integrate public health and environmental sustainability, and plans to provide 50% of its public food services with plant-based foods by 2025. Furthermore, 46% of Swedish consumers reported consuming plant-based meat at least once a week. Consumer perceptions of alternative foods vary across countries. According to a European survey, 37% of consumers have a "positive" or "very positive" attitude toward consuming cultured meat, while this figure is reported as 54% and 58% in Sweden and the Netherlands, respectively. In contrast, this figure is lower in Turkey, with 68% of consumers stating that they lack sufficient information about cultured meat and insect-based foods. Young people, in particular, are among the groups with higher environmental awareness and have been reported to be more open to alternative foods. The ethical dimension of sustainable nutrition is directly related not only to individual health but also to the well-being of living beings, climate change, and intergenerational justice. Compliance with bioethical principles in food production should be considered in conjunction with the reduction of animal suffering and the equitable use of resources. Therefore, supporting alternative foods is not only a technological and environmental necessity but also an ethical responsibility. In light of all these findings, for alternative foods to have a meaningful place within food systems, scientific evidence must be shared with society, food literacy must be increased, and cultural transition processes must be supported. Universities, civil society organizations, and policymakers must play leading roles in this transformation. Furthermore, the economic accessibility of these foods can be increased through international collaborations and incentive policies.

Keywords: Alternative foods; Sustainable nutrition; Plant-based proteins; Cultured meat; Environmental impact

Giriş ve Amaç

Günümüz dünyasında artan nüfus, hızlı kentleşme ve yoğun endüstriyel faaliyetler doğal kaynakların tükenmesine ve çevresel bozulmaya neden olmakta; bu da hem ekosistem hem de insan sağlığı üzerinde geri dönülmez tehditler oluşturmaktadır. Sürdürülebilir beslenme, çevre dostu gıda üretimi ve tüketimi, gelecek nesillerin sağlıklı şekilde yetişmesini de hedeflemektedir. Mevcut gıda üretim sistemlerinin yüksek karbon salınımı, su ve toprak kullanımı ile doğrudan ilişkili çevresel etkileri; alternatif gıdalara olan ihtiyacı giderek artırmaktadır. Özellikle hayvansal üretimin çevresel ayak izinin büyüklüğü, bitkisel temelli ve düşük etkili protein kaynaklarının önemini ortaya koymaktadır. Alternatif gıdalar, hem sürdürülebilirliği destekleyen üretim süreçlerine sahip olmaları hem de besleyici özellikleriyle önem arz etmektedir. Bu nedenle, toplumun bu alternatif konusunda bilinçlendirilmesi ve bu ürünlerin kabul edilebilirliğinin artırılması önem taşımaktadır. Bu araştırmada; bitki bazlı proteinler, laboratuvar ortamında üretilen et ve süt ürünleri, yenilebilir böcekler, algler ve fermente gıdalar gibi alternatif gıdaların besin içeriği, çevresel etkileri ve sürdürülebilir beslenmedeki potansiyellerini güncel bilimsel veriler kapsamında değerlendirilmiştir. Ayrıca bu gıdaların toplum tarafından kabul edilebilirliğine dair bulguların analiz edilmesi ve etik boyutlarının tartışılması da yer verilmiştir.

Bulgular

Elde edilen bulgular, alternatif gıdaların geleneksel hayvansal ürünlere kıyasla daha düşük karbon ayak izine ve daha az su tüketimine sahip olduğu belirtilmiştir. Ayrıca bu ürünlerin bazıları, yüksek protein, esansiyel amino asit, vitamin ve mineral içeriğiyle sağlıklı nesillerin gelişimi için önemli bir beslenme desteği sunacaktır. Alternatif gıdaların yaygınlaştırılması, yalnızca bireysel sağlık düzeyinin artırılmasına değil; aynı zamanda çevresel sürdürülebilirliğin sağlanmasına da katkıda bulunabilir.

Tartışma ve Sonuç

Günümüzde sürdürülebilir gıda sistemlerinin geliştirilmesi, yalnızca çevresel zorunlulukların değil aynı zamanda toplumsal sağlık hedeflerinin de bir parçası haline gelmiştir. Alternatif gıdaların (özellikle bitki bazlı proteinlerin, kültür etinin, alglerin ve yenilebilir böceklerin) hem çevresel etkiler hem de besleyici değerler açısından geleneksel hayvansal ürünlere kıyasla daha avantajlı olduğu birçok çalışmada gösterilmiştir. Kültür eti üretiminin, geleneksel kırmızı ete göre sera gazı emisyonunu %78'e kadar azaltabileceği, su kullanımını ise %82'e düşürebileceği belirtilmiştir. Yenilebilir böcekler, gram başına yüksek biyoyararlanıma sahip protein, demir ve çinko içerirken; aynı zamanda düşük sera gazı salımı ve toprak kullanımı ile çevresel sürdürülebilirliğe katkı sunabileceği bildirilmiştir. Mikroalgler kısa üretim süresi, CO_2 absorpsiyon kapasitesi ve fonksiyonel bileşenler bakımından zengin içerikleri ile dikkat çekmekte; özellikle omega-3 yağ asitleri, karotenoidler ve polisakkaritler açısından alternatif kaynak olarak değerlendirilmektedir. ABD merkezli "Beyond Meat" ve "Impossible Foods" firmalarının pazara sürdüğü bitki bazlı et alternatifleri, yalnızca vejetary enler ve veganlar tarafından değil, aynı zamanda çevresel kaygı taşıyan tüketiciler tarafından da tercih edildiği belirtilmiştir. ABD'de bitki bazlı et satışları yıllık %27 oranında artmıştır ve bu artışın %80'i hayvansal ürün tüketmeye devam eden tüketicilerden geldiğini belirtilmiştir. Hollanda, Avrupa'da alternatif gıda üretimi ve tüketimi konusunda öncü ülkelerden biridir. Wageningen Üniversitesi'nin desteklediği projelerle kültür eti üretiminde dünya çapında ilk prototiplerden biri 2013 yılında geliştirilmiştir. Hollanda'da 2030 yılına kadar hayvansal ve bitkisel protein tüketimi oranının %40 hayvansal, %60 bitkisel olacak şekilde değiştirilmesi hedeflenmektedir. İsveç ise, halk sağlığı ve çevresel sürdürülebilirliği entegre eden "Eat Lancet" kılavuzuna yakın diyet örüntülerini desteklemekte ve 2025 itibarıyla kamu yemek hizmetlerinin %50'sini bitki bazlı gıdalarla sunmayı planlamaktadır. Ayrıca İsveçli tüketicilerin %46'sı haftada en az bir kez bitki bazlı et tükettiğini belirtilmiştir. Alternatif gıdalara yönelik tüketici algısı ülkeden ülkeye değişiklik göstermektedir. Avrupa genelinde yapılan bir araştırmaya göre, tüketicilerin %37'si kültür eti tüketmeye "olumlu" ya da "çok olumlu" yaklaşırken, bu oran İsveç ve Hollanda'da sırasıyla %54 ve %58 olarak bildirilmiştir. Buna karşılık Türkiye'de bu oran daha düşüktür; tüketicilerin %68'i kültür eti ve böcek bazlı gıdalar hakkında yeterince bilgi sahibi olmadığını ifade edilmiştir. Özellikle genç bireyler, çevre bilinci daha yüksek olan gruplar arasında yer almakta ve

alternatif gıdalara daha açık olacakları belirtilmiştir. Sürdürülebilir beslenmenin etik boyutu, yalnızca bireyin sağlığı ile değil, aynı zamanda canlıların refahı, iklim değişikliği ve kuşaklar arası adalet ile doğrudan ilişkilidir. Gıda üretiminde biyoetik ilkelere uyum, hayvansal acının azaltılması ve adil kaynak kullanımı ile birlikte değerlendirilmesi gerekir. Bu nedenle alternatif gıdaların desteklenmesi, yalnızca teknolojik ve çevresel bir gereklilik değil, aynı zamanda etik bir sorumluluktur. Tüm bu bulgular kapsamında, alternatif gıdaların gıda sistemleri içerisinde anlamlı bir yere sahip olabilmesi için bilimsel kanıtların toplumla paylaşılması, gıda okuryazarlığının artırılması ve kültürel geçiş süreçlerinin desteklenmesi gerekir. Üniversiteler, sivil toplum kuruluşları ve politika yapıcılar bu dönüşümde öncü roller üstlenmesi gerekir. Ayrıca uluslararası iş birlikleri ve teşvik edici politikalar sayesinde bu gıdaların ekonomik olarak erişilebilirliği artırılabilir.

Anahtar kelimeler: Alternatif gıdalar; Sürdürülebilir beslenme; Bitki bazlı proteinler; **K**ültür eti; Çevresel etki

STRATEGIC APPROACHES TO THE ECOLOGICAL SIGNIFICANCE AND CONSERVATION OF PLANT BIODIVERSITY IN ÇARŞAMBA PLAIN HABITATS

ÇARŞAMBA OVASI HABİTATLARINDA BİTKİ BİYOÇEŞİTLİLİĞİNİN EKOLOJİK ÖNEMİ VE KORUNMASINA YÖNELİK STRATEJİK YAKLAŞIMLAR

Ayla SARIOĞLU

Ondokuz Mayıs Üniversitesi, Lisansüstü Eğitim Enstitüsü, Biyoloji A.B.D., Samsun, Türkiye

Hamdi Güray KUTBAY

Ondokuz Mayıs Üniversitesi, Fen Fakültesi, Biyoloji Bölümü, Samsun, Türkiye

Özet

Çarşamba Ovası, Yeşilırmak Nehri'nin taşıdığı alüvyonlarla Karadeniz kıyısında oluşmuş, zengin habitat çeşitliliği ve geçiş zonu özelliğiyle dikkat çeken bir delta ekosistemidir. Avrupa-Sibirya ile İran-Turan fitocoğrafik bölgeleri arasında yer alması, bu alanı biyocoğrafik açıdan önemli bir geçit konumuna getirmektedir.

Ovada yürütülen floristik araştırmalar sonucunda, 56 familyaya ait 341 vasküler bitki türü kaydedilmiştir. Bu türlerin orman (G1.7), kumul (B1.2–B1.3), çayır ve mera (E2.1–E2.2), tuzcul bataklık (A2.5), sazlık (D5.2) ve iç su yüzeyi (C1) gibi farklı EUNIS habitat tiplerine göre dağılımları belirlenmiştir. Toprak özellikleri (pH, organik madde, tuzluluk vb.) ile tür kompozisyonu arasındaki ilişkiler incelenmiştir.

Özellikle kumul, bataklık ve tuzcul alanların nadir ve habitatlara özgü türleri barındırdığı saptanmış; tür örtüş oranları bu habitatlarda belirgin biçimde yüksek bulunmuştur. Toprak özellikleri ile bitki türleri arasındaki güçlü ilişkiler, edafik ve hidrolojik faktörlerin habitatlar arası çeşitliliği şekillendirdiğini göstermiştir.

Bu bulgular doğrultusunda, yalnızca tür zenginliğine değil, habitat özgünlüğüne dayalı çok katmanlı koruma stratejilerinin geliştirilmesi önerilmektedir. Kumul, bataklık ve tuzcul habitatların öncelikli koruma alanı olarak planlanması; geçiş zonlarında ekolojik koridorların oluşturulması ve habitat mozaikliğinin korunması, alanın ekolojik bütünlüğünün sürdürülebilirliği açısından stratejik öneme sahiptir.

Anahtar kelimeler: Çarşamba Ovası, habitat temelli koruma, biyoçeşitlilik, delta ekosistemi, vasküler flora.

Abstract

The Çarşamba Plain is a delta ecosystem formed by the alluvium carried by the Yeşilırmak River along the Black Sea coast, distinguished by its rich habitat diversity and transitional zone characteristics. Its location between the Euro-Siberian and Irano-Turanian phytogeographical regions makes it a biogeographically significant corridor.
Floristic surveys conducted in the plain have recorded 341 vascular plant species belonging to 56 families. The distribution of these species has been identified across different EUNIS habitat types,

including forests (G1.7), coastal dunes (B1.2–B1.3), grasslands and meadows (E2.1–E2.2), saltmarshes (A2.5), reedbeds (D5.2), and inland surface waters (C1). The relationships between soil properties (pH, organic matter, salinity, etc.) and species composition were also examined.
It was particularly observed that dune, marsh, and saltmarsh habitats host rare and habitat-specific species, with species overlap ratios found to be markedly high in these ecosystems. The strong correlations between soil properties and plant species reveal that edaphic and hydrological factors play a crucial role in shaping inter-habitat diversity.
In light of these findings, it is recommended to develop multilayered conservation strategies that prioritize not only species richness but also habitat uniqueness. The designation of dunes, marshes, and saltmarshes as priority conservation areas, the establishment of ecological corridors in transitional zones, and the preservation of habitat mosaics are of strategic importance for maintaining the ecological integrity and sustainability of the area.

Keywords: Çarşamba Plain, habitat-based conservation, biodiversity, delta ecosystem, vascular flora.

Giriş

Çarşamba Ovası, Karadeniz'in güney kıyısında Yeşilırmak Nehri'nin taşıdığı alüvyonlarla oluşmuş tipik bir delta ekosistemidir. Delta ekosistemleri, sahip oldukları habitat çeşitliliği ve geçiş zonu özellikleri nedeniyle yüksek düzeyde biyolojik çeşitlilik barındıran, aynı zamanda insan faaliyetlerinden en fazla etkilenen ekosistemler arasında yer almaktadır (Day vd., 2007; Mitsch ve Gosselink, 2015). Çarşamba Ovası, Avrupa-Sibirya ve İran-Turan fitocoğrafik bölgeleri arasında yer alması nedeniyle biyocoğrafik açıdan önemli bir geçiş alanı niteliği taşımaktadır. Delta ve sulak alan ekosistemleri, ekolojik fonksiyonları (su rejiminin düzenlenmesi, karbon depolama, besin döngüsü) ve sağladıkları habitat çeşitliliği ile ekosistem hizmetleri açısından kritik öneme sahiptir (Zedler ve Kercher, 2005; Barbier vd., 2011). Bununla birlikte, deltalar özellikle tarımsal drenaj, endüstriyel faaliyetler ve kentleşme baskısı altında hızla değişime uğramakta ve habitat bütünlüğünü kaybetmektedir (Nicholls ve Cazenave, 2010). Çarşamba Ovası da benzer şekilde tarımsal genişleme, sulak alanların kurutulması ve plansız yapılaşma baskıları altında olan bir deltadır. Habitat temelli koruma yaklaşımları, yalnızca tür zenginliği odaklı korumadan farklı olarak, ekosistemlerin bütüncül yapısının korunmasını hedeflemektedir (Margules & Pressey, 2000). Bu bağlamda, Çarşamba Ovası'nda yürütülen floristik araştırmalar, habitat özgünlüğüne dayalı çok katmanlı koruma stratejilerinin geliştirilmesine yönelik bilimsel temeller sağlamaktadır. Özellikle kumul, bataklık ve tuzcul habitatlar, nadir ve habitatlara özgü türlerin varlığı ile öncelikli koruma alanı olarak öne çıkmaktadır.
Bu çalışma, Çarşamba Ovası'nın habitat çeşitliliğini ekolojik ve koruma biyolojisi perspektifinden değerlendirmeyi, habitat özgünlüğüne dayalı koruma stratejilerini tartışmayı ve delta ekosisteminin sürdürülebilir yönetimine yönelik öneriler sunmayı amaçlamaktadır.

Materyal ve Metot

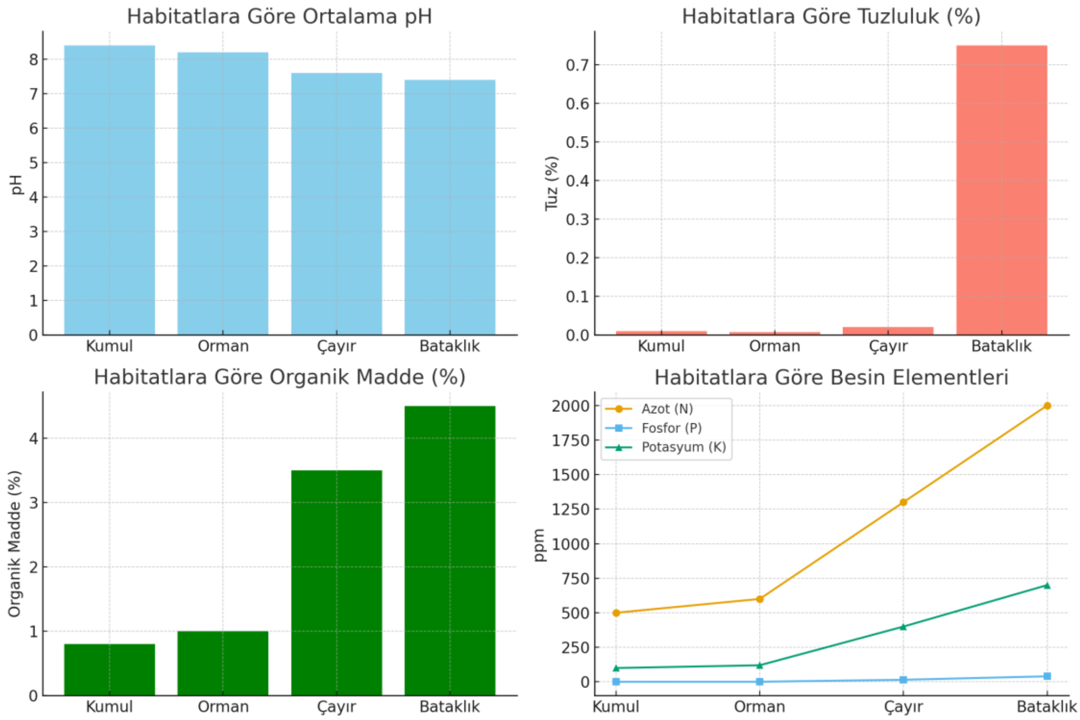
Çarşamba Ovası, Karadeniz kıyısında Yeşilırmak Nehri'nin taşıdığı alüvyonlarla oluşmuş tipik bir delta ekosistemidir. Arazi çalışmaları 2023–2025 yılları arasında gerçekleştirilmiş ve örnek alanlar Avrupa Doğa Bilgi Sistemi (EUNIS) sınıflandırması kullanılarak tanımlanmıştır (European Environment Agency [EEA], 2012). Çalışmada ele alınan başlıca habitat tipleri; orman habitatları (G1.7), kumullar (B1.2–B1.3), çayır ve meralar (E2.1–E2.2), tuzcul bataklıklar (A2.5), sazlık habitatları (D5.2) ve iç su yüzeyleridir (C1).
Floristik veriler, line intercept (Canfield, 1941) yöntemi kullanılarak kaydedilmiştir. Her habitat tipinde en az üç tekrar alanı seçilmiş, tür bolluk ve örtüş değerleri belirlenmiştir. Habitat özgünlüğünü değerlendirmek amacıyla hem yaygın hem de nadir türler kaydedilmiştir. Örnek alanlardan 0–30 cm derinlikten alınan toprak örnekleri laboratuvar ortamında analiz

edilmiştir. pH, organik madde, tuzluluk, azot, fosfor, potasyum, magnezyum ve kalsiyum parametreleri ölçülmüştür. Bu parametreler ile tür kompozisyonu arasındaki ilişkiler değerlendirilmiştir (Craft, 2001; Ersoy vd., 2020).

Göllerden yüzey suyu örnekleri alınarak pH, tuzluluk, çözünmüş oksijen, elektriksel iletkenlik ve besin elementleri (N, P, K) temel parametreler olarak ölçülmüştür. Çalışmada Çarşamba Ovası'nda yer alan **Akgöl ve Simenit sulak alanlarındaki farklı lokasyonlardan** alınan su örneklerinde temel fizikokimyasal parametreler ve başlıca iyon içerikleri standart yöntemlerle analiz edilmiştir. Su örneklerinin pH değerleri cam elektrotlu pH metre ile, elektriksel iletkenlik ise iletkenlik ölçer yardımıyla belirlenmiştir (APHA, 2017). Çözünmüş oksijen miktarı, Winkler titrasyon yöntemi ile ölçülmüştür (Eaton vd., 2005). Tuzluluk, elektriksel iletkenlik değerinden türetilmiş ve uluslararası standartlara göre hesaplanmıştır. Toplam azot (N), Kjeldahl yöntemi ile belirlenmiştir (Bremner, 1965). Çözünmüş fosfor, molybdate-blue spektrofotometrik yöntemi ile ölçülmüştür (Murphy ve Riley, 1962). Potasyum (K), alev fotometresi veya ICP-OES kullanılarak tayin edilmiştir. Katyonlar alev fotometresi (Na^+, K^+) ve atomik absorpsiyon spektrofotometresi (Ca^{2+}, Mg^{2+}) ile ölçülmüştür. Anyonlar (Cl^-) Mohr titrasyon yöntemiyle belirlenmiştir. SO_4^{2-} iyonu türbidimetrik yöntemle ölçülmüştür (APHA, 2017). HCO_3^- iyonu, asidimetrik titrasyon yöntemi ile belirlenmiştir (Eaton vd., 2005). Sodyum Adsorbsiyon Oranı (SAR) Na^+, Ca^{2+} ve Mg^{2+} iyonlarının miliekivalan konsantrasyonları kullanılarak hesaplanmıştır (Richards, 1954). Bu parametreler, sucul habitatlardaki bitki tür zenginliği ve çeşitlilik değerleri ile ilişkilendirilmiş ve suyun kimyasal özelliklerinin floristik kompozisyon üzerindeki etkisi değerlendirilmiştir (Maltby ve Acreman, 2011; Ersoy vd., 2020). Verilerin değerlendirilmesinde habitat özgünlüğü, nadir türlerin dağılımı ve tür örtüş oranları dikkate alınmıştır. Çalışma, yalnızca tür zenginliği değil, aynı zamanda habitatların ekolojik bütünlüğünü koruma biyolojisi perspektifinden ele almıştır (Margules ve Pressey, 2000).

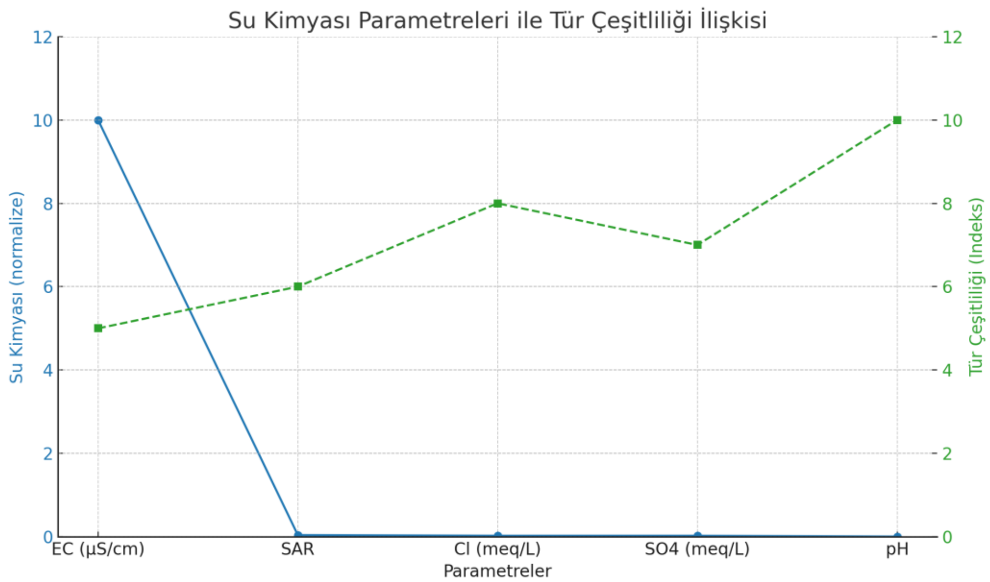
Bulgular

Arazi gözlemleri, özellikle kumul habitatları (B1.2–B1.3), tuzcul bataklıklar (A2.5) ve sazlık habitatlarının (D5.2) habitat özgünlüğü yüksek, nadir türleri barındırdığını ortaya koymuştur. Kumul alanlarında ekstrem edafik koşullara uyum sağlamış psamofitik türler öne çıkarken, tuzcul bataklık alanlarında halofitik türler gözlenmiştir. Sazlık habitatlarında ise hidrofil bitki toplulukları yoğunlaşmış, tür çeşitliliği sınırlı kalmış ancak habitat özgünlüğü yüksek bulunmuştur. Toprak analizleri, habitatlar arası çeşitlilik farklarının edafik ve hidrolojik koşullarla güçlü biçimde bağlantılı olduğunu göstermiştir. Kumul alanlarında yüksek pH (8.5–8.9) ve düşük organik madde (%0.2–0.6), tür çeşitliliğini sınırlandırmış; buna karşılık çayır habitatlarında yüksek organik madde (%3–5.3) ve azot-fosfor zenginliği, yüksek tür çeşitliliğini desteklemiştir. Tuzcul bataklıklarda artan tuzluluk (%0.68–0.85), floristik çeşitliliği sınırlamış, ancak bu habitatlarda tuza toleranslı nadir türlerin yoğunlaştığı görülmüştür (Şekil 1).



Şekil 1. Farklı habitatlarda edafik faktörlerin etkisi

Su analizleri, Çarşamba Ovası sulak alanlarında **su kalitesinin bitki çeşitliliğini şekillendiren temel faktörlerden biri** olduğunu ortaya koymaktadır. Yüksek EC ve SAR değerleri çeşitliliği sınırlandırırken, pH ve orta düzeyde iyon konsantrasyonları daha dengeli bir çeşitliliği desteklemektedir (Şekil 2).



Şekil 2. Su kimyası ile tür çeşitliliği arasındaki ilişki

Bu çalışma kapsamında elde edilen bulgular koruma önceliği taşıyan habitatların kumul, tuzcul bataklık ve sazlık ekosistemleri olduğunu göstermektedir. Bu alanlar, düşük alfa çeşitlilik değerlerine rağmen, habitat özgünlüğü ve nadir türlerin varlığı nedeniyle ekolojik açıdan kritik rol oynamaktadır. Buna karşılık, orman ve çayır habitatları, yüksek tür zenginlikleriyle biyoçeşitlilik açısından önemli olup, sürdürülebilir yönetim stratejileri kapsamında korunmaları gereken ekosistemlerdir.

Tartışma

Çarşamba Ovasında yürütülen floristik araştırmalar, habitat özgünlüğünün ve edafik-hidrolojik faktörlerin çeşitlilik örüntülerinde belirleyici rol oynadığını ortaya koymuştur. Özellikle kumul, tuzcul bataklık ve sazlık habitatlarının, alfa çeşitlilik açısından düşük değerler göstermesine karşın, barındırdıkları nadir ve habitat spesifik türlerle koruma açısından kritik öneme sahip oldukları belirlenmiştir (Zedler ve Kercher, 2005; Barbier vd., 2011). Orman ve çayır habitatları, tür zenginliği bakımından yüksek çeşitlilik sergilemiş, bu durum delta ekosistemlerinde bitki topluluklarının edafik koşulların yanı sıra antropojenik baskılardan da etkilendiğini göstermiştir (Kutbay ve Yücel, 2019; Ersoy vd., 2020). Avrupa deltalarında yapılan çalışmalarda da benzer bulgular elde edilmiş, örneğin Po Deltası ve Tuna Deltası'nda orman ve çayır habitatlarının yüksek çeşitlilik değerlerine sahip olduğu bildirilmiştir (Boros vd., 2013). Habitat temelli koruma yaklaşımları, yalnızca tür zenginliğine odaklanmaktan ziyade habitat özgünlüğü ve ekosistem bütünlüğünü dikkate almaktadır (Margules ve Pressey, 2000). Çarşamba Ovası özelinde, kumul ve tuzcul habitatların korunması, delta ekosisteminin bütünlüğünün sürdürülmesi açısından stratejik öneme sahiptir. Ayrıca, habitat mozaikliğinin korunması ve ekolojik koridorların oluşturulması, tür göçlerinin ve genetik çeşitliliğin sürekliliği açısından hayati bir gerekliliktir (Opdam vd., 2006). Türkiye'de Kızılırmak Deltası'nda yürütülen araştırmalar, habitat kaybı ve parçalanmanın biyolojik çeşitlilik üzerinde ciddi tehditler oluşturduğunu göstermektedir (Çakan vd., 2015). Bu durum, Çarşamba Ovası için geliştirilecek koruma stratejilerinin yalnızca biyolojik değil, aynı zamanda sosyo-ekonomik faktörleri de içermesi gerektiğini ortaya koymaktadır.

Sonuç ve Öneriler

Çarşamba Ovası, sahip olduğu habitat çeşitliliği ve biyocoğrafik konumu nedeniyle hem ulusal hem de küresel ölçekte önemli bir delta ekosistemidir. Arazi çalışmaları sonucunda elde edilen bulgular, kumul, tuzcul bataklık ve sazlık habitatlarının düşük tür zenginliğine rağmen barındırdıkları özgün ve nadir türlerle ekolojik açıdan kritik öneme sahip olduğunu ortaya koymuştur. Buna karşılık, orman ve çayır habitatları yüksek tür zenginliği ile bölgenin alfa çeşitliliğini temsil eden ekosistemlerdir.

Delta ekosistemlerinin sürdürülebilirliği için yalnızca tür zenginliği değil, aynı zamanda habitat özgünlüğü ve ekolojik bütünlüğün korunması gerekmektedir. Bu bağlamda, Çarşamba Ovası'nda koruma ve yönetim açısından şu stratejik öneriler öne çıkmaktadır:

1. Öncelikli Koruma Alanları: Kumul, tuzcul bataklık ve sazlık habitatları, nadir türlerin varlığı nedeniyle öncelikli koruma alanları olarak tanımlanmalıdır.
2. Habitat Mozaikliğinin Korunması: Çayır, mera ve orman habitatları arasındaki ekolojik koridorlar korunmalıdır.
3. Antropojenik Baskıların Azaltılması: Tarımsal drenaj, yapılaşma ve arazi kullanım değişiklikleri sınırlandırılmalıdır.
4. Çok Katmanlı Koruma Yaklaşımı: Koruma stratejileri flora, fauna ve ekosistem hizmetlerini kapsamalıdır.
5. Yerel Toplum Katılımı: Yerel halk bilinçlendirilerek ekoturizm gibi doğa dostu faaliyetler desteklenmelidir.

Sonuç olarak, Çarşamba Ovası'nın korunmasına yönelik stratejiler, biyolojik çeşitlilik ile birlikte ekosistem fonksiyonlarının ve sosyo-ekonomik faydaların sürdürülebilirliğini hedeflemelidir.

Kaynakça

APHA (American Public Health Association). (2017). Standard methods for the examination of water and wastewater (23rd ed.). Washington, DC: APHA/AWWA/WEF.

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C. ve Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. Ecological Monographs, 81(2), 169–193.

Boros, E., Horváth, Z., Wolfram, G. ve Várbíró, G. (2013). Salinity and aquatic macrophyte occurrence in continental soda pans and wetlands of the Carpathian Basin. Aquatic Botany, 111, 25–39.

Bremner, J. M. (1965). Total nitrogen. In C. A. Black (Ed.), Methods of soil analysis. Part 2 (pp. 1149–1178). ASA.

Canfield, R. H. (1941). Application of the line interception method in sampling range vegetation. Journal of Forestry, 39(4), 388–394.

Çakan, H., Yücel, E., Kutbay, H. G. ve Kavgacı, A. (2015). Habitat loss and fragmentation in the Kızılırmak Delta and its effects on biodiversity. Turkish Journal of Botany, 39(1), 1–12.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B. ve van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. Nature, 387, 253–260.

Craft, C. B. (2001). Biology of wetland soils. In J. L. Richardson ve M. J. Vepraskas (Eds.), Wetland soils: Genesis, hydrology, landscapes, and classification (pp. 107–136). CRC Press.

Day, J. W., Christian, R. R., Boesch, D. M., Yáñez-Arancibia, A., Morris, J., Twilley, R. R. ve Stevenson, C. (2007). Consequences of climate change on the ecogeomorphology of coastal wetlands. Estuaries and Coasts, 31(3), 477–491.

Eaton, A. D., Clesceri, L. S., Rice, E. W. ve Greenberg, A. E. (2005). Standard methods for the examination of water and wastewater (21st ed.). APHA, AWWA, WEF.

Ersoy, Ş., Yücel, E. ve Kutbay, H. G. (2020). Effects of edaphic factors on plant diversity in coastal wetlands of the Black Sea Region. Turkish Journal of Botany, 44(2), 177–188.

European Environment Agency (EEA). (2012). EUNIS habitat classification. European Environment Agency. Retrieved from https://eunis.eea.europa.eu/habitats.jsp

Kutbay, H. G. ve Yücel, E. (2019). Edaphic factors shaping plant community diversity in wetland ecosystems. Wetlands Ecology and Management, 27(3), 321–334.

Maltby, E. ve Acreman, M. C. (2011). Ecosystem services of wetlands: Pathfinder for a new paradigm. Ecohydrology & Hydrobiology, 11(1–2), 1–19.

Margules, C. R. ve Pressey, R. L. (2000). Systematic conservation planning. Nature, 405, 243–253.

Murphy, J. ve Riley, J. P. (1962). A modified single solution method for the determination of phosphate in natural waters. Analytica Chimica Acta, 27, 31–36.

Nicholls, R. J. ve Cazenave, A. (2010). Sea-level rise and its impact on coastal zones. Science, 328(5985), 1517–1520.

Opdam, P., Steingröver, E. ve van Rooij, S. (2006). Ecological networks: A spatial concept for multi-actor planning of sustainable landscapes. Landscape and Urban Planning, 75(3–4), 322–332.

Richards, L. A. (Ed.). (1954). Diagnosis and improvement of saline and alkali soils. USDA Handbook No. 60. Washington, DC: U.S. Department of Agriculture.

Zedler, J. B. ve Kercher, S. (2005). Wetland resources: Status, trends, ecosystem services, and restorability. Annual Review of Environment and Resources, 30, 39–74.

ECOLOGICAL ASSESSMENT OF PLANT BIODIVERSITY IN ÇARŞAMBA PLAIN HABITATS USING ALPHA AND BETA DIVERSITY INDICES

ÇARŞAMBA OVASI HABİTATLARINDA BİTKİ BİYOÇEŞİTLİLİĞİNİN ALFA VE BETA ÇEŞİTLİLİK İNDEKSLERİYLE EKOLOJİK DEĞERLENDİRİLMESİ

Ayla SARIOĞLU

Ondokuz Mayıs Üniversitesi, Lisansüstü Eğitim Enstitüsü, Biyoloji A.B.D., Samsun, Türkiye

Hamdi Güray KUTBAY

Ondokuz Mayıs Üniversitesi, Fen Fakültesi, Biyoloji Bölümü, Samsun, Türkiye

Özet

Çarşamba Ovası, Karadeniz'in alüvyal deltalarından biri olup, farklı ekolojik koşullara sahip habitatlarıyla yüksek bitki çeşitliliği barındırmaktadır. Bu çalışma, ovada yer alan orman (G1.7), sabit ve hareketli kumullar (B1.2–B1.3), çayır ve mera alanları (E2.1–E2.2), tuzcul bataklık (A2.5), sazlık (D5.2) ve iç su yüzeyleri (C1) gibi dokuz farklı EUNIS habitatında vasküler bitki biyoçeşitliliğinin belirlenmesini ve çeşitlilik örüntülerinin analizini amaçlamaktadır.

Ovada yapılan arazi çalışmaları sonucunda 56 familyaya ait toplam 341 vasküler bitki türü tespit edilmiştir. Habitatlardaki tür zenginliği alfa çeşitliliği kapsamında Shannon-Wiener İndeksi (H') ile değerlendirilmiş; en yüksek değerlerin nemli çayır ve bataklık habitatlarında, en düşük değerlerin ise insan etkisine açık mera alanlarında ortaya çıktığı belirlenmiştir. Beta çeşitliliği analizleri Bray-Curtis benzerlik katsayısına dayalı olarak yapılmış; habitatlar arasında güçlü tür kompozisyonu farklılıkları saptanmıştır.

Beta çeşitliliği analiz sonuçları, mikrohabitat düzeyindeki ekolojik ayrışmaların bitki topluluklarını anlamlı biçimde etkilediğini göstermektedir. Veriler, yalnızca tür zenginliği açısından değil, aynı zamanda habitatlar arası floristik farklılıkların korunması gereken ekolojik bütünlükler sunduğunu ortaya koymaktadır.

Bu bağlamda, özellikle yüksek beta çeşitliliğe sahip kumul, bataklık ve tuzcul alanların öncelikli koruma alanı olarak değerlendirilmesi gerektiği vurgulanmaktadır. Habitat temelli koruma stratejilerinin geliştirilmesi, Çarşamba Ovası'nın ekolojik bütünlüğünün sürdürülebilirliği açısından önem arz etmektedir.

Anahtar Kelimeler: Çarşamba Ovası, vasküler flora, Shannon-Wiener indeksi, beta çeşitliliği, habitat farklılığı, ekolojik analiz.

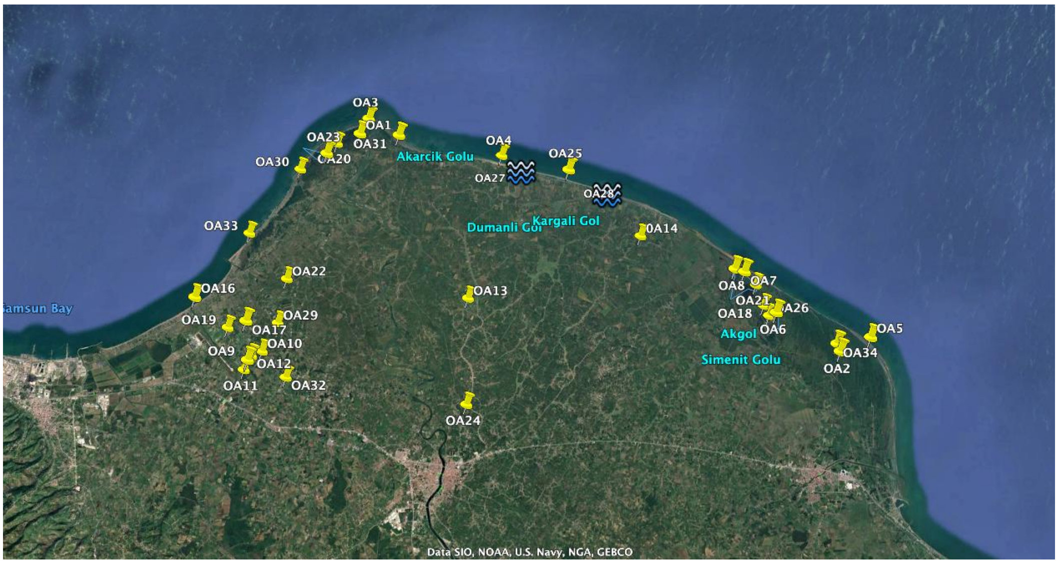
Abstract

The Çarşamba Plain is one of the alluvial deltas of the Black Sea, harboring high plant diversity across habitats with distinct ecological conditions. This study aims to identify the vascular plant biodiversity and analyze diversity patterns within nine different EUNIS habitats of the plain, including forest (G1.7), fixed and shifting sand dunes (B1.2–B1.3), grasslands and pastures (E2.1–E2.2), salt marsh (A2.5), reed beds (D5.2), and inland water bodies (C1).

Field surveys revealed a total of 341 vascular plant species belonging to 56 families. Species richness within habitats was assessed under the scope of alpha diversity using the Shannon-Wiener Index (H'). The highest values were recorded in wet meadow and marsh habitats, while the lowest values were observed in pasturelands exposed to human disturbance. Beta diversity analyses, based on the Bray-Curtis similarity coefficient, demonstrated pronounced differences in species composition among habitats.
The results of beta diversity analyses indicate that microhabitat-level ecological differentiation significantly influences plant community structure. The findings highlight that ecological integrity in the plain should be considered not only in terms of species richness but also in preserving floristic distinctiveness among habitats.
In this context, dune, marsh, and salt-marsh habitats, which exhibit high beta diversity, should be prioritized for conservation. Developing habitat-based conservation strategies is essential for maintaining the ecological integrity and sustainability of the Çarşamba Plain.
Key Words: Çarşamba Plain, vascular flora, Shannon-Wiener index, beta diversity, habitat differentiation, ecological analysis.

Giriş

Çarşamba Ovası, Karadeniz'in en önemli alüvyal deltalarından biridir ve barındırdığı farklı ekolojik koşullar nedeniyle yüksek floristik çeşitliliğe sahiptir. Avrupa-Sibirya ve İran-Turan fitocoğrafik bölgeleri arasında geçiş kuşağında yer alması, alanın biyocoğrafik önemini artırmaktadır. Ovada orman parçaları (G1.7), sabit ve hareketli kumullar (B1.2–B1.3), çayır ve mera alanları (E2.1–E2.2), tuzcul bataklıklar (A2.5), sazlıklar (D5.2) ve iç su yüzeyleri (C1) gibi farklı habitat tipleri bulunmaktadır (European Environment Agency [EEA], 2012). Biyoçeşitliliğin ölçülmesinde kullanılan alfa, beta ve gama çeşitlilik kavramları, ekosistemlerin yapısal özelliklerini anlamada ve karşılaştırmalı ekolojik değerlendirmelerde önemli rol oynamaktadır (Whittaker, 1972; Jurasinski vd., 2009; Magurran, 2004). Alfa çeşitlilik, belirli bir habitat içindeki tür zenginliğini yansıtırken, beta çeşitlilik, habitatlar arası tür bileşimi farklılıklarını göstermektedir. Gama çeşitlilik ise bölgesel ölçekte toplam tür zenginliğini ifade etmektedir (Magurran, 2004).
Çeşitlilik ölçümünde kullanılan indekslerden Shannon-Wiener (H') ve Simpson indeksi, hem tür zenginliği hem de bolluk dağılımlarını dikkate alarak ekosistemlerin yapısal özelliklerini yansıtır (Hill, 1973; Magurran, 2013). Habitatlar arası benzerliğin değerlendirilmesinde ise Bray-Curtis benzerlik katsayısı, floristik farklılıkların ortaya konmasında sıkça tercih edilmektedir (Faith vd., 1987; Legendre ve Gallagher, 2001).
Bu çalışma, Çarşamba Ovası'nda yer alan farklı habitatlarda vasküler bitki biyoçeşitliliğinin alfa ve beta çeşitlilik indeksleriyle değerlendirilmesini, habitatlar arası floristik benzerliklerin incelenmesini ve edafik faktörlerle ilişkilerinin tartışılmasını amaçlamaktadır. Araştırma alanının uydu görüntüsü şekil 1'de verilmiştir.



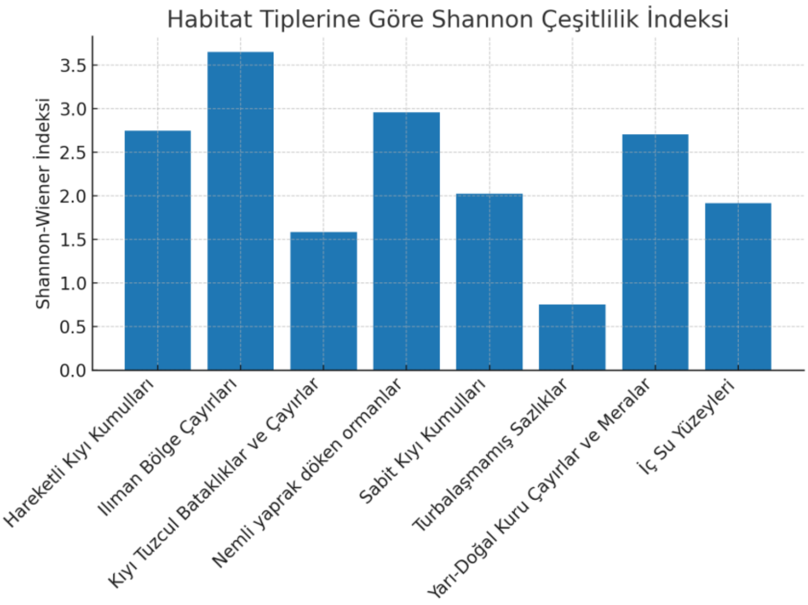
Şekil 1. Araştırma alanının uydu görüntüsü

Materyal ve Metot

Çarşamba Ovası, Yeşilırmak Nehri'nin taşıdığı alüvyonlarla Karadeniz kıyısında oluşmuş geniş bir delta ekosistemidir. Arazi çalışmaları Avrupa Doğa Bilgi Sistemi (EUNIS) sınıflandırma sistemi temel alınarak yürütülmüştür (EEA, 2012). Çalışmada değerlendirilen başlıca habitat tipleri: Orman habitatları (G1.7), kumullar (B1.2–B1.3), çayır ve meralar (E2.1–E2.2), tuzcul bataklıklar (A2.5), sazlıklar (D5.2) ve iç su yüzeyleri (C1). Floristik veriler 2023–2025 yılları arasında gerçekleştirilen arazi çalışmaları ile toplanmıştır. Bitki örtüsünün belirlenmesinde line intercept yöntemi (Canfield, 1941) kullanılmıştır. Her habitat tipinde en az üç tekrar alanı seçilmiş, tür bolluk ve örtüş yüzdeleri hesaplanmıştır. Her örnek alanın 0–30 cm derinliğinden toprak örnekleri alınmış ve laboratuvar analizleri gerçekleştirilmiştir. Bu çalışmada örnek alanlardan alınan toprak örneklerinde temel kimyasal ve fiziksel parametreler standart analitik yöntemler kullanılarak belirlenmiştir. Toplam azot miktarı, **Kjeldahl yöntemi** ile belirlenmiştir (Bremner, 1965). Bitkiye yarayışlı fosfor, **Olsen spektrofotometrik yöntemi** (Olsen et al., 1954) ile saptanmıştır. **Değişebilir Potasyum (K), Magnezyum (Mg) ve Kalsiyum (Ca)** elementlerinin belirlenmesinde **Amonyum Asetat ekstraksiyonu** (1 N NH_4OAc, pH 7.0) ve sonrasında **ICP-OES (Inductively Coupled Plasma - Optical Emission Spectroscopy)** cihazı kullanılmıştır (Helmke ve Sparks, 1996). Toprak reaksiyonu (pH) ve tuzluluk, **doygunluk çamuru yöntemiyle** ölçülmüştür (McLean, 1982). pH ölçümleri cam elektrotlu pH metre ile, tuzluluk ise elektriksel iletkenlik ölçümünden dönüştürülerek hesaplanmıştır. Kireç miktarı, **Scheibler kalsimetresi** ile hacimsel olarak belirlenmiştir. Organik madde içeriği, **Walkley-Black yöntemi** ile belirlenmiştir (Walkley ve Black, 1934). Toprağın mekanik bileşimi hidrometre yöntemi ile belirlenmiş ve örnekler **Bouyoucos yöntemi** kullanılarak kum, silt ve kil fraksiyonlarına ayrılmıştır (Bouyoucos, 1962).
Habitatların alfa çeşitliliği Shannon-Wiener (H') ve Simpson indeksi, beta çeşitliliği ise Bray-Curtis benzerlik katsayısı kullanılarak hesaplanmıştır (Magurran, 2013; Legendre ve Gallagher, 2001). İstatistiksel analizler ve görselleştirmeler için PAST 4.0 yazılımı kullanılmıştır (Hammer vd., 2001).

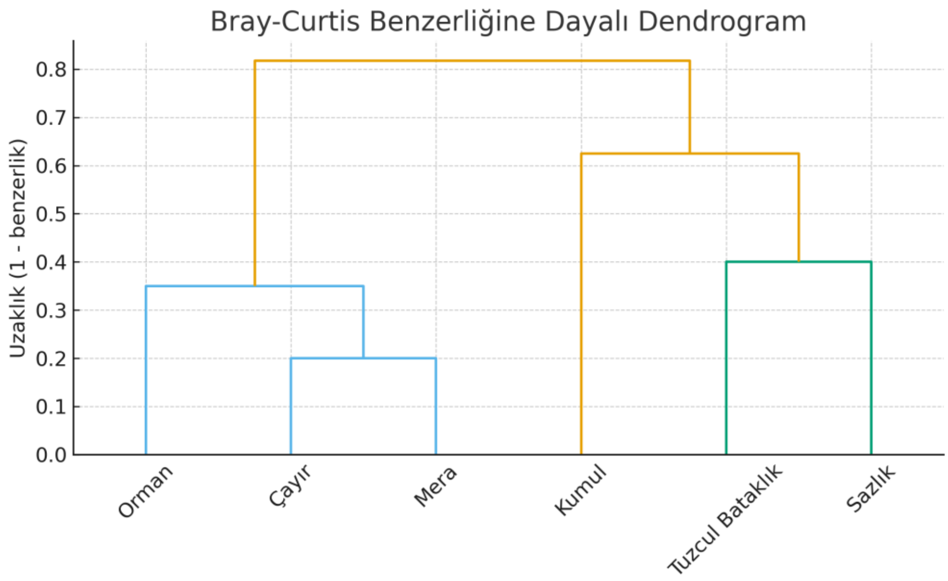
Bulgular

Çarşamba Ovası'nda gerçekleştirilen floristik çalışmalar, habitat tipleri arasında belirgin çeşitlilik farklılıkları olduğunu göstermiştir. En yüksek alfa çeşitlilik değerleri ılıman bölge çayırlarında (H'=3.65; 61 tür) ve nemli yaprak döken orman habitatlarında (H'=2.96; 43 tür) bulunmuştur. Yarı-doğal kuru çayırlar ve meralar (H'=2.71; 30 tür) ile hareketli kumullar (H'=2.75; 25 tür) de görece yüksek çeşitlilik değerlerine sahiptir. Buna karşın sabit kumullar (H'=2.03; 22 tür), tuzcul bataklıklar (H’=1.59; 14 tür) ve sazlıklar (H’=0.75; 3 tür) daha düşük çeşitlilik değerleri göstermiştir (Şekil 2).



Şekil 2. Habitat tiplerine göre Shannon çeşitlilik indeksi

Bray-Curtis analizine dayalı dendrogram, habitatların floristik açıdan belirgin gruplar oluşturduğunu ortaya koymuştur. Orman habitatları kendi içinde kümelenirken, çayır ve meralar ayrı bir grup oluşturmuş, kumullar ise diğerlerinden belirgin biçimde ayrışmıştır. Tuzcul bataklıklar ve sazlıklar izole konumlarda yer almıştır. PCA analizi de bu ayrışmayı desteklemiş, çayır ve ormanlar merkezi konumda, tuzcul bataklıklar ve sazlıklar uç bölgelerde yer almıştır (Şekil 3).



Şekil 3. Habitat benzerliğine dayalı dendogram

Toprak analizleri, organik madde ve besin elementlerindeki artışın çeşitliliği artırdığını, yüksek pH ve tuzluluğun ise çeşitliliği sınırlandırdığını göstermiştir. Kumul habitatlarında yüksek pH ve düşük organik madde, sınırlı fakat özgün türlerin varlığına yol açarken, çayır ve bataklıklarda zengin edafik koşullar yüksek alfa çeşitliliği desteklemiştir. Tuzcul bataklıklar ve sazlıklar, düşük çeşitlilik düzeyleriyle habitat özgünlüğü taşıyan ekosistemlerdir.

Tartışma

Bu çalışmanın sonuçları, Çarşamba Ovası'ndaki biyoçeşitlilik örüntülerinin edafik ve hidrolojik koşullara güçlü biçimde bağlı olduğunu göstermektedir. Çayır ve orman habitatları yüksek alfa çeşitliliğe sahipken, tuzcul bataklıklar ve sazlıklar düşük çeşitlilik düzeyleriyle öne çıkmıştır. Benzer bulgular Po ve Tuna deltaları gibi diğer delta ekosistemlerinde de rapor edilmiştir (Boros vd., 2013; Cuttelod vd., 2008). Beta çeşitlilik analizleri, habitatlar arasında belirgin floristik ayrışmalar olduğunu göstermiş, özellikle kumulların özgünlüğü vurgulanmıştır (Grime, 2001; Legendre, 2008). Toprak analizleri ise çeşitliliğin besin elementleriyle pozitif, tuzluluk ve alkaliniteyle negatif ilişkili olduğunu ortaya koymuştur (Yücel ve Kutbay, 2019; Ersoy vd., 2020). Bu bulgular, habitat özgünlüğünün korunmasının delta ekosistemlerinin sürdürülebilirliği açısından kritik olduğunu göstermektedir.

Sonuç ve Öneriler

Bu çalışma, Çarşamba Ovası'ndaki habitatlar arasında çeşitlilik düzeylerinin belirgin biçimde farklılık gösterdiğini ortaya koymuştur. Ilıman bölge çayırları ve nemli yaprak döken ormanlar yüksek çeşitlilik değerleriyle öne çıkarken, tuzcul bataklıklar ve sazlıklar düşük çeşitliliğe rağmen habitat özgünlükleriyle ekolojik öneme sahiptir. Çalışma sonucunda, yüksek çeşitlilik değerlerine sahip habitatların sürdürülebilir yönetimi, özgün habitatların öncelikli koruma kapsamına alınması ve ekolojik koridorların desteklenmesi önerilmektedir. Bu yaklaşım, delta ekosisteminin ekolojik bütünlüğünün korunması açısından stratejik öneme sahiptir.

Kaynakça

Allison, L. E. ve Moodie, C. D. (1965). Carbonate. In C. A. Black (Ed.), Methods of soil analysis. Part 2. Agronomy Monograph 9 (pp. 1379–1396). ASA.

Boros, E., Horváth, Z., Wolfram, G. ve Várbíró, G. (2013). Salinity and aquatic macrophyte occurrence in continental soda pans and wetlands of the Carpathian Basin. Aquatic Botany, 111, 25–39.

Bouyoucos, G. J. (1962). Hydrometer method improved for making particle size analysis of soils. Agronomy Journal, 54(5), 464–465.

Bremner, J. M. (1965). Total nitrogen. In C. A. Black (Ed.), Methods of soil analysis. Part 2 (pp. 1149–1178). ASA.

Canfield, R. H. (1941). Application of the line interception method in sampling range vegetation. Journal of Forestry, 39(4), 388–394.

Cuttelod, A., García, N., Malak, D. A., Temple, H. J. ve Katariya, M. (2008). The Mediterranean: A biodiversity hotspot under threat. IUCN.

Ersoy, Ş., Yücel, E., ve Kutbay, H. G. (2020). Effects of edaphic factors on plant diversity in coastal wetlands of the Black Sea Region. Turkish Journal of Botany, 44(2), 177–188.

European Environment Agency (EEA). (2012). EUNIS habitat classification. European Environment Agency. Retrieved from https://eunis.eea.europa.eu/habitats.jsp

Faith, D. P., Minchin, P. R., ve Belbin, L. (1987). Compositional dissimilarity as a robust measure of ecological distance. Vegetatio, 69(1–3), 57–68.

Grime, J. P. (2001). Plant strategies, vegetation processes, and ecosystem properties (2nd ed.). John Wiley & Sons.

Hammer, Ø., Harper, D. A. T. ve Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica, 4(1), 1–9.

Helmke, P. A. ve Sparks, D. L. (1996). Lithium, sodium, potassium, rubidium, and cesium. In D. L. Sparks (Ed.), Methods of soil analysis. Part 3. Chemical methods (pp. 551–574). SSSA.

Hill, M. O. (1973). Diversity and evenness: A unifying notation and its consequences. Ecology, 54(2), 427–432.

Jurasinski, G., Retzer, V. ve Beierkuhnlein, C. (2009). Inventory, differentiation, and proportional diversity: A consistent terminology for quantifying species diversity. Oecologia, 159(1), 15–26.

Legendre, P. (2008). Studying beta diversity: Ecological variation partitioning by multiple regression and canonical analysis. Journal of Plant Ecology, 1(1), 3–8.

Legendre, P. ve Gallagher, E. D. (2001). Ecologically meaningful transformations for ordination of species data. Oecologia, 129(2), 271–280.

Magurran, A. E. (2004). Measuring biological diversity. Blackwell.

Magurran, A. E. (2013). Measuring biological diversity (2nd ed.). Wiley-Blackwell.

McLean, E. O. (1982). Soil pH and lime requirement. In A. L. Page (Ed.), Methods of soil analysis. Part 2. Chemical and microbiological properties (pp. 199–224). ASA.

Olsen, S. R., Cole, C. V., Watanabe, F. S. ve Dean, L. A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular No. 939.

Walkley, A. ve Black, I. A. (1934). An examination of the Degtjareff method for determining organic carbon in soils, and a proposed modification of the chromic acid titration method. Soil Science, 37(1), 29–38.

Whittaker, R. H. (1972). Evolution and measurement of species diversity. Taxon, 21(2/3), 213–251.

Yücel, E. ve Kutbay, H. G. (2019). Edaphic factors shaping plant community diversity in wetland ecosystems. Wetlands Ecology and Management, 27(3), 321–334.

RELATIONSHIP BETWEEN CAFFEINE CONSUMPTION AND BODY COMPOSITION IN FEMALE NUTRITION AND DIETETICS STUDENTS AGED 18–25

Buse SARIKAYA

Amasya University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Amasya, Turkey

ORCID ID: https://orcid.org/0000-0001-8555-6662

Burak TÖNGÜŞ

Amasya University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Amasya, Turkey

ORCID ID: https://orcid.org/0009-0007-7677-5098

Gökdeniz YÜCEL

Amasya University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Amasya, Turkey

ORCID ID: https://orcid.org/0009-0001-2566-2022

Melike Ebrar ÜNAL

Amasya University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Amasya, Turkey

ORCID ID: https://orcid.org/0009-0004-8500-252X

Mehmet Arif İÇER

Amasya University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Amasya, Turkey

ORCID ID: https://orcid.org/0000-0002-1632-7484

ABSTRACT

Introduction and Purpose: Caffeine is a widely consumed psychoactive compound globally and has been shown to enhance both cognitive performance and physical endurance. However, excessive intake may have detrimental effects on health. This study aimed to evaluate the relationship between caffeine consumption and body composition parameters among female students aged 18–25 enrolled in a Nutrition and Dietetics program.

Materials and Methods: This cross-sectional study was conducted between January and March 2025 and included 64 female students. Caffeine intake was calculated using detailed questionnaires and caffeine content data supported by the literature. Body composition was assessed using the Bioelectrical Impedance Analysis (BIA) method.

Results: The participants' mean daily caffeine intake was found to be 158.50 ± 213.58 mg, with 90.6% classified within the low caffeine consumption group (≤250 mg/day). No statistically significant associations were observed between caffeine intake levels and demographic variables such as age, meal skipping, or smoking status. However, alcohol consumption was found to be more prevalent among high caffeine consumers ($p = 0.003$). No statistically significant relationships were identified between caffeine consumption and body weight, body mass index, body fat percentage, muscle mass, or other anthropometric measures ($p > 0.05$). In conclusion, the relationship between caffeine intake and body composition appears to be complex and may be influenced by individual health status, dietary habits, and physical activity. Further comprehensive, long-term interventional studies are warranted.

Keywords: Body Composition, Caffeine Consumption, University Students.

ÖZET

18–25 Yaş Arası Kadın Beslenme ve Diyetetik Öğrencilerinde Kafein Tüketimi ile Vücut Kompozisyonu Arasındaki İlişkinin Belirlenmesi

Kafein, dünya genelinde yaygın olarak tüketilen psikoaktif bir bileşiktir ve bilişsel performans ile fiziksel dayanıklılığı artırabilmektedir. Ancak aşırı tüketimi sağlık üzerinde olumsuz etkiler yaratabilmektedir. Bu çalışmanın amacı, Beslenme ve Diyetetik Bölümü'nde öğrenim gören 18-25 yaş arası kadın öğrencilerde kafein tüketimi ile vücut kompozisyonu parametreleri arasındaki ilişkiyi değerlendirmektir. 2025 Ocak-Mart ayları arasında yürütülen kesitsel araştırmaya 64 kadın öğrenci katılmıştır. Kafein alımı, detaylı anketlerle ve literatür destekli kafein içeriklerine göre hesaplanmıştır. Vücut kompozisyonu ise Biyoelektrik İmpedans Analizi yöntemiyle ölçülmüştür. Katılımcıların günlük ortalama kafein alımı 158,50 ± 213,58 mg olarak belirlenmiş, %90,6'sı düşük kafein tüketimi (≤250 mg/gün) grubunda yer almıştır. Kafein tüketim düzeyleri ile yaş, öğün atlama, sigara kullanımı gibi demografik değişkenler arasında anlamlı fark bulunmamış, ancak yüksek kafein tüketenlerde alkol kullanımı daha yaygın bulunmuştur ($p=0,003$). Kafein tüketimi ile vücut ağırlığı, beden kütle indeksi, yağ oranı, kas kütlesi ve diğer antropometrik ölçüler arasında istatistiksel olarak anlamlı ilişki saptanmamıştır ($p>0,05$). Sonuç olarak, kafein ve vücut kompozisyonu ilişkisi karmaşık olup, bireysel sağlık durumu, diyet ve fiziksel aktivite gibi faktörlerin bu ilişki üzerine etkileri olasıdır. Daha kapsamlı, uzun dönem müdahale çalışmaları gereklidir.

Anahtar kelimeler: Üniversite öğrencileri, kafein tüketimi, vücut kompozisyonu

Giriş

Kafein, dünya genelinde en yaygın tüketilen psikoaktif bileşiklerden biridir. Kahve, çay, enerji içecekleri, çikolata ve bazı takviyelerde doğal veya eklenmiş olarak bulunur (McGuire, 2014; Temple ve ark., 2017). Merkezi sinir sistemi üzerindeki uyarıcı etkileri sayesinde bilişsel performansı artırabilir ve fiziksel dayanıklılığı destekleyebilir (Heckman ve ark., 2010). Orta düzeyde kafein alımı genellikle güvenli kabul edilse de, aşırı tüketim kardiyovasküler rahatsızlıklar, uyku bozuklukları ve anksiyete gibi çeşitli sağlık sorunlarına yol açabilir (Alimyar ve ark., 2024; El-Nimr ve ark., 2019).

Avrupa Gıda Güvenliği Otoritesi (EFSA) tarafından 2015 yılında yayımlanan rapora göre, sağlıklı bireylerde günlük 400 mg'a kadar kafein alımı güvenli kabul edilmiştir. Ancak, özellikle genç bireylerde enerji içecekleri gibi ürünlerin yaygınlaşmasıyla birlikte kafein alımı kontrolsüz şekilde artabilmektedir. (EFSA Panel on Dietetic Products & Allergies, 2015; Rath, 2012).

Üniversite öğrencileri arasında kafein tüketiminin yaygın olduğu bilinmektedir (Kaya & Açar, 2021; Kharaba ve ark., 2022). Sağlık bilimleri üniversite öğrencileri ile yapılan bir çalışmada, öğrencilerin genellikle uyanıklık sağlama ve odaklanmayı artırma amacıyla tükettikleri belirlenmiştir (Kaya & Açar, 2021).

Kafein tüketiminin vücut kompozisyonu üzerindeki etkileri ise henüz net değildir. Bazı çalışmalar, kafein alımının yağsız vücut kütlesiyle pozitif yönde ilişkili olabileceğini öne sürmektedir. Bazı bulgular, kafein tüketiminin yağsız vücut kütlesi ile pozitif ilişkili olabileceğini, özellikle kadınlar ve genç bireylerde bu etkinin daha belirgin olabileceğini göstermektedir (Mattioli, 2025). Ancak bu ilişki yaş, cinsiyet, hormon düzeyleri ve genetik faktörler gibi çeşitli değişkenlerden etkilenmektedir.

Bu çalışmada, Beslenme ve Diyetetik Bölümünde öğrenim gören 18–25 yaş arası bekar kadın öğrencilerde kafein tüketimi ile vücut kompozisyonu arasındaki ilişkinin değerlendirilmesi amaçlanmıştır.

Yöntem

Çalışmanın Evren ve Örneklemi

Çalışma, 2025 yılı Ocak-Mart ayları arasında Amasya Üniversitesi Sağlık Bilimleri Fakültesi Beslenme ve Diyetetik Bölümü'nde öğrenim gören kadın öğrenciler ile yürütülmüştür. Araştırma örneklemi, 18-25 yaş aralığında olan bekar kadın öğrencilerden oluşmaktadır (n = 64). Katılımcıların kafein tüketim sıklığı, sosyodemografik özellikleri ve sağlıkla ilişkili verileri, araştırmacı tarafından geliştirilen bir anket formu aracılığıyla yüz yüze görüşme yöntemi ile toplanmıştır. Vücut kompozisyonu, Biyoelektrik İmpedans Analizi (BIA) yöntemiyle belirlenmiş ve antropometrik ölçümleri kaydedilmiştir. Çalışma, Amasya Üniversitesi Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu'ndan onay almıştır (onay tarihi: 09 Ocak 2025, karar no: 2024/172).

Antropometrik Ölçümler ve Vücut analizi

Katılımcıların vücut analizi Tanita BC 545 N Innerscan segmental vücut anazli cihazı ile, takı, kemer ve ağır giysiler çıkarıldıktan sonra, çıplak ayakla dik pozisyonda ve en az 8 saat açlık sonrası sabah saat 8:30-9:30 arasında gerçekleştirilmiştir. Ölçümler sırasında katılımcılardan cihaz platformunda çıplak ayakla durmaları ve el elektrotlarını tutmaları istenmiştir. Vücut analizi parametreleri; vücut ağırlığı (kg), vücut yağ oranı (%), vücut kas kütlesi (kg) ve vücut su oranı (%) parametrelerinden oluşmaktadır.

Antropometrik ölçümler boy uzunluğu (cm), beden kitle indeksi (BKİ), bel çevresi (cm), kalça çevresi (cm), boyun çevresi (cm) ve bel/kalça oranından oluşmaktadır. Tüm ölçümler normal eksalasyonla santimetre cinsinden kaydedilmiştir. Boy uzunluğu, ayaklar yan yana ve Frankfurt düzleminde ölçülmüş (Pekcan, 2008); boyun çevresi tiroid kıkırdağının en çıkıntılı yerinden, baş dik ve gözler karşıya bakacak şekilde esnek olmayan mezura ile ölçülmüştür (Jiang ve ark., 2017). Bel çevresi, göbek hizasında giysi olmadan; kalça çevresi ise bel ve uyluk arasındaki en geniş bölgeden esnek olmayan mezura ile alınmıştır (Saghafi-Asl ve ark., 2013). Bel/kalça oranı bel çevresinin kalça çevresine bölünmesiyle hesaplanmıştır. BKİ, vücut ağırlığının boy uzunluğunun karesine bölünmesiyle (kg/m^2) hesaplanmıştır.

Kafein miktarını hesaplanması

Kafein tüketim sıklığını değerlendirmek amacıyla, araştırmacı tarafından geliştirilen ve enerji içecekleri, kolalı içecekler, kahveler, çaylar ile çikolatalar gibi kafein içeren ürünleri kapsayan toplam 19 maddelik ayrıntılı anket formu tüketim sıklığı ve miktarı ile birlikte katılımcılara uygulanmıştır. Anket kapsamında yer alan ürünlerin kafein içerikleri, etiketli ürünler için ilgili markaların resmi internet sitelerinden temin edilmiş, diğer ürünlerde ise literatürden yararlanılmıştır (Rocha ve ark., 2022). Tüm bu veriler doğrultusunda bireylerin günlük kafein alım düzeyleri hesaplanmıştır. Kafein tüketimi önceki çalışmaya dayanarak **düşük (≤250 mg/gün)** ile **yüksek (>250 mg/gün)** olarak kategorize edilmiştir (Ramamoorthy ve ark., 2018).

İstatistiksel Analiz

Çalışma sonunda elde edilen veriler, nitel değişkenler için sayı (n) ve yüzde (%), nicel değişkenler için ise ortalama (x̄) ve standart sapma (SS) olarak gösterilmiştir. İstatistiksel analizler SPSS 24.0 (Statistical Package for the Social Sciences) programı kullanılarak yapılmıştır. Kategorik değişkenlerin karşılaştırılmasında Ki-kare (χ^2) testi, sürekli değişkenlerin karşılaştırılmasında Mann-Whitney U testi ve değişkenler arasındaki ilişkiyi değerlendirmek amacıyla ise Spearman sıra korelasyon analizi uygulanmıştır. Tüm istatistiksel değerlendirmeler %95 güven aralığında yapılmış ve anlamlılık düzeyi $p<0,05$ olarak kabul edilmiştir.

Bulgular

Çalışmaya katılan bireylerin yaş ortalaması 20,31 ± 1,85 olup, %95,3'ü herhangi bir diyet programı uygulamamakta ve takviye ürün kullanmamaktadır. Günlük ortalama su tüketimi 1,83 ± 0,69 L, kafein alımı ise 158,50 ± 213,58 mg olarak belirlenmiştir. Katılımcıların %90,6'sı düşük düzeyde kafein tüketmektedir. Kafein tüketim düzeyine göre gruplar arasında yaş, ikamet edilen yer, öğün atlama durumu, atlanan öğün türü, su tüketimi ve sigara kullanımı açısından anlamlı bir fark saptanmamıştır. Ancak, alkol kullanımının yüksek kafein tüketen grupta anlamlı düzeyde daha fazla olduğu belirlenmiştir (p=0,003) (Tablo 1).

ablo 1 Katılımcılara ait sosyo-demografik veriler

Demografik veriler	n (%)	**Düşük kafein ≤250mg/gün (n = 58)**	**Yüksek kafein >250mg/gün (n = 6)**	*p*
Yaş (x̄ ± SS)	20,31 ± **1,85**	20,31 ± 1,93	20,31 ± 1,93	0,769
Yaşanılan yer				
Ev	10 (15,6)	9 (15,5)	1 (16,7)	0,656
Yurt	54 (84,4)	49 (84,5)	5 (83,3)	
Öğün atlama				
Evet	55 (85,9)	49 (84,5)	6 (100,0)	0,387
Hayır	9 (14,1)	9 (15,5)	0 (0,0)	
Atlanan öğün				
Kahvaltı	21 (38,2)	17 (34,7)	4 (66,7)	
Öğle	33 (60,0)	31 (63,3)	2 (33,3)	0,309
Akşam	1 (1,8)	1 (2,0)	0 (0,0)	
Sigara kullanımı				
Evet	20 (31,3)	16 (27,6)	4 (66,7)	0,071
Hayır	44 (68,8)	42 (72,4)	2 (33,3)	
Alkol kullanımı				
Evet	9 (14,1)	5 (8,6)	4 (66,7)	**0,003**
Hayır	55 (85,9)	53 (91,4)	2 (33,3)	
Su tüketimi (x̄ ± SS)	1,83 ± **0,69**	1,85 ± 0,68	1,67 ± 0,88	0,562
Su tüketimi				
<1,5 L	15 (23,4)	13 (22,4)	2 (33,3)	
1,5–2 L	24 (53,1)	31 (53,4)	3 (50,0)	0,811
>2 L	15 (23,4)	14 (24,1)	1 (16,7)	
Toplam Kafein (mg), (x̄ ± SS)	158,50 ± **213,58**	96,31 ± 53,79	759,71 ± 251,41	**0,000**

Katılımcıların en fazla kafein aldığı kaynaklar sırasıyla siyah çay (33,54 ± 28,87 mg) ve Türk kahvesi (32,61 ± 75,90 mg) olmuştur. Enerji içecekleri, çikolatalar ve diyet içecekler ise kafein alımına en az katkıda bulunan kaynaklardır (Tablo 2).

Tablo 2 Ortalama kafein miktarları

Kafein kaynağı	Kafein miktarı
Siyah çay	33,54 ± 28,87
Türk kahvesi	32,61 ± 75,90
Espresso (soğuk)	24,57 ± 94,49
Espresso (sıcak)	22,85 ± 111,05
Instant kahve (sıcak)	13,24 ± 29,91
Bitter çikolata	12,40 ± 29,25
Instant kahve (soğuk)	4,96 ± 22,56
Orijinal kola	2,65 ± 4,47
Yeşil çay	2,54 ± 5,12
Soğuk çay	2,35 ± 7,71
Enerji içeceği	2,00 ± 9,22
Sütlü çikolata	1,75 ± 6,48
Orijinal Pepsi	1,20 ± 3,13
Sıcak çikolata	0,50 ± 1,00
Çikolata aromalı süt	0,41 ± 0,70
Diyet kola	0,35 ± 1,44
Bitki çayı	0,32 ± 0,58
Pepsi Max	0,21 ± 0,96
Diyet Pepsi	0,04 ± 0,16

Kafein tüketimi ile vücut kompozisyonu arasında istatistiksel olarak anlamlı bir ilişki saptanmamıştır ($p>0.05$). Spearman korelasyon katsayılarına göre en yüksek pozitif ilişki vücut yağ oranı ($r=0,128$) ve kalça çevresi ($r=0,129$) ile, en yüksek negatif ilişki ise su oranı ($r=–0,115$) ile gözlenmiştir; ancak bu ilişkiler istatistiksel olarak anlamlı bulunmamıştır.

Tablo 3 Kafein tüketim düzeylerine göre vücut kompozisyonu ölçümleri

Değişkenler	**Toplam**	**Kafein Tüketimi**			**Korelasyon**	
		Düşük kafein ≤250mg/day	**Yüksek kafein >250mg/day**	**p**	**r**	**p**
Vücut ağırlığı (kg)	60,17 ± 11,02	60,27 ± 11,11	59,20 ± 11,00	0,920	0,079	0,534
BKİ (kg/m²)	22,16 ± 3,66	22,16 ± 3,75	22,20 ± 2,97	0,866	0,103	0,417
Vücut yağ oranı (%)	26,31 ± 7,40	26,17 ± 7,60	27,72 ± 5,26	0,711	0,128	0,312
Kas kütlesi (kg)	41,08 ± 6,49	41,17 ± 6,67	40,23 ± 4,72	0,728	0,086	0,498
Su oranı (%)	54,80 ± 5,04	54,93 ± 5,17	53,52 ± 3,64	0,566	–0,115	0,368
Bel çevresi (cm)	72,63 ± 8,87	72,53 ± 8,65	73,50 ± 11,67	0,920	0,056	0,663
Kalça çevresi (cm)	97,86 ± 8,40	97,76 ± 8,55	98,83 ± 7,36	0,661	0,129	0,308
Boyun çevresi (cm)	30,67 ± 3,02	30,78 ± 3,10	29,67 ± 2,16	0,271	0,047	0,710
Bel/kalça oranı	0,74 ± 0,05	0,74 ± 0,05	0,74 ± 0,08	0,728	–0,026	0,840

Tartışma

Bu çalışmada üniversite öğrencisi kadın bireylerde kafein tüketimi ile vücut kompozisyonu parametreleri arasındaki ilişki incelenmiştir. Elde edilen bulgulara göre; yüksek ve düşük kafein tüketen gruplar arasında vücut ağırlığı, BKİ, vücut yağ oranı, kas kütlesi, su oranı, bel/kalça çevresi gibi parametrelerde istatistiksel olarak anlamlı bir fark saptanmamıştır. Aynı şekilde kafein tüketim miktarı ile bu değişkenler arasındaki korelasyon analizinde de anlamlı ilişkiler gözlemlenmemiştir.

Literatürde kafein tüketimi ve vücut kompozisyonu arasındaki ilişkiyi ele alan çalışmaların sonuçları oldukça karmaşıktır. Ramamoorthy ve ark. (2018) HIV'li bireylerde yürüttükleri çalışmada, daha yüksek kafein alımı daha düşük yağ kütlesi ile anlamlı şekilde ilişkili bulunmuş (b = -0,994, p = 0,042), ancak BKİ ve yağsız vücut kütlesi ile anlamlı bir ilişki saptanmamıştır. Bununla birilikte literatürdeki bazı çalışmalar bulgularımızı destekler niteliktedir (Ayhan ve ark., 2021; Malek ve ark., 2006; Williamson ve ark., 2018). Akut kafein tüketiminin vücut kompozisyonu üzerinde sadece önemsiz değişikliklere yol açtığı bildirilmiştir. Benzer şekilde, Malek ve ark. (2006)'ın sekiz haftalık müdahale çalışmasında, kafein takviyesine rağmen vücut ağırlığı veya kompozisyonunda anlamlı bir değişiklik izlenmemiştir. **Ayhan ve ark. (2021)**'ın erkek sporcularla gerçekleştirdiği çalışmada da (n=43; 19 futbolcu, 24 voleybolcu) kafein alımı ile vücut ağırlığı arasında istatistiksel olarak anlamlı bir iliki bulunmamıştır.

Diğer yandan, bazı müdahale çalışmaları kafein tüketiminin özellikle fazla kilolu ve obez bireylerde yağ kütlesini azaltabileceğini ve kas kütlesi yüzdesini artırabileceğini göstermektedir (Fernández-Cardero ve ark., 2024). Henn ve ark. (2023) orta düzeyde kafeinli kahve tüketiminin toplam vücut yağı, gövde yağı ve viseral yağ dokusunda azalmalarla ilişkili olduğunu belirtmiş, hayvan çalışmalarında ise kafeinin lipolizi uyararak yağ kütlesini azaltabileceği bildirilmiştir (Kobayashi-Hattori ve ark., 2005). Ayrıca, kafein alımındaki artışların uzun vadeli kilo alımında hafif bir azalma sağlayabileceği de raporlanmıştır (Lopez-Garcia ve ark., 2006). Bu bulgular, kafeinin vücut kompozisyonu üzerindeki etkilerinin bireyin sağlık durumu, alım süresi, alışılmış tüketim düzeyi ve diyet/egzersiz gibi diğer faktörlerle birlikte değerlendirilmesi gerektiğini göstermektedir. Çalışmamızda elde edilen sonuçların istatistiksel olarak anlamlı olmaması, örneklem büyüklüğünün sınırlı olması, bireylerin alışılmış kafein tüketim düzeylerinin farklılık göstermesi, fiziksel aktivite düzeyleri, beslenme alışkanlıkları ve genetik farklılıklar gibi faktörlerle ilişkili olabilir. Ek olarak, kafein tüketimi ile vücut yağ oranı arasında ilişki olduğunu bildiren çalışmalarda bu ilişkinin antrenman durumu ve serum kafein düzeylerinden bağımsız olabileceği vurgulanmıştır (Skinner ve ark., 2014) Bu nedenle daha büyük örneklemlerle, alışılmış tüketim düzeylerini ve diyet-fiziksel aktivite gibi etmenleri dikkate alan ileri düzey araştırmalara ihtiyaç vardır.

Kaynaklar

Alimyar, O., Nahiz, A., Monib, A. W., Baseer, A. Q., Hassand, M. H., Kakar, U. M., Sediqi, S., Sarwari, A., Hejran, A. B., & Rahimi, M. (2024). Coffea plant (Caffeine): Examining its impact on physical and mental health. *European Journal of Medical and Health Research*, *2*(2), 143-154.

Ayhan, A., Müftüoğlu, S., & Köse, B. (2021). Profesyonel futbol ve voleybol oyuncularının beslenme durumları, beslenme bilgi düzeyleri, kafein alımları ve vücut kompozisyonları arasındaki ilişkinin değerlendirilmesi. *Spor Bilimleri Dergisi*, *32*(3), 123-134.

EFSA Panel on Dietetic Products, N., & Allergies. (2015). Scientific opinion on the safety of caffeine. *EFSA Journal*, *13*(5), 4102.

El-Nimr, N. A., Bassiouny, S. H., & Tayel, D. I. (2019). Pattern of caffeine consumption among university students. *Journal of High Institute of Public Health*, *49*(3), 154-161.

Fernández-Cardero, Á., Sierra-Cinos, J. L., Bravo, L., & Sarriá, B. (2024). Consumption of a coffee rich in phenolic compounds may improve the body composition of people with overweight or obesity: Preliminary insights from a randomized, controlled and blind crossover study. *Nutrients*, *16*(17), 2848.

Heckman, M. A., Weil, J., & De Mejia, E. G. (2010). Caffeine (1, 3, 7-trimethylxanthine) in foods: a comprehensive review on consumption, functionality, safety, and regulatory matters. *Journal of food science*, *75*(3), R77-R87.

Henn, M., Babio, N., Romaguera, D., Vázquez-Ruiz, Z., Konieczna, J., Vioque, J., Torres-Collado, L., Razquin, C., Buil-Cosiales, P., & Fitó, M. (2023). Increase from low to moderate, but not high, caffeinated coffee consumption is associated with favorable changes in body fat. *Clinical Nutrition*, *42*(4), 477-485.

Jiang, J., Cui, J., Yang, X., Wang, A., Mu, Y., Dong, L., Wang, S., Gaisano, H., Dou, J., & He, Y. (2017). Neck circumference, a novel indicator for hyperuricemia. *Frontiers in physiology*, *8*, 965.

Kaya, P. S., & Açar, Y. (2021). Üniversite Öğrencilerinde Kafein Tüketiminin Değerlendirilmesi. *Samsun Sağlık Bilimleri Dergisi*, *6*(3), 595-606.

Kharaba, Z., Sammani, N., Ashour, S., Ghemrawi, R., Al Meslamani, A. Z., Al-Azayzih, A., Buabeid, M. A., & Alfoteih, Y. (2022). Caffeine consumption among various university students in the UAE, exploring the frequencies, different sources and reporting adverse effects and withdrawal symptoms. *Journal of nutrition and metabolism*, *2022*(1), 5762299.

Kobayashi-Hattori, K., Mogi, A., Matsumoto, Y., & Takita, T. (2005). Effect of caffeine on the body fat and lipid metabolism of rats fed on a high-fat diet. *Bioscience, biotechnology, and biochemistry*, *69*(11), 2219-2223.

Lopez-Garcia, E., van Dam, R. M., Rajpathak, S., Willett, W. C., Manson, J. E., & Hu, F. B. (2006). Changes in caffeine intake and long-term weight change in men and women. *The American journal of clinical nutrition*, *83*(3), 674-680.

Malek, M. H., Housh, T. J., Coburn, J. W., Beck, T. W., Schmidt, R. J., Housh, D. J., & Johnson, G. O. (2006). Effects of eight weeks of caffeine supplementation and endurance training on aerobic fitness and body composition. *The Journal of Strength & Conditioning Research*, *20*(4), 751-755.

Mattioli, A. V. (2025). Sex-specific impacts of caffeine on body composition: commentary on a retrospective cohort study. *Journal of the International Society of Sports Nutrition*, *22*(1), 2454633.

McGuire, S. (2014). Institute of Medicine. 2014. Caffeine in food and dietary supplements: examining safety—workshop summary. Washington, DC: the National Academies Press, 2014. *Advances in Nutrition*, *5*(5), 585-586.

Pekcan, G. (2008). Beslenme durumunun saptanmasi. *Diyet El Kitabi*, *726*, 67-141.

Ramamoorthy, V., Campa, A., Rubens, M., Martinez, S. S., Fleetwood, C., Stewart, T., Liuzzi, J. P., George, F., Khan, H., & Li, Y. (2018). Caffeine Intake and Its Association with Body Composition Measures and Macronutrient Intakes in People Living with HIV in the Miami Adult Studies on HIV Cohort. *Journal of caffeine and adenosine research*, *8*(1), 10-17.

Rath, M. (2012). Energy drinks: what is all the hype? The dangers of energy drink consumption. *Journal of the American Association of Nurse Practitioners*, *24*(2), 70-76.

Rocha, P. L. d. A., Lima, A. L. C., Saunders, B., & Reis, C. E. G. (2022). Development of a caffeine content table for foods, drinks, medications and supplements typically consumed by the Brazilian population. *Nutrients*, *14*(20), 4417.

Saghafi-Asl, M., Pirouzpanah, S., Ebrahimi-Mameghani, M., Asghari-Jafarabadi, M., Aliashrafi, S., & Sadein, B. (2013). Lipid profile in relation to anthropometric indices and insulin resistance in overweight women with polycystic ovary syndrome. *Health promotion perspectives*, *3*(2), 206.

Skinner, T. L., Jenkins, D. G., Leveritt, M. D., McGorm, A., Bolam, K. A., Coombes, J. S., & Taaffe, D. R. (2014). Factors influencing serum caffeine concentrations following caffeine ingestion. *Journal of science and medicine in sport*, *17*(5), 516-520.

Temple, J. L., Bernard, C., Lipshultz, S. E., Czachor, J. D., Westphal, J. A., & Mestre, M. A. (2017). The safety of ingested caffeine: a comprehensive review. *Frontiers in psychiatry*, *8*, 80.

Williamson, C. M., Nickerson, B. S., Bechke, E. E., McLester, C. N., & Kliszczewicz, B. M. (2018). Influence of acute consumption of caffeine vs. placebo over Bia-derived measurements of body composition: a randomized, double-blind, crossover design. *Journal of the International Society of Sports Nutrition*, *15*(1), 7.

CHARACTERIZATION OF VOLATILE PROFILES IN CHERRY FRUITS USING ELECTRONIC NOSE (E-NOSE) AND HS-SPME-GC-MS

Aliza Naeem

Bushra Niaz

Farhan Saeed

Muhammad Afzaal

Muhammad Bilal Hussain

Department of Food Sciences, Government College University Faisalabad, Pakistan

Marwa Waheed

Department of Food Science Technology, Riphah International University Faisalabad, Pakistan

Abstract

Aroma has a profound effect on the sensory character and consumer acceptance of sweet cherries. This research conducted a wide screening of volatile compounds from 37 cherry genotypes with an electronic nose (E nose) in conjunction with headspace solid-phase microextraction gas chromatography–mass spectrometry (HS SPME GC MS). 363 volatile compounds were identified and distributed into 14 chemical classes. Terpenoids, esters, and alcohols were the three dominant classes by content. Cultivar-specific variations arose: "Saylor" showed the greatest volatile content at 76.98 $\mu g \cdot g^{-1}$, whereas "Minnie Royal" contained the lowest content at 67.27 $\mu g \cdot g^{-1}$. Out of the volatiles, 51 major compounds—of which 1 nonen 3 one, (E) 2 nonenal, and 2,4 nonadienal were top contributors to aroma profiles—were determined as major contributors to aroma profiles. Multivariate analyses through principal component analysis (PCA) and E nose sensor outputs traced out different odor signatures, with "Cao5" cultivar standing out prominently due to a distinct aroma pattern. The combination of E nose quick detection and HS SPME GC MS description offers a robust platform for rapid, precise flavor profiling and cultivar discrimination. They provide the foundation for future breeding programs that target improved sensory attractiveness and can aid industry quality control and cultivar selection efforts based on flavor.

Keywords:

Volatile compounds, Electronic nose (E nose), HS SPME GC MS, Sweet cherry aroma, Cultivar differentiation

ENHANCEMENT OF BIOACTIVE COMPOUND SYNTHESIS IN AROMATIC AND MEDICINAL PLANTS BY ENDOPHYTIC MICROORGANISMS: A REVIEW

Hamza EL KISSANY

Biotechnology and Sustainable Development of Natural Resources Unit, Polydisciplinary Faculty of Beni Mellal, Sultan Moulay Slimane University, Beni Mellal, Morocco.

Hicham EL-BOUKHARY

Biotechnology and Sustainable Development of Natural Resources Unit, Polydisciplinary Faculty of Beni Mellal, Sultan Moulay Slimane University, Beni Mellal, Morocco.

Hicham EL KISSANI

Biotechnology and Sustainable Development of Natural Resources Unit, Polydisciplinary Faculty of Beni Mellal, Sultan Moulay Slimane University, Beni Mellal, Morocco.

Adil LAAZIZ

Laboratory of Biotechnology, Environment, Agri-food and Health, Faculty of Sciences Dhar El Mahraz, Sidi Mohamed Ben Abdellah University, Fez, Morocco.

Abdelouahed HAJJAJI

Biotechnology and Sustainable Development of Natural Resources Unit, Polydisciplinary Faculty of Beni Mellal, Sultan Moulay Slimane University, Beni Mellal, Morocco.

Laboratory of Biotechnology, Environment, Agri-food and Health, Faculty of Sciences Dhar El Mahraz, Sidi Mohamed Ben Abdellah University, Fez, Morocco.

ABSTRACT

Aromatic and medicinal plants are a valuable source of bioactive compounds used in various fields, including pharmacology, cosmetics, the agri-food industry, and agriculture. Recently, interest in endophytic microorganisms such as bacteria and fungi that live inside plant tissues without causing harm has significantly increased. These microorganisms play a key role in modulating the secondary metabolism of host plants, contributing to the increased production of bioactive compounds. This symbiotic interaction can stimulate the synthesis of substances such as alkaloids, flavonoids, terpenes, and phenols, often in response to biotic or abiotic stress. In addition to enhancing plant resistance to pathogens and adverse environmental conditions, endophytes can also improve plant growth. Several studies have demonstrated the ability of certain endophytic strains to produce valuable metabolites themselves, opening up promising prospects in biotechnology. This work aims to explore the potential of endophytes as promoters of secondary metabolite biosynthesis in aromatic and medicinal plants, highlighting plant-microorganism interaction mechanisms and associated biotechnological perspectives.

Keywords: Aromatic and medicinal plants, agriculture, endophytic microorganisms, bacteria, Fungi, bioactive compounds, secondary metabolites,

FOOD ADDITIVES USED IN BREAKFAST CEREALS: TECHNOLOGICAL FUNCTIONS, HEALTH EFFECTS AND RECOMMENDATIONS

KAHVALTILIK GEVREKLERDE KULLANILAN GIDA KATKI MADDELERİ: TEKNOLOJİK İŞLEVLER, SAĞLIK ETKİLERİ VE ÖNERİLER

PhD Student, Nazmiye ÇEKİM

Atatürk University, Graduate School Natural and Applied Sciences, Department of Food Engineering, Erzurum, Turkey

ORCID ID: https://orcid.org/0000-0002-6786-7843

Prof. Dr. Songül ÇAKMAKÇI

Atatürk University, Faculty of Agriculture, Department of Food Engineering, Erzurum, Turkey
ORCID ID: https://orcid.org/0000-0003-0334-5621

ABSTRACT

Breakfast is one of the most important meals of the day, and nutritional recommendations stipulate that dietary fat and cholesterol intake should be reduced and that calorie intake from complex carbohydrates should be increased. Therefore, owing to their ease of preparation, high fiber content, and vitamin and mineral supplementation, breakfast cereals are emerging as a healthy breakfast option, and their consumption is steadily increasing. The variety of breakfast cereals, which hold a significant place in modern eating habits, is constantly expanding. These grain-based products (such as corn, wheat, rice, oats, and barley) contain certain amounts of nutrients, such as starch, protein, fatty acids, minerals, vitamins B and E, and various phytochemicals, and their energy values vary.

Breakfast cereals can be classified as traditional (hot) cereals, which require more cooking or heating before consumption, and ready-made (cold) cereals, which can be consumed straight from a box or with the addition of milk. Cold cereals are preferred. The most important raw material in any type of breakfast cereal is grain. Most breakfast cereals contain other ingredients, such as salt, yeast, sweeteners, flavorings, colors, vitamins, minerals, and preservatives. This study examines the food additives used for various purposes during the production of breakfast cereals, their functions, and their potential health effects. For this purpose, information is provided on the most commonly used sweeteners, colorants, preservatives, emulsifiers and stabilizers, flavoring/enhancing agents, and enriching vitamins and minerals. Furthermore, the aim is to raise awareness of heavy metal contamination during the cultivation of raw grains and to provide warnings and recommendations for the government, producers, and consumers.

Key Words: Breakfast cereals, Food additives, Nutrition, Food safety, Health

ÖZET

Kahvaltı günün en önemli öğünlerinden olup beslenme önerilerinde diyetle alınan yağ ve kolesterol alımının azaltılması ve kompleks karbonhidratlardan alınan kalori alımının artırılması gerektiği belirtilmektedir. Bu nedenle; pratik hazırlanabilir oluşları, yüksek lif içeriği ve vitamin-mineral takviyesiyle zenginleştirilmiş bileşimleri nedeniyle kahvaltılık gevreklerin sağlıklı bir kahvaltı seçeneği olarak öne çıktığı ve tüketimlerinin giderek arttığı görülmektedir. Modern beslenme alışkanlıklarında önemli bir yer tutan kahvaltılık gevreklerin ürün çeşitliliği her geçen gün artmaktadır. Tahıl temelli (mısır, buğday, pirinç, yulaf ve arpa gibi) bu ürünler; nişasta, protein, yağ asitleri, mineraller, B ve E vitaminleri ile çeşitli fitokimyasallar vb. besin öğelerini belirli oranlarda içermekte ve enerji değerlerinde çeşitlilik olmaktadır.

Kahvaltılık gevrekler, 1. tüketilmeden önce daha fazla pişirme veya ısıtma gerektiren geleneksel (sıcak) gevrekler ve 2. kutudan veya süt ilavesiyle tüketilebilen hazır (soğuk) gevrekler olarak sınıflandırılabilir. Soğuk gevrekler daha çok tercih edilmektedir. Herhangi bir çeşitteki kahvaltılık gevrekte en önemli hammadde tahıldır. Çoğu kahvaltılık gevrek, tuz, maya, tatlandırıcılar, aroma vericiler, renklendiriciler, vitaminler, mineraller ve koruyucular gibi başka bileşenler içermektedir.

Bu çalışmada, kahvaltılık tahılların üretimi sırasında çeşitli nedenlerle kullanılan gıda katkı maddeleri, fonksiyonları ve olası sağlık etkileri incelenmiştir. Bu amaçla en çok kullanılan tatlandırıcılar, renklendiriciler, koruyucular, emülgatör ve stabilizörler, aroma ve lezzet veren/artıran maddeler, zenginleştirme vitaminleri ve mineraller hakkında bilgi verilmiştir. Ayrıca hammadde tahılların yetiştirilmesi sırasındaki ağır metal kontaminasyonu ve uyarılar yapılarak devlet, üreticiler ve tüketiciler için öneriler verilerek konuya dikkat çekmek amaçlanmıştır.

Anahtar kelimeler: Kahvaltılık tahıllar, Gıda katkı maddeleri, Beslenme, Gıda güvenliği, Sağlık

Giriş

Şehirleşme ile birlikte beslenme alışkanlıkları da önemli ölçüde dönüşmüş/dönüşmektedir. Küresel kültürün etkisi ve pratik yaşamanın gereği olarak geleneksel sofralarda yer almayan pek çok hazır gıda; kolaylıkla hazırlanması, ekonomik oluşu ve doyuruculuğu nedeniyle günlük beslenmede daha sık tercih edilmektedir (Budagova, 2022). Beslenme uzmanları, kahvaltının günün en önemli öğünlerinden biri olduğunu ve beslenme önerilerinde diyetle alınan yağ ve kolesterol alımının azaltılması ve kompleks karbonhidratlardan alınan kalori alımının artırılması gerektiğini belirtmektedir (Rehal vd., 2012). Bu süreçte, kahvaltılık gevrekler de özellikle sabah kahvaltılarında giderek yaygınlaşan bir tüketim alışkanlığı haline gelmiştir. Bu ürünlere olan talep giderek artmakta ve bu durum araştırmacıları ürün ve lezzette daha fazla çeşitlendirme ile kaliteli ürünler geliştirmeye teşvik etmektedir. 5-12 yaş arası çocuklarda, haftada üç veya daha fazla kez hazır kahvaltılık gevrek yiyenlerin, hiç kahvaltılık gevrek yemeyenlere göre daha az yağ ve kolesterol, ancak daha fazla lif, B, A ve D vitamini tükettiği bildirilmiştir (Rehal vd., 2012). Pratik hazırlanabilir oluşları, yüksek lif içeriği ve vitamin-mineral takviyesiyle zenginleştirilmiş bileşimleri nedeniyle kahvaltılık gevrekler, sağlıklı bir kahvaltı seçeneği olarak öne çıkmaktadır. Tahıl temelli bu ürünler; nişasta, protein, yağ asitleri, mineraller, B ve E vitaminleri ile çeşitli fitokimyasallar vb. besin öğelerini belirli oranlarda içermekte ve enerji değerlerinde çeşitlilik olmaktadır (Budagova, 2022). Bu nedenlerle modern beslenme alışkanlıklarında önemli bir yer tutan kahvaltılık gevreklerin lezzet maddeleri ve çeşitli katkılarla ürün çeşitliliği de her geçen gün artmaktadır. Şekerle kaplanmış, mikro besinlerle zenginleştirilmiş veya meyvelerle zenginleştirilmiş şişirilmiş, pullanmış, parçalanmış veya ekstrüde edilmiş mısır, buğday, pirinç, yulaf veya diğer tahıllar genellikle kahvaltılık gevrek olarak adlandırılır (Rehal vd., 2012).

Kahvaltılık gevrekler, 1. tüketilmeden önce daha fazla pişirme veya ısıtma gerektiren geleneksel (sıcak) gevrekler ve 2. kutudan veya süt ilavesiyle tüketilebilen hazır (soğuk) gevrekler olarak sınıflandırılabilir. Soğuk gevrekler daha çok tercih edilmektedir. Herhangi bir çeşitteki kahvaltılık gevrekte en önemli hammadde tahıldır. Çoğu kahvaltılık gevrek, tuz, maya, tatlandırıcılar, aroma vericiler, renklendiriciler, vitaminler, mineraller ve koruyucular gibi başka bileşenler içerir (Rehal vd., 2012).

Kahvaltılık Gevrek Türleri/Çeşitleri

Tahıl bazlı kahvaltılık gevrekler, kullanım şekillerine göre iki ana gruba ayrılmaktadır: tüketime hazır ve pişirme gerektiren gevrekler. Tüketime hazır olanlar; tahıl gevrekleri, şişirilmiş ürünler, granüller, parçalanmış ve ekstrüde edilmiş tahılları kapsarken;

1. Geleneksel Kahvaltılık Tahıllar, Pişirmeye hazır tahıllar

Bu tahıllar, tüketilmeden önce pişirilmesi veya ısıtılması gereken tahıllardır (Rehal, 2012). Bunlar yulaf ezmesi, buğday unu ve mısır kırması gibi ön işlem görmüş, ancak tüketim öncesi pişirme gerektiren ürünleri içermektedir (Budagova, 2022). Piyasadaki geleneksel tahılların neredeyse tamamı (%99), yulaf (%81'den fazlası) ve irmik (yaklaşık %18) kullanılarak üretilen ürünlerdir.

- Yulaf gevrekleri,
- Buğday gevrekleri,
- Mısır gevreği.

2. Tüketime Hazır Tahıllar (Soğuk tahıllar)

Hazır kahvaltılık gevrekler, aşağıdaki temel gevrek türlerine göre gruplandırılarak tanımlanabilir (Rehal, 2012):

- Pul gevrekler
- Şişirilmiş gevrekler
- Rendelenmiş gevrekler.

Tahıl tanelerinin şişirilmesi ve patlatılması eski bir geleneksel işlemdir. Bu şişirilmiş ürünler iyi bir atıştırmalık yiyecek olarak kabul edilmektedir (Swarnakar vd., 2022). Kahvaltılık gevrek çeşitleri; yulaf ezmesi, mısır gevreği, meyveli müsli, glutensiz yulaf ezmesi gibi ürünlerdir Müsli; birçok tahıl, kuruyemiş, kuru meyve ve çeşitli tohumlardan oluşan kahvaltılık gevrek olup lif ve omega-3 yağ asidi içeriği zengindir (Budagova, 2022). Hazır kahvaltılık gevreklerin kimyasal kompozisyonu, bilgi amacıyla Tablo 1'de verilmiştir.

Tablo 1. Tahıl ürünlerinin kimyasal kompozisyonu (%) (Rehal, 2012)

Ürün Tipi/çeşidi	Nem	Nişasta	Protein	Lif	Yağ	Şeker	Tuz
Pul gevrekler	3.0-8.0	40-80	8-16	4-25	4.0-8.0	0-28	0.25-1.10
Şişirilmiş tahıllar	3.5-6.0	32-80	7-15	2-8	0-4.0	0-55	0.0-0.50
Parçalanmış tahıllar	2.5-6.5	45-88	4-20	7-11.5	0-7.6	0-23	0.0-1.14

Kahvaltılık Gevreklerde Kullanılan Gıda Katkı Maddeleri ve Sağlığa Etkileri

Kahvaltılık gevrekler, özellikle şehirleşmiş ve hızlı yaşam tarzına sahip toplumlarda kahvaltı öğünü için önemli bir alternatif haline gelmiştir. Bu ürünlerin raf ömrü, lezzet ve dokusunu iyileştirmek için çok sayıda katkı maddesi kullanılmaktadır. Literatürde araştırması sonucu, katkı maddelerinin büyük çoğunluğunun yasal sınırlar dahilinde kullanıldığında güvenli olduğu kabul edilmektedir

(EFSA, 2013; FDA, 2021). Bununla birlikte, özellikle çocuklar olmak üzere hassas tüketici gruplarında katkı maddelerine uzun süreli maruziyetin potansiyel etkileri konusunda bilimsel endişeler devam etmektedir (WHO, 2023; Chassaing vd., 2015). Kahvaltılık gevrek ürünlerinde kullanılan katkı maddeleri hem teknolojik gereklilikleri karşılamak hem de duyusal kaliteyi artırmak amacıyla formülize edilmektedir.

Bu çalışmada, gevreklerde yer alan katkılar, fonksiyonlarına göre değerlendirilmiştir: tatlandırıcılar, renklendiriciler, koruyucular, emülgatörler, kıvam artırıcılar/stabilizörler, vitamin-mineral takviyeleri ve aroma ve lezzet maddeleri.

Tatlandırıcılar: Tatlandırıcılar, çocuk ürünlerinde yaygın olarak kullanılmakta, ilave şeker (sakkaroz, glukoz-fruktoz şurubu) enerji değeri ve obezite riski açısından sorun oluşturabilmektedir (International Agency for Research on Cancer (IARC, 2023). Alternatif olarak kullanılan yapay tatlandırıcılar (sodyum sakkarin, E954; aspartam, E951 gibi), kalori içermez ancak uzun vadeli etkileri tartışmalıdır. Yapay tatlandırıcıların diyabet, metabolik bozukluk ve mikrobiyota üzerindeki etkilerinin netleşmemiş olduğu ve dikkatle izlenmesi gereken bir alan olduğu rapor edilmiştir (World Health Organisation, WHO, 2023). Dünya Sağlık Örgütü (WHO, 2023) bu katkıların vücut ağırlığı kontrolünde uzun süreli yarar sağlamadığını belirtmiştir. Aspartam, insan gıda tedarikinde en çok incelenen yapay tatlandırıcı olup FDA bilim insanları, aspartamın onaylı koşullar altında kullanıldığında herhangi bir güvenlik endişesi oluşturmadığını belirtmiş (FDA, 2025), IARC ise aspartamı “muhtemel kanserojen” olarak sınıflandırmıştır (IARC, 2023), EFSA ve FDA gibi kurumlar “bir kişinin yaşamı boyunca her gün tüketilmesinin güvenli olduğu düşünülen bir madde miktarı” olarak tanımlanan ADI değerinden daha az kullanıldığında aspartamın güvenli olduğunu bildirmişlerdir (EFSA, 2013; FDA, 2025). Aspartam ısıya dayanıklı değildir ve ısıtıldığında tatlılığını kaybeder, bu nedenle genellikle unlu mamullerde kullanılmaz, ancak soğuk kahvaltılık gevreklerde kullanılabilir (FDA, 2025).

Renklendiriciler: Renklendiriciler, çocuk ürünlerinde yaygın olarak kullanılmaktadır. Ancak sentetik boyaların kullanımı özellikle çocuk ürünlerinde sınırlandırılmalıdır. Azo boyalarının popülaritesi, bol miktarda canlı renkle sonuçlanan kimyasal çok yönlülüklerine dayanmaktadır. Ayrıca, düşük maliyetlidirler, kolayca erişilebilirler, stabildirler, tutarlıdırlar ve herhangi bir tat veya hoş olmayan kokuya sahip değildirler (Barciela vd., 2023). Bununla birlikte, gıda azo boyalarının olumsuz sağlık etkileri olabilir (Monisha vd., 2023). ADI sınırlarının altında, yapay boyaların alımı güvenlidir, ancak, daha yüksek dozlar, özellikle çocuklarda sağlık sorunlarına neden olabilir. Bildirilen olası sağlık sorunları arasında alerji, dikkat eksikliği hiperaktivite bozukluğu (DEHB), astım, sitotoksisite ve genotoksisite bulunmaktadır (Barciela vd., 2023). Sentetik azo boyalar (E102, E110, E129 vb.), özellikle çocuk ürünlerinde sık kullanılır. AB ve Türkiye’de azo boyalarının kullanıldığı ürün etiketlerinde “çocukların dikkat ve aktivitesi üzerinde olumsuz etkiler olabilir” uyarısı zorunlu olmuştur (EFSA, 2013; Türk Gıda Kodeksi Gıda Katkı Maddeleri Yönetmeliği, 2023). ABD’de bu yönde bir etiket uyarısı bulunmamaktadır (FDA, 2021). Gıda sanayisinde doğal renklendiricilerin kullanımı teşvik edilerek tüketici sağlığı korunmalıdır (Shahidi ve Zhong, 2010).

Koruyucular: Gevreklerde mikrobiyal bozulma riski düşük olsa da yağların oksidasyonunu önlemek için BHA – E320, BHT – E321 gibi bazı antioksidanlar eklenir. Oksidasyona karşı yaygın kullanılan BHA ve BHT gibi sentetik antioksidanların (Çakmakçı, 2022), hayvan deneylerinde tümör oluşumları ile ilişkilendirildiği bildirilmektedir. Her ne kadar insanlara ait net kanıtlar sınırlı olsa da bunlara alternatif olarak doğal antioksidanların tercih edilmesi daha güvenli bir yaklaşımdır (Shahidi, ve Zhong, 2010). GRAS statülerine rağmen, BHA ve BHT, özellikle yüksek dozlarda tüketildiğinde veya uygulandığında potansiyel sağlık riskleriyle ilişkilendirilmiştir. Uzun süreli maruz kalmanın üreme toksisitesi, hormon bozuklukları ve kanser gibi sağlık sorunlarına yol açtığı bildirilmektedir (Environmental Working Group, EWG, 2025). BHA, IARC tarafından “olası insan kanserojeni” olarak sınıflandırılmıştır (IARC, 2023). Ancak EFSA ve FDA gibi kuruluşlar, bu katkıların belirlenen maksimum dozlarda güvenli olduğunu ifade etmektedir (EFSA, 2013; FDA, 2021; EWG, 2025).

Emülgatörler: Lesitin (E322), mono-digliseritler (E471), polisorbat-80 (E433) gibi katkılar; homojen yapı, kaplama stabilitesi ve lezzet dağılımı sağlamak için kullanılır. Son yıllarda bazı emülgatörlerin (özellikle CMC ve E433) bağırsak mikrobiyotası üzerinde olumsuz etkiler ve glukoz intoleransı gibi sonuçlara işaret ettiği hayvan deneyleriyle gösterilmiştir (Chassaing vd., 2015). Ancak bu bulgular insanlar için henüz yeterli kanıt teşkil etmemektedir. Emülgatörler ve katkı karışımlarının uzun süreli sağlık etkilerini değerlendiren epidemiyolojik çalışmalar artırılmalıdır (Chassaing vd., 2015).

Stabilizörler, kıvam artırıcılar: Ksantan zamkı (E415), guar zamkı (E412), karragenan (E407) gibi stabilizörler, ürün dokusunu dengelemek ve paketleme sırasında kırılmayı önlemek amacıyla eklenir. Karragenan’ın yüksek dozlarda kolit benzeri inflamasyonlara yol açabileceği hayvan çalışmaları bulunmakla birlikte, EFSA ve FDA bu katkıyı genel gıdalarda güvenli kabul etmektedir (FDA, 2021). AB ise bebek mamalarında tedbir olarak yasaklamıştır (European Commission, 2011).

Vitamin-mineral takviyeleri: Fortifikasyon amacıyla eklenen vitaminler (B1, B3, B6, folik asit) ve mineraller (demir, çinko) bunlarla ilgili yetersizliklerin önlenmesinde yararlıdır. Kahvaltılık gevreklerde zenginleştirme seviyesindeki artış, tüketicilerin multivitamin tabletlerini, yüksek oranda zenginleştirilmiş bir gevrek markasıyla değiştirmelerini sağlayabileceği belirtilmektedir (Rehal vd., 2012). Ancak çocukların yüksek dozda fortifiye ürün tüketmesi bazı mikro besinlerde tolere edilebilir üst alım düzeylerinin (ADI) aşılmasına neden olabilir.

Aroma ve lezzetlendiriciler: Vanilin, malt ekstraktı ve çilek aroması gibi katkılar, ürüne lezzet kazandırmak için eklenir. Genellikle ppm düzeyinde kullanıldıklarından sağlık açısından doğrudan etkileri sınırlıdır. Ancak bazı bireylerde aroma kimyasallarına karşı duyarlılık bildirilmiştir (FDA, 2021). Gıda sanayisinde doğal aroma ve lezzet maddelerinin kullanımı teşvik edilmelidir (Shahidi ve Zhong, 2010; Çakmakçı, 2022).

Avrupa Birliği, 1333/2008/EC sayılı tüzük ile katkı maddelerinin hangi gıdalarda hangi dozda kullanılabileceğini düzenlemekte ve etiketleme kuralları koymaktadır. Türkiye’de Türk Gıda Kodeksi Gıda Katkı Maddeleri Yönetmeliği ile, ABD’de ise katkı maddeleri GRAS kriterlerine göre sınıflandırılır ve FDA tarafından düzenlenir. Özellikle tatlandırıcılar, renklendiriciler ve antioksidanlar gibi hassas katkı grupları için ulusal düzenlemeler titizlikle uygulanmaktadır (FDA, 2021). Kısacası özellikle çocuklara yönelik kahvaltılık ürünlerde kullanılan şeker, yapay tatlandırıcı ve sentetik boya kullanımı sınırlanmalı veya alternatif doğal katkılarla değiştirilmelidir (McCann vd., 2007). Tüketicilerin katkı maddeleriyle ilgili farkındalığı artırılmalı; özellikle ebeveynler, çocuk ürünlerini alırken etiketindeki içerik dikkatle incelemelidir.

Tablo 2’de kahvaltılık gevreklerde kullanılan bazı katkı maddeleri; kullanım amaçları, sağlıkla ilgili özet değerlendirmeler ve Türkiye/AB/ABD mevzuatlarına göre yasal durumlar verilmiştir.

Tablo 2. Kahvaltılık tahıllarda kullanılan bazı gıda katkı maddeleri / zenginleştirme bileşenleri

Gıda Katkı Maddeleri Sınıfı	**Kullanım Amacı**	**Örnek Katkılar ve E Kodları**	**Sağlık ile İlgili Notlar**	**Mevzuat Notları (Türkiye/AB/ABD)**	**Kaynak**
Tatlandırıcılar	Şeker tadı vermek; şekere ikame, kalori düşürmek	Sakkaroz, HFCS, Aspartam (E951), Stevia (E960)	Obezite ve diyabet riski; aspartam FDA (2025) normal sınırlar içinde güvenli	TR/AB'de sınırlı; Aspartam için fenilketonuri uyarısı zorunlu. ABD'de ADI belirlenmiştir	(IARC, 2023; FDA, 2025)
Renklendiriciler	Görünüşü cazip hale getirmek, karakteristik renk vermek.	Tartrazin (E102), Karmosin (E122), β-karoten (E160a)	Hiperaktivite, alerji riski; E102-E129 için dikkat önerilir	AB: E102, E129 vb. için etiket uyarısı zorunlu; ABD'de uyarı yok	(EFSA, 2009)
Koruyucular	Raf ömrünü uzatmak: mikrobiyal bozulmayı ve yağların oksidasyonunu önlemek	BHA (E320), BHT (E321), Askorbik asit (E300)	Yüksek dozda tümör/hormonal etki; BHA	TR/AB: En çok 200 mg/kg; ABD: BHA ≤200 ppm, etikette belirtme zorunlu	IARC 2B sınıfı
Emülgatörler	Yağ ve su fazını karıştırmak; homojen doku, parlak kaplama sağlamak	Lesitin (E322), E471, Polisorbat 80 (E433)	Bazı emülgatörler (E433) bağırsak florasını etkileyebilir	TR/AB: Onaylı listede; ABD'de GRAS listesi, alerjen kaynağı belirtilmeli	(Chassaing vd., 2015)
Kıvam artırıcılar	İstenen kıvamı oluşturmak, karışımı stabilize etmek, parçaları bir arada tutmak	Guar zamkı (E412), Ksantan zamk (E415), Karragenan (E407)	Karragenan bazı araştırmalarda kolit ile ilişkilendirilmiştir	TR/AB: Bebek ürünlerinde kısıtlama; ABD: GRAS ancak etiket zorunlu	
Aroma ve lezzet maddeleri, lezzet artırıcılar	Özgün tat ve koku kazandırmak, lezzeti artırmak	Vanilin, Diasetil, Meyve özütleri, MSG (E621)	Düşük dozlarda güvenli; hassas bireylerde baş ağrısı/mide ağrısı	TR/AB: Aroma yönetmeliği kapsamında izlenir	
Vitamin-mineral takviyeleri	Ürünün besin değerini artırmak, eksiklikleri önlemek (zenginleştirme)	A, D, E, K; B1-B12; Demir, Çinko, Kalsiyum, İyot	Fazla vitamin/mineral toksisite yapabilir (özellikle A vitamini, çinko)	TR: Gönüllü zenginleştirme, AB: 1925/2006/EC sınırlar var, ABD: yaygın zenginleştirme	

Kahvaltılık Gevreklerin Zenginleştirilmesi

Tahıl taneleri bazı vitamin ve mineraller için iyi bir kaynak oluştursa da bunların işlenmesi sırasında bazı besin maddelerinde kayıplar oluşmaktadır. Bu nedenle hem kaybolanı ilave etmek hem de zenginleştirme amacıyla gevreklere bazı ilaveler yapılmaktadır. Zenginleştirme uygulamalarında en önemli nokta, hangi besin ögesinin ne miktarda katılacağının tespitidir. Spesifik besin ögeleri ve miktarları üründen ürüne değişmekle birlikte, zenginleştirme ile elde edilen ürünlerin bu besin ögelerini günlük alınması gereken miktarlar açısından en az %25 oranında karşılaması gerekmektedir. Bazı özel durumlarda bu oran %45'e kadar çıkabilmektedir (Akbaş ve Özkaya, 2006). Kahvaltılık gevrekler genellikle vitamin ve minerallerle zenginleştirilir. Zenginleştirme nedenleri; 1. gevrek yapımında kullanılan tahıl kaynaklarının çoğunun, özünü çıkarmak için öğütülmüş ve bu nedenle de vitamin içeriklerinin azalmış olması, 2. tüketicilerin gevreklerin dengeli bir kahvaltının "parçası" olduğu yönündeki önerileri genellikle görmezden gelmeleri nedeniyle gevreklerle dengeli bir kahvaltı olmasını istemeleridir (Rehal, 2012). Zenginleştirme ile üretim sırasında kaybolan bir besin maddesi takviye edilebildiği gibi, üründe bulunmayan bir besin maddesi de ilave edilebilmektedir (Akbaş ve Özkaya, 2006). Zenginleştirmede ürünün rengi, kokusu ve lezzeti olumsuz etkilenmemeli ve ilave edilen besin ögeleri stabil olup, üretim ve depolama sırasında meydana gelen kayıpları telafi edebilecek düzeylerde katılmalıdır. Zenginleştirilmiş ürünlere doğru ilerleyen gidişat, gelişmiş ülke toplumlarının çeşitli kesimleri tarafından yönlendirilmekte olup hem tıp ve düzenleyici topluluklar hem de gıda işleyicileri, tüketici grupları ve medyadan destek görmektedir (Rehal, 2012). Kahvaltılık gevreklerde zenginleştirme seviyesindeki artış, tüketicilerin multivitamin tabletlerini, yüksek oranda zenginleştirilmiş bir gevrek markasıyla değiştirmelerini sağlayabileceği belirtilmektedir (Rehal, 2012). Hazır tahıl gevreği tüketen çocukların, tüketmeyenlere kıyasla günlük A, B6 vitamini, tiamin, niasin, riboflavin ve demir alımlarının daha yüksek olduğu gösterilebilir. Karbonhidrat, lif, tiamin, riboflavin, folat, kalsiyum, demir ve A, C ve E vitaminleri alımının, kahvaltılık gevrek tüketen tüm yaş gruplarındaki kişilerde, tüketmeyenlere kıyasla daha yüksek olduğu bulunmuştur. Son üründe hangi besin maddelerinin gerekli olduğuna karar verildikten sonra, gıda mühendisleri/teknologları bu işi tamamlamakla kalmayıp, aynı zamanda şu hususları dikkate almalıdır (Rehal, 2012);

- Ürünün koku, tat veya renk açısından olumsuz etkilenmediği,
- Eklenen besin maddesi takviyesinin, işleme ve depolama kayıplarını telafi edecek kadar fazla miktarda kabul edilebilir düzeyde stabil olup olmadığı,
- Son ürünün üretiminin pratik ve ekonomik olarak sürdürülebilir olacağı.

İşleme koşulları ne kadar karmaşık ve kötü olursa, bu amaçlara ulaşmak o kadar zorlaşır. Zenginleştirme yöntemi, sağlam üretim uygulamalarının yanı sıra gıda kimyası ve ürün ve süreç hakkında iyi bir bilgiye dayanmalıdır. Hazır tahıllarda, takviye paketinin vitamin kısmı genellikle iki aşamada eklenir: hassas veya ısıya duyarlı vitaminler, üretim sürecinde hızla bozulma gösterebildiğinden bunların kayıplarının önlenmesi için, ekstrüzyon aşamasından sonra sprey şeklinde uygulanırlar. Ayrıca, istenmeyen tat ve kokuları en aza indirerek ürünü tüketici için daha kabul edilebilir yapar. Mineraller ve stabil vitaminler genellikle ekstrüzyondan önce kuru karışıma eklenir (Rehal vd., 2012).

Ağır Metal Kontaminasyonu ve Mikotoksin Riski

Çok önemli bir husus olarak da gıdalardaki ağır metal kontaminasyonu, gıda kalite kontrolünün en kritik konuları arasındadır. Ancak, tahıl bazlı kahvaltılık öğünlerin tüketicilerinin toksik metallere ne ölçüde maruz bıraktığına dair veri kıtlığı bulunmaktadır. Ayrıca, kirlenmiş tarlalarda yetiştirilen tahıllar, topraktan tahıllarına toksik metaller taşıyabilir (Du vd., 2018). Sonuç olarak, tahıllar dünyanın çoğu yerinde temel gıda maddelerinin başında geldiği için, özellikle yüksek tüketim oranları nedeniyle toksik metallere maruz kalmaya katkıda bulunabilirler (Mousavi Khaneghah, 2020). Bu nedenle de kahvaltılık tahıllarda ana bileşen olan tahılların bu açıdan güvenli olduğundan emin olunmalı, bu konularda araştırmalar yapılmalıdır. Oduro vd. (2023) tarafından yapılan bir araştırma sonucunda, tahıl bazlı gıdalarda (buğday, pirinç, yulaf, mısır, darı ve sorgum) analiz edilen metallerin (As, Cd, Cr, Ni, Mn ve Pb) konsantrasyonlarının FAO/WHO limitlerini aştığı belirlenmiştir. Özellikle Cd ve Ni için tehlike katsayısı (HQ) değerlerinin 1'in üzerinde olduğu, dolayısıyla çeşitli yaş grupları arasında, özellikle de yeni yürümeye başlayan çocuklarda olası bir olumsuz sağlık etkisine işaret ettiği rapor edilmiştir. Bu araştırmada sonucunda, özellikle Cd ve Ni varlığı açısından tahıl bazlı kahvaltılık tüketiminin sürekli izlenmesi ve yönetiminin gerekliliği vurgulanmıştır. Tahıl bazlı gıdalardaki metallerin birincil kaynağı toprak olduğundan, sürekli olarak çevresel izleme ve yönetimin önemi vurgulanmıştır. Tahıl bazlı kahvaltılıklarda daha geniş bir kahvaltılık gevrek ve metal yelpazesini ele alan daha kapsamlı çalışma önerilmiştir. Ayrıca ağır metallerin oluşturduğu gerçek sağlık risklerini belirlemek için bireysel duyarlılık, genel beslenme ve yaşam tarzı gibi diğer faktörlerin de dikkate alınması gerekmektedir (Oduro vd. (2023).

Kahvaltılık gevreklerin faydaları dışında, içermesi muhtemel riskler açısından değerlendirilmesi de önemli bir zorunluluk olup süreklilik arz eden tüketimlerin ortaya çıkarabileceği tehlikelerin risk analizleri ile ortaya konulması gereklidir (Budagova, 2022). Önemli biyolojik kaynaklı riskler olarak mikotoksinlerin araştırılması, özellikle tahıl, kakao ve kuru meyve içeren çeşitlerde ön plana çıkmaktadır. İstanbul genelinde farklı çeşitte 100 adet kahvaltılık tahıl örneğinde 10 farklı mikotosin varlığının araştırıldığı bir çalışma sonucunda, 93 örneğin mikotoksinler açısından negatif olduğu bulunmuş ve tahılların hasadı, depolanması, tahıl bazlı ürünlerin işlenmesi ve depolanması sırasında mikotoksin kontrollerinin sıkı şekilde devam ettirilmesi rapor edilmiştir (Budagova, 2022).

Sonuç ve Öneriler

- Pratik hazırlanabilir oluşları, yüksek lif içeriği ve vitamin-mineral takviyesiyle zenginleştirilmiş bileşimleri nedeniyle kahvaltılık gevreklerin sağlıklı bir kahvaltı seçeneği olarak öne çıktığı ve tüketimlerinin giderek arttığı gözönüne alınarak, üretimlerinde kullanılan maddeler, özellikle gıda katkı maddeleri ve zenginleştirme bileşenlerinin, önemine dikkat çekmek amacıyla bazı öneriler sıralanmıştır.

- Tüketicilerin katkı maddeleriyle ilgili farkındalığı artırılmalı; özellikle ebeveynler, çocuk ürünlerini alırken içerik etiketlerini incelemelidir. Tüketicilerin gıda etiketlerindeki besin bilgileri açık ve açıklayıcı olarak yazılmalı, dünya geneline hitap edecek araştırmalar yapılmalıdır.

- Kullanılan tatlılık veren maddeler, renklendirici ve diğer katkı maddeleri sınıf ve miktarları gözden geçirilmelidir: Çocuklara yönelik kahvaltılık ürünlerde şeker, yapay tatlandırıcı ve sentetik boya kullanımı sınırlanmalı veya alternatif doğal gıda katkı maddeleri/bileşenleri teşvik edilmelidir.

- Renklendiriciler, emülgatörler, tatlandırıcılar ve katkı maddesi karışımlarının ve risk oluşturan bulaşanların uzun süreli sağlık etkilerini değerlendiren çalışmalar artırılmalıdır.

- Hammaddeden gelebilecek riskler dikkate alınarak gerekli kontroller sürekli yapılmalıdır. Kullanılan tahıllarla ilgili kapsamlı ağır metal varlığı tespit edilmelidir: Tahıl bazlı gıdalardaki metallerin birincil kaynağı toprak olduğundan, sürekli olarak çevresel izleme ve yönetim sağlanmalıdır. Tahıl bazlı kahvaltılıklarda geniş bir kahvaltılık gevrek ve metal yelpazesini ele alan kapsamlı çalışmalar yapılmalıdır. Ayrıca ağır metallerin oluşturduğu gerçek sağlık risklerini belirlemek için bireysel duyarlılık, genel beslenme ve yaşam tarzı gibi faktörler de dikkate alınmalıdır.

- Yasal düzenlemeler güncellenmeli, denetim mekanizması daha işler hale getirilmelidir.

Sonuç olarak, kahvaltılık gevreklerdeki katkı maddeleri, teknolojik zorunlulukların yanı sıra tüketici taleplerine karşılık vermek için formülize edilse de bunların tüketici sağlığı üzerindeki uzun dönem etkileri de göz önünde bulundurulmalıdır. Tüketici sağlığını önceleyen araştırmalar/düzenlemeler ve bilinçli tüketim politikaları geliştirilmeli, üretici ve tüketicilere konu hakkında eğitimler verilmelidir.

KAYNAKLAR

Akbaş, Ş., Özkaya, H. (2006). Kahvaltılık tahıl ürünlerinde zenginleştirme uygulamaları. Türkiye 9. Gıda Kongresi, Bolu, Türkiye.

Barciela, P., Perez-Vazquez, A., Prieto, M.A. (2023). Azo dyes in the food industry: Features, classification, toxicity, alternatives, and regulation. Food Chem Toxicol 178, 113935. https://doi.org/10.1016/j.fct.2023.113935.

Budagova, G. (2022). Piyasada Satışa Sunulan Kahvaltılık Gevreklerde LC-MS/MS Yöntemi İle Mikotoksin Tayini. Yüksek Lisans Tezi, İstanbul Üniversitesi-Cerrahpaşa Lisansüstü Eğitim Enstitüsü, İstanbul, Türkiye.

Chassaing, B., Koren, O., Goodrich, J. K., Poole, A.C., Srinivasan, S., Ley, R.E., Gewirtz, A.T. (2015). Dietary emulsifiers impact the mouse gut microbiota promoting colitis and metabolic syndrome. Nature 519(7541), 92–96. https://doi.org/10.1038/nature14232

Çakmakçı, S. (2022). Gıda Katkı Maddeleri (7. Bölüm), p171-194, In: Endüstriyel Gıda Üretim Teknikleri. Eds.: Şanlıbaba P., Güçer Y.), Nobel Yayınevi. ISBN: 978-625-417--615-9.

Environmental Working Group, EWG. (2025). Despite health harm concerns, BHA and BHT remain in food and cosmetics. https://www.ewg.org/news-insights/news/2025/04/despite-health-harm-concerns-bha-and-bht-remain-food-and-cosmetics

European Food Safety Authority (EFSA). (2009). *Scientific Opinion on the re-evaluation of tartrazine (E 102) as a food additive*. EFSA Journal 7(11), 1331. https://doi.org/10.2903/j.efsa.2009.1331

Food and Drug Administration (FDA) (2021). Substances Added to Food. https://www.fda.gov/food/food-additives-petitions/food-additive-status-list

Food and Drug Administration (FDA) (2025). Aspartame and other sweeteners in food. U.S. Food and Drug Administration. https://www.fda.gov/food/food-additives-petitions/aspartame-and-other-sweeteners-food

IARC (2023). Aspartame: IARC Monographs on the Identification of Carcinogenic Hazards to Humans. https://www.who.int/news/item/14-07-2023-aspartame-hazard-and-risk-assessment-results-released

McCann, D., Barrett, A., Cooper, A., Crumpler, D., Dalen, L., Grimshaw, K. et al. (2007). Food additives and hyperactive behaviour in 3-year-old and 8/9-year-old children in the community: A randomised, double-blinded, placebo-controlled trial. The Lancet, 370(9598), 1560–1567. https://doi.org/10.1016/S0140-6736(07)61306-3

Monisha, B., Sridharan, R., Kumar, P.S., Rangasamy, G., Krishnaswamy, V.G., Subhashree, S. (2023). Sensing of azo toxic dyes using nanomaterials and its health effects - A review. Chemosphere, 313, 137614. https://doi.org/10.1016/j.chemosphere.2022.137614

Mousavi Khaneghah, A., Fakhri, Y., Nematollahi, A., Pirhadi, M. (2020). Potentially toxic elements (PTEs) in cereal-based foods: a systematic review and meta-analysis. Trends Food Sci Technol 96:30–44. https://doi.org/10.1016/j.tifs.2019.12.007

Oduro, P.A., Ankar-Brewoo, G., Dodd, M., Ansah, E., Darko, C., Borquaye, LS., Darko, G. (2023). Health risks of potentially toxic metals in cereal-based breakfast meals in the Kumasi Metropolis, Ghana. Discover Food, 3, 25. https://doi.org/10.1007/s44187-023-00067-3

Rehal, J., Sharma, S., Nagi, H.P.S. (2012). Chapter 12. Breakfast cereals– An overview. Jagmander Book Agency, s 127-146., New Delhi.

Shahidi, F., Zhong, Y. (2010). Novel antioxidants in food quality preservation and health promotion. Eur J Lipid Sci Technol 112(9), 930–940. https://doi.org/10.1002/ejlt.201000044

Swarnakar, AK., Mohapatra, M., Das, SK. (2022). A review on processes, mechanisms, and quality influencing parameters for puffing and popping of grains. J Food Process Preserv 46: e16891. https://doi.org/10.1111/jfpp.16891

Türk Gıda Kodeksi Gıda Katkı Maddeleri Yönetmeliği (2023). Resmî Gazete Tarihi: 13.10.2023 Resmî Gazete Sayısı: 32338 (Mükerrer).

WHO (2023). Non-sugar sweeteners and health: WHO guideline. World Health Organization. https://www.who.int

INNOVATIVE DIRECTIONS AND PROSPECTS OF MICROBIOLOGICAL BIOTECHNOLOGY IN ENSURING FOOD SECURITY IN AGRICULTURE

Shirinboyeva Dilrabo Komilovna

Samarkand State University of Veterinary Medicine, Animal Husbandry and Biotechnology

Kutliyeva Guzal Dzhumaniyozovna

Institute of Microbiology, Academy of Sciences of the Republic of Uzbekistan

Daminov Asadullo Suvonovich

Samarkand State University of Veterinary Medicine, Animal Husbandry and Biotechnology

Abstract. Ensuring food security is a global priority in the face of population growth, climate change, and resource scarcity. Microbiological biotechnology offers innovative and sustainable solutions for increasing agricultural productivity while preserving environmental health. This paper explores the current trends and future prospects of using microbial biotechnologies—such as biofertilizers, biopesticides, and growth-promoting bacteria—in agriculture. The results of analytical and experimental studies show that these technologies significantly improve crop yields, soil fertility, and food safety. Their application reduces dependence on chemical inputs and supports the transition to eco-friendly farming. The study concludes that microbiological biotechnology has great potential to play a leading role in ensuring food security in the coming decades.

Keywords.*Food security, microbiological biotechnology, sustainable agriculture, microbial biopreparations, biofertilizers, biopesticides, soil fertility, crop productivity, eco-friendly farming, agricultural innovation.*

Introduction. Today, ensuring food security is one of the most urgent global challenges. With increasing population and limited natural resources, the need for sustainable agricultural practices is becoming more critical. In this context, innovative approaches in microbiological biotechnology are gaining wide application for improving productivity, protecting the environment, and reducing dependency on chemical inputs.

Purpose. The main aim of this study is to analyze the innovative directions of microbiological biotechnology in agriculture and to assess their potential for enhancing food security.

Methodology. The study employed analytical and comparative research methods. Scientific literature, modern biotechnological developments, and current agricultural practices involving microbial preparations were reviewed. The effectiveness of microbial biopreparations was evaluated through both laboratory and field experiments.

Results. Analysis showed that biotechnology-based microbial products (such as nitrogen-fixing bacteria, phosphate-solubilizing strains, and bioinsecticides) stimulate plant growth, enhance soil fertility, and reduce the need for chemical fertilizers and pesticides. Moreover, they improve the quality of agricultural products without negative effects on human health, thus contributing to food safety and sustainability.

Conclusion. Innovative directions in microbiological biotechnology play a vital role in ensuring food security in agriculture. With continued scientific research and government support, this sector holds great promise for improving agricultural efficiency and environmental sustainability in the near future.

EDUCATIONAL STRATEGIES AND CLASSROOM ENVIRONMENTS FOR STUDENTS WITH ASPERGER'S SYNDROME: A MULTISENSORY APPROACH

Ana-Lucia Blendea

Student at Nutrition and Dietetics, UMF Iasi, University of Medicine and Pharmacy

Alin Ciobica

Ciobica Alin, Habil. PhD Principal Investigator Alexandru Ioan Cuza University, Faculty of Biology, Iasi, Romania, Romanian Academy of Science

Ioan Gotca

Doctor of Medicine, CSM Iasi, Socola Psychiatry Institute

Daniela DIMITRIU

Alexandru Ioan Cuza" University, "Mihai Eminescu" Central Library, Iași, Romania

Abstract

Learners with Asperger's Syndrome often encounter obstacles in mainstream classrooms due to sensory sensitivities, rigid patterns of thinking, and challenges in social communication. This paper explores how multisensory teaching methods combined with structured classroom arrangements can enhance learning outcomes and engagement. Drawing on principles from cognitive psychology and neurodevelopmental research, it examines practical applications of visual tools, tactile resources, auditory prompts, and movement-based activities. Case examples illustrate how predictable routines, designated low-stimulation areas, and tailored adjustments can meet both sensory and educational needs. The discussion also stresses the importance of teacher training and collaboration with specialists such as occupational therapists. The aim is to offer a flexible, inclusive framework that values neurodiversity and supports students with Asperger's Syndrome in achieving their academic potential.

Keywords: Asperger's Syndrome, multisensory instruction, inclusive education, sensory integration, teaching strategies

Introduction

This study focuses on Asperger Syndrome based on direct experiences with students diagnosed with the condition or High-Functioning Autism (Klin & Volkmar, 1996; Munro, 1999; Moreno & Sepúlveda, 2003) in general education classrooms. These observations have highlighted the pressing need for inclusive practices that address the unique challenges these learners face. Many such students progress through school without formal recognition, with teachers—unfamiliar with the condition—perceiving them as typical in appearance yet noticing distinct interests, unusual behaviors, and communication differences that can lead to misunderstandings. Some may be mischaracterized as disruptive, while others struggle socially due to differences in tone, emotional expression, or regulation.

The purpose of this article is to outline practical approaches for successfully integrating students with Asperger Syndrome into mainstream educational settings. These recommendations draw from both research literature and direct instructional experience, aiming to answer common teacher concerns while providing actionable strategies.

Diagnostic definitions for Asperger Syndrome have historically come from the DSM-IV (American Psychiatric Association, 1994) and ICD (World Health Organization, 1992). In the DSM-5, Asperger Syndrome is no longer a separate diagnosis, now classified under Autism Spectrum Disorder (ASD) (Ghaziuddin, 2010). For this discussion, the traditional DSM-IV-TR description is used, defining the syndrome as a Pervasive Developmental Disorder characterized by challenges in social interaction, verbal and non-verbal communication, and imaginative abilities—a triad of symptoms widely cited in the literature (Alberta Learning, 2003; Winter, 2005; Bogdashina, 2005; Pittman, 2007).

Key Characteristics of Asperger Syndrome

Students with Asperger Syndrome may share a pattern of traits that educators should be aware of to offer meaningful support. According to Myles et al. (2005), these characteristics often include intense, narrowly focused interests; low tolerance for frustration; difficulty adjusting to changes in routine; and limited social skills. Figurative or abstract language may be misunderstood, and some learners face motor coordination challenges. Emotional sensitivity is common, often presenting as mood variability or heightened anxiety. Academic challenges may emerge due to issues with attention, organization, or task completion, while speech may be notably formal or precise.

Characteristic	**Description**
Narrow, intense interests	Focus on specific subjects or activities
Low frustration tolerance	Difficulty managing stress or unexpected changes
Difficulty adapting to change	Challenges when routines are disrupted
Poor social skills	Trouble making friends and understanding social cues
Literal interpretation of language	Struggle with abstract or figurative speech
Motor skill challenges	Clumsiness or difficulty with fine motor tasks
Emotional sensitivity	Vulnerability to mood swings and anxiety
Academic difficulties	Problems with concentration or organizational skills
Pedantic speech	Formal or unusual language use

Table 1: Common traits observed in students with Asperger Syndrome.

Educational Theories Informing Interventions

Theory of Mind

Theory of Mind, introduced by Premack and Woodruff (1978), refers to the capacity to understand that others have distinct thoughts, beliefs, and emotions. Research indicates that many individuals with Asperger Syndrome have difficulty with this skill (Baron-Cohen, Leslie, & Frith, 1985), leading to misunderstandings in social exchanges. Educators can address these challenges by explicitly teaching social norms, using role-play to practice emotional interpretation, integrating social stories, and avoiding ambiguous or figurative language. Providing clear feedback and self-regulation strategies, as well as guided discussions about humor and empathy, can further develop students' social understanding.

Observed Difficulty	**Recommended Educational Approach**
Difficulty predicting others' behavior	Teach explicit social rules and routines
Misinterpretation of social cues	Use role-playing and social stories to build empathy
Problems sharing attention or understanding sarcasm	Use clear, concrete language and avoid idioms
Lack of awareness about impact of actions	Provide feedback and teach self-regulation techniques
Trouble understanding deception or humor	Foster awareness through guided discussion and examples

Table 2: Theory of Mind difficulties and corresponding educational strategies.

Central Coherence

Frith's (1989) Central Coherence theory proposes that individuals with Asperger Syndrome often focus on specific details rather than integrating information into a broader context. While this can be advantageous in detail-oriented tasks, it may also lead to rigid thinking and difficulty generalizing skills. Teachers can mitigate these challenges by structuring lessons, incorporating visual aids, breaking tasks into smaller steps, and providing multiple contexts for applying learned skills. Encouraging flexible thinking and connecting detailed information to overarching themes can support broader comprehension.

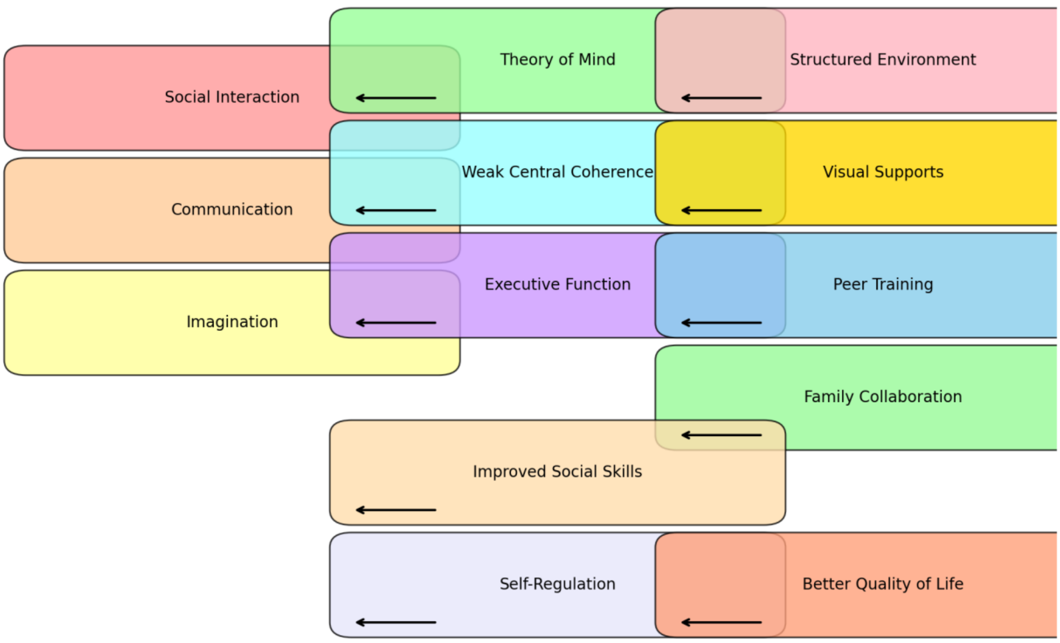


Figure 1: Educational Strategies for Supporting Students with Asperger Syndrome in Mainstream Classrooms

Methodology

This article employs a theoretical-descriptive approach, synthesizing findings from previous empirical studies, psychological theories, and practical teaching guidelines to address the educational needs of students with Asperger Syndrome (AS) in mainstream classrooms. The authors review core diagnostic frameworks, including the DSM-IV and ICD-10 criteria, to outline the disorder's defining features—impairments in social interaction, communication, and imagination (American Psychiatric Association, 2002; World Health Organization, 1992).

Drawing upon seminal psychological theories such as Theory of Mind (Premack & Woodruff, 1978; Baron-Cohen et al., 1985), Weak Central Coherence (Frith, 1989), and Executive Function Deficits (Ozonoff, 1997), the authors identify common cognitive and behavioral challenges in students with AS. These theoretical perspectives are then translated into educational implications, supported by practical interventions and classroom strategies described in prior literature (Cumine et al., 2000; Attwood, 2009; Mesibov & Howley, 2010).

The methodology integrates qualitative case examples to illustrate individual differences among students with AS, based on observational reports from existing studies (Cumine et al., 2000; Wall, 2007). Recommendations are drawn from validated educational programs, such as the TEACCH model, and from collaborative frameworks involving teachers, families, and multidisciplinary support staff (Tsang et al., 2007; Mesibov & Howley, 2010).

Discussion

The reviewed literature emphasizes that students with AS present heterogeneous profiles, requiring tailored interventions that account for their unique strengths and challenges. Findings support the use of structured teaching environments, consistent routines, and visual supports to facilitate comprehension and reduce anxiety (Jordan & Powell, 1995; Mesibov & Howley, 2010). Interventions should target pragmatic language use, emotional understanding, and social integration, while minimizing unstructured and unpredictable situations that may cause stress (Attwood, 2009; Winter, 2005).

The integration of Theory of Mind interventions can enhance social understanding, whereas strategies based on Weak Central Coherence theory can help students link details to broader concepts through explicit instruction and visual sequencing (Frith, 1989; Cumine et al., 2000). Similarly, addressing Executive Function deficits through step-by-step task planning and explicit goal-setting fosters autonomy and problem-solving abilities (Ozonoff, 1997; Félix, 2005).

An important implication is the necessity of coordinated efforts between mainstream teachers, special education staff, and families. Teachers require professional development to apply evidence-based strategies, while peers should be educated on inclusive practices to reduce bullying and promote social acceptance (Dubin, 2007; Plimley & Bowen, 2007). These findings align with the broader literature on inclusive education, which highlights collaboration and environmental adaptation as critical to student success (Rivière, 2001; Paula, 2003).

Conclusion

Inclusion of students with AS in mainstream classrooms demands a systemic approach involving the entire educational community—students, teachers, support professionals, and families (Sepúlveda, 2011). Schools should ideally offer small class sizes, structured teaching methods, and predictable routines to accommodate the cognitive and social needs of these learners (Paula, 2003).

No universal strategy exists that applies to all students with AS, as individual profiles vary considerably. However, interventions grounded in the affective, relational, and cognitive dimensions of the disorder can significantly improve social communication skills, self-regulation, and overall quality of life within educational contexts (Attwood, 2009; Cumine et al., 2000). The findings reinforce the importance of flexible, evidence-based practices that adapt to each student's developmental trajectory, ensuring equitable access to learning and participation in inclusive school environments.

References

Alberta Learning. (2003). *Teaching Students with Asperger Syndrome*. Alberta Education.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition*, 21(1), 37-46.

Bogdashina, O. (2005). *Theory of Mind and the Triad of Perspectives on Autism and Asperger Syndrome*. Jessica Kingsley Publishers.

Cumine, V., Leach, J., & Stevenson, A. (2000). *Asperger Syndrome: A Guide for Parents and Professionals*. Jessica Kingsley Publishers.

Frith, U. (1989). *Autism: Explaining the Enigma*. Blackwell.

Ghaziuddin, M. (2010). Asperger syndrome: diagnosis and treatment. *Current Psychiatry Reports*, 12(2), 117-122.

Klin, A., & Volkmar, F. (1996). *Asperger Syndrome*. Guilford Press.

Munro, J. (1999). *High Functioning Autism and Asperger Syndrome*. Jessica Kingsley Publishers.

Moreno, M., & Sepúlveda, L. (2003). Educational strategies for Asperger syndrome. *Electronic Journal of Research in Educational Psychology*, 9(2), 869-892.

Pittman, R. (2007). *Teaching Children with Autism*. Scholastic.

Winter, E. (2005). Understanding Asperger Syndrome. *Educational Psychology in Practice*, 21(2), 105-117.

American Psychiatric Association. (2002). *Diagnostic and Statistical Manual of Mental Disorders (4th ed., Text Revision)*. Barcelona: Masson.

Attwood, T. (2009). *Guía del Síndrome de Asperger*. Barcelona: Paidós.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition*, *21*(1), 37–46.

Cumine, V., Leach, J., & Stevenson, G. (2000). *Asperger Syndrome: A Practical Guide for Teachers*. London: David Fulton.

Dubin, N. (2007). *Asperger Syndrome and Bullying: Strategies and Solutions*. London: Jessica Kingsley Publishers.

Félix, V. (2005). Recent perspectives in neuropsychological and behavioral evaluation of ADHD. *Electronic Journal of Research in Educational Psychology*, *3*(3), 215–232.

Frith, U. (1989). *Autism: Explaining the Enigma*. Oxford: Blackwell.

Jordan, R., & Powell, S. (1995). *Understanding and Teaching Children with Autism*. London: John Wiley & Sons.

Mesibov, G., & Howley, M. (2010). *El acceso al currículo por alumnos con Trastornos del Espectro del Autismo: Uso del Programa TEACCH para favorecer la inclusión*. Ávila: Autismo Ávila.

Ozonoff, S. (1997). Components of executive function in autism and other disorders. In J. Russell (Ed.), *Autism as an Executive Disorder* (pp. 179–211). New York: Oxford University Press.

Paula Pérez, I. (2003). *Educación Especial. Técnicas de Intervención*. Madrid: McGraw-Hill.

Plimley, L., & Bowen, M. (2007). *Social Skills and Autistic Spectrum Disorders*. London: Paul Chapman Publishing.

Rivière, A. (2001). *Autismo: Orientaciones para la intervención educativa*. Madrid: Trotta.

Sepúlveda Velásquez, L. (2011). Guía orientativa para el profesorado del aula regular relativa a la integración del alumnado con síndrome Asperger. *Revista REPSI, 113/114,* 28–40.

Tsang, S., Shek, D., Lam, L., Tang, F., & Cheung, P. (2007). Application of the TEACCH program on Chinese preschool children with autism. *Journal of Autism and Developmental Disorders, 37*(2), 390–396.

Winter, M. (2005). *Asperger Syndrome: What Teachers Need to Know*. London: Jessica Kingsley Publishers.

World Health Organization. (1992). *The ICD-10 Classification of Mental and Behavioural Disorders*. Geneva: WHO.

IN SILICO DRUG-LIKENESS/ADME-T STUDIES AND MOLECULAR DOCKING OF COMPOUNDS FROM TEPHROSIA BRACTEOLATA LEAVES AGAINST SOME TARGETS OF DIBETIC COMPLICATIONS

Emmanuel Iyiola
Department of Microbiology, University of Ilorin, Ilorin, Kwara State, Nigeria.

Precious Idakwoji
Department of Microbiology, University of Ilorin, Ilorin, Kwara State, Nigeria.

Endaline Madu
Department of Biochemistry, Faculty of Biological Sciences, University of Nigeria, Nsukka, Enugu State, Nigeria.

Hannah Nsude
Department of Biochemistry, Renaissance University, Ugbawka, Enugu State, Nigeria.

Micheal Adeyeye
Department of Biochemistry, College of Natural and Applied Sciences, Salem University, Lokoja, Kogi State, Nigeria.

Racheal Chinweuba
Department of Science and Laboratory Technology (Biochemistry Option), School of Natural and Applied Sciences, Federal Polytechnic, Bida, Niger State, Nigeria.

Aanuoluwa Iyiola
Department of Biochemistry, Federal University of Technology, Minna, Niger State, Nigeria.

Okpanachi Oyibo
Department of Biochemistry, Faculty of Natural Sciences, Prince Abubakar Audu University, Anyigba, Kogi State, Nigeria.

Josiah Aderinto
Department of Plant Breeding and Seed Technology, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria.

Abstract

Diabetes mellitus, a chronic metabolic disorder, often leads to severe complications such as neuropathy, nephropathy and retinopathy, primarily due to hyperglycaemia-induced oxidative stress and inflammation. Identifying and targeting the molecular mechanisms underlying these complications is crucial for developing effective therapeutic strategies. This study focused on molecular docking and drug-likeness/ADME-T tests of some compounds (Myo-Inositol, 2-methoxy-4-vinyl phenol, 1-D-thioglucitol and 4-Piperidone) identified through GC-MS analysis of *Tephrosia bracteolata* leaves. These compounds were docked against key molecular targets associated with diabetic complications. The targets considered include Angiotensin Converting

Enzyme (ACE), Dipeptidyl Peptidase IV (DPP-IV), Sodium-Glucose Co-transporter-2 (SGLT-2), Aldose reductase (AR) and Alpha-amylase (*α*-amylase). 3D Structures of ACE, DPP-IV, SGLT-2, AR and *α*-amylase were obtained from protein databank (www.rcsb.org) with PDB ID: 1O86, 3WQH, 7VSI, 3S3G and 1B2Y respectively. The SDF (structure-data file) structures of the ligands; Myo-Inositol, 2-methoxy-4-vinyl phenol, 1-D-thioglucitol and 4-Piperidinone were obtained from the PubChem database. Site-specific auto-docking was carried out and the binding affinities (Kcal/mol) were determined using Autodock Vina from PyRX. The 2D diagrams of the molecular interactions between targets and ligands were viewed with discovery studio 2024. Drug-likeness and ADME-T analyses of the ligands were carried out using SwissADME Tool, The docking results revealed that methoxy-4-vinyl phenol exhibited strong binding affinities towards ACE, DPP-IV, SGLT-2 and AR while Myo-Inositol exhibited strong binding affinity towards *α*-amylase. ADME-T analysis revealed that the compounds possess favorable ADMET profiles indicating good oral bioavailability, metabolic stability and low toxicity. Furthermore, drug-likeness evaluation using Lipinski's rule of five and other criteria suggested that these compounds have promising drug-like properties. It was concluded that this study underscores the therapeutic potentials of these compounds in managing diabetic complications, making them suitable candidates for further drug development processes.

Keywords: Drug-Likeness, ADME-T Studies, Molecular Docking, Myo-Inositol, 2-methoxy-4-vinyl phenol, DPP-IV, SGLT-2

ASSESSING MAIZE AGRONOMIC AND PHYSIOLOGICAL BENEFITS IN SEMI-ARID REGIONS: IMPACTS OF TRICKLING FILTER-TREATED WASTEWATER IRRIGATION

Ahmed Osmane

Laboratory of Organic Chemistry and Physical Chemistry (Fundamental and Applied Chemistry)Faculty of Sciences, Agadir University Ibn Zohr

Laboratory of Biomolecular and Medicinal Chemistry, Faculty of Science Semlalia, University Cadi Ayyad, Marrakech, Morocco.

Khadija Zidan

National Center for Studies and Research on Water and Energy (CNEREE), Cadi Ayyad University, Marrakech, Morocco.

Laboratory of Water, Biodiversity and Climate Change, Faculty of Sciences Semlalia, Cadi Ayyad University, Marrakech, Morocco

Moustapha Belmouden

Laboratory of Organic Chemistry and Physical Chemistry (Fundamental and Applied Chemistry) Faculty of Sciences, Agadir University Ibn Zohr

Abstract

The aim of this work was to investigate the effect of treated wastewater irrigation on the physiological and agronomic properties of *Zea mays*. An experimental reuse study was performed using raw (RWW) and treated urban wastewater (TWW) by Trickling Filter (TF) process to irrigate maize *(Zea mays)* in comparison to well water (WW) as a control over a period of 5 months. The water quality was determined for irrigation based on sodium adsorption ratio (SAR), sodium percentage (Na %) and residual sodium carbonate (RSC) indicating that all treatments were suitable for irrigation purposes. In this study, we also assessed the agro-physiological and biochemical proprieties of the crops. Hence, the highest productivity of maize and leaf area were obtained in response to irrigation with RWW and TWW compared to WW; while macro-elements (TP, TKN, and K) were also affected in maize irrigated with RWW compared to TWW and WW. However, the plants irrigated with well water accumulate more Ca, Na, and Mg than those irrigated with RWW and TWW. All the crops irrigated with three water treatments showed a relatively similar concentration of micro-nutriments. The prevalence of total chlorophyll content in the plants increased with well water irrigation. Nevertheless, the biochemical parameters (protein and sugar content) were adversely affected in maize irrigated with RWW as compared to TWW and WW. Moreover, the use of treated urban wastewater improves the physicochemical properties and fertility of the soil compared to well water and enhances crop productivity.

Keywords: *Zea mays;* irrigation; treated wastewater reuse; physiological proprieties; agronomic properties ; Trickling Filter.

Introduction

Water is crucial for the development of crops. It is regarded as one of the most significant factors affecting agricultural yields. To meet plant water requirements and prevent water stress, which affects plant physiological and morphological processes and lowers crop yields, crop production needs a constant supply of water (Sadras et al., 2016). Although municipal wastewater is usually applied as a source of irrigation water for crops, it is also a source of nutrients (macronutrients N, P, K, Ca, Mg and micronutrients Fe, Zn, Cu, Mn....), that are essential for both soil and plant nutrition (Rezapour et al., 2021). However, the nutrient content of wastewater can exceed plant needs. It can also cause excessive vegetative growth, lowering the quality of irrigated crops. Therefore, the concentration of nutrients is present in the treated municipal wastewater as part of the fertilization program for irrigated crops. The concentration of nutrients as well as toxic metals content in wastewater depends upon on the water supply, the type and degree of wastewater treatment, and the quality of the wastewater. Mohsin et al. (2021) find a significant accumulation of N and P by two willow cultivars, including *Salix schwerinii* and Klara irrigated with WW under greenhouse conditions. Furthermore, the study showed a very low metal concentration in soils after growth season. The proportion of nutrients recovered varies greatly and is contingent on the nutrient concentration in wastewater, nutrient loading, the timing of application and harvesting intervals, the ability of plant species for nutrient uptake, and accumulation in aboveground biomass (Tzanakakis et al., 2009). Usually, for the treatment process, each stage reduces the concentration of both N and P. In this regard, wastewater should be monitored at least once at the beginning of the agricultural season (FAO, 2003). Farmers always have access to water for crop irrigation because wastewater is climate-independent (unlike rain), even during droughts (Verlicchi et al., 2012). By preserving ideal soil moisture on their farms and fields, farmers can produce stable, greater agricultural yields throughout the year (Ouda et al., 2016). Often, wastewater reuse generates enough water to satisfy irrigation needs. Farmers may gain more finance from this, particularly in arid and semi-arid countries such as Morocco. Despite the beneficial effects of wastewater reuse on soil and plant growth due to the availability of nutrients with easy uptake (Vergine et al., 2017), there is significant worry about its negative environmental effects and health hazards to the environment (Jiries et al., 2009). Recovery and reuse of wastewater are typically described in terms of standards that have been published or are suggested by regional authorities or international organizations. To meet those standards, wastewater must be treated before it is used for irrigation.

Several technologies, including physical (Combined sewer overflow in urban watersheds) (Gasperi et al., 2012); electrochemical (Electrochemical Oxidation) (Murthy et al., 2011); and biological technology such as (Activated sledge, constructed wetland, multi-soil-layering) (El Moussaoui et al., 2019; Elfanssi et al., 2018; Zidan et al., 2022) processes of them has been applied to remove effectively compounds from wastewater. However, when the aim is to use the wastewater again for crop use, early elimination of organic particles and nutrients from the wastewater is frequently unsuitable. Preserving organic particles as well as some nutrients like N and P can be interesting and advantageous for soil and plants (Ahmali et al., 2020). The existing urban wastewater treatment technologies are not efficient in removing organic particles and nutrients, so it is necessary to investigate a novel wastewater treatment and reuse technology that can be both selective and ecologically safe.

The Trickling Filter (T F) system is an innovative and cost-effective technology that requires simple maintenance. It functions by using a porous medium to filter wastewater, serving as both a physical filter and a platform for aerobic and anaerobic biological reactions. The TF system is specifically designed for secondary treatment of wastewater (Song et al., 2020). The arrangement of soil mixture layers, including soil, sawdust, charcoal, and iron particles, in alternating bricks with gravel layers prevents clogging issues (An et al., 2016; Zidan et al., 2023). This system is a practical solution for wastewater treatment in small communities and offers several advantages (An et al., 2016). Numerous studies highlight the effectiveness of the TF system in treating various types of wastewater worldwide, positioning it as an emerging technology (Sbahi et al., 2022). Furthermore, current research focuses on enhancing the TF technology by investigating the removal of conventional pollutants. However, despite the extensive exploration of the TF field, no studies have demonstrated the benefits of using Multi-Soil-Layering technology-treated domestic wastewater in agriculture.

Numerous studies have investigated the impacts of both raw and treated wastewater on soil properties and plant agronomic characteristics. One approach to enhance soil fertility and increase crop yield is through the utilization of effective soil amendments, such as carbon-rich materials (Dai et al., 2014; Jin et al., 2019). Preserving organic matter and essential nutrients like N and P can also have beneficial impacts on both soil and plants (El Moussaoui et al., 2017).

Abegunrin et al. (2013) conducted a study in southwestern Nigeria to examine the effects of kitchen wastewater, rainwater, and groundwater irrigation on cucumber (*Cucumis sativus*) growth parameters and soil properties. They found that while there were some negative effects on cucumber growth parameters, the soil condition was not significantly impacted by the use of kitchen wastewater compared to groundwater or rainwater. Pereira et al. (2011) investigated the impacts of increasing wastewater irrigation rates on soil properties under tropical conditions. Their findings revealed a reduction in soil acidity in areas irrigated with urban wastewater. Furthermore, research conducted by Kouraa et al. (2002) in Morocco demonstrated a clear improvement in crop production for potatoes and lettuce when irrigated with treated wastewater.

However, several researchers have investigated the profound impact of domestic wastewater, whether it is raw or processed, on the physiological characteristics of crops. In their study, Castro et al. (2013) investigated the impact of using treated domestic wastewater for irrigating lettuce (*Lactuca sativa* L.) on soil properties and the lettuce crop. The researchers observed that the primary adverse effect of employing treated wastewater was the elevation of salt and sodium levels in the soil. In the same context, Abegunrin (2013) reported the effects of irrigation with treated groundwater, rainwater, and kitchen wastewater on soil properties and cucumber (*Cucumis sativus*) growth characteristics. It was found that the use of kitchen wastewater had no harmful effects on soil quality compared to rainwater and groundwater. However, there were some adverse effects on the growth indices of cucumbers. The study done by Munir et al. (2007) examined the effects of long-term sewage irrigation on soil properties and crop quality parameters and found that irrigation had an important effect on both the soil and crop parameters. According to Kouraa et al. (2002), TWW reuse clearly improves the culture yield of lettuce and potatoes.

The main objective of this work is to evaluate the impact of irrigating treated wastewater using a hybrid multi-soil-layering (TF) technology on the physicochemical properties of soil and the agro-physiological characteristics of maize (*Zea mays*) cultivated in an arid climate. The planned specific objectives are: 1) to evaluate the physicochemical and microbial parameters of water and soil irrigated with raw wastewater (RWW), treated wastewater (TWW), and well water (WW) to determine their suitability for irrigation and potential impacts on soil quality; 2) to assess the agro-physiological characteristics of maize crops irrigated with RWW, TWW, and WW, focus-ing on parameters such as biomass parameters, nutrient content, and accumulation of protein and sugar contents, to understand the effects of different water qualities on crop growth and productivity; 3) to determine the potential of treated wastewater, processed using the multi-soil-layering (MSL) technology, as a source of plant nutrients and soil fertilizers, aiming to reduce the need for additional fertilizer application, improve soil fertility, and enhance the productivity of poorly fertile soils.

Material and methods

Experimental set-up

The effect of processed wastewater on soil properties and the agro-physiological properties of maize (*Zea mays*) was investigated under arid conditions in three separate pot experiments. Maize (*Zea* *mays*) is a monoecious annual herbaceous plant from the grass family. It comes from North America. It is a leguminous plant, with good nutritional quality, and high protein content, is more cultivated in the world, and also benefits soil fertility (Harbouze et al., 2019). The experiment site is Imintanoute (Marrakech, Morocco). This region has an arid climate, with an average annual rainfall of 240 mm. Urban wastewater was treated with TF plant, which has been implemented at the university since 2016 (Zidan et al., 2022; 2023). A test field is established across from the TF hybrid and is designated for the cultivation of three plots (P1, P2, and P3), each measuring (3.65 m × 2.5 m) and separated by a 3m alley, each plot divided into four lines with 10 replications (Figure 1). In total, three types of irrigation water were used to irrigate 120 corn trees: RWW, TWW, and WW. Irrigation was applied twice weekly to keep moisture content levels in the three plots under study at 60% of field capacity, as suggested for arid regions with high temperatures based on prior studies (Nasta et al., 2023). This reduced saturation level, which is controlled by air temperature, has been found to boost maize growth, according to Xiong et al. (2020). The experiment was carried out in 2019, from March through July, which is a hot season of the year in Marrakech. The irrigation technique employed was drip irrigation, and each irrigation treatment required 93 liters of water per plot.

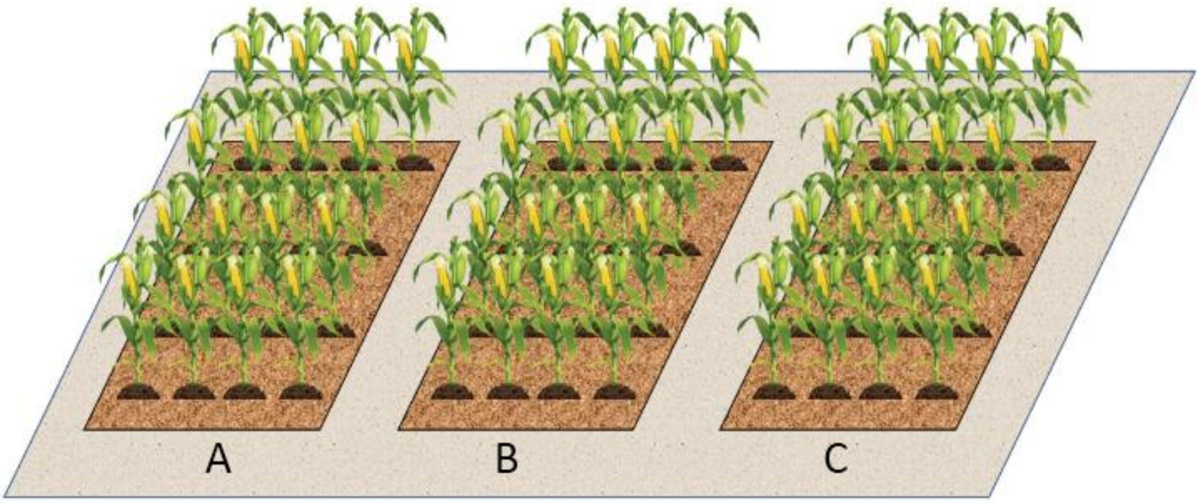


Figure 1. Experimental setup of the maize plants, irrigated by the three water treatments (RWW: raw wastewater (A); TWW: treated wastewater (B); Well water: WW (C))

Water sampling and analyses

Water samples were collected from the inlet and outlet of the wastewater treatment plant (hybrid multi-soil-layering system), which represent, respectively, RWW and TWW. For WW, it was taken from the tap connected with the well water. The depth of the well exceeds 55 m, and it is protected from all the activities nearby. Ten samples were taken from each irrigation water source from March to July. They were stored in sterile glass bottles for physicochemical analysis. The bottles were transported in a cooler at a temperature of 4 °C to the analysis laboratory.

The WTW multi-340i/multiparameter set's probe (WTW Büro-Weilheim, Germany) was used to analyze in situ parameters. The chemical oxygen demand (COD) content was measured using the dichromate open reflux method (APHA et al., 2005). The filtering method was used to quantify the suspended solids concentration (TSS); the indophenol technique was used to measure NH_4^+ concentration; the diazotization technique was used to determine the concentration of NO_2^-; regarding NO3-, this parameter was reduced to NO_2^- after passing via a cadmium-copper column (Rodier, 2009). Kjeldahl mineralization, ammonium distillation, and an acidimetric titration were used to estimate total Kjeldahl Nitrogen (TKN). The sum of NO_2^-, NO_3^-, and TKN was used to compute total Nitrogen (TN). Potassium peroxodisulfate digestion was used to determine total P (TP) (AFNOR, 1997). The technique described by APHA (1992) was used to evaluate exchangeable anions (Cl, CO_3, and HCO_3). An inductive coupled plasma method (ICP-AES) was used to assess the levels of exchangeable Na^+, K^+, Ca^{2+}, Mg^{2+}, heavy metals (Co, Ni, Pb, As, Cr, Be, and Al), and micronutrients (Fe, Zn, Mn, and Cu).

The Na%, SAR, and RSC were determined as follows:

Eq. (A.1): $Na\% = [(Na^+ + K^+)/(Ca^{2+} + Mg^{2+} + Na^+ + K^+)] \times 100$

Eq. (A.2): $SAR = Na^+/\sqrt{(Ca^{2+} + Mg^{2+})/2}$

Eq. (A.3): $RSC = (HCO3^- + CO3^{2-}) - (Ca^{2+} + Mg^{2+})$

Fecal coliforms, total coliforms, and fecal streptococci were determined using a spread plate method and selective media including Lactose 2,3,5 Triphenyl Tetrazolium Chloride (TTC) (Panreac, Spain), Tergitol agar (Himedia, India), and Bile Aesculin Agar (Biokar Diagnostics, France). The dilution process was employed for RWW, and the filtering method employing a membrane (0.45 µm) was applied for TWW and WW (Moroccan Standards, 2006). The number of bacterial indicators was measured in colony-forming units (CFU) per 100 milliliters (log CFU/100 ml) (Moroccan Standard 03.7.001, 2006).

Soil sampling and analyses

Twelve discrete soil samples were taken from each plot (three per line). Composite soil samples were made as bulk aliquots (200 g) from the previously homogenized twelve discrete soil samples taken from each plot. Soil samples were collected at 30 cm depth (Rocco et al., 2016). Soil sampling was done before the irrigation experiment began (T0) and then after the irrigation took place by the three different water qualities (RWW, TWW, and WW). The soil collection took place in the study area by gathering the different samples in plastic bags before analysis. After combining certain grams of soil with distilled water (1:2 w/v soil water for pH and 1:5 w/v soil water suspensions for the EC), a multi-parameter probe (HI 9829, Hana; Romania) was used to measure the potential of hydrogen (pH) and electrical conductivity (EC). The Kjeldahl technique was used to investigate total N (Bremner, 1996). According to Nelson and Sommers (1982), the Smith-Weldon method was used to analyze soil organic matter. P (P) was analyzed with the OLSEN extraction using 0.5 M of $NaHCO_3$ (Olsen et al., 1954).

The concentration of Macro and micro-elements (Ca, Na, K, Mg, Mn, Zn, Fe, and Cu) was analyzed using an inductive coupled plasma mass spectroscopy (ICP-AES).

Plant sampling and analytical methods

When the crops reached maturity, a total of eight plants were randomly selected from each field per treatment (RWW, TWW, and WW). From each chosen plant, leaves at level four, measured from the plant's height, were collected in a random manner. They were subsequently measured in the laboratory.

Growth parameters such as root, aerial, and grain dry weights were measured when the crops reached maturity. The maximum leaf area is calculated by the product of the maximum length and width (L_{max} and l_{max}), influenced by the coefficient 0.75 (Ruget et al., 1996). The plants underwent 48 hours of 70°C drying before being weighed to determine their dry weight. The amount of total chlorophyll in the plant leaves was settled using acetone in tubes, followed by sedimentation for 48 hours. A spectrophotometer was used to measure chlorophyll a, b, and c at three different wavelengths (470, 644, and 662 nm) (Upadhyaya & Panda, 2004). Ethanol and liquid N were used for the plant's extraction determined for the examination of total proteins and sugar, followed by centrifugation for 20 minutes and then left at -20° until analysis by Bradford reactor for the proteins (Bradford, 1976), phenol, and H_2SO_4 for the total soluble sugars (DuBois et al., 1956). For the plant grain, the total P was determined by the OLSEN extraction. The ash was melted in chloride acid after being converted to ash by around 0.5 g of plant grain in a furnace for 6 hours at 500°C. Using the molybdate blue technique, a calorimetric determination of the P concentration was made (Murphy & Riley, 1962). After color development at 100 °C for 10 minutes, the P concentration was determined by reading the absorbance at 820 nm. The Kjeldahl technique was used to quantify the concentration of N (Bremner, 1996). The P content was determined by observing the absorbance at 820 nm following 10 minutes of color development at 100 °C. Using the Kjeldahl technique, the concentration of N was determined (Bremner, 1996). Macro/Micronutrients (Ca, K, Mg, Na, Mn, Fe, Zn, and Cu) and heavy metals were determined by the Inductive Coupled Plasma Analyzer (ICP-AES). The ash was melted in chloride acid after being converted to ash by using 0.5 g of plant grain in a furnace for 6 hours at 500 °C. Using the molybdate blue method, a calorimetric analysis of the P concentration was made (Murphy and Riley, 1962). After color development at 100°C for 10 minutes, the absorbance at 820 nm was read to determine the P content. N (N) concentration was measured using the Kjeldahl method (Bremner, 1996). Macro/micronutrients (Ca, K, Mg, Na, Mn, Fe, Zn, and Cu) and heavy metals were identified using an inductive coupled plasma analyzer (ICP-AES).

Statistical analysis

To examine the significant differences, the normality test has been verified before the Tukey test. The Tukey test is employed at the significance level of $\alpha = 0.05$. A notched boxplot test was used to demonstrate the impacts of three water treatments on the characteristics of soil and plants.

RESULTS AND DISCUSSION

Suitability of Water for irrigation

Physicochemical analysis

The investigation of the new Trickling Filter TF technology in a Moroccan urban community unit confirmed the efficiency of this technology to remove organic matter, nutrients, and fecal contamination from domestic wastewater under an HLR between 160 and 250 L m^{-2} day^{-1}. resulted in significant organic matter removal as well as a significant reduction ($p < 0.05$) in N and P, with an abatement of 97%, 79%, 76%, and 27%, respectively, for TSS, COD, TP, and TN. For fecal bacteria indicators, the hybrid MSL system achieved high log removals, reaching 2.88 log units during two years of monitoring (Zidan et al., 2022). The performance of the TF system was good, and no clogging problem was detected during the monitoring period. The MSL system has the capacity to disinfect domestic wastewater due to the implication of different mechanisms, including filtration, precipitation, and biodegradation (Zidan et al., 2023). For example, the major part of organic matter was reduced by biological degradation, especially in the upper parts where oxygenated conditions were more developed, causing a proliferation of microorganisms and the overgrowth of biofilms in the soil-based layer (SBL) (Sato et al., 2011). The performance of the hybrid technology was very high due to the adsorption and precipitation of P through the addition of iron metal to SBL (Zhang et al., 2020). The presence of nitrification and denitrification processes has a significant impact on TN removal inside the TF system. Finally, the removal of coliforms in the TF system is carried out by physical filtration, adsorption, and other processes, including predation and microbial cell death (die-off) (Song 2020; Sbahi et al. 2022).

Table 1 presents the physicochemical characteristics of three different water qualities used in the experimental study. The pH values of the three types of water were within the WHO limits of 6.5–8.5 (WHO, 2012). The (EC) and total dissolved solids (TDS) were higher in the RWW and WW than TWW. The greater values of these two parameters could be a result of the geological composition of the soil found in the groundwater of the study area.

Additionally, the EC values of three different water qualities were within the permissible limits of Morocco's irrigation standards. The total hardness is due to the concentration of magnesium and calcium in the different waters (Dudziak et al. 2019). The total hardness of treated water equals the hardness of hard water (350–550 mg $CaCO_3$/L). Regarding Na, K, Ca, and Mg, which are crucial elements for plant production and better soil fertility, the results showed high concentrations in WW compared to RWW and TWW.

The WW exhibited higher average concentrations of $CaCO_3$, Na, Ca, Mg, Cl, HCO_3, and TDS compared to both the RWW and TWW. Additionally, the levels of Cl and HCO_3 surpassed the limits set by Morocco's irrigation standards. In the continental zone, particularly in the Marrakech region, the natural salinization of groundwater by aquifer rocks (Hssaisoune et al., 2020) and anthropogenic contamination from agricultural activities (El Mokhtar et al., 2012) contribute to this phenomenon. Such characteristics make it difficult to consider this well water as a reference of good water quality to compare with.

The most important water indicators to measure water quality are organic matter, total P, and N. COD, TSS, TP, NH_4^+, and NO_3^- were not detected in WW. The quality of the treated water conformed to Morocco's irrigation standard limits. The concentration of chlorides was higher in WW, and a significant difference was found between the three water qualities. The concentration of chlorides in TWW and RWW was below the permissible limits of Morocco's irrigation standards.

Table 1: Physicochemical characteristics of the three water treatments (RWW: raw wastewater; TWW: treated wastewater; WW: WW) used for maize irrigation (mean ± standard deviation)

Parameters	Unit	RWW	TWW	WW	The admissible limit for wastewater reuse
pH		8.11 ± 0.33^a	7.70 ± 0.37^a	8.60 ± 0.1^a	6.5 -8.4
EC (20°C)	dS/m	1.109 ± 0.003^a	1.006 ± 0.002^b	1.65 ± 0.003^c	12
TDS	mg/l	980 ± 3.55^a	672 ± 3.87^b	1020 ± 4.98^a	7680
$CaCO_3$	mg/l	468 ± 2.1^a	477 ± 1.1^a	706 ± 2^b	
COD	mg/L	130.69 ± 42.77^a	27.74 ± 13.70^b	Not detected	_
TSS	mg/L	56.58 ± 37.97^a	1.54 ± 1.75^b	Not detected	2
NH_4^+	mg/L	18.19 ± 3.75^a	3.05 ± 2.17^b	0.1 ± 0.02^c	
NO_3^-	mg/L	1.92 ± 1.09^a	14.23 ± 5.69^b	0.02 ± 0.001^c	30
TP	mg/L	2.31 ± 0.95^a	0.55 ± 0.46^b	0.10 ± 0.02^c	
Na	meq/L	4.74 ± 0.03^a	4.87 ± 0.038^a	11.57 ± 0.04^b	
Ca	meq/L	6.98 ± 0.05^a	6.49 ± 0.036^a	9.58 ± 0.02^b	
K	meq/L	0.82 ± 0.041^a	0.72 ± 0.031^b	0.23 ± 0.024^c	
Mg	meq/L	2.96 ± 0.037a	2.97 ± 0.04a	4.28 ± 0.03c	
Cl	mg/l	57 ± 1.2^a	162 ± 3.2^b	863 ± 2.1^c	350
CO_3^-	meq/L	0.0 ± 0^a	0.3 ± 0.01^a	0.1 ± 0.02^a	
HCO_3^-	meq/L	0.24 ± 0.01^a	3.25 ± 0.01^b	2.4 ± 0.03^c	8.48 mg/l
Al	g/l	<0.001	<0.001	<0.001	0.005
B	g/l	<0.001	<0.001	<0.001	0.003
Be	g/l	<0.001	<0.001	<0.001	0.0001
Cd	g/l	<0.001	<0.001	<0.001	0.00001
Cr	g/l	<0.001	<0.001	<0.001	0.001
Cu	g/l	0,001	<0.001	0,002	0.002
Fe	g/l	0,001	<0.001	0,001	0.005
Zn	g/l	<0.001	<0.001	<0.001	0.002
Hg	g/l	<0.001	<0.001	<0.001	10-6
Li	g/l	<0.001	<0.001	<0.001	$2.5*10^{-3}$
Mn	g/l	<0.001	<0.001	<0.001	0.0002
Mo	g/l	<0.001	<0.001	<0.001	0.00001
Ni	g/l	<0.001	<0.001	<0.001	0.002
Pb	g/l	<0.001	0.001	0,001	0.005
Total coliforms	Log.	6.50 ± 0.77	3.48 ± 0.48	Not detected	
Fecal coliforms	Log.	5.44 ± 0.5	2.56 ± 0.40	Not detected	3
Total streptococci	Log.	5.2 ± 0.57	2.36 ± 0.33	Not detected	

The different letters (a, b, and c) represent the significant difference according to the Tukey test at $p < 0.05$.

The concentrations of micronutrients (Fe, Mn, Cu, and Zn) and heavy metals (Al, Cd, Cr, Hg, Li, etc.) are noted in Table 1. The results showed that the average concentration of micronutrients and heavy metals was well within the standard limits for agricultural irrigation (Moroccan Standards, 2006).

The findings demonstrated that the average concentration of micronutrients and heavy metals was within the permissible limits for irrigation of agricultural land (Moroccan Standards, 2006).

The microbiological characteristics of the three treatments of irrigation water are presented in Table 1. The average content of fecal bacteria in treated water was 3.48 ± 0.48log/100 ml, 2.56 ± 0.40 log /100 ml and 2.36 ± 0.33 log /100 ml for total coliform (TC), fecal coliform (FC), and fecal streptococci (FS), respectively.

The comparison between the three irrigation water qualities shows that RWW contains a high content of fecal bacteria, whereas WW was free from fecal contamination (not detected). However, TWW quality was below the norms suggested by Moroccan standards for irrigating crops that are destined for human consumption: 3 logs/100 ml for FC (Moroccan Standards, 2006).

Sodium absorption ratio (SAR)

SAR is defined as a monitoring indicator to determine water quality for the irrigation of crops and to calculate the sodium hazard linked with the application of irrigation water for determining the sodium hazard associated with an irrigation water application (Alam et al. 2012). In addition, if the SAR value is less than 6, the water is suitable for irrigation. However, if the SAR is higher than 6, the water can produce sodium accumulation in the soil, which could negatively impact soil infiltration and cause soil crusting (Lesch & Suarez, 2009). Table 2 showed that values of SAR were between 2.12 and 4.39 meq/L. The three types of water were within permissible limits for irrigation, and soil sodification risk is considered slight to moderate.

Sodium percentage (Na %)

The proportion of sodium was determined using the Doneen method. The results of the sodium percentage of the water samples are categorized into three categories: good (20-40 Na%), acceptable (40-60 Na%), and doubtful (60-80 Na%) (Doneen, 1975). The sodium percentages of all treatments were in the permissible range (40-60 Na%) (Table 2).

Residual sodium carbonate (RSC)

Other parameters are most important for evaluating the irrigation suitability of water, such as the residual sodium carbonate (RSC), which helps identify the negative effects of carbonate (CO_3^{2-}) and bicarbonate (HCO_3) on the availability of water used for agricultural purposes (Raju, 2007).
The precipitation of magnesium and calcium ions is influenced by the high content of CO_3^{-2} and HCO_3^- ions. When the content of Ca^{2+} and Mg^{2+} ions is higher than the content of CO_3^{-2} and HCO_3^- ions in wastewater, the effluent is acceptable for irrigation.
According to Table 2, the RSC values are less than zero, which indicates that the three water qualities are safe for irrigation practices and that there is a possibility that Ca^{2+} and Mg^{2+} ions did not completely precipitate as carbonates.

Table 2. SAR, Na%, and RSC values at the three irrigations' water quality

	Unit	RWW	TWW	WW
SAR	meq/L	2.12±0.02[a]	2.24±0.03[b]	4.39±0.02[c]
Na% (SSP)	meq/L	44%±1%[a]	46%±2%[a]	53%±1%[b]
RSC	meq/L	-9.7±0.1[a]	-5.9±0.2[b]	-11.3±0.1[c]

Effect of water quality on irrigated soil

The properties of the soil collected before and after the application of the three different treatments are summarized in Table 3.

A slight difference in pH was observed between the soils after the maize harvest. The soil irrigated with WW showed the highest value of pH (8.54) compared to the soil irrigated with TWW (8.51) and RWW (8.35). But no significant difference (*$p > 0.05$)*. Compared to RWW and WW, irrigated soil with TWW has a lower conductivity (Table 3). According to previous studies by Elfanssi et al. (2018) and El Moussaoui et al. (2018), the primary contributor of salt accumulation in the soil is the irrigation water. In our own research, we found that the average electrical conductivity (EC) of the soil irrigated with TWW was 0.367 ± 0.02 ds/m. This value indicates a low level of salinity, posing no significant risk to crop yields. Overall, the water quality during the crop seasons was considered quite satisfactory. Other researchers have also noted the inconsistent effects of irrigation on the soil EC. For example, El-Nahhal, (2013) noted that water irrigation increased soil salinity, measured as the EC of the 1:5 soil extract in ds/m, due to the accumulation of less soluble salts in the topsoil layer. The solubilization, transportation, and redistribution of salts within the root zone, as well as additions from external sources such as irrigation water, could all be contributing to the increase in soil salinity levels (Ganjegunte et al. 2017; Musslewhite et al. 2009). Additionally, Munir et al. (2007) claimed that irrigation of wastewater for 2, 5, and 10 years increased the salt content of the soil. Salts will continue to accumulate in the topsoil, which will negatively affect plant development, soil productivity, and the activity of soil microorganisms (Durán–Álvarez & Jiménez–Cisneros, 2014). There were significant effects on the total organic carbon (TOC) of the soil ($p < 0.001$) due to different water irrigation applications. The TOC concentrations of the soils irrigated with RWW were more significant than those of other irrigated soils ($p<0.05$). The parameters (TOC) dropped significantly with TWW irrigation (3.38%) compared to soil irrigated by RWW soils (4.43%). The soil irrigated with WW showed the lowest concentrations of organic matter (2.53%). The TKN and TP concentrations of soil irrigated with RWW, TWW, and WW were higher than before irrigation (Table 3), which is probably due to the fertigation effect. However, an increase in TKN and TP concentrations was noticed on soil that had been irrigated with RWW compared with TWW and WW (Table 3). It found a similarity between the organic matter and nitrogen contents of the soils. In accordance with this topic, many investigations showed that, after wastewater use, there was an increase in organic matter and N in soils, which was strongly related to the nutrients and organic compounds in the wastewater irrigation used (El Moussaoui et al. 2019; Elfanssi et al. 2018; Kiziloglu et al. 2008). Other studies, including short- and long-term investigations, claimed that wastewater treatments enhanced soil fertility (Adrover et al., 2017; Chakrabarti, 1995; Kiziloglu et al., 2008). According to the findings of Munir et al. (2007) and Segal et al. (2011) from their experiments, the concentration of N and P in the soil increased as the duration of wastewater irrigation prolonged. The researchers attributed this increase in the upper layer of soil to the intensive application of wastewater.

The element contents (Na, Ca, and Mg) were significantly higher in WW-irrigated soils than in the other soil treatments (RWW and TWW). Compared to soils irrigated with TWW and WW, soils irrigated with RWW had higher K concentrations. The concentrations of the macro-elements in the applied waters were likely the cause of the differences between the macro-element content in soils irrigated with RWW, TWW, and WW (Table 1). Burns et al. (1985) found in their experiment that wastewater irrigation applied in this study increased N, P, and K in contents 4, 10, and 8 times more than those recommended for forage crops. Regarding the concentrations of micronutrients reported in Table 3, the plots tested in the three treatments had no significant differences. It should be mentioned that, as reported in many studies, the accumulation of microelements and heavy metals as a response to wastewater irrigation is evident, especially under long-term application, and can lead to toxicity problems either because of heavy metals and/or high levels of nutrient accumulation or because of deterioration of soil and crop quality parameters. Especially, accumulation of microelements and heavy metals from wastewater application could be caused directly by the wastewater composition or indirectly through increasing solubility of the indigenous insoluble soil heavy metals (Friedel et al. 2000; Rattan et al. 2005; Lucho- Constantino et al. 2005; Mapanda et al. 2005; Qian and Mecham 2005).

Table 3: Characteristics of the soil after the application of different treatments.

Parameters	**T_0**	RWW	TWW	WW
EC (ds/m)	0,327±0.04^{a}	0.565±0.03^{c}	0.367±0.02^{a}	0.432±0.10^{b}
pH	8.05±0.02 ^{a}	8.35±0.01^{b}	8.51±0.03^{c}	8.54±0.01^{d}
NTK (%)	1,1±0.11^{a}	8.90±0.28^{d}	8.08±0.20^{c}	7.66±0.10^{b}
COT (%)	2,51±0.01^{a}	4.43±0.07^{c}	3.38±0.03^{b}	2.53±0.01^{a}
TP (mg kg-1)	187±0.30^{a}	240±0.40^{d}	194±0.30^{c}	190±0.10^{b}
Ca %	19±0.03^{a}	20.85±0.04^{c}	20±0.03^{b}	25.48±0.02^{d}
Mg %	4,14±0.01^{a}	4.71±0.02^{b}	5.21±0.06^{c}	5.49±0.01^{d}
K %	4,01±0.01^{a}	4.63±0.04^{d}	4.34±0.04^{c}	4.17±0.04^{b}
Na %	0.67±0.01^{a}	0.68±0.02^{c}	1.69±0.01^{c}	1.76±0.03^{b}
Fe %	9.32±0.01^{a}	9.34±0.02^{a}	10.03±0.02^{b}	10.46±0.01^{d}
Mn %	0.02±0.01^{a}	0.04±0.01^{b}	0.03±0.02^{b}	0.05±0.01^{b}
Cu (g/t)	3.8±0.20^{a}	4±0.80^{b}	5±0.40^{b}	6±0.30^{b}
Zn (g/t)	55±0.40^{a}	59±0.20^{a}	56±0.30^{a}	60±0.20^{a}

The different letters (a, b, c) indicate the significant difference at $p<0.05$ by Tukey test.

Effect of irrigation water quality on maize (*Zea mays*) crop

Growth parameters

Figure 2 presents the biomass production (roots, aerial, and grain dry weight) and leaf area of maize plants under different irrigation treatments: RWW, TWW, and WW during the experimental study. Notably, there was a significant increase ($p < 0.001$) in maize biomass when irrigated with RWW, followed by the TWW plots. The leaf area also showed a similar trend, reaching approximately 162.48 ± 7.67 cm^2 when irrigated with RWW. In contrast, the leaf area was lower, not exceeding 152.26 ± 2.45 cm^2 and 147.31 ± 4.31 cm^2 when irrigated with TWW and WW, respectively. The influence of wastewater irrigation on plant productivity varied depending on the chemical composition of the irrigation water. The contrasting nutrient content among the different water sources can account for the observed differences in productivity and growth. The results highlight that the higher nutrient content in RWW, acting as a fertilizer source, contributed to an increase in plant productivity.

Consistent with prior research, our findings demonstrate the positive impact of utilizing domestic wastewater on biomass production compared to crop cultivation with well water. This aligns with the observations made by Rusan et al. (2007), who noted that barley irrigated with wastewater exhibited taller biomass compared to barley irrigated with well water. The increase in biomass was attributed to the nutrient content in the wastewater. Similarly, Abegunrin et al. (2013) reported enhanced growth traits in cucumber irrigated with kitchen wastewater compared to groundwater. Mojiri et al. (2013) also found that irrigation with wastewater significantly increased root length and shoot length in *Lepidium sativum* compared to plants irrigated with fresh water. These improvements in biomass can be attributed to various factors, such as changes in cell wall extensibility associated with protein composition (Hasegawa et al., 1984), reduction in photosynthetic capacity (Erice et al., 2011), and alterations in hormonal metabolism (Wilkinson and Davies, 2002). *Zea mays* exhibited better adaptation to the quality of treated wastewater, as it benefited from the nutrients present, particularly nitrogen and phosphorus. These nutrients significantly contribute to plant growth compared to the relatively limited growth associated with well water.

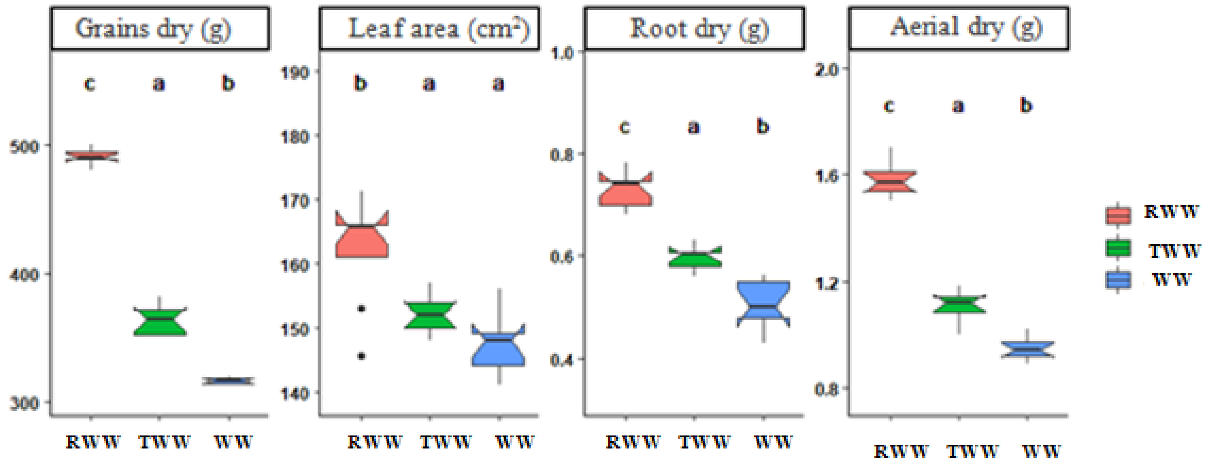


Fig. 2. The biomass production (roots, aerial parts, and grain dry) and leaf area of maize plants, irrigated by the three water treatments (RWW: raw wastewater; TWW: treated wastewater; WW: WW). The three letters (a, b, and c) represent a significant difference by notched boxplot test.

Macro and micronutrient parameters

Water quality was not found to be detrimental to plant health, taking into account macroelements (N, P, K, Ca, Mg, and Na), which are considered necessary for the health of *Zea mays* (N, P, K, Ca, Mg, and Na), as reported by Orhue (2005) and Rezapour et al. (2021). Domestic wastewater application significantly affected the content of macro-elements (N, P, K, Ca, Mg, and Na) in *Zea mays* (Fig. 3). Plants irrigated with RWW produced the highest amounts of N with 6.7 ± 0.91%, P with 6.2±1.1%, and K with 2.05±0.5%. However, the plants irrigated with WW had a high content of Ca with 0.3±0.8%, Na with 0.4±0.95%, and Mg with 0.1±0.82 %. Furthermore, compared to RWW and WW, the TWW yielded a medium concentration of N (4.3±0.45%), P (5.62±1.2%, and K (1.85±0.15%, Ca (0.17±0.68%), Mg (0.5±0.87%), and Na (1±0.96%). This was the direct consequence of the important amount of nutrients provided by irrigation with RW, TWW by the multi-soil-layering system. Based on these results, it can be concluded that water irrigation significantly affects Zea mays yield and mineral content. The enhancement of plant macronutrient content with domestic wastewater irrigation indicates that wastewater irrigation supplied the soil with these nutrients, which improved plant growth and soil fertility (Orhue et al., 2005). Indeed, plant growth and nutrient content can be enhanced by properly managed irrigation with preserved nutrients in treated wastewater (Alawsy et al., 2018). Consequently, TWW-irrigated plants showed medium levels of biomass production and nutrient content compared to those irrigated with RWW and WW. As we discussed previously, these treated wastewaters by multi-soil-layering system, in addition to the significant load of nutrients, meet standards for wastewater reuse in agriculture (Blumenthal et al. 2000; Moroccan standards 2007). The micronutrient contents (Fe, Zn, Mn, and Cu) of Zea mays treated by water of the three different qualities are shown in Fig. 4. These micronutrients are necessary for plant nutrition only if they are required by the crops in much lower quantities compared to macronutrients (Elfanssi et al., 2018). The metrics indicate that *Zea mays* uptake a lower and similar content of micronutrients than RWW, TWW, and WW. These results were in line with prior research investigating the effect of short-term irrigation on micronutrient accumulation in plants (Adrover et al., 2012; Kiziloglu et al., 2008; Mapanda et al., 2005; Younas et al., 2022). Additionally, the accumulation of micronutrients might be affected directly by irrigation water quality or indirectly by an increase in the solubility of the native, insoluble soil micronutrient (El Moussaoui et al., 2019; Lucho-Constantino et al., 2005; Mapanda et al., 2005; Yu et al., 2007).

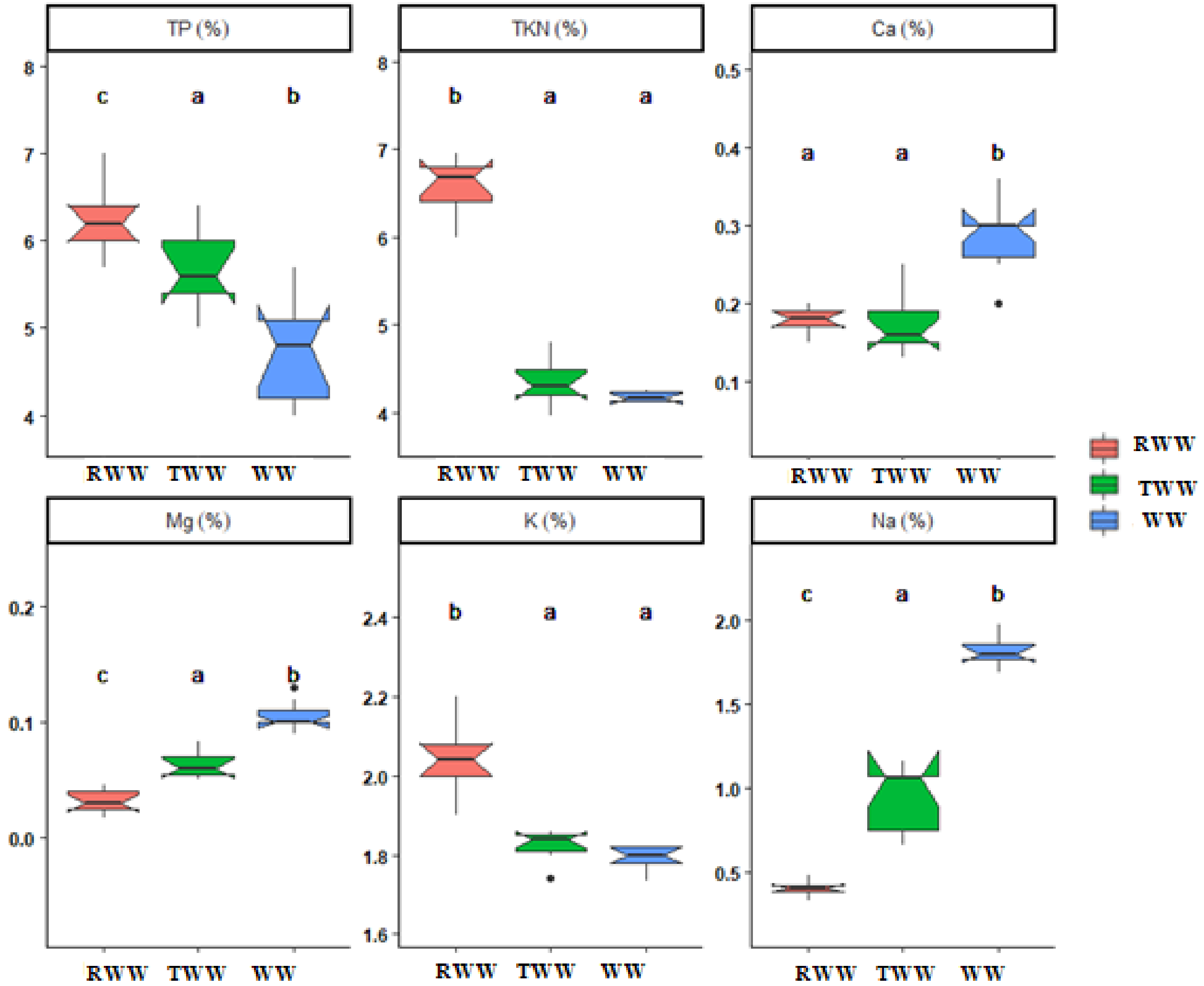


Fig. 3. The macronutrient contents of plant grain, irrigated by the three water treatments (RWW: raw wastewater; TWW: treated wastewater; WW: WW)

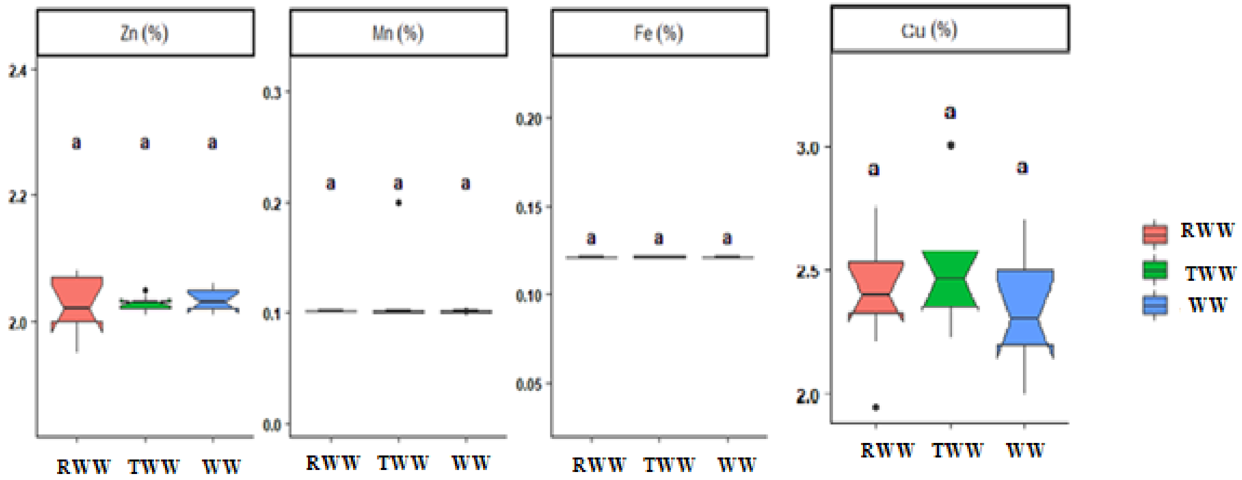


Fig. 4. The micronutrient contents (Fe, Mn, Cu, and Zn) of plant grain, irrigated by the three water treatments (RWW: raw wastewater; TWW: treated wastewater; WW: WW)

Total Chlorophyll

Figure 5 illustrates the impact of the three water qualities on the total chlorophyll content of *Zea mays* crops. The application of WW and TWW resulted in significantly higher chlorophyll content. The obtained results confirmed that even after irrigation with WW and TWW, the chlorophyll concentration in the plants remained higher. This indicates a greater potential for capturing light energy and enhancing photosynthetic activity. Additionally, TWW did not demonstrate any discernible effect on the photosynthetic activity of the plants under investigation. These findings align with the research conducted by Jóźwiakowski et al. (2020), who reported that potassium (K) deficiency had the most significant inhibitory impact on photosynthesis in maize plants. Conversely, the study did not observe any notable influence of phosphorus (P) content on overall chlorophyll levels during a short-term deviation from optimal macronutrient levels. Previous studies have utilized chlorophyll content to explain phenomena such as heavy metal stress (Mallick & Mohn, 2003), nutritional deficiencies in raw domestic wastewater (Elfanssi et al., 2018), and reclaimed wastewater (Bañón et al., 2011). Conversely, Ahmali et al. (2020) found that irrigation water with high salinity can induce photosynthetic stress in plants, with total chlorophyll serving as an indicator of this stress.

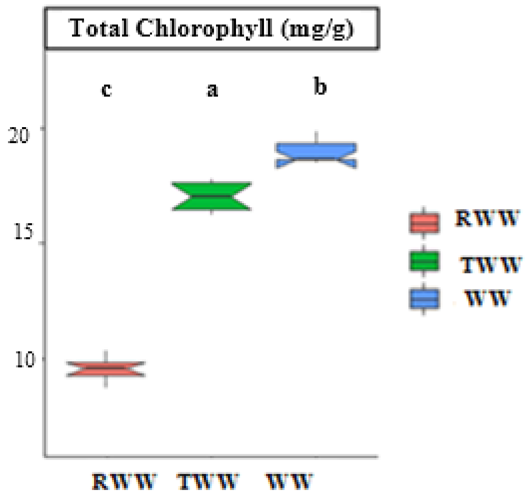


Figure 5. Total chlorophyll leaves contents of the corn irrigated by the three water treatments (RWW: raw wastewater; TWW: treated wastewater; Well water: WW).

Biochemical parameters

Sugar

Figure 6A shows the concentrations of sugars determined in *Zea mays* leaves obtained under irrigation with WW, RWW, and TWWs. However, significant variations ($P < 0.05$) were observed among treatments. Maize crops grown under irrigation with RWW and TWW showed comparable concentrations of total sugars. Indeed, Zea mays irrigated with WW showed significantly lower values of total sugar compared to those irrigated with RWW and TWW. The lower abundance of sugars in *Zea mays* leaves might be ascribable to the salinity of the WW used for irrigation, which showed a Cl concentration exceeding the Moroccan legal limits for water reuse (Table 1). The high concentrations of chloride (Cl) present in the irrigation water could have resulted in a water deficit within the maize plants. This salt stress can have detrimental effects on plant growth, including a reduction in relative water potential, as observed in previous studies (El Sabagh et al., 2020). Additionally, the negative impacts of salt stress can extend to the quality of both soil and water, both in the short and long term, as highlighted by research conducted by Seleiman et al. (2021).

Protein

Figure 6B illustrates the impact of irrigation water quality on the protein content of maize leaves. It was observed that plants irrigated with raw wastewater (RWW) exhibited higher protein accumulation, reaching 22.01 ± 2.53 mg/g. In contrast, the protein content in leaves irrigated with TWW and WW did not exceed 13.23 ± 1.33 mg/g and 12.90 ± 2.03 mg/g, respectively. This disparity suggests that while RWW induced physiological stress, TWW and WW did not adversely affect the physiological state of maize, as supported by findings from Newson et al. (2015).
Similar observations have been reported by Suke et al. (2011), who found that maize protein content increased with higher levels of NPK and biofertilizers. Rija et al. (2005) also reported comparable outcomes in their study on the impact of sewage irrigation on crops such as *Cicer arietinum*, *Lens culinaris*, and *Vigna radiata*. They attributed the rise in total protein and carbohydrate levels in leaf samples from *C. arietinum* and *L. culinaris* to the activities of various microorganisms present in sewage water, which convert organic matter into by-products such as CO_2, NH_3, H_2S, NO_3, PO_4, SO_4, and CH_4. Furthermore, Latef and Ahmad (2015) proposed that the higher concentrations of

macronutrients in wastewater serve as cofactors for the enzymes involved in protein production in maize plants.

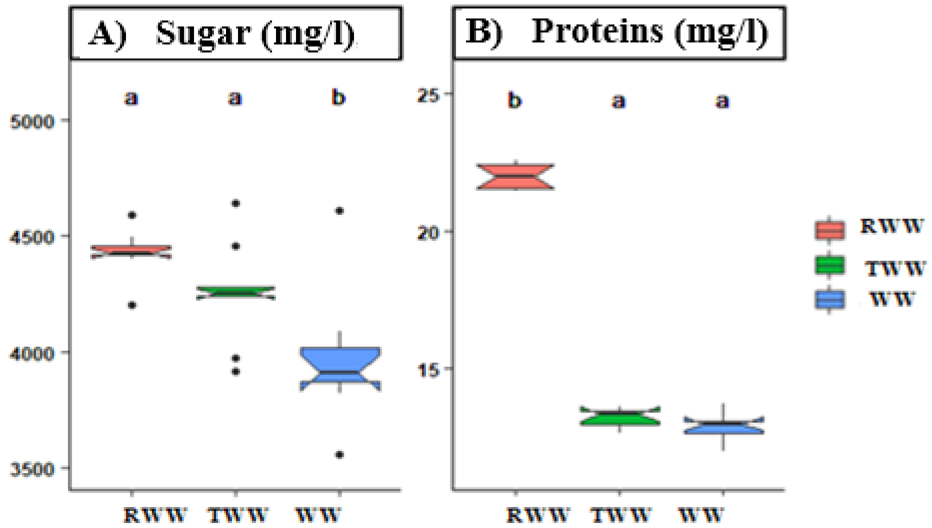


Figure 6. Sugar (A), and Proteins (B) leaves contents of crops, irrigated by the three water treatments (RWW: raw wastewater; TWW: treated wastewater; Well water: WW).

Conclusions

In arid regions, treated wastewater is a valuable resource for irrigation as it provides water and some nutrients (N, P, and K) to crops. The present study reveals significant variations in the physicochemical and microbial characteristics of water and soil, as well as the physiological responses of maize crops, among the three types of irrigation waters investigated (WW, RWW, and TWW). The quality of TWW, treated using the Trickling Filter (TF) technology, has successfully met the permissible limits for reuse in irrigation without posing any health risks according to Moroccan standards. However, WW exhibits high salinity, with chloride concentrations surpassing the legal limits for water reuse in Morocco.

Moreover, the values of RSC, SAR, and Na% indicate that all treatments are suitable for irrigation. However, soil analyses reveal that soils irrigated with RWW contain elevated levels of physicochemical parameters such as COT, NTK, and TP, which can be detrimental to plants when they exceed specific thresholds. Despite the fact that RWW has a high nutritional value that can promote plant growth, albeit with noticeable variations compared to TWW using the TF eco-technology, irrigation with RWW leads to a decrease in overall chlorophyll content in maize, but stimulates the significant accumulation of parameters such as total soluble protein and sugars. In contrast, TWW demonstrates important nutritive value that has the potential to enhance plant growth, reduce the need for fertilizer application (including the cost of mineral fertilization), and increase the productivity of infertile soils. However, WW results in a lower abundance of sugars in *Zea mays* leaves, which might be attributed to the salinity of the WW used for irrigation, thereby questioning its use as a reference.

In conclusion, among the investigated irrigation water sources, TWW produced through the *TF process could be considered the most suitable option for water reuse in agriculture and* can serve as a valuable source of plant nutrients and soil fertilizers. TWW possesses significant nutritive value that can enhance plant growth, reduce the need for fertilizer application and associated costs, and ultimately improve the productivity of infertile soils. Nonetheless, further research is necessary to evaluate the long-term effects of TWW irrigation on soil and crops.

References

Abegunrin, A. (2013). Effect of kitchen wastewater irrigation on soil properties and growth of cucumber (Cucumis sativus). *Journal of Soil Science and Environmental Management*, *4*(7), 139–145. https://doi.org/10.5897/jssem2013.0412

Adrover, M., Farrús, E., Moyà, G. & Vadell, J. (2012). Chemical properties and biological activity in soils of Mallorca following twenty years of treated wastewater irrigation. *Journal of Environmental Management*, *95 (Suppl.)*, S188–S192. https://doi.org/10.1016/J.JENVMAN.2010.08.017

Adrover, M., Moyà, G. & Vadell, J. (2017). Seasonal and depth variation of soil chemical and biological properties in alfalfa crops irrigated with treated wastewater and saline groundwater. *Geoderma*, *286*, 54–63. https://doi.org/10.1016/j.geoderma.2016.10.024

AFNOR. (1997). *Recueil de normes françaises : eau, méthodes d'essai. 2eme édition, Paris.*

Ahmali, A., Mandi, L., Loutfi, K., El Ghadraoui, A., El Mansour, T. E., El Kerroumi, A., Hejjaj, A., Del Bubba, M., & Ouazzani, N. (2020). Agro-physiological responses of Koroneiki olive trees (Olea europaea L.) irrigated by crude and treated mixture of olive mill and urban wastewaters. *Scientia Horticulturae*, *263*(September 2019). https://doi.org/10.1016/j.scienta.2019.109101

Alam, M., Rais, S. & Aslam, M. (2012). Hydrochemical investigation and quality assessment of groundwater in rural areas of Delhi, India. *Environmental Earth Sciences*, *66*(1), 97–110. https://doi.org/10.1007/S12665-011-1210-X

Alawsy, W. S. A., Alabadi, L. A. S., & Khaeim, H. M. (2018). Effect of sewage water irrigation on growth performance, biomass and nutrient accumulation in maize and barley. *International Journal of Agricultural and Statistical Sciences*, *14*(2), 519–524.

An, C.J., McBean, E., Huang, G.H., Yao, Y., Zhang, P., Chen, X.J., Li, Y.P. (2016) Multi-soil-layering systems for wastewater treatment in small and remote communities, J. Environ. Inform. 27 (2) 131–144. https://doi.org/10.3808/ jei.201500328.

APHA, 1992. (n.d.). *Standard Methods for Examination of Water and Waste Water. APHA, AWWA, Washington, DC., USA.*

APHA, AWWA, WEF, 2005. (n.d.). *Standard Methods for the Examination of Water and Wastewater, 21st ed. American Public Health Association/American Water Works Association/Water Environment Federation, Washington, DC, USA.*

Bañón, S., Miralles, J., Ochoa, J., Franco, J. A. & Sánchez-Blanco, M. J. (2011). Effects of diluted and undiluted treated wastewater on the growth, physiological aspects and visual quality of potted lantana and polygala plants. *Scientia Horticulturae*, *129*(4), 869–876. https://doi.org/10.1016/j.scienta.2011.05.027

Bradford, M. M. (1976). A Rapid and Sensitive Method for the Quantitation of Microgram Quantities of Protein Utilizing the Principle of Protein-Dye Binding. *ANALYTICAL BIOCHEMISTRY*, *5*(5), 407–415. https://doi.org/https://doi.org/10.1016/0003-2697(76)90527-3

Bremner, M. (1996). Chapter 37: N-Total. *Methods of Soil Analysis Part 3. Chemical Methods-SSSA Book Series 5*, *5*, 1085–1121. https://doi.org/https://doi.org/10.2136/sssabookser5.3.c37

Burns, J. C., Westerman, P. W., King, L. D., Cummings, G. A., Overcash, M. R. & Goode, L.

(1985). Swine Lagoon Effluent Applied to 'Coastal' Bermudagrass: I. Forage Yield, Quality, and Element Removal. *Journal of Environmental Quality*, *14*(1), 9–14. https://doi.org/10.2134/JEQ1985.00472425001400010002X

C.J. An, E. McBean, G.H. Huang, Y. Yao, P. Zhang, X.J. Chen, Y.P. Li, Multi-soil-layering systems for wastewater treatment in small and remote communities, J. Environ. Inform. 27 (2) (2016) 131–144. https://doi.org/10.3808/ jei.201500328.

Caeiro, S., Costa, M. H., Delvalls, A., Repolho, T., Gonçalves, M., Mosca, A., Coimbra, A. P., Ramos, T. B. & Painho, M. (2009). Ecological risk assessment of sediment management areas: application to Sado Estuary, Portugal. *Ecotoxicology 2009 18:8*, *18*(8), 1165–1175. https://doi.org/10.1007/S10646-009-0372-8

Carvalhais, L. C., Dennis, P. G., Fedoseyenko, D., Hajirezaei, M. R., Borriss, R. & Von Wirén, N. (2011). Root exudation of sugars, amino acids, and organic acids by maize as affected by N, P, potassium, and iron deficiency. *Journal of Plant Nutrition and Soil Science*, *174*(1), 3–11. https://doi.org/10.1002/JPLN.201000085

Castro, E., Mañas, P. & De Las Heras, J. (2013). EFFECTS OF WASTEWATER IRRIGATION IN SOIL PROPERTIES AND HORTICULTURAL CROP (LACTUCA SATIVA L.)., *36*(11), 1659–1677. https://doi.org/10.1080/01904167.2013.805221

Chakrabarti, C. (1995). Residual effects of long-term land application of domestic wastewater. *Environment International*, *21*(3), 333–339. https://doi.org/10.1016/0160-4120(95)00021-C

Dai Z, Li R, Muhammad N, Brookes PC, Wang H, Liu X, Xu J. 2014. Principle component and hierarchical cluster analysis of soil properties following biochar incorporation. Soil Sci Soc Am J. 78(1), 205-213. https://doi.org/10.2136/sssaj2013.05.0199

Doneen, L. D. (1975). *Water Quality for Irrigated Agriculture*. *1952*, 56–76. https://doi.org/10.1007/978-3-642-80929-3_5

DuBois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. A. & Smith, F. (1956). Colorimetric Method for Determination of Sugars and Related Substances. *Analytical Chemistry*, *28*(3), 350–356. https://doi.org/10.1021/ac60111a017

Dudziak, M., Wyczarska-Kokot, J., Łaskawiec, E. & Stolarczyk, A. (2019). Application of Ultrafiltration in a Swimming Pool Water Treatment System. *Membranes 2019, Vol. 9, Page 44*, *9*(3), 44. https://doi.org/10.3390/MEMBRANES9030044

Durán–Álvarez, J. C. & Jiménez–Cisneros, B. (2014). Beneficial and Negative Impacts on Soil by the Reuse of Treated/Untreated Municipal Wastewater for Agricultural Irrigation – A Review of the Current Knowledge and Future Perspectives. In (Ed.), Environmental Risk Assessment of Soil Contamination. IntechOpen. https://doi.org/10.5772/57226

El Mokhtar, M.; Fakir, Y.; El Mandour, A.; Benavente, J.; Meyer, H.; Stigter, T. Salinisation des Eaux Souterraines aux Alentours des Sebkhas de Sad Al Majnoun et Zima (plaine de la Bahira, Maroc). Secheresse 2012, 23, 48–56.

El Moussaoui, T., Mandi, L., Wahbi, S., Masi, S. & Ouazzani, N. (2019). Soil proprieties and alfalfa (Medicago sativa L.) responses to sustainable TWW reuse. *Archives of Agronomy and Soil Science*, *65*(13), 1900–1912. https://doi.org/10.1080/03650340.2019.1580359

El-Nahhal Y. (2013). *Effect of treated waste water irrigation on plant growth and soil properties in Gaza Strip, Palestine*. https://doi.org/http://dx.doi.org/10.4236/ajps.2013.49213

Elfanssi, S., Ouazzani, N., Latrach, L., Hejjaj, A. & Mandi, L. (2018). Phytoremediation of domestic wastewater using a hybrid constructed wetland in mountainous rural area. *International Journal of*

Phytoremediation, *20*(1), 75–87. https://doi.org/10.1080/15226514.2017.1337067

EL Sabagh ,A., Hossain, A., Barutçular, C., Iqbal, MA., Islam, MS., Fahad, S., Sytar, O., Çiğ, F., Meena RS,. Erman, M. (2020).Consequences of salinity stress on the quality of crops and its mitigation strategies for sustainable crop production: an outlook of arid and semi-arid regions. In: Environment, Climate, Plant and Vegetation Growth. Springer: Cham; 2020a, p. 503-533

Fan, D. (2019). The Effect of Calcium to Maize Seedlings under Drought Stress. *American Journal of Plant Sciences*, *10*(08), 1391–1396. https://doi.org/10.4236/ajps.2019.108099

Friedel JK, Langer T, Siebe C, Stahr K. 2000. Effects of long-term waste water irrigation on soil organic matter, soil microbial biomass and its activities in central Mexico. Biol Fertil Soils. 31(5): 414-421. https://doi.org/10.1007/s003749900188

Ganjegunte, G. K., Clark, J. A., Sallenave, R., Sevostianova, E., Serena, M., Alvarez, G., & Leinauer, B. (2017). Soil salinity of an urban park after long-term irrigation with Saline ground water. *Agronomy Journal*, *109*(6), 3011–3018. https://doi.org/10.2134/AGRONJ2017.06.0369

Gasperi, J., Zgheib, S., Cladière, M., Rocher, V., Moilleron, R. & Chebbo, G. (2012). Priority pollutants in urban stormwater: Part 2 – Case of combined sewers. *Water Research*, *46*(20), 6693–6703. https://doi.org/10.1016/J.WATRES.2011.09.041

Harbouze, R., Pellissier, J.-P., Rolland, J.-P., & Khechimi, W. (2019). *Rapport de synthèse sur l ' agriculture au Maroc.* 105. https://hal.archives-ouvertes.fr/hal-02137637/document

Hasegawa, P.M., Bressan, R.A., Handa, S., Handa, A.K., 1984. Cellular mechanisms of tolerance to water stress. J. Hort. 19, 371–376. https://doi.org/10.21273/HORTSCI.19.3.371

Hssaisoune, M.; Bouchaou, L.; Sifeddine, A.; Bouimetarhan, I.; Chehbouni, A. (2020). Moroccan Groundwater Resources and Evolution with Global Climate Changes. Geosciences 2020, 10, 81.

Jin Z, Chen C, Chen X, Hopkins I, Zhang X, Han Z, Billy G. (2019). The crucial factors of soil fertility and rapeseed yield-A five year field trial with biochar addition in upland red soil, China. Science of the Total Environment, 649, 1467-1480. https://doi.org/10.1016/j.scitotenv.2018.08.412

Jiries, A., Ta'any, R. & Abbassi, B.(2009). *Agriculture Water Use Efficiency in Wadi Shu'eib Area, Jordan*. Agriculture Water Use Efficiency in Wadi Shu'eib Area, Jordan. http://www.pjoes.com/Agriculture-Water-Use-Efficiency-in-Wadi-Shu-eib-Area-Jordan,88389,0,2.

Jóźwiakowski, K., Bugajski, P., Kurek, K., Cáceres, R., Siwiec, T., Jucherski, A., Czekała, W. & Kozłowski, K. (2020). Technological reliability of pollutant removal in different seasons in one-stage constructed wetland system with horizontal flow operating in the moderate climate. *Separation and Purification Technology*, *238*(November). https://doi.org/10.1016/j.seppur.2019.116439

Kiziloglu, F. M., Turan, M., Sahin, U., Kuslu, Y. & Dursun, A. (2008). Effects of untreated and treated wastewater irrigation on some chemical properties of cauliflower (Brassica olerecea L. var. botrytis) and red cabbage (Brassica olerecea L. var. rubra) grown on calcareous soil in Turkey. *Agricultural Water Management*, *95*(6), 716–724. https://doi.org/10.1016/J.AGWAT.2008.01.008

Kouraa, A., Fethi, F., Fahde, A., Lahlou, A., & Ouazzani, N. (2002). Reuse of urban wastewater treated by a combined stabilization pond system in Benslimane (Morocco). *Urban Water*, *4*(4), 373–378. https://doi.org/10.1016/S1462-0758(01)00067-X

Latef, A. A. H. A., & Ahmad, P. (2015). Legumes and breeding under abiotic stress: An overview. *Legumes under Environmental Stress: Yield, Improvement and Adaptations*, 1–20. https://doi.org/10.1002/9781118917091.CH1

Lesch, S. M., & Suarez, D. L. (2009). A short note on calculating the adjusted SAR index. *Transactions of the ASABE*, *52*(2), 493–496.

Lucho-Constantino, C. A., Prieto-García, F., Del Razo, L. M., Rodríguez-Vázquez, R. & Poggi-Varaldo, H. M. (2005). Chemical fractionation of boron and heavy metals in soils irrigated with wastewater in central Mexico. *Agriculture, Ecosystems & Environment*, *108*(1), 57–71. https://doi.org/10.1016/J.AGEE.2004.12.013

Mallick, N. & Mohn, F. H. (2003). Use of chlorophyll fluorescence in metal-stress research: a case study with the green microalga Scenedesmus. *Ecotoxicology and Environmental Safety, 55*(1), 64–69. https://doi.org/10.1016/S0147-6513(02)00122-7

Mapanda, F., Mangwayana, E. N., Nyamangara, J. & Giller, K. E. (2005). The effect of long-term irrigation using wastewater on heavy metal contents of soils under vegetables in Harare, Zimbabwe. *Agriculture, Ecosystems & Environment*, *107*(2–3), 151–165. https://doi.org/10.1016/J.AGEE.2004.11.005

Mohsin, M., Kaipiainen, E., Salam, M. M. A., Evstishenkov, N., Nawrot, N., Villa, A., Wojciechowska, E., Kuittinen, S., & Pappinen, A. (2021). Biomass production and removal of N and P from processed municipal wastewater by Salix Schwerinii: A field trial. *Water (Switzerland), 13*(16).

https://doi.org/10.3390/w13162298

Mojiri, A., Aziz, H.A., Aziz, S.Q., Gholami, A., Aboutorab, M., 2013. Impact of urban wastewater on soil properties and Lepidium sativum in an arid region. Int. J. Sci. Res. Environ.Sci.1 (1),1–9. https://doi.org/10.12983/IJSRES-2013-P007-015

Moroccan Standards. (2006). *Moroccan standard approved by order of the Minister of Industry, Trade and Economy Last Level. Rabat: Moroccan Industrial Standardization Service.*

Munir J, Mohammad R., Hinnawi, S. & Rousan, L. (2007). Long term effect of wastewater irrigation of forage crops on soil and plant quality parameters. *Desalination*, *215*(1–3), 143–152. https://doi.org/10.1016/J.DESAL.2006.10.032

Murphy, J. & Riley, J. P. (1962). *A modified single-solution method for the determination of P in natural waters. J. Anal. Chim. Acta. 27, 31–36. 30514*, 291–292.

https://doi.org/10.1016/S0003-2670(00)88444-5

Murthy, U. N., Rekha, H. B. & Bhavya, J. G. (2011). Performance of Electrochemical Oxidation in Treating Textile Dye Wastewater by Stainless Steel Anode. *International Journal of Environmental Science and Development*, *2*(6), 483–487. https://doi.org/10.7763/ijesd.2011.v2.174

Musslewhite, B. D., Vinson, J. R., Johnston, C. R., Brown, T. H., Wendt, G. W., & Vance, G. F. (2009). Salinity and Sodicity of Weathered Minesoils in Northwestern New Mexico and Northeastern Arizona. *Journal of Environmental Quality*, *38*(3), 1266–1273. https://doi.org/10.2134/JEQ2007.0490

Muyen, Z., Moore, G. A. & Wrigley, R. J. (2011). Soil salinity and sodicity effects of wastewater irrigation in South East Australia. *Agricultural Water Management*, *99*(1), 33–41. https://doi.org/10.1016/J.AGWAT.2011.07.021

Nasta, P., Franz, T. E., Gibson, J. P., & Romano, N. (2023). Revisiting the definition of field capacity as a functional parameter in a layered agronomic soil profile beneath irrigated maize. Agricultural Water Management, 284, 108368. https://doi.org/10.1016/j.agwat.2023.108368

Newson, W. R., Rasheed, F., Kuktaite, R., Hedenqvist, M. S., Gällstedt, M., Plivelic, T. S., & Johansson, E. (2015). Commercial potato protein concentrate as a novel source for thermoformed bio-based plastic films with unusual polymerisation and tensile properties. *RSC Advances*, *5*(41), 32217–32226. https://doi.org/10.1039/C5RA00662G

Olsen, S.R., Cole, C.V., Watanabe, F.S. & Dean, L. A. (1954). *Estimation of Available P in Soils by Extraction with Sodium Bicarbonate 939. USDA Circular, Washington, DC, pp. 1–19.*

Ouda, O. K. M., Raza, S. A., Nizami, A. S., Rehan, M., Al-Waked, R., & Korres, N. E. (2016). Waste to energy potential: A case study of Saudi Arabia. *Renewable and Sustainable Energy Reviews*, *61*, 328–340. https://doi.org/10.1016/J.RSER.2016.04.005

Orhue, E. R., Osaigbovo, A. U., & Wvioko, D. E. (2005). Growth of maize (Zea mays L.) and changes in some chemical properties of an ultisol amended with brewery effluent. *African Journal of Biotechnology*, *4*(9), 973–978

Pereira, B.F.F., He, Z.L., Silva, M.S., Herpin, U., Nogueira, S.F., Montes, C.R., Melfi, A.J., 2011. Reclaimed wastewater: impact on soil–plant system under tropical conditions. J. Hazard. Mater. 192, 54–61. https://doi.org/10.1016/j.jhazmat.2011.04.095

Qian YL, Mecham B. 2005. Long-term effects of recycled wastewater irrigation on soil chemical properties on golf course fairways. Agron J. 97(3):717-721. https://doi.org/10.2134/agronj2004.0140

Raju, N. J. (2007). Hydrogeochemical parameters for assessment of groundwater quality in the upper Gunjanaeru River basin, Cuddapah District, Andhra Pradesh, South India. *Environmental Geology*, *52*(6), 1067–1074. https://doi.org/10.1007/s00254-006-0546-0

Rattan RK, Datta SP, Chhonkar PK, Suribabu K, Singh, AK. (2005). Long-term impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater-a case study. Agric Ecosyst Environ. 109(3): 310-322. https://doi.org/10.1016/j.agee.2005.02.025

Ray, K., Banerjee, H., Duttaid, S., Hazra, A. K., & Majumdar, K. (2019). *Macronutrients influence yield and oil quality of hybrid maize (Zea mays L.)*. https://doi.org/10.1371/journal.pone.0216939

Rezapour, S., Nouri, A., Jalil, H. M., Hawkins, S. A., & Lukas, S. B. (2021). Influence of treated wastewater irrigation on soil nutritional-chemical attributes using soil quality index. *Sustainability (Switzerland)*, *13*(4), 1–21. https://doi.org/10.3390/su13041952

Rija, H., Siddiqui, Z.S. & Arif-uz-Zaman, K. U. (2005). *Changes in chlorophyll, protein and carbohydrate contents of Vigna radiata,Cicer arietinum and Lens culinaris after irrigation with sewage waste water*. https://agris.fao.org/agris-search/search.do?recordID=PK2006000536

Rubio, S. J., & Casino, B. (2002). A note on cooperative versus non-cooperative strategies in international pollution control. *Resource and Energy Economics*, *24*(3), 251–261. https://doi.org/10.1016/S0928-7655(02)00002-7

Ruget, F. & Bonhomme, R. & Chartier, M. (1996). Estimation simple de la surface foliaire de plantes de maïs en croissance. *Agronomie*, *23*(May), 407–418. https://doi.org/10.1051/agro:19960903

Rusan, M.J., Hinnawi, M., Rusan, S.L., 2007. Long term effect of wastewater irrigation of forage crop on soil and plant quality parameters. J. Desalin. 215, 143–152. https://doi.org/10.1016/j.desal.2006.10.032

Rocco, C., Duro, I., Di Rosa, S., Fagnano, M., Fiorentino, N., Vetromile, A., & Adamo, P. (2016). Composite vs. discrete soil sampling in assessing soil pollution of agricultural sites affected by solid waste disposal. *Journal of Geochemical Exploration*, *170*, 30–38. https://doi.org/10.1016/j.gexplo.2016.08.004

Sadras, V. O., Villalobos, F. J., Orgaz, F., & Fereres, E. (2016). Effects of Water Stress on Crop

Production. Principles of Agronomy for Sustainable Agriculture, 24, 189- 204. https://doi.org/10.1007/978-3-319-46116-8

Saha, S., Reza, A. H. M. S., & Roy, M. K. (2019). Hydrochemical evaluation of groundwater quality of the Tista floodplain, Rangpur, Bangladesh. *Applied Water Science*, *9*(8), 1–12. https://doi.org/10.1007/s13201-019-1085-7

Sbahi, S., Mandi, L., Masunaga, T., Ouazzani, N., Hejjaj, A. 2022. Multi-Soil-Layering, the Emerging Technology for Wastewater Treatment: Review, Bibliometric Analysis, and Future Directions. Water. 14, 3653. https://doi.org/10.3390/w14223653

Segal, E., Dag, A., Ben-Gal, A., Zipori, I., Erel, R., Suryano, S., & Yermiyahu, U. (2011). Olive orchard irrigation with reclaimed wastewater: Agronomic and environmental considerations. *Agriculture, Ecosystems & Environment*, *140*(3–4), 454–461. https://doi.org/10.1016/J.AGEE.2011.01.009

Seleiman MF, Almutairi KF, Alotaibi M, Shami A, Alhammad BA, Battaglia ML. Nano-fertilization as an emerging fertilization technique: why can modern agriculture benefit from its use?. Plants. 2021b:10(1):2

Song, G., Huang, Y., Hong, C., An, X., Xin, P., Zhang, A. (2020). biophysiological perspective on enhanced nitrate removal from decentralized domestic sewage using gravitational-flow multi-soil-layering systems, Chemosphere 240 (240.2020), https://doi.org/10.1016/j.chemosphere.2019.124868.

Suke, S. N., Deotale, R. D., Priyanka, H., Mitali, D. & Sorte, N. V. (2011). *Effect of nutrients and biofertilizers of chemical and biochemical parameters of maize (Zea mays L.).* https://www.cabdirect.org/cabdirect/abstract/20113231492

Tzanakakis, V.A.; Paranychianakis, N.V.; Angelakis, A.N. Nutrient Removal and Biomass Production in Land Treatment Systems Receiving Domestic Effluent. Ecol. Eng. 2009, 35, 1485–1492. https://doi.org/10.1016/j.ecoleng.2009.06.009

Upadhyaya, H., & Panda, S. K. (2004). Responses of Camellia sinensis to drought and rehydration. *Biologia Plantarum*, *48*(4), 597–600. https://doi.org/10.1023/B:BIOP.0000047158.53482.37

Vergine, P., Salerno, C., Libutti, A., Beneduce, L., Gatta, G., Berardi, G., & Pollice, A. (2017). Closing the water cycle in the agro-industrial sector by reusing treated wastewater for irrigation. *Journal of Cleaner Production*, *164*, 587–596. https://doi.org/10.1016/J.JCLEPRO.2017.06.239

Verlicchi, P., Al Aukidy, M., Galletti, A., Zambello, E., Zanni, G., & Masotti, L. (2012). A project of reuse of reclaimed wastewater in the Po Valley, Italy: Polishing sequence and cost benefit analysis. *Journal of Hydrology*, *433*, 127–136. https://doi.org/10.1016/J.JHYDROL.2012.02.024

World Health Organisation, (2006). *Guidelines for the Safe Use of Wastewater, Exctreta and Grey Water Wastewater Use in Agriculture 182 WHO, Geneva.*

Wilkinson, S., Davies, W.J., 2002. ABA-based chemical signalling: the co-ordination of responses to stress in plants. J. Plant Cell Environ. 25, 195–210.

https://doi.org/10.1046/j.0016-8025.2001.00824.x

Xiong, P., Zhang, Z., Hallett, P.D. et al. (2020).Variable responses of maize root architecture in elite cultivars due to soil compaction and moisture. Plant Soil 455, 79–91 (2020). https://doi.org/10.1007/s11104-020-04673-3

Younas, F., Niazi, N. K., Bibi, I., Afzal, M., Hussain, K., Shahid, M., Aslam, Z., Bashir, S., Hussain, M. M., & Bundschuh, J. (2022). Constructed wetlands as a sustainable technology for wastewater treatment with emphasis on chromium-rich tannery wastewater. *Journal of Hazardous Materials*, *422*. https://doi.org/10.1016/j.jhazmat.2021.126926

Yu, Q. G., Chen, Y. X., Ye, X. Z., Tian, G. M., & Zhang, Z. J. (2007). Influence of the DMPP (3,4-dimethyl pyrazole phosphate) on N transformation and leaching in multi-layer soil columns. *Chemosphere*, *69*(5), 825–831. https://doi.org/10.1016/j.chemosphere.2007.05.047

Zhang QY, Yang P, Liu LS, Liu ZJ (2020) Formulation and characterization of a heterotrophic nitrification-aerobic denitrification synthetic microbial community and its application to livestock wastewater treatment. Water (Switzerland) 12. https:// doi.org/ 10.3390/ w1201 0218

Zidan, K., Mandi, L., Hejjaj, A., Sbahi, S., El, A., El, A., Ouazzani, N., & Assabbane, A. (2023). Efficiency of a new hybrid multi-soil-layering eco-friendly technology for removing pollutants from domestic wastewater under an arid climate. *Journal of Water Process Engineering*, *51*(October 2022), 103482. https://doi.org/10.1016/j.jwpe.2022.103482

Zidan, K., Sbahi, S., Hejjaj, A., Ouazzani, N., Assabbane, A., & Mandi, L. (2022). Removal of bacterial indicators in on-site two-stage multi-soil-layering plant under arid climate (Morocco): prediction of total coliform content using K-nearest neighbor algorithm. *Environmental Science and Pollution Research*, *0123456789*. https://doi.org/10.1007/s11356-022-21194-x

A REVIEW ON THE EVALUATION OF DIFFERENT ANIMAL MANURE AND WHEY IN BIOGAS PRODUCTION

Fatma Ersöz

Ardahan University, Department of Food Engineering, Ardahan, Türkiye

ABSTRACT

In the world, the human population is increasing daily, and fossil fuels are being depleted. For this reason, there is a growing demand for new, alternative, and environmentally friendly energy sources. Biogas is a gas produced from organic materials and is a renewable energy source. Biogas can be used in the production of electricity and heat. Thus, it has the potential to be actively utilized in meeting the basic energy needs of various technological areas. It is known that environmentally friendly technologies are used in the production of biogas. Within the scope of this review study, the utilization capacity of environmental wastes such as animal manure and whey for biogas production is reported. Biogas is produced using a batch fermentation technique under suitable pH and temperature conditions by mixing animal manure and whey. In the literature, numerous studies have been conducted on the production of biogas from organic waste materials. In related studies, biogas was produced by mixing different animal manure (swine and cow) with whey at various ratios. It's known that manure and whey are potential sources of pollution in water. Therefore, converting waste into biogas is essential for both the disposal of environmental waste and the production of a valuable energy source. This review study aims to present data on the evaluation of whey, a significant waste product in the cheese production industry, and includes improvements in waste disposal methods.

Keywords: Anaerobic, Animal manure, Biogas, Fermentation, Whey, Waste

INTRODUCTION

Fossil fuels are natural fuels formed from the remains of plants and dead animals, resulting from geological processes in prehistoric times. They are used for various purposes, including heating, electricity generation, and vehicular fuel. Fossil fuels are non-renewable energy sources rich in carbon and are also known as mineral fuels. The types of fossil fuels can be listed as coal, coal products, natural/derived gas, crude oil, and petroleum products (Demirbas, 2007). According to the Energy institute-statical review of world energy (2025) report, the annual global use of current fossil fuels is evaluated in terms of reserve/product ratios, it is reported that coal, oil and gas have 139, 56 and 49 years of reserves, respectively *(Energy Institute - Statistical Review of World Energy (2025) – with major processing by Our World in Data. "Gas" [dataset]. Energy Institute, "Statistical Review of World Energy").* Due to the depletion and non-renewability of natural resources, a search for a renewable and environmentally friendly resource has emerged. There has been an increasing interest in renewable energy sources, such as biogas, in recent days.

Biogas is a gas that is produced from renewable energy sources and raw materials such as agricultural waste, animal manure, municipal waste, plant material, sewage, green waste, wastewater, and different food wastes (Pandit et al., 2022). Biogas production is defined as the production of carbon dioxide and methane gas from organic waste through microbial fermentation in an oxygen-free environment. (Jameel et al., 2024) Biogas is obtained from the biomass of microorganisms in anaerobic conditions and reduces the dependence on fossil fuels (Stolze et al., 2015). It is a clean, renewable, and reliable source, offering climate benefits. The biogas production process, in which waste is utilized to produce energy, contributes to the local economy and waste remediation (Zarkadas et al., 2016). Biogas production through microbial anaerobic fermentation also helps reduce foul odor, pathogens and water pollution (Jameel et al., 2024). The part of the digestion process, also known as digestate, is used as fertilizer and reduces the need for chemical fertilizers (Li et al., 2013) and, is used as soil amendments.

METHODOLOGY

In the biogas production process, various wastes, including livestock waste (such as manure), agricultural waste, wastewater, and food waste, are combined in specific proportions in an anaerobic reactor and subjected to microbial fermentation under suitable temperature and pH conditions to produce biogas. The schematic representation of the biogas production process is given in Figure 1.

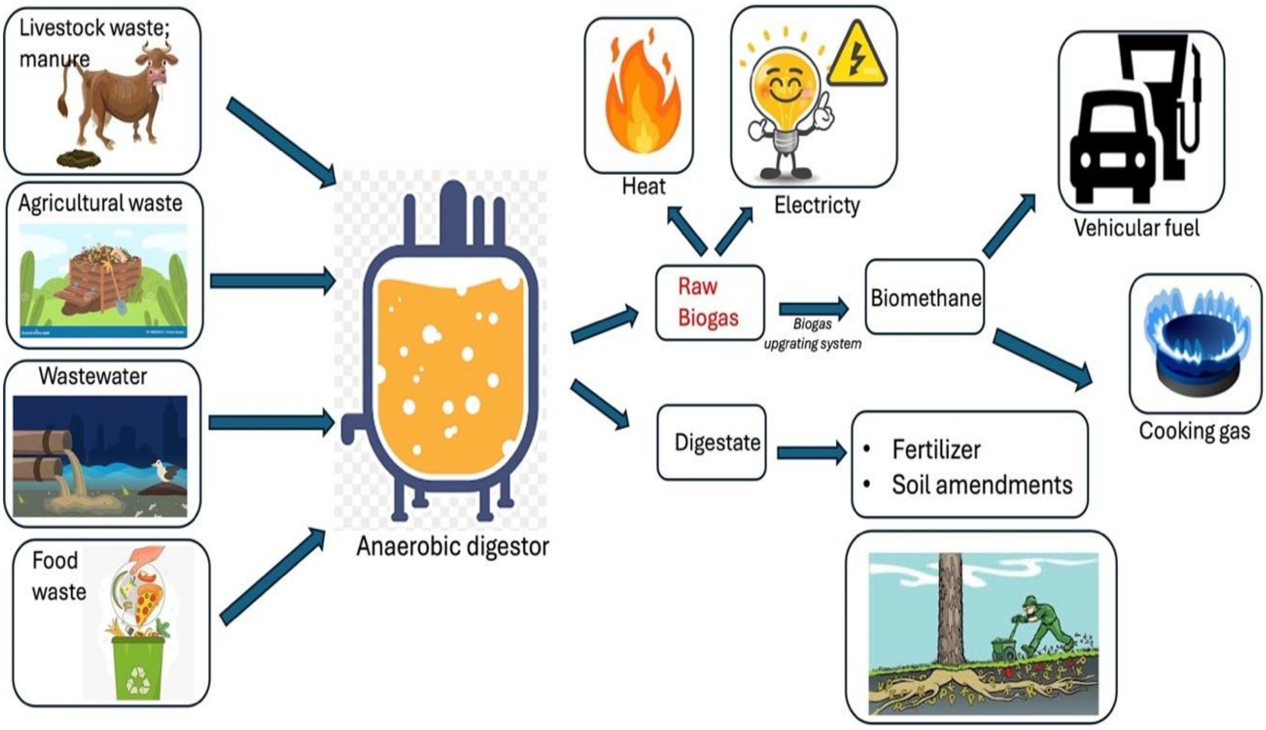


Figure 1. Schematic representation of biogas production, adapted from Upadhykav et al. (Upadhyay et al., 2023) and October 2017 EESI report (https://www.eesi.org/papers/view/fact-sheet-biogasconverting-waste-to-energy)

Several parameters must be taken into consideration during the anaerobic fermentation process. These parameters are; waste type and characteristics (*protein, lipid, carbohydrates and nutrients content)*, digester microbiology and biochemistry (*microorganism type and suitabilty)*, biogas production and composition (*methanol content (55-68%), CO2 (32-45%) amonnia (3%) and H_2S)*, digester types *(covered lagoon fixed film, complete mix, plug flow, mixed system)*, temperature *(mesophilic and thermophilic)*, acidity vs. alkalinity (pH) *(6.8-7.5 optimum; sodium/potassium bicarbonate, calcium carbonate/hydrate…),* retention time *(15-21 days)*, agitation and loading (Shelford et al., n.d.). The metabolic pathway of anaerobic digestion and fermentation is composed of four parts, in which different microorganisms are responsible: hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Chen et al., 2023; Mudzanani et al., 2021).

In the dairy industry, whey is a waste from the cheese production process and contains water, lactose, lactic acid, protein, citric acid, and minerals(Ganju et al., 2017) . Also, it's known that both whey and manure contain organic carbon, nitrogen, and phosphorus (Kavacik et al., 2010). Whey and manure are the primary waste products of the dairy industry, and it is essential to ensure their recycling. In the dairy industry, the milk involved in cheese production processes converts into whey at a ratio of approximately 80-90%. Buchanan et al. reported that approximately 180-190 million tonnes of waste/year are generated (Buchanan et al., 2023). Livestock farming is a field with a wide range, and manure constitutes a significant waste product for the livestock industry, with a high pollution ratio. Although animal manure is highly nutritious for the soil, its direct use is limited due to its foul odor (Fernández-Rodríguez et al., 2021). The anaerobic digestion of this waste produces bioenergy, soil amendments, and reduces greenhouse gas emissions. In this review study, we aim to provide data on biogas production from a mixture of manure and whey. In Table 1, we summarize the biogas production from mixtures of whey and manure with different ratios.

Media Composition	**Methane content**	**Biogas**	**Day**	**Temperature**	**pH**	**Reference**
2:1 whey-manure ratio (8% total solid)	60%	1.5 $m^3 m^{-3} d^{-1}$	5	34°C	-	(Kavacik et al., 2010)
10% whey 90% cow manure * 5g/dm^3 $NaHCO_3$	78.7%	21.8 $dm^3 dm^{-3}$	12	55°C	7.5	(Hublin et al., 2012)
100% whey	63%	270 L ($kg\text{-}sv^{-1}$) (Total accumulation)	9	32°C	7.45	(Antonelli et al., 2016)
50% whey 50% swine manure	76.3%	9789.5 cm^3 (Total accumulation)	65	20-26°C	Not controlled	(Machado et al., 2022)
75% whey 25% swine manure	294,75 mL (Total accumulation)	-	94	35°C	7.13	(dos Santos et al., 2024)

Table 1. The summary of some studies on biogas production from the manure and whey

CONCLUSION AND DISCUSSION

Biogas production processes are complex and lengthy. In this process, the type of waste is crucial for achieving maximum biogas production yield and the type of biogas produced. In this study, the biogas production capacities of two types of waste were evaluated: cheese whey, a major by-product of the cheese industry, and animal manure, the primary waste type of the livestock industry. It was observed that anaerobic fermentation processes occurred at various temperatures and generally at near-neutral pH values. It was observed that several factors influence the biogas yield and the methane content ratio. However, the optimum pH value is close to neutral, and it is necessary to add the agent, such as NaHCO3, to adjust the pH, as in the study by Hublin et al. (Hublin et al., 2012).The reaction temperature was setted at mesophilic conditions as in the studies mentioned in Table 1 (Antonelli et al., 2016; dos Santos et al., 2024; Kavacik et al., 2010). In a study conducted by Machado et al. (Machado et al., 2022) the fermentation temperature was setted between 20-26°C conditions, however the fermentation time is extended up to 65 days for biogas production. Another critical parameter in biogas production is the initial substrate mixture. The ratio of whey and manure in the substrate mixture directly affects the amount of produced biogas. The studies in the literature demonstrated that biogas production can be performed with mixing with manure and whey with different ratio, such as 10% whey + 90% cow manure, 100% whey, 50% whey + 50% swine manure and, 75% whey + 25% swine manure. The expected methane content in biogas produced from waste, is likely to be between 50-70% by volume (Jameel et al., 2024). According to the table 1, the methane content is between the expected ratio, so it is shown that both whey and manure are suitable substrates for biogas production via the anaerobic digestion fermentation process. However, it should be developed to increase the production level. Additionally, the type of manure, such as swine or cow, is vital in terms of its carbon and nitrogen content. Biogas production through anaerobic digestion offers several advantages, including low operational costs, waste evaluation, and sustainable waste management, as well as serving as a renewable energy source. Therefore, future studies should focus on enhancing biogas production and achieving products through a shorter fermentation process.

REFERENCES

Antonelli, J., Lindino, C. A., de Azevedo, J. C. R., de Souza, S. N. M., Cremonez, P. A., & Rossi, E. (2016). Biogas production by the anaerobic digestion of whey. *Revista de Ciências Agrárias*, *39*(3). doi: 10.19084/rca15087

Buchanan, D., Martindale, W., Romeih, E., & Hebishy, E. (2023). Recent advances in whey processing and valorisation: Technological and environmental perspectives. In International Journal of Dairy Technology (Vol. 76, Issue 2). doi: 10.1111/1471-0307.12935

Chen, T. H., Shen, M. Y., Chen, C. Y., Chen, Y. W., Wang, L. H., Chu, C. Y., Lee, M. C., & Sun, H. L. (2023). Biogas production from food waste hydrolysate using a subcritical water pretreated process and pulp wastewater seed sludge. *Sustainable Energy Technologies and Assessments*, *59*, 103392. doi: 10.1016/J.SETA.2023.103392

Demirbas, M. F. (2007). Progress of fossil fuel science. *Energy Sources, Part B: Economics, Planning and Policy*, *2*(3). doi: 10.1080/15567240500402909

dos Santos, A. C. S., Peiter, F. S., de Oliveira, M. V. A., de Amorim, E. L. C., & de Resende, M. M. (2024). Biomethane production using goat manure and cheese whey: statistical analysis of the effect of mixture composition. *Brazilian Journal of Chemical Engineering*. doi: 10.1007/s43153-024-00442-2

Fernández-Rodríguez, M. J., Puntano, N. F., Mancilla-Leytón, J. M., & Borja, R. (2021). Batch mesophilic anaerobic co-digestion of spent goat batch mesophilic anaerobic co-digestion of spent goat straw bedding and goat cheese whey: Comparison with the mono-digestion of the two sole substrates. *Journal of Environmental Management*, *280*, 111733. doi: 10.1016/J.JENVMAN.2020.111733

Ganju, S., & Gogate, P. R. (2017). A review on approaches for efficient recovery of whey proteins from dairy industry effluents. *Journal of Food Engineering*, *215*, 84–96. doi: 10.1016/J.JFOODENG.2017.07.021

Hublin, A., Zokić, T. I., & Zelić, B. (2012). Optimization of biogas production from co-digestion of whey and cow manure. *Biotechnology and Bioprocess Engineering*, *17*(6). doi: 10.1007/s12257-012-0044-z

Jameel, M. K., Mustafa, M. A., Ahmed, H. S., Mohammed, A. jassim, Ghazy, H., Shakir, M. N., Lawas, A. M., Mohammed, S. khudhur, Idan, A. H., Mahmoud, Z. H., Sayadi, H., & Kianfar, E. (2024). Biogas: Production, properties, applications, economic and challenges: A review. *Results in Chemistry*, *7*. doi: 10.1016/j.rechem.2024.101549

Kavacik, B., & Topaloglu, B. (2010). Biogas production from co-digestion of a mixture of cheese whey and dairy manure. *Biomass and Bioenergy*, *34*(9), 1321–1329. doi: 10.1016/J.BIOMBIOE.2010.04.006

Li, Y., Zhang, R., Liu, G., Chen, C., He, Y., & Liu, X. (2013). Comparison of methane production potential, biodegradability, and kinetics of different organic substrates. *Bioresource Technology*, *149*, 565–569. doi: 10.1016/J.BIORTECH.2013.09.063

Machado, L. R., Ferrarez, A. H., Junior, J. L., & Alves, F. C. (2022). Biogas production and composition optimization in an anaerobic digestor using cheese whey and swine manure as substrate. *Acta Scientiarum - Technology*, *44*. doi: 10.4025/actascitechnol.v44i1.56923

Mudzanani, K., Van Heerden, E., Mbhele, R., & Daramola, M. O. (2021). Enhancement of biogas production via co-digestion of wastewater treatment sewage sludge and brewery spent grain: Physicochemical characterization and microbial community. *Sustainability (Switzerland)*, *13*(15). doi: 10.3390/su13158225

Pandit, G. K., Tiwari, R. K., Shanvi, Singh, V., & Singh, M. (2022). *Recent Advances in Biogas Production from Food Waste*. doi: 10.1007/978-981-19-0813-2_5

Shelford, T., Gooch, C., Choudhury, A., & Lansing, S. (n.d.). *A Technical Reference Guide for Dairy-Derived Biogas Production, Treatment and Utilization*.

Stolze, Y., Zakrzewski, M., Maus, I., Eikmeyer, F., Jaenicke, S., Rottmann, N., Siebner, C., Pühler, A., & Schlüter, A. (2015). Comparative metagenomics of biogas-producing microbial communities from production-scale biogas plants operating under wet or dry fermentation conditions. *Biotechnology for Biofuels*, *8*(1). doi: 10.1186/s13068-014-0193-8

Upadhyay, A., Kovalev, A. A., Zhuravleva, E. A., Kovalev, D. A., Litti, Y. V., Masakapalli, S. K., Pareek, N., & Vivekanand, V. (2023). Recent Development in Physical, Chemical, Biological and Hybrid Biogas Upgradation Techniques. In Sustainability (Switzerland) (Vol. 15, Issue 1). doi: 10.3390/su15010476

Zarkadas, I., Dontis, G., Pilidis, G., & Sarigiannis, D. A. (2016). Exploring the potential of fur farming wastes and byproducts as substrates to anaerobic digestion process. *Renewable Energy*, *96*, 1063–1070. doi: 10.1016/J.RENENE.2016.03.056

THE FUNCTIONAL CONTRIBUTION OF PLANT–MICROORGANISM SYMBIOSES TO HEAVY METAL TOLERANCE AND PHYTOREMEDIATION PERFORMANCE

Dr,Öğr. Üyesi Sibel BOYSAN CANAL

Van Yüzüncü Yıl Üniversitesi, Ziraat Fakültesi

ABSTRACT

Introduction and Purpose:This section aims to elucidate the potential of microbe-assisted phytoremediation as a synergistic strategy leveraging plant–microorganism interactions to enhance the remediation of heavy metal-contaminated environments. Given the ecological harm caused by anthropogenic metal pollution and the limitations of conventional methods, microbially mediated approaches represent a sustainable, cost-effective, and ecologically sound alternative.

Result: The utilization of biological materials such as AMF (Arbuscular mycorrhizal fungus) presents an economical, effective, and safe option for the removal of heavy metals. Thanks to the unique chemical composition of amf, fungal biomass retains metal ions by forming metal complexes with specific reactive groups on cell surfaces. AMF-supported phytoremediation is considered a natural, ecologically sound, cost-effective, and comprehensive strategy to enhance the metal removal efficiency of plants. Due to the potential of AMF to alleviate metal toxicity, their inoculations enhance plant growth and alter the bioavailability of metals in soils. Mycorrhizal fungi can colonize the roots of some hyperaccumulator plants in metal-contaminated soils and can provide greater plant biomass and faster growth compared to non-mycorrhizal plants. AMF can thus have an enhancing and progressive effect on phytoextraction and phytostabilization. In microbial studies, another effective microorganism is endophytic bacteria. In soil contaminated with heavy metals, the partnership between plants and bacteria causes changes in many vital functions, positively affecting growth and development. Endophytic bacteria improve stress conditions by increasing the uptake of nutrients that enhance the development and growth of hyperaccumulator plants in the presence of heavy metals. For this purpose, effective (metal-resistant) endophytic bacteria are used on various hyperaccumulator plants to enhance their phytoremediation potential.

Conclusion: Therefore, the symbiotic interactions between hyperaccumulator plants and microorganisms such as AMF and endophytic bacteria significantly enhance the effectiveness of phytoremediation, offering an environmentally friendly and sustainable strategy for the remediation of heavy metal-contaminated environments

Keywords: Heavy metal, AMF, Endophytic bacteria, Phytoremediation

ÖZET

Amaç Bu bölümün amacı, mikroorganizma ile bitki ortaklığının fitoremediasyonu iyileştirmek için mikrobiyal destekli yaklaşımların potansiyelini araştırmaktadır. Tarımsal uygulamalar ve metal işleme endüstrileri de dahil olmak üzere çeşitli antropojenik kaynaklardan ağır metallerin çevreye yayılması olumsuz etkilere neden olduğu bilinmektedir. Kirli ortamlardan ağır metallerin uzaklaştırılması için kullanılan geleneksel teknolojiler genellikle verimli olsa da, genellikle pahalıdır ve büyük miktarda toksik kimyasal ürün üretirler.

Bulgular AMF (Arbüsküler mikorhizal fungus) gibi biyolojik materyallerin kullanımı, ağır metallerin uzaklaştırılması için ekonomik, etkili ve güvenli bir seçenek sunar. Benzersiz kimyasal bileşimi sayesinde, mantar biyokütlesi, hücre yüzeylerinde belirli reaktif gruplarla metal kompleksleri oluşturarak metal iyonlarını tutar. Sideroforlar, temel metal iyonlarını bağlayarak, bitki alımı için çözünürlüklerini ve bioyararlanımları artırır. Mikrobiyal destek, siderofor üretebilen mantarlar da dahil olmak üzere belirli mikropların kullanımını içerir**.** AMF destekli fitoremediasyon, bitkilerin metal giderme verimliliğini artırmak için doğal, ekolojik olarak sağlam, uygun maliyetli ve kapsamlı bir strateji olarak kabul edilmiştir. AMF' nin metal toksisitesini hafifletme potansiyeli nedeniyle, aşılamaları bitki büyümesini artırır ve topraklardaki metal biyoyararlanımını değiştirir. Mikorizal mantarlar, metalle kirlenmiş topraklardaki bazı hiper akümülatör bitkilerin köklerini kolonize edebilir ve mikorizal olmayan bitkilere göre daha fazla bitki biyokütlesi ve daha hızlı büyüme sağlayabilir. Böylece fitoekstraksiyonu ve fitostabilizasyonu artırıcı ve ilerletici etki yapabilir. AMF ayrıca antioksidatif bileşikler, metalotiyoninler ve fitoşellatinler üretimini artırarak ağır metallere karşı bitki savunma mekanizmalarını iyileştirir. Mikrobiyel çalışmalarda bir başka etkin mikroorganizma endofitik ve PGPR bakterilerdir. Ağır metalle kirli toprakta, bitki ile bakteri ortaklığı bir çok hayati fonksiyon üzerinde değişime neden olarak büyüme ve gelişimi olumlu yönde etkiler. Bitkinin gelişimi ve büyümesini artırmaya neden olan besin elementi alımını artırarak stres koşullarını iyileştirir.

Sonuç Bu nedenle, akümülatör bitkiler ile AMF ve endofitik bakteriler gibi mikroorganizmalar arasındaki simbiyotik etkileşimler, fitoremediasyonun etkinliğini önemli ölçüde artırarak, ağır metallerle kirlenmiş ortamların iyileştirilmesi için çevre dostu ve sürdürülebilir bir strateji sunmaktadır.

Anahtar Kelimeler: Ağır Metal, AMF, Endofitik bakteri, Fitoremediasyon

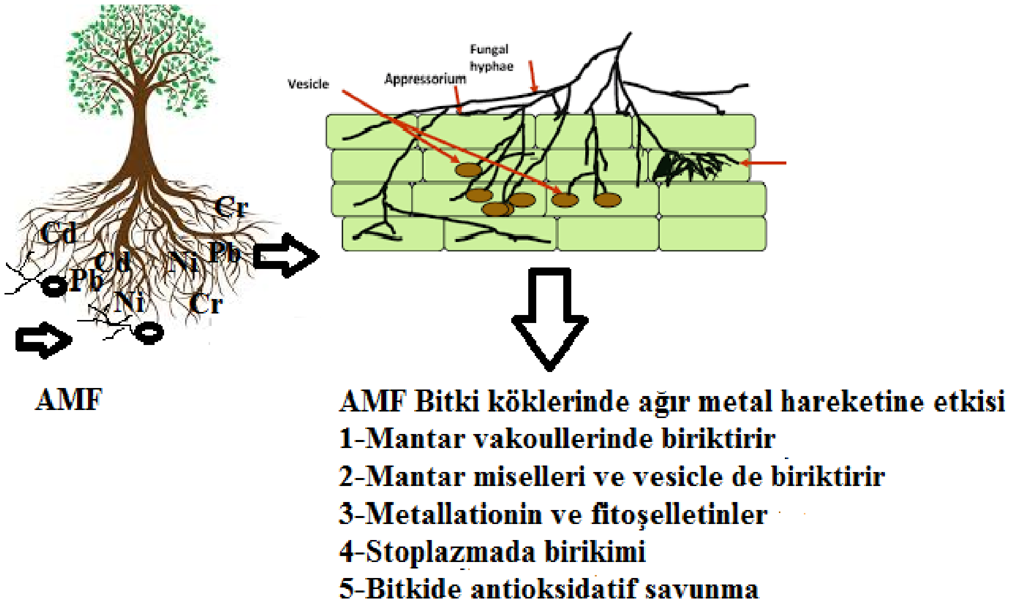
GİRİŞ

Gerçekte ağır metaller, yoğunluğu 5 g/cm^3'ten daha yüksek olan metaller için kullanılır. Demir (Fe), manganez (Mn), bakır (Cu), çinko (Zn) ve nikel (Ni) gibi ağır metaller bitki büyümesi ve işlevi için gereklidir. Ancak Cd, Cr, As ve Pb gibi bazı ağır metaller bitki büyümesi için gerekli değildir ve özellikle yüksek seviyeleri bitki büyümesini olumsuz etkileyebilir. Ağır metaller aşırı reaktif oksijen türleri ve metil glioksil birikimi vardır, bu nedenle bitkisel hücrelerde lipitlerin peroksidasyonu, proteinlerin oksidasyonu, enzimlerin inaktivasyonu ve DNA hasarı meydana gelir, bazen DNA diğer hücre bileşenleriyle reaksiyona girer. Pestisitler, gübreler ve metalle kirlenmiş kanalizasyon, toprakta ağır metal birikiminin başlıca nedenleridir. Fosil yakıtların yakılması, topraktaki bu ağır metalleri artırmıştır. Cd, Pb ve Zn konsantrasyonu son iki yüzyılda toprakta hızla artmıştır (Candelone ve ark.1995). Yüksek konsantrasyonlarda ağır metaller, bitkilerde protein yapısını etkileyerek enzimlerin yapısını ve dolayısıyla işlevselliğini etkiler. H^+−ATP azlar gibi plazma membran proteinlerinin yapısı ağır metaller tarafından değişikliğe karşı hassas olduğundan; ağır metallerin toksik etkileri plazma membranın geçirgenliğini ve işlevini etkileyebilir. Ayrıca, ağır metaller oksidatif strese (reaktif oksijen türlerinin üretimi) neden olur, farklı hücresel bileşenleri ve dolayısıyla bitki dokularını olumsuz etkiler (Sajedi et al., 2010). Topraktaki ağır metal stresi sonucu çeşitli fizyolojik, biyokimyasal ve moleküler süreçler bozulur. Bitki büyümesi engellenir ve bu ağır metaller düşük tohum çimlenmesi, turgor kaybı, kloroz, nekroz, yaşlanma ve en sonunda bitki ölümü gibi çeşitli kusurlara neden olur. Ağır metaller, kök gelişimini engelleyerek köklerin su ve besin elementi alım kapasitesini azaltır. Kök hücrelerinde birikim yapması kök uzamasını durdurur (Bono ve Ashfaq, 2013). Fitoremediasyon, ağır metal kaynaklı toksisitesini azaltmak için kirlenmiş ortamlarda bitkilerin kullanıldığı bir yöntemdir. Bu yöntemde genellikle hiperakümülatör olarak bilinen, yüksek miktarda ağır metali bünyesinde biriktirebilmesine rağmen gelişimini sürdürebilen bitki türleri tercih edilir (Parmar ve Sing, 2015). Arbusküler mikorizal (AM) mantarlar, çoğu karasal bitkiyle simbiyotik ilişki geliştiren toprak mantarlarıdır. Böyle bir simbiyoz da, mantarlar konak bitkiye karbon karşılığında su ve besin sağlar. Toprakta, karasal bitkilerin çoğuyla simbiyotik ilişki geliştiren AMF bulunur. Bu simbiyozda AMF, konak bitkinin karbon (C) karşılığında su ve besinleri emme yeteneğini önemli ölçüde artırabilir. Toprak ağır metal içeriğinin artması toprak bakteri ve mantar popülasyonun azalmasına neden olmaktadır. Ancak canlı organizmalarda ağır metal toksisitesini gidermek veya metalle kirlenmiş toprağı tarıma uygun hale getirmek için çeşitli yaklaşımlar uygulanmaktadır. Mantar biyo kütlesinin kadmiyum, bakır, civa, kurşun ve çinko gibi ağır metalleri çok verimli bir şekilde biriktirdiği bulunmuştur (Li and Yuan 2006; Javaid et al. 2010). AMF, besin alımını artırarak ve topraktaki ağır metallerin fitostabilizasyonunu sağlayarak, ayrıca ağır metallerin emilimi ve detoksifikasyonu ile anaç bitkinin ağır metallerin stresine karşı hayatta kalmasına yardımcı olabilir (Miransari, 2011). PGPR (bitki büyümesini destekleyen kök bakterileri), ağır metal toksisitesine maruz kalan bitkilerde tolerans mekanizmalarının güçlendirilmesinde önemli bir rol üstlenmektedir. Bu amaçla, mikroorganizma kökenli polisakkaritler, glikoproteinler, lipopolisakkaritler, peptitler ve sideroforlar gibi hücre dışı polimerik bileşikler ağır metallerle şelat kompleksi oluşturabilir. Bu kompleksleşme, ağır metallerin toprak ortamındaki hareketliliğini değiştirerek bitkilerdeki toksik etkilerini azaltır (Ansari ve ark., 2023). Endotifitik bakteriler, ağır metalle kirli toprakta, azot fiksasyonu, IAA ve siderofor üretimi, fosfat çözündürme gibi çeşitli mekanizmalarla bitkinin büyüme ve gelişimini artırabilirler. Endofitik bakterilerin bitkiye sağladıkları besin elementleri ağır metal stres koşullarında büyüme ve gelişmeyi artırmaktadır. Bununla birlikte, kök bölgesinde, stoma düzenlemesi, kök morfolojisinin değişmesi, mineral besin elementi alımında artışa neden olur (Rajkumar ve ark., 2009; Ma ve ark., 2016). Bu bölümde arbüsküler mikorhizal mantarların, endofitik ve PGPR bakterilerin ağır metal stres koşullarında hiperakümülatör bitkilerin gelişimine büyümesine üzerine etkileri ve fitoremediasyonu artırmada etkileri inceleneceklerdir

BULGULAR

Fitoremediasyon Üzerine AMF Etkisi

AMF, bitki köklerini kolonize eden ve çeşitli mekanizmalarla bitki büyümesini destekleyen, özellikle besin alımını iyileştiren, büyüme hormonları üreten ve bitkiyi patojenlerden koruyan bitki büyümesini destekleyen kök bakterilerinin yararlı toprak mikroorganizmaları arasındadır (Tiodar ve ark,2021). Ağır metallerle kirlenmiş topraklarda, mikorhiza ile bitkiler arasındaki simbiyotik ilişki, mantar hiflerinin uzaması yoluyla bitkinin emici yüzey alanını artırır (Hodge ve ark., 2015). Mikorizal simbiyozdaki bitkiler, temel mikro ve makro besinlerin hareketliliğini korurken toksik ve aşırı metalleri etkili bir şekilde hareketsizleştirebilir. Bu yetenek, bitki verimini önemli ölçüde artırabilir Mikorizal ilişki nedeniyle bazı ağır metallerin hareketsizleşmesi muhtemelen mikorizosferdeki pH'ın hafif artışından kaynaklanmaktadır. Ağır metaller çoğunlukla mantar hiflerinde ve arbüsküllerde birikir (Bono ve Ashfaq, 2013).



Şeki1. Ağır metal hareketini yönlendiren AMF(mantarları).

AM mantarlarının stres altında bitki büyümesini gelişmesini önemli ölçüde artırabildiği de belirtilmiştir. AM mantarlarının bitki büyümesi ve ekosistem verimliliği üzerinde şu etkileri vardır: 1) Bitki su ve besin alımını artırır, 2) toprak yapısını iyileştirir, 3) diğer toprak mikroplarıyla etkileşime girer, 4) patojenleri kontrol eder (Smith ve Read, 2008). Mikorhiza mantarları tarafından bitki köklerine ağır metal hareketini yönlendiren mekanizmalar belirtilmiştir. Bu mekanizmaları sırası ile 1) ağır metaller hücre duvarına veya mantar vakuollerinde birikebilir, genel olarak, ağır metaller bitkilerle simbiyotik ilişki içinde yaşayan mantar hiflerin de hareketsiz hale gelirler, bu da ağır metallerin şellasyon yoluyla hücre duvarında, vakuol de veya sitoplazmada tutarak bitkilerin bunlara erişimini azaltır ve böylece bitkilerdeki metal toksisitesini azaltır (Punamiya ve ark., 2010). 2) AMF 'nin daha yüksek bitki köklerinde kolonizasyonu, bitkinin köklerinde ve dış miselyum da ağır metallerin tutulmasını sağlar. AMF, yüksek miktarda ağır metallerin yoğunlaştığı mantar miselyumu ve veziküller gibi mikorizal yapılarda ağır metalleri tutarak bitkilerde ağır metal toksisitesini iyileştirmek için bir mekanizma gösterir ve bu da ağır metalin bitki dokularına mobilize olmasını daha fazla önler (Vogel ve ark., 2006). 3) Metallotioneinler veya fitoşelatinler mantar veya bitki hücrelerinde ağır metallerin birikmesine neden olabilir. Mikorizal bitkilerin ağır metalleri emmesini sağlayabilen diğer ilginç mekanizma, sadece yüksek bitkiler tarafından üretilen glutatyon türevi peptitler olan fitoşelatinlerin artan üretimidir. Buna göre, bitkiler ağır metalleri ve metaloitleri şellatlayabilir (Garg ve Aggarwal 2011;Pollard ve ark. 2014). Ağır metallerin sitoplazmadan tahsisi her iki simbiontun plazmalemma veya tonoplastında bulunan metal taşıyıcıları tarafından gerçekleştirilir (Schutzendubel ve Polle, 2002) Şekil 1. 5- AMF bitkide antioksidatif savunmayı etkiler. Bitkiler, ağır metal stresine karşı kendilerini korumak için antioksidatif savunma sistemlerine sahiptir. Bu savunma sistemleri, bitki hücrelerinde bozulma ve işlev bozukluğuna karşı koruyan glutatyon peroksidaz (GPX), katalaz (CAT), süperoksit dismutaz (SOD), glutatyon redüktaz (GR), peroksidaz (POD) ve askorbat peroksidaz (APX) gibi çeşitli enzimleri içerir (Abdelhameed, ve ark., 2019). Bu antioksidan enzimler, metal stresi sırasında oldukça aktiftir. Genellikle, SOD süperoksit radikallerini (O_2^-) detoksifiye ederek stres kaynaklı hücresel hasarı önler. Stres esnasında üretilen H_2O_2 radikali ise APX veya CAT tarafından suya dönüştürülür (Bi ve ark., 2019). Çeşitli araştırmacılar tarafından yapılan çalışmalar, AMF' nin antioksidanların sentezini teşvik etme ve metal stresi altında aktivitelerini artırma yeteneğine sahip olduğunu göstermiştir. Wu ve ark., (2014) yürüttükleri çalışmada, AMF' nin oksidatif stres altında antioksidatif enzim aktivitesini artırdığını ve konukçu bitki güvercin bezelyesinde (*Cajanus cajan)* radikal üretimini azalttığını ve metal stresini hafifletmeye yardımcı olduğunu bildirmişlerdir. Kadmiyum stresi koşullarında AMF aşılanmış ayçiçeği (*Helianthus annuus L*) bitkisinde MDA düzeyinde azalma ile birlikte, SOD, CAT ve POD enzim aktivitelerini artırarak bitkiyi korumuştur. Kadmiyum nedeniyle azalan palmitoleik (C16:1), oleik (C18:1), linoleik (C18:2) ve linolenik (C18:3) asit seviyeleri AMF ile normale dönmüştür (Abd-Allah ve ark., 2015).

Arbüsküler mikorizal (AM) mantarlar, çoğu yüksek bitki türüyle karşılıklı yarar esasına dayalı simbiyotik ilişkiler kuran toprak kökenli mikroorganizmalardır. Bu simbiyozda mantarlar, konak bitkiye su ve temel besin elementlerinin alımında yardımcı olurken, bitkiden fotosentez ürünleri olan karbonhidratları alarak beslenirler. Mikorizal mantarlar, ağır metallerle kirlenmiş topraklarda yetişen bazı hiperakümülatör bitki türlerinin kök sistemini kolonize edebilmekte ve bu sayede mikorizal olmayan bitkilere kıyasla daha yüksek bitki biyokütlesi üretimi ve daha hızlı büyüme oranları sağlayabilmektedir (Riaz ve ark. 2021). Bitkiler, fitoremediasyon süreciyle ağır metallerin stresini hafifletebilir. Bitki köksapında Cd'nin varlığı, organik asitler de dahil olmak üzere kök eksüdatlarının üretimini etkiler ve bu da Cd'nin biyoyararlanımını ve bitki tarafından fito-stabilizasyonunu (fito-immobilizasyon) veya daha sonra emilimini (fitoextraksiyonu) etkiler (Visconti ve ark. 2022). AM mantarları, kök eksüdatlarının kombinasyonunu değiştirerek bitkide ağır metaller için biyoremediasyon potansiyelini artırarak, konuk bitkinin fitoremediasyon ve fito-stabilizasyon (fitoimmobilizasyon) yeteneğini artırabilir (Zeng ve ark., 2018). AMF aşılaması, fitoremediasyonu geliştiren, bitki büyümesini destekleyen ve ağır metal toksisitesine karşı toleransı artıran umut vadeden bir aracılı mikrobiyal yardım ve şelasyon destek tekniğidir. PGPR ve AMF' nin EDTA şelasyonuyla birlikte kullanılmasının, yerel bitki türlerinin büyümesini ve ağır metal alımını iyileştirdiği bulunmuştur (Seth, 2012). Benzer olarak endofitik bakteri ile birlikte uygulanan hümik asit ve biochar gibi biostumulantlar fitoremediasyonu artırmada etkili olduğu bulunmuştur (Canal Boysan, ve ark., 2024). kadmiyum stresinin hafifletilmesinde Mikorizal mantarların etkisi, kök eksüdatlarını etkileyerek olur; bu da örneğin metal çözünürlüğünü etkileyerek fitoremediasyon ve fitostabilizasyonu tetikleyebilir. Test edilen bitkiler, özellikle mikorizal olanlar, ağır metalleri hareketsizleştirebildikleri ve toprak üstü kısma tahsisini önleyebildikleri için Cd'nin fitoremediasyonu için kullanılabilir. Mikorizal mantarlar, bitki büyümesini ve besin alımını (artırılmış kök alım alanı) artırarak test edilen bitkilerin fitoremediasyon potansiyelini artırabilmektedir. Elde edilen bulgulara göre, mikorizal bitkiler (biberiye ve amarant) mikorizal olmayan bitkiyle (süs lahanası) karşılaştırıldığında, kirli topraktaki Cd stresini önemli ölçüde azalttı. Buna göre, biberiye kirlenmiş topraklardaki ağır metallerin bir biyomonitörü, hiper akümülatörü ve fito-stabilizatörü olarak işlev görebilir (Nasiri ve ark., 2022) (Çizelge 1).

PGPR Bakterilerinin Fitoremediasyona Etkisi

PGPR bakterileri bitki ile yeterince iletişime geçerek kök bölgesinde kolonize olarak bitkinin büyüme ve gelişmesini teşvik eden bakterilerdir. Bitkilere besin sağlama, fitohormon üretimi ve topraktaki ağır metallerin bulunabilirliğini değiştirme ve biyolojik kontrolde önemli görev alır (Feng ve ark., 2021). Hiperakümülatör bitkiler genellikle sınırlı biyokütle ve uzun büyüme döngüleri gibi zorluklarla karşı karşıyadır (Ma ve ark., 2016). PGPR, azot fiksasyonu, fosfor çözünürlüğü ve demir taşıyıcı üretimi yoluyla doğrudan besin sağlar. Ayrıca bitki büyümesini desteklemek ve ağır metal direncini artırmak için bitki büyüme hormonlarını düzenler Ayrıca, PGPR, organik asit salgılanması, biyosürfaktan üretimi ve redoks reaksiyonları yoluyla bitkilerde ağır metal birikimini artırarak topraktaki ağır metallerin biyoyararlanımını artırır. Buna göre, kök bakterilerinin bitkiler tarafından ağır metallerin alımı üzerindeki yardımcı etkisi, aşağıdaki mekanizmaları içeren çeşitli düzenleyici mekanizmaların birleşiminden kaynaklanmaktadır.

Biyolojik N fiksasyonu

Azot bitkilerin toprak üstü aksamını büyüten ve geliştiren besin elementidir. Kök bakterileri toprak enzimlerinden üraz ve proteaz enzimlerinin aktivitesinin artmasına neden olarak azot fiksasyonunu artırır (Jiang ve ark., 2008). Bununla birlikte akümülatör bitki ile bakteri arasındaki simbiyoz bitkide biyolojik azot fiksasyonunu artırabilir (Gomez-Godínez ve ark., 2019). Buna göre, N-fiksasyonuna bağlı olarak hiperakümülasyon yapan bitkilerin biyokütlesini artırarak fitoremediasyon verimliliğini dolaylı yoldan teşvik eder.

Fosfat Çözünürlüğü

P, bitkilerde çeşitli enzimatik reaksiyonlarda önemli bir rol oynar (Ahemad, 2015). Buna karşılık, topraktaki P'nin %75'i bitki kullanımına elverişli olmayan çözünmeyen kompleksler halinde bulunur. Ek olarak, fosfat mineralleri, ağır metal ile kirlenmiş topraklarda kompleksleşme reaksiyonları ve iyonik çökelme yoluyla ağır metal iyonlarıyla kolayca çözünmeyen çökeltiler oluşturur (Li ve ark., 2021), bu da bitkilerin ağır metal ile kirlenmiş topraklardan P alımını zorlaştırır. Özellikle, PGPR, topraktaki çözünmeyen P'yi aktive ederek ve asitleştirme, şelasyon ve iyon değişimi yoluyla bitkiler için kullanılabilirliğini artırarak fosfat çözünürlüğünü kolaylaştırmada önemli bir rol oynar (Ma vd., 2016).

Bitki Hormonlarının ve Antioksidatif Enzimlerin Salgılanması ve Düzenlenmesi

PGPR, bitkilerde çeşitli fizyolojik süreçleri düzenleyen IAA, gibberellin (GA), absisik asit (ABA) ve etilen (ETH) gibi hormonlar üretir (Shi ve ark., 2009). Örneğin, PGPR tarafından üretilen IAA'lar ve GA'lar bitki kök uzunluğunu ve hacmini artırarak toprak ve bitki kökleri arasındaki temas alanını artırır ve bu da bitki besin durumunu iyileştirerek ağır metal alımını teşvik eder (Goswami vd., 2016). Ağır metal stresi koşullarında, kök ve sürgün büyümesinde azalmaya neden olan etilen üretimi artış gösterir (Etesami ve ark., 2015)). PGPR bakterilerinin de farklı türlerinde etilen seviyesini düşürmeye neden olabilecek 1-aminosiklopropan 1- karboksilik asit (ACC) deaminaz enzimine sahip olduğunu göstermiştir (Glick, 2007). ACC deaminaz enzimi kök den rizosfer bölgesine salgılandığında etilen'in stres koşullarında neden aynı zamanda sürgün ve kök büyümesini de iyileştirebilir (Fan ve ark., 2018). Bakteriler ağır metal streskoşullarında, süperoksit dismutaz (SOD), katalaz (CAT) ve peroksidaz (POD) gibi temel antioksidan enzimlerin aktivasyonu veya serbest radikaller (O2), hidrojen peroksit ve hidroksil radikalleri (OH) gibi zararlı reaktif oksijen türlerinin (ROS) dönüştürülmesini sağlar (Zhu ve ark., 2023).

Endofitik bakteriler, ağır metal kirliliğine maruz kalmış topraklarda fitoremediasyon süreçlerine önemli katkılar sağlamakta olup, aynı zamanda bitki büyümesini ve gelişimini destekleyici etkiler göstermektedir (Afzal ve ark., 2019). Endofitler, bitki dokularının içinde yaşayan, konakçıya zarar vermeyen ve herhangi bir dış yapı geliştirmeyen mikroorganizmalardır. Bitki-endofit simbiyozunda, endofitler bitkilerden karbonhidrat alır ve bitkileri ağır metal stres koşullarına karşı direncini artırır (Sharma ve ark. 2024). Bu yararlı bakteriler, bitki büyümesini ve sağlığını hem doğrudan hem de dolaylı mekanizmalar aracılığıyla artırma yeteneğine sahiptir. Doğrudan etkileri; biyolojik azot fiksasyonu, fosfor ve potasyumun çözünürlüğünün artırılması, siderofor üretimi ve fitohormon sentezini içermektedir. Dolaylı etkiler ise; antibiyotik üretimi, hiperparazitizm, rekabet yoluyla baskılama, ekzopolisakkarit salgılanması ve indüklenmiş sistemik direncin aktive edilmesi gibi çeşitli biyolojik mücadele stratejilerini kapsamaktadır (dos Santos ve ark., 2020).

Çizelge1 Mikroorganizmaların Fitoremediasyona Etkisi

Mikroorganizmalar	Akümülatör Bitki	Mikroorganizma Etkileri	KAYNAKLAR
Staphylococcus arlettae	Kolza (Brassica juncea (L.)	Bitki Büyümesi ve Çözünmüş fosfatı teşvik ederek bitkilerde ağır metal birikimini artırmaktadır	Srivastava ve ark., (2013)
Enterobacter sp.	Kolza (Brassica napus)	Bitkilerin IAA,ACC enzim üreterek ağır metal biriktirme yeteneğini artırır.	He ve ark.,(2013)
Bacillus thuringiensis GDB-1	Kızıl ağaç (Alnus Firma)	IAA, sideroforlar,ACC üretimi ve fosfor (P)Çözündürülmesi ağır metal birikimini artırmaktadır	Babu ve ark.,(2015)
Pantoea agglomerans, G129K1-1 Bacillus mojavensis, G106K1	Kolza (Brassica napus)	Bitki Büyümesi ve antioksidatif enzim aktivitesinde(SOD,CAT VE APX)artışlar.Ağır metal birikimini artırmaktadır.	Boysan Canal ve ark.,(2024)
Glomus mosseae	Kolza (Brassica oleracea) Biberiye (Salvia rosmarinus (Amaranthus sp)	Mikorizal mantarlar bitki büyümesini, besin maddesi alımını ve fitoremediasyon potansiyelini önemli ölçüde artırarak stresi hafifletebilmiştir.	Nasiri ve ark.,(2022)
Glomus intraradices	Berkheya coddi	Mantar aşılanmış bitkinin sürgün yaş ağırlığı aşılanmamış bitkiye göre daha fazla ağır metal konsantrasyonu daha yüksek	Turnau and Mesjasz-Przybylowicz (2003)
Glomus mosseae, G. etunicatum, G. intraradices a hartiga, ve G. fasciculatum)	Medicago sativa	Aşılanmış bitkilerde daha yüksek ağır metal konsantrasyonu vardı ve G. mosseae ağır metallerin sürgünlere taşınmasını artırdı	Zaefarian ve ark.,(2013)

SONUÇ

Ağır metal stresi, sanayileşme ve aşırı kimyasal kullanımı sonucunda ortaya çıkan bir durumdur ve dünyanın büyük alanlarını etkileyen önemli bir sorundur. Farklı yöntemler ağır metallerle kirlenmiş ortamları iyileştirmek için kullanılsa da, bitkiler ve mikropların tek başına veya bir arada kullanıldığı biyolojik yöntemler en etkili olanlar arasında yer almıştır. Bu bölümde, en bol bulunan toprak mantarı türü olan AMF mikorhiza mantarlarının ve endofitik ve kök bakterilerin, akümülatör bitkileriyle simbiyotik ilişki geliştirerek bitki büyümesi ve ağır metal stres üzerindeki rahatlatıcı etkileri sunulmuş ve analiz edilmiştir. Mikroorganizmalar ve akümülatör bitkilerin simbiyozunun daha iyi anlaşılması fitoremediasyon tekniklerinin iyileştirilmesine yardımcı olacaktır.

KAYNAKLAR

Afzal I, Shinwari ZK, Sikandar S, Shahzad S (2019) Plant beneficial endophytic bacteria: Mechanisms, diversity, host range and genetic determinants. *Microbiol Res* 221:36–49

Abdelhameed, R.E.; Metwally, R.A. Alleviation of cadmium stress by arbuscular mycorrhizal symbiosis. *Int. J. Phytoremediation* 2019, 21, 663–671

Abd-Allah, E.F.; Abeer, H.; Alqarawi, A.A.; Hend, A. (2015). Alleviation of adverse impact of cadmium stress in sunflower (*Helianthus annuus L*.) by arbuscular mycorrhizal fungi. *Pak. J. Bot*., 47, 785–795.

Ansari, M., Devi, B. M., Sarkar, A., Chattopadhyay, A., Satnami, L., Balu, P & Jailani, A. A. K. (2023). Microbial exudates as biostimulants: role in plant growth promotion and stress mitigation. *J. Xenobiot* 13, 572–603.

Ahemad, M., (2015). Phosphate-solubilizing bacteria-assisted phytoremediation of metalliferous soils: a review. 3 Biotech 5 (2), 111–121. https://doi.org/10.1007/ s13205-014-0206-0.

Bi, Y., Xiao, L.; Liu, R. (2019)Response of arbuscular mycorrhizal fungi and phosphorus solubilizing bacteria to remediation abandoned solid waste of coal mine. *Int. J. Coal Sci. Technol.*, 6, 603–610.

Babu, A.G., Kim, J.D., Oh, B.T., 2013. Enhancement of heavy metal phytoremediation by Alnus firma with endophytic Bacillus thuringiensis GDB-1. *J. Hazard. Mater*. 250, 477–483. https://doi.org/10.1016/j.jhazmat.2013.02.014.

Bano, S. A., & Ashfaq, D. 2013. Role of mycorrhiza to reduce heavy metal stress. *Natural Science* 5(16), 16-20.

Boysan Canal, S., Bozkurt, M. A., & Ucar, C. P. (2024). The Effects of Endophytic Bacteria Along with Humic Acid and Biochar On Phytoremediation of Rapeseed (Brassica Napus L.). *Journal of Crop Health*, *76*(6), 1615-1625.

Candelone, J.P., Hong, S., Pellone, C. and Boutron, C.F. (1995) Post-industrial revolution changes in large-scale atmospheric pollution of the northern hemisphere by heavy metals as documented in central Greenungus Glomus mossaeland snow and ice. *Journal of Geophysics Research,* 100, 16605-16616.

dos Santos RM, Diaz PA, Lobo LL, Rigobelo EC (2020) Use of plant growth-promoting rhizobacteria in maize and sugarcane: characteristics and applications. *Front Sustain Food Syst* 4:136

Etesami, H., Alikhani, H.A., Mirseyed Hosseini, H., 2015. *Indole-3-Acetic acid and 1-aminocyclopropane-1-carboxylate deaminase: bacterial traits required in rhizosphere, rhizoplane and/or endophytic competence by beneficial bacteria*. In: Maheshwari, D. (Ed.), Bacterial Metabolites in Sustainable Agroecosystem. Sustainable Development and Biodiversity, vol. 12. Springer, Cham. https://doi.org/ 10.1007/978-3-319-24654-3-8.

Fan, M., Liu, Z., Nan, L., Wang, E., Chen, W., Lin, Y., Wei, G., 2018. Isolation, characterization, and selection of heavy metal-resistant and plant growth-promoting endophytic bacteria from root nodules of Robinia pseudoacacia in a Pb/Zn mining area. *Microbiol. Res*. 217, 51–59. https://doi.org/10.1016/j.micres.2018.09.002.

Feng, W., Lin, Z., Li, Y., Chi, H., Wang, S., Chao, Y., Qiu, R., 2021. Interaction between bacteria and soil minerals and application of bacterial-mineral composites in remediation of heavy metals polluted soil. *Acta Pharmacol. Sin*. 58 (4), 851–861. https://doi.org/10.11766/trxb202007280143.

Garg N, Aggarwal N (2011) Effects of interactions between cadmium and lead on growth, nitrogen fixation, phytochelatin, and glutathione production in mycorrhizal Cajanus cajan (L.) Millsp. *J Plant Growth Regul* 30:286–300.

Goswami, D., Thakker, J.N., Dhandhukia, P.C., 2016. Portraying mechanics of plant growth promoting rhizobacteria (PGPR): a review. *Cogent Food Agric*. 2 (1), 1127500 https://doi.org/10.1080/23311932.2015.1127500.

Gomez-Godínez, L.J., Fernandez-Valverde, S.L., Romero, J.C.M., Martínez-Romero, E., (2019). Metatranscriptomics and nitrogen fixation from the rhizoplane of maize plantlets inoculated with a group of PGPRs. *Syst. Appl. Microbiol*. 42 (4), 517–525. https://doi.org/10.1016/j.syapm.2019.05.003.

He, H., Ye, Z., Yang, D., Yan, J., Xiao, L., Zhong, T., Yuan, M., Cai, X., Fang, Z., Jing, Y., 2013. Characterization of endophytic Rahnella sp. JN6 from Polygonum pubescens and its potential in promoting growth and Cd, Pb, Zn uptake by Brassica napus. *Chemosphere* 90 (6), 1960–1965. https://doi.org/10.1016/j. chemosphere.2012.10.057

Hodge A. & Storer K. Arbuscular mycorrhiza and nitrogen: implications for individual plants through to ecosystems. *Plant and Soil* 386, 1–19 (2015).

Javaid A,Rukhsana B, Arshad J (2010) Biosorption of heavy metals using a dead macro fungus Schizophyllum commune fries: evaluation of equilibrium and kinetic models. *Pak J Bot* 42,2105–2118.

Jiang, C.Y., Sheng, X.F., Qian, M., Wang, Q.Y. (2008). Isolation and characterization of a heavy metal-resistant Burkholderia sp. from heavy metal-contaminated paddy field soil and its potential in promoting plant growth and heavy metal accumulation in metal-polluted soil. *Chemosphere* 72 (2), 157–164. https://doi.org/10.1016/j. chemosphere.2008.02.006

Li Z,Yuan H (2006) Characterization of cadmium removal by Rhodotorrula sp. Y11. *Appl Microbiol Biotechnol*., 73:458–463.

Li, M., Chen, L., Yang, X., Zhao, F., Sun, L., Xu, S., Yang, L. (2021). Community characteristic and functional variability of soil microbes in urban-rural complex ecosystem. *Acta Pharmacol. Sin*. 58 (6), 1368–1380. https://doi.org/10.11766/ trxb202007110387.

Ma, Y., Rajkumar, M., Zhang, C., Freitas, H., (2016). Beneficial role of bacterial endophytes in heavy metal phytoremediation. *J. Environ. Manag*. 174, 14–25. https://doi.org/10.1016/j.jenvman.2016.02.047.

Miransari, M. (2011). Hyperaccumulators, arbuscular mycorrhizal fungi and stress of heavy metals. *Biotechnology advances*, *29*(6), 645-653.

Nasiri, K., Babaeinejad, T., Ghanavati, N., & Mohsenifar, K. (2022). Arbuscular mycorrhizal fungi affecting the growth, nutrient uptake and phytoremediation potential of different plants in a cadmium-polluted soil. *Biometals*, *35*(6), 1243-1253.

Parmar, S., Singh, V. 2015. Phytoremediation approaches for heavy metal pollution: a review. *J. Plant Sci. Res*. 2 (2), 139.

Pollard AJ, Reeves RD, Baker AJ (2014) Facultative hyperaccumulation of heavy metals and metalloids. *Plant Sci* 217:8–17.

Riaz M, Kamran M, Fang Y, Wang Q, Cao H, Yang G, Deng L,Wang Y, Zhou Y, Anastopoulos I, Wang X (2021) Arbuscular mycorrhizal fungi-induced mitigation of heavy metal phytotoxicity in metal contaminated soils: a critical review. *J Hazard Mater* 402:123919.

Sajedi NA, Ardakani MR, Rejali F, Mohabbati F, Miransari M. Yield and yield components of hybrid corn (Zea mays L.) as affected by mycorrhizal symbiosis and zinc sulfateunder drought stress. *Physiol Mol Biol Plants* 2010;16:343–51.

Seth, C.S., 2012. A review on mechanisms of plant tolerance and role of transgenic plants in environmental clean-up. *Bot. Rev*. 78, 32–62.

Smith SE, Read DJ. Mycorrhizal Symbiosis. San Diego: Academic Press; 2008. Toler HD, Morton JB, Cumming JR. Growth and metal accumulation of mycorrhizal sorghum exposed to elevated copper and zinc. *Water Air Soil Pollut* 2005;164:155–72.

Schutzendubel A, Polle A. Plant responses to abiotic stresses: heavy metal-induced oxidative stress and protection by mycorrhization. *J Exp Bot* 2002;53:1351–65.

Sharma G, Sinha PG, Mathur V (2024) Molecular evidence of crosstalkbetween bacterial endophytes and plant transcriptome in brassica juncea. *J Plant Growth Regul*: 1–19.

Shi, Y., Lou, K., Li, C., 2009. Promotion of plant growth by phytohormone-producing endophytic microbes of sugar beet. Biol. Fertil. Soils 45, 645–653. https://doi.org/ 10.1007/s00374-009-0376-9.

Srivastava, S., Verma, P.C., Chaudhry, V., Singh, N., Abhilash, P.C., Kumar, K.V., Sharma, N., Singh, N., 2013. Influence of inoculation of arsenic-resistant Staphylococcus arlettae on growth and arsenic uptake in Brassica juncea (L.) Czern. Var. R-46. J. Hazard. Mater. 262, 1039–1047. https://doi.org/10.1016/j. jhazmat.2012.08.019.

Punamiya, P.; Datta, R.; Sarkar, D.; Barber, S.; Patel, M.; Das, P. (2010). Symbiotic role of Glomusmosseae in phytoextraction of lead in vetiver grass Chrysopogon zizanioides L. *J. Hazard. Mater.*, 177, 465–474.

Turnau K, Mesjasz-Przybylowicz J. (2003). Arbuscular mycorrhiza of Berkheyacoddii and other Ni-hyperaccumulating members of Asteraceae from ultramafic soils in South Africa. *Mycorrhiza* 13:185–190.

Tiodar ED, Văcar CL, Podar D Phytoremediation and micro-organisms-assisted phytoremediation of mercury-contaminated soils: challenges and perspectives. *Int J Environ Res Public Health* 18(5),2435 (2021).

Vogel Mikuš, K.; Pongrac, P.; Kump, P.; Necemer, M.; Regvar, M. (2006). Colonisation of a Zn, Cd and Pb hyperaccumulator Thlaspi praecoxWulfen with indigenous arbuscular mycorrhizal fungal mixture induces changes in heavy metal and nutrient uptake. *Environ. Pollut.*, 139, 362–371.

Visconti D, Ventorino V, Fagnano M, Woo SL, Pepe O, Adamo P, Caporale AG, Carrino L, Fiorentino N (2022). Compost and microbial biostimulant applications improve plant growth and soil biological fertility of a grass-based phytostabilization system. *Environ Geochem Health in press*

Wu, Q.S.; Zou, Y.N.; AbduAllah, E.F. (2014) *Mycorrhizal association and ros in plants*. In Oxidative Damage to Plants; Ahmad, P., Ed.; Academic Press: Cambridge, MA, USA, 2014; pp. 453–475.

Zeng P, Guo Z, Xiao X, Cao X, Peng C (2018) Response to cadmium and phytostabilization potential of Platycladus orientalis in contaminated soil. *Int J Phytoremediation* 20:1337–1345

Zaefarian F, Rezvani M, Ardakani MR, Rejali F, Miransari M. 2013. Impact of mycorrhizae formation on the phosphorus and heavy-metal uptake of Alfalfa. *Commun Soil Sci Plant Anal*. 44:1340–1352.

Zhu, Y.X., Wang, Y., Zheng, H.Y., Xiang, X.B., Wang, H., Xie, M.H., Liu, H.J., Fang, Z.G., Liu, L.J., Du, S.T., 2023b. N fertilizers promote abscisic acid-catabolizing bacteria to enhance heavy metal phytoremediation from metalliferous soils. *Sci. Total Environ*. 894, 164964 https://doi.org/10.1016/j.scitotenv.2023.164964.

ISOLATION AND IDENTIFICATION OF MOST PREDOMINANTFUNGI RESPONSIBLE FOR THE SPOILAGE OF TOMATO

Haruna Karamba
School of Science and Technology, Department of Science Laboratory Technology, Hussaini Adamu Federal Polytechnic Kazaure, Jigawa State, Nigeria.

Zainab Umar Zandam
School of Science and Technology, Department of Science Laboratory Technology, Hussaini Adamu Federal Polytechnic Kazaure, Jigawa State, Nigeria

Abstract

Tomatoes are staple fruit and a major source of vitamins and minerals in many diets, yet they are highly susceptible to spoilage, especially by fungi, due to their high moisture content and nutrient richness. This study aimed to isolate and identify the predominant fungi responsible for the spoilage of tomatoes obtained from Gada and Kanti markets in Kazaure metropolis. A total of 30 tomato samples (15 from each market) were collected and analyzed using Sabouraud Dextrose Agar (SDA) as the growth medium, following the modified method of Uzuegbu et al. (2002). Each sample's injured or visibly spoiled part was inoculated on SDA plates, incubated at room temperature, and observed for colony formation over a period of five days. Microscopic macroscopic examinations revealed the presence of four predominant fungal genera: Aspergillus, Rhizopus, Penicillium, and yeast (Saccharomycetes). Among these, Aspergillus and Rhizopus species were found to be the most prevalent, with each having a frequency of 20%, followed by Penicillium (15.5%) and yeast (11.1%). The findings indicate that Aspergillus and Rhizopus species are the primary agents of tomato spoilage in these markets. This study underscores the need for improved storage and handling practices to minimize fungal contamination and extend the shelf life of tomatoes in local markets. Further research on antifungal treatments and natural preservation methods could aid in reducing tomato spoilage and ensuring food safety.

Key words: Fungi, Tomato, Spoilage, Isolation

IMPACT OF SUSTAINABLE NUTRITION EDUCATION ON SUSTAINABLE EATING BEHAVIORS AND SUSTAINABLE FOOD CHOICE MOTIVES

Gökçe ÜNAL

Ondokuz Mayıs University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Samsun, Türkiye

ORCID ID: https://orcid.org/0000-0002-9657-2358

Sevtap KABALI

Ondokuz Mayıs University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Samsun, Türkiye

ORCID ID: https://orcid.org/0000-0003-4524-8205

ABSTRACT

Introduction and Purpose: Sustainable nutrition interventions can help to develop sustainable and healthy nutritional patterns among nutrition and dietetics students—future nutritionist or dietitians who are cited as strategic partners in collaborative actions for sustainable development. For this purpose, in this research, we aimed to investigate the impact of sustainable nutrition education on sustainable eating behaviors and sustainable food choice motives in undergraduate nutrition and dietetics students.

Materials and Methods: This quasi-experimental study was conducted with undergraduate students from the Nutrition and Dietetics Department of a public university in Türkiye between November 2024 and January 2025. The students were divided into intervention (n=36) and control (n=43) groups. The intervention group received sustainable nutrition education for two hours per week (ten sessions). Self-reported data were collected pre- and post-education using a face-to-face questionnaire. The Sustainable and Healthy Eating Behaviors Scale (SHEBS) and Sustainable Food Choice Questionnaire (SUS-FCQ) were included. Participants self-rated their sustainable nutrition knowledge, nutritional status, and overall health status on a scale from 1 (very poor) to 5 (very good).

Results: Following the intervention, within the SHEBS sub-dimensions, the meat reduction score significantly increased. The students' self-evaluation of sustainable nutrition knowledge also increased significantly after the intervention. However, although the scores showed an increasing trend after education, there were no statistically significant differences between the total SHEBS and SUS-FCQ scores.

Discussion and Conclusion: The class setting sustainable nutrition education in undergraduate nutrition and dietetics students effectively increases their willingness to reduce meat consumption. The findings of this study may be used to inform decision-makers in higher education to integrate more comprehensive sustainable nutrition education and sustainable dietary practices into the nutrition and dietetics curriculum.

Key Words: Dietitian; Environment; Nutritionist; Sustainability

THE EVALUATION OF PRICKLY PEAR (*Opuntia ficus-indica*) IN FUNCTIONAL FRUIT LEATHER PRODUCTION

Ebru ERBAY

Manisa Celal Bayar University, Faculty of Engineering and Natural Sciences,

Food Engineering Department, Manisa, Türkiye

ORCID ID: https://orcid.org/0009-0005-3174-2749

Neriman BAĞDATLIOĞLU

Manisa Celal Bayar University, Faculty of Engineering and Natural Sciences,

Food Engineering Department, Manisa, Türkiye

ORCID ID: https://orcid.org/0000-0003-4758-4472

ABSTRACT

Opuntia ficus-indica is a tropical or subtropical plant and it belongs to the cactus family. Prickly pear is the fruit of this cactus contains significant amounts of ascorbic acid, vitamin E, carotenoids, dietary fiber, amino acids, and antioxidant compounds (flavonoids, betaxanthin and betalain) while having hypoglycemic, hypolipidemic, and antioxidant properties. In this study it is aimed to evaluate prickly pear in the production of functional fruit leather.

The fruit leather was produced using two different gelling agents (5% wheat starch and 5% maltodextrin) and two different drying methods (only hot air and microwave + hot air). Fruit pulps were dried in microwave oven at power levels of 100 W and 180 W and hot air at 60°C in conventional oven. The changes in physicochemical, textural, and sensory properties of fruit leathers produced by different methods were investigated.

Moisture, water activity, total ash, pH, total phenolics, total flavonoids, betalain contents and antioxidant activity of fruit leather samples were evaluated. The highest betalain (0,53±0,02 µg/g) and phenolic (30,19±0,16 mg GAE/100g) contents were determined at the sample dried at 180 W for 90 seconds in microwave oven and than 60^{0}C in tray drying oven for 90 minutes.

It is aimed to produce high-quality products in a shorter time and under hygienic conditions, maximizing the utilization of bioactive compounds in the fruit. Overall, the production of functional fruit leather from the highly nutritious prickly pear fruit has been successfully achieved.

Key Words: prickly pear, fruit leather, functional food product

INTRODUCTION

Opuntia ficus-indica is a tropical plant of North American origin, belonging to the subfamily *Opuntioideae* of the family *Cactaceae* (Yahia & Sáenz, 2011). The fruit has a thick, spiny pericarp with numerous small stony seeds that vary in shape, size and colour (yellow, red, orange and purple). Its weight varies between 100-200 g and the edible part constitutes 45-67% of the fruit. (Yahia & Sáenz, 2017). Hypoglycemic, hypolipidemic and antioxidative effects of prickly pear are due to the soluble fibers, high amounts of betalain, flavonoids (kaempferol, quercetin, isorhamnetin), phenolic compounds, ascorbic acid, carotenoids, vitamin E, amino acids (proline, taurine, serine) and minerals (mostly K, Ca, P) in its structure. (Cano et al., 2017; Fernandez-Lopez et al., 2010; Feugang et al., 2006; Scaffaro et al., 2019). The chemical composition of the fruit depends on various factors such as species, cultural practices, climatic conditions, age of the plant, harvest time and fruit maturity. High sugar content (12-17%) and low acidity (0.03-0.12) are the characteristic features of the fruit. The glucose is 53% of the reducing sugar in its structure, while the remainder is fructose (Piga, 2004; Yahia and Sáenz, 2011). Studies on prickly pear (stem and fruit) extracts have shown hypoglycemic activity. Consumption of the extract reduces glucose concentrations by promoting glycogen formation in skeletal muscles and liver. Thus, its benefits for type 2 diabetes can be explained by its potential to trigger insulin release, which converts glucose into glycogen. It has an antioxidant effect thanks to its flavonoids (kaempferol, quercetin, and isorhamnetin). Phenolic compounds can delay the prooxidative effects on proteins, DNA, and lipids by producing stable radicals (Ennouri et al., 2006). Betalains are water-soluble nitrogenous chromo alkaloids found in abundance in the flowers and fruits of plants of the Caryophyllales order and in small amounts in the roots and stems. The fruit's colour ranged from green to yellow-orange and red to purple, is due to the betalains it contains. The red-purple colour of the betalains is caused by betacyanins, while the yellow-orange colour is caused by betaxanthins. (Stintzing et al., 2001). Betalains have antioxidant, anti-inflammatory, anti-diabetic, and anti-carcinogenic properties (García-Cayuela et al., 2019). Vitamin E, tocopherols, and β-carotene are also found in its fruits and seeds. In addition, fruit is a good source of amino acids (proline, taurine, and serine) and minerals (calcium, potassium, and magnesium) (Feugang et al., 2006). Potassium is a mineral not found in many foods that helps regulate fluid balance and nerve signals in the body (Sáenz, 2002). Dietary fibers consist of indigestible carbohydrates such as cellulose, β-glucan, hemicellulose, gums, mucilage, pectin, resistant starch, and oligosaccharides. Dietary fibers are known to reduce the risk of some types of cancer, such as colon cancer. (Hernández-Carranza et al., 2019). Ascorbic acid is very important due to its antioxidant properties, although its amount varies depending on the maturity of the fruit. (Cano et al., 2017).

Prickly pear fruit is generally consumed fresh, and its shelf life is limited to 3-4 weeks (Piga, 2004). Because it is not suitable for long-term storage, researchers have tried to preserve it using different methods. Not only the fruit but also the cladode part has been used for many years in the food industry (fresh fruit, jam, refreshing drinks), the pharmaceutical industry (antidiabetic agent) and the production of other industrial products (alcohol, soap, commercial colorant, pectin production, etc.) (Lahsasni et al., 2004).

Drying is one of the oldest methods used to preserve the long-term benefits of a food product without spoiling. Pestil (fruit leather) is obtained by adding thickening agents such as sugar and starch to fruit juice or pulp, heating the mixture, spreading it thinly on cloths, and drying it in the sun (or shade) (Yuksel et al., 2022). At this point, fruit leather, a source of vitamins, minerals and various nutrients, is attracting the attention of those looking for a healthy snack. Moreover, fruit leather is lower in calories (100 kcal per serving) than many other fruit-based snacks. (Cagindi & Otles, 2005; Yuksel et al., 2022) Various formulations are used in fruit leather production, and these formulations aim to improve flavour, adjust desired firmness, and prevent non-enzymatic browning reactions. Various formulation studies have been conducted using one or more of the following ingredients in fruit leather: corn syrup, honey, citric acid, pectin, maltodextrin, lecithin, vegetable oils, and ascorbic acid. (Torres et al., 2015). For example, wheat starch or flour is added to achieve the desired hardness and then heat treatment is applied to gelatinize the starch (Tontul & Topuz, 2017). Natural white soil (molasses soil) containing $CaCO_3$ could be added to prevent Maillard reactions. (Cagindi & Otles, 2005).

In this study, to utilize the functional properties of prickly pear fruit and develop a healthy snack, the different combinations of hot air and microwave drying methods is applied to produce fruit leather.

MATERIALS AND METHODS

Material

Five hundred *Opuntia-ficus indica* fruit samples were purchased from a local producer in Çeşme-İzmir, Türkiye (38°18'N, 26°18'E; 12 m above sea level). 50 samples were stored for raw material analysis. The remaining samples were washed, sorted, peeled, cut into pieces and their seeds were separated. The fruit puree is obtained for fruit leather production.

Fruit Leather Production

The fruit leather production was carried out with two different thickeners (5% wheat starch and 5% maltodextrin) and three different drying methods. Firstly, fruit puree and 5% wheat starch (as gelling agents) were mixed and boiled at 90^0C. Gelatinized mixture is poured into circle shaped glass moulds (15 cm diameter, 4 mm thickness). Besides the samples added maltodextrin as a gelling agent were mixed and directly poured into glass moulds. The mixtures were poured into muslin sheets and were dried by three different conditions. Drying processes were applied in a tray dryer (hot air) and a microwave oven using different combinations:

Codes	Gelling Agents	Drying Conditions
WS	Wheat starch	Hot air (60°C, 1 m/s air flow, 180 min)
WS 100 W	Wheat starch	Microwave oven (100W, 90 s) + Hot air (60°C, 90 min)
WS 180 W	Wheat starch	Microwave oven (180W, 90 s) + Hot air (60°C, 90 min)
MD	Maltodextrin	Hot air (60°C, 1 m/s air flow, 180 min)
MD 100 W	Maltodextrin	Microwave oven (100W, 90 sec) + Hot air (60°C, 90 min)
MD 180 W	Maltodextrin	Microwave oven (180W, 90 sec) + Hot air (60°C, 90 min),

Drying times were determined to keep the moisture content of the fruit leather samples below 15%.

Physical and Chemical Analysis

Thickness: The thickness of fruit leathers was measured by taking the average of 5 different points of the sample by using a caliper.

Proximate Analysis: Total dry matter analysis of fruit leather samples was carried out by gravimetric method in a vacuum oven at 70°C temperature and 0.1 MPa vacuum pressure (AOAC, 2023). Water activity (aw) was determined by using water activity measurement set (Rotronic Hygropalm, Bassersdorf, Swiss). Total ash content was carried out by gravimetric method (AOAC, 2023). The pH values of fruit puree were directly measured using a WTW brand 7110 model pH-meter. Also 2 g of fruit leather sample was weighed into a beaker and 18 mL of deionized water was added. Following the homogenization process, the pH probe was immersed into the solution and the measurement wase recorded (Tontul & Topuz, 2017).

Ascorbic acid Analysis: Ascorbic acid (mg/100 g) content was determined by titrimetric method (Cemeroglu, 2010)

Extract Preparation for total phenolics, total flavonoids and radical scavenging activity: 10 mL of methanol: water: acetic acid (300:100:10) was added to 2 g of sample weighed into centrifuge tubes and kept in an ultrasonic water bath. The centrifuge tubes were then centrifuged at 4100 rpm at room temperature for 15 min and the upper phase was transferred to a 50 mL volumetric flask. The same process was applied to the residue two more times, the upper phases were collected and completed to a volume of 50 mL with methanol: water: acetic acid solution. The extracts were stored at -20°C in amber bottles and used in the analyses of total phenolic, flavonoid, and antioxidant activity (Rodríguez et al., 2015).

Total phenolic and total flavonoid compositions of prickly pear samples and fruit leathers were determined according to Rodríguez et al. (2015). Determination of Free Radical Scavenging Activity of samples was carried out by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method (Brand-Williams et al., 1995; Cai et al., 2003).

Betalain Analysis: Determination of betalain content was carried out by spectrophotometric method using the method described in Cai et al., (2003). For this purpose, 5 g of homogenized sample was taken and 10 mL of a mixture of 80% methanol: 20% distilled water was added. Homogenized for 10 s in a waring blender. Transferred to a centrifuge tube and centrifuged at 4000 g for 20 min at +4°C. The supernatant was filtered through an 0.45 µm membrane filter. The absorbance value at 535 nm for betacyanin and 483 nm for betaxanthin determination was recorded (Multiskan Go Microplate Spectrophotometer, Thermo Scientific, USA).

Betalain Content (mg/kg) = (A*(Df)*(MW)*(Vd)/Ɛ*(L)*(Wd))

A: The absorbance value at 535 nm and 483 nm wavelength

DF: Dilution factor

MW: Molecule weight (Betacyanin: 550 g/mol, Betaxanthin: 308 g/mol)

Vd: The volume of sample solution (mL)

Ɛ: Molar extinction coefficient (betacyanin: 60000 L/mol-cm, betaxanthin: 48000 L/mol-cm)

L: Light path (1 cm); Wd: Sample weight (g)

Colour Measurements: A Konica Minolta Chromometer CR-5 (Japan) device was used to measure the colour of fruit samples and fruit leathers. The commonly used colour scales (L*, a*, and b* values) were determined. Using these values, the ΔE value was calculated from the following equation (Sarkar et al., 2020).

$$\Delta E = \sqrt{[(L* - L*ref)^2 + (a* - a*ref)^2 + (b* - b*ref)^2]}$$

L^*, a^*, b^*: The colour values of samples

L^*_{ref}, a^*_{ref}, b^*_{ref} : The colour values of reference fruit samples

Sugar Analysis: Sugar Analysis was performed by an HPLC-RID (Agilent 1260 Series, USA) using an Aminex HPX-87P column (300x7,8 mm) with a 0.01 N H_2SO_4 mobile phase (flow 0.6 mL/min; injection volume 10 µL).

For sample preparation, 3 g of fruit or fruit leather samples were weighed into a beaker and 10 mL of ultrapure water was added. The samples digested in a homogenizer, were transferred to a 50 mL centrifuge tube, and after centrifugation at 4100 rpm for 15 minutes. This process was repeated three times, and the supernatants were collected into a 50 mL flask. Sample solutions transfer to HPLC vials after filtered through a 0.45 µm membrane filter. Sugars were detected by refractive index detector (RID). Glucose, fructose and sucrose contents of samples were calculated as g/100g using calibration curves.

Texture Analysis: Texture Profile Analysis were performed by using TA.XT 2 Plus (Stable Micro Systems, Surrey, UK) brand texture analyser. Measurement parameters are as follows: P/35 cylindrical prob; pre-test, test end post-test speeds are 0.5, 0.2 and 0.2 mm/s, respectively. Distance 20 mm, compression ratio 30%, cool down 5 s, trigger force 5.0 g. Hardness, elasticity, chewiness values were calculated (Sarkar et al., 2020).

Statistical Analysis: Statistical analyses were performed by SPSS version 20.0 program using analysis of variance (ANOVA-$p<0.05$). Duncan's Multiple Comparison Test was used to determine differences between samples.

RESULTS AND DISCUSSION

Prickly Pear Fruit Composition

Physical and chemical properties of prickly pear fruits are given in Table 1.

Table 1. Physical and chemical properties of prickly pears used in this research

Prickly pear	Mean ± SD	References
Size (apical diameter), cm	8,06±0,69	Cano et al., 2017 Chougui et al., 2014
Weight, (g)	115,33±15,58	
Total dry matter (%)	15,58±0,24	Piga et al., 2003 Chougui et al., 2014
Brix (°Bx)	14,97±0,06	García-Cayuela et al., 2019 Coria Cayupán et al., 2011 Cano et al., 2017
pH	5,937±0,01	García-Cayuela et al., 2019 Cano et al., 2017
Titratable Acidity (%)	0,045±0,02	Feugang et al., 2006 Bourhia et al., 2020
Ash (%)	0,404±0,012	Medina et al., 2007 Moßhammer et al., 2006
Water activity (aw)	0,881±0,002	Moussa-Ayoub et al., 2011
Ascorbic acid (mg/100 g)	23,61±3,22	Cemeroğlu, 2010
Glucose (g/100g KM) Fructose (g/100g KM) Sucrose (g/100G KM)	60,38±0,68 24,30±0,27 1,76±0,02	Vohra et al., 2015
Total phenolic content (mg GAE/100 g)	401,11±42,28	Osorio-Esquivel et al., 2011 Rodriguez et al., 2015
Total flavonoid content (mg catechin equivalent/ 100 g)	53,23±1,91	Dehbi et al., 2013 Rodriguez et al., 2015
Betalain (µg/g)	68,25±6,58	Cai et al., 2003 García-Cayuela et al., 2019
DPPH radical scavenging activity (%)	53,18±0,95	Osorio-Esquivel et al., 2011
Colour (L^*, a^*, b^*)	L^*: 34,95±1,07 a^*: 27,76±0,23 b^*: 50,92±0,36	Belviranlı, 2016

Some physical and chemical properties of prickly pear fruits leathers dried by different methods are given in Table 2.

Table 2. Some physicochemical properties of prickly pear leathers

Codes	Moisture	pH	a_w	Ash	Thickness	ΔE
WS	13,57±0,45^{A}	5,98±0,001^{B}	0,605+0,01^{A}	3,61±0,06^{D}	0,65±0,01^{A}	40,33±0,88^{B}
WS 100 W	13,40±0,17^{A}	5,97±0,001^{D}	0,524±0,02^{B}	3,92±0,03^{C}	0,64±0,01^{A}	41,72±0,25^{A}
WS 180 W	13,51±0,42^{A}	5,98±0,002^{C}	0,536±0,01^{B}	3,86±0,07^{C}	0,64±0,01^{A}	42,27±0,28^{A}
MD	10,21±0,58^{B}	5,94±0,001^{E}	0,462±0,01^{C}	4,57±0,07^{A}	0,53±0,01^{C}	27,77±0,04^{D}
MD 100 W	10,43±0,53^{B}	5,99±0,001^{A}	0,525±0,01^{B}	4,45±0,05^{B}	0,58±0,01^{B}	29,78±0,39^{C}
MD 180 W	10,61±0,19^{B}	5,98±0,002^{B}	0,521±0,00^{B}	4,40±0,09^{B}	0,58±0,02^{B}	30,15±0,08^{C}

The moisture content of the samples complied with the limit value (<15g/100g) at which microbial activity is not observed (Suna, 2019). The higher moisture content in the fruit leathers with wheat starch as a gelling agent is thought to be due to the gel structure resulting from the heat treatment applied during gelatinization.

The water activity value was also found to be above the limit value (0.80) for pathogenic microorganism and mold growth (Cemeroglu, 2010). Ash contents in fruit leather samples were found to range from 4.62% to 6.05%. Studies in the literature have found similar to our results of ash content in the range of 0.2% to 4.62% (Cagindi & Otles, 2005; Demarchi et al., 2018; Kaya & Maskan, 2003; Sarkar et al., 2020; Setiaboma et al., 2019). The pH values of the fruit leathers were found to vary between 5.94 and 5.99.

The thickness of fruit leathers was found between 0.53-0.65 mm. Wheat starch contained fruit leathers was found to be greater than samples contained maltodextrin ($p<0.05$). In the literature, grape leather thickness was 0.60±0.05 mm (Kaya & Kahyaoglu, 2004), mango 0.369-0.403 mm (da Silva Simão et al., 2019), apricot 0,49-0,68 and mulberry 1,46-1,72 (Cagindi & Otles, 2005). In another study on grape leather thickness was found as 0.71-2.86 mm (Maskan et al., 2002).

The ΔE value expresses the total colour difference between the fresh fruit puree and fruit leather samples, with the higher value indicating a greater difference. The ΔE values of the fruit leathers were determined between 27.77 and 42.27. The ΔE values of the fruit leathers with maltodextrin were found to be less than the samples with wheat starch ($p<0.05$). It is thought that the fruit leathers containing starch were more affected by heat treatment.

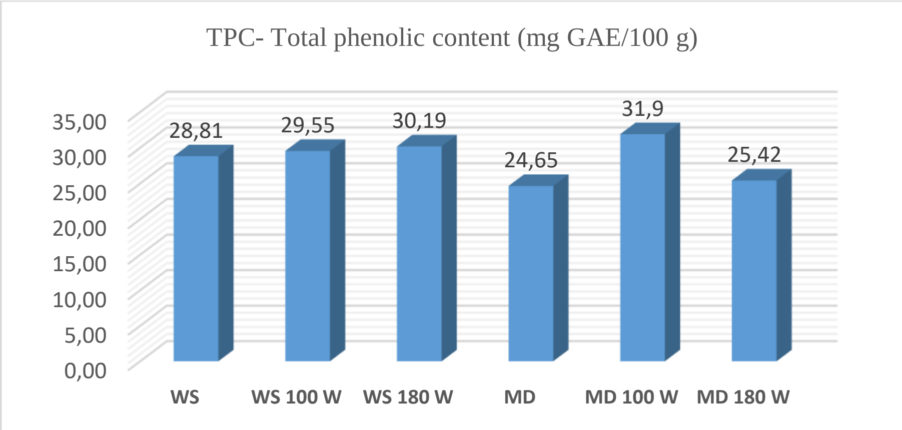


Figure 1. Total phenolic content of prickly pear leathers dried by different methods

Total phenolic contents in prickly pear leathers were determined in the range between 24.65 and 31.90 mg GAE/100 g. The highest total phenolic content was found in samples coded MD100W.

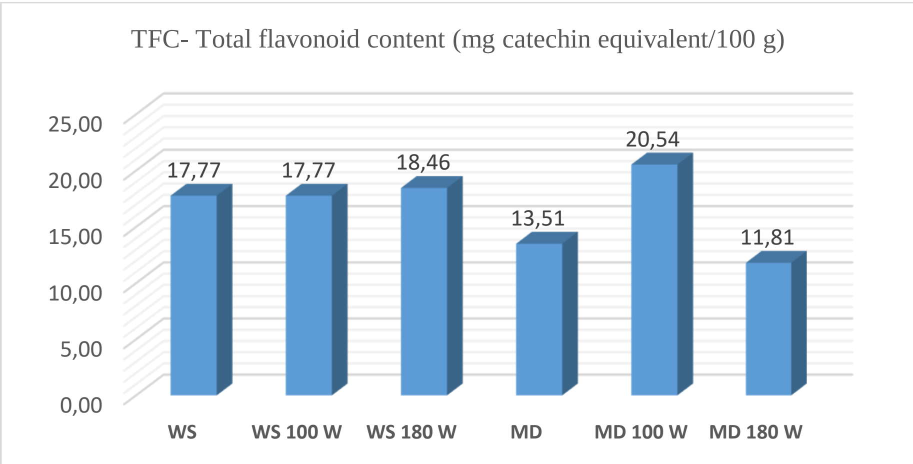


Figure 2. Total flavanoid content of prickly pear leathers dried by different methods

Total flavonoid contents in prickly pear leathers were determined in the range between 11,81 and 20,54 mg catechin equivalent /100 g. Also, the highest total flavonoid content was found in samples coded MD100W.

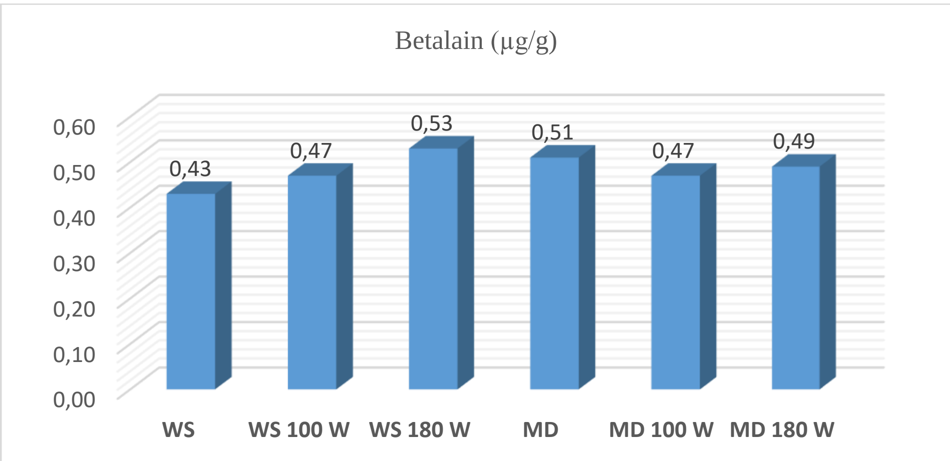


Figure 3. Betalain content of prickly pear leathers dried by different methods

Betalain results in fruit leather samples were found in the range between 0.43 and 0.53 µg/g. The highest betalain content was WS180W ($p<0.05$). Betalain stability was found to be preserved in the sample with lower water activity.

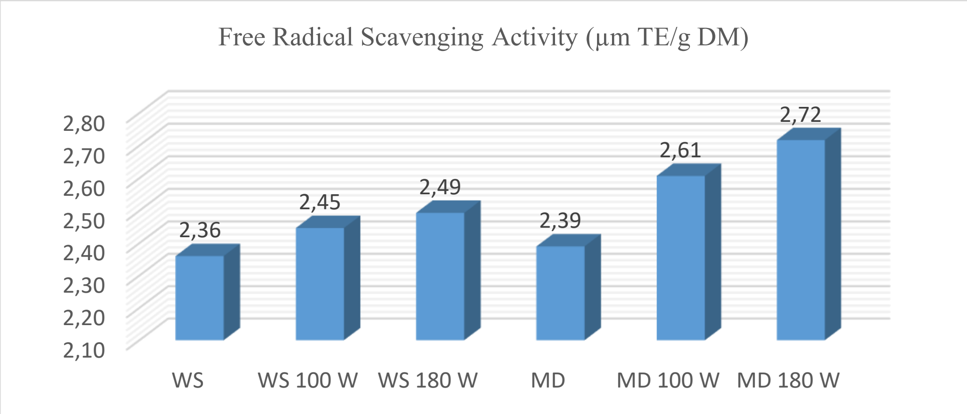


Figure 1. Radical scavenging activity of prickly pear leathers dried by different methods

The radical-scavenging properties of antioxidants are the most important lipid oxidation inhibition mechanism. DPPH radical scavenging activity (%) values of the fruit leather samples were found in the range from 2.36 to 2.72 µm TE/g DM. MD180W sample had the highest radical scavenging activity ($p<0.05$). The free radical scavenging activity values were found to be higher in microwave-dried samples than in hot air-dried samples. It is thought to be due to the shorter duration of microwave-assisted drying.

Table 3. Fruit Leather Texture

Codes	**Hardness (g)**	**Elasticity**	**Chewiness (g.mm)**
WS	1295,35±180,90^{B}	0,92±0,01	1219,68±53,48^{AB}
WS 100 W	1540,23 ±32,87^{A}	0,96±0,01	1307,40±101,56^{A}
WS 180 W	1420,85±67,62^{AB}	0,96±0,03	1176,18 ±27,28^{B}
MD	814,38±77,70^{C}	0,93±0,03	607,98±15,84^{C}
MD 100 W	891,44±103,58^{C}	0,95±0,01	685,10±97,68^{C}
MD 180 W	833,14±57,01^{C}	0,93±0,02	621,43±9,08^{C}

The hardness and chewiness values of the samples with starch were found to be higher than those of the maltodextrin containing samples ($p<0.05$). Since the chewiness value is affected by the hardness properties, it is known that the factors affecting the hardness value also affect the chewiness property. Furthermore, it is expected that hardness and chewiness values would be higher in thicker samples.

Conclusion

This study investigated the effects of drying methods and gelling agents on the functional properties of prickly pear fruit leather. While the drying time of the samples in hot air (60°C) was 180 minutes, the time decreased to 90 minutes in microwave-assisted drying. Microwave drying is an alternative method that reduces drying time and better preserves the bioactive components of the samples. Microwave drying has been found to have positive effects on some chemicals properties such as total phenolics, total flavonoids, betalain, and free radical scavenging activity. Furthermore, considering the effects of gelling agents on fruit leather texture, using different amounts of thickeners may be a good alternative for better properties. The products obtained not only provide ideas for healthy and delicious alternatives for the food industry but also contribute new data to the literature on new alternatives produced from prickly pear fruit.

Acknowledgements: The authors thank to The Council of Scientific Research Projects (Project nr BAP 2020-086) of Manisa Celal Bayar University.

KAYNAKLAR

AOAC, 2023. Official Methods of Analysis of AOAC International. 22nd Edition. https://doi.org/10.1093/9780197610145.002.001

Belviranlı, B. 2016. Hint inciri (*Opuntia ficus-indica* L.) meyvesi ve tohumlarının bazı fiziko-kimyasal özellikleri üzerine lokasyonun etkisi. Doktora tezi. Selçuk Üniversitesi, Fen Bilimleri Enstitüsü, Gıda Müh ABD.

Bourhia, M., Elmahdaoui, H., Ullah, R., Ibenmoussa, S., Shahat, A.A. 2020. Physicochemical evaluation of the fruit pulp of Opuntia spp growing in the Mediterranean area under hard climate conditions. Open Chem. 18, 565–575. https://doi.org/10.1515/chem-2020-0097

Brand-Williams, W., Cuvelier, M.E., Berset, C. 1995. Use of a free radical method to evaluate antioxidant activity. 28, 25–30.

Cagindi, O., Otles, S. 2005. Comparison of some properties on the different types of pestil: A traditional product in Turkey. Int J Food Sci Technol. 40, 897–901. https://doi.org/10.1111/j.1365-2621.2005.00962.x

Cai, Y., Sun, M., Corke, H. 2003. Antioxidant activity of betalains from plants of the *Amaranthaceae*. J Agric Food Chem. 51, 2288–2294. https://doi.org/10.1021/ JF030045U

Cano, M.P., Gómez-Maqueo, A., García-Cayuela, T., Welti-Chanes, J. 2017. Characterization of carotenoid profile of Spanish Sanguinos and Verdal prickly pear tissues. Food Chem. 237: 612–622. https://doi.org/10.1016/j.foodchem.2017.05.135

Cemeroğlu, B., Gıda Analizleri. Gıda Teknolojisi Derneği Yayınları, Ankara, 2010, 682s.

Chougui, N., Djerroud, N., Naraoui, F., Hadjal, S., Aliane, K., Zeroual, B., Larbat, R. 2014. Physicochemical properties and storage stability of margarine containing *Opuntia ficus-indica* peel extract as antioxidant. Food Chem. 90: 173-182. https://doi.org/10.1016/ j.foodchem.2014.10.025

Coria Cayupán, Y.S., Ochoa, M.J., Nazareno, M.A. 2011. Health-promoting substances and antioxidant properties of Opuntia sp. fruits. Changes in bioactive-compound contents during ripening process. Food Chem. 126, 514–519. https://doi.org/10.1016/J.FOODCHEM. 2010.11.033

Dehbi, F., Hasib, A., Tilaoui, M., El Batal, H., Zaki, N., Ouatmane, A., Jaouad, A., Zyad, A. 2013. Bioactive constituents, antioxidant activity and in vitro cancer cell cytotoxicity of Moroccan prickly pear (*Opuntia ficus indica* L.) juices. Journal of Natural Sciences Research 3(14): 12-20.

Demarchi, S.M., Torrez Irigoyen, R.M., Giner, S.A. 2018. Vacuum drying of rosehip leathers: Modelling of coupled moisture content and temperature curves as a function of time with simultaneous time-varying ascorbic acid retention. J Food Eng. 233, 9–16. https://doi.org/10.1016/j.foodeng.2018.03.027

Ennouri, M., Fetoui, H., Bourret, E., Zeghal, N., Attia, H. 2006. Evaluation of some biological parameters of *Opuntia ficus indica*. 1. Influence of a seed oil supplemented diet on rats. Bioresour Technol. 97, 1382–1386. https://doi.org/10.1016/j.biortech.2005.07.010
Fernández-López, J.A., Almela, L., Obón, J.M., Castellar, R. 2010. Determination of antioxidant constituents in cactus pear fruits, *Plant Foods for Human Nutrition* 65, 3: 253–259 (2010). doi: 10.1007/s11130-010-0189-x
Feugang, J.M., Konarski, P., Zou, D., Stintzing, F.C., Zou, C. 2006. Nutritional and medicinal use of Cactus pear (*Opuntia* spp.) cladodes and fruits. Frontiers in Bioscience 11(3): 2574-2589. https://doi.org/10.2741/1992.
García-Cayuela, T., Gómez-Maqueo, A., Guajardo-Flores, D., Welti-Chanes, J., Cano, M.P. 2019. Characterization and quantification of individual betalain and phenolic compounds in Mexican and Spanish prickly pear (*Opuntia ficus-indica* L. Mill) tissues: A comparative study. Journal of Food Composition and Analysis. 76, 1–13. https://doi.org/10.1016/ j.jfca.2018.11.02
Hernández-Carranza, P., Rivadeneyra-Mata, M., Ramos-Cassellis, M.E., Aparicio-Fernández, X., Navarro-Cruz, A.R., Ávila-Sosa, R., Ochoa-Velasco, C.E. 2019. Characterization of red prickly pear peel (*Opuntia ficus-indica* L.) and its mucilage obtained by traditional and novel methodologies. Journal of Food Measurement and Characterization. 13, 1111–1119. https://doi.org/10.1007/s11694-018-00026-y
Kaya, S., Kahyaoglu, T. 2004. Thermodynamic properties and sorption equilibrium of pestil (grape leather). Journal of Food Engineering 71(2): 200-207. https://doi.org/10.1016/ j.jfoodeng.2004.10.034
Kaya, S., Maskan, A. 2003. Water vapor permeability of pestil (a fruit leather) made from boiled grape juice with starch. Journal of Food Engineering 57(3): 295-299.
Lahsasni, S., Kouhila, M., Mahrouz, M., Idlimam, A., Jamali, A. 2004. Thin layer convective solar drying and mathematical modeling of prickly pear peel (*Opuntia ficus indica*). Energy. 29, 211–224. https://doi.org/10.1016/j.energy.2003.08.09
Maskan, A., Kaya, S., Maskan, M. 2002. Hot air and sun drying of grape leather (pestil). Journal of Food Engineering 54 (1): 81-88.
Medina, E.M.D., Rodríguez, E.M.R., Romero, C.D. 2007. Chemical characterization of *Opuntia dillenii* and *Opuntia ficus indica* fruits. Food Chemistry 103, 38–45. https://doi.org/10.1016/j.foodchem.2006.06.064
Moussa-Ayoub, T.E., El-Samahy, S.K., Rohn, S., Kroh, L.W. 2011. Flavonols, betacyanins content and antioxidant activity of cactus *Opuntia macrorhiza* fruits. Food Research International. 44, 2169–2174. https://doi.org/10.1016/j.foodres. 2011.02.014
Moßhammer, M.R., Stintzing, F.C., Carle, R. 2006. Cactus Pear Fruits (*Opuntia* spp.). A Review of processing technologies and current uses. Journal of the Professional Association for Cactus Development. 8:1-25. https://doi.org/10.56890/jpacd.v8i.274
Osorio-Esquivel, O., Alicia-Ortiz-Moreno, Álvarez, V.B., Dorantes-Álvarez, L., Giusti, M.M. 2011. Phenolics, betacyanins and antioxidant activity in *Opuntia joconostle* fruits. Food Research International. 44, 2160–2168. https://doi.org/10.1016/j.foodres.2011.02.01
Piga, A. 2004. Cactus Pear: a Fruit of nutraceutical and functional importance Cactus Pear: A Fruit of nutraceutical and functional importance. Journal of the Professional Association for Cactus Development, 6(9): 22. https://jpacd.org/jpacd/article/view/294
Rodríguez, M.M., Rodriguez, A., Mascheroni, R.H. 2015. Color, texture, rehydration ability and phenolic compounds of plums partially osmodehydrated and finish-dried by hot air. J Food Process Preserv. 39, 2647–2662. https://doi.org/10.1111/jfpp.12515
Sáenz, C. 2002. Cactus pear fruits and cladodes: a source of functional components for foods. Acta Hortic. 581, 253-263. https://doi.org/10.17660/ActaHortic. 2002.581.2816
Sarkar, T., Salauddin, M., Kumar Hazra, S., Chakraborty, R. 2020. A novel data science application approach for classification of nutritional composition, instrumental colour, texture and sensory

analysis of bael fruit (*Aegle marmelos* (L) correa). International Journal of Intelligent Networks. 1, 59–66. https://doi.org/10.1016/ j.ijin.2020.07.003
Scaffaro, R., Maio, A., Gulino, E.F., Megna, B. 2019. Structure-property relationship of PLA-*Opuntia Ficus Indica* biocomposites. Compos B Eng. 167:199-206. https://doi.org/10.1016/j. compositesb.2018.12.025
Setiaboma, W., Fitriani, V., Mareta, D.T. 2019. Characterization of fruit leather with carrageenan addition with various bananas. In: IOP Conference Series: Earth and Environmental Science. Institute of Physics Publishing.
da Silva Simão, R., de Moraes, J.O., de Souza, P.G., Mattar Carciofi, B.A., Laurindo, J.B. 2019. Production of mango leathers by cast-tape drying: Product characteristics and sensory evaluation. LWT. 99, 445–452. https://doi.org/10.1016/j.lwt.2018.10.013
Stintzing, F.C., Schieber, A., Carle, R., Stintzing, F.C., Schieber, A., Carle, R. 2001. Phytochemical and nutritional significance of cactus pear. Eur. Food Res Technol 212: 396-407. https://doi.org/10.1007/s002170000219
Suna, S. 2019. Effects of hot air, microwave and vacuum drying on drying characteristics and in vitro bioaccessibility of medlar fruit leather (pestil). Food Sci Biotechnol. 28, 1465–1474. https://doi.org/10.1007/s10068-019-00588-7
Tontul, I., Topuz, A. 2017. Effects of different drying methods on the physicochemical properties of pomegranate leather (pestil). LWT 80: 294-303. https://doi.org/10.1016/j.lwt. 2017.02.035
Torres, C.A., Romero, L.A., Diaz, R.I. 2015. Quality and sensory attributes of apple and quince leathers made without preservatives and with enhanced antioxidant activity. LWT- Food Science and Technology. 62, 996–1003. https://doi.org/10.1016/J.LWT.2015.01.056
Vohra, M., Jain, P., Jha, T., Sharma, M., Dureja, P., Sarmaab, P. and Lalab, B. 2015. Separation of acetone and butyric acid for simultaneous analysis of sugars, volatile fatty acids, acetone and alcohols by HPLC using flow programming. Analytical methods. 7: 7618-7624. DOI:10.1039/C5AY01162K
Yahia, E.M., Sáenz, C. 2011. Cactus pear (*Opuntia species*). In: Postharvest Biology and Technology of Tropical and Subtropical Fruits. pp. 290–331e. Elsevier
Yahia, E.M., Sáenz, C. 2017. Cactus Pear Fruit and Cladodes. Fruit and Vegetable Phytochemicals: Chemistry and Human Health, 2nd Edition, pp. 941-956.
Yüksel, F., Yavuz, B., Baltacı, C. 2022. Some physicochemical, color, bioactive and sensory properties of a pestil enriched with wheat, corn and potato flours: An optimization study based on simplex lattice mixture design. Int J Gastron Food Sci. 28. https://doi.org/10.1016/j.ijgfs.2022.100513

A NEW DIETARY THERAPY FOR CHRONIC RENAL FAILURE: INTESTINAL DIALYSIS TECHNOLOGY

Aamir Jalal Al Mosawi

Advisor in Pediatrics and Pediatric Psychiatry, Baghdad Medical City and the Iraqi Ministry of Health

Recent advancements in chronic renal failure research have illuminated the possibility of achieving significant urea lowering and clinical improvements with the use of a new dietary therapy.. The journey of evidence-based medicine entails a understanding of the levels of available research evidence and the application of this knowledge by physicians based on their qualifications and clinical experience, in alignment with the needs and expectations of their patients. Developing an evidence-based approach to the practice of medicine has become a key component of Medical leadership as the practice of evidence-based medicine is the most important method of improving medical practices, updating them and introducing innovations. Early during the 1990s, Gordon Henry Guyatt ,Canadian physician emphasized that many practicing physicians have limited understanding and use of the available evidence.

He emphasized the need for educating physicians about the use of research evidence to improve clinical care. It is generally recommended that general practitioners, family doctors, and recently board certified physicians have to use the best high level evidence (The strongest evidence) which includes evidence from a meta-analysis or systematic review of randomized controlled trials. David L Sackett and William M C Rosenberg emphasized that physicians in general have to use the best possible evidence in their practice. They described the physician's ability to appropriately use the growing research evidence as the practice of evidence-based medicine. This is because updating and innovating medical practices and patient care should, ideally be based on strong evidence, but this is not always possible, and there is no best evidence to deal with many of the medical problems that have no known effective or satisfactory treatment.

More expert doctors including expert consultants and advisor doctors can use less strong evidence from published research including evidence from controlled and uncontrolled trials, and even the evidence available from published case reports. Chronic renal failure results from a variety of pathophysiological mechanisms and etiologies and is associated with progressive and irreversible damage and loss of the kidneys' tissue leading to failure of the kidneys to excrete waste products, and also failure to perform some other functions. Failure of the kidneys to perform their excretory, regulatory and endocrine functions leads to the development of the uremic syndrome which is the complex clinical and biochemical manifestations resulting from the retention of nitrogenous waste products, imbalance in the body content and distribution of water and electrolytes, and from abnormalities of hormone functions as a consequence of chronic renal failure.

The most prominent features of the uremic syndrome (nausea, anorexia, vomiting and fatigue) result from nitrogen retention with increase in plasma concentrations of the products of protein metabolism especially urea. When blood urea exceeds 180 mg per deciliter patients generally develop nausea, vomiting, and anorexia. These symptoms result from the accumulation of nitrogenous waste products and can be relieved by restricting dietary protein intake and initially anti- emetics may be needed. Ingested proteins are degraded into amino acids metabolized by the liver and yield nitrogen mainly in the form of urea which represents 80% or more of the total nitrogen excreted into the urine in patients with chronic renal failure maintained on diets containing

40 grams or more of protein. 25 to 40 % of the manufactured urea are recycled through the gastrointestinal tract and excreted fecally.

This extra-renal excretion of urea remains constant at less than 3 grams daily even in uremia despite the marked increase in blood urea. What if we can increase this extra-renal excretion ? What if we can use a dietary material to increase this extra renal excretion and shift the urinary excretion of urea to the intestinal excretion. Peritoneal dialysis actually acts by shifting the urinary excretion of urea to the peritoneal excretion with use of intra-peritoneal dialysis fluids. The use of a dietary material to increase extra-renal excretion and shift the urinary excretion of urea to the intestinal excretion has been increasingly called “Intestinal dialysis technology. Management of non-terminal chronic renal failure is largely directed at compensating the diminished renal functions conservatively through dietary and pharmacologic measures which include protein and phosphorus restriction, calorie and water soluble vitamins supplementation, phosphate binders

, and correction of other abnormalities that may be associated with chronic renal failure such as fluid and salt retention, hypocalcaemia, hyperkalemia and hypertension. The dietary interventions in chronic renal failure are directed at diminishing the accumulation of the products of nitrogen metabolism which are responsible for many of the symptoms and disturbances of uremia, and thus preventing the development of the uremic symptoms and complications. In contrast to fats and carbohydrate, which are metabolized to carbon dioxide, which is easily excreted even in uremic subjects via the lungs and skin, the products of protein and amino acid metabolism depend largely on the kidneys for excretion. Therefore, the most essential strategy to decrease the accumulation of the products of nitrogen metabolism in chronic renal failure is dietary protein restriction,

and this can be achieved safely with avoiding consequences of protein deficiency through the provision of low quantity of high quality protein diet. High biologic value proteins reduce the accumulation of nitrogenous waste products and also acid load for renal excretion and helps in maintaining a positive nitrogen balance. Egg protein has the highest biologic value (1 large egg contains 6 grams protein), and therefore egg is the most useful protein for this purpose. It’s very difficult and not really practical to limit the intake of proteins only to the high biologic value egg protein, and preferably 50% of the protein intake should be provided as egg, and 50% provided with the intake of vegetables, rice, and bread. Thus, avoiding restriction of caloric intake which may lead to negative nitrogen balance, muscle wasting and growth failure in case of children.

Protein restriction decreases endogenous protein catabolism and the accumulation of nitrogenous waste products, also reduces the phosphorus load and thus may prevent the onset of hyperparathyroidism and renal osteodystrophy. Protein restriction also reduces the intake of potential hydrogen ions, because every 10 grams of protein provides 7 milli-equavlents of hydrogen ion in the form of sulfated amino-acids .Therefore, protein restriction helps to ameliorate acidosis. The second important strategy in the dietary interventions in chronic renal failure is adequate intake of carbohydrate and fats for their protein sparing effect which decreases endogenous protein catabolism and the production of urea. Fats are less effective than carbohydrates in minimizing protein catabolism, but they are given to provide essential fatty acids and to enhance the palatability of the diet.

Dietary restrictions of sodium and potassium depend on the presence of oliguria, edema, hypertension, and hyperkalemia. Pharmacologic therapies are used to prevent or correct abnormalities which are expected to appear during the course of chronic renal failure including anemia, iron and vitamin deficiency, hypocalcaemia, hyperphosphatemia, hypertension, acidosis, growth retardation, and renal osteodystrophy. With appropriate dietary and pharmacologic management, patients with non-terminal chronic renal failure can be maintained surprisingly well and the transition from non-terminal chronic renal failure to terminal renal failure represents a small decrement of renal function resulting in a large physiologic hurdle for the patient. Dietary and pharmacologic measures are only successful in non-terminal chronic renal failure.

The addition to these effective traditional measures, a dietary agent that enhances extra-renal fecal nitrogen excretion can bridge this gap resulting from this small decrement of renal function and obviating the need for dialysis for some time. There has been an accumulating evidence suggesting that supplementation with dietary fiber including acacia gum can increases fecal nitrogen excretion and lower serum concentrations of urea & other retained metabolites in chronic renal failure patients. Increased fecal nitrogen excretion from the ingestion of dietary fiber has also been reported in animals, normal humans and patients with cirrhosis. The daily excretion of urea 20 to 30 grams, with extra-renal excretion less than 3 grams remains constant even in uremia. 25 to 45% of the urea formed in the liver is hydrolyzed by bacteria within the colon and recycles at least once as ammonia.

Colonic bacteria ferment dietary fibers which provide energy substrate for bacterial nitrogen incorporation and growth, in turn increasing fecal nitrogen mass and nitrogen excretion without changing the type of bacteria. As early as the 1980s, it was well known that dietary fibers such locust bean gum and ispaghula can lower urea in uremic patients on low protein diet by increasing fecal nitrogen excretion through microbial fermentation in the large intestine and modifying the enterohepatic cycle of nitrogen and increasing the amount of nitrogen eliminated as fecal waste. As early as 1980, Hippocrates Yatzidis and his research group showed that dietary fiber (locust bean gum) supplementation of chronic renal failure patients on low-protein diet reduced serum urea and creatinine by 11 to 23% over 5 days of intake. Improvement of clinical symptoms was observed during this period and deterioration was observed when supplementation was stopped.

The low palatability of locust bean gum was considered a serious disadvantage. Similarly patients ingested ispaghula found it unpalatable, felt unwell, or had diarrhea. Therefore , these dietary fibers were not considered to have a practical value for clinical use because patients found them unpalatable or felt unwell when ingested them. In 1984, Rampton et al reported that six and 8 weeks of ispaghula and arabinogalactan (Larch gum high molecular weight non-starch polysaccharides consisting of arabinose and galactose monosaccharides) reduced mean plasma urea level in uremic patients 19% and 11% respectively. In 1996, Tetens et al showed in an experimental study on rats that dietary fiber (maize bran) supplementation caused a dose dependent significant increase in fecal nitrogen excretion in association with reduction in nitrogen retention.

The shift in nitrogen excretion from urine to feces was explained largely by the degree of microbial fermentation in the large intestine caused by dietary fiber that have modifying role on the enterohepatic cycle of nitrogen. In 1996, Donna Bliss and the supervisors of her PhD dissertation reported that acacia gum lowers urea level in patients with asymptomatic chronic renal failure on low protein diet by increasing fecal nitrogen excretion. In contrast to locust bean gum and ispaghula, patients found acacia gum palatable and its clinical use was considered applicable.

In the study of Donna Bliss, acacia gum supplementation was associated with lower serum urea, and the patients had greater fecal masses and greater fecal nitrogen excretion in comparison with period they were on low protein diet alone and in comparison with control patients on pectin supplementation instead of acacia. The components of intestinal Dialysis include powdered acacia gum, the urea lowering agent , the dietary therapies of chronic renal failure, and the pharmacologic therapies of chronic renal failure which are also used during management with chronic hemodialysis and peritoneal dialysis.

Early during the 2000s, children with chronic renal failure in Baghdad and Iraq were mostly treated with intermittent peritoneal dialysis using temporary peritoneal catheters, and treatment was associated with a significant and an unacceptable risk of morbidity and mortality, and many parents were taking their children to die at home without subjecting them to dialysis. The combined use of intestinal dialysis with intermittent peritoneal dialysis was the first reported use of intestinal dialysis in symptomatic uremia. This paper, described the use of intestinal dialysis plus intermittent peritoneal dialysis to treat a seven year old boy with an extreme form of end-stage renal disease (anuric with no renal function). Before publishing this paper, I shared my early experiences with intestinal dialysis with pioneers of nephrology such as Ira Greifer who was the secretary general of the International Association of Pediatric Nephrology and the executive editor of its journal.

Ira Griefer wrote " I was very pleased to receive your letter and know that you are working very hard to bring the benefit of modern knowledge, techniques and treatment to children in your country with Kidney and Urologic problems. Ira Greifer also wrote " I was most fascinated by your use of gum Arabic in children with chronic renal failure, in attempt to promote low protein diet. With this experience and your general experience with acute glomerular nephritis in Iraqi children, should be considered for publication in our journal "Pediatric Nephrology", if it was presented for review to our editors." Ira Griefer also sent me an application for membership in the International Pediatric Nephrology Association, and I soon became the first Iraqi physician to be member of the international association.

Despite the significant lowering of urea levels associated with intestinal dialysis, the process of urea lowering is slow and its effectiveness remains much less than the traditional dialysis especially in the more advanced stages of chronic renal failure. Therefore, the combined use of intestinal dialysis with intermittent peritoneal dialysis was the first reported use of intestinal dialysis in symptomatic uremia, and it was published during May,2002, in Pediatric Nephrology". In this paper, before referral, the patient was treated with peritoneal dialysis sessions intermittently whenever became symptomatic with marked nausea, tachypnea (acidotic breathing), and generalized edema from fluid overload. When the patient was symptomatic, blood urea usually ranged from 37.4 to 53.9 milli mol per liter. After each 24-72 hour peritoneal dialysis session, blood urea usually fell to below 16.6 milli mol per liter**.**

During 108 days of anuria, the boy was treated with 12 sessions of intermittent peritoneal dialysis , average frequency: one session of dialysis every 9 days. When, I first saw the child, despite low-protein diet and fluid restriction, he required 12 sessions of peritoneal dialysis. He was receiving nifedipine 2 per kilogram body weight daily to control hypertension. His diastolic blood pressure was reduced to 100 milli meter mercury. He was also given frusemide for 3 days, but the effect was almost negligible. Propranolol was added at a dose of 2 mg per kilogram body weight daily and lowered blood pressure to 120 over 80 milli meter mercury. Intestinal dialysis was initiated and continued for 48 days. Dietary protein was restricted to 0.5 grams per kilograms body weight per day given largely in the form of egg albumin.

Fluid and salt were also restricted. A high-caloric diet was encouraged, together with supplementation of water-soluble vitamins, calcium, and iron. Acacia gum powder was given at a dose of 0.5 gram per kilogram body weight daily in 2 to 3 divided doses. Acacia gum was diluted with the minimal amount of water to make it acceptable. The patient became symptomatic with anorexia, tachypnea (acidotic breathing), and edema 27 days after the initiation of intestinal dialysis. His blood urea was 49.8 milli mol per liter, and he required a dialysis session. The child became symptomatic and needed the second session of intermittent peritoneal dialysis after another 21 days. The child found acacia gum acceptable, palatable, but taking it was associated with one or two voluminous stools daily that had an unusual smell, similar to the smell of urine.

This effect of acacia on stool did not interfere with compliance. A suitable dose of acacia gum powder was 0.5 grams per kilogram bodyweight daily. A trial of a higher dose of grams per kilogram bodyweight daily in this patient was performed in an attempt to increase the efficiency of intestinal dialysis. However, this increase resulted in abdominal distention and discomfort that interfered with sleep at night. The dose of acacia gum powder was reduced again to 0.5 grams per kilogram bodyweight daily. In this child, intestinal dialysis was associated with a beneficial antihypertensive effect. Before the initiation of intestinal dialysis, diastolic blood pressure was maintained at 80 milli meter mercury with nifedipine and propranolol. Diastolic blood pressure was maintained at 80 milli meter with intestinal dialysis alone for 3 weeks.

Compliance with all of the components of intestinal dialysis was better during the first 27 days of therapy. After two weeks of the initiation of intestinal dialysis, It was necessary to stop antihypertensive medications (nifedipine and propranolol) because the diastolic blood pressure dropped to 45–50 milli meter mercury for no obvious reason (such as gastrointestinal bleeding). Although the parents noticed the beneficial effect of intestinal dialysis, they couldn't ensure the child's compliance with treatment. Non adherence to intestinal dialysis therapeutic components led to severe hypertension (blood pressure 160 over 140 milli meter mercury) and the uremic symptoms reappeared, and the child died shortly after an intermittent peritoneal dialysis session.

In 2004, a study reported the use of intestinal dialysis in three of six patients who had symptomatic uremia that required at least one session of intermittent peritoneal dialysis despite low protein diet and other conservative measures of symptomatic uremia. The aim was improving wellbeing and reducing the need for dialysis. The three patients treated with intestinal dialysis aged between 11-13 years (each with, oxalosis, cystinosis, and end-stage renal disease of undetermined etiology). They had no reductions in urine output nor edema and were normotensive. Their pre -dialysis creatinine clearance was less than 5 milli-liters per minute when calculated by a formula developed by Cock and Gault. One of the patients complied with intestinal dialysis therapy for only 10 days and died after 6 months despite treating him with intermittent peritoneal dialysis.

1-year dialysis freedom with intestinal dialysis was achieved in 2 of the patients. They had less severe disease than the first reported patient treated with this method. They had excellent compliance with the therapy, achieved improved wellbeing. Neither became acidotic or uremic, and didn't require dialysis with maintaining serum creatinine and urea levels not previously achieved without dialysis. The other three patients were treated with intermittent peritoneal dialysis; all died with in less than 6 months. Of the 2 surviving patients treated with intestinal dialysis, one patient couldn't comply with therapy and stopped most of the components of intestinal dialysis after one year and died within one month despite treatment with intermittent peritoneal dialysis. The other patient continued to be treated with intestinal dialysis and continued to experience improved wellbeing and dialysis freedom during 6 completed years.

The achievement of four-year dialysis freedom was reported in 2007, and the achievement of six-year dialysis freedom was reported in 2009. The patient who achieved six-year dialysis freedom was an 11-year-old girl with terminal renal failure who initially required 4 sessions of intermittent peritoneal dialysis to control uremic symptoms despite conservative measures. The parents refused further treatment by dialysis. Thereafter, she was treated with intestinal dialysis, and during 6 years of therapy, the girl continued in experiencing improved well-being and good participation in outdoor activities. Mild uremic symptoms occurred only during periods of noncompliance. Periods of decreased compliance with medical therapies were associated with anemia and renal osteodystrophy & some degree of genue vulgum has resulted. The chronicity of her illness was confirmed by the presence of small contracted kidneys, a finding that has not changed during the subsequent follow-up.

In 2006, the use of intestinal dialysis was reported in 11 patients with symptomatic uremia aged 14 to 65 years was described. Two of them were on hemodialysis. The remaining patients were on low protein diet combined with other medical treatments of chronic renal failure, including one patient has undergone one peritoneal dialysis session before referral. The intestinal dialysis therapeutic regimen included dietary proteins restriction to 0.5 grams per kilogram bodyweight with at least 50% of the total intake given as egg albumin. Protein and phosphorus restriction was primarily achieved by restriction of meat, poultry, fish, milk, cheese, yogurt, and legumes. Additional restriction of potassium rich foods was made during elevations of serum potassium above 5 millimol per liter. Powder acacia gum 1gram kilograms per day (Maximum 75 grams) in 2-3 divided doses diluted with desired amounts of water.

The use of intestinal dialysis in this study was associated with amelioration of the uremic symptoms and improved general wellbeing as long as the patients were compliant with the therapeutic protocol. The patients were followed for 2-16 weeks. The most significant finding in this study was the achievement of hemodialysis freedom in 2 of these patients, both of them has a vascular access, but they considered hemodialysis to be associated with a significant amount of discomfort and suffering, and they were not satisfied with the quality of life associated with hemodialysis. Two patients who didn't comply with the therapeutic protocol died, one during treatment with intermittent peritoneal dialysis and one within one month after renal transplantation.The achievement of eight-year dialysis freedom was reported in 2019. The use of intestinal dialysis in adult patients with symptomatic uremia caused by insulin dependent diabetes was reported in 2020.

Thereafter, the successful use of intestinal dialysis in the treatment of intestinal dialysis has been increasingly reported. Acacia gum is a complex polysaccharide obtained mostly from the dried gummy material of the stem and branches of acacia trees (Senegal leguminosae). It is recognized as safe by the FDA. It's widely used in the production of foods such as puddings, candy, and beverages. It has demulcent properties and therefore, it is often added to medicines. Acacia gum is a water soluble fermentable polysaccharide resistant to gut enzymes, and thus can be described as dietary fiber. The principle fermenter bacteria able to use acacia as the only carbohydrate source are bacteriods and bifidobacterium. Recently, an article provided a practical treatment guide for intestinal dialysis and a more detailed guideline was included in a book which has been translated into several languages.

In conclusion, intestinal dialysis represents a promising, patient-centered innovation in the management of chronic renal failure especially for those populations currently underserved by conventional dialysis modalities. By leveraging the natural excretory capacity of the gut, supported by accessible agents like acacia gum, this approach opens new avenues for safe, sustainable, and affordable renal support and offers a novel, accessible approach. The early clinical pioneering work has laid the foundation for this intervention which holds the potential to benefit countless patients globally who are currently left without viable treatment options. I hope you are all satisfied for what you came for.

STUDY ANALYSIS OF THE SPREADING PROCESS OF ORGANIC GRANULAR FERTILIZERS TO SUSTAINABLE ENVIRONMENT

Eglė Jotautienė

Vytautas Magnus university

ORCID number: 0000-0003-1692-4032

Raimonda Zinkevičienė

Vytautas Magnus university

ORCID number: 0009-0006-7750-839X

Conventional agricultural practices frequently lead to the depletion of soil resources. To compensate for reduced soil fertility and to sustain crop yields, the application rates of mineral fertilizers are often increased. However, this approach exacerbates soil degradation and contributes to broader environmental harm, including nutrient runoff and pollution. A viable strategy for advancing sustainable agriculture involves the use of organic fertilizers, which are derived from biological waste products. Recent research is focused on optimizing the use of these organic materials, particularly by developing more sustainable spreading methods.

Granulated organic fertilizers are usually spread with mineral fertilizer spreaders. However, the physical characteristics (such as particle size, density, and moisture content) of organic granules differ substantially from those of mineral fertilizers. These differences frequently result in inconsistent spreading patterns and suboptimal coverage, as the organic pellets may not achieve the intended working width or uniform distribution across the field.

The present study evaluated the dynamics of organic fertilizer application, analyzing the effects of different fertilizer types and application rates on distribution uniformity. The results indicated that poultry manure granules were distributed more uniformly across the soil surface compared to granules derived from grain processing waste. The study also confirmed that the physical properties of granulated fertilizers significantly affect the uniformity of their field application.

Keywords: spreading process, organic, granular, fertilizers

EFFECT OF EARLY ACCLIMATIZATION AND GINSENG (*PANAX GINSENG)* EXTRACT ALONE AND WITH VITAMINS AND MINERALS SUPPLEMENTATION TO DRINKING WATER ON SOME PRODUCTIVE TRAITS OF BROILER CHICKENS

Nadia AL-Muslimawi

University of Baghdad, College of Agricultural and Engineering Sciences, Department of Animal Production, Baghdad, Iraq

Dhia Ibrahim

University of Baghdad, College of Agricultural and Engineering Sciences, Department of Animal Production, Baghdad, Iraq, 0000-0002-8126-1215

Abstract

The experiment was conducted to study the effect of early acclimatization and the addition of Ginseng *(Panax ginseng)* extract alone and with vitamins and minerals mixture to drinking water on some productive traits of broiler chickens. A total of 540, one day old unsexed Ross 308 broiler chicks were randomly allocated in to 12 sub treatment groups in 4 ×3 factorial experiment to evaluate the interaction between four types of early acclimatization by exposing the five day old chick to 38-40 Cº for 0,2,4 and 6 hours (assigned P0,P2,P4 and P6 resp.) and three type of ginseng extract supplemented to the drinking water G0 (control) without adding ginseng , ginseng extract alone (G1) by dissolving 120 mg ginseng/litter water and ginseng extract with vitamins and minerals mixture (G2) by dissolving 8mg ginseng and mixture of vitamins and minerals /litter water, the experiment last for 6 weeks under cyclic temperature (25-34 -25 C°) . The results revealed that body weight and body gain weight reduced in P2,P4,P6 compare with P0 and increased in G1,G2 compared with G0 and the interactions between P and G were augmented in G1,G2 with all group of P, also feed consumption show up diminished in P2,P4,P6 and increased in G1,G2 compared with G0 the interaction between P,G increased with G2 and decreased with G1 compared with G0 meanwhile feed coefficient ratio improve in G1,G2 and the interaction with G1,G2 improve with P0, P2,P4,P4 however water consumption increased in G and P and most the interaction also increased in addition dressing percentage increased in all groups. İn general some resalts significantly $P \leq 0.05$ effects and other mathematically effects. We concluded that early acclimatization periods degrade productive traits while ginseng extract addition alone and with vitamins and minerals augments these traits .

Keywords: early acclimatization, ginseng (*Panax ginseng)* extract, broiler chickens, productive traits.

MOLECULAR DOCKING STUDIES OF 3-DIAZO-1-METHYL-1,3-DIHYDRO-INDOL-2-ONE FROM *ANOGEISSUS LEIOCARPUS* LEAVES AGAINST SOME INFLAMMATORY MEDIATORS

Iyiola Aanuoluwa Temitayo

Department of Biochemistry, Federal University of Technology, Minna, Niger State, Nigeria.

Precious Idakwoji

Department of Biochemistry, Faculty of Biological Sciences, University of Nigeria, Nsukka, Enugu State, Nigeria.

Emmanuel Iyiola

Department of Microbiology, University of Ilorin, Ilorin, Kwara State, Nigeria.

Hannah Nsude

Department of Biochemistry, College of Natural and Applied Sciences, Salem University, Lokoja, Kogi State, Nigeria.

Micheal Adeyeye

Department of Science and Laboratory Technology (Biochemistry Option), School of Natural and Applied Sciences, Federal Polytechnic, Bida, Niger State, Nigeria

Racheal Chinweuba

Department of Biochemistry, Faculty of Natural Sciences, Prince Abubakar Audu University, Anyigba, Kogi State, Nigeria.

Abstract

Targeting key proteins in inflammatory pathways can be an effective strategy for developing new anti-inflammatory therapies. This study focused on molecular docking of 3-diazo-1-methyl-1, 3-dihydro-indol-2-one against key molecular targets such as cyclooxygenase 2 (COX-2), prostaglandin E_2 (PDE) synthase, tumor necrosis factor (TNF-α), interleukin 1 beta (IL-1β) and N-methyl-D-Aspartate (NMDA) receptor. 3D Structures of COX-2 (PDB ID: 5IKR), NMDA receptor (PDB ID: 5EWJ), PGE-Synthase (PDB ID: 4AL1), TNF-α (PDB ID: 5MU8), and IL-1β (PDB ID: 4G6J) were obtained from protein databank. The 3D format of 3-diazo-1-methyl-1, 3-dihydro-indol-2-one and standard anti-inflammatory drug were downloaded from PubChem database in SDF file. Molecular docking was performed using AutoDock Vina Software. The 2D diagrams and the 3D (surface) views of the protein-ligand interactions renderings were done using Discovery studio software and Pymol software respectively. The Physicochemical, lipophilicity, solubility, pharmacokinetics and Lipinski drug-likeness of the compound and standard drug were determined using SwissADME Server. The docking results revealed that 3-diazo-1-methyl-1, 3-dihydro-indol-

2-one exhibited strong binding affinity towards COX-2 (-7.2 kcal/mol). ADME-T analysis revealed that the compound possesses favorable ADMET profiles indicating good oral bioavailability, metabolic stability and low toxicity. It was concluded that 3-diazo-1-methyl-1, 3-dihydro-indol-2-one could be a useful candidate for further development into an anti-inflammatory drug.

Keywords: 3-diazo-1-methyl-1, 3-dihydro-indol-2-one, COX-2, NMDA receptor, PGE synthase, IL-1β, TNF-α

THE LEVEL OF KNOWLEDGE AND AWARENESS IN SOCIETY REGARDING FOOD DRUG INTERACTIONS: THE CASE OF ERZURUM

TOPLUMDA GIDA İLAÇ ETKİLEŞİMLERİ KONUSUNDA BİLGİ VE FARKINDALIK DÜZEYİNİN BELİRLENMESİ: ERZURUM ÖRNEĞİ

Meryem KERSEN

Bayburt Üniversitesi, Lisansüstü Eğitim Enstitüsü, Kimya Anabilim Dalı

Prof. Dr. Engin ŞAHİN

Bayburt Ünivesirtesi, Sağlık Bilimleri Fakültesi

Dr. Öğr. Üyesi Fatma CEBECİ

Bayburt Ünivesirtesi, Sağlık Bilimleri Fakültesi

ABSTRACT

Food-drug interactions are considered a significant research area at the intersection of pharmacology and nutritional sciences. These interactions can directly affect drug absorption, metabolism, distribution, and excretion, thereby influencing treatment outcomes. This study aims to determine the knowledge and awareness level of individuals in Erzurum regarding food-drug interactions. A cross-sectional survey was conducted with 400 participants. Data were collected via questionnaires assessing demographics, knowledge, and awareness levels. The results revealed that knowledge and awareness were generally low, especially among older individuals and those with lower education levels, while healthcare professionals and young adults demonstrated higher awareness. The findings highlight the need for educational interventions, public health campaigns, and simplified information in drug prospectuses. This study provides guidance for policymakers and healthcare professionals to reduce risks and improve public health outcomes.

Keywords: Food, Drug, Interaction, Public Health, Knowledge, Awareness

ÖZET

Gıda ve ilaç etkileşimleri, farmakoloji ve beslenme bilimlerinin kesişiminde önemli bir araştırma alanı olarak kabul edilmektedir. Bu etkileşimler, ilaçların emilim, dağılım, metabolizma ve atılım süreçlerini etkileyerek bireylerin sağlık durumunu ve tedavi başarısını doğrudan etkileyebilir. Özellikle sürekli ilaç kullanan bireylerde ve kronik hastalıklara sahip kişilerde bu durum daha belirgin bir sorun teşkil etmektedir. Bununla birlikte, toplumun büyük bir kısmında bu konuda yeterli bilgi ve farkındalık bulunmadığı gözlemlenmektedir. Bu çalışma, gıda-ilaç etkileşimleri ile ilgili toplumun bilgi düzeyini değerlendirmek ve bu alandaki bilgi eksikliklerinin sağlık üzerindeki olası sonuçlarını analiz etmek amacıyla gerçekleştirilmiştir. Araştırmada gıda-ilaç etkileşimlerinin mekanizmaları ele alınmıştır. Özellikle bazı gıdaların ilaç metabolizmasında rol oynayan enzim sistemlerini (örneğin, sitokrom P450 enzimi) nasıl etkilediği, ilacın biyoyararlanımını artırma veya azaltma potansiyeline sahip olduğu detaylandırılmıştır. Bunun yanında bazı gıdaların ilaçlarla olan kritik etkileşimleri üzerinde durulmuştur. Toplumun bilgi ve farkındalık düzeyini ölçmek amacıyla

400 kişiyle Erzurum ilini hastaların bilgi, tutum ve uygulamaları sayacak şekilde yürütülmüştür. Çalışmada anket yöntemiyle katılımcılardan yaş vb. bilgiler toplanmıştır ve katılımcılara gıda ilaç etkileşimlerine yönelik bilgi ve farkındalık düzeylerini ölçen sorular sorulmuştur. Bu çalışma katılımcıların büyük bir kısmının gıda-ilaç etkileşimleri hakkında yetersiz bilgiye sahip olduğunu ve ilaç kullanım talimatlarına tam anlamıyla uymadığını ortaya koymuştur. Özellikle yaşlı bireyler, düşük eğitim düzeyine sahip gruplar bu konuda daha büyük bir bilgi eksikliği olduğunu göstermiştir. Sonuç olarak, gıda-ilaç etkileşimleri konusunda toplumda farkındalığı artırmaya yönelik çeşitli öneriler geliştirilmiştir. Sağlık profesyonellerinin bu konuda eğitim alması ve hastaları VI daha etkin bilgilendirmesi gerektiği, toplumsal bilinci artırmak için kamu spotları, eğitim programları ve sağlık okuryazarlığını teşvik eden kampanyaların düzenlenmesi gerektiği vurgulanmıştır. Ayrıca, ilaç firmalarının, prospektüslerde yer alan bilgileri daha sade ve anlaşılır bir dilde sunmaları önerilmektedir. Bu tez, toplum sağlığına yönelik riskleri azaltmaya katkı sağlamayı ve sağlık hizmetlerinin kalitesini artırmaya yönelik politika yapıcılar ve sağlık profesyonelleri için rehber bir kaynak oluşturmaktadır.

Anahtar Kelimeler: Gıda, ilaç, gıda ilaç etkileşimi, toplum sağlığı, bilgi düzeyi, farkındalık düzeyi

GİRİŞ

Gıda-ilaç etkileşimi, ilaç ve gıdaların birbirlerinin farmakolojik etkilerini değiştirmesiyle ortaya çıkar. Bu etkileşimler; emilim, dağılım, metabolizma ve atılım süreçlerinde gerçekleşerek tedavi etkinliğini azaltabilir veya toksisiteye yol açabilir (Özaydın vd., 2016). Örneğin; azitromisinin emilimi gıdalarla %43 azalırken, teofilin yüksek yağlı gıdalarla toksik düzeyde serbest kalabilir. Diyet posası, digoksin ve asetaminofen gibi ilaçların emilimini azaltırken; K vitamini warfarin gibi antikoagülanların etkisini zayıflatabilir. Greyfurt suyu CYP3A4 enzimini inhibe ederek ilaç biyoyararlanımını artırabilir (Verkempinck vd., 2022).

Risk grupları arasında yaşlılar, çocuklar, gebeler, kronik hastalığı olanlar ve çoklu ilaç kullananlar öne çıkmaktadır. Eğitim düzeyi, bilgi ve farkındalık üzerinde önemli bir belirleyicidir; düşük eğitim seviyesine sahip bireylerde bilgi eksiklikleri daha yaygındır (Öztürk & Aslan, 2024). Bu eksiklik, tedaviye uyumsuzluk, yan etki artışı, hastanede kalış süresinin uzaması ve sağlık maliyetlerinde yükselişe neden olmaktadır (Büyükyılmaz & Çulha, 2018). Ayrıca vitamin ve mineral etkileşimleri de önemlidir: B12 eksikliği (metformin/antiasit kullanımı), folik asit eksikliği (metotreksat), D vitamini ile atorvastatin düzeyi düşüşü, yüksek doz E vitamini ile kanama riskinde artış gibi örnekler klinik açıdan kritik sonuçlar doğurabilmektedir (Thomas, 1995).

Sonuç olarak, gıda-ilaç etkileşimleri tedavi başarısını doğrudan etkileyen, halk sağlığı açısından kritik bir konudur. Toplumda bilgi ve farkındalık düzeyinin artırılması; eğitim, bilgilendirme ve sağlık profesyonellerinin rehberliğiyle mümkündür.

Gıda-İlaç Etkileşimini Etkileyen Faktörler

İlaçlar gıdalarla emilim, dağılım, metabolizma ve atılım aşamalarında etkileşime girerek tedavinin etkinliğini değiştirebilir (Çelik & Şanlıer, 2014; McCabe et al., 2003).

- **Emilim düzeyi:** Greyfurt suyu CYP3A4'ü inhibe ederek ilaçların emilimini artırırken, yüksek yağlı gıdalar lipofilik ilaçların emilimini yükseltir, antiasitli gıdalar ise azaltabilir (Bailey et al., 2013; Hathcock, 1985).
- **Dağılım:** Besin bileşenleri ilaçların plazma proteinlerine bağlanmasını etkileyebilir. Örneğin sarımsak, warfarin bağlanmasını azaltarak kanama riskini artırır (Kalantzi et al., 2006; Alkış & Gök Durnalı, 2016).

- **Metabolizma:** Greyfurt CYP3A4 inhibisyonu ile simvastatin gibi ilaçların toksisite riskini artırırken, brokoli CYP1A2 indüksiyonu ile teofilin metabolizmasını hızlandırabilir (Bailey et al., 2013; Won et al., 2012).
- **Atılım:** Diyetteki sodyum ve protein düzeyi lityum, kinidin veya nitrofurantoinin eliminasyonunu değiştirir. İdrar pH'sını etkileyen besinler de ilaç atılımını önemli ölçüde etkiler (Bellows & Moore, 2013).
- **Farmakodinamik etkileşimler:** K vitamini warfarinin etkisini azaltırken, levodopa aminoasitlerle rekabet ederek etkinliğini düşürebilir (Öztürk & Aslan, 2024; Çorum & Üney, 2017).

Risk grupları; yaşlılar, gebeler, çocuklar, kronik hastalar ve çoklu ilaç kullananlardır. Ayrıca eğitim, yaş ve meslek bireylerin farkındalığını etkileyen önemli faktörlerdir.

Eğitim: Eğitim seviyesi arttıkça gıda-ilaç etkileşimlerine dair bilgi ve bilinç artmaktadır. Sağlık eğitimi alan bireyler daha bilinçli iken lise altı eğitimlilerde yanlış kullanım yaygındır. Bu nedenle eğitim düzeyine uygun bilgilendirme stratejileri kritik öneme sahiptir (Mekonnen et al., 2020).

Yaş: Yaşlı nüfusun artışıyla birlikte ilaç kullanımı da artmıştır. Yaşlılarda organ fonksiyonlarının azalması ve çoklu ilaç kullanımı gıda-ilaç etkileşimlerini daha riskli hale getirir. Akılcı ilaç kullanımı (AİK) ilkelerine uyum, beslenme planı ve hasta eğitimi tedavinin güvenliği için zorunludur (Turnheim, 2003).

Meslek: bilgi düzeyi açısından belirleyici bir unsurdur. Sağlık çalışanları genel olarak daha bilinçli olsa da, literatürde doktor, hemşire ve eczacılarda dahi eksiklikler saptanmıştır (Zawiah et al., 2020).

Gıda-İlaç Etkileşimi ve Vitaminler

Vitaminler bağışıklık sistemi için hayati olup, ilaçlarla önemli etkileşimlere girebilir (Yaşar & Melek, 2014):

- **A vitamini:** Tetrasiklin ile birlikte toksisite riskini artırır.
- **B6:** Oral kontraseptifler ihtiyacı artırır.
- **B9 (Folat):** Metotreksat ve bazı ağrı kesiciler emilimi azaltır.
- **C vitamini:** Aspirin ile birlikte emilimi azalır.
- **D vitamini:** Kortikosteroidler ihtiyacı artırır.
- **E vitamini:** Warfarin ve aspirinle birlikte kanama riskini artırır.

Takviye gıdaların bilinçsiz kullanımı geri dönüşsüz sağlık sorunlarına yol açabileceğinden doğru bilgilendirme şarttır (Çetin, 2020).

Metilksantinler (Teofilin, Teobromin, Kafein) ve İlaç Etkileşimleri

Metilksantinler (çay, kahve, kakao, çikolata) ilaçlarla etkileşerek toksisite riskini artırabilir.

- **Teofilin ve Teobromin:** Çikolata ve bazı antibiyotiklerle toksisite riskini yükseltir.
- **Kafein:** Analjeziklerin emilimini artırabilir, anksiyolitiklerin etkisini azaltabilir. Antikonvülsanlarla birlikte kullanıldığında yan etki riski artar.
- **MAO inhibitörleri ve antiaritmiklerle çikolata/kafein alımı:** Taşikardi ve düzensiz ritim riskini artırır (Smith, 2020).

YÖNTEM

Araştırma Şubat–Temmuz 2024 tarihleri arasında Erzurum'da yaşayan 18–65 yaş aralığında 400 gönüllü birey üzerinde yürütülmüştür. Etik kurul onayı Bayburt Üniversitesi Etik Kurulu'ndan alınmıştır (04.04.2024, Karar No: 197738). Veriler, online anket ve yüz yüze görüşmeler yoluyla toplanmıştır. Anket formu; demografik bilgiler, bilgi testi ve farkındalık testinden oluşmuştur. Elde edilen veriler SPSS 29.0 programı ile analiz edilmiştir. Frekans, yüzde, ortalama ve standart sapma değerleri hesaplanmış; gruplar arası ilişkiler Ki-Kare testi, Independent Sample t-testi ve ANOVA ile incelenmiştir. İstatistiksel anlamlılık düzeyi p<0,05 olarak kabul edilmiştir.

BULGULAR

Katılımcıların %55,7'si kadın, %44,3'ü erkek olup; en yüksek oran %29 ile 25-34 yaş grubundadır. Katılımcıların %63,7'si sağlık hizmetleriyle ilgili bir meslek yapmamakta, %63,5'inin bilinen kronik hastalığı bulunmamaktadır (Tablo 1)

Tablo 1. Katılımcıların Demografik Özellikleri

Değişken	n	%
Kadın	226	55.7
Erkek	180	44.3
18-24	73	17.8
25-34	119	29.0
35-44	109	26.6
45-54	109	26.6
Sağlık Hizmetleri Meslek: Evet	147	36.3
Sağlık Hizmetleri Meslek: Hayır	258	63.7
Kronik Hastalık: Evet	148	36.5
Kronik Hastalık: Hayır	258	63.5

Bilgi testinde en yüksek doğru cevap oranı %70 ile 'Bilgi sahibi olmak gerekli mi?' sorusuna verilmiştir. En yüksek yanlış oranı ise %57,1 ile 'Gıda-ilaç etkileşimi ölüme yol açabilir mi?' sorusudur (Tablo 2).

Tablo 2. Bilgi Sorularına Verilen Yanıtların Dağılımı

Soru	Doğru (%)	Yanlış (%)
B1 Bilginiz var mı?	46.8	53.2
B2 Bilgi gerekli mi?	70.0	30.0
B3 Ciddi yan etki yapar mı?	49.3	50.7

Farkındalık testinde en yüksek doğru cevap oranı %58,5 ile 'Greyfurt birçok ilaçla etkileşime girer' ifadesinde görülmüştür. En yüksek yanlış oranı ise %88,3 ile 'Diyabet ilaçları kullananların kaçınması gereken besin' sorusudur (Tablo 3).

Tablo 3. Farkındalık Sorularına Verilen Yanıtların Dağılımı

Soru	Doğru (%)	Yanlış (%)
C1 Riskli yaş grubu	41.2	58.8
C2 Antiasit emilimi azaltır	34.4	65.6
C7 Greyfurt etkileşimi	58.5	41.5

Bilgi testi puanları yaşa göre anlamlı farklılık göstermektedir. 18-24 yaş grubunun bilgi düzeyi 35-44 yaş grubundan anlamlı olarak yüksektir. Sağlık hizmetlerinde çalışanların bilgi düzeyi, çalışmayanlara göre daha yüksektir (Tablo 4).

Tablo 4. Bilgi Testi Sonuçları ve Demografik Değişkenler

Değişken	Ortalama	SS
Kadın	4.74	2.6
Erkek	4.24	2.56
18-24 yaş	5.08	2.53
25-34 yaş	4.8	2.67
35-44 yaş	3.96	2.45
45-54 yaş	4.38	2.62
Sağlık Meslek: Evet	4.89	2.64
Sağlık Meslek: Hayır	4.28	2.55
Kronik Hastalık: Evet	4.49	2.5
Kronik Hastalık: Hayır	4.55	2.65

Farkındalık testi sonuçları cinsiyete göre anlamlı farklılık göstermektedir. Kadınların farkındalık düzeyi erkeklere göre daha yüksek bulunmuştur. Yaş, sağlık mesleği ve kronik hastalık durumuna göre fark saptanmamıştır (Tablo 5).

Tablo 5. Farkındalık Testi Sonuçları ve Demografik Değişkenler

Değişken	Ortalama	SS
Kadın	2.5	1.67
Erkek	2.16	1.71
18-24 yaş	2.67	1.71
25-34 yaş	2.39	1.73
35-44 yaş	2.06	1.6
45-54 yaş	2.36	1.74
Sağlık Meslek: Evet	2.53	1.81
Sağlık Meslek: Hayır	2.24	1.62
Kronik Hastalık: Evet	2.22	1.65
Kronik Hastalık: Hayır	2.41	1.73

Genel bilgi ve farkındalık düzeyleri kadınlarda, 18-24 yaş grubunda ve sağlık mesleklerinde çalışanlarda daha yüksek bulunmuştur. Kronik hastalık varlığına göre anlamlı bir fark görülmemiştir (Tablo 6).

Tablo 6. Bilgi ve Farkındalık Testi Sonuçları ve Demografik Değişkenler

Değişken	Ortalama	SS
Kadın	7.24	3.74
Erkek	6.41	3.74
18-24 yaş	7.75	3.67
25-34 yaş	7.19	3.89
35-44 yaş	6.02	3.51
45-54 yaş	6.73	3.82
Sağlık Meslek: Evet	7.42	3.98
Sağlık Meslek: Hayır	6.52	3.6
Kronik Hastalık: Evet	6.72	3.64
Kronik Hastalık: Hayır	6.96	3.84

SONUÇ, TARTIŞMA VE ÖNERİLER

Bu araştırma, Erzurum'daki bireylerin gıda-ilaç etkileşimlerine dair bilgi ve farkındalık düzeylerini değerlendirmeyi amaçlamıştır. Literatürde de görüldüğü üzere hem sağlık profesyonellerinde hem de öğrencilerde gıda-ilaç etkileşimleri konusunda bilgi eksiklikleri yaygındır (Beirão et al., 2024;

Elajez et al., 2024; Jelińska et al., 2024; Syed et al., 2022; Alharbi et al., 2024). Bizim çalışmamızda da katılımcıların genel bilgi seviyelerinin düşük olduğu saptanmıştır.

Çeşitli çalışmalarda sağlık çalışanlarının ve öğrencilerin gıda-ilaç etkileşimleri konusundaki bilgi, tutum ve farkındalık düzeylerinin yetersiz olduğu görülmektedir. Ürdün'de yapılan bir araştırmada eczacıların yaygın gıda-ilaç etkileşimleri hakkında yeterli bilgiye sahip olmadıkları, hastane ve toplum eczacıları arasında anlamlı fark bulunmadığı bildirilmiştir (Zawiah vd., 2020). Katar'da hemşireler üzerinde yapılan çalışmada katılımcıların %56,4'ünün bilgi düzeyi tatmin edici bulunmuştur (Elajez vd., 2024). Malezya'daki eczacılar arasında bilgi ve uygulama düzeyi arasında ilişki olduğu, ancak cevapların tutarsızlık gösterdiği belirtilmiştir (Khong vd., 2024). Sağlık profesyonelleri genelinde bilgi ve tutum düzeylerinin yetersiz olduğu da ifade edilmiştir (Osuala vd., 2021).

Öğrenciler arasında yapılan araştırmalarda da benzer sonuçlar elde edilmiştir. Beslenme Bilimleri öğrencilerinde bilgi eksikliği ve farkındalık düşüklüğü saptanmıştır (Beirão vd., 2024). Tıp fakültesi öğrencilerinde gıda-ilaç etkileşimleri konusundaki bilgi düzeyinin yetersiz olduğu bulunmuştur (Jelińska vd., 2024). Suudi Arabistan'da eczacılık ve hemşirelik öğrencileri üzerine yapılan çalışmalarda da bilgi düzeylerinin düşük olduğu rapor edilmiştir (Syed vd., 2022; Alharbi vd., 2024).

Hasta gruplarında yapılan araştırmalarda ise gıda-ilaç etkileşimlerini tanımlayabilen hasta oranının %30-50 arasında değiştiği görülmüştür (Osuala vd., 2022). Warfarin kullanan bireylerde bilgi ihtiyacının yüksek olduğu bildirilmiştir (Mercan vd., 2011). Kardiyovasküler hastalarda tamamlayıcı ve alternatif gıdalarla ilaçların birlikte kullanımının yaygın olduğu ve potansiyel risk oluşturduğu belirlenmiştir (Wood vd., 2003; Güven vd., 2013).

Bizim çalışmamızda da benzer şekilde sağlık hizmetlerinde çalışan bireylerin bilgi düzeylerinin daha yüksek olduğu ($p<0,05$), yaş grupları arasında özellikle 18–24 yaş grubunun daha bilinçli olduğu ($p<0,05$), kronik hastalık varlığının bazı sorularda bilgi ve farkındalık düzeyiyle anlamlı ilişki gösterdiği saptanmıştır. Ancak farkındalık testi ile meslek durumu ve kronik hastalık varlığı arasında anlamlı bir farklılık bulunmamıştır ($p>0,05$

Analizler sonucunda; sağlık alanında çalışanların ve genç yaş grubundaki bireylerin bilgi ve farkındalık düzeylerinin daha yüksek olduğu, kronik hastalığı olanlarda ise bazı sorulara verilen yanıtların anlamlı farklılık gösterdiği belirlenmiştir. Eğitim düzeyi, gıda-ilaç etkileşimlerinde farkındalık ve bilgi artışı sağlayan önemli bir faktör olarak öne çıkmaktadır.

Sonuçlar, toplumda bu konuya dair farkındalık oluşturulması gerektiğini göstermektedir. Sağlık profesyonellerinin hastaları bilgilendirmesi, eğitim materyalleri ve kamu spotları hazırlanması önerilmektedir. Gelecekte farklı demografik gruplar üzerinde yapılacak çalışmaların ve belirli ilaç-gıda kombinasyonlarının klinik etkilerini inceleyen araştırmaların alana önemli katkılar sağlayacağı düşünülmektedir.

Genel olarak, gıda-ilaç etkileşimlerinin daha iyi anlaşılması, tedavi etkinliğini artıracak ve sağlık risklerini azaltacaktır.

KAYNAKÇA

Alharbi, A., Alharthi, M., Alghamdi, A., Alzahrani, A., & Aljuaid, F. (2024). Knowledge of food–drug interactions among nursing students in Saudi Arabia. *Journal of Nursing Education and Practice, 14*(2), 45–53. https://doi.org/[DOI]

Alkış, N., & Gök Durnalı, A. (2016.). İlaç-besin etkileşimi. *Türkiye Klinikleri. Erişim adresi*: https://www.turkiyeklinikleri.com/article/tr-ilac-besin-etkilesimi-75458.html

Bailey, D. G., Dresser, G. K., & Arnold, J. M. O. (2013). *Grapefruit–medication interactions: Forbidden fruit or avoidable consequences?* CMAJ, 185(4), 309-316. https://doi.org/10.1503/cmaj.120951

Beirão, C., Silva, M., & Fernandes, P. (2024). Knowledge and awareness of food–drug interactions among nutrition students: A cross-sectional study. *Nutrition & Health, 30*(1), 56–65. https://doi.org/[DOI]

Büyükyılmaz, F., & Çulha, Y. (2018). Yaşlılarda çoklu ilaç kullanımı ve üriner sisteme etkileri. İnönü Üniversitesi Sağlık Hizmetleri Meslek Yüksek Okulu Dergisi, 6(2), 77- 85. https://doi.org/10.33715/inonusaglik.464561

Çelik, N., & Şanlıer, N. (2014). *Besin-ilaç etkileşimlerine güncel bakış: İçecekler. ERÜ Sağlık Bilimleri Fakültesi Dergisi*, 2(1), 94-101.

Çetin, F. (2020). Bağışıklık sistemi desteklerinin besin-ilaç etkileşimi. *İstanbul Sabahattin Zaim Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 2(1), 14-19

Çorum, D., & Üney, K. (2017). Besin-ilaç etkileşimleri. *Dicle Üniversitesi Veteriner Fakültesi Dergisi*, 10(1), 38-55.

Elajez, R., Al-Azzam, S., & Hassan, N. (2024). Nurses' knowledge of food–drug interactions at Hamad General Hospital, Qatar. *BMC Nursing, 23*(1), 112–120. https://doi.org/[DOI]

Güven, S., Yılmaz, M., & Koç, G. (2013). Hypertension patients' use of complementary and alternative foods and their knowledge of food–drug interactions. *Journal of Clinical Nursing, 22*(9–10), 1328–1336. https://doi.org/[DOI]

Jelińska, A., Kowalska, M., & Nowak, P. (2024). Knowledge of food–drug interactions among medical students in Poland. *International Journal of Environmental Research and Public Health, 21*(3), 287. https://doi.org/[DOI]

Kalantzi, L., Goumas, K., Kalioras, V., et al. (2006). Biopharmaceutical aspects of drugs absorbed through specific transporters: Influence of food and transport inhibitors. *European Journal of Pharmaceutics and Biopharmaceutics*, 64(2), 145-156.

Khong, T. K., Ahmad, N., & Lim, S. (2024). Pharmacists' knowledge and practice regarding food–drug interactions in Malaysia. *Pharmacy Education, 24*(1), 76–85. https://doi.org/[DOI]

Mercan, Y., Demir, S., & Şimşek, H. (2011). Knowledge and awareness of food–drug interactions among patients using warfarin. *Turkish Journal of Cardiology, 39*(5), 345–352.

Mekonnen, T., Yesuf, N., & Mulu, W. (2020). Knowledge and practice of food-drug ınteractions among health science students. *Integrated Pharmacy Research and Practice*, 9, 41–49. https://doi.org/10.2147/IPRP.S243929

Osuala, E., Pillay, S., & Naidoo, S. (2021). Health professionals' knowledge and attitudes regarding food–drug interactions. *African Journal of Primary Health Care & Family Medicine, 13*(1), e1–e8. https://doi.org/[DOI]

Osuala, E., Naidoo, S., & Gounden, S. (2022). Patients' awareness of potential food–drug interactions in KwaZulu-Natal public hospitals. *South African Medical Journal, 112*(7), 482–488. https://doi.org/[DOI]

Özaydın, N., Şensoy, F., & Özaydın, N. (2016). *Yaşlılarda gıda ilaç etkileşimi*. STED, 25(3), 125-130

Öztürk, M. H., & Aslan, D. (2024). Halk sağlığı perspektifiyle besin-ilaç etkileşimleri ESTÜDAM *Halk Sağlığı Dergisi*, 9(2), 213-221

Smith, J. (2020). The pharmacology of methylxanthines: A review of teofilin, theobromine, and caffeine interactions. *Journal of Clinical Pharmacology*, 58(4), 289-299.

Syed, M., Alqahtani, A., & Alharthi, K. (2022). Evaluation of pharmacy students' knowledge of food–drug interactions at King Saud University. *Saudi Pharmaceutical Journal, 30*(5), 564–570. https://doi.org/[DOI]

Turnheim, K. (2003). When drug therapy gets old: Pharmacokinetics and pharmacodynamics in the elderly. *Experimental Gerontology*, 38(8), 843–853. https://doi.org/10.1016/S0531-5565(03)00055-2

Thomas, J. A. (1995). Drug-nutrient interactions. *Nutrition Reviews*, 53(10), 271–282. https://doi.org/10.1111/j.1753-4887.1995.tb01573.x

Verkempinck, S. H. E., Duijsens, D., Michels, D., Guevara-Zambrano, J. M., Infantes Garcia, M. R., Pälchen, K., & Grauwet, T. (2022). Studying semi-dynamic digestion kinetics of food: Establishing a computer-controlled multireactor approach. Food Research International, 156, 111301. https://doi.org/10.1016/j.foodres.2022.111301.

Yaşar, H.& Melek, S. (2014). *Beslenme ve besinler*. Ankara: Hatipoğlu Yayınları

Wood, M., Cockburn, J., & Johnson, B. (2003). Concurrent use of cardiovascular drugs and complementary/alternative medicines: A survey in patients with heart disease. *European Journal of Clinical Pharmacology, 59*(4), 327–333. https://doi.org/[DOI]

Zawiah, A., Alsharif, M., & Al-Qahtani, A. (2020). Pharmacists' knowledge of common food–drug interactions in Jordan. *International Journal of Clinical Pharmacy, 42*(2), 351–359. https://doi.org/[DOI]

THE RELATIONSHIP BETWEEN ULTRA-PROCESSED FOOD CONSUMPTION AND SUSTAINABLE NUTRITION PATTERNS WITH OBESITY IN WOMEN

KADINLARDA ULTRA İŞLENMİŞ BESİN TÜKETİMİ VE SÜRDÜRÜLEBİLİR BESLENME EĞİLİMLERİNİN OBEZİTE İLE İLİŞKİSİ

Begüm ONSUN

Ankara Medipol University, School of Health Sciences, Department of Nutrition and Dietetics, Ankara, Turkey

ORCID ID: https://orcid.org/0009-0000-2374-5513

Sümeyra SEVİM

Ankara Medipol University, School of Health Sciences, Department of Nutrition and Dietetics, Ankara, Turkey

ORCID ID: https://orcid.org/0000-0001-9724-2628

ABSTRACT

Introduction and Purpose: In recent years, increasing industrialization has shifted women's dietary habits toward the consumption of ultra-processed foods (UPFs). These foods are low in nutritional value but high in environmental impact. This situation poses significant risks in terms of obesity development and sustainable nutrition. This study evaluated the relationship between UPF consumption, sustainable nutrition levels, and obesity in women.

Materials and Methods: This cross-sectional study examined 183 normal-weight and 107 overweight or obese women, aged 19–65, living in Ankara. UPF consumption was assessed using the "Highly Processed Food Consumption Short Screening Questionnaire," and adherence to the Mediterranean diet and sustainable nutritional status were evaluated using the "MedQ-Sus-Tr" scale. The women self-reported their height and weight, and the researcher measured their waist and hip circumference. Correlation and regression analyses were applied to examine relationships between variables.

Results: The consumption score for UPFs was significantly higher for overweight individuals than normal-weight individuals ($p=0.029$). Overweight individuals were found to have lower adherence to the Mediterranean diet ($p = 0.001$) and lower sustainable nutrition scores ($p = 0.014$). Additionally, a significant negative correlation was observed between sustainable nutrition scores and UPF consumption ($r = -0.135$; $p = 0.020$). Individuals with low adherence to sustainable nutrition had higher waist circumferences and waist-to-height ratios ($p < 0.05$). Logistic regression analysis revealed that high UPF intake increased the risk of being overweight (OR = 1.11; $p = 0.016$), while higher adherence to the Mediterranean diet reduced it (OR = 0.86; $p = 0.008$).

Discussion and Conclusion: The findings indicate that high consumption of UPFs increases obesity risk in women and undermines sustainable eating habits. Encouraging sustainable dietary behaviors and reducing UPF intake in the population constitutes a critical area for public health intervention.

Keywords: Ultra-processed food; Mediterranean diet; sustainable nutrition; obesity

ÖZET

Amaç ve Giriş: Son yıllarda artan sanayileşme ile birlikte kadın bireylerin beslenme alışkanlıkları besin değeri düşük ancak çevresel yükü yüksek olan ultra işlenmiş besinlerin (UİB) tüketimi yönünde değişmiştir. Bu durum hem obezite gelişimi hem de sürdürülebilir beslenme açısından önemli riskler doğurmaktadır. Bu çalışmada, kadın bireylerde UİB tüketimi, Akdeniz diyetine uyum ve sürdürülebilir beslenme düzeylerinin obezite ile ilişkisi değerlendirilmiştir.

Gereç ve Yöntem: Kesitsel tanımlayıcı türde yürütülen bu çalışma, 19–65 yaş aralığında Ankara'da yaşayan 183'ü normal kilolu, 107'si fazla kilolu veya obez kadın bireyler ile gerçekleştirilmiştir. UİB tüketimi "Çok İşlenmiş Besin Tüketimi Kısa Tarama Anketi", Akdeniz diyetine uyum ve sürdürülebilir beslenme durumu ise "MedQ-Sus-Tr" ölçeğiyle değerlendirilmiştir. Boy ve ağırlık beyana dayalı, bel ve kalça çevresi araştırmacı tarafından ölçülmüştür. Değişkenler arası ilişkiler için korelasyon ve regresyon analizleri uygulanmıştır.

Bulgular: Fazla kilolu bireylerin UİB tüketim puanı, normal kilolu bireylere göre anlamlı düzeyde daha yüksektir ($p=0{,}029$). Akdeniz diyetine uyum ($p=0{,}001$) ve sürdürülebilir beslenme puanları ($p=0{,}014$) ise fazla kilolu bireylere göre daha düşük bulunmuştur. Ayrıca, sürdürülebilir beslenme puanı ile UİB tüketimi arasında negatif yönde anlamlı bir ilişki tespit edilmiştir ($r=-0{,}135$; $p=0{,}020$). Sürdürülebilir beslenmeye düşük düzeyde uyum gösteren bireylerde bel çevresi ve bel-boy oranı daha yüksek bulunmuştur ($p<0{,}05$). Lojistik regresyon analizine göre, yüksek düzeyde UİB tüketimi, fazla kilolu olma riskini artırmaktadır ($OR=1{,}1145$; $p=0{,}016$). Akdeniz diyetine yüksek uyum ise fazla kilolu olma riskini anlamlı düzeyde azaltmaktadır ($OR=0{,}8551$; $p=0{,}008$).

Tartışma ve Sonuç: Elde edilen bulgular, yüksek düzeyde UİB tüketiminin kadın bireylerde obezite riskini arttırdığını ve sürdürülebilir beslenme alışkanlıklarını olumsuz etkilediğini göstermektedir. Bu bulgular hem bireysel sağlık hem de çevresel sürdürülebilirlik hedefleri açısından UİB tüketiminin azaltılması ve Akdeniz diyetine yönelimin artırılmasının önemini ortaya koymaktadır. Toplumda sürdürülebilir beslenme alışkanlıklarının teşvik edilmesi hem bireysel sağlık hem de çevresel sürdürülebilirlik açısından önemli bir müdahale alanı olacaktır.

Anahtar Kelimeler: Ultra işlenmiş besin; Akdeniz diyeti; sürdürülebilir beslenme; obezite

THE EFFECTS OF WORK-FAMILY CONFLICT IN WOMEN'S COOPERATIVES ON FIGHTING CLIMATE CHANGE-INDUCED FOOD CRISIS

Bengü KURTEGE SEFER

Istanbul Nisantasi University, Faculty of Economics, Administrative and Social Sciences, Department of Sociology, Istanbul, Turkey

ORCID ID: https://orcid.org/0000-0002-0539- 8375

ABSTRACT

Introduction and Purpose: The industrialized food production system, which focuses on increasing production with cheap labor and high technology without considering sustainable use of natural resources, exacerbates the negative impacts of climate change. Studies assessing the relationship between climate change and gender depict women as climate victims and emphasize their vulnerability to the climate crisis. However, women's cooperatives are organizations where women play an active role in combating food crisis exacerbated by climate change. According to food sovereignty approach, women's cooperatives value the knowledge and experience of producers, provide consumers with direct access to products, aiming for women's social and economic empowerment. This presentation will examine the impact of work-family role conflict on the sustainability of food-producing women's cooperatives and offer policy recommendations to support work-life balance in women's cooperatives.

Materials and Methods: This presentation is based on a thematic analysis of existing studies in the literature. This qualitative research design is instrumental in finding patterns and making critical analysis of them. It makes possible to highlight similar and different findings on work and family conflict in the working of women's cooperatives specialized on food production and to make policy recommendations on topic.

Results: Women's cooperatives are directly affected by gendered norms and expectations including work and family role conflict. It creates obstacle for the empowerment of rural women and negatively affects the working of women's cooperatives focusing on sustainable food production.
Discussion and Conclusion: The view that women's primary responsibility is childcare prevents young women from establishing cooperatives and working as cooperative members or managers. Furthermore, because care work is invisible and devalued, most cooperative members and managers with children work double shifts and experience work-family role conflict. Gender stereotypes and prejudices that shape the behavior and attitudes of workers in the institutions and organizations with which women's cooperatives interact are also among affect working conditions in women's cooperatives. Designing macro policies to prevent work-family role conflict will positively affect the sustainability of women's cooperatives specialized on food production in rural Turkey.

Key Words: Food Crisis; Women's Cooperatives; Work-Family Conflict

LIVESTOCK AND DAIRY DEVELOPMENT UNDER BUHARINOMICS: A REVIEW OF POLICY GAPS AND PROSPECTS

Sadiq, M.S

Department of Agricultural Economics and Agribusiness, FUD, Dutse, Nigeria

0000-0003-4336-5723

Singh, I.P

Department of Agricultural Economics, SKRAU, Bikaner, India

0000-0002-1886-5956

Ahmad, M.M

Department of Agricultural Economics and Extension, BUK, Kano, Nigeria

0000-0003-4565-0683[c]

Sani, B.S

PhD Scholar, Department of Agricultural Economics and Agribusiness, FUD, Dutse, Nigeria

0000-0001-7773-3796

Abstract

This review explores livestock and dairy sector policies under *Buharinomics*—the economic paradigm of President Muhammadu Buhari's administration (2015–2023)—highlighting key developments, structural weaknesses, and emerging opportunities. Although, several flagship initiatives like the National Livestock Transformation Plan (NLTP), Anchor Borrowers' Programme (ABP), and RUGA settlements were introduced, their implementation was marred by policy inconsistencies, infrastructural deficits, conflict, and low private sector investment. The paper reveals that livestock productivity stagnated and Nigeria remained heavily reliant on dairy imports, despite rising domestic demand. Key challenges include farmer-herder conflict, weak institutional synergy, poor veterinary services, and inadequate market infrastructure. Nevertheless, opportunities exist in climate-smart livestock systems, public-private partnerships, and regional market integration. Recommendations include integrated rural land reforms, conflict-sensitive livestock planning, and incentivized private sector investment.

Keywords: Agriculture; Government; Policy; Nigeria

Introduction

Background of the Study

Livestock and dairy production constitute a vital part of Nigeria's agricultural economy, contributing significantly to national food security, employment, and rural livelihoods. The sector accounts for approximately 7–10% of Nigeria’s GDP and provides livelihood support to more than 30% of rural households (Eeswaran *et al*., 2022). Livestock, especially cattle, play multifunctional roles in

Nigeria, including serving as sources of meat, milk, income, manure, traction power, and cultural identity, particularly among Fulani pastoralists (Haruna *et al.*, 2025). Despite this potential, Nigeria remains heavily dependent on imported dairy products, spending over $1.5 billion annually on milk and dairy imports due to low local production and processing capacity (Ogbimi & Oyewale, 2000; Archibong *et al.*, 2021; Haruna *et al.*, 2025).

President Muhammadu Buhari’s administration (2015–2023) introduced what has been popularly described as *Buharinomics*, an economic policy framework with strong nationalist, protectionist, and agrarian overtones. The administration emphasized domestic food production, import substitution, and rural economic revitalization, especially through its Agricultural Promotion Policy (APP), Anchor Borrowers' Programme (ABP), and the National Livestock Transformation Plan (NLTP) (Ojong & Anam, 2018; Gao *et al*., 2023). These interventions were intended to reposition livestock and dairy production as central pillars of Nigeria’s drive toward food self-sufficiency and economic diversification.

However, the Buhari era also witnessed a rise in violent farmer-herder conflicts, poor infrastructural investments in the livestock value chain, weak policy coordination, and a lack of effective implementation mechanisms (Ekpo & Tobi, 2019; Adesola & Onwutuebe, 2024). Initiatives like the Rural Grazing Area (RUGA) scheme and cattle colony proposals were met with public backlash, perceived ethnic bias, and governance ambiguity. As a result, much of the promise of Buharinomics in transforming the livestock and dairy sector remained largely unfulfilled.

The Nigerian Dairy and Livestock Paradox

Nigeria has an estimated cattle population of over 20 million, with indigenous breeds such as White Fulani, Sokoto Gudali, and Muturu being the most common (Abubakar *et al*., 2023). Despite this, average milk yield per cow remains between 1–2 liters per day compared to over 20 liters in industrialized systems, resulting in chronic supply-demand gaps. Factors contributing to this productivity gap include poor animal genetics, inadequate feed and pasture systems, rudimentary animal health services, and limited cold chain infrastructure (Haruna *et al*., 2025).

Additionally, Nigeria’s livestock system is predominantly extensive and nomadic, posing serious environmental, security, and public health challenges. The transhumant nature of livestock movement has fuelled protracted farmer-herder conflicts, particularly in the Middle Belt and North-West regions, undermining food systems and rural stability (Buba, 2021; Peace, 2017).

The Buhari Administration’s Response

In response to these challenges, the Buhari administration rolled out several strategic initiatives aimed at modernizing the livestock sector:

- National Livestock Transformation Plan (NLTP) (2019): Aimed at transitioning from open grazing to ranching while integrating peace-building strategies.
- Anchor Borrowers' Programme (ABP): Although initially crop-focused, it later extended to livestock actors, offering subsidized loans to encourage productivity.
- RUGA Policy (Rural Grazing Area): Intended to establish dedicated settlements for pastoralists but failed due to widespread public resistance and lack of legal clarity (Ekpo & Tobi, 2019).

Despite the policy intentions, implementation has faced major setbacks—ranging from political resistance at the state level to funding constraints and lack of stakeholder engagement (Ukase & Ityonzughul, 2020).

Problem Statement

Despite Nigeria's abundant livestock population—estimated at over 20 million cattle, 43 million goats, and 76 million poultry birds—productivity in the livestock and dairy sectors remains critically low (Canton, 2021; Eeswaran *et al*., 2022). Under President Muhammadu Buhari's administration (2015–2023), a host of ambitious agricultural policies were introduced, such as the National Livestock Transformation Plan (NLTP) and the Anchor Borrowers' Programme (ABP), as part of the broader *Buharinomics* strategy aimed at diversifying the economy, ensuring food self-sufficiency, and reducing reliance on imports (Ojong & Anam, 2018; Gao *et al*., 2023). However, the implementation and outcomes of these initiatives reveal significant structural and policy-level shortcomings.

One of the core contradictions under *Buharinomics* is the persistent reliance on dairy imports, which soared to over $1.5 billion annually by 2022, despite government claims of prioritizing local production (Abubakar *et al*., 2023). Nigeria's per capita milk consumption remains one of the lowest in Africa at about 10 liters per annum, far below the global average of 50 liters, largely due to limited local supply and poor processing capacity (Abubakar *et al*., 2023). Indigenous cattle breeds such as the White Fulani and Sokoto Gudali have low milk yields, averaging only 1–2 liters/day, compared to commercial breeds producing over 20 liters/day under optimal conditions (Haruna *et al*., 2025).

Furthermore, key policies like RUGA (Rural Grazing Area) and cattle colonies were politically contentious, leading to widespread ethnic and regional resistance, especially in Southern and Middle Belt states. These initiatives were perceived as attempts to institutionalize the dominance of Fulani pastoralists, thereby eroding local land rights and inflaming identity-based tensions (Ekpo & Tobi, 2019; Ukase & Ityonzughul, 2020; Ajetunmobi *et al*., 2024). Consequently, the objectives of these policies—to create secure grazing reserves, reduce conflict, and increase livestock productivity—were largely unrealized.

Equally problematic was the escalation of farmer-herder conflicts, which intensified during Buhari's tenure and displaced thousands of pastoralists and farmers across northern and central Nigeria. Between 2016 and 2022, more than 3,600 deaths were attributed to such conflicts, significantly disrupting livestock routes and affecting dairy supply chains (Peace, 2017; Buba, 2021). These conflicts were exacerbated by land degradation, climate change, and population pressures, all of which were poorly addressed by existing policy frameworks.

In terms of institutional implementation, multiple challenges emerged:

- Fragmented coordination between federal and state governments
- Absence of effective monitoring and evaluation mechanisms
- Lack of private sector engagement and incentive frameworks for dairy value chain actors
- Poor investment in veterinary services, feed infrastructure, and cold chain logistics (Adesola & Onwutuebe, 2024; Gao *et al*., 2023)

Despite the Buhari administration's rhetoric around agricultural revolution and livestock modernization, most interventions remained policy statements with limited grassroots execution, poor funding absorption, and negligible impact on household nutrition or dairy sufficiency. This mismatch between policy ambition and practical implementation underscores a major governance gap in Nigeria's livestock and dairy development efforts.

Therefore, this study seeks to critically evaluate these gaps and highlight missed opportunities, while providing evidence-based insights for restructuring the livestock sector through sustainable, inclusive, and conflict-sensitive policy mechanisms.

Justification of the Study

The strategic importance of livestock and dairy development to Nigeria's food security, employment generation, rural development, and national economic diversification cannot be overstated. The livestock sub-sector contributes significantly to agricultural GDP and provides nutrition, income, and socio-cultural value to millions of Nigerians—particularly rural households and nomadic communities (Eeswaran *et al*., 2022). Despite this significance, systemic inefficiencies, poor policy implementation, and insecurity have limited its performance, especially during the Buhari administration (2015–2023), a period marked by intense policy rhetoric but modest practical gains in the livestock sector (Gao *et al.*, 2023; Abubakar *et al.*, 2023). Succinctly, this study is therefore justified on several interrelated grounds:

1. Need for Critical Policy Evaluation

While multiple initiatives such as the National Livestock Transformation Plan (NLTP), the Anchor Borrowers' Programme (ABP), and the RUGA scheme were introduced during Buhari's tenure, there is limited scholarly evaluation of their actual outcomes, implementation bottlenecks, and regional impacts. Most government reports focus on project inputs and targets, rather than evidence-based assessments of impact or sustainability (Ojong & Anam, 2018; Ukase & Ityonzughul, 2020). This review provides a critical and independent academic lens to assess whether Buharinomics achieved its objectives in the livestock and dairy sub-sector.

2. Persistent Dairy Import Dependence

Despite having over 20 million cattle and large grazing lands, Nigeria still imports over 60% of its dairy requirements, placing a strain on foreign exchange reserves and exposing the country to global price shocks (Haruna et al., 2025; Abubakar *et al*., 2023). This paradox underscores the failure of past and recent policies to build a sustainable local dairy value chain. A detailed review of what went wrong during the Buhari era can help redirect future strategies toward more resilient domestic production systems.

3. Rising Farmer-Herder Conflicts

The proliferation of violent clashes between pastoralists and sedentary farmers during the Buhari administration posed a serious threat to national cohesion, food security, and rural development. Between 2016 and 2022, these conflicts resulted in thousands of deaths, mass displacement, and destruction of property and farmland, especially in the Middle Belt region (Peace, 2017; Buba, 2021). While the government's policies—like RUGA and cattle colonies—aimed to resolve these crises, they were met with fierce opposition and distrust. Understanding the socio-political roots of these failures is essential for designing inclusive and conflict-sensitive livestock policies.

4. Weak Institutional Synergy and Policy Fragmentation

Another justification for this study is the lack of coordination between federal and sub-national authorities, which significantly undermined the delivery of livestock programs. Land governance, a critical aspect of livestock development (especially for ranching), is constitutionally controlled by state governments, while many livestock initiatives were federally driven, leading to jurisdictional conflicts (Ekpo & Tobi, 2019; Adesola & Onwutuebe, 2024). This study explores such institutional disconnects and provides lessons for multi-level governance in agriculture.

5. Need for Forward-Looking, Evidence-Based Recommendations

As Nigeria moves into a post-Buhari political era, there is an urgent need to build forward-looking policies informed by past lessons. This study not only evaluates the outcomes of livestock and dairy interventions under *Buharinomics*, but also highlights opportunities for future reforms, including public-private partnerships, regional market integration (via AfCFTA), climate-smart livestock systems, and digital traceability tools.

6. Academic and Policy Relevance

This research contributes to the growing body of literature on agricultural policy effectiveness in Sub-Saharan Africa. It also provides critical insights for:

- Policy makers (e.g., Federal Ministry of Agriculture and Rural Development)
- Development partners (e.g., FAO, IFAD, ECOWAS)
- Private sector actors in the livestock and dairy value chains
- Scholars of agricultural economics, rural development, and political economy

By addressing both the policy architecture and on-ground realities, the study bridges a key gap between theory and practice.

Objectives of the Study

- To review livestock and dairy policy interventions under the Buhari administration.
- To identify critical gaps in policy implementation.
- To explore future prospects for sustainable livestock development in Nigeria.
- To offer policy recommendations based on empirical evidence.

Scope of the Review

This review assesses the overall performance of livestock and dairy development policies under Buharinomics. It investigates the alignment between policy intentions and outcomes, identifies key structural and political barriers to implementation, and explores opportunities for future transformation in the sector. Given the urgent need to enhance food security, reduce import dependence, and resolve land-use conflicts, this analysis provides a timely and critical evaluation of one of the most significant but underperforming sectors of Nigeria's agricultural policy landscape.

Theoretical Framework

This study is grounded in the Political Economy of Agricultural Policy Reform (PEAPR) and Institutional Theory, both of which provide a robust lens for analyzing how political, economic, and institutional dynamics interact to shape the outcomes of livestock and dairy policies under *Buharinomics*.

Political Economy of Agricultural Policy Reform (PEAPR)

The Political Economy of Agricultural Policy Reform examines how power, interests, ideologies, and resource control affect policy formulation and implementation, particularly in developing countries. It assumes that agricultural policies are not formed in neutral or purely technocratic environments but are instead shaped by the strategic interactions among various actors, including the state, private sector, interest groups, and local communities (Anderson & Swinnen, 2008).

This theory is particularly relevant in the Nigerian context, where policy reforms such as the National Livestock Transformation Plan (NLTP) and RUGA settlements were introduced with economic objectives but became politically contentious due to ethno-regional tensions and historical land grievances (Ekpo & Tobi, 2019). These policies were perceived by certain groups, especially in Southern Nigeria, as promoting Fulani hegemony, thereby igniting resistance that undermined implementation.

Under President Buhari, who hails from a Fulani background, livestock-related policies were heavily politicized and interpreted through ethnic lenses. The PEAPR helps explain why technically sound policy ideas like ranching and dairy investment failed in practice due to the misalignment of political incentives, social trust, and institutional legitimacy (Adesola & Onwutuebe, 2024).

Application: The theory reveals how the Buhari administration's centralization of livestock policies, without adequate local buy-in or institutional cooperation from state governments (who constitutionally control land), created friction and hindered progress (Ukase & Ityonzughul, 2020).

Institutional Theory

Institutional Theory explores how formal rules (laws, regulations) and informal norms (traditions, beliefs) influence organizational behavior and policy outcomes. In the context of livestock development, institutional theory is relevant for understanding disconnection between policy design and field-level implementation.

Nigeria's agricultural policy space suffers from institutional fragmentation, where multiple agencies (e.g., Federal Ministry of Agriculture, National Food Reserve Agency, State Ministries, and private actors) operate with overlapping mandates, poor coordination, and limited accountability (Gao *et al*., 2023). Institutional inertia—where old practices persist despite new policies—is another factor that weakens reform effectiveness.

This theoretical framework is instrumental in explaining why the Anchor Borrowers' Programme (ABP), though well-funded and nationally promoted, recorded limited success in the livestock value chain due to:

- Weak monitoring mechanisms
- Lack of data on pastoralist productivity
- Poor veterinary and extension service delivery systems (Eeswaran *et al*., 2022; Gao *et al*., 2023)

Institutional theory also helps clarify why land governance complications—where land is controlled by state governments under the Land Use Act of 1978—limited the ability of federal actors to implement RUGA or ranching infrastructure (Ekpo & Tobi, 2019).

Application: The theory explains how institutional weaknesses—including the absence of cross-ministerial coordination, poor extension services, and top-down policy rollouts—undermined otherwise promising livestock transformation plans under Buharinomics.

Synergy of both Theories in this Study

Together, the Political Economy and Institutional Theory frameworks provide a dual lens:

- Political economy explains *why* policies were designed and contested, focusing on interests, identities, and power.
- Institutional theory explains *how* policies failed or succeeded, focusing on structures, routines, and implementation mechanisms.

This combined approach allows us to:

- Trace the influence of elite interests and identity politics on livestock policy choices
- Evaluate the roles of institutional design and administrative capability in shaping outcomes
- Understand the dynamics behind public backlash, policy failures, and missed development opportunities

Conceptual Framework

The conceptual framework for this study builds upon insights from the Political Economy of Agricultural Policy Reform and Institutional Theory, illustrating the complex interaction between policy interventions, institutional and socio-political dynamics, and livestock and dairy sector outcomes under *Buharinomics*.

This framework helps to visualize how government-initiated livestock development programs are influenced by both technical and non-technical variables—such as political will, institutional capacity, land tenure systems, security, and community acceptance. It also emphasizes how these intervening variables shape the effectiveness, sustainability, and inclusivity of livestock and dairy development in Nigeria.

Key Constructs and Relationships

Table 1: Key constructs and relationships

Category	Variables / Components
Inputs	Policy reforms (NLTP, ABP, RUGA) Federal investment Technical support
Institutional Factors	Federal-state coordination Land use control Bureaucratic capacity
Socio-Political Factors	Ethnic/regional perceptions Farmer-herder conflict Community engagement
Processes	Implementation design Stakeholder involvement Resource allocation
Outputs	Increased milk production Reduction in conflict Ranching adoption
Outcomes	Improved food security Reduced dairy imports Inclusive rural development

Source: Authors' own synthesis, 2025

Conceptual Framework Diagram

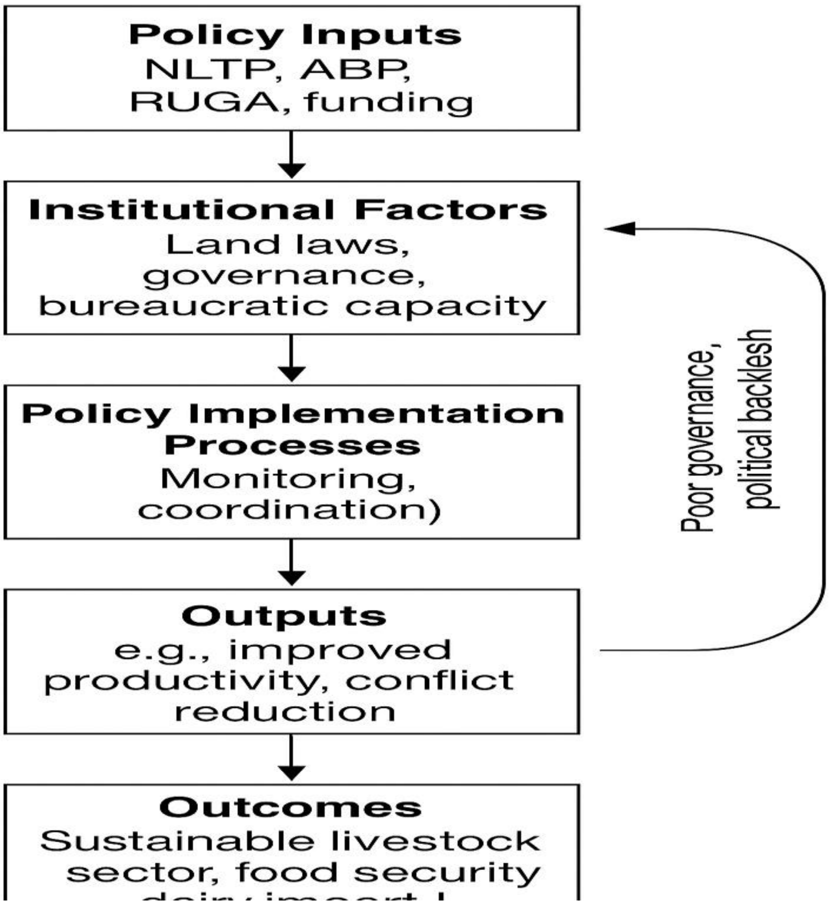


Figure 1: Conceptual framework

Source: Python software, 2025

Explanation of the Model

1. Inputs refer to the policy instruments and resources deployed by the federal government under Buhari—such as funding for ranching, policy blueprints, and subsidized loans.

2. These inputs are mediated by institutional factors like the level of collaboration between federal and state governments, which is crucial in a decentralized land governance context.

3. Socio-political dynamics such as communal conflict, ethnic mistrust, and resistance to centralized policies further influence whether policies are accepted or rejected.

4. Processes reflect how policies are implemented—whether inclusively, transparently, and with sufficient stakeholder involvement.

5. The outputs refer to the immediate results such as ranching infrastructure, dairy collection centers, or reduced transhumance.

6. Outcomes are the long-term impacts like food security, employment, and reduced reliance on dairy imports.

The feedback loop in the diagram indicates that poor implementation or exclusionary politics can trigger public distrust, institutional failure, and conflict—ultimately undermining policy success.

Research Methodology

This section outlines the methodological approach employed in reviewing livestock and dairy development under the Buhari administration (*Buharinomics*). A qualitative, desk-based research design was adopted, drawing upon policy documents, academic literature, government reports, and stakeholder analyses published between 2015 and 2024.

Research Design

This study employs a qualitative research design utilizing systematic review and policy analysis techniques. The review approach is suitable for synthesizing evidence from multiple sources to explore complex socio-economic and political phenomena—specifically, the relationship between livestock policies and sectoral outcomes under Buhari's economic doctrine.

Data Sources

The study relied on secondary data from a range of peer-reviewed journals, government publications, and policy papers. Key sources included:

- Scholarly articles from journals such as *SN Social Sciences*, *Food Reviews International*, and *African Journal of Peace and Conflict Studies*
- Reports from institutions like the International Crisis Group, Cambridge University Press, and CGIAR
- Official government documents such as the National Livestock Transformation Plan (NLTP) and Central Bank of Nigeria's Anchor Borrowers' Programme (ABP) policy briefs
- Development partner documents including FAO and ECOWAS livestock investment profiles

A total of 25 primary sources were systematically reviewed and selected based on relevance, recency, and credibility.

Data Collection Procedure

Data was gathered using the following approach:

- **Systematic Academic Search**: Keyword queries such as "livestock development in Nigeria", "Buharinomics", "RUGA policy", "NLTP", and "dairy sector Buhari" were used in scholarly databases including Google Scholar, ResearchGate, Springer, and JSTOR.
- **Policy Documents Review**: Government reports, strategy documents, and legal frameworks (e.g., Land Use Act, NLTP blueprint) were collected from official platforms like the Ministry of Agriculture and Rural Development (FMARD), Central Bank of Nigeria (CBN), and National Planning Commission.
- **Content Validity Filtering**: Only publications between 2015 and 2024 were considered to ensure temporal relevance to the Buhari administration.

Data Analysis Technique

A thematic content analysis was conducted to categorize data into key policy interventions, implementation outcomes, gaps, and future prospects. The following steps were taken:

1. Coding policy documents and articles into themes: e.g., "dairy import reduction", "conflict resolution", "policy coordination", etc.
2. Synthesizing data across documents to identify convergence and divergence of findings.
3. Triangulating academic insights with government reports and stakeholder opinions to validate observations.

This multi-level analytical approach ensured depth, rigor, and cross-verification of claims.

Ethical Considerations

As a desk-based study relying solely on secondary data, no primary human or animal subjects were involved. However, proper academic integrity was ensured by:

- Citing all sources correctly
- Using reputable and peer-reviewed materials
- Avoiding biased or politically charged interpretations
- Maintaining objectivity throughout the analysis

Limitations

- Data Scarcity on Implementation Metrics: Many livestock projects under Buharinomics lacked clear monitoring and evaluation indicators, limiting quantitative assessment.
- Regional Disparities: Policy implementation varied across states due to political resistance, which may not be fully captured in federal-level documents.
- Access to Internal Government Reports: Some classified or unpublished strategy documents were inaccessible, potentially narrowing the evidence base.

Results and Discussion

This section presents and interprets the major findings related to livestock and dairy policy outcomes under the Buhari administration. Drawing upon a critical review of academic literature, government reports, and empirical studies, the discussion focuses on:

- Implementation of key policies
- Institutional performance
- Livestock productivity and dairy value chain dynamics
- Conflict-related outcomes
- Future opportunities and innovations

Implementation of Key Livestock Policies under Buharinomics

Several livestock-focused policies were launched under Buhari's presidency, yet their results were mixed and often fell short of targets due to political, institutional, and operational challenges.

a. The National Livestock Transformation Plan (NLTP)

Designed in 2019 to transition Nigeria from open grazing to ranching and reduce farmer-herder conflict, the NLTP aimed to establish 119 ranches in 7 pilot states. However, by 2023, only a few pilot schemes were functional due to inadequate funding, poor state-level buy-in, and community mistrust (Adesola & Onwutuebe, 2024; Ukase & Ityonzughul, 2020).

Finding: The NLTP lacked inclusive community consultation and faced resistance in Southern states, where it was perceived as a strategy to resettle Fulani herders on ancestral lands.

b. Anchor Borrowers' Programme (ABP)

Although initially focused on crops, the ABP extended credit to livestock producers through the Central Bank of Nigeria. However, disbursement to livestock actors was minimal, and the program suffered from poor loan recovery and monitoring issues (Eeswaran *et al*., 2022; Gao *et al*., 2023).

Finding: ABP's livestock arm was underutilized due to poor targeting, bureaucratic bottlenecks, and weak extension service support.

c. RUGA Settlements and Cattle Colonies

These controversial policies were introduced to establish settlements for herders, but implementation was suspended in 2019 after public backlash and fears of ethno-religious domination (Peace, 2017; Ekpo & Tobi, 2019).

Finding: The politicization of livestock policy undermined public trust and exposed deep governance deficits in participatory decision-making.

Institutional Performance and Governance Gaps

One of the most consistent findings across the literature is the failure of institutions to harmonize federal initiatives with state and local realities. Under the 1978 Land Use Act, states retain authority over land allocation, making federal livestock policies (e.g., ranching, grazing reserves) difficult to enforce without state consent (Buba, 2021).

- Coordination between ministries—Agriculture, Environment, and Interior—was weak, and monitoring frameworks were either non-existent or poorly enforced (Haruna *et al*., 2025).
- There was a clear absence of multi-stakeholder governance involving pastoralists, farmers' associations, local chiefs, and NGOs.

Finding: Structural decentralization without institutional cooperation severely limited policy effectiveness, especially in land-intensive initiatives like ranching.

Livestock Productivity and Dairy Sector Outcomes

Despite rhetoric around livestock transformation, national productivity indicators remained stagnant:

- Milk yield among indigenous cattle breeds averaged just 1.5 liters/day, compared to 20–30 liters/day in commercial herds globally (Haruna *et al*., 2025).
- Nigeria's annual dairy import bill rose to over $1.5 billion by 2022, with powdered milk accounting for more than 85% of imports (Eeswaran *et al*., 2022).
- Only 15% of milk produced locally enters the formal processing sector—most is consumed raw or wasted due to lack of cold storage and transportation (Ogbimi & Oyewale, 2000).

Finding: No significant improvement in dairy productivity occurred during the Buhari administration, due to poor breed quality, inadequate feed systems, and lack of investment in the dairy cold chain.

Conflict, Security, and Displacement Impacts

One of the gravest outcomes was the escalation of farmer-herder conflicts, especially in Benue, Plateau, Kaduna, Zamfara, and Nasarawa states. From 2016 to 2022, over 3,600 lives were lost, and over 300,000 people displaced due to these conflicts (Peace, 2017; Buba, 2021).

- Insecurity led to abandonment of grazing routes and markets, especially in the North West.
- Displacement of pastoralists led to urban migration and overcrowding in peri-urban abattoirs and markets.

Finding: Security failures undermined the implementation of livestock policy, with persistent violence reducing access to grazing land and disrupting the dairy supply chain.

Missed Opportunities and Emerging Prospects

Despite underwhelming results, there are emerging innovations and future opportunities in the sector:

a. Climate-Smart Livestock Systems

Technologies such as silage-making, improved pasture seeding, and livestock feed blocks have been piloted successfully in Niger and Kaduna states (Eeswaran *et al*., 2022).

b. Digital Traceability and Livestock Health Monitoring

Mobile-based livestock health apps and RFID tagging have shown early success in disease tracking and movement control, particularly in commercial ranches (Haruna *et al*., 2025).

c. AfCFTA and Regional Dairy Trade

With the African Continental Free Trade Agreement (AfCFTA), Nigeria could position itself as a hub for regional livestock trade, provided domestic processing and quality standards improve (Gao *et al*., 2023).

Finding: While Buhari's administration failed to achieve significant transformation, the sector still holds potential—if guided by smarter governance, private sector engagement, and conflict-sensitive programming.

Conclusion

The Buhari administration (2015–2023), operating under the ideological and economic framework of *Buharinomics*, presented a bold policy shift toward agricultural self-sufficiency and rural revitalization. However, while the administration invested heavily in programs such as the National Livestock Transformation Plan (NLTP), Anchor Borrowers' Programme (ABP), and proposed RUGA settlements, the outcomes in the livestock and dairy sectors were largely underwhelming.

This review reveals that policy intentions often outpaced institutional capacity and political reality. The politicization of livestock initiatives—particularly those associated with Fulani pastoralism—ignited regional tensions and undermined the legitimacy of federally driven interventions. Weak coordination between federal and state authorities, combined with structural land governance issues, further constrained effective policy rollout.

Moreover, despite policy efforts, livestock productivity, milk yield, veterinary coverage, and feed availability remained critically low, with Nigeria still importing over 60% of its dairy needs as of 2023. Farmer-herder conflicts escalated under Buhari, intensifying insecurity and displacement, and severely disrupting livestock markets.

Nonetheless, the post-Buhari era presents an opportunity to reframe livestock and dairy policy through a more inclusive, decentralized, and conflict-sensitive approach, grounded in institutional reforms and private sector partnerships.

Recommendations

Based on the findings, the following actionable recommendations are proposed:

Institutional and Governance Reforms

- Strengthen federal-state coordination through formal livestock governance councils that include state ministries, traditional institutions, and livestock cooperatives.
- Decentralize policy implementation while aligning it with national strategy frameworks. This would enhance ownership and reduce regional resistance.

Land and Conflict Resolution

- Review the Land Use Act (1978) to allow for livestock development planning at the community level while protecting farmers' land rights.
- Institutionalize peace-building mechanisms within livestock policies, including community dialogue, compensation systems, and local security arrangements.

Dairy Value Chain Modernization

- Invest in breed improvement programs, such as crossbreeding local breeds with high-yielding dairy species.
- Support cold chain infrastructure, milk collection centers, and rural processing hubs to reduce waste and improve product quality.
- Incentivize private sector participation via tax reliefs, access to credit, and technical support for dairy cooperatives and processors.

Capacity Building and Research

- Expand veterinary services and animal health systems, especially in conflict-prone and underserved regions.
- Strengthen partnerships with universities and research institutions for data generation, feed innovations, and extension systems.

Digital Integration

- Scale up digital livestock management platforms (e.g., traceability, disease reporting, mobile extension) as piloted in states like Niger and Kaduna.

Policy Implications

The review highlights several critical policy implications:

From Political Rhetoric to Operational Policy

Policymakers must bridge the gap between policy documents and field-level execution, avoiding top-down impositions and ethnicized framings that create resistance.

Conflict Sensitivity in Policy Design

Given the role of livestock in communal conflict, all livestock-related policies must integrate conflict risk analysis, peace-building components, and grievance redress systems.

Regional Integration Potential

Under the African Continental Free Trade Agreement (AfCFTA), Nigeria could become a regional hub for livestock trade. However, this will require compliance with quality, disease control, and traceability standards.

Private Sector as Driver, Government as Enabler

The future of livestock transformation lies in creating an enabling environment for private investment, rather than relying on state-led interventions. This includes reforms in taxation, financing, and regulation.

Data-Driven Policymaking

There is a pressing need for evidence-based livestock data systems to guide investment, track productivity, and monitor interventions, currently lacking in Nigeria’s agricultural policy space.

REFERENCES

Adesola, F., & Onwutuebe, C. (2024). Interrogating cattle colony and farmer/herder clashes in Nigeria. *SN Social Sciences*, *4*(1), 16. https://doi.org/10.1007/s43545-023-00814-4

Anderson, K., & Swinnen, J. (Eds.). (2008). *Distortions to agricultural incentives in Europe's transition economies*. World Bank Publications.

Buba, A. B. (2021). The Farmer-Herder Conflicts in Nigeria's Open Space: Taming the Tide. In *Decolonising Conflicts, Security, Peace, Gender, Environment and Development in the Anthropocene* (pp. 367-383). Cham: Springer International Publishing.

Peace, P. W. S. (2017). Herders against farmers: Nigeria's expanding deadly conflict. *Africa Report*, *19*(252), 1-32.

Ekpo, C. E., & Tobi, B. E. (2019, November). Fear, distrust and the political climate of the Rural Grazing Area (RUGA) policy in Nigeria. In *Being a paper presented at the 13th Annual International Conference of the Society for Peace Studies and Practice (SPSP)*.

Ajetunmobi, U. O., Oseni, A. I., Onifade, A. B., & Adegboyega, T. A. (2024). Fear of Expansion and Domination: Toxic and Ethnic Frames Amidst Call to# SayNoToRUGA on Nigerian Twittersphere. *Media Watch*, *15*(2), 246-266.

Canton, H. (2021). Food and agriculture organization of the United Nations—FAO. In *The Europa directory of international organizations 2021* (pp. 297-305). Routledge.

Eeswaran, R., Nejadhashemi, A. P., Faye, A., Min, D., Prasad, P. V., & Ciampitti, I. A. (2022). Current and future challenges and opportunities for livestock farming in West Africa: Perspectives from the case of Senegal. *Agronomy*, *12*(8), 1818.

Ojong, F. E., & Anam, B. E. (2018). Agriculture promotion policy 2016-2020 and rural development in Nigeria: Challenges and prospects. *Journal of Humanities and Social Science*, *23*(2), 24-29.

Haruna, A. E., Alhaji, N. B., Adama, J. Y., Monday, O. M., Muhammed, H. L., & Makun, H. A. (2025). Assessment of pesticide residues in milk from agro-pastoral cattle settlements in Niger State, Nigeria: implications for public health and food safety. *Research Directions: One Health*, *3*, e3. doi:10.1017/one.2025.5

Abubakar, Y., Jibril, A., Usman, M., & Bashir, M. (2023). Comparative Analyses of the Physicochemical Parameters of Milk of Lactating Cows from Unguwar Fulani Sokoto, Nigeria. *Fudma Journal of Agriculture and Agricultural Technology, 9*(3), 99-104.

Gao, Y., Zhao, T., Xu, X., & Ndidiamaka, A. P. (2023). Can agricultural protectionist policies help achieve food security in Nigeria?. *Frontiers in Sustainable Food Systems*, *7,* 1095914.

Ogbimi, F. E., & Oyewale, A. A. (2000). Analysis of the experience of developing the dairy industry in Southwestern Nigeria. *Food Reviews International*, *16*(4), 485-502.

Ukase, P. I., & Ityonzughul, T. T. (2020). Policy Options/StrategiesTowards a Resolution of Farmers-Nomadic Cattle Herders Conflicts in Nigeria. *Covenant University Journal of Politics and International Affairs*, *8*(2).

Archibong, B., Coulibaly, B., & Okonjo-Iweala, N. (2021). Washington consensus reforms and lessons for economic performance in Sub-Saharan Africa. *Journal of Economic Perspectives*, *35*(3), 133-156.

POTENTIAL SOURCE OF PLANT BIOMASS FOR BIOFUEL PRODUCTION

Dr. Zineb Mahi

Department of Life and Environment, Faculty of Natural and Life Sciences, Laboratory of Toxicology, Environment and Health (LATES), University of Science and Technology Mohamed Boudiaf (USTO-MB),0ran 31000, Algeria.

ORCID: 0000-0001-5539-9184

Pr. Bouhameur Mansour

Department of Earth Sciences, Oran 2 University, Mohamed Ben Ahmed, Algeria

Laboratory of Stratigraphic Paleontology and Paleoenvironment (LPSP)

ABSTRACT

Bioethanol is a natural product mostly produced by the sugar fermentation process of agricultural feedstock. The main source of sugar required to produce ethanol comes from fuel or energy crops. The fuel crops grown for energy use includes sugar cane, bagasse, miscanthus, sugarbeet, sorghum, molasses, corn stover, grain, wheat, straw, cotton and other biomass, as well as many types of cellulosic waste. Crops available for human consumption being used presently as biofuel feedstock may be replaced with halophytes as these plants have great capability to grow in saline soil and can be irrigated with saline water. Significant and good quality of lignocellulosic biomass is produced in halophytes which can be converted into bioethanol using enzymatic hydrolysis and microbial fermentation. Halophytes have greatest potential in their utilization in restoration of degraded saline locations, coastal stabilization, as a source of nonconventional cash-crop, food, forage, fodder, oilseed and production of cheap biomass for sustainable agriculture. A vision of using halophyte plants for bioethanol production can only be achievable if we can recognize alternate species that can be cultivate on saline soils and would not compete with conventional agricultural resources. Here, we review current progress and highlight the key species of halophytes of Algeria for greater economic approach and energy efficiency use in near future.

Key words: bioethanol, biofuel, halophytes, lignocellulosic, *Atriplex*

PROSPECTIVE STUDY ON THE CONSUMPTION OF FOOD SUPPLEMENTS AMONG ATHLETES IN ALGERIA

Dr. Zineb Mahi

University of Science and Technology Mohamed Boudiaf (USTO-MB), 0ran 31000, Algeria
Faculty of Natural and Life Sciences, Department of Life and Environment, Laboratory of Toxicology Environment and Health (LATES).

ORCID: 0000-0001-5539-9184

ABSTRACT

This research was conducted as part of the Master's program in Fundamental and Applied Toxicology. Its aim is to explore the consumption patterns of sports-related dietary supplements among the population of Oran in Algeria. A prospective survey was carried out using a questionnaire distributed online and in several fitness centers (Ma Fitness, Power Gym, and Fit Park). The results show that most consumers are young adults aged between 18 and 35 years, with a male predominance. The most commonly used supplements include protein powders (whey), amino acids (BCAA, EAA), creatine and multivitamins. The main motivation for use is the enhancement of physical performance and body appearance. However, the study revealed a lack of awareness regarding potential risks, such as side effects, drug interactions, and overdosing. These findings highlight the need for better regulation and targeted nutritional education for consumers.

Keywords: Dietary supplements, sport, consumption, risks, Oran, toxicology

EFFECTS OF METHANOL SEED EXTRACT OF *ACACIA NILOTICA* ON INDOMETHACIN-INDUCED ULCER IN WISTAR RATS

Nwamaka Maureen Odu

Federal University of Technology, Minna, Nigeria.
Africa Centre for Excellence for Mycotoxin and Food Safety, Federal University of Technology, Minna, Nigeria

Saudat Bisola Bello

Federal University of Technology, Minna, Nigeria.

Mary Uchenna Ogunsanya

Federal University of Technology, Minna, Nigeria.

Ulcers are acid-induced lesions that develop on the mucous membrane and duodenum, often accompanied by inflammation, leading to abdominal pain, bleeding and perforation. Current treatments strategies for ulcers have limitations, including side effects, antibiotic resistance, and recurrence. Therefore, there is a need for alternative therapeutic agents with minimal side effects. Traditionally, medicinal plants which include *Acacia nilotica*, have been used for centuries to treat wide range of ailments including ulcer. The aim of this study was to authenticate this claim by investigating the effects of *Acacia nilotica* seed extract on indomethacin induced ulcer in Wistar rats. The phytochemical composition of *Acacia nilotica*, total acidity, pH, gastric volume and histopathological examinations were determined using standard methods. Six groups (three per group) of rats were induced with ulcer and treated with a standard drug and different concentrations of *Acacia nilotica* seed extract. Thereafter, the body weight of the animals were observed for a period of 21 days and then, sacrificed. The result showed the presence of bioactive compounds such as alkaloids, flavonoids, phenols, saponins and tannins with phenols having highest concentration (274.73±0.22 mg/100 g) while alkaloids had the lowest concentration (13.20±0.15 mg/100 g). The results also showed a significant ($p < 0.05$) increase in body weight in groups treated with *Acacia nilotica* seed extract when compared to the untreated group. Again, *Acacia nilotica* seed extract, particularly at the 400mg/kg body weight dose showed significant ($p < 0.05$) differences in the anti-ulcerative effects, with total acidity (64.07±1.08 meq/L**)**), pH (2.94±0.16), gastric volume (7.40±0.47 ml) and mild gastric mucosal damage as compared to the untreated group; indicating significant protection. The results demonstrate the potential of *Acacia nilotica* extract as the natural source of antiulcer and this suggests that the plant could have relevance in the management of ulcer disorders.

Keywords: Ulcer, Acacia nilotica, Phytochemicals.

OPTIMIZING SWEET POTATO PRODUCTIVITY THROUGH PRECISION PROPAGATION BY VINE CUTTING POSITION AND VARIETY SYNGERY IN TROPICAL NIGERIA

Solomon Oluwaseyi ADEWUYI
Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka.
https://orcid.org/0009-0000-6724-4366

Uchenna Noble UKWU
Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka.
https://orcid.org/0000-0003-4683-3596

Nathaniel DAUDA
Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka.
https://orcid.org/0000-0001-5706-0416

Ayomide Benjamin OLUGBADE
University of Fairfax, USA.
https://orcid.org/0009-0002-1455-8999

Vivian Ogechi OSADEBE
Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka
https://orcid.org/0000-0002-5984-2400

Patience Amaka ISHIEZE
Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka.
https://orcid.org/0000-0002-8671-5626

Chinenye Blessing ARUAH
Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka.
https://orcid.org/0009-0008-8003-5604

Adebisola Benedicta FADOJU
Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka.
https://orcid.org/0009-0002-1395-9205

Abstract

Sweet potato (*Ipomoea batatas* (L.) Lam) is critical for food security in developing nations, yet yields are limited by suboptimal propagation practices. Vine cutting is the main method, but interaction between varietal genetics and cutting position on growth and yield is poorly understood. This study investigated vine cutting position and variety effects on sweet potato performance in southeast Nigeria. A 2x2 factorial experiment, conducted in 2024 at University of Nigeria, used a randomized complete block design with three replications. Two varieties (Beauregard and Hannah) were propagated using 30 cm top (apical) and basal cuttings. Beauregard outperformed Hannah across all traits ($P < 0.05$), yielding 34.17% more roots (32. 55 vs. 24.26 Kg/plot), with larger tubers (13.22 cm vs. 12.40 cm length). Top part cuttings surpassed basal, with 87 % more roots (102.60 vs. 55.00 No./plot) and 72% higher yield (35.89 kg/plot vs 20.92 kg/plot). A significant genotype x cutting position interaction ($p < 0.05$) revealed Beauregard-Top part of vine cutting combinations as optimal achieving peak yield (44.97 Kg/plot) -123% higher than Beauregard-basal. Hannah showed stability but lower yields. Strong correlations emerged between root yield and both root number (r= +0.93**) and stem count (r= +0.92**), establishing these as reliable key yield predictors. GGE biplot confirmed revealed Beauregard-Top part of vine cutting as the highest yielding, most stable combination, and driving resources efficient tuber enlargement. In conclusion top part cuttings of high performing varieties (e.g. Beauregard) synergistically enhance productivity though optimized physiological vigor. This precision propagation strategy offers Smal holders a low input solution to sustainably intensity sweet potato production, addressing both yield gaps and climate resilience in tropical agroecologes.

Key words: Top part of vine, genotype x environment interaction, propagation efficiency, food security, root yield, sustainable intensification.

A GENERAL OVERVIEW OF THE IMPACT OF GLOBAL CLIMATE CHANGE ON APRICOT

Abbas KIRMIZIBAYRAK

Apricot Research Institute Directorate, Turgut Ozal University, Graduate Education Institute, Malatya, Turkey, [1]ORCID ID: https://orcid.org/0009-0001-3549-7251,

ABSTRACT

Global climate change is a major environmental problem that directly affects apricot production. Rising temperatures, changing precipitation regimes and extreme weather events pose major risks, especially during the flowering and fruit set periods of apricots. Warming climate conditions cause flowering to occur earlier, which leads to damage to flowers due to late spring frosts and serious yield losses.

Research conducted in Malatya, an important apricot production center in Türkiye, shows that temperatures have increased significantly in the last 40 years and that this situation has negatively affected the crop pattern. Similarly, there have been declines in apricot production in European production areas due to early flowering and frost damage.

Adaptation strategies such as preferring late-flowering varieties in apricot production against climate change and developing irrigation and frost control techniques are of great importance. Otherwise, serious declines in apricot production and economic losses will be inevitable in the coming years.

In this compilation study, the effects of climate change on apricots were investigated.

Key Words: Global Climate Change, Apricot

PLANT-BASED FUNCTIONAL FOODS: A PATH TO BETTER NUTRITION AND HEALTH

Marwa Waheed

Department of Food Science and Technology, Riphah International University, Faisalabad, Pakistan

Muhammad Bilal Hussain

Azha Fatima

Farhan Saeed

Muhammad Afzaal

Department of Food Sciences, Government College University Faisalabad, Pakistan

Abstract:

Plant-based functional foods like flaxseed, chia, quinoa, and spirulina have been receiving growing attention because of their impressive nutritional benefits and positive effects on health. These foods are packed with bioactive compounds that provide a wide range of health benefits. Flaxseed, it's rich in omega-3 fatty acids, lignans, and fiber, which have been shown to support heart health, help regulate blood sugar, and aid digestion. Chia seeds, are loaded with essential fats, antioxidants, and fiber, making them great for heart health, managing weight, and reducing inflammation. Quinoa stands out as a complete protein, offering a variety of amino acids along with important vitamins and minerals like magnesium, iron, and zinc. This makes it an excellent choice for supporting muscle repair, boosting the immune system, and maintaining strong bones. Similarly, spirulina, a nutrient-dense blue-green alga, provides a wealth of proteins, vitamins (including B12, A, and K), and minerals such as calcium and iron. It's known for its immune-boosting properties, anti-inflammatory effects, and potential detox benefits. These plant-based foods owe their health benefits to the high concentrations of antioxidants, essential fats, and other bioactive compounds they contain. Together, they help improve metabolic health and can reduce the risk of chronic diseases. With more people shifting towards plant-based diets, these functional foods are being recognized for their role in promoting health and offering sustainable alternatives to animal-based products. This review explores the nutritional value, health benefits, and potential uses of Flaxseed, Chia seeds, Quinoa, and Spirulina, highlighting their growing importance in modern diets for overall wellness.

Keywords: Plant based Functional Foods, Nutritional importance, Health Benefits, Potential uses.

POSTHARVEST QUALITY COMPARISON OF TWO COMMERCIAL STRAWBERRY VARIETIES: PHYSICO-CHEMICAL AND SENSORY PERSPECTIVES

Sana El Moutaouakil

Laboratory of Natural Resources and Sustainable Development, Department of Biology, Faculty of Sciences, Ibn Tofail University, BP 133, Kenitra, 14000, Morocco.

Youssef El Madhi

Laboratory of Education, Environment and Health, CRMEF Rabat–Sale–Kenitra, Morocco.

Fathalah Elwahab

Plant and Animal Production and Agro-Industry Laboratory, Faculty of Science, Ibn Tofail University, B.P 133, Kenitra, 14000, Morocco.

Mohammed Ouhssine

Laboratory of Natural Resources and Sustainable Development, Department of Biology, Faculty of Sciences, Ibn Tofail University, BP 133, Kenitra, 14000, Morocco.

Abstract

Strawberries are widely appreciated for their sensory appeal and nutritional value, making them a key crop for both fresh consumption and food processing industries. However, differences in cultivar characteristics can significantly influence postharvest quality and market suitability. This study presents a comparative evaluation of two commercially important strawberry cultivars grown in Morocco: FORTUNA and SABRINA. Three key physico-chemical parameters were analyzed—pH, soluble solids content (°Brix), and average fruit weight—alongside sensory quality attributes such as texture, flavor, and appearance. The results revealed notable differences between the two cultivars. FORTUNA demonstrated higher °Brix values and better overall consumer acceptability, while SABRINA exhibited greater firmness and acidity. These findings highlight the importance of cultivar selection based on specific market or processing requirements, and contribute to improved postharvest quality management strategies for strawberries under Moroccan growing conditions.

Keywords: Strawberry, FORTUNA, SABRINA, physico-chemical analysis, sensory evaluation, pH, °Brix, fruit weight, postharvest quality, cultivar selection

PATHWAYS TO SUSTAINABLE FOOD PRODUCTION: CLIMATE-SMART AND RESILIENT AGRI-FOOD SYSTEMS OF THE FUTURE

Prof. Dr. Ramazan ÇAKMAKÇI

Çanakkale Onsekiz Mart University, Faculty of Agriculture, Department of Field Crops, Çanakkale, Türkiye

ORCID ID: https://orcid.org/0000-0002-1354-1995

Öğr. Gör. Muhammet Fatih ÇAKMAKÇI

Department of Computer Programming, Vocational School, Mudanya University, 16940 Mudanya/Bursa, Türkiye

ORCID ID: https://orcid.org/0000-0001-8035-0278

ABSTRACT

Climate-smart agriculture (CSA) is an approach to transform and reorient agricultural systems by integrating precision agriculture technologies into the agricultural industry to support food security by increasing resilience and resource use efficiency in agricultural production systems under the impact of climate change. Based on the integration of multiple agricultural techniques for sustainable productivity with less environmental impact, climate-smart agriculture supports efficient water management and food security, promotes the resilience of agricultural systems to climate change, and aims to increase agricultural production and reduce farm-related greenhouse gas emissions. This agricultural system offers the opportunity to meet the world's food demands by mitigating the impact of climate change, adapting and increasing productivity in the face of climate variability through practices such as crop rotation and diversification, integrated crop-livestock systems, fertilizer management, controlled and micro-irrigation, soil fertility management, agroforestry, agroecological agriculture, family farming, regenerative farming systems, agri-based circular bioeconomy, synthetic biology, digital technologies, hydroponics, intercropping, mixed cropping, conservation agriculture, terracing, mulching, perennial plantation, nitrogen/fertilizer reduction, minimum tillage, region-specific nutrient management and the use of cover crops. The aim of this review is to compile scientific evidence and data on climate smart technologies widely applied in climate resilient agriculture as a subset of climate smart agriculture strategies and to compile, define and create future strategies in terms of food security, safety and sufficiency. This article focuses on future sustainable food production and security, environmental protection, strengthening resilience to climate variability and alternative agricultural techniques, highlighting scientific and technological developments and research directions, and offering recommendations for resilient, resource-efficient and sustainable food production trends.

Key Words: Climate smart agriculture, Climate change, Future foods; Sustainability, Food security, Alternative production systems

INTRODUCTION

Agricultural food systems face three interconnected challenges: ensuring food security, promoting environmental sustainability, and restoring soil fertility and health in the face of climate change. Conventional practices and industrial agriculture have prioritized productivity over ecological resilience, ultimately leading to inefficient resource utilization, soil degradation, and increased greenhouse gas emissions (Wang et al., 2025 a,b). In many cases, socio-economic vulnerabilities can be as, or more, important than ecological vulnerabilities for climate change adaptation in agriculture. Agriculture and food production systems are threatened by the impacts of climate change, including extreme weather events such as droughts, heatwaves, irregular rainfall, and floods, which pose serious risks to food security and livelihoods (Benitez-Alfonso et al., 2023; Arif et al., 2025). Climate change further exacerbates the challenge of agricultural food production by altering weather patterns, reducing water availability, and increasing the frequency and severity of extreme weather events such as droughts, floods, and pests, which threaten crop yields and agricultural productivity (Brown, 2023).

Today's dominant modern industrial agriculture systems, based on high input-high output, have increased yields and food availability and have achieved significant growth over time, but current food systems are not sustainable and cause many problems, especially environmental impacts. Industrial agriculture causes excessive water and land use, pesticide pollution, soil degradation and habitat destruction, depletion of natural resources, loss of biodiversity and the fragility of agricultural systems, while also contributing to and being affected by the climate crisis (Fatima et al., 2024; Qu et al., 2024). Agricultural food production is both affected by and contributes to climate change, and the risks of crop loss increase with climate change, so there is an urgent need to increase the resilience of food systems against climate change (Heinz et al., 2024). Food systems contribute significantly to climate change through carbon emissions, and regenerative and agroecological low-emission agricultural practices should be encouraged to develop sustainable agriculture and strengthen climate resilience. In addition to being heavily affected by changing climate conditions, agricultural production systems also contribute to global warming and transformative food system changes are required. The main objectives of an agricultural system's climate resilience are sustainability in production, adaptation to climate change and mitigation of climate change.

Climate change negatively impacts all components of food systems, including the biodiversity and ecosystem services of agricultural production systems, reducing the productivity and projected yield of staple food crops. Climate change is the increase in sudden extreme weather events and gradual, long-term changes in climate events. Climate change poses a significant challenge to global agriculture and requires innovative approaches to ensure sustainable livelihoods and food security (Bhatnagar et al., 2024). Climate change affects agricultural production through various mechanisms, including rising temperatures, droughts, rising atmospheric $CO2$ levels, changes in water resources, and changes in other factors such as humidity, extreme weather events, and climate fluctuations. Climate change not only causes instability in food production through increased temperatures and extreme weather events but also causes serious effects on agricultural production by changing precipitation, evaporation, soil and water resources (Wang et al., 2025a). Climate change increases the vulnerability of agricultural systems.

Integrated nutrient and water management, changing planting dates according to soil water content, and alternative crop cultivation (Islam et al., 2022) have been suggested to improve food security and health, strengthen resilience to climate variability and restore ecosystems. In the face of the sustainability of agricultural systems and the challenges posed by climate change, it is increasingly important to try to transform agriculture into an ecologically sustainable climate-resilient agriculture (CRA) management model (Zong et al., 2022). Alternative systems such as climate-smart regenerative agriculture, which combine biotechnology, engineering and farming technologies, following the laws of nature, are needed to increase resilience to climate change, increase sustainable productivity and improve ecological, economic and social processes along with food security (Keshavarza and Sharafi, 2023). Climate change poses challenges for agriculture and requires the development of resilient climate-smart agricultural systems, stress-tolerant crop varieties, and efficient water and resource management strategies to maintain food security, farmer incomes, and environmental sustainability (Arif et al., 2025).

The need for innovative scientific solutions and technological approaches against threats in the agriculture and food industry has revealed the transition to plant-based nutrition and digital transformation trends in food production and consumption models (Hassoun et al., 2022). In recent years, food trends have emerged, including unusual food sources such as insects, algae, food waste and byproducts, production systems such as hydroponics, aquaponics, and aeroponics, and cell cultures. However, digitalization and the shift to plant-based nutrition have received the most attention. Since a sustainable food system depends on precision agricultural land use, adoption of modern technologies such as information technology, land sensors, urban agriculture, hydroponic technology, robotics, as well as precision or smart agricultural systems, can be useful in increasing crop productivity.

Agricultural food systems today face three increasingly complex challenges: food security, environmental sustainability and soil health, each occurring independently or often simultaneously, and are interconnected (Wang et al., 2025 b). Overuse of synthetic agricultural chemicals and continuous monoculture further degrade the chemical and biological integrity of soil, microbial communities, and biodiversity, leading to nutrient imbalances, soil salinization, acidification, water pollution, and habitat destruction

As climate change continues to pose challenges for agriculture, there is an urgent need to develop sustainable strategies that increase crop productivity while reducing the negative effects of stressors.This article focuses on future sustainable food production and security, environmental protection, strengthening resilience to climate variability and alternative agricultural techniques, highlighting scientific and technological developments and research directions, and offering recommendations for resilient, resource-efficient and sustainable food production trends. Additionally, this review also offers suggestions for future research and food trends in light of future perspective

DIGITAL TECHNOLOGIES

Effectively combating climate change requires agricultural digitalization and a comprehensive transformational approach encompassing a range of sustainability measures and innovations, offering opportunities for efficiency, resource optimization and decision-making (Büyüközkan and Uztürk, 2024). The integration of digital technologies promotes data-driven decision-making, promising efficiency gains and innovative solutions to complex challenges. Although it is at an early stage, the food industry includes artificial intelligence (AI), internet of things (IoT), big data (BD), robotics, blockchain and smart sensors. Industry 5.0 has emerged as a transformative shift to integrate advanced computational technologies such as artificial intelligence, the internet of things, robotics, and big data with human-centered collaboration to achieve sustainable food production systems (Singh et al., 2025). Integrating data-driven agriculture and robotic solutions (Martos et al., 2021), reducing costs and making the agricultural sector energy efficient (Ragazou et al., 2022) are among the strategic goals of agriculture 5.0.

The development of high technologies forms the basis of Agriculture 5.0, which is based on social, environmental, and economic sustainability, enabling farmers to increase productivity while minimizing environmental impacts and addressing challenges in the food production and supply system (Balaska et al., 2023; Paudel et al., 2025). Innovative microclimate modeling, as an alternative or complement to drone and sensor technologies, helps identify progression through key phenological stages such as flowering, fruit fill, and physiological maturity, and how local climate change may impact grape quality and productivity, in addition to detecting biotic and abiotic stresses

(Fonseca et al., 2025). An important advantage of CSAF systems is the distribution of risk, as small farms are not subject to growing only one crop.

DIGITALISATION IN AGRICULTURE AND THE FOOD INDUSTRY

Digitalization is used in primary production, food processing, distribution, and marketing stages; it is constantly evolving to increase efficiency, reduce food safety risks, and improve the overall sustainability of the vegetable supply chain (Hassoun et al., 2022). Many technologies such as AI, IoT, BD, blockchain, 3D printing, robotics and smart sensors are used by the entire vegatal supply chain. Digital technology approaches that are safe and climate-adaptive provide agri-food producers with a roadmap to develop climate-smart, resource-efficient, sustainable and stress-resilient agri-food systems (Çakmakçı et al., 2023).

New advanced digital technologies such as sensors, unmanned aerial vehicles, autonomous monitoring devices, the Internet of Things (IoT), wireless sensor networks (WSN), remote sensing (RS), unmanned aerial vehicles (UAVs), big data analytics (BDA), machine learning (ML), deep learning (DL), and artificial intelligence (AI) offer promising solutions for increasing productivity and resource use efficiency while reducing greenhouse gas emissions (Çakmakçı and Çakmakçı, 2023a). Digitalization of agriculture offers opportunities such as precision agriculture, predictive analysis, supply chain optimization, decision support systems, farm management systems, sustainable agriculture, financial management, and collaboration platforms (Paudel et al., 2025). The integration of digital technologies such as sensors, drones, Decision Support Systems (DSSs), and IoT platforms enables the optimization of resource use, contribution to environmental sustainability, optimization of resource use, risk management, reduction of chemical inputs, and improved environmental traceability (Benos vd., 2024).

Recent technological advancements in big data analytics have led to a transformative revolution in smart agriculture, enabling farmers to make informed data-driven decisions, manage sustainability and supply chains, optimize resources, and increase productivity and sustainability (Paudel et al., 2025). Big data reduces risks associated with climate variability, pests, and market fluctuations, and supports informed resource allocation, climate change adaptation, and food security by developing predictive models and alerts, as well as facilitating sustainable management throughout the entire food supply chain. Big data enables farmers to optimize efficiency, productivity, and resilience (Tantalaki et al., 2019); can improve crop management, irrigation strategies, and risk assessments (Chergui and Kechadi, 2022); enables decision-making and smart agricultural practices (Wolfert et al., 2017); optimizes yields while reducing costs by enabling targeted and efficient resource allocation (Toscano et al., 2019); increases transparency throughout the supply chain; and supports climate change adaptation and food security. Big data and digital technologies are reshaping agriculture, increasing efficiency, sustainability, and competitiveness. Meanwhile, the integration of technologies such as IoT, AI, and robotics is streamlining agricultural operations and strengthening data-driven decision-making (Liu et al., 2021). It is clear that big data, which has the potential to digitally transform the future of agriculture, will be the source of the next agricultural revolution.

The agricultural sector, including the production, processing and distribution of agricultural products, has undergone transformative change in recent years by adopting cutting-edge technologies such as artificial intelligence (AI), big data, machine learning (ML) algorithms and the Internet of Things (IoT), enabling improvements in production, making informed choices in resource management, enhancing climate resilience and mitigating sustainability challenges (Çakmakçı and Çakmakçı, 2023a; Paudel et al., 2025).

PRECISION AGRICULTURE TECHNOLOGIES AND ITS IMPACTS

Using cutting-edge technology and data analysis, precision agriculture increases agricultural production, reducing waste while mitigating climate risks and minimizing negative environmental impacts (Ammoniaci vd. 2021). Precision agriculture is a key component of digital agriculture, which can play a significant role in addressing various problems facing agriculture, such as rising production costs, labor shortages, and climate change. The rapid advancement of precision agriculture technologies, including the Internet of Things (IoT), drones, and artificial intelligence (AI), is transforming the global agricultural landscape, increasing efficiency, sustainability, and climate resilience, while optimizing resource use and reducing costs (Roy and Medhekar, 2025). Supported by technologies such as smart farming using IoT, drones, AI, ML and robotics, precision farming offers the ability to monitor and optimize every aspect of agriculture, from soil health to irrigation systems, climate adaptation to efficient use of resources, crop yields and weed and pest control. Precision agriculture (PA) technologies, including sensors, drones, GPS, and variable-rate applications, can optimize resource use, reduce environmental impacts, increase agricultural sustainability and productivity, and improve farm economics (Guamán-Rivera, 2023). Cutting-edge technologies such as IoT, blockchain, AI, and PA have been reported to promote sustainability Roy (2025), and PA practices have been reported to increase water and fertilizer efficiency and reduce greenhouse gas emissions (Idier et al., 2024). Avances in Precision Agriculture technologies offer innovative solutions to agricultural challenges such as climate change, resource inefficiency and food security (Roy and Medhekar, 2025).

SUSTAINABLE FOOD SYSTEMS AND FARMING PRACTICES FOR CLIMATE CHANGE RESILIENCE, AGRI-FOOD SECURITY AND STABILITY

Mitigation and adaptation to climate change require climate-smart and environmentally friendly agricultural practices, such as coordinated management of nutrients, water and pests; improved management of rangelands and forestry combined with restoration of degraded lands; and improved soil quality, which improves productivity, adaptation and mitigation by regulating carbon, oxygen and nutrient cycles. Furthermore, digital agriculture and artificial intelligence (AI) technologies are increasing the climate resilience and mitigation potential of agri-food systems through monitoring, fertilization, irrigation, and management (Biswas et al., 2024; Hong et al., 2025). Research shows that integrated farming approaches significantly increase crop yields compared to conventional practices. Many agricultural practices have been emerged to maximize agricultural food productivity and stability, such as optimized irrigation, diversified cropping systems, improved soil management, biochar application, multi-crop rotation, no-till or reduced tillage, straw management, improved crop management, which are transformative towards climate-smart, equitable, and resilient agri-food systems (Wang et al., 2025 b). However, strategies including crop diversification should be adapted to local contexts and the integration of innovative and proven practices. Crop varieties with increased stress tolerance must be urgently developed to ensure food security, adaptation to climate change, and agricultural and environmental sustainability (Ngongolo and Mmbando, 2024).

Nowadays, research on the use of biotechnology and sustainable agriculture to increase ecosystem resilience against climate change is becoming widespread (Arif et al., 2025). Research has identified key practices that increase productivity while reducing environmental impacts, such as optimized fertigation, diversified cropping systems, organic amendments, Integrating legumes and cover crops, and precise nitrogen management. Agricultural sector-specific policies, such as preventing land use conversions, protecting soils, investing in low-emission technologies, improving nitrogen use efficiency, integrated nutrient management, yield optimization, organic fertilization incentives, and integrated monitoring systems, have been recommended (Mohammed et al., 2025). Innovative strategies such as soil and water conservation, crop rotation, development of stress-resistant crop varieties, development of new varieties with increased productivity and disease resistance, establishment of climate-resilient systems, forecasting weather conditions, analysis of climate change impacts, and identification and use of climate-smart and climate-resilient technologies have been adopted to respond to the impacts of climate change on food production and food security. Applying climate-resilient techniques can improve soil organic content and structure, thus improving soil health and fertility (Grover et al., 2024).

It has been emphasized that multifunctional urban agriculture increases biodiversity and climate resilience, improves producer-consumer relations, reduces food insecurity, creates economic value and strengthens social cohesion through agro-ecological practices. Urban agriculture is an important sustainable food production strategy for addressing the challenges of climate change, food security, and urban development, enhancing community well-being and urban biodiversity, and creating green spaces (Bernaschi et al., 2025). In addition to providing fresh produce, urban agriculture reduces food insecurity, improves nutrition, creates livelihoods, contributes to urban resilience by reducing the urban heat island effect, increases biodiversity and improves air quality, and makes cities more livable by addressing urban challenges such as waste management and climate change adaptation. Cities should reduce their ecological footprint by focusing on shortening food supply chains, promoting sustainable diets, and increasing local production capacity by converting rooftops and other urban spaces into green spaces and urban farms and by adopting vertical farming and hydroponic systems. By integrating agriculture into urban environments, cities, especially in developing regions, can provide fresh produce and reduce food insecurity, improve waste management and climate adaptation, and increase self-sufficiency and resilience.

Agroecology, which plays a transformative role in the food system, is critical to strengthening the relationship between humans, agriculture and nature and developing a sustainable and resilient urban food system (Marino et al., 2024). Prioritizing biodiversity, reducing chemical inputs, and strengthening local production capacity address climate change challenges, mitigating environmental impacts, and supporting economic self-sufficiency. Urban and peri-urban agriculture contributes significantly to the city's landscape, ecological balance, air quality, environmental and social sustainability, economy and social well-being (Marino et al., 2023).

Adaptation strategies in agriculture include crop rotation and diversification, resilient varieties, selecting adapted cultivars, perennial plantation, intercropping, mixed cropping, cover crops, controlled and micro-irrigation, integrated farming system, integrated crop-livestock systems, improved water management, terracing and mulching, fertilizer and soil fertility management, ecosystem-based adaptation strategies, region-specific nutrient management, impact mitigation strategies against climate change, hydroponics, remote sensing-based land use analysis, sustainable agroecological practices, and risk reduction through early warning systems. Meanwhile, a few strategies have been developed to increase resilience and promote sustainable crop production, including climate-smart agriculture (CSA), developing and growing climate-resilient crops, biotechnological innovations, improving soil health, sustainable water management, improved irrigation practices, the use of stress-tolerant beneficial microbes, agroecological practices, early warning systems, and resilient supply chains. Some sustainable agricultural food production systems and practices resistant to climate change are listed in Table 1.

CLIMATE-ADAPTED ALTERNATIVE CROPS

Diversification of agricultural systems and cultivation of alternative plants such as less used, wild edible plants, and niche crops underutilized, or orphan crops are expected to have great potential in increasing the resilience of plant systems against climate variability and change. Alternative plants that are resistant to various environmental conditions, can grow in poor soil and high altitudes, and are adapted to climatic conditions are promising protein sources in reducing greenhouse gas emissions, environmental impacts and meat consumption.For example, climate-adapted alternative crops such as quinoa, durum wheat, almonds, pecans, lupins, borage and lentils can diversify the sustainability of current production systems and lead to a transformation towards closing the nutrient gap and climate-resilient agro-food systems (Heinz et al., 2024).

PREDICTIVE SYSTEMS FOR ABIOTIC STRESS IN CHANGING CLIMAT

Abiotic stresses such as drought, salinity, and extreme temperatures threaten crop productivity by disrupting physiological processes and complicate sustainable agriculture under climate change. Advances in technology, particularly artificial intelligence (AI) and machine learning models, are improving stress management through stress prediction, irrigation optimization, and image-based phenotyping approaches (Mushtaq et al., 2025). Various new applications of modern technologies, especially when combined with AI, machine learning (ML), remote sensing (RS), and the Internet of Things (IoT), are transforming precision agriculture by enabling data-driven, adaptive, and sustainable agricultural practices (Pagano. Et al., 2023; Usigbe et al., 2024). New technologies increase resource efficiency and climate resilience in orchards. Artificial intelligence and deep machine learning have significant potential in managing abiotic stress and improving horticultural resilience, especially under climate change (Mushtaq et al., 2025). Smart water management practices, shade management techniques, and optimized growing environments to reduce heat and water stress can help mitigate the impact of climate events and extreme temperatures (Fonseca et al., 2025).

Table 1. Climate-resilient and environmentally friendly agri-food systems and practices.

Agri-food systems/ practices	Reference
Agricultural and Sustainable Intensification	Duff et al., 2022; Çakmakçı et al., 2023a
Agroforestry systems	Wang et al., 2022
Agroecology	Marino et al., 2024
Developing and breeding climate- resilient crops	(Goel et al. 2018; Ngongolo and Mmbando, 2024
Climate-adapted alternative crops	Heinz et al., 2024
Climate-Smart Agriculture	Mabhaudhi et al., 2025
Climate- smart ırrigation	Driscoll et al., 2024
Climate-resilient farming	Roy and Medhekar, 2025
Conservation tillage and agroecology	Hong et al., 2025
Conservation agriculture	Arif et al., 2025
Digital transformation of the agri-food system	Vahdanjoo et al., 2025
Digitally integrated urban food systems, precision and vertical farming	Lepore et al., 2025
Diversified cropping system	Zhou et al. 2019; Frison and Clément, 2020; Tuan, 2024.
Environment-smart agriculture	Islam et al., 2022
Improved water management	Gultekin et al., 2023; Sismani, et al.,2024
Microclimate modelling	Fonseca et al., 2025
Mixed crop–livestock systems	Bisht et al., 2020
Organic Farming	Çakmakçı and Çakmakçı, 2023b
Perennial alley cropping	Wolz et al., 2018
Precision agriculture	Erickson and Fausti, 2020
Precision agriculture and technology adoption	Demestichas and Daskalakis, 2020; Michler et al., 2019
Regional Food Systems	Bisht et al., 2020
Regenerative Farming Systems	Çakmakçı et al., 2023
Reduced- tillage farming systems	Jayaraman et al. 2021
Small-scale ecological farming	Bisht, 2021
Soil management techniques	Blanco- Canqui and Ruis, 2018; Topp et al., 2024
Stress- tolerant varieties	Wong et al., 2022
Urban and peri-urbanagriculture	Bernaschi et al., 2025
Use of stress- tolerant beneficial microbes	
Utilising climate data and early warning systems for agricultural resilience	Li et al., 2021; Riaz et al., 2023
Integrated cropping strategies: - enhancing system resilience by integrating existing and novel Technologies - promoting carbon source-to-sink strategies - stimulating biological processes to enhance water and nutrient use efficiency - improving soil biochemical properties reducing reliance on synthetic nitrogen	Wang et al., 2025b

CLIMATE-RESILIENT AGRICULTURAL PRACTICES

Climate-resilient agriculture is a sustainable approach to food security that uses adaptation and mitigation measures simultaneously, aiming to improve the current system by reorienting and transforming it according to changing climate conditions (Islam et al., 2022). Adaptation measures are climate resilient if they can increase agricultural productivity, achieve resource management, reduce greenhouse gas emissions and improve carbon sequestration under changing climate conditions without endangering social and environmental resources. The environmentally friendly integrated agricultural approach, which provides climate resilience and brings together corrective, preventive, physical, biological, traditional and environmentally friendly agricultural practices, reduces environmental problems and contributes to coping with current climate change conditions (Islam et al., 2022). Agritech startups play a key role in the efficient use of resources and addressing climate change challenges as they develop innovative solutions, such as drought-resistant crops and climate-resilient methods, and when these advancements are integrated with agricultural science principles. Climate-smart agriculture (CSA) practices include rainwater harvesting, agroforestry, conservation agriculture, diversifying, composting, cover cropping, high-yielding crop varieties, drought-resistant seeds, crop diversification, terracing, crop rotations, organic fertilizer, organic farming, mulching, manure, minimum tillage, intercropping, relay cropping, row planting, integrated pest management, irrigation, solar-powered drip irrigation systems, climate information systems, integrated soil fertility management, zero tillage, and improved varieties (Bhatnagar et al., 2024; Mabhaudhi et al., 2025). Climate-resilient agricultural practices are essential for ensuring sustainable food production and food security and protecting natural resources and biodiversity.

CLIMATE-SMART AGRICULTURE

Climate-smart agriculture, which has the potential to promote sustainability and food security, is considered a socially beneficial and environmentally friendly agricultural production method to cope with climate change and extreme weather conditions. This system aims to increase the capacity of agricultural production to adapt to climate change, strengthen the resilience of the agricultural system, and sustainably increase agricultural productivity and farmers' income (Wang et al., 2025 a). Climate-smart agriculture (CSA) is resilient to climate change, produces lower greenhouse gas emissions than conventional agriculture, and has the potential to increase farmers' crop yields and food production. While climate-smart agriculture reduces food scarcity, climate change threatens a stable food supply chain (Khan et al., 2025). Climate-smart agriculture, which emerged to address the negative effects of climate change on agricultural systems, contributes to sustainable agricultural development by integrating practices that increase agricultural productivity and resilience to climate variability and reduce greenhouse gas emissions. Climate-Smart agriculture encompasses practices such as agroforestry, intercropping, mulching, row cropping, crop rotation, water harvesting, selecting adapted cultivars and improved varieties, and provides improvements in yields and incomes for farmers, optimises productivity, reduces greenhouse gas emissions and increases resilience to the impacts of climate change (Bhatnagar et al., 2024). Crop diversification across broad agricultural sectors is one of the most effective adaptation measures. Smart agriculture integrates and utilizes advanced technologies such as IoT, AI, and automated systems, which are key components in optimizing resource efficiency and crop yields to increase agricultural sustainability and productivity (Debangshi et al., 2023). IoT applications in agriculture, ranging from wireless sensors to cloud computing and robotics, are revolutionizing traditional farming practices (Dhanaraju et al., 2022), while UAVs offer the potential for automated operations when integrated into smart farming systems (Islam et al., 2021), and IoT-based smart farming, supported by AI and ML, offers a sustainable solution to increase agricultural productivity while minimizing environmental impact (Shahab et al. (2024).

DIVERSIFIED CROPPING SYSTEM

Crop diversification and reducing dependence on external inputs are approaches to reducing the negative environmental impacts of intensive agricultural systems and represent one of the main ways to increase climate resilience. Diversification of agri-food systems is the use of techniques such as rotation extension, intercropping, multiple cropping, and the establishment of multi-service cover crops. These systems can enhance the general robustness of agricultural production to drought and climate change due to the combination of different crop species and strains. Agro-ecological practices such as crop-livestock integration, trees and intercropping can make cropping systems less vulnerable (Altieri et al., 2015; Frison and Clément 2020), while more diverse cropping systems can be developed through climate-smart approaches that include crop rotation, cover cropping and conservation agriculture practices (Richard et al. 2022). Crop diversification increases the environmental sustainability of crop systems and can potentially serve as a remedy against climate change. Various cropping systems increase water retention capacity and productivity by improving soil structure, increasing soil organic matter content, improving biological activity, and reducing resource competition.

AGROFORESTRY

Environmental distress in rural areas, climate change mitigation, and adaptation necessitate the adoption of integrated sustainable rural development strategies such as climate-smart agroforestry (CSA) practices, which combine trees, crops, and sometimes animals. Overall, CSA applications as a natural resource management technology have the potential to optimize different socio-economic returns, increase and diversify food security, contribute to rural development, maintain environmental services, transform agricultural systems and so on. CSA encompasses practices that aim to increase farmers' profits and resilience, while also improving many environmental parameters, including climate change mitigation and adaptation, biodiversity enhancement, sustainable landscape management, and soil and water conservation (Octavia et al., 2022). Agroforestry is an effective tool for overcoming the challenges associated with sustainable agriculture and a changing climate (Sharma et al., 2023).

CSA practices are a path to mitigation and adaptation of climate change, the greatest challenge of our time. CSA is location specific, incorporating a variety of models based on resource availability, soil, water, plants, and prevailing climate, but common practices include multi-layered systems such as annual and perennial crops under shade, home gardens, silvopastoral systems, living fences, and windbreaks. CSA practices have many benefits in meeting daily needs, increasing the biodiversity of flora and fauna, regulating microclimates, mitigating and adapting to climate change, promoting soil and water conservation and soil health, and improving landscapes (Octavia et al., 2022; Santos et al., 2022).

FAMILY FARMING AND SMALLHOLDER AGRICULTURE

Building the resilience of smallholder agriculture requires new crop technologies, zero tillage, conservation agriculture, laser land leveling, site-specific nutrient management, drought-resistant crops, water management, digital tools, rainwater harvesting, solar energy, and other technologies, as well as science-based practices to prevent productivity declines (Prateek, 2025).

CONSERVATION AGRICULTURE

Conservation agriculture (CA), mulching, crop rotation/intercropping with cereals and legumes, intercropping, and zero or minimum tillage and crop residue management practices are effective methods to achieve climate-smart agriculture goals that preserve soil and water. Conservation agriculture, based on crop rotation, soil cover, and no-till farming, is widely adopted due to its advantages such as maintaining continuous physical cover on the soil surface and minimizing soil disturbance, helping to combat climate change, facilitating crop management, saving energy, costs, and time, and conserving soil and water.

WATER HARVESTING AND IRRIGATION

Water harvesting, a vital strategy, is the method of collecting rainwater runoff from a specific area for various purposes, using it immediately or capturing it in above-ground ponds, tanks, or reservoirs for later use, or storing it in underground cisterns or shallow aquifers. Implementing appropriate rainwater harvesting techniques improves irrigation efficiency, increases resilience to water scarcity, is important for sustainable water management and agricultural productivity in response to climate change

SHORT FOOD SUPPLY CHAIN

The global food system is undergoing significant transformations towards a Short Food Supply Chain, which prioritizes sustainability, local sourcing, and direct producer-consumer relationships, and aims to reduce intermediaries and physical distance between producers and consumers. These supply chains have the potential to increase the profitability of small and medium-sized farms, reshape the food industry, and create more resilient and inclusive food systems to global challenges like climate change (Jia et al., 2024; Ge et al., 2022). As a promoter of sustainable agriculture and a way to build resilience in the food system, practices such as crop diversification in the Short Food Supply Chain increase productivity by reducing risks, improving soil health, and meeting consumer demands, thereby reducing vulnerability to climate-related challenges (Tedesco et al., 2017). Blockchain technology is important for improving transparency and traceability in short supply chains, while the impact of digitalization, including digitization and smart management, for agricultural supply chain security is considerable (Xie and Jin, 2023).

CONCLUSION

Sustainable food production, soil health and greenhouse gas reduction can be achieved by integrating agricultural, biological and technological interventions such as diversified cropping systems, organic fertilization, optimized fertigation, precision nitrogen management, conservation tillage, biofertilizers and digital agriculture. Strengthening local food systems and expanding urban agriculture practices can further enhance environmental and social resilience and a city's capacity for self-sufficiency, ensuring the food system remains resilient in the face of urbanization and climate change challenges. Enhancing the accessibility of precision agriculture technologies and sustainable water management practices will be crucial in developing early warning systems and climate data services, optimizing resource use, and increasing agricultural resilience. By taking an integrated approach, leveraging innovation and strengthening adaptive capacities, the agricultural sector can cope with climate uncertainties, develop more resilient agricultural systems and ensure long-term productivity, food security and sustainability in the face of climate uncertainty and change.

Strengthening the resilience of the food system to climate change requires, first of all, adopting sustainable practices, increasing resource use efficiency, improving agricultural infrastructure, improving water resources management, increasing crop resilience and promoting climate-smart agricultural Technologies. In response to the adverse effects of climate change, climate-smart agricultural practices, utilizing modern biotechnological tools and technologies, and developing climate-resilient crops are vital for the sustainability of all life forms. There is a growing need for innovative approaches to climate-resilient food production systems that prioritize productivity and sustainability to meet food demands while minimizing environmental degradation. Artificial intelligence is revolutionizing agriculture by enabling precise, data-driven input applications that optimize crop growth and reduce waste. Emerging digital technologies like sensors, uncrewed aerial vehicles, GPS-guided systems autonomous monitoring devices, and advanced data analytic offer promising solutions for improving productivity and resource use efficiency while reducing GHG emissions.

REFERENCES

Altieri, M.A., Nicholls, C.I., Henao, A., Lana, M.A. (2015). Agroecology and the design of climate change- resilient farming systems. Agronomy for Sustainable Development 35(3), 869–890.

Ammoniaci, M., Kartsiotis, S.P., Perria, R., Storchi, P. (2021). State of the art of monitoring technologies and data processing for precision viticulture. Agriculture 11(3), 201.

Arif, M., Shamshad, J., Khalid, F., Kuzyakov, Y., Younas, A., Li, L. (2025). Biotechnological and sustainable approaches to climate- resilient agriculture. Journal of Agronomy and Crop Science 211, e70105.

Balaska, V., Adamidou, Z., Vryzas, Z., Gasteratos, A. (2023). Sustainable crop protection via robotics and artificial intelligence solutions. Machines 11, 774.

Benitez-Alfonso, Y., Soanes, B.K., Zimba, S., Sinanaj, B., German, L., sharma, V. et al. (2023). Enhancing Climate Change Resilience in Agricultural Crops. Current Biology 33, R1246–R1261.

Benos, L., Tagarakis, A.C., Dolias, G., and Bochtis, D. (2024). Digital transformation in agriculture: Impacts of the Internet of Things (IoT) on production efficiency and sustainability. Artificial Intelligence Review 57(2), 947–975.

Bernaschi, D., Felici, F.B., Marino, D. (2025). Urban food production and sustainable communities. Encyclopedia of Agriculture and Food Systems, 3rd Edition. Elsevier.

Bhatnagar, S., Chaudhary, R., Sharma, S., Janjhua, Y., Thakur, P., Sharma, P., Keprate, A. (2024). Exploring the dynamics of climate-smart agricultural practices for sustainable resilience in a changing climate. Environmental and Sustainability Indicators 24, 100535.

Bisht, I.S. (2021). Agri-food system dynamics of small-holder hill farming communities of Uttarakhand in north-western India: Socio economic and policy considerations for sustainable development. Agroecology and Sustainable Food Systems 45, 417–449.

Bisht, I.S., Rana, J.C., Ahlawat, S.P. (2020). The future of smallholder farming in India: Some sustainability considerations. Sustainability 12, 3751.

Biswas, A., Maddocks, I., Dhar, T., Dube, L., Dutta, A., Talukder B., Ponnambalam, K. (2024). Guiding sustainable transformations in food systems. Nature Revievs Earth & Environment 5,607–608.

Blanco- Canqui, H., Ruis, S. (2018). No-tillage and soil physical environment. Geoderma 326, 164–200.

Brown, A. (2023). Green Horizons: sustainable practices for a better tomorrow. International Journal of Research and Review Techniques 2 (2), 14–20.

Büyüközkan, G., Uztürk, D. (2024). Integrated design framework for smart agriculture: Bridging the gap between digitalization and sustainability. Journal of Cleaner Production 449, 141572.

Chergui, N., Kechadi, M.T. (2022). Data analytics for crop management: a big data view. Journal of Big Data 9, 123.

Çakmakçı, M.F., Çakmakçı, R. (2023a). Remote Sensing, Artificial Intelligence and Smart Agriculture Technology Trends of the Future. European Journal of Science and Technology. 52, 234-246.

Çakmakçı, S., Çakmakçı, R. (2023b). Quality and nutritional parameters of food in agri-food production systems. Foods 12, 351.

Çakmakçı, R., Salık, M.A., Çakmakçı, S. (2023). Assessment and principles of environmentally sustainable food and agriculture systems. Agriculture 13, 1073.

Debangshi, U., Sadhukhan, A., Dutta, D., Roy, S. (2023). Application of smart farming technologies in sustainable agriculture development: a comprehensive review on present status and future advancements. Int. J. Environ. Clim. Change 13 (11), 3689–3704.

Demestichas, K., Daskalakis, E. (2020). Data lifecycle management in precision agriculture supported by ınformation and communication technology. Agronomy 10 (11), 164.

Dhanaraju, M., Chenniappan, P., Ramalingam, K., Pazhanivelan, S., Kaliaperumal, R. (2022). Smart farming: internet of things (IoT)-based sustainable agriculture. Agriculture 12 (10), 1745.

Driscoll, A.W., Conant, R.T., Marston L.T., Choi, E., Mueller, N.D. (2024). Greenhouse gas emissions from us ırrigation pumping and ımplications for climate- smart ırrigation policy. Nature Communications 15(1), 675.

Duff, H., Hegedus, P.B., Loewen, S., Bass, T., Maxwell, B.D. (2022). Precision agroecology. Sustainability 14, 106.

Erickson, B., Fausti, S.W. (2020). The role of precision agriculture in food security. Agronomy Journal 113, 4455–4462.

Fatima S, Abbas S, Rebi A, Ying Z (2024). Sustainable forestry and environmental impacts: Assessing the economic, environmental, and social benefits of adopting sustainable agricultural practices. Ecological Frontiers 44, 1119–1127.

Fonseca, A., Cruz, J., Fraga, H., Andrade, C., Valente, J., Alves, F., Neto, C., Flores, R., Santos, J.A. (2025). Enhancing climate change impact assessment in viticulture by resolving microclimates European Journal of Agronomy 170, 127740.

Frison, E., Clément, C. (2020). The potential of diversified agroecological systems to deliver healthy outcomes: making the link between agriculture, food systems & health. Food Policy 96, 101851.

Ge, H., Gómez, M., Peters, C. (2022). Modeling and optimizing the beef supply chain in the Northeastern U.S. Agricultural Economics 53,702–718.

Goel, R., Suyal, D.C., Kumar, V., Jain, L., Soni, R. (2018). Stress- tolerant beneficial microbes for sustainable agricultural production." in microorganisms for green revolution: volume 2: microbes for sustainable agro- ecosystem, 141–159. Springer Singapore.

Grover, D., Mishra, A.K., Rani, P., Kalonia, N., Chaudhary, A., Sharma, S. (2024). Soil management in sustainable agriculture: principles and techniques. In Technological Approaches for Climate Smart Agriculture, 41–77. Springer.

Guamán-Rivera, S.A. (2023). Aplicación de tecnologías en la agricultura de precisión mediante evidencia de fuentes científicas. Horizon Nexus Journal 1 (2), 1–13.

Gultekin, R., Kadri, A.V., Görgişen, C., Öztürk, Ö., Yeter, T., Alsan, P. B. (2023). Effect of deficit ırrigation practices on greenhouse gas emissions in drip ırrigation. Scientia Horticulturae 310, 111757.

Hassoun, A., Boukid, F., Pasqualone, A., Bryant, C.J., García, G.G., Parra-López, C. Et al (2022). Emerging trends in the agri-food sector: Digitalisation and shift to plant-based diets. Current Research in Food Science 5, 2261–2269.

Heinz, M., Galetti, V., Holzkämper, A. (2024). How to find alternative crops for climate-resilient regional food production. Agricultural Systems 213, 103793.

Hong C., Zhong, R., Xu, M., He, P., Mo, R., Qin, Y., Shi, D., Chen, X., He, H., Zhang, Q. (2025). Interactions among food systems, climate change, and air pollution: A review. Engineering 44, 215–233.

Idier, H., Dehhaoui, M., Maatala, N., Kadi, K.A.E. (2024). Assessing the impact of precision farming technologies: a literature review. World Journal of Agricultural Science and Technology 24, 161–179.

Islam, N., Rashid, M.M., Pasandideh, F., Ray, B., Moore, S., Kadel, R. (2021). A review of applications and communication technologies for internet of things (IoT) and unmanned aerial vehicle (UAV) based sustainable smart farming. Sustainability 13 (4), 1821.

Islam, Z., Sabiha, N.E., Salim, R. (2022). Integrated environment-smart agricultural practices: A strategy towards climate-resilient agriculture. Economic Analysis and Policy 76, 59–72.

Jayaraman, S., Dang, Y.P., Naorem, A., Page, K.L., Dalal, R.C. (2021). Conservation agriculture as a system to enhance ecosystem services. Agriculture 11(8), 718.

Jia, F., Shahzadi, G., Bourlakis, M., John, A. (2024). Promoting resilient and sustainable food systems: A systematic literature review on short food supply chains. Journal of Cleaner Production 435, 140364.

Keshavarza, M., Sharafi, H. (2023). Scaling up climate-smart regenerative agriculture for the restoration of degraded agroecosystems in developing countries. Sustainable Production and Consumption 38, 159–173.

Khan, Y., Bojnec, S., Daraz, U. (2025). Infrastructure, knowledge and climate resilience technologies enhancing food security: Evidence from Northern Pakistan. Sustainable Futures 10, 100769.

Lepore, F., Ortolani, L., Vergamini, D., Brunori, G. (2025). Digital transformation in agri-food systems: Systemic impacts, disruptive innovations and sustainability. 10.1016/B978-0-443-15976-3.00130-6.

Li, H.-C., Hsiao, Y.H., Chang, C.W., Chen, Y.M., Lin, L.Y. (2021). Agriculture adaptation options for flood ımpacts under climate change—a simulation analysis in the Dajia River Basin. Sustainability 13(13), 7311.

Liu, Y., Ma, X., Shu, L., Hancke, G.P., Abu-Mahfouz, A.M. (2021). From industry 4.0 to agriculture 4.0: current status, enabling technologies, and research challenges. IEEE Transactions on Industrial Informatics 17, 4322–4334.

Mabhaudhi, T., Dirwai, T.L., Taguta, C., Senzanje, A., Abera, W., Govid, A. et al. (2025). Linking weather and climate information services (WCIS) to Climate-Smart Agriculture (CSA) practices. Climate Services 37, 100529.

Marino, D., Barone, A., Marucci, A., Pili, S., and Palmieri, M. (2023). Impact of land use changes on ecosystem services supply: A meta-analysis of the Italian context. Land 12(12), 2173.

Marino, D., Curcio, F., Felici, F.B., Mazzocchi, G. (2024). Toward evidence-based local food policy: An agroecological assessment of urban agriculture in Rome. Land 13(1), 30.

Martos, V., Ahmad, A., Cartujo, P., Ordoñez, J. (2021). Ensuring agricultural sustainability through remote sensing in the era of agriculture 5.0. Applied Sciences 11, 5911.

Michler, J.D., Baylis, K., Arends-Kuenning, M., Mazvimavi, K. (2019). Conservation Agriculture and Climate Resilience. Journal of Environmental Economics and Management 93, 148–169.

Mohammed, S., Raihan, A., Arshad, S., Ata, B., Ocwa A., Al-Dalahmeh, M., Harsanyi, E. (2025). European Union agro-climate policies toward sustainability: Analyzing emission trends and land use dynamics (1990–2021). Resources, Environment and Sustainability 21, 100239.

Mushtaq, M.A, Ateeq, M., Ikram M., Alam S.M., Kaleem, M.M., Ashraf, M.A. et al. (2025). Securing fruit trees future: AI-driven early warning and predictive systems for abiotic stress in changing climate. Plant Stress 17, 100953.

Ngongolo, K., Mmbando, G.S. (2024). Harnessing biotechnology and breeding strategies for climate-resilient agriculture: pathways to sustainable global food security. Discover Sustainability 5, 431.

Octavia, D., Suharti, S., Murniati, Dharmawan, I.W.S., Nugroho, H.Y.S.H., Supriyanto, B. et al. (2022). Mainstreaming smart agroforestry for social forestry implementation to support sustainable development goals in Indonesia: a review. Sustainability 14, 9313.

Pagano, A., Amato, F., Ippolito, M., De Caro, D., Croce, D., Motisi, A., et al., 2023. Machine learning models to predict daily actual evapotranspiration of citrus orchards under regulated deficit irrigation. Ecological Informatics 76, 102133.

Paudel, B., Riaz, S., Teng, S.W., Kolluri, R.R., Sandhu, H. (2025). The digital future of farming: A bibliometric analysis of big data in smart farming research. Cleaner and Circular Bioeconomy 10, 100132.

Prateek, G. (2025). Productivity versus sustainability: paradigms of climate-resilient development in South Asian smallholder agriculture. Current Opinion in Environmental Sustainability 74,101520.

Qu, B., Xiao, Z., Upadhyay, A., Luo, Y. (2024). Perspectives on sustainable food production system: characteristics and green technologies. Journal of Agriculture and Food Research 15, 100988.

Ragazou, K., Garefalakis, A., Zafeiriou, E., Passas, I. (2022). Agriculture 5.0: a new strategic management mode for a cut cost and an energy efficient agriculture sector. Energies 15, 3113

Riaz, K., McAfee, M., Gharbia, S.S. (2023). Management of climate resilience: exploring the potential of digital twin technology, 3d city modelling, and early warning systems. Sensors 23 (5), 2659.

Richard, B., Qi, A., Fitt, B.D. (2022). Control of crop diseases through ıntegrated crop management to deliver climate- smart farming systems for low- and high- ınput crop production. Plant Pathology 71,187–206.

Roy, M. (2025). Harnessing technology and leadership for sustainable agri-food supply chains: advancing circular economy practices. In: Burrell, D.N., Nguyen, C. (Eds.), New Horizons in Leadership: Inclusive Explorations in Health, Technology, and Education. IGI Global Scientific Publishing, pp. 435–474.

Roy, M., Medhekar, A. (2025). Transforming smart farming for sustainability through agri-tech Innovations: Insights from the Australian agricultural landscap. Farming System 3, 100165.

Santos, M., Cajaiba, R.L., Bastos, R., Gonzalez, D., Bakıs, A.L.P., Ferreira, D. et al. (2022). Why do agroforestry systems enhance biodiversity? Evidence from habitat amount hypothesis predictions. Frontiers in Ecology and the Environment 9, 630151.

Shahab, H., Iqbal, M., Sohaib, A., Khan, F.U., Waqas, M. (2024). IoT-based agriculture management techniques for sustainable farming: a comprehensive review. Computers and Electronics in Agriculture 220, 108851.

Sharma, P., Bhardwaj, D.R., Singh, M.K., Nigam, R., Pala, N.A., Kumar, A. et al (2023). Geospatial technology in agroforestry: status, prospects, and constraints. Environmental Science and Pollution. Research 30, 116459–116487.

Singh, K.A., Patra, F., Ghosh, T., Mahnot, N.K., Dutta, H., Duary, R.K. (2025). Advancing food systems with industry 5.0: A systematic review of smart technologies, sustainability, and resource optimization. Sustainable Futures 9, 100694.

Sismani, G., Pisinaras, V., Arampatzis, G. (2024). Water governance for climate- resilient agriculture in mediterranean countries. Water 16(8),1103.

Tantalaki, N., Souravlas, S., Roumeliotis, M. (2019). Data-driven decision making in precision agriculture: the rise of big data in agricultural systems. Journal of Agricultural & Food Information 20(4), 344-380.

Tedesco, C., Petit, C., Billen, G., Garnier, J., Personne, E. (2017). Potential for recoupling production and consumption in peri- urban territories: The case-study of the Saclay plateau near Paris, France. Food Policy 69, 35–45.

Topp, E., Stephan, A., Varela, E., Cicek, H., Plieninger, T. (2024). Mediterranean farmers' understandings of 'good soil management' and 'good farmer' identity in the context of conservation agriculture. International Journal of Agricultural Sustainability 22, 2335083.

Toscano, P., Castrignan`o, A., Di Gennaro, S.F., Vonella, A.V., Ventrella, D., Matese, A. (2019). A precision agriculture approach for durum wheat yield assessment using remote sensing data and yield mapping. Agronomy 9, 437

Tuan, H. (2024). Agricultural practices and climate resilience: case study in vietnam. International Journal of Climatic Studies 3, 24–36.

Usigbe, M.J., Asem-Hiablie, S., Uyeh, D.D., Iyiola, O., Park, T., Mallipeddi, R. (2024). Enhancing resilience in agricultural production systems with AI-based technologies. Environment, Development and Sustainability 26, 21955–21983.

Vahdanjoo M., Sørensen, C.G., Nørremark, M. (2025). Digital transformation of the agri-food system. Current Opinion in Food Science 63,101287.

Wang, L., Garland, G.M., Ge, T., Guo, S., Kebede, E.A. He, C. et al. (2025 b). Integrated strategies for enhancing agrifood productivity, lowering greenhouse gas emissions, and improving soil health. The Innovation 6(11), 101006.

Wang, Y.-J., Wang, N., Huang, G.Q. (2025 a). Driving mechanism for farmers' acceptance of climate-smart agriculture. Journal of Cleaner Production 501, 145299.

Wang, Z., Zhou, M., Liu, H., Huang, C., Ma, Y., Ge, H.X. et al. (2022). Pecan agroforestry systems improve soil quality by stimulating enzyme activity. PeerJ 10, e12663.

Wolfert, S., Ge, L., Verdouw, C., Bogaardt, M.J. (2017). Big data in smart farming – A review. Agricultural Systems 153, 69–80.

Wolz, K.J., Lovell, S.T., Branham, B.E., Eddy, W.C., Keeley, K., Revord, R.S. et al. (2018). Frontiers in alley cropping: transformative solutions for temperate agriculture. Global Change Biology 24 (3), 883–894.

Wong, A.C.S., Massel, K., Lam, Y., Hintzsche, J., Chauhan, B.S. (2022). Biotechnological road map for innovative weed management. Frontiers in Plant Science 13, 887723.

Xie, C., Jin, X. (2023). The role of digitalization, sustainable environment, natural resources and political globalization towards economic well-being in China, Japan and South Korea. Resources Policy 83, 103682.

Xu, Z., Pandey, G.K., Ali, Z., Zhang, D. (2024). Molecular Basis of Stress Resistant Signal Transduction in Plants: A Biotechnological Intervention to Develop Climate- Resilient Crops. Frontiers in Plant Science 15, 1356520.

Zhou, Z., Robinson, G.M., Song, B. (2019). Experimental research on trade- offs in ecosystem services: The agro- ecosystem functional spectrum. Ecological Indicators 106,105536.

Zong, X., Liu, X., Chen, G., Yin, Y. (2022). A deep-understanding framework and assessment indicator system for climate-resilient agriculture. Ecological Indicators 136, 108597.

AGRICULTURE-BASED CIRCULAR BIOECONOMY FOR SUSTAINABLE PRODUCTION, FOOD SECURITY, AND RESOURCE AND ENVIRONMENTAL PROTECTION

Prof. Dr. Ramazan ÇAKMAKÇI

Çanakkale Onsekiz Mart University, Faculty of Agriculture, Department of Field Crops, Çanakkale, Türkiye

ORCID ID: https://orcid.org/0000-0002-1354-1995

Prof. Dr. Songül ÇAKMAKÇI

Atatürk University, Faculty of Agriculture, Department of Food Engineering, Erzurum, Türkiye[2]

ORCID ID: https://orcid.org/0000-0003-0334-5621

ABSTRACT

The circular bioeconomy is a sustainable production and consumption strategy based on limited resources that promotes more sustainable use of resources using the principles of reduction, reuse, recycling, and recovery. Circular economy in food systems means sustainable management of soil, reduction of waste, reuse of food, better utilization of by-products and food waste, development of advanced technologies and processes for the reuse of waste biomass, nutrient recycling and diverse and efficient changes in diets to increase agricultural productivity and ensure food security. Adopting the principles of a circular economy can ensure the preservation of natural capital and the promotion of system efficiency, increase resource efficiency by optimizing resource use, and minimize waste generation and environmental impact. Sustainable and circular economy plays a vital role in the development of agriculture and food production and in mitigating climate change through sustainable practices in the food industry, sustainable food production systems and resilient agricultural practices. The biggest advantages of the circular economy for the food sector are reducing environmental impact and significantly increasing resource efficiency, profitability and sustainability. In this review, opportunities for the security and protection of food systems, sustainable consumption, resilient and diverse ecosystems, sustainable resource management, improvement of soil microbiota structure, recovering and recycling biomass into new production cycles, converting waste into high-quality products, development of optimized microbial inoculants with bioengineering strategies are discussed on the basis of new approaches, innovative interpretations, future possibilities and technologies. This article focuses on new strategies based on bio-based and circular bioeconomy approaches for sustainable management of depleted soils, optimization of renewable resources, plants, all wastes and by-products to improve agricultural sustainability.

Key Word: Circular bioeconomy, Resource efficiency, Microbial inoculants, Resilient agricultural practices, Reuse; Recycling

INTRODUCTION

As a result of rapid population growth and other human activities, a large amount of waste, a significant portion of which is organic, is generated from various sectors, and the waste produced is usually disposed of in an open area, which poses a serious concern and threat to humans, animals and the environment. In the context of developing low-cost and efficient technologies for waste disposal, the production of value-added bioproducts such as bioplastics, biocompost, and organic acids, and the conversion of bioorganic waste into value-added bioproducts, are gaining increasing importance (Ashokkumar et al., 2022). Bioeconomy, which offers the opportunity to use resources more efficiently and environmentally friendly by developing new bio-based industries, involves the use of renewable agricultural waste biomass for the sustainable production of food, feed, paper, energy and industrial goods.

One way to build a more resilient and sustainable future and mitigate climate change is to transition to a bioeconomy that uses renewable biological resources and low-carbon value chains to meet food, energy and material demands (Warchold and Pradhan, 2025). An integral part of the bioeconomy, the circular economy aims to minimize waste and maximize resource efficiency through a continuous material cycle, treating products and resources as capital in constant circulation rather than as waste (Mesa et al., 2024). As a holistic approach that supports sustainable consumption patterns and economic growth through bio-based innovations, CBE contributes to food security and climate change mitigation by replacing fossil resources with biological alternatives and optimizing resource use.

Food safety and security are becoming an increasingly global issue, and the need for environmental efficiency-maximizing output and benefits while minimizing negative environmental impacts-is growing. The circular bioeconomy, which integrates principles from the circular and bioeconomy to enhance sustainability in the food sector, has emerged as a promising strategy (Barra and Falcone, 2024).

The circular bioeconomy approach, which reduces waste and increases energy production and other healthcare products, supports this approach. Circular bioeconomy is an economic strategy that supports sustainable development by using biomass as a carbon feedstock instead of fossil fuels, preserving existing limited resources and thus protecting the environment (Nagarajan et al., 2024). Circular economy is based on the theory of "Reuse-Repair-Renew-Recycle", focusing on the use of outputs of one process as inputs of another process or waste outputs as resources, and focusing on the production from waste of industrial systems, resilience through diversity, use of renewable energy sources (Pomoni et al., 2024). Circular economy is a system that is based on the principle of cyclicity in the agricultural sector, is restorative, regenerative, understandable, and can sustain and develop ecosystem services (Morseletto, 2020). Circular economy aims at resource efficiency and optimization, waste reduction, minimizing waste and maximizing resource use, efficient resource cycling and reuse, and increasing the productivity and resilience of farm families (Pedro et al., 2024; Siankwilimba et al., 2025).

Environmental problems caused by the use of synthetic chemicals can be improved through a circular sustainable bioeconomy model through the valorization of renewable resources such as agricultural waste biomass (Sarangi et al., 2023). Innovation in circular economy approaches promotes waste reduction, increases resource efficiency, improves food availability and sufficiency, creates new revenue streams and encourages the development of value-added products from by-products, contributing to more sustainable growth and food supply chains (Said et al., 2025; Siankwilimba et al., 2025; Nguyen et al., 2025). The biobased economy not only focuses on the sustainable production and use of biological resources, but also on the sustainable production of chemicals, materials, and fuels from biomass, which can help mitigate climate change, reduce negative environmental impacts, and reduce dependence on fossil fuels.

Circular and sustainable agriculture, integrating emerging technologies and supported by nature-based solutions, has the potential to enhance food security, increase soil fertility, mitigate climate impacts, promote environmental resilience, protect biodiversity, reduce pollution, and serve as a critical mechanism for carbon sequestration (Nassary, 2025). In the agricultural sector, extracting resources in a way that does not interfere with the ecosystem's regenerative capacity, preventing waste of food and non-food products, prioritizing human needs, safely reusing and recycling abundant waste, and designing processes that mimic natural flows to reduce energy consumption parameters have been proposed to achieve a circular bioeconomy and sustainable development (Muscat et al., 2021). Recycling is a key component of the circular economy and adds value to existing products and materials by reincorporating surplus materials into the production process to reduce the use of primary products and materials (Pomoni et al., 2024). The second popular and traditional way is the refurbishment of old and used product or products that restores the value of a component. In addition to the careful use of resources and increasing their efficiency, protecting and enhancing natural capital such as air quality, reducing water pollution, and protecting biodiversity is an important part of the circular economy strategy (Pomoni et al., 2024).

Waste biomass from agricultural sources offers promising potential for producing sustainable chemicals and fuels. Biomass to biofuel and bioenergy conversion technologies focus on converting agricultural, industrial and municipal waste into renewable energy, reducing environmental impacts and promoting sustainability (Kag et al., 2024). The use of organic wastes, such as renewable wood, plant and algae biomass, food, kitchen, garden, agricultural and animal waste, which cause environmental problems including air, soil and water pollution, is a reliable approach to ensuring energy security, pollution regulation, process economy, sustainable production and social development. It is critical to effectively manage organic waste to prevent depletion of natural resources, reduce the hazard to human health and environmental burdens, and maintain the overall balance of the ecosystem.

Ecology and food security issues can be addressed with a viable solution through a circular bioeconomy that supports the energy-environment nexus and provides a cleaner and lower carbon footprint. Agricultural, industrial, and even urban waste can all be used to produce biogas, biodiesel, and fertilizer. Agricultural waste, a common source of organic waste, can be used as agricultural land, biogas production, soil erosion prevention, mulching, feed and compost, and provides economic and strategic benefits in the production of a wide variety of products (Pomoni et al., 2024) .Circular economy is a very promising strategy to ensure sustainable development, restoration and renewal of agriculture and contributes to ensuring sufficient and secure food of high nutritional value without the threat of resource depletion and ecosystem destruction.

Artificial intelligence (AI) and machine learning are transforming biomass-to-energy conversion by optimizing processes, resources, and costs through computational simulations and modelling (Al-Othman et al., 2022; Entezari et al., 2023). One of the fundamental perspectives defining Industry 5.0, which focuses on sustainability, waste reduction, and the creation of high-quality, personalized products, is bioeconomy and sustainability, which aims to establish a balance between ecology, industry, and the economy by using biological resources for industrial purposes (Singh et al., 2025). Bioeconomic principles are essential for combating climate change, addressing resource constraints, promoting circular economies, preserving biodiversity, and ensuring sustainable food production (von Braun, 2018; Demir et al., 2019).

BENEFITS OF IMPLEMENTING A CIRCULAR ECONOMY

Circular bioeconomy (CBE) minimizes energy use for product production and extraction of natural resources, and emissions that pollute soil, water, and air, thus creating environmental and natural resource security and economic opportunities. Some of the benefits of the Circular Economy are shown in Figure 1. The circular economy focuses on minimizing the use and waste of resources and food; eliminating, reducing, reusing and recovering waste; recycling outputs; protecting, reproducing and repairing resources, and contributes to the sustainability of the environment, economy and society (McCarthy et al., 2019; Tomic and Schneider, 2020; Sherwood, 2020; Pomoni et al., 2024).

On the other hand, it is to develop biodegradable, renewable and sustainable packaging materials and thus to ensure the preservation, improvement and protection of food quality during transportation, distribution and storage processes. As a promising path for sustainable development, the circular bioeconomy plays a role in developing innovative food products from biological sources, extending product life with biodegradable films and bio-based compounds, and improving food safety through sustainable packaging, increasing plant yields, optimizing resource use, increasing profitability, and creating new revenue streams from waste (Nguyen et al., 2025).

CBE offers sustainable solutions that conserve resources, improve food production processes, increase social well-being, expand food choices, and produce new food products from biobased materials or waste through Biorefineries that convert biomass into energy or other biobased products and the production of bio-based products (Ahmad and Ashraf, 2023; Wu et al., 2023). It has been demonstrated that CBE applications can significantly benefit food systems by increasing food availability and sufficiency at all stages of food supply chains, reducing costs, increasing profitability for food providers, and reducing environmental footprints (Nguyen et al., 2025). A circular food system reduces waste to sub-zero levels and addresses environmental, social and economic challenges, thereby enhancing food safety and security while promoting the environmental, social and economic well-being of all stakeholders involved (Cusenza et al., 2021). CBE improves the environmental performance of the food industry by supporting the efficient use of natural resources, encouraging the development of biobased food products, improving water use efficiency, promoting natural regeneration and assisting natural capital regeneration, and reducing carbon emissions (Arsic et al., 2023; Zabochnicka et al., 2023).

CIRCULAR BIOECONOMY PRACTICES AND SUSTAINABLE FOOD SYSTEMS

Waste from fruits and vegetables can be used as bioenergy, biofuel, animal feed or soil fertilizer (Pettersson et al., 2024). CBE minimizes food waste through resource-efficient biorefinery practices, allowing the recovery of surplus or unsold food biomass and the production of high-value compounds for use in other industries, and can increase profitability by creating new revenue streams and reducing input costs (Gubitosa et al., 2024; Lamine et al., 2024; Gugel et al., 2024). For example, valuable compounds for the pharmaceutical industry such as proline, alpha-linolenic acid and alpha-amyrin can be obtained from citrus residue biomass with CBE technologies (Lamine et al., 2024), banana peel powder can be converted into bioplastic films with a very simple process (Silva et al., 2024), various bioactive compounds can be obtained from broccoli by-products (Vásquez et al., 2024) and plum processing waste can be used to produce biocomposite edible films (Sheikh et al., 2023).

Turning waste into secondary raw materials can completely or partially reduce economic and ecological problems, while underexploited and wasted bioresidues contributes to the recovery of high value-added biosource molecules on the one hand, and the reduction of pollutant effects on the other, thus promoting sustainable development and bioeconomy with a zero-waste integrated approach (Lamine et al., 2024). Crop stover, which constitute a significant portion of agricultural waste, can be converted into biofuels and bio-based chemicals, reducing environmental pollution and contributing to both environmental sustainability and economic growth in the agricultural sector. By adopting circular practices, such as using animal waste as fertilizer or converting it into biogas for energy production, the livestock sector can effectively reduce waste and mitigate its environmental impact, creating a significant resource for climate-smart agriculture.

WASTE-TO-BIOFUEL AND OTHER BIO-BASED PRODUCT CONVERSION TECHNOLOGIES AND WASTE MANAGEMENT STRATEGIES

The concept and strategies of bioeconomy, which align agricultural practices with economic pathways that use and regenerate biological resources more effectively, have become an urgent need. Generally, the bioeconomy mainly uses non-waste biomass, while the circular bioeconomy uses waste from biomass, which increases material cycles and reduces resource depletion and loss of byproducts and waste (Temmes and Peck, 2020; Muscat et al., 2021). Converting biomass into renewable energy products is vital to achieve sustainable development and circular economy goals. Key mechanisms for CBE targets include the production of innovative new food products from biological sources to expand dietary options, extend product life and availability, improve food safety and shelf life, and increase crop yields through biological and organic inputs (Nguyen et al., 2025).

Among the technologies for converting plant and algae-derived materials and the organic part of municipal solid waste into biofuels, options such as ethanol production from waste through hydrolysis and fermentation, biogas production through anaerobic fermentation, and biodiesel production through transesterification have come to the fore (Ashokkumar et al., 2022**).** Advanced pretreatment methods, improving cellulose and hemicellulose availability, appropriate bioreactor design, innovations in biocatalysts, nanotechnology, 'omics technologies' and database systems increase the efficiency of biomass conversion to biofuels and useful bioproducts (Chaudhary et al., 2025). Innovations in biochemical and thermochemical processes and their integration with nanotechnology and artificial intelligence, bioreactor design, advanced biocatalysts, and hybrid systems increase efficiency, reduce energy consumption, and minimize waste.

Combustion, enzymatic hydrolysis, fermentation, gasification, anaerobic digestion, pyrolysis and hydrothermal conversion are some of the commonly used biomass conversion technologies (Chaudhary et al., 2025). A biochemical conversion process, which involves pretreatment and then the use of microbes and their enzymes, is necessary to convert organic biomass into products of higher economic value. Therefore, it is necessary to focus primarily on technical, chemical and biological processes to produce biobased products from biological waste.

Microorganisms could enzymatically convert biomass into various organic substances (Ren et al., 2019), and various phenolic compounds are produced from agricultural industrial wastes through various fermentation/microbial bioconversion strategies (Saeed et al., 2021). With a circular bioeconomy, algae-based biofuels with higher photosynthetic efficiency and the ability to grow in saltwater and wastewater can accelerate the transition to a more sustainable economy due to lower greenhouse gas emissions (Abdullah et al., 2024). The utilization of waste biomass and the production of high-value components are carried out by applying physical, chemical, and biochemical procedures, but the development of integrated biorefinery models is very important, and microbial bioconversion is the most effective method for valorizing lignocellulosic biomass. Various studies targeting productive microbial species, process pathways, and ideal product residues characterize solid-state fermentation as an efficient microbial transformation approach for the utilization of agricultural wastes (Sarangi et al. 2023). However, it is necessary to select and develop criteria for suitable and compatible substrates, strains and optimum process parameters that facilitate the appropriate growth of the relevant microbes for the desired metabolites. A critical aspect of CBE is using biomass as a renewable carbon and energy source in industrial plants known as advanced multi-process biorefineries.

Glycoside hydrolases, polysaccharide lyases, cellobiose dehydrogenases, ligninase, xylanase and other hydrolytic oxidative enzymes produced by microorganisms play an important role in biochemical transformation and are used to produce valuable products by degrading cellulose, hemicellulose and lignin (Vasić et al., 2021). Integration of genetic engineering, synthetic biology, and omics technologies (genomics, proteomics, transcriptomics, and metabolomics) supporting a circular bioeconomy improves crop yields, microbial metabolism, and inhibitor tolerance (Amer and Baidoo, 2021).

CONVERTING DAIRY WASTES INTO AMINO ACID FERTILIZERS AND OTHER BIOBASED PRODUCTS

Climate change, dwindling mineral resources, increasing sustainability requirements and high fertilizer prices are encouraging agriculture to develop new nutrient sources such as dairy waste. The dairy industry generates significant amounts of waste, leading to both environmental and economic challenges. Organic waste generally decomposes quickly and poses a serious threat to the environment and human health. For example, while slaughterhouse waste, manure or untreated sewage sludge poses risks to soil and living beings, whey is the main pollutant from dairy processing industries that can harm the environment due to its high organic content and larger volume. More than twenty human diseases, including asthma, heart attacks, emphysema, malaria, and respiratory allergies, have been identified as being linked to improper solid waste disposal (Ashokkumar et al., 2022)**.** Although not applied directly, milk waste can be used in plant nutrition as a valuable source of macronutrients and biostimulants such as free amino acids and short peptides that support plant growth. Dairy industry wastes are rich in organic salts, proteins, carbohydrates, fatty acids, macronutrients such as nitrogen, phosphorus, and potassium, as well as lactose and soluble vitamins.

Biofertilizers based on free amino acids and peptides can be produced from dairy wastes such as milk sludge, whey and milk wastewater as fertilizers through chemical and enzymatic hydrolysis, improving soil health, increasing crop yields and reducing dependence on synthetic fertilizers; supporting the circular economy by converting dairy waste by-products into valuable inputs for sustainable agriculture (Gil et al., 2024). The main biotechnology applications in the utilization of dairy industry wastes include the production of bioplastics (biofilms), biofertilizers, biofuels, biomass, single-cell proteins, organic acids, bioactive peptides, polysaccharides, and biosurfactants. Turning dairy waste into innovative fertilisers can reduce the need for synthetic fertilisers, waste disposal challenges and environmental pollution, and improve soil health, help mitigate climate change, increase resource efficiency and improve food security (Gil et al., 2024).

ARTIFICIAL INTELLIGENCE IN BIOFUEL AND BIOENERGY PRODUCTION AND MANAGEMENT

In the biofuel and bioenergy industries, artificial intelligence (AI) technologies, including machine learning (ML) and deep learning, are integrated into various stages of biofuel production, from raw material selection to conversion and waste management, improving efficiency and promoting sustainability (Khanal et al., 2023). These technologies improve biofuel production and supply chain management through optimization of biomass-to-bioenergy processes, predictive modelling, real-time monitoring, and simulations of parameter variations (Chaudhary et al., 2025). ML algorithms can model biochemical and thermochemical transformation mechanisms such as anaerobic digestion, pyrolysis, and gasification, increasing bio-oil yield by improving operational parameters (Okolie, 2024), while AI-supported monitoring and control systems enable efficient biofuel production by adapting to variable conditions and optimizing waste management and emissions regulation in biofuel production. Additionally, technologies such as Big Data, IoT, and ML improve bioprocesses by optimizing biomass content, microbial yield, and anaerobic digestion efficiency. AI tools also improve sustainability by enabling real-time optimization of processes, predicting biomass availability and quality, assisting in resource management, and increasing process efficiency, stability, and scalability.

Artificial intelligence (AI), used in circular economy applications such as smart waste bins, waste production models, waste separation robots, waste monitoring and tracking, plastic pyrolysis, resource recovery and smart cities, can reduce costs and distance in waste logistics operations, save time and significantly improve energy conversion processes (Fang et al., 2023). If the design and applications are carried out appropriately, artificial intelligence increases the efficiency and cost-effectiveness in smart city waste management systems (Bilgili et al., 2024).

Integrating circular economy principles supported by digital technologies with information logistics has been shown to enhance sustainability by optimizing information flows, reducing waste, and increasing resource efficiency in supply chains (Roy and Sarker (2025). AI tools also enhance sustainability by enabling real-time optimization of processes, predicting biomass availability and quality, assisting in resource management, and increasing process efficiency, stability, and scalability (Chaudhary et al., 2025).

BYPRODUCTS FROM THE AGRICULTURAL AND FOOD SECTORS

As promising resources for the circular bioeconomy, organic content found in by-products and waste from agriculture and food sectors is an abundant source of bioactive and greener phenolic compounds that can exhibit anti-inflammatory, antioxidant, cardioprotective, anticancer potential and many other important applications (Sarangi et al., 2023). Agricultural wastes can be used to produce a variety of beneficial polyphenols, flavonoids, stilbenes, and lignans. Food waste, consisting of proteins, carbohydrates, lipids and other inorganic elements, can be converted into bioactive compounds such as pigments, antioxidants, polysaccharides and polyphenols, biofuels or bioenergy such as biodiesel, biomethane, biohydrogen and biogas, and bioplastics (Sharma et al., 2021). Agricultural wastes are sources of industrially and pharmaceutically important phenolic compounds belonging to the class of aromatic acids or phenylpropanoids. Indeed, microbial bioconversion, enzymatic hydrolysis, and fermentation have enabled the production of phenolic compounds such as fumaric acid, coumaric acid, vanillin, salicylic acid, vanillic acid, caffeic acid, and sinapic acid (Zulkarnain et al., 2016; Nascimento et al., 2019). Approaches to the utilization of farm waste have enabled the biosynthesis of beneficial compounds used in the food, cosmetics, and pharmaceutical industries, including phenolics, antioxidants, structural polymers, signalling compounds, attractants, and defense response chemicals. Kiwi and strawberry agro-industrial byproducts have been shown to be sources of antioxidant, antimicrobial, and anti-inflammatory properties due to their content of phenolic compounds, vitamins, volatile compounds, minerals, and dietary fiber (Villamil et al., 2021; Chamorro et al., 2022). Lignocellulosic biomass is a preferred resource for producing useful products in the growing circular bioeconomy (Srivastava et al., 2020).

LIMITATIONS

With the increasing demand for biofuels and bio-based chemicals, it can significantly reduce greenhouse gases from fossil fuels but increase agricultural water use and loss of forest areas (Többen et al., 2024). While CBE is often seen as a catalyst for Sustainable Development Goal progress, current practices remain inadequate and demonstrate only a moderate transformational role (Warchold and Pradhan, 2025). Despite advances, biomass conversion has challenges such as feedstock variability, logistics, high processing costs, scaling of technologies, and technical limitations (Singh, et al., 2022). Although enzymatic hydrolysis has many advantages in biochemical transformation, its optimization depends on the type of feedstock and enzymatic efficiency is limited by changes in the source microorganism profiles, which are affected by species, strains and carbon sources (Guo et al., 2023).

CONCLUSION

A circular economy in food systems means reducing waste, reusing food, better utilizing by-products and food waste, nutrient recycling, and diverse and productive changes in diets. The production of bioplastics from renewable and biodegradable resources through circular bioeconomy and technological innovations stands out as an important strategy for sustainability. Combining sustainable agricultural practices, circular bioeconomy and technological innovations is essential to address global challenges related to food security and the use of natural resources. Agriculture, the biomass production sector, has a transformative potential for the bioeconomy, and agricultural waste management based on circular bioeconomic principles can eliminate harmful trends such as waste burning and uncontrolled animal waste disposal, reduce environmental degradation, and contribute to food and health security, rural employment, and agricultural resilience. Circular bioeconomy plays a vital role in protecting natural capital, promoting system efficiency, increasing resource efficiency by optimizing resource use, mitigating climate change, reusing waste biomass and converting it into high-quality products, developing sustainable food production systems and resilient agricultural practices, and reducing waste production and environmental impact.

REFERENCES

Abdullah, M., Ali, Z., Yasin, M.T., Amanat, K., Sarwar, F., Khan, J., Ahmad, K. (2024). Advancements in sustainable production of biofuel by microalgae: recent insights and future directions. Environment Research 262, 119902.

Ahmad, A., Ashraf, S. (2023). Sustainable Food and Feed Sources from Microalgae: Food security and the Circular Bioeconomy. Algal Research 74, 103185.

Al-Othman, A., Tawalbeh, M., Martis, R., Dhou,, S., Orhan, M., Qasim, M., Olabi A.G. (2022). Artificial intelligence and numerical models in hybrid renewable energy systems with fuel cells: Advances and prospects. Energy Conversion and Management 253, 115–154.

Amer B., Baidoo E.E. (2021). Omics-driven biotechnology for industrial applications. Frontiers in Bioengineering and Biotechnology 9, 613307.

Arsic, M., O'Sullivan, C., Wasson, A., Antille, D., Clarke, W. (2023). Beyond waste-to- energy: bioenergy can drive sustainable Australian agriculture by integrating circular economy with net zero ambitions. Detritus 23, 28.

Ashokkumar, V., Flora, G., Venkatkarthick, R., SenthilKannan, K., Kuppam, C. Stephy, G.M et al. (2022). Advanced technologies on the sustainable approaches for conversion of organic waste to valuable bioproducts: Emerging circular bioeconomy perspective. Fuel 324, 124313.

Barra, C., Falcone, P., (2024). Unraveling the impact of economic policy uncertainty on environmental efficiency: how do institutional quality and political orientation matter? Economics and Politics 36 (3), 1450–1490.

Bilgili, F., Önderol, S., Kuşkaya, S., Alnour, M., Hoque, M.E., Balsalobre-Lorente D. (2024). Renewable energy and technology adoption: mitigating CO2 emissions through implementation strategies. Natural Resources Forum, Blackwell Publishing Ltd, Oxford, UK.

Chamorro, F., Carpena, M., Fraga, C.M., Echave, J., Rajoka, M.S.R., Barba, F.J. et al. (2022). Valorization of kiwi agricultural waste and industry by-products by recovering bioactive compounds and applications as food additives: a circular economy model. Food Chemistry 370, 131315.

Chaudhary, A., Rathour, R.K., Solanki, P., Kakkar, P.M., Pathania, S., Walia, A. (2025). Recent technological advancements in biomass conversion to biofuels and bioenergy for circular economy roadmap. Renewable Energy 244 (2025) 122714.

Cusenza, M., Longo, S., Guarino, F., Cellura, M. (2021). Energy and environmental assessment of residual bio-wastes management strategies. Journal of Cleaner Productio 285, 124815.

Demir, K.A., Döven, G., Sezen, B., (2019). Industry 5.0 and human-robot co-working. Procedia Computer Science 158, 688–695.

Entezari, A., Aslani, A., Zahedi, R., Noorollahi, Y. (2023). Artificial intelligence and machine learning in energy systems: A bibliographic perspective. Energy Strategy Reviews 45, 101017.

Fang, B., Yu, J., Chen, Z., Osman, A.I., Farghali, M., Ihara, I. et al. (2023). Artificial intelligence for waste management in smart cities: a review, Environmental Chemistry Letters, 21,1959–1989.

Gil, F., Taf, R., Mikula, K., Skrzypczak, D., Izydorczyk, G., Moustakas, K. et al. (2024). Advancing sustainable agriculture: Converting dairy wastes into amino acid fertilizers. Sustainable Chemistry and Pharmacy 42, 101782.

Gubitosa, J., Rizzi, V., Fini, P., Nuzzo, S., Cosma, P. (2024). Kiwi peel waste as a recyclable adsorbent to remove textile dyes from water: Direct Blue 78 removal and recovery. Physical Chemistry Chemical Physics 26 (13), 9891–9905.

Gugel, I., Vahidinasab, M., Benatto Perino, E.H., Hiller, E., Marchetti, F., Costa, S. et al. (2024). Fed-batch bioreactor cultivation of Bacillus subtilis using vegetable juice as an alternative carbon source for lipopeptides production: A shift towards a circular bioeconomy. Fermentation 10 (6), 323.

Guo, H., Zhao, Y., Chang, J.S., Lee, D.J. (2023). Enzymes and enzymatic mechanisms in enzymatic degradation of lignocellulosic biomass: a mini-review. Bioresource Technology 367, 128252.

Kag, S., Kukreti, N., Kumar, P., Kataria, R. (2024). Bioeconomy for sustainable bioenergy and biofuel generation, in: Bioeconomy for Sustainability, Springer Nature Singapore, Singapore, pp. 83–105.

Khanal, S.K., Tarafdar, A., You, S. (2023). Artificial intelligence and machine learning for smart bioprocesses. Bioresource Technology 375, 128826.

Lamine, M., Hamdi, Z., Zemni, H., Rahali, F., Melki, I., Mliki, A., Gargouri, M. (2024). From residue to resource: the recovery of high-added values compounds through an integral green valorization of citrus residual biomass. Sustainable Chemistry and Pharmacy 37, 101379.

McCarthy, B., Kapetanaki, A.B., Wang, P. (2019). Circular agri-food approaches: will consumers buy novel products made from vegetable waste? Rural Society 28 (2), 91–107.

Mesa, J.A., Sierra-Fontalvo, L., Ortegon, K., Gonzalez-Quiroga, A. (2024). Advancing cir- cular bioeconomy: a critical review and assessment of indicators. Sustainable Production and Consumption 46, 324–342.

Morseletto, P. (2020). Restorative and regenerative: Exploring the concepts in the circular economy. Journal of Industrial Ecology 24 (4), 763–773.

Muscat, A., de Olde, E.M., Ripoll-Bosch, R., Van Zanten, H.H.E., Metze, T.A.P. et al. (2021). Principles, drivers and opportunities of a circular bioeconomy. Nature Food 2, 561–566.

Nagarajan, D., Chen, C.-W., Ponnusamy, V.K., Dong, C.-D., Lee, D.-J. Chang, J.-S. (2024). Sustainable aquaculture and seafood production using microalgal technology - A circular bioeconomy perspective. Chemosphere 366, 143502.

Nascimento, T.A.d, Furtado, M.d.S.C., Pereira, W.C., Barberena, F.F.V.A. (2019). *Vanilla bahiana* Hoehne (Orchidaceae): studies on fruit development and new perspectives into crop improvement for the *Vanilla planifolia* group. Biota Neotropica 19 (3), e20180696.

Nassary, E.K. (2025). Exploring the role of nature-based solutions and emerging technologies in advancing circular and sustainable agriculture: An opinionated review for environmental resilience. Cleaner and Circular Bioeconomy 10, 100142.

Nguyen, T.H., Wang, X., Utomo, D., Gage, E., Xu, B. (2025). Circular bioeconomy and sustainable food systems: What are the possible mechanisms?. Cleaner and Circular Bioeconomy 11, 100145.

Okolie J.A. (2024). Introduction of Machine Learning and artificial intelligence in biofuel technology. Current Opinion Green and Sustainable. Chemistry 47, 100928.

Pedro, A.C., Maciel, G.M., Lima, N.P., Lima, N.F., Ribeiro, I.S., Pinheiro, D.F., Haminiuk C.W. I. (2024). Valorization of bioactive compounds from juice industry waste: Applications, challenges, and future prospects. Trends in Food Science & Technology 152(2),104693.

Pettersson, S., Asplund, T., Ostwald, M. (2024). Circumstantial factors and local collaboration determine farmers' perceptions and practices on circular bioeconomy – examples from Southern Sweden. Cleaner and Circular Bioeconomy 9,100114.

Pomoni, D.I., Koukou, M.K., Vrachopoulosa, M.Gr. Vasiliadis, L. (2024). Circular economy: A multilevel approach for natural resources and wastes under an agri-food perspective. Water-Energy Nexus 7, 103–123.

Ren, J., Jiang, N., Shang, K., Lu, N., Li, J., Wu, Y. (2019). Synergistic degradation of trans- ferulic acid by water falling film DBD plasma coupled with cobalt oxyhydroxide: performance and mechanisms. Chemical Engineering Journal 172, 321–331.

Roy, M., Sarker, J. (2025). Integration of circular economy principles within information logistics: case study of Australia. In: Burrell, D.N. (Ed.), Organizational Readiness and Research: Security, Management, and Decision Making. IGI Global Scientific Publishing, pp. 449–490.

Saeed, S., Baig, U.U.R., Tayyab, M., Altaf, I., Irfan, M., Raza, S.Q. et al. (2021). Valorization of banana peels waste into biovanillin and optimization of process parameters using submerged fermentation. Biocatalysis and Agricultural Biotechnology 36, 102154.

Said, Z., Vigneshwaran, P., Shaik, S., Rauf, A., Ahmad, Z. (2025). Climate and carbon policy pathways for sustainable food systems. Environmental and Sustainability Indicators 27, 100730.

Sarangi, P.K., Vivekanand, V., Mohanakrishna, G., Pattnaik, B., Muddapur, U.M., Aminabhavi, T.M. (2023). Production of bioactive phenolic compounds from agricultural by-products towards bioeconomic perspectives. Journal of Cleaner Production 414, 137460.

Sharma, P., Gaur, V., Sirohi, R., Varjani, S., Kim, S., Wong, J. (2021). Sustainable processing of food waste for production of bio-based products for circular bioeconomy. Bioresource Technology 325, 124684.

Sheikh, M.A., Saini, C.S., Sharma, H.K. (2023). Harnessing plum (*Prunus domestica* L.) processing wastes for the fabrication of bio-composite edible films: an attempt towards a food circular bioeconomy. Food Hydrocolloids 142,108790.

Sherwood, J. (2020). The significance of biomass in a circular economy. Bioresource Technology 300,122755.

Siankwilimba, E., Hogue, M.E., Gaspari, F., Harmayanti, A., Gunawan, P., Hang'ombe. B.M. (2025). Exploring agricultural circular economy models in emerging bioecosystems: Opportunities and challenges. Sustainable Futures 9, 100723.

Silva, R., Pacheco, T.F., de Santi, A.D., Manarelli, F., Bozzo, B.R., Brienzo, M., Azeredo, H. (2024). From bulk banana peels to active materials: slipping into bioplastic films with high UV-blocking and antioxidant properties. Journal of Cleaner Production 438, 140709.

Singh, A., Prajapati, P., Vyas, S., Gaur, V.K., Sindhu, R. Binod, P. et al. (2022). A comprehensive review of feedstocks as sustainable substrates for next-generation biofuels. BioEnergy Research 16, 105–122.

Singh, K.A., Patra, F., Ghosh, T., Mahnot, N.K., Dutta, H., Duary, R.K. (2025). Advancing food systems with industry 5.0: A systematic review of smart technologies, sustainability, and resource optimization. Sustainable Futures 9, 100694.

Srivastava, R.K., Shetti, N.P., Reddy, K.R., Aminabhavi, T.M. (2020). Sustainable energy from waste organic matters via efficient microbial processes. Science of the Total Environment 722, 137927.

Temmes, A., Peck, P. (2020). Do forest biorefineries fit with working principles of a circular bioeconomy? A case of Finnish and Swedish initiatives. Forest Policy and Economics 110, 101896.

Többen, J., Stöver, B., Reuschel, S., Distelkamp, M., Lutz, C. (2024). Sustainability impli- cations of the EU's bioeconomy transition along global supply chains. Journal of Cleaner Production 461, 142565.

Tomic, T., Schneider, D.R. (2020). Circular economy in waste management– Socio economic effect of changes in waste management system structure. Journal of Environmental Management 267,110564.

Vasić, K., Knez, Ž, Leitgeb, M. (2021). Bioethanol roduction by Enzymatic Hydrolysis from Different Lignocellulosic Sources. Molecules 26(3), 753.

Vásquez, L.M.Q., Muñoz, A.D.P.Z., Martínez, D.H.F. (2024). Identification of knowledge and technologies for postharvest use of broccoli (*Brassica oleracea* var. *italica*) and its by-products: A scientometric analysis. Ciencia y Tecnología Agropecuaria 25 (2), e3343.

Villamil, G.E., Van de, V.F., Piagentini, A.M. (2021). Strawberry agro-industrial by- products as a source of bioactive compounds: effect of cultivar on the phenolic profile and the antioxidant capacity. Bioresources and Bioprocessing 8, 61.

von Braun, J. (2018). Bioeconomy–The global trend and its implications for sustainability and food security, Global Food Security 19, 81–83.

Warchold, A., Pradhan, P. (2025). Bioeconomy and sustainable development goals: How do their interactions matter?. Geography and Sustainability 6, 100293.

Wu, B., Lin, R., Bose, A., Huerta, J., Kang, X., Deng, C., Murphy, J. (2023). Economic and environmental viability of biofuel production from organic wastes: A pathway towards competitive carbon neutrality. Energy 285, 129322.

Zabochnicka, M., Wolny, L., Zawieja, I., Sanchez, F. (2023). Biogas production from waste food as an element of circular bioeconomy in the context of water protection. Desalination and Water Treatment 301, 289–295.

Zulkarnain, A., Bahrin, E.K., Ramli, N., Phang, L.Y., Abd-Aziz, S. (2016). Alkaline hydrolysate of oil palm empty fruit bunch as potential substrate for biovanillin production via two-step bioconversion. Waste Biomass Valorization 9 (1), 13–23.

ANALYSIS OF MEAT PRODUCTS SOLD IN KAYSERI PROVINCE FOR ADULTERATION USING MOLECULAR AND HISTOLOGICAL METHODS

This study was supported by the Erciyes University Scientific Research Projects Unit under project code TYL-2024-13941.

KAYSERİ İLİNDE SATIŞA SUNULAN ET ÜRÜNLERİNİN TAĞŞİŞ YÖNÜNDEN MOLEKÜLER VE HİSTOLOJİK YÖNTEMLERLE ANALİZİ

Bu çalışma; Erciyes Üniversitesi Bilimsel Araştırma Projeleri Birimi tarafından TYL-2024-13941 kodlu proje ile desteklenmiştir.

Rumeysa Nur KARAKUŞ

Erciyes University, Institue of Health Sciences Department of Veterinary Food Hygiene and Technology, Kayseri, Turkiye

ORCID ID: https://orcid.org/0009-0000-8966-6105

Nurhan ERTAŞ ONMAZ

Erciyes University, Faculty of Veterinary Medicine, Department of Veterinary Public Health, Kayseri, Turkiye

ORCID ID: https://orcid.org/0000-0002-4679-6548

Emel ALAN

Erciyes University, Faculty of Veterinary Medicine, Department of Histology and Embryology, Kayseri, Turkiye

ABSTRACT

Introduction and Purpose: Adulteration is a practice that compromises the naturalness and reliability of food, posing a threat to human health. It occurs through the alteration of food components, substitution with other substances, or the reduction of quality. It is generally carried out for economic gain and adversely affects both the nutritional value and consumer health. In this study, it was aimed to determine species- and tissue-based adulteration in meat products offered for sale in butcher shops and delicatessens in the province of Kayseri.

Materials and Methods: In this study, adulteration practices in meat products sold in butcher shops and delicatessens in Kayseri Province were investigated, particularly the presence of unspecified animal species and undesirable tissues such as hair, skin, liver, cartilage, and bone. Within this scope, a total of 15 randomly selected establishments were visited in groups of five at different dates between January and March 2025, and a total of 109 samples were evaluated using PCR and histological analyses.

Results: According to the PCR results, cattle DNA was detected in 108 out of 109 samples (99%), while sheep or buffalo DNA was found in only 6% of the samples. No DNA belonging to horse, donkey, pig, or goat was detected in any of the samples. Histological analysis of sausage samples revealed 80% fat, 77% nerve/tendon tissue, 16% cartilage, and 5% bone tissue, with kidney and uterus tissues also observed in some samples. In salami samples, 73% fat and 18% cartilage tissue were identified, while nerve tissue was detected at low levels. In frankfurter samples, 50% fat and 67% nerve tissue were determined, with no cartilage observed. In minced meat samples, 75% fat and 50% nerve tissue were detected, whereas in meatball samples 58% fat, 88% nerve/tendon tissue, 8% cartilage, and 4% bone with lymphoid tissue were identified.

Discussion and Conclusion: In this study, although the rate of species-level adulteration in the analyzed samples was found to be low, tissue-level adulteration was widespread and negatively affected product quality. It is considered that the increased effectiveness of official inspections in recent years, public awareness activities, and the deterrent effect of imposed penalties have played an important role in the low rates of species-level adulteration. Therefore, the combined use of PCR and histological methods stands out as an effective control approach for both label accuracy and quality assessment. It is recommended that legislation be more strictly enforced and that molecular techniques be integrated into routine inspections.

KeyWords:
Meat Products, Adulteration, PCR, Histological Analysis, Molecular Analysis

ÖZET

Giriş ve Amaç: Tağşiş, gıdanın doğallığını ve güvenilirliğini bozan, insan sağlığını tehdit eden bir uygulamadır. Gıdanın bileşenlerinin değiştirilmesi, başka maddelerle ikame edilmesi veya kalitesinin düşürülmesiyle ortaya çıkar. Genellikle ekonomik kazanç amacıyla yapılır ve hem besin değerini hem de tüketici sağlığını olumsuz etkiler.Bu çalışmada, Kayseri ilindeki kasap ve şarküteri işletmelerinde satışa sunulan et ürünlerinde tür ve doku bazlı tağşişin belirlenmesi amaçlanmıştır.

Gereç ve Yöntem: Çalışmada, Kayseri ilindeki kasap ve şarküteri işletmelerinde satılan et ürünlerinde tür belirtilmeyen hayvanlara ait et ve kıl, deri, karaciğer, kıkırdak, kemik gibi istenmeyen doku varlıklarını içeren tağşiş uygulamaları araştırılmıştır. Bu kapsamda, Ocak–Mart 2025 tarihleri arasında rastgele seçilen toplam 15 işletme, farklı tarihlerde beşerli gruplar halinde ziyaret edilmiş ve toplam 109 örnek PCR ve histoljik analizler ile değerlendirildi.

Bulgular: PCR sonuçlarına göre, 109 örneğin 108'inde (%99) sığır DNA'sı tespit edilmiştir; koyun veya manda DNA'sı ise yalnızca %6 oranındaki örneklerde bulunmuştur. At, eşek, domuz ve keçiye ait DNA'ya ise hiçbir örnekte rastlanmamıştır. Sucuk örneklerinin histolojik analizinde %80 yağ, %77 sinir/tendon dokusu, %16 kıkırdak ve %5 kemik dokusu tespit edilmiştir; bazı örneklerde böbrek ve uterus dokusu da gözlenmiştir. Salam örneklerinde %73 yağ ve %18 kıkırdak dokusu bulunmuş; sinir dokusu düşük seviyelerde tespit edilmiştir. Sosis örneklerinde %50 yağ ve %67 sinir dokusu belirlenmiş, kıkırdak dokusuna rastlanmamıştır. Kıyma örneklerinde %75 yağ ve %50 sinir dokusu; köfte örneklerinde ise %58 yağ, %88 sinir/tendon, %8 kıkırdak ve %4 kemik ile lenfoid doku tespit edilmiştir.

Tartışma ve Sonuç: Çalışmada, analiz edilen örneklerde tür düzeyinde tağşiş oranı düşük bulunmasına rağmen, doku düzeyinde tağşiş yaygın olup ürün kalitesini olumsuz etkilemektedir. Tür düzeyindeki düşük tağşiş oranlarında, son yıllarda artırılan etkin resmî denetimlerin, kamuoyuna yönelik bilgilendirme faaliyetlerinin ve uygulanan cezai yaptırımların caydırıcı etkisinin önemli rol oynadığı değerlendirilmektedir. Bu nedenle, PCR ve histolojik yöntemlerin birlikte kullanımı hem etiket doğruluğu hem de kalite kontrol açısından etkili bir denetim yaklaşımı olarak öne çıkmaktadır. Mevzuatın daha sıkı uygulanması ve moleküler tekniklerin rutin denetimlere entegre edilmesi önerilmektedir.

Anahtar Kelimeler: Et Ürünleri, Tağşiş, PCR, Histolojik Analiz, Moleküler Analiz

ISOLATION OF SAHARAN ACTINOBACTERIA FOR BIOLOGICAL CONTROL AGAINST PHYTOPATHOGENS: TOWARDS SUSTAINABLE AGRICULTURE

Fedwa BEGHDADI

Laboratory of Molecular Biology, Genomics and Bioinformatics (LBMGB), Faculty of Natural Sciences and Life (SNV), Hassiba Benbouali University of Chlef, Hay Salem, 02000 Chlef, Algeria.

El-Hadj DRICHE

Laboratory of Molecular Biology, Genomics and Bioinformatics (LBMGB), Faculty of Natural Sciences and Life (SNV), Hassiba Benbouali University of Chlef, Hay Salem, 02000 Chlef, Algeria.

Abstract:

Throughout their lives, plants interact with various organisms, which can negatively or positively impact their health, leading to significant agricultural losses. Biological control, particularly through the use of antagonistic actinomycetes, represents a promising method to combat these phytopathogens. Therefore, this study aims to screen new strains of actinomycetes isolated from Saharan soil, which produce bioactive molecules that inhibit some phytopathogenic agents.

For the isolation of Saharan actinomycetes, several soil samples were collected from various oases in Algeria. These samples were treated using the CaCO3 method and subjected to a series of decimal dilutions, and subsequently inoculated onto the CHV medium with or without selective agents, with incubation carried out at 30°C for 21 days. The antimicrobial activity of actinomycetes against these pathogens was assessed using the cross streaking method on ISP2 and YGB mediums. Incubation was done at 30°C for 24 hours for bacteria and up to 3 days for fungi (Aouiche et al 2013).

This method of isolation among us has resulted in obtaining a significant number of actinomycete isolates with the potential to inhibit phytopathogenic bacteria and fungi, with the inhibition diameter reaching up to 40mm for some strains on the solid YGB medium.

The intensity of the variable activity largely depends on the type or group to which the strains belong. These variations in the number of activities are due to the fact that a strain of actinobacteria can produce several antimicrobial molecules with different modes of action depending on the composition of the culture medium (Berdy, 2005 and 2012).

In view of the results obtained, we can consider that our actinomycete isolates have the ability to inhibit certain phytopathogenic agents. The production, extraction, and characterization of these bioactive molecules is the subject of our current research.

Keywords: Actinomycetes, Bioactive molecules, Phytopathogenic agents, Biological control.

HEALTH AND FUNCTIONAL IMPLICATIONS OF SORGHUM IRRIGATED WITH TRICKLING FILTER-TREATED WASTEWATER IN SEMI-ARID NORTH AFRICA

Ahmed Osmane

Laboratory of Organic Chemistry and Physical Chemistry (Fundamental and Applied Chemistry)Faculty of Sciences, Agadir University Ibn Zohr

Laboratory of Biomolecular and Medicinal Chemistry, Faculty of Science Semlalia, University Cadi Ayyad, Marrakech, Morocco.

ORCID ID: https://orcid.org/0000-0003-0246-2885

Khadija Zidan

National Center for Studies and Research on Water and Energy (CNEREE), Cadi Ayyad University, Marrakech, Morocco.

Laboratory of Water, Biodiversity and Climate Change, Faculty of Sciences Semlalia, Cadi Ayyad University, Marrakech, Morocco

ORCID ID: https://orcid.org/0000-0003-3466-2323

Moustapha Belmouden

Laboratory of Organic Chemistry and Physical Chemistry (Fundamental and Applied Chemistry)Faculty of Sciences, Agadir University Ibn Zohr

ORCID ID: https://orcid.org /0000-0002-3083-2620

Abstract

sorghum one of the most commonly cultivated and consumed cereals throughout the world. Though phytochemicals and antioxidants in the cereal grains have not been studied as in fruits and vegetables, given the role of wheat in our diet plate, it is a given of primary importance to understand the chemistry of our major food of sorghum. The presence of diverse polyphenols and their action against leading cause of death, including heart diseases, cancer, obesity, and diabetes, widens the scope ofsorghum . Phytochemicals such as phenolic acids, alkylresorcinols, flavonoids, phytosterols, and carotenoids are present in whole wheat. The majority of phytochemicals are located in the wheat bran/germ fraction, and they are the leading contributors to the health promoting activities. However, the presence of anti-nutrients and binding of phenolic acids with protein may have adverse effect on health. This review mainly focuses on studies that have been carried out in the past decade to present, emphasizing the importance of and whole sorghum based products in preventing major diseases and disease conditions, potentials threats, current lacks, and future prospects.Deficiencies of micronutrients such as iron, zinc, and vitamin A (“hidden hunger”) afflict over three billion people. Currently there is an increasing preference among consumers for foods that contain not only traditional nutrients but also provide other compounds that are beneficial to health and well-being. Food systems that feed the world must be changed in ways that will insure that balanced nutrient supplies are available continuously to all people in adequate, affordable amounts. This paper reviews about the most important wheat grain components and their nutritional value. The opportunities of plant breeding and other technologies to improve the nutritional quality of sorghum are also discussed.Sweet sorghum (*Sorghum bicolor*) is a highly adaptable sugar crop with significant potential for bioenergy and ethanol production. Notably resilient, it thrives under marginal growing conditions, including water deficits, waterlogging, salinity, and alkalinity. Its key advantage is a high ethanol yield potential of up to 6000 L ha^{-1}, offering an energy output more than three times greater than the input invested.This crop exhibits considerable genetic diversity, with reported variations in crucial traits such as Brix (13-24%), juice sucrose concentration (7.2-15.5%), total stalk sugar yield (up to 12 Mg ha^{-1}), fresh stalk yield (24-120 Mg ha^{-1}), and total biomass yield (36-140 t ha^{-1}), indicating strong potential for further agronomic improvement.Despite its promise, the transition of sweet sorghum to a large-scale bioenergy crop faces challenges. The primary constraints are the lack of adequate technology for the harvest, transport, and storage of its vast quantities of biomass and juice, particularly within a short harvest window. Furthermore, while ethanol conversion can be achieved either by fermenting expressed stem juice or directly fermenting chopped stalks, the integration of sweet sorghum processing into existing corn ethanol infrastructure has not yet been realized.

Keywords: sorghum; bioenergy crop; ethanol; biomass yield; sugar; fermentation

Introduction

Sweet sorghum is a widely adapted sugar crop with potential for bio-energy production. Sweet sorghum was introduced to the United States in the 1850s for syrup production [1]. Production peaked at about 136 million L yr^{-1} of syrup in 1946, substituting for sugar during World War II [2]. Sweet sorghum production declined steadily after the war because of low sugar prices coupled with inadequate advancement in harvesting and processing technology. Sweet sorghum is now of interest for ethanol production to be mixed with gasoline or to produce ethyl *tert*-butyl ether (E*T*BE), an octane additive to gasoline.

Sweet sorghum is often competitive with corn (*Zea mays* L.) and grain sorghum for ethanol yield when grain yield is less than 9 Mg ha^{-1}, and for water and nitrogen use efficiency [3]. Sweet sorghum can easily substitute for corn or grain sorghum in many annual cropping systems while adding to crop diversity.

Currently most ethanol produced in the US is from corn grain with federal subsidies. Energy gains with production of ethanol from grain are modest typically ranging from 30 to 80%, depending partly on the efficiency of use of the distillers grain co-product. Sweet sorghum can be produced at less cost than corn with higher energy gains [3]. Rather than producing starch, sweet sorghum carbohydrates are stored in the stalk as sugar with sugar concentrations of 12-20% [4]. Sweet sorghum has the potential to produce up to 6000 L ha^{-1} of ethanol [2], equivalent to corn grain yields of approximately 20 Mg ha^{-1}. Sweet sorghum can yield more ethanol per unit area of land than many other common energy crops including corn (Table 1)

Table 1. Crop and ethanol yield of sweet sorghum compared to major potential energy crops (after Kersenbrock, [57]).

Crop	Crop Yield (Mg ha^{-1})	Ethanol Yield (L ha^{-1})
Sugar cane	12.5*	5860
Sweet sorghum	7.60*	3560
Sugar Beets	7.10*	3300
Corn (grain)	5.70	2220
Grain Sorghum (Grain)	3.70	1370
Wheat (grain)	2.00	790

*Yield is given in tones of fermentable sugars per hectare which is roughly 16% of the fresh plant weight

Seasonal availability, the need to transport and maybe store much mass, and storability of sweet sorghum constrain sweet sorghum as a bio-energy crop.

Sweet Sorghum Production

The agronomic principles and production practices for sweet sorghum and grain sorghum are similar [2]. Sweet sorghum can produce grain as well as sugar. Reddy et al.

[5] reported much diversity among sweet sorghum genotypes with ranges in India of 13 to 24% for Brix (a measure of sugar and soluble starch in plant sap based on light refraction; a typical Brix measure for sweet sorghum sap is 85% sugar and 15% soluble starch), 7.2 to 15.5% for sucrose concentration in juice, 24 to 120 Mg ha^{-1} for fresh stalk yield, 36 to 140 t ha^{-1} fresh biomass yield, and 27.1 to 47.6 Mg ha^{-1} mill-ready stalk yield. Plant height can be as tall as 480 cm [6] and stalks can be more than 45 mm thick [7].

Sweet sorghum is relatively well-adapted compared with corn to marginal growing conditions such as water deficit stress, water logging, salinity, alkalinity, and other edaphic constraints but yields are typically highest in deep, well-drained soils with good fertility. This adaptability and resilience often makes sweet sorghum more suited for biofuel than corn. After harvesting, the stalks of most cultivars can ratoon to produce another crop under suitable environments although ratoon yields are typically less than with first harvest.

Planting date and length of growing period

A base temperature of 13ºC has been used for calculating sweet sorghum growing degree days and thermal time [8,9]. Lueschen et al. [10] reported that rapid emergence and vigorous seedling growth occurs when soil temperature is above 18ºC at planting and that planting for mid-to-late September harvest maximized stalk Brix values in the upper Midwest.

Sugar yield is generally favored by earlier planting. Early planting increased yield significantly [8] and yield increased with increased radiation during the reproductive stage of the crop. Ricaud and Arenneaux [11] reported mean stalk yields across several cultivars in Louisiana to be 56 and 49 Mg ha^{-1} with 26 Apr and 25 May planting, respectively. Yield of stalk sugar in excess of 10 Mg ha^{-1} was observed for early sown crops and the sugar yield dropped to 3 Mg ha^{-1} for late planted crops [8]. Juice yield was not affected by planting date in Mississippi but sugar yield was highest for early May planting [12] and similar for April and June planting [13]. Stalk and sugar yields were significantly depressed by delaying planting to mid June. In another study, delayed planting reduced dry matter yield but had little effect on Brix and sap content [10]. They found 13% higher fermentable carbohydrate and ethanol yields from earlier compared with later planting dates and recommended early planting of late-maturing sweet sorghum cultivars, despite the problem of lodging, for high sugar yields in the upper Midwest.

Sugar concentration of sweet sorghum increased as a function of the duration of growth and generally decreased with delayed planting irrespective of sampling stage [14, 15]. Planting date can influence sugar yield by (i) altering phenology and development time since the rate of sugar accumulation is nearly constant and (ii) by the amount of radiation received during early reproductive growth, especially for genotypes with long pre-anthesis growth periods. Concentration and accumulation of sugars were near linear functions of either time of growth or the total radiation received. Long season, tall and thick stalk sweet sorghum cultivars were reported to be best for production of highly recoverable concentrated sugars [14, 15]. Total intercepted radiation bracketing the growth stages of boot and early seed formation accounted for 75% of the variation in sweet sorghum yield [16].

Plant population and stand establishment

Uniform seedling emergence and stand establishment is important but relatively difficult to achieve for sweet sorghum because of small seed size and often low germination rate compared to grain sorghum, especially with constraints such as soil crusting, limited soil water after planting, uneven planting depth, weed competition, and insect pests. Poor stand establishment in sweet sorghum can lead to slow early growth. Agronomic management enhancing emergence and seedling establishment is critical.

Sorghum has vigorous growth and is aggressively competitive after the fifth leaf stage.

In Turkey, biomass yield was more with 15 plants m^{-2} than with lower plant populations when sweet sorghum was planted in 65-cm rows [17]. Lueschen et al. [10] did not find an effect of seeding rate on sweet sorghum fermentable carbohydrate or ethanol yield. Ferraris and Charles-Edwards [8] found plant density effects on sugar concentration to be slight. Others, however, found a drop in Brix, sucrose content, sugar yield, and juice content with increased plant density [18, 19]. The stalk and water soluble carbohydrate yield of sweet sorghum with 8 and 16 plants m^{-2} was increased as row spacing decreased from 105 to 35 cm [20]. Stalk and water soluble carbohydrate yield were greater with 16 compared with 8 plants m^{-2}. The benefit with 35-cm rows was attributed to greater photosynthetic productivity before anthesis resulting in higher yield at anthesis and the production of taller, thicker stalks, the volume of which was closely

related to post-anthesis carbohydrate accumulation. Broadhead and Freeman [18] reported increased stalk yield and Brix by growing sweet sorghum in 52.5 cm rows compared with wider row spacing but plants in wider rows weighed more and had more juice and less lodging. However, Freeman and Broadhead [6] reported results from Mississippi that indicated as much stalk and sugar yield with 76-cm compared with narrower row spacing, but reduced yield with 105-cm row spacing.

1.1 *Resource use efficiency*

Geng et al. [15] reported sweet sorghum root growth and extraction of available water to 270 cm depth under water deficit conditions with less yield loss compared to corn, sugarbeet, and fodderbeet. Reddy et al. [21] found that sweet sorghum requires 310 compared to 370 kg water kg^{-1} dry matter for corn. When fertilized and irrigated adequately, sweet sorghum produced 10.0 Mg hexose ha^{-1} compared to 8.15 for corn [15]. Under water deficit conditions, sweet sorghum extracted more soil water and had 29% more hexose yield compared with corn. Smith and Buxton [3] found that total sugar and ethanol yield were similar under non-irrigated and irrigated conditions even though total biomass yield was increased with irrigation.

Response to applied nutrients varies with location. Biomass yield was increased in Louisiana by 40% by applying 100 kg ha^{-1} N with no further increase with an additional 100 kg ha^{-1} N but an additional 10% increase with addition of 90 kg ha^{-1} K [11]. Total sugar yield was increased by 50% by applying 100 kg ha^{-1} N with a further increase 4% with an additional 100 kg ha^{-1} N and an additional 13% increase with application of 80 kg ha^{-1} K. Nutrient uptake at soft dough stage ranged from 109 to 214 with a median of 142 kg ha^{-1} for N, 11 to 31 with a median of 18 kg ha^{-1} for P, and 60 to 161 with a median of 113 kg ha^{-1} for K [22].

In Turkey, biomass yield was increased by 16% and stalk diameter by 7% with application of 100 kg ha^{-1} N; the effect on sugar yield was not reported [17]. Geng et al.

[15] found that sweet sorghum required 36% of the fertilizer N required by corn to maximize hexose yield while producing 23% more hexose yield than corn. In other studies, N application did not affect fermentable sugar yield [3], total and stalk dry matter yield at harvest [9], or fermentable carbohydrate and ethanol yield [10]. Freeman and Broadhead [6] reported results from Mississippi where stalk yield was increased by 24% with the application of 45 kg ha^{-1} N but no further increase occurred with an additional 45 kg ha^{-1} N or with P application. High rates of N application decreased the total dissolved solids in juice [23]. Similar lack of N response was observed when sweet sorghum was intercropped with alfalfa [24]. However, farmers producing sweet sorghum for syrup generally apply 34 to 56 kg ha^{-1} of fertilizer N [19]. Yoneyama et al. [25], using the ^{15}N natural abundance technique, found that from 0-18% of sweet sorghum N may be derived from the atmosphere through associative N fixation depending on the variety.

Lime application increased sweet sorghum fresh and dry biomass yield and the juice sugar extracted from stalks grown on soil with a pH of 5 [26]. In this study, surface soil organic matter was 10 g kg^{-1} soil and N application with no lime applied depressed yield.

Harvesting, Juice Extraction, and Transport

Harvesting and stalk handling

Harvesting can be done any time from early dough stage to physiological maturity

[27] without much effect on sugar yield. Using modeling, Shih et al. [28] found that biomass yield of sweet sorghum can be estimated from leaf area index and stalk length for scheduling of harvest.

Traditionally, harvesting of sweet sorghum for syrup included topping the plants and stripping the leaves before crushing the stalks for sugar extraction [1]. Two to three plantings with intervals of about two weeks insured staggered maturation and prolonged harvest without much effect on juice yield [27]. The crushers varied from simple machines with two wooden rollers to those with three metal rollers. These harvesting and processing procedures were time-consuming and labor intensive [29, 30]. Kuepper [19] suggested three actions during stalk processing that could lead to a comparable syrup yield without removing leaves: 1) wilting leaves on the cut stalks before crushing; 2) settling juice for at least two hours and discarding the sediment; and 3) using alpha- amylase enzymes during preheating of the juice. Removal of leaves and head may not be essential when sweet sorghum is used for ethanol production since juice taste is not an issue.

Bennett and Anex [31] found that harvesting and post-harvest handling of 50 to

100 Mg ha^{-1} of biomass with short harvest windows in temperate zones are major challenges to economically efficient sweet sorghum production. Transport costs may be reduced by in-field extraction of juice, but sugar extracted may be 30-40% less than with larger stationary extraction equipment [32].

Stage of maturity had no effect on stalk yield following flowering, but extraction decreased, and Brix and starch increased, with maturity [27]. Sucrose increased with maturity through the dough stage and purity increased from flower to milk stage. Syrup production is optimized if sweet sorghum is harvested during the late milk to hard dough growth stage [12, 33].

Extraction and purity decreased respectively by 3% and 5% during 24 hours in storage, and sucrose and starch decreased respectively by 0.5% and 0.1% during 48 hours in storage [27]. Juice purity was similar for stalks harvested in the milk, dough, and physiological maturity if the stalks were not stored. After 24 hours of storage, however, juice purity was 70 and 73% less for stalks harvested in the milk compared with the dough and physiological maturity stages, respectively. Broadhead [13] reported no effect on juice yield, extraction, or purity due to delaying stalk harvest until physiological maturity but Brix was reduced by 6% and sucrose by 4% if harvest was delayed until 3-4 weeks after physiological maturity.

Sugar loss is slow in harvested intact stalks but rapid in chopped stalks [31]. Sugar loss from heaped stalks was just 3% in four days [22]. No significant sucrose inversion was observed from storing mature stalks outdoors for up to 24 hours after cutting. Little sucrose was lost with outdoor storage of mature stalks for up to 48 hours.

Sweet sorghum fermentable sugar loss can occur following expression of the juice because of microbial activity resulting in change of odor, discoloration, and foaming.

Sulfur dioxide at 3000 ppm was found to preserve chopped sweet sorghum in ambient storage for two months with negligible drop in fermentable sugar content. Sweet sorghum

stalks can be stored as silage without appreciable sugar loss when treated with acrylic acid to inhibit fermentation [34].

1.2 *Juice expression, handling and processing*

The process of crushing and pressing juice from sweet sorghum is called expression. Historically, expression of sweet sorghum juice for syrup was a community activity where local farmers brought stalks to an expression facility and provided the labor needed for expression and cooking the juice.

Sweet sorghum harvest may consist of removing the whole or chopped stalks.

Alternatively, stalks may be crushed and pressed in the field, removing the juice or removing the juice and the pressed stalk residue. Whole stalk harvest should be followed by juice expression within one or two days of storage to minimize sugar loss to respiration. Forage harvest equipment may be modified to increase the length of stalk segments and used to harvest sweet sorghum but juice expression should follow soon after. Modified forage harvesters that cut stalks into billets may be used for chopping and harvesting sweet sorghum stalks [31] before transporting to a central location where juice expression could follow soon after.

Roberts [30] designed a self-propelled harvester that expresses the juice in the field for reduced storage loss and reduced labor requirement while leaving the residue in the field for ground cover and nutrient recycling. Kundiyana et al. [32] proposed a field harvester capable of expressing juice into large bladders for juice storage and fermentation. Mobile units would then be used for distillation although quality control and ethanol recovery efficiency might be less than with established facilities.

Removal of panicles and leaves, as typically done in sugar cane harvest, improves juice expression efficiency [29]. Expression efficiency may be improved by repeated re- watering and re-expression. Jankins [35] recommended maceration of the stalks before expression by crushing, cutting or shredding to increase the bulk density of the stalks and the efficiency of expression. Plant water content is important to juice expression with low efficiency for sugar cane when plant water content is below 45% [35]. Therefore, more sugar is flushed from the plant material with repeated wetting and expression following the initial expression.

Bennett and Anex [31] compared harvesting systems for stalks and found harvest with a self-propelled 4-row forage harvester to be economically competitive. They estimated that, when co-product value was included, the net farm-gate cost of fermentable carbohydrates ranged from $6.9 to $24 Mg^{-1}. These costs were considerably less than comparable net farm-gate fermentable carbohydrate costs for corn. Moreover, if sweet sorghum feed stocks are located in close proximity to processing facilities, the lower fermentable carbohydrates costs will be sufficient to offset increased transportation costs associated with moving wet biomass. Mobile juice harvesting alternatives were not found to be economically competitive.

Sugar yield

In Louisiana, wet and dry weight yield ranged from 47-103 Mg ha^{-1} and 10-31 Mg ha^{-1}, respectively at soft dough stage [22]. Dry matter yield at flowering was only 22 to 30% of yield at soft dough. Total sugar content in stalks ranged from 8.3 to 14.0% at flowering and 12.8 to 16.6% at soft dough. Total sugar yield in stalks ranged from 4.3 to

8.5 Mg ha^{-1} at flowering and from 6.6 to 11.7 Mg ha^{-1} at soft dough.

Smith et al. [36] evaluated 4-6 sweet sorghum cultivars across the continental USA and Africa and found total sugar yield ranging from 4 to 10.7 Mg ha^{-1} for continental USA and up to 12 Mg ha^{-1} for Hawaii. These yields are equivalent to ethanol yields of 2129 to 5696 L ha^{-1} indicating strong potential of sweet sorghum to provide fermentable carbohydrates across much of the US. The potential ethanol yield obtained from sweet sorghum is reported to be comparable to that of maize [36].

Vermerris et al. [37] reported biomass yields of sweet sorghums of 20 to 119 Mg ha^{-1} with juice contents of 65 to 80%. The combined sugar content of the juice varied between 9 and 15%. Sugar yields varied from 4 to 17 Mg ha^{-1}. Bagasse represented approximately two-thirds of the dry matter. Fermentation of the sugar in the juice yielded 3740 to 5610 L ha^{-1}.

Sugar content of sweet sorghum ranged from 14 to 20% of the plant mass [3]. Reddy et al. [5] reported that expressed sweet sorghum juice varied from 16-23% Brix. Smith and Buxton [3] reported sugar yields of sweet sorghum as high as 6 Mg ha^{-1} with a sugar composition of 54% sucrose, 26% glucose, and 20% fructose.

The concentration of stalk sugar varies with the cultivar and the stage of growth of the plant. Early cultivars tend to have peak stalk sugar concentration just before flowering while late maturing long season cultivars tend to add sugar to the stalks until maturity [2]. Lingle [38] reported that stalk sugar content is often the lowest at boot stage and the highest at the soft dough stage. Ricaud et al. [22], however, found total sugar content in stalks ranged from 8.3 to 14.0% at flowering, 12.8 to 16.6% at soft dough.

Depending on the cultivars, the best growth stage to harvest sweet sorghum could range from early milk stage to hard dough stage [12, 33].

Sugar content of stalk varies according to growth stage, the plant part or internodes sampled, and the physiology of the plant [38, 39]. In primary culms of the cultivar Rio, sucrose concentration was found to increase seven-fold between the boot and mid-grain filling stages and the increase was associated with stage of growth mediated decline in key enzymes involved in sucrose metabolism, mainly soluble acid invertase and sucrose synthase [38]. The onset of sucrose accumulation was associated with the onset of the reproductive phase of growth and the decrease in acid invertase activity [38].

Concentrations of carbohydrates are not uniform along the stalk of sweet sorghum [40]. Compared to grain sorghum, the concentration of nonstructural carbohydrates is 1.4 times higher in the upper and to 2.7 times higher in the lower internodes of sweet sorghum. Some sweet sorghum cultivars partitioned a significant amount of carbon to nodal tillers [40]. Coleman [41] reported greater total sugar and sucrose concentration in the upper compared with the lower internodes at physiological maturity. Krishnaveni et al. [42] reported that in a plant of 11 internodes, the highest concentration of sugar was at the 7th internode. This could be related to a high enzymatic activity at the younger internodes making these internodes primary or secondary sinks [38]. Tarpley et al. [33] argued that mechanisms more complicated than enzymatic activities and sink strength may have been involved and suggested further investigation.

In general, sugar yield increases as the plant matures while juice yield is reduced [43]. Stalk sugar content of juice increased continuously until frost kill but stalk sugar content declined after frost kill [44]. Sugar content of the stalk was usually higher at the middle stalk while the top 30-45 cm has lesser yield and thus can be discarded without

significant loss of sugar or juice yield [43]. Sugar yield at dough stage increased linearly as photosynthetically active radiation increased from 20 to 80 Mj plant^{-1} and sugar content increased with early sowing and longer growing periods [8]. Thus, the relationship of sugar accumulation and length of growing season was linear.

De-heading of sweet sorghums at anthesis significantly increased the number of productive tillers, main stalk diameter by 20%, juice yield by 30%, and sugar yields by 10% in India although concentrations of Brix and sucrose and juice purity were decreased by about 5% with deheading [45). As long as the terminal meristem developed, the internodes increased in biomass and plant height increased especially in late maturing cultivars [46]. Sugar continued to accumulate in the fully developed internodes well into seed development [2]. In another study, de-heading increased Brix and concentration of sucrose and starch at milk, dough and physiological maturity growth stages [47]. De- heading also reduced plant lodging and increased tillering both of which contributed to increased juice yield. De-heading reduced the stalk water content and therefore the juice without affecting the sugar yield [2, 47].

Fermentation and energy yields from juice

The theoretical yield of ethanol, which has a weight of 789.3 g L^{-1}, was 719.6, 646.1, and 680.3 L Mg^{-1} starch, glucose or fructose, and sucrose, respectively [3]. The ethanol yield of maize was about 0.37 L kg^{-1}. Smith and Buxton [3] estimated that 5% of the sugar is used to produce microbial growth and non-ethanol products. Monti and Ventura [48] used the following values in energy calculations: 16 Mj kg^{-1} of biomass combustion; 18.5 Mj kg^{-1} for gasified wheat straw; ethanol yield of 0.36 L kg^{-1} of wheat;

18.3 Mj kg^{-1} for processing wheat to ethanol, including drying of the by-product; 7 Mj kg^{-1} energy content of fresh bagasse of 50% dry weight; and 3.2 Mj kg^{-1} theoretical ethanol energy yield of fresh bagasse.

Conversion of sweet sorghum juice to alcohol can be accomplished either by fermenting the juice or by fermenting the chopped stalks in a solid state process. Solid state fermentation is a process in which microbial growth and product formation occur on the surfaces of solid substrates instead of liquid. Some studies have indicated superior alcohol conversion efficiency from chopped sweet sorghum than the corresponding juice [49]. Heating juice to 85°C increased fermentation efficiency and the inclusion of yeast improved juice fermentation at all temperatures [49]. The addition of yeast reduced the temperature effect on fermentation yield and fermentation yield was maximized by heating juice to 60° C with addition of 0.25 g L^{-1} of yeast.

The US Department of Energy estimated potential ethanol yield of 5590 L ha^{-1} from sweet sorghum [50]. The net energy ratio for sweet sorghum was estimated to exceed 1.0, with two units of energy recovered in the ethanol for each unit used for crop production and processing [51]. Several sweet sorghum cultivars have the potential of producing greater than 25 Mg dm ha^{-1} $year^{-1}$ [7]. In Iowa [52], yields of 11 sweet sorghum cultivars grown at six site-years ranged from 15.8 to 18.4 Mg ha^{-1} of dry matter,

7.1 to 8.2 Mg ha^{-1} of total sugar, and 3850 to 4410 L ha^{-1} of ethanol production based on the assumption of 95% extraction of sugars and 1.76 kg fermentable carbohydrate per liter of ethanol produced. Lueschen et al. [10] reported yields of 20 to 25 Mg ha^{-1} dry biomass and 3050 to 4000 L ha^{-1} ethanol.

Bi-product uses

In addition to producing carbohydrates that can be easily fermented to ethanol, sweet sorghum has high biomass yield, some grain yield, and bagasse remaining after juice expression that can be an energy source for ethanol processing facilities [31]. Some sweet sorghum co-products may be used for animal feed. The bagasse can be used in paper production, biofuel, livestock feed, or for soil application. The grain can be used for ethanol production as well as food or feed.

With the development of hybrid sweet sorghum varieties, the potential for high sugar (ethanol) yield as well as co-production of grain has increased as demonstrated in China where sweet sorghum biomass and grain yields of 25 and 5 Mg ha^{-1}, respectively, were obtained in a production environment with similar latitude to the Midwest [53]. At this level of production the income generated from grain yield as a co-product and other co-products from processing will cover the cost of producing the crop making whatever income generated from ethanol a profit.

Energy requirements and costs

Reed et al. [54] estimated crop production input of energy L^{-1} potential ethanol as 6.42, 5.25, 6.35, and 5.95 MJ L^{-1}, respectively, for corn, sweet sorghum, fodder beet (*Beta vulgaris* L.), and sugar beet (*Beta vulgaris* L.) grown in California. The respective theoretical ethanol yields for these crops were 4814, 5784, 7782, and 6886 L ha^{-1}.

Estimated energy consumption for sweet sorghum compared to corn production was greater for fuel and transportation but less for N fertilizer and irrigation. Energy required for converting the product to ethanol was not estimated.

Monti and Venturi [48] compared energy efficiency of sweet sorghum, fiber sorghum, and wheat with and without N applied, assuming gasification of the crop residues. The net energy supplied was 17, 40 and 50% greater with sweet sorghum compared with fiber sorghum, wheat with no N, and wheat with N applied, respectively. The energy efficiency of ethanol production was estimated to be 90% compared with gasification. Table 2 and 3

Table 2. Energy input requirements for sweet sorghum, corn, and wheat in California.

	Sweet sorghum	Corn
Fermentable carbohydrate yield (Mg ha^{-1})	9.71	8.09
Potential ethanol yield (L ha^{-1})	5,784	4814
Potential ethanol yield (Mj ha^{-1})	133,000	111,000
Energy input in N Fertilizer (Mj L^{-1})	0.72	2.34
Energy input in irrigation pumping (Mj L^{-1})	0.79	1.01
Energy input in liquid fuel for operation (Mj L^{-1})	2.45	1.85
Total production energy input (Mj L^{-1})	5.25	6.42

Source: Reed et al., [54]

Table 3. Comparison of sweet sorghum to some other food and biomass crops for energy yield and energy yield efficiency.

Crop	Energy Use Efficiency (MJ/ kg DM)[a]	Energy production per energy consumed [b]	Energy net gain [b]	Energy gain per invested [c]
Sweet sorghum	0.74-0.91	5.66	3.90	3.63
Sugar cane		4.53	2.43	
Corn				1.53
Wheat	0.96-1.28			
Cassava		1.71	1.16	

[a] Monti, G. Venturi, [48] [b] J.D. De Silva et al. [58] [c] Drew Lyon Personal

shows potential energy and input energy requirements of sweet sorghum as compared to some other energy crops.

Geng et al. [15] compared sweet sorghum with other crops for production costs near Davis CA. The cost ha^{-1} of sweet sorghum production was greater than for corn because of high harvest costs. However, hexose yield was greater with sweet sorghum and the costs L^{-1} were very similar.

Rahmani and Hodges [55] calculated the cost of ethanol energy production to be

\$0.48, \$0.53, \$0.58 L^{-1} respectively for corn, sugarcane and sweet sorghum under best production potential scenarios in Florida. Processing and harvesting were major expenses for sweet sorghum. The processing cost of sugarcane juice to ethanol was estimated to be

\$0.13 L^{-1} in Florida [55] and a similar cost may apply to converting sweet sorghum juice to ethanol. Less N and water is required to produce sweet sorghum compared to other crops, such as corn, sugar beet, and sugarcane which contribute to sustainability and an improved energy balance (higher net energy) for sweet sorghum.

Limitations of Sweet Sorghum Bioenergy

The primary limitations of sweet sorghum for bioenergy include seasonality of harvest and large masses to be transported and stored. Fermentation of the expressed juice must be initiated quickly after harvest to avoid sugar loss. Wu et al. [56] reported as much as 20% loss of fermentable sugars from storing fresh juice at room temperature for about 3 days and up to 50% loss during one week of juice storage. In temperate climates, the harvest window for sweet sorghum is limited by length of the growing season. Seed production is costly because of low seed yield and usually very tall plants. Few open pollinated or hybrid cultivars are available for production. An advantage of sweet sorghum is that ethanol distillation and distribution may be integrated into the existing grain-based ethanol processing system to take advantage of existing infrastructure in the short term

References

[1] J. Winberry, The sorghum syrup industry 1854-1975, In Agricultural History (1984) 54:343-352.

[2] E.L. Hunter, I.C. Anderson, Sweet sorghum, Hort. Rev. 21 (1997) 73-104.

[3] G.A. Smith, D.R. Buxton, Temperate zone sweet sorghum ethanol production potential, Bioresource Tech. 43 (1993) 71-75.

[4] G.C. Rains, J.S. Cundiff, D.H. Vaughan, Development of a whole-stalk sweet sorghum harvester, Transactions in Agriculture 33 (1990) 56-62.

[5] B.V.S. Reddy, S. Ramesh, P.S. Reddy, B. Ramaih, P.M. Salimath, R. Kachapur, Sweet sorghum−A potential alternative raw material for bio-ethanol and bio-energy, International Sorghum and Millets Newsl. 46 (2005) 79-86.

[6] K.C. Freeman, D.M. Broadhead, Culture of Sweet sorghum for syrup production, USDA Agricultural Handbook No 441 (1973), USDA.

[7] A. Turhollow, The economics of energy crop production, Biomass and Bioenergy, 6 (1994) 229-241.

[8] R. Ferraris and D.A. Charles-Edwards, A comparative analysis of the growth of sweet and forage sorghum crops. II. Accumulation of soluble carbohydrates and nitrogen, Aust.
J. Agric Res. 37 (1986) 513-522.

[9] L. Barbanti, S. Grandi, A. Vecchi, G. Venturi, Sweet and fiber sorghum (*Sorghum bicolor* (**L**) **Moench**), energy crops in the frame of environmental protection from excessive nitrogen loads. Europ. J. Agron. 25 (2006) 30-39.

[10] W.E. Lueschen, D.H. Putnam, B.K. Kanne, T.R. Hoversted, Agronomic practices for production of ethanol from sweet sorghum. J. Prod. Agric. 4 (1991) 619-625.

[11] R. Ricaud and A. Arenneaux, Sweet sorghum for biomass and sugar production in 1990. Manuscript report from the St. Gabriel Experiment Station, 1990.

[12] D.M. Broadhead, Effect of planting date and maturity on juice quality of Rio sweet sorghum, Agron. J. 64 (1972) 389-390.

[13] D.M. Broadhead, Sugar production from sweet sorghum as affected by planting date, after-ripe harvesting, and storage, Agron. J. 61 (1969) 811-812.

[14] R. Ferraris, Early assessment of sweet sorghum as an agro-industrial crop. I. Varietal evaluation. Aust. J. Exp. Agric. Anim. Husb. 21 (1981) 75-82.

[15] S. Geng, F.J. Hills, S.S. Johanson, R.N. Sah, Potential yields and on-farm ethanol cost of corn, sweet sorghum, fodder beet and sugarbeet. J. Agron. Crop Sci. 162 (1989) 21-29.

[16] B.W. Hipp, W.R. Cowley, C.J. Gerard, B.A. Smith, Influence of solar radiation and date of planting on yield of sweet sorghum, Crop Sci. 10 (1970) 91-92.

[17] I. Turgut, U. Biligili, A. Duman, E. Acikgoz, Production of sweet sorghum (*Sorghum bicolor* L. Moench) increased with increased plant density and nitrogen fertilizer levels, Acta Agriculturae Scandinavica, 55 (2005) 236-240.

[18] D.M. Broadhead, K.C. Freeman, Stalk and sugar yield of sweet sorghum as affected by spacing, Agron. J. 72 (1980) 523-524.

[19] G. Kuepper, Sweet sorghum: production and processing, Kerr Center for Sustainable Agriculture, Poteau, OK, 1992.

[20] P.M. Martin, F.M. Kelleher, Effects of row spacing and plant population on sweet sorghum yield, Aust. J. Exp. Agric. Anim. Husb, 24 (1984) 386-390.

[21] B.V.S. Reddy, A.A. Kumar, S. Ramesh, Sweet sorghum: a water saving bio-energy crop, International conference on linkages between energy and water management for agriculture in developing countries, IWMI, ICRISAT, Hydrabad, India, 2007
[22] R.B. Ricaud, Cochran, A. Arenneaux, G. Newton, Sweet sorghum for sugar and biomass production in Lousiana, Manuscript report from the St. Gabriel Experiment Station, 1979.
[23] R.Wiendenfeld, Nutrient requirement and use efficiency by sweet sorghum, Energy Agr., 3 (1984) 49-59.
[24] D.R. Buxton, I.C. Anderson, A. Hallam, Intercropping sorghum into alfalfa and reed to increase biomass yield, J. Prod. Agric. 11 (1998) 481-486.
[25] T. Yoneyama, J. Terakado, T. Masuda, Natural abundance of ^{15}N in sweet potato, pumpkin, sorghum, and castor bean: possible input of N2-derived nitrogen in sweet potato, Biol. Fert. Soils 26 (1998) 152-154.
[26] J.M. Soileau, B.N. Bradford, Biomass and sugar yield response of sweet sorghum to lime and fertilizer, Agron. J. 77 (1985) 471-475.
[27] D.M. Broadhead, Effect of planting date and maturity on juice quality of Rio sweet sorghum, Agron. J. 64 (1974) 389-390.
[28]S.F. Shih, G.J. Gascho, G.S. Rahi. Modeling biomass production of sweet sorghum. Agron. J. 73 (1981) 1027-1032.
[29] M. Lamb, Mechanical expression of sweet sorghum for juice recovery. M.Sc. thesis, University of Nebraska-Lincoln, USA, 1982
[30] A.L. Roberts, United State Patent 3 (1965), 394 (1965), 535 (1965).
[31] A.S. Bennett, R.P. Anex, Farm-gate production cost of sweet sorghum as a bioehtanol feedstock. Trans. of the ASABE. 51 (2008) 603-613.
[32] D.D. Kundiyana, D. Bellmer, R. Huhanke, M. Wilkins, "Sorganol": Production of ethanol from sweet sorghum, ASABE Annual Meeting Presentation, Portland, OR, USA, 2006
[33] L. Tarpley, S.E. Lingle, D.M. Vietor, D.L. Andrews, F.R. Miller, Enzymatic control of nonstructural carbohydrate concentrations in stems and panicles of sorghum, Crop Sci. 33 (1994) 446-452.
[34] N.S. Hill, G.L. Posler, K.K. Bolsen, Fermentation inhibition of forage and sweet sorghum silages treated with acrylic or maleic acid, Agron. J. 79 (1987) 619-623.
[35] G. Jankins, Introduction to cane sugar technology, Elsevier Publishing, Amesterdam, 1966, The Netherlands.
[36] G.A. Smith, M.O. Bagby, R.T. Lewellan, D.L. Doney, P.H. Moore, F.J. Hills, L.G. Campbell, G.J. Hogaboam, G.E. Coe, K. Freeman, Evaluation of Sweet Sorghum for Fermentable Sugar Production Potential, Crop Sci. 27 (1987) 788-793.
[37] W. Vermerris, C. Rainbolt, D. Wright, Y. Newman, Production of biofuel crops in Florida: Sweet sorghum, 2007, http://edis.ifas.ufl.edu Retrieved 08 01, 2008.
[38] S. Lingle, Sucrose metabolism in the primary Culm of sweet sorghum during development, Crop Sci. 27 (1987) 1214-1219.
[39] J.S. Wall, C.W. Blessin, Composition of sorghum plant and grain. p 118-166. *In* J.S. Wall, W.M. Ross (Eds), Sorghum production and utilization, AVI, West Port, CT, 1970, pp. 118-166.
[40] D.M. Vietor, F.R. Miller, Assimilation, partitioning and nonstructural carbohydrates in sweet compared with grain sorghum, Crop Sci. 30 (1990) 1109-1115.
[41] O.H. Coleman, Syrup and sugar from sweet sorghum. p. 416-440. *In* J. W. Wall, W. M. Ross (Eds.) Sorghum production and utilization, AVI Publishers, Westport, CT, 1970, pp. 416-440.
[42] S. Krishnaveni, T. Balasubramanian, S. Sadasivam, Potentiality of sweet sorghum (Sorghum bicolor, Poaceae) for syrup preparation and alcohol production in India, Econ. Bot. 44 (1990) 355-359.
[43] G. Janssen, C.K. McClelland, W.H. Metzger, Sup extraction of Sorghum and the localization

of juice and sugars in internodes of the plant, Agron. J. 22 (1930) 627-629.
[44]G.A. Nuese, D.R. Hunt, Field harvest of sweet sorghum juice. Transaction of ASAE 26 (1983):656-660.
[45] C. Rajendran, K. Ramamoorthy, S. Backiyarani, Effect of deheading on juice quality characteristics and sugar yield of sweet sorghum, J. Agron. and Crop Sci. 185 (2000) 23- 26.
[46] O.H. Coleman, B. A. Belcher, Some response of sorgo to short photoperiods and variations in temperature, Agron. J. 44 (1952) 35-39.
[47] D.M. Broadhead, Effects of dehaeading on stalk yield and juice quality of Rio sweet sorghum, Crop Sci. 13 (1973) 395-397.
[48] A. Monti, G. Venturi, Comparison of the energy performance of fiber sorghum, sweet sorghum and wheat monocultures in northern Italy, Eur. J. Agron. 19 (2003) 35- 43.
[49] B. Rein, Fermentation of sweet sorghum juice as affected by heating and yeast inoculums. Thesis . Lincoln, Nebraska, 1984, USA.
[50] US Department of Energy, The report of the alcohol fuels policy review, Report No. DOE/PE-0012. USDOE, Washington DC, 1979, USA.
[51] G.J. Sheehan, P.F. Greenfield, D.J. Nicklin, Energy economics, ethanol- a literature review, Alcohol Fuels Conf., Sydney, 1978, Australia.
[52] E.L.Hunter, Development, sugar yield and ethanol potential of sweet sorghum. M.S. thesis, Iowa State Univ., Ames.1994, USA
[53] M. Hong-Tu, H. Xiu-Ying, Breeding for sweet sorghum with high grain yield and sweet stalks, Sorghum Newsl., 29 (1986) 2-3.
[54] W. Reed, S. Geng, F.J. Hills, Energy input and output analysis of four field crops in California. J. Agron. Crop Sci. 157 (1986) 99-104.
[55] M. Rahmani, A. Hodges, Potential feedstock sources for ethanol production in Florida, 2006, http://edis.ifas.ufl.edu/pdffiles/FE/FE65000.pdf. Retrieved 08 01, 2008
[56] X.Wu, S. Staggenborg, J.L. Propheter, W.L. Rooney, J. Yu, D. Wang, Features and fermentation performance of sweet sorghum juice after harvest, Paper presented at the 2008 ASABE meeting, June 29- July 2, 2008, Providence, Rhode Island
[57]Kersenbrock, L. 1979. A learning guide for alcohol production. Colby Community College, Colby, Kansas.
[58] J.G. DeSilva, G.E. Serra, J.R. Moreira, J.C. Concalves, J. Goldemberg, Energy balance of ethanol alcohol production from crops. Science 201 (1978):903-906.

CARBON FOOTPRINT OF FOOD PRODUCTION: THE ROLE OF AGRICULTURE AND LIVESTOCK IN GLOBAL CLIMATE CHANGE

BESİN ÜRETİMİNİN KARBON AYAK İZİ: KÜRESEL İKLİM DEĞİŞİKLİĞİNDE TARIM VE HAYVANCILIĞIN ROLÜ

Şemsi Gül YILMAZ KOCAMAN

Karamanoğlu Mehmetbey Üniversitesi, Sağlık Bilimleri Fakültesi, Beslenme ve Diyetetik Bölümü, Karaman, Türkiye

ORCID ID: 0000-0002-2825-7401

ÖZET

Giriş ve Amaç: Küresel ısınma, insan kaynaklı sera gazı (GHG) emisyonlarının artmasıyla tetiklenmekte ve ciddi iklim dengesizliklerine ve çevresel bozulmalara yol açmaktadır. Besin üretimi -özellikle de tarım ve hayvancılık faaliyetleri- bu emisyonların önemli bir kaynağını oluşturmaktadır. Bu çalışmanın amacı, besin üretim süreçlerinden kaynaklanan karbon emisyonlarının küresel iklim değişikliğine nasıl katkı sağladığını incelemek ve olası azaltma stratejilerini detaylı biçimde tartışmaktır.

Gereç ve Yöntem: Bu çalışma, bilimsel literatürün kapsamlı bir derlemesine dayanmaktadır. Pirinç tarımı, sentetik gübre kullanımı ve anız yakma gibi temel tarımsal uygulamalar ile, enterik fermantasyon, gübre yönetimi ve yem üretimi gibi hayvancılığa özgü faaliyetler, karbon ayak izi ve sera gazı emisyonları açısından değerlendirilmiştir.

Bulgular: Tarımsal faaliyetlerin metan (CH_4) ve diazot monoksit (N_2O) emisyonlarına önemli ölçüde katkı sağladığı; hayvancılığın ise hem sindirim süreçlerinden kaynaklanan doğrudan hem de yem tedarik zinciri ve atık yönetimi yoluyla oluşan dolaylı emisyonlara neden olduğu tespit edilmiştir. Türkiye gibi gelişmekte olan ülkelerde besin üretiminin ulusal sera gazı envanterindeki payı giderek artmaktadır.

Tartışma ve Sonuç: Besin üretiminin karbon ayak izinin azaltılması, sürdürülebilir tarım uygulamaları, biyogaz sistemleri, gübre yönetiminin iyileştirilmesi ve yem optimizasyonunu içeren bütüncül bir yaklaşım gerektirmektedir. Toplumsal farkındalık, politika teşvikleri ve uluslararası iş birliği bu süreçte kritik öneme sahiptir. Bu önlemler, yalnızca iklim üzerindeki olumsuz etkileri azaltmakla kalmayacak, aynı zamanda sürdürülebilir beslenme ve küresel besin güvenliğine de katkı sağlayacaktır.

Anahtar Kelimeler: Besin Üretimi, Karbon Ayak İzi, Sera Gazı Emisyonları, Hayvancılık, İklim Değişikliği

ABSTRACT

Introduction and Purpose: Global warming is driven by anthropogenic greenhouse gas (GHG) emissions and results in significant climate instability and environmental degradation. Food production—particularly agriculture and livestock—constitutes a major source of these emissions. This study aims to examine how carbon emissions arising from food production processes contribute to global climate change and to discuss potential mitigation approaches in detail.

Materials and Methods: This work is based on a comprehensive review of scientific literature. Key agricultural practices such as paddy rice cultivation, synthetic fertilizer application, and stubble burning, as well as livestock-related activities including enteric fermentation, manure storage, and feed production, were assessed in relation to their carbon footprint and GHG emissions.

Results: Agricultural activities are found to significantly contribute to methane (CH_4) and nitrous oxide (N_2O) emissions, while livestock operations produce both direct emissions from digestive processes and indirect emissions via feed supply chains and waste handling. In developing countries such as Turkey, the share of food production in the national GHG inventory is steadily increasing.

Discussion and Conclusion: Reducing the carbon footprint of food production requires an integrated approach involving sustainable agricultural practices, biogas systems, improved manure management, and feed optimization. Public awareness, policy incentives, and international cooperation are also essential. These measures will not only mitigate climate impacts but also support sustainable nutrition and global food security.

Keywords: Food Production, Carbon Footprint, Greenhouse Gas Emissions, Livestock, Climate Change

GİRİŞ

Günümüzde bireylerin en temel arzusu, sağlıklı bir çevrede uzun ve kaliteli bir yaşam sürmektir. Ancak yaşam standartlarını sürekli olarak yükseltme isteği, doğal kaynakların bilinçsizce tüketilmesine ve çevrenin kirlenmesine yol açmaktadır. Bu süreç, atmosfere salınan karbon emisyonlarını artırarak küresel ısınmayı hızlandırmakta ve beraberinde çeşitli çevresel felaketleri getirmektedir (Chophel, 2022).

Küresel ısınma; insan faaliyetleri sonucu atmosfere salınan sera gazlarının (CO_2, CH_4, N_2O, O_3, CFC'ler ve H_2O buharı) doğal sera etkisini güçlendirmesiyle ortaya çıkan, dünyanın ortalama yüzey sıcaklığındaki artış ve buna bağlı iklim değişiklikleri olarak tanımlanmaktadır. Özellikle sanayi devriminden günümüze kadar geçen süreçte, sera gazı emisyonlarındaki artış belirgin bir şekilde gözlenmiştir (Manabe, 2019).

Küresel iklim değişikliğinin etkileri çok boyutludur. Bu kapsamda; tropikal kasırgaların sayısı ve şiddetinde artışlar, meteorolojik kökenli doğal afetlerin (don, ani ve şiddetli yağış, dolu, yıldırım, fırtına, çığ vb.) sıklığında ve etkisinde yükselişler rapor edilmektedir. Ayrıca kuraklığa bağlı tarımsal verimlilik kayıpları, yüksek sıcaklıkların tetiklediği orman yangınları ve ozon, ultraviyole ışınları ile hava kirliliğine bağlı sağlık sorunları da önemli sonuçlar arasındadır. Bunun yanı sıra, konfor sıcaklıklarını sağlamak amacıyla artan enerji tüketimi, buzulların erimesiyle yükselen deniz seviyelerinin kıyı bölgelerinde yaratacağı riskler ve büyük okyanus akıntılarının yapısındaki değişimlerin küresel iklim desenlerini bozma olasılığı ciddi tehditler oluşturmaktadır. Ayrıca atmosferdeki yoğun kirlilik sonucu ortaya çıkan asit yağmurları, toprak ve yeraltı sularının kimyasal bileşiminde bozulmalara neden olarak ekosistemlerin işleyişini olumsuz etkilemektedir (Adedeji ve ark., 2014 ve Gahlawat ve Lakra, 2020).

Bu çalışmanın amacı, küresel iklim değişikliğinin oluşumunda önemli bir rol oynayan karbon salınımının özellikle besin üretiminden kaynaklanan boyutlarını ortaya koymak ve bu alanda literatür temelli bir değerlendirme yapmaktır.

KAVRAMSAL ÇERÇEVE

Karbon Ayak İzi Tanımı

Karbondioksit (CO_2), ısı tutma kapasitesi, atmosferdeki yoğunluğu ve uzun süre kalıcılığı nedeniyle çevre üzerinde en önemli etkiye sahip sera gazıdır. Bu özellikleri, doğal ekosistemlerde uzun vadeli tahribatlara yol açmakta ve biyolojik kapasitenin aşılmasına neden olmaktadır (Müller ve ark., 2020).

Karbon ayak izi, insan faaliyetleri sonucu ortaya çıkan ve bir ürünün yaşam döngüsü boyunca doğrudan veya dolaylı şekilde oluşan toplam CO_2 emisyonlarını ifade eder. Ölçüm birimi "kg CO_2-eşdeğer" veya "ton CO_2-eşdeğer" olarak tanımlanmaktadır (Güven ve ark., 2016). Sera gazı emisyonlarının en önemli kaynakları arasında enerji üretimi, ısınma amacıyla fosil yakıtların kullanımı, sanayi faaliyetleri, ulaşım, arazi kullanım değişiklikleri, atık yönetimi ve tarımsal uygulamalar (anız yakma, çeltik üretimi, hayvancılık ve gübre kullanımı gibi) yer almaktadır (Gołasa ve ark., 2021). Karbon ayak izi hesaplamaları, bireylerin ve kurumların kaynak kullanımlarını takip etmesine ve sürdürülebilirlik düzeylerini değerlendirmesine olanak sağlamaktadır. Bu parametreler sayesinde hangi alanlarda çevresel zararın yoğunlaştığı belirlenebilir ve bireyler ile kurumlar gerekli önlemleri alarak sorumluluklarını yerine getirebilirler (Güven ve ark., 2016).

Karbon ayak izi iki temel kategoride incelenmektedir: kişisel ve kurumsal karbon ayak izi. Kişisel karbon ayak izi, bireylerin günlük yaşamda tüketimleri sonucu atmosfere salınan emisyon miktarını ifade eder. Bu kavram, kişisel bilinç ve farkındalık ile emisyonların azaltılmasında kritik öneme sahiptir. Kişisel karbon ayak izi iki alt başlıktan oluşur: Birincil ayak izi, evsel enerji tüketimi ve ulaşım faaliyetleri (otomobil, uçak vb.) sonucu doğrudan ortaya çıkan CO_2 emisyonlarını kapsar. İkincil ayak izi, bireylerin kullandığı ürünlerin üretim, dağıtım ve bertaraf süreçlerinden kaynaklanan dolaylı emisyonları ifade eder (Chuvieco ve ark., 2021). Kurumsal karbon ayak izi ise, kurumların yıllık faaliyetleri sonucu ortaya çıkan emisyonları kapsar. Üç temel alt bileşeni bulunmaktadır: Doğrudan Karbon Ayak İzi: Kurumların enerji tüketimi (ısınma, üretim süreçleri) ve kuruma ait araçların fosil yakıt kullanımıyla ortaya çıkan emisyonlardır. Dolaylı Karbon Ayak İzi: Elektrik tüketimi, satın alınan buhar, soğutma ve sıcak su kullanımıyla ilişkili emisyonları kapsar. Diğer Dolaylı Karbon Ayak İzi: Kurumların kullandığı hammaddeler, basılı materyaller, taşeron faaliyetler, kiralık araçların tüketimleri ve çalışanların iş amaçlı seyahatlerinden kaynaklanan emisyonları içerir. Bu kategorideki emisyonların hesaplanması zor olmakla birlikte, artan düzenlemeler ve veri şeffaflığı sayesinde kurumlar arasında hesaplanabilirliği giderek artmaktadır (Harangozo ve Szigeti, 2017 ve Klaaßen ve Stoll, 2021).

Tarımsal Üretimde Sera Gazı Salınımı

Tarım sektörü, iklim değişikliğinden en fazla etkilenen alanlardan biri olmakla birlikte aynı zamanda iklim değişikliğine yol açan önemli bir faktördür. Toprak işleme, gübreleme, pestisit kullanımı, ürün arz zinciri, enerji tüketimi ve hayvansal üretim süreçleri tarımsal sera gazı emisyonlarının başlıca kaynaklarıdır (Yue ve ark., 2017).

Türkiye'de tarım sektörü özellikle N_2O ve CH_4 emisyonları açısından dikkat çekmektedir. Tarımsal faaliyetler, atıklarla birlikte N_2O salınımında %79,4, CH_4 salınımında ise %46,5 oranında paya sahiptir. Tarımsal süreçlerde CO_2 emisyonları ise makinelerin çalıştırılması, inorganik gübrelerin üretimi ve tarım kimyasallarının kullanımından kaynaklanmaktadır (Şahin ve Avcıoğlu, 2016).

Özellikle pirinç tarımı, sera gazı emisyonlarının önemli bir kaynağıdır. Sulu pirinç tarlalarında organik maddelerin oksijensiz ortamda ayrışması metan salınımına yol açmaktadır. Sulama sırasında toprak ve sudaki oksijenin azalmasıyla metanojenik bakteriler devreye girmekte ve metan üretimini artırmaktadır. Salınan metan miktarı, organik madde miktarı ve sulama rejimi gibi faktörlere bağlı olarak değişmektedir (Bayraç ve Doğan, 2016).

Diğer önemli tarımsal emisyon kaynakları; anız yakılması, tarımsal topraklarda yoğun azotlu gübre kullanımı ve biyokütlenin açık alanda yakılmasıdır. Anız yakılması hem topraktaki organik madde kayıplarına yol açmakta hem de atmosfere yoğun CO_2 salınımına neden olmaktadır. Mevcut yasal yasaklara rağmen ülkemizde anız yakma uygulaması yaygınlığını sürdürmektedir (Gottipati ve ark., 2021).

Azotlu gübre kullanımı da önemli bir çevresel sorun oluşturmaktadır. Yanlış ve yoğun kullanım, toprak ve su kirliliğine, biyolojik çeşitliliğin azalmasına ve sera gazı emisyonlarının artmasına neden olmaktadır. Çözüm olarak yavaş salınımlı gübreler, nitrifikasyon ve üreaz inhibitörleri önerilmekte ve bu yöntemlerle azot kayıplarının azaltılması hedeflenmektedir (Şahin ve Avcıoğlu, 2016).

Hayvancılık Kaynaklı Sera Gazları

Hayvansal üretim, artan nüfus ve yükselen protein talebiyle birlikte küresel ölçekte giderek büyüyen bir sektör haline gelmiştir. Bu büyüme yalnızca gıda güvenliğini sağlamaya katkı sunmakla kalmamakta, aynı zamanda sera gazı emisyonlarını da önemli ölçüde artırmaktadır. Özellikle metan (CH_4) ve diazot monoksit (N_2O) emisyonları, küresel ısınmanın hızlanmasında kritik bir role sahiptir. Çeşitli çalışmalar, tarımsal kaynaklı sera gazları içinde hayvancılığın payını oldukça yüksek göstermektedir. Küresel ölçekte metan ve N_2O'nun iklim değişikliğine katkısının %17–27 arasında olduğu, bu katkının ise yaklaşık %21'inin doğrudan hayvansal üretim faaliyetlerinden kaynaklandığı bildirilmektedir (Herrero ve ark., 2016).

Hayvancılığın iklim değişikliğine katkısında en önemli süreçlerden biri enterik fermantasyondur. Bu biyolojik süreç, özellikle geviş getiren hayvanların (sığır, koyun, keçi, manda vb.) sindirim sistemi içerisinde gerçekleşmekte ve yüksek miktarda metan gazı üretmektedir. Türkiye özelinde yapılan değerlendirmeler, ruminant kaynaklı metan emisyonunun yaklaşık %85'inin enterik fermantasyondan kaynaklandığını ve bu emisyonun %76'sının sığır popülasyonuna ait olduğunu ortaya koymaktadır (Yalçınkaya, 2024). Bu durum, hayvancılık politikalarının sera gazı azaltım hedeflerinde kritik bir unsur olduğunu göstermektedir.

Bunun yanı sıra, hayvansal gübre yönetimi de sera gazı emisyonlarının önemli bir kaynağıdır. Özellikle gübrelerin oksijensiz koşullarda depolandığı alanlarda, sıcaklık ve nemin artışıyla birlikte metan ve N_2O salınımları hızlanmaktadır. Sığır, koyun ve manda gibi ruminantlardan elde edilen gübrelerin yanı sıra, domuz ve tavuk gibi monogastrik hayvanların gübreleri de uygun olmayan koşullarda depolandığında önemli miktarda emisyon açığa çıkarmaktadır (Pratt ve ark., 2015). Gübrelerin açıkta depolanması, anaerobik parçalanmayı artırmakta ve hem hava kalitesi hem de iklim açısından olumsuz sonuçlar doğurmaktadır.

Hayvancılığın sera gazı emisyonlarına katkısı yalnızca doğrudan süreçlerle sınırlı değildir. Hayvan yeminin üretimi ve lojistiği de önemli bir dolaylı emisyon kaynağıdır. Yem bitkilerinin üretiminde kullanılan suni gübreler, fosil yakıt temelli enerji tüketimi nedeniyle CO_2 emisyonlarını artırmaktadır. Ayrıca yem için yapılan aşırı otlatma ve mera açma faaliyetleri, toprakta karbon depolama kapasitesini düşürmekte, orman ve çayır ekosistemlerinin bozulmasına yol açmaktadır. Bu durum hem biyoçeşitliliğin azalmasına hem de karbon döngüsünün zayıflamasına sebep olmaktadır (Ejedegba, 2024).

Özetle, hayvancılık sektörü; enterik fermantasyon, gübre yönetimi ve yem üretimi süreçleri aracılığıyla hem doğrudan hem dolaylı yollardan sera gazı emisyonlarını artırmakta ve küresel ısınmayı tetiklemektedir. Bu nedenle, sürdürülebilir hayvancılık uygulamaları, metan emisyonunu azaltmaya yönelik yem katkıları, gübrelerin biyogaz tesislerinde değerlendirilmesi ve meraların dengeli kullanımı gibi yöntemler, iklim değişikliğiyle mücadelede stratejik öneme sahiptir.

Türkiye'nin Karbon Ayak İzi ve Kyoto Protokolü

Küresel Ayak İzi Ağı (Global Footprint Network), her yıl 150'den fazla ülkenin biyolojik kapasite talebini ve ekolojik ayak izini hesaplayarak Ulusal Ayak İzi Hesaplarını yayımlamaktadır. Bu hesaplamalar, ülkelerin tüketim kalıplarının ekosistemler üzerindeki baskısını ve mevcut biyokapasite ile olan dengesini ortaya koymaktadır. Türkiye özelinde yapılan değerlendirmeler, ekolojik ayak izinin biyolojik kapasitesinin yaklaşık iki katına ulaştığını göstermektedir. Başka bir ifadeyle, Türkiye'de bir yıl içinde tüketilen doğal kaynakların yeniden üretilebilmesi ve atmosfere salınan karbonun ekosistemlerce tutulabilmesi için mevcut biyokapasitenin iki katına ihtiyaç vardır. Bu durum, ülkenin üretim ve tüketim yapısının sürdürülebilirlikten uzak olduğunu ve ekosistem üzerinde yoğun baskı oluşturduğunu ortaya koymaktadır. Türkiye'nin toplam ekolojik ayak izi içinde karbon ayak izi %46 ile en büyük payı oluşturmaktadır ve kişi başına yaklaşık 1,17 kha değerine karşılık gelmektedir (Öztürk ve Toprak, 2025).

Küresel ölçekte sera gazı emisyonlarını sınırlamaya yönelik en önemli hukuki düzenlemelerden biri Kyoto Protokolüdür. 1997 yılında imzalanan ve 2005 yılında yürürlüğe giren bu protokol, iklim değişikliğiyle mücadelede uluslararası iş birliğinin çerçevesini belirlemiştir. Protokol, özellikle sanayileşmiş ülkelere 2008–2012 yılları arasında sera gazı salınımlarını 1990 seviyelerinin en az %5 altına indirme yükümlülüğü getirmiştir. Bunun yanı sıra, fosil yakıt kullanımının azaltılması, enerji verimliliğinin artırılması ve yenilenebilir enerji kaynaklarının yaygınlaştırılması temel hedefler arasında yer almaktadır (Bayraç ve Doğan, 2016 ve Kayakuş ve ark., 2023). Ayrıca Kyoto Protokolü, esneklik mekanizmaları (Emisyon Ticareti, Ortak Yürütme ve Temiz Kalkınma Mekanizması) aracılığıyla ülkelerin hedeflerine piyasa temelli çözümlerle ulaşmasını mümkün kılmıştır (Kayakuş ve ark., 2023).

Sera gazları içerisinde en büyük tehdit, atmosferdeki yoğunluğu ve uzun süreli kalıcılığı nedeniyle karbondioksit (CO_2)'tir. CO_2, diğer sera gazlarına kıyasla ısınma üzerindeki etkisi bakımından daha belirleyici olup küresel ısınmanın en kritik faktörü olarak görülmektedir. Bununla birlikte, metan (CH_4) ve diazot monoksit (N_2O) gibi diğer sera gazlarının küresel ısınma potansiyeli CO_2'ye kıyasla çok daha yüksek olmakla birlikte, atmosferdeki yoğunlukları daha düşüktür. Özellikle metan, antropojenik faaliyetler sonucunda (tarım, enerji, atık yönetimi vb.) küresel metan emisyonlarının yaklaşık %60'ını oluşturmaktadır; geri kalan %40'lık kısım ise doğal kaynaklardan (örneğin bataklıklar, okyanuslar, termitler ve hidratlar) salınmaktadır (Aydın ve ark., 2011 ve Karakurt ve ark., 2012).

Bu çerçevede değerlendirildiğinde, Türkiye'nin karbon ayak izi yoğunluğu hem enerji üretim ve tüketim alışkanlıkları hem de tarımsal ve endüstriyel faaliyetlerden kaynaklanmaktadır. Kyoto Protokolü'nün hedefleri doğrultusunda, fosil yakıtlara bağımlılığın azaltılması ve yenilenebilir enerji kullanımının artırılması, Türkiye'nin ekolojik ayak izini biyolojik kapasite sınırlarıyla uyumlu hale getirebilmesi açısından büyük önem taşımaktadır.

METODOLOJİ

Bu çalışma, tarımsal üretim ve hayvancılığa bağlı karbon ayak izi ve sera gazı emisyonlarını inceleyen ulusal ve uluslararası bilimsel literatürün kapsamlı bir derlemesine dayanmaktadır. Literatür taraması PubMed, Scopus, Web of Science, ScienceDirect ve Google Scholar gibi önde gelen veri tabanları kullanılarak gerçekleştirilmiştir. Tarama sürecinde "rice cultivation", "synthetic fertilizers", "stubble burning", "enteric fermentation", "manure management", "feed production", "carbon footprint", "greenhouse gas emissions" ve "climate change" gibi anahtar kelimeler ve bunların Türkçe karşılıkları kullanılmıştır. Çalışmaya, 2000–2024 yılları arasında yayımlanmış, hakemli dergilerdeki araştırma ve derleme makaleler, uluslararası kuruluşların (FAO, IPCC, UNEP) raporları ve metodolojik açıdan güçlü olan diğer bilimsel kaynaklar dahil edilmiştir. Yöntemsel tanımlamaları yetersiz, yalnızca anekdot niteliğinde bilgi sunan veya tarımsal süreçlerle doğrudan ilişkili olmayan yayınlar kapsam dışında bırakılmıştır.

Uygun bulunan çalışmalar, üç ana başlık altında sınıflandırılmıştır: bitkisel üretime ilişkin uygulamalar (pirinç tarımı, sentetik gübre kullanımı, anız yakma), hayvancılığa özgü faaliyetler (enterik fermantasyon, gübre yönetimi, yem üretimi) ve genel tarımsal uygulamalar (enerji kullanımı, su tüketimi, atık yönetimi). Bu kaynaklarda raporlanan sera gazı türleri (CO_2, CH_4, N_2O) ve karbon ayak izi değerleri karşılaştırmalı olarak değerlendirilmiştir. Ayrıca, farklı çalışmalarda kullanılan metodolojiler (örneğin yaşam döngüsü analizi ve emisyon faktörleri yaklaşımı) dikkate alınarak bulgular sentezlenmiştir.

Elde edilen veriler, IPCC'nin sera gazı emisyon faktörleri ve FAO'nun sürdürülebilir besin üretimi kılavuzları temel alınarak analiz edilmiştir. Böylece hem tarımsal hem de hayvansal üretim süreçlerinin çevresel yükleri sistematik biçimde karşılaştırılmıştır. Çalışma yalnızca daha önce yayımlanmış verileri içerdiğinden etik kurul onayı gerekmemektedir. Bununla birlikte literatür seçimi, şeffaflık, tekrarlanabilirlik ve bilimsel geçerlilik ilkeleri çerçevesinde yürütülmüştür.

TARTIŞMA ve SONUÇ

Tarım Kaynaklı Emisyonların Azaltılması

Tarımsal üretim süreçleri, özellikle pirinç yetiştiriciliği ve anız yakma uygulamaları nedeniyle önemli miktarda sera gazı salınımına neden olmaktadır. Ancak bu emisyonların azaltılması mümkündür. Çin ve Japonya gibi pirinç tarımının yoğun olduğu bölgelerde yaygın olarak kullanılan "midseason drenajı" yöntemi, tarlanın büyüme döneminde belirli aralıklarla kurutulmasını sağlayarak metan üretimini kayda değer ölçüde düşürmektedir (Chiodi ve ark., 2016). Benzer şekilde Hindistan'ın kuzeydoğusunda uygulanan aralıklı sulama tekniği de atmosferdeki metan salınımını azaltıcı bir yöntem olarak öne çıkmaktadır. Araştırmalar, yağmur suyuna dayalı pirinç tarımının sürekli su altında tutulan pirinç tarlalarına kıyasla daha düşük metan emisyonu ürettiğini göstermektedir. Bunun temel nedeni, pirinç tarlalarının sulu kaldığı sürece oksijensiz ortamda gerçekleşen mikrobiyal faaliyetlerin organik bileşenleri hızla parçalayarak yoğun metan oluşumuna yol açmasıdır. Dolayısıyla, pirinç tarımında kullanılacak organik girdilerin oksijenli koşullara uyumlu olması, emisyon azaltımında önemli bir strateji olarak görülmektedir. Ayrıca, pirinç tarlalarındaki metan emisyonlarının toprak yapısı, sıcaklık, nem düzeyi ve iklim koşulları gibi çevresel faktörlerden de etkilendiği bilinmektedir (Sah ve Devakumar, 2018).

Tarımsal uygulamalar arasında anız yakma da önemli bir sera gazı kaynağıdır. Anız yakma sırasında atmosfere salınan CO_2, CH_4 ve N_2O emisyonları çevre kirliliğini artırmakta ve ekosistem dengelerini olumsuz etkilemektedir. Bu durum, yalnızca sera gazı emisyonlarını artırmakla kalmamakta, aynı zamanda toprağın verimliliğini düşürerek sürdürülebilir tarıma zarar vermektedir. Sorunun çözümü için üreticilerin bilinçlendirilmesi ve mevcut yasal düzenlemelerin etkin biçimde uygulanması gerekmektedir. Özellikle yerel yönetimlerin ve tarımsal eğitim programlarının desteklenmesi, anız yakmanın yerine toprağı koruyan alternatif yöntemlerin teşvik edilmesi sera gazı salınımlarını azaltmada kritik öneme sahiptir (Şahin ve Avcıoğlu, 2016).

Hayvancılık Kaynaklı Emisyonların Azaltılması

Hayvancılık, küresel sera gazı emisyonlarının en önemli kaynaklarından biridir. Bu sektörde özellikle enterik fermantasyon ve gübre yönetimi yoluyla ortaya çıkan metan ve N_2O salınımları dikkat çekmektedir. Emisyonların azaltılması için çeşitli stratejiler geliştirilmiştir. Bunlardan ilki, hayvan beslenmesinde kullanılan yem katkı maddelerinin metan üretimini sınırlayıcı şekilde seçilmesidir (White ve Hall, 2017). Örneğin, hayvan dışkıları anaerobik koşullarda biyogaz üretimi için yüksek potansiyele sahiptir. Bu yöntem yalnızca sera gazı salınımını azaltmakla kalmamakta, aynı zamanda enerjide dışa bağımlılığı düşürerek ekonomik fayda da sağlamaktadır. Almanya, Fransa, İsviçre, İtalya ve Avusturya başta olmak üzere birçok Avrupa ülkesinde hayvansal atıklar anaerobik arıtım tesislerinde biyogaz üretimi için kullanılmakta, Danimarka'da ise merkezi biyogaz tesisleri aracılığıyla çiftliklerden toplanan gübre işlenerek doğal gaz şebekesine aktarılmakta ve yan ürün olan gübre tekrar tarımda değerlendirilmektedir. Benzer şekilde Çin, Hindistan ve Brezilya gibi ülkelerde de biyogaz teknolojisi yaygın şekilde kullanılmakta ve bu alandaki araştırmalar hızla devam etmektedir (Honan ve ark., 2021 ve Llonch ve ark., 2017).

Sindirim sisteminde besin madde kullanım etkinliğinin artırılması, doğrudan hayvan kaynaklı sera gazı salınımlarının azaltılmasında temel bir ilkedir (White ve Hall, 2017). Çeşitli çalışmalar, rasyon kompozisyonunun metan üretimi üzerinde belirleyici olduğunu ortaya koymaktadır. Örneğin, Beauchemin ve McGinn (2005) kaba yem oranının artmasının metan üretimini yükselttiğini; McGinn ve ark. (2004) ise rasyona yağ ilavesinin mikrobiyal faaliyetleri değiştirerek metan üretimini azaltabileceğini bildirmiştir. Shinkai ve ark. (2012), kaju yemişinden elde edilen aktif bileşenlerin süt sığırı rasyonlarına eklenmesiyle metan emisyonlarının %20 oranında azaldığını rapor etmiştir. Benzer şekilde Morgavi ve ark. (2011), saponin içeren bitkilerin (Yucca schidigera, Sapindus saponaria, çay) koyun rasyonlarında metan üretimini %10–27 düzeyinde düşürdüğünü göstermiştir. Christophersen ve ark. (2008) ise koyunlarda tahıl oranının artırılmasıyla rumen pH'sının düşmesi ve protozoa popülasyonunun azalması sonucu metan üretiminin gerilediğini ortaya koymuştur.

Hayvancılığa bağlı sera gazı salınımının azaltılmasında öne çıkan stratejiler arasında şunlar yer almaktadır: Gübreyle toprağa bırakılan azot miktarının azaltılması, hayvan başına verimliliğin artırılarak toplam hayvan sayısının düşürülmesi, yem rasyonlarında kaba yem oranının azaltılıp kesif yem oranlarının artırılması, tanen ve saponin gibi ikincil metabolitlerce zengin yem bitkilerinin kullanılması, bitkisel yağlar ve uçucu yağlar gibi alternatif yem katkılarının rasyona dahil edilmesidir (Llonch ve ark., 2017).

Bu önlemlerin yanı sıra, iklim değişikliğinin etkilerini azaltmada karbon yutaklarının korunması ve geliştirilmesi büyük önem taşımaktadır. Ormanlar, sulak alanlar, deniz ve kıyı ekosistemleri, çayırlar ve turbalıklar karbon tutma kapasitesine sahip ekosistemlerdir. Bu alanların korunması ve rehabilite edilmesi, sera gazı emisyonlarının azaltılmasına yönelik tarımsal ve hayvansal tedbirlerle birlikte iklim değişikliğine karşı daha etkili bir çözüm sunmaktadır (VijayaVenkataRaman ve ark., 2012).

Sonuçta, küresel ölçekte sera gazı salınımlarının sınırlandırılması sağlansa dahi, atmosferde mevcut gazların etkisinin uzun yıllar devam edeceği öngörülmektedir. Bu nedenle, emisyon azaltım stratejileri ile uyum politikalarının eş zamanlı yürütülmesi gerekmektedir. Başarılı bir sera gazı yönetimi, yalnızca çevresel sürdürülebilirliği desteklemekle kalmayacak, aynı zamanda tarımsal üretim sistemlerinin dayanıklılığını da artıracaktır.

Sonuç ve Öneriler

Küresel ısınma ve iklim değişikliği, günümüzün en ciddi çevresel tehditleri arasında yer almaktadır. Bu tehdidin azaltılmasında karbon ayak izinin düşürülmesi temel adımlardan biridir. Bu çalışma, özellikle pirinç tarımı, sentetik gübre kullanımı, anız yakma gibi bitkisel üretim süreçleri ile enterik fermantasyon, gübre yönetimi ve yem üretimi gibi hayvancılığa özgü faaliyetlerin sera gazı emisyonlarının başlıca kaynakları olduğunu ortaya koymaktadır. Bu bağlamda, artan nüfusun besin gereksinimlerini karşılamak amacıyla başvurulan uygunsuz üretim yöntemlerinin çevresel sürdürülebilirliği tehdit ettiği görülmektedir.

Karbon ayak izini azaltmak için öncelikli olarak üretim alanlarında daha sürdürülebilir uygulamaların hayata geçirilmesi gereklidir. Organik ve çevre dostu gübrelerin kullanımı, pirinç tarımında su yönetimi ve alternatif ekim tekniklerinin benimsenmesi, hayvancılıkta ise yem formülasyonlarının geliştirilmesi, metan emisyonunu azaltan besleme stratejilerinin uygulanması ve gübre yönetiminde biyogaz teknolojilerinin kullanılması önemli katkılar sağlayacaktır. Ayrıca üreticilerin, çiftçilerin ve tüketicilerin bilinçlendirilmesi, bu dönüşümün başarısı açısından kritik bir öneme sahiptir.

Politika yapıcıların, çevresel etkisi düşük üretim sistemlerini teşvik eden destek mekanizmaları geliştirmesi ve karbon salınımını azaltmaya yönelik yasal düzenlemeleri güçlendirmesi de büyük önem taşımaktadır. Bununla birlikte, tüketicilerin bilinçli tercihler yapmaları, düşük karbon ayak izine sahip besinleri talep etmeleri ve israfı azaltmaları, gıda sistemlerinde çevresel yükün azaltılmasına doğrudan katkı sağlayacaktır.

Sonuç olarak, besin üretiminde sürdürülebilirlik odaklı bir yaklaşım benimsenmedikçe, küresel ısınmanın önlenmesi mümkün görünmemektedir. Hem üretici hem tüketici hem de karar vericilerin ortak sorumluluk alması, geleceğin sağlıklı ve yaşanabilir bir dünya olabilmesi için zorunludur.

KAYNAKLAR

Adedeji, O., Reuben, O., Olatoye, O. (2014). Global climate change. *Journal of Geoscience and Environment Protection*, 2 (2), 114-122.

Aydın, G., Karakurt, İ., Aydıner, K. (2011). Antropojenik metan emisyonlarının sektörel analizi. *TÜBAV Bilim Dergisi*, 4 (1), 42-51.

Bayraç, H. N., Doğan, E. (2016). Türkiye'de iklim değişikliğinin tarım sektörü üzerine etkileri. *Eskişehir Osmangazi Üniversitesi İİBF Dergisi*, 11 (1), 23-48.

Beauchemin, K. A., McGinn, S. M. (2005). Methane emissions from feedlot cattle fed barley or corn diets. *Journal of animal science*, 83 (3), 653-661.

Chiodi, A., Donnellan, T., Breen, J., Deane, P., Hanrahan, K., Gargiulo, M., Ó Gallachóir, B. P. (2016). Integrating agriculture and energy to assess GHG emissions reduction: a methodological approach. *Climate Policy*, 16 (2), 215-236.

Chophel, Y. (2022). Global warming and climate change (GWCC) realities. *The Nature, Causes, Effects and Mitigation of Climate Change on the Environment, 3.*

Christophersen, C. T., Wright, A. G., Vercoe, P. E. (2008). In vitro methane emission and acetate: propionate ratio are decreased when artificial stimulation of the rumen wall is combined with increasing grain diets in sheep. *Journal of animal science*, 86 (2), 384-389.

Chuvieco, E., Burgui-Burgui, M., Orellano, A., Otón, G., Ruíz-Benito, P. (2021). Links between climate change knowledge, perception and action: Impacts on personal carbon footprint. *Sustainability*, 13 (14), 8088.

Ejedegba, E. O. (2024). Advancing green energy transitions with ecofriendly fertilizer solutions supporting agricultural sustainability. *International Research Journal of Modernization in Engineering Technology and Science*.

Gahlawat, I. N., Lakra, P. (2020). Global Climate change and its effects. *Integrated Journal of Social Sciences*, 7 (1), 14-23.

Gołasa, P., Wysokiński, M., Bieńkowska-Gołasa, W., Gradziuk, P., Golonko, M., Gradziuk, B., Gromada, A. (2021). Sources of greenhouse gas emissions in agriculture, with particular emphasis on emissions from energy used. *Energies*, 14 (13), 3784.

Gottipati, R., Burra, P. M., Menon, S. (2021). Stubble burning: Root cause, impacts and its management in Indian scenario. *Environment Conservation Journal*, 22 (3), 37-45.

Güven, G., Aysel, İ. (2016). Food Footprint In Daily Life: Opinions About The Consumption of Convenience Food/Gündelik Hayatta Gida Ayak İzi: Hazır Gıda Tüketimine Yönelik Görüşler. *Eğitimde Kuram ve Uygulama*, 12 (2), 403-426.

Harangozo, G., Szigeti, C. (2017). Corporate carbon footprint analysis in practice–With a special focus on validity and reliability issues. *Journal of cleaner production*, 167, 1177-1183.

Herrero, M., Henderson, B., Havlík, P., Thornton, P. K., Conant, R. T., Smith, P., Stehfest, E. (2016). Greenhouse gas mitigation potentials in the livestock sector. *Nature Climate Change*, 6 (5), 452-461.

Honan, M., Feng, X., Tricarico, J. M., Kebreab, E. (2021). Feed additives as a strategic approach to reduce enteric methane production in cattle: modes of action, effectiveness and safety. *Animal Production Science*.

Karakurt, I., Aydin, G., Aydiner, K. (2012). Sources and mitigation of methane emissions by sectors: A critical review. *Renewable energy*, 39 (1), 40-48.

Kayakuş, M., Terzioğlu, M., Erdoğan, D., Zetter, S. A., Kabas, O., Moiceanu, G. (2023). European Union 2030 carbon emission target: The case of Turkey. *Sustainability*, 15 (17), 13025.

Klaaßen, L., Stoll, C. (2021). Harmonizing corporate carbon footprints. *Nature communications*, 12 (1), 6149.

Llonch, P., Haskell, M. J., Dewhurst, R. J., Turner, S. P. (2017). Current available strategies to mitigate greenhouse gas emissions in livestock systems: an animal welfare perspective. *Animal*, 11 (2), 274-284.

Manabe, S. (2019). Role of greenhouse gas in climate change. *Tellus A: Dynamic Meteorology and Oceanography*, 71 (1), 1620078.

McGinn, S. M., Beauchemin, K. A., Coates, T., Colombatto, D. (2004). Methane emissions from beef cattle: Effects of monensin, sunflower oil, enzymes, yeast, and fumaric acid. *Journal of animal science*, 82 (11), 3346-3356.

Morgavi, D. P., Eugène, M., Martin, C., Doreau, M. (2011). Reducing methane emissions in ruminants: is it an achievable goal. *Challenging strategies to promote the sheep and goat sector in* *the current global context. CIHEAM/CSIC/Universidad de Leon/FAO, Zaragoza.(Options Méditerranéennes: Série A. Séminaires Méditerranéens, n. 99)*, 65-73.

Müller, L. J., Kätelhön, A., Bringezu, S., McCoy, S., Suh, S., Edwards, R., Bardow, A. (2020). The carbon footprint of the carbon feedstock CO 2. *Energy & Environmental Science*, 13 (9), 2979-2992.

Öztürk, Ş. T., Toprak, Z. F. (2025). The success of the Kyoto Protocol in reducing carbon emissions in the EU. *International Journal of Global Warming*, 36 (1), 53-66.

Pratt, C., Redding, M., Hill, J., Jensen, P. D. (2015). Does manure management affect the latent greenhouse gas emitting potential of livestock manures?. *Waste management*, 46, 568-576.

Sah, D., Devakumar, A. S. (2018). The carbon footprint of agricultural crop cultivation in India. *Carbon Management*, 9 (3), 213-225.

Shinkai, T., Enishi, O., Mitsumori, M., Higuchi, K., Kobayashi, Y., Takenaka, A., Mochizuki, M. (2012). Mitigation of methane production from cattle by feeding cashew nut shell liquid. *Journal of dairy science*, 95 (9), 5308-5316.

Şahin, G., Avcıoğlu, A. O. (2016). Tarımsal üretimde sera gazları ve karbon ayak izi. *Tarım Makinaları Bilimi Dergisi*, 12 (3), 157-162.

VijayaVenkataRaman, S., Iniyan, S., Goic, R. (2012). A review of climate change, mitigation and adaptation. *Renewable and Sustainable Energy Reviews*, 16 (1), 878-897.

White, R. R., Hall, M. B. (2017). Nutritional and greenhouse gas impacts of removing animals from US agriculture. *Proceedings of the National Academy of Sciences*, 114 (48), E10301-E10308.

Yalcinkaya, S. (2024). Spatiotemporal analysis and mitigation potential of GHG emissions from the livestock sector in Turkey. *Environmental Impact Assessment Review*, 105, 107441.

Yue, Q., Xu, X., Hillier, J., Cheng, K., Pan, G. (2017). Mitigating greenhouse gas emissions in agriculture: From farm production to food consumption. *Journal of Cleaner Production*, 149, 1011-1019.

THERAPEUTIC POTENTIAL OF COENZYME Q_{10} IN METABOLIC SYNDROME: A NUTRACEUTICAL APPROACH TO OXIDATIVE STRESS, INSULIN RESISTANCE, AND INFLAMMATION

METABOLİK SENDROMDA KOENZİM Q_{10}'UN TEDAVİSEL POTANSİYELİ: OKSİDATİF STRES, İNSÜLİN DİRENCİ VE İNFLAMASYONA NUTRASİYONEL BİR YAKLAŞIM

Şemsi Gül YILMAZ KOCAMAN

Karamanoğlu Mehmetbey Üniversitesi, Sağlık Bilimleri Fakültesi, Beslenme ve Diyetetik Bölümü, Karaman, Türkiye

ORCID ID: 0000-0002-2825-7401

ÖZET

Giriş ve Amaç: Koenzim Q10 (CoQ10), mitokondriyal elektron taşınması ve hücresel enerji üretiminde önemli bir rol oynayan lipit çözünür bir bileşiktir. Biyokimyasal işlevinin ötesinde, CoQ10 hücresel savunma mekanizmalarına katkıda bulunan güçlü bir antioksidan görevi görmektedir. Son yıllarda, metabolik sendrom (MetS)'un çeşitli bileşenlerini hafifletmedeki potansiyel rolü nedeniyle CoQ10'a olan ilgi artmıştır. Bu derleme, CoQ10'un biyokimyasal, fizyolojik ve terapötik etkilerini özetlemeyi amaçlamaktadır, özellikle obezite, hipertansiyon, insülin direnci ve kardiyovasküler sağlık üzerindeki etkilerine vurgu yapılmaktadır.

Gereç ve Yöntem: Bu yapılandırılmış literatür incelemesi, PubMed, Scopus ve Web of Science gibi başlıca bilimsel veritabanları kullanılarak gerçekleştirilmiştir. “Koenzim Q10”, “metabolik sendrom”, “oksidatif stres”, ‘hipertansiyon’ ve “insülin direnci” gibi anahtar kelimeler kullanılarak güncel ve ilgili hakemli makaleler seçilmiştir. Çalışmalar, metodolojik kaliteleri ve klinik alaka düzeyleri temelinde değerlendirilmiştir.

Bulgular: Kanıtlar, CoQ10 takviyesinin endotel fonksiyonunu iyileştirdiğini, oksidatif stresi azalttığını ve kan basıncını düzenlediğini göstermektedir. Ayrıca, insülin duyarlılığını ve lipit profillerini iyileştirmede umut verici sonuçlar göstermiştir. Buna ek olarak, dokuya özgü emilim ve dağılım modelleri, klinik etkinliğini etkilemektedir.

Tartışma ve Sonuç: CoQ10, MetS'li bireyler için umut verici bir yardımcı tedavi olarak ortaya çıkmaktadır ve minimal yan etkilerle kardiyometabolik ve antioksidan faydalar sunmaktadır. Enerji metabolizması, mitokondriyal fonksiyon ve redoks homeostazındaki rolü, onu önleyici ve terapötik stratejilerde önemli bir molekül olarak konumlandırmaktadır. Çeşitli hasta popülasyonlarında optimal doz miktarı, biyoyararlanım ve uzun vadeli güvenliğini belirlemek için daha fazla randomize kontrollü çalışma yapılması gerektiği düşünüllmektedir.

Anahtar Kelimeler: Beslenme; Koenzim Q10; Metabolik Sendrom; Nutrasötikler; Oksidatif Stres

ABSTRACT

Introduction and Purpose: Coenzyme Q10 (CoQ10) is a lipid-soluble compound that plays a pivotal role in mitochondrial electron transport and cellular energy production. Beyond its biochemical function, CoQ10 acts as a potent antioxidant that contributes to cellular defense mechanisms. Recent years have seen increased interest in CoQ10 for its potential role in mitigating various components of metabolic syndrome (MetS). This review aims to summarize the biochemical, physiological, and therapeutic effects of CoQ10, with a particular emphasis on its implications in obesity, hypertension, insulin resistance, and cardiovascular health.

Materials and Methods: This structured literature review was conducted using major scientific databases including PubMed, Scopus, and Web of Science. Recent and relevant peer-reviewed articles were selected using keywords such as “Coenzyme Q10,” “metabolic syndrome,” “oxidative stress,” “hypertension,” and “insulin resistance.” Studies were evaluated based on their methodological quality and clinical relevance.

Results: Evidence suggests that CoQ10 supplementation improves endothelial function, reduces oxidative stress, and regulates blood pressure. It has also shown promise in enhancing insulin sensitivity and lipid profiles. Additionally, tissue-specific absorption and distribution patterns influence its clinical efficacy.

Discussion and Conclusion: CoQ10 emerges as a promising adjunctive therapy for individuals with MetS, offering cardiometabolic and antioxidative benefits with minimal side effects. Its role in energy metabolism, mitochondrial function, and redox homeostasis positions it as a crucial molecule in preventive and therapeutic strategies. Further randomized controlled trials are warranted to establish optimal dosing, bioavailability, and long-term safety in diverse patient populations.

Keywords: Coenzyme Q10; Metabolic Syndrome; Nutraceuticals; Nutrition; Oxidative Stress

GİRİŞ

CoQ10, en sık kullanılan besin desteklerinden biri olup hücresel biyoenerjide merkezi bir rol üstlenmektedir. Mitokondriyal enerji üretiminde görev almakla birlikte güçlü bir antioksidan özelliğe sahiptir. Ancak lipofilik yapısı ve yüksek moleküler ağırlığı nedeniyle, diyet yoluyla alındığında gastrointestinal sistemde emilimi sınırlı ve yavaş gerçekleşmektedir. Buna karşın, takviye formunda çözeltilmiş halde bulunan CoQ10’un biyoyararlanımı daha yüksektir. Deneysel çalışmalar, özellikle yüksek doz uygulamalarında, CoQ10’un kalp ve beyin mitokondrisi başta olmak üzere farklı dokular tarafından etkin biçimde alındığını göstermektedir (Cirilli ve ark., 2021).

Günümüzde CoQ10 üzerine yapılan araştırmalar hem tanısal hem de terapötik açıdan artış göstermiştir. Özellikle kardiyovasküler ve nörodejeneratif hastalıklarda faydalı etkilerine ilişkin güçlü bilimsel kanıtlar bulunmaktadır. Son yıllarda yapılan çalışmalar ise, CoQ10 takviyesinin MetS tedavisinde umut verici bir potansiyel taşıdığını ortaya koymaktadır (Casagrande ve ark., 2018 ve Dai ve ark., 2022). Bu bağlamda, bu çalışmada CoQ10’un kimyasal, metabolik ve fizyolojik özellikleri ile birlikte, MetS üzerindeki terapötik etkilerinin ayrıntılı olarak incelenmesi amaçlanmaktadır.

KAVRAMSAL ÇERÇEVE

Metabolik Sendrom

MetS, dislipidemi, arteriyel hipertansiyon, insülin direncine eşlik eden hiperglisemi ve abdominal obezite gibi çeşitli klinik belirti ve semptomlarla karakterize kompleks bir sendromdur. Aynı zamanda mitokondriyal disfonksiyonun gelişiminde önemli rol oynayan çoklu patofizyolojik mekanizmaları içermektedir. MetS’te tümör nekroz faktörü-α (TNF-α), interlökin-6 (IL-6) ve monosit kemotaktik protein-1 (MCP-1) düzeylerinde artışla seyreden inflamatuvar yanıtlar, özellikle obezite ve metabolik bozukluklarda adiposit disfonksiyonu ile insülin direncinin gelişiminde kritik rol oynamaktadır. Adipositlerdeki inflamasyon, azalmış mitokondriyal biyogenez ve bozulmuş enerji homeostazı ile ilişkilendirilmiştir (Casagrande ve ark., 2018).

MetS'nin patogenezinde insülin direnci temel belirleyici mekanizmalardan biridir. Dislipidemi, hiperglisemi, hipertansiyon ve obezite gibi MetS'i oluşturan tüm bileşenler insülin direncinin bir sonucu olarak ortaya çıkmakta ve bu tablo, endotel disfonksiyonu ile ateroskleroz sürecini hızlandırarak klinikte koroner arter hastalığı, inme ve periferik arter hastalığı gibi yüksek mortaliteye sahip komplikasyonlara yol açmaktadır (Earl ve ark., 2005 ve Jakubiak ve ark., 2021).

Tanı kriterleri açısından, Ulusal Kolesterol Eğitim Programı (NCEP) Erişkin Tedavi Paneli, MetS tanısı için beş kriterden en az üçünün bulunmasını yeterli görmektedir. Bu kriterler; abdominal obezite (bel çevresi: kadınlarda >88 cm, erkeklerde >102 cm), düşük HDL kolesterol düzeyleri (erkeklerde <40 mg/dL, kadınlarda <35 mg/dL), hipertansiyon (≥130/85 mmHg), hiperglisemi (açlık plazma glukozu ≥110 mg/dL) ve plazma trigliserit düzeyinin ≥150 mg/dL olmasıdır (Ion ve ark., 2023 ve NCEP Adult Treatment Panel, 2002).

Epidemiyolojik veriler, MetS'in küresel çapta yaygın bir sağlık sorunu olduğunu göstermektedir. NCEP kriterlerine göre Amerika Birleşik Devletleri'nde yapılan bir çalışmada MetS prevalansı erkeklerde %33,7, kadınlarda %35,4 olarak bildirilmiştir (Neeland ve ark., 2024). Türkiye'de Metabolik Sendrom Derneği tarafından gerçekleştirilen 4057 bireyi kapsayan geniş ölçekli saha çalışmasında ise MetS prevalansı kadınlarda %43,5, erkeklerde %41,4 bulunmuştur. Özellikle 60–64 yaş aralığında prevalansın en yüksek düzeye ulaşması, yaşlanmanın MetS gelişiminde önemli bir risk faktörü olduğunu doğrulamaktadır (Engin, 2024 ve Oğuz ve ark., 2010).

Koenzim Q10

CoQ10'un varlığı ilk kez Frederick Crane ve arkadaşları tarafından 1957 yılında mitokondriyal membranlarda tanımlanmıştır. Bu molekül, lipitte çözünebilen ve önemli metabolik rollere sahip benzokinon türevlerinden biridir. CoQ10'un kimyasal formülü 2,3-dimetoksi-5-metil-6-poliizoprenil-1,4-benzokinon olup, doğada yaygın bulunmasından dolayı Latince "her yerde bulunan" anlamına gelen ubikinon olarak da adlandırılmaktadır. CoQ10, biyokimyasal açıdan dokularda hem indirgenmiş formda (ubikinol) hem de okside formda (ubikinon) bulunabilen bir redoks molekülüdür. Molekülün adındaki "10", poliizopren zincirinde yer alan izopren ünitelerinin sayısını ifade etmektedir. İnsanlarda bu zincir 10 üniteden oluştuğu için CoQ10 olarak adlandırılmaktadır. Yapısal olarak K vitaminine benzerlik göstermesine karşın, vücutta endojen olarak sentezlenebilmesi nedeniyle vitamin sınıfına dahil edilmez (Raizner, 2019).

CoQ10, insan vücudunda tüm dokularda bulunmakla birlikte özellikle enerji gereksinimi yüksek organlarda (kalp, böbrek, karaciğer, kas dokusu) yoğun olarak yer almaktadır. Mitokondri, en yüksek CoQ10 konsantrasyonuna sahip hücresel organeldir. CoQ10, adenozin trifosfat (ATP) sentezinde oksidatif fosforilasyon sürecine katılan mitokondriyal enzim kompleksleri için temel bir kofaktördür. Bu nedenle kalp kası gibi yüksek metabolik aktivite gösteren dokularda hücresel enerji üretiminde kritik rol üstlenir (Varela-López ve ark., 2016).

Biyoenerjik fonksiyonlarının yanı sıra CoQ10'un indirgenmiş formu olan ubikinol, güçlü bir lipofilik antioksidan özelliğe sahiptir. Bu form, vücuttaki diğer antioksidanları (ör. α-tokoferol, askorbat) geri dönüştürerek antioksidan savunma sistemini destekler. Aynı zamanda hücre membranlarını oksidatif hasara karşı korur, lipid peroksidasyonunu inhibe eder, kalsiyum kanallarının dolaylı regülasyonuna katkıda bulunur ve α-tokoferolün rejenerasyonunda görev alır. Ek olarak, hücre sinyalizasyonu, gen ekspresyonunun düzenlenmesi ve membran stabilizasyonu gibi biyolojik işlevlerde de rol almaktadır (Casagrande ve ark., 2018).

Biyoyararlanımı ve Taşınımı

CoQ10 lipofilik bir molekül olduğundan, gastrointestinal sistemdeki emilim mekanizması yağda çözünen vitaminler (özellikle E vitamini) ile benzerlik göstermektedir. Emilim, lipitlerin varlığıyla artış gösterir. İnce bağırsakta pankreas enzimleri ve safra tuzları, yağların emilimi için gerekli olan emülsiyon ve misel oluşumunu kolaylaştırır. CoQ10 için bağırsak boyunca belirli bir emilim bölgesi tanımlanamamıştır. Emilim sonrasında, tıpkı E vitamini ve diğer lipofilik bileşiklerde olduğu gibi CoQ10 şilomikronlar aracılığıyla lenf sisteminden dolaşıma taşınır. Karaciğerde metabolize olduktan sonra plazma lipoproteinlerine bağlanır; bunun yaklaşık %58'i LDL, %26'sı ise HDL fraksiyonuna dahil edilir. Daha sonra dalak, akciğer ve böbrek gibi dokulara dağılım gösterir. Oral alımdan sonra plazma CoQ10 düzeyleri 1–2 saat içinde yükselmeye başlar, 6–8 saat içerisinde maksimum seviyeye ulaşır ve yaklaşık 34 saate kadar uzayabilen bir yarılanma ömrüne sahiptir (Bhagavan ve Chopra, 2006).

Bununla birlikte, CoQ10'un suda düşük çözünürlüğü ve yüksek molekül ağırlığı biyoyararlanımını kısıtlamaktadır. Ratlarda yapılan çalışmalarda, oral yolla alınan CoQ10'un yalnızca %2–3 oranında emildiği rapor edilmiştir (Arenas-Jal ve ark., 2020). İnsan çalışmalarında ise besinlerle birlikte alınan CoQ10'un yaklaşık %6'sının absorbe edildiği bildirilmiştir (Alcázar-Fabra ve ark., 2016). Emilim düzeyi, kullanılan formülasyona bağlı olarak değişiklik gösterebilir; CoQ10'un toz formu, suda çözünebilir formları, yağ emülsiyonları veya nanopartikül preparatları farklı biyoyararlanım düzeyleri sunmaktadır. Örneğin, polisorbat 80 gibi emülgatörlerin eklenmesi biyoyararlanımı artırabilmektedir (Raizner, 2019). Ayrıca, indirgenmiş form olan ubikinol, oksitlenmiş form (ubikinon)'a kıyasla daha yüksek biyoyararlanıma sahiptir (Langsjoen ve Langsjoen, 2014).

Besinlerle alındığında CoQ10 başlangıçta oksitlenmiş formda bulunur, eritrositlerde ubikinol formuna indirgenir. Ubikinolün emilim etkinliğinin ubikinona göre daha yüksek olduğu gösterilmiştir. Diyetin içeriği de emilim oranını etkilemektedir; yağ içeren bir öğünle birlikte alındığında CoQ10 emiliminin yaklaşık üç kat arttığı bildirilmiştir (Raygan ve ark., 2016).

Dağılımı ve Metabolizması

İnsanlarda ve hayvanlarda CoQ10 tüm dokularda farklı miktarlarda bulunur. İnsanlarda ve uzun ömürlü diğer memelilerde baskın homolog CoQ10'dur. CoQ10 özellikle mitokondrilerin iç membranlarında yoğunlaşmıştır. İnsan dokularında en yüksek konsantrasyon kalp, karaciğer ve böbrekte gözlenirken, en düşük düzeyler akciğer dokusunda saptanmıştır (Bhagavan ve Chopra, 2006).

CoQ10, tüm dokularda bulunmakla birlikte özellikle yüksek enerji gereksinimi ve yoğun metabolik aktiviteye sahip kalp, böbrek, karaciğer ve kas gibi dokularda daha yüksek konsantrasyonlarda yer almaktadır. Bu dokularda CoQ10 çoğunlukla indirgenmiş formu olan ubikinol şeklinde bulunur ve esas olarak mitokondri içinde yoğunlaşır. Bu durum, molekülün mitokondriyal fonksiyonlar açısından kritik rolünü yansıtmaktadır. İnsanlarda CoQ10 metabolizması tam olarak aydınlatılamamış olsa da, hayvan modelleri üzerinde yapılan çalışmalar CoQ10'un tüm dokularda metabolize edildiğini göstermektedir. Vücuttan atılımı esas olarak safra ve feçes yoluyla gerçekleşirken, daha küçük bir kısmı idrarla uzaklaştırılmaktadır (Alcázar-Fabra ve ark., 2016 ve Arenas-Jal ve ark., 2020).

Fonksiyonları

CoQ10, mitokondriyal solunum zincirinin temel bileşenlerinden biridir ve iç mitokondriyal membranda elektron ve proton transferinde görev alarak enerji üretiminde kritik bir rol oynar. Hücresel redoks reaksiyonlarında, enerji metabolizmasında ve hücre büyümesinde işlev görmesinin yanı sıra, çeşitli çalışmalar CoQ10'un apoptozu baskılayarak hücre ölümünü engelleyebildiğini göstermiştir. Ayrıca, hücre dışı askorbatın redükte formda tutulmasına ve sitozolik NAD^+/NADH oranının düzenlenmesine katkı sağlamaktadır (Toprak ve Ayaz, 2019).

Doğal bir lipofilik antioksidan olan CoQ10, özellikle indirgenmiş formu (ubikinol) ile membran fosfolipid tabakasını ve yapısal bütünlüğünü oksidatif hasardan korur. Hücre membranlarında çoğunlukla doymamış yağ asidi zincirlerine yakın konumlanarak lipid peroksidasyonunu engeller. Lenfosit ve monositler üzerindeki etkileri de dikkate değerdir; CoQ10'dan zengin lenfositlerde oksidatif DNA hasarının azaldığı ve onarıcı enzimatik aktivitelerin arttığı rapor edilmiştir (Raygan ve ark., 2016). Buna ek olarak, CoQ10 hücre içi sinyalizasyon ve gen ekspresyonunun düzenlenmesinde de görev alır. Elektron transferi sırasında oluşan semikinon formlarının oksidasyonu, hidrojen peroksit (H_2O_2) üretimine yol açabilir. Bu reaktif oksijen türü, nükleer faktör kappa B (NF-κB) gibi transkripsiyon faktörlerini aktive ederek gen ekspresyonunu uyarmakta ve hücresel adaptasyon süreçlerinde rol oynamaktadır (Casagrande ve ark., 2018).

Kaynakları

CoQ10, insan organizmasında hem endojen hem de eksojen kaynaklardan sağlanmaktadır. Endojen olarak, asetil-KoA ve tirozin üzerinden kolesterol biyosentezi ile ortak yolağa sahip bir metabolik süreçte sentezlenmektedir. Eksojen kaynaklar arasında ise kırmızı et, kümes hayvanları ve balık en zengin diyet kaynaklarını oluşturmaktadır. Ticari CoQ10 ise üç farklı yöntemle elde edilmektedir: hayvan dokularından ekstraksiyon, mikroorganizma fermantasyonu ve kimyasal sentez (Ercan ve Sedef, 2010).

CoQ10 için günlük önerilen spesifik bir alım miktarı bulunmamaktadır. Bununla birlikte, diyet yoluyla alınan CoQ10 miktarının ortalama 3–5,5 mg/gün arasında olduğu, bunun %50'den fazlasının kırmızı et ve kümes hayvanlarından, geri kalan kısmının ise balık, süt ürünleri, yağlar, meyve ve sebzelerden sağlandığı bildirilmiştir. İsveç'te yapılan bir çalışmada ortalama alımın 2–20 mg/gün arasında değiştiği belirlenmiştir. Ancak bu miktar, serum CoQ10 düzeylerini terapötik etki gösterecek düzeye çıkarmak için yetersizdir. Nitekim, serum CoQ10 düzeyinde anlamlı bir artışın sağlanabilmesi için günde yaklaşık 100 mg CoQ10 takviyesi gerekmektedir. Kandaki fizyolojik seviyeler yaklaşık 1 µg/mL iken, terapötik etkinlik için bu düzeyin 2 µg/mL civarında olması gerektiği bildirilmektedir. Diyetle bu düzeye ulaşmak oldukça güçtür; örneğin, ringa balığı gibi CoQ10 açısından zengin besinlerin tüketimi bile bu miktarı karşılamada yetersiz kalmaktadır (Raizner, 2019).

CoQ10'un tüm dokularda sentezleniyor olması, normal koşullarda vücudun eksojen kaynaklara bağımlı olmadığını göstermektedir. Ancak endojen biyosentez yaşla birlikte azalma eğilimine girmekte ve çeşitli patofizyolojik durumlarda dokulardaki CoQ10 seviyeleri kritik düzeylere düşebilmektedir. Genetik mutasyonlar, yaşlanma, kanser ve özellikle statin grubu ilaçlar bu düşüşte önemli rol oynamaktadır. Statinler, kolesterol biyosentezinde hız kısıtlayıcı basamağı inhibe ettiklerinden, yalnızca kolesterol düzeylerini değil aynı zamanda CoQ10 seviyelerini de azaltabilmektedir (Varela-López ve ark., 2016).

Dolayısıyla, CoQ10'un endojen sentezi, toplam vücut havuzuna diyetle alınan CoQ10'dan çok daha fazla katkıda bulunmaktadır. Normal koşullarda diyetle alınan CoQ10'un vücut düzeylerine katkısının %1'den az olduğu bildirilmiştir. Bu nedenle, serum veya doku seviyelerinin riskli düzeylere düştüğü durumlarda eksojen takviye ile destek sağlanması gerekmektedir (Raizner, 2019). Doz ve Güvenirlik

CoQ10, günümüzde farklı ticari formlarda – toz, kapsül ya da yağ çözeltisi – ve hem indirgenmiş (ubikinol) hem de oksitlenmiş (ubikinon) formda piyasada bulunmaktadır. Çözünmüş formülasyonların biyoyararlanımı, toz veya kristalize formlara göre belirgin şekilde daha yüksektir.

Klinik ve farmakokinetik çalışmalar, ubikinol formunun ubikinona kıyasla daha iyi emildiğini ve plazma konsantrasyonlarını daha hızlı yükselttiğini göstermiştir. Ayrıca, plazma CoQ10 düzeylerindeki artış ile alınan doz arasında belirli bir eşiğe kadar doğrusal bir ilişki bulunmakta, çözünmüş formülasyonlar daha yüksek plazma düzeyleri sağlamaktadır (Langsjoen ve Langsjoen, 2014).

Çeşitli klinik araştırmalarda farklı hastalık gruplarında CoQ10'un farklı dozlarda uygulandığı bildirilmiştir. Genel olarak 22–400 mg/gün dozlarının güvenli kabul edildiği, yan etkilerin ise çoğunlukla 1200 mg/gün üzerindeki dozlarda daha sık görüldüğü rapor edilmiştir (Sifuentes-Franco ve ark., 2022). Bununla birlikte, CoQ10 hem bir besin bileşeni hem de farmasötik bir ajan olarak oldukça güçlü bir güvenlik profil sergilemektedir. Sağlıklı yetişkinlerde plazma CoQ10 referans aralığı 0,40–1,91 mmol/L arasında değişmekte olup, terapötik etki için genellikle öğünlerle birlikte günde iki kez 100 mg CoQ10 kullanımı önerilmektedir (Cirilli ve ark., 2021 ve Villalba ve ark., 2010).

Kardiyovasküler hastalıklarla ilişkili klinik çalışmalarda günlük 100–400 mg CoQ10 kullanıldığı, nörodejeneratif hastalıklar (Parkinson, Huntington, amyotrofik lateral skleroz) söz konusu olduğunda ise 600–3000 mg/gün gibi daha yüksek dozların uygulandığı bildirilmektedir (Cirilli ve ark., 2021 ve Raygan ve ark., 2016). Hayvan modellerinde yapılan kronik yüksek doz çalışmalarında, CoQ10'un kalp ve beyin mitokondrileri dahil olmak üzere birçok dokuda biriktiği ve yalnızca biyokimyasal düzeyde değil, aynı zamanda fonksiyonel iyileşmelere de yol açtığı gösterilmiştir (Arenas-Jal ve ark., 2020; Hou ve ark., 2023 ve Raizner, 2019). Bu bulgular, CoQ10'un yüksek güvenlik profili sayesinde farklı klinik alanlarda geniş bir kullanım potansiyeline sahip olduğunu ortaya koymaktadır.

Yan Etkileri

CoQ10 takviyeleri genel olarak oldukça güvenli kabul edilmektedir. Endojen olarak sentezlenmesi ve organizma tarafından iyi tolere edilmesine rağmen, çeşitli klinik çalışmalarda nadiren hafif düzeyde yan etkiler rapor edilmiştir. Özellikle gebelik, emzirme dönemi ve çocukluk çağında güvenli kullanımı konusunda yeterli kanıt bulunmadığından, bu gruplarda dikkatle uygulanmalıdır. Bildirilen yan etkiler arasında dispepsi, ishal, bulantı, kusma gibi gastrointestinal şikâyetlerin yanı sıra baş ağrısı, baş dönmesi ve alerjik deri döküntüleri yer almaktadır (Raizner, 2019).

Ayrıca CoQ10'un antiplatelet ve hipotansif etkileri olabileceği için, bu takviyeyi kullanan hastaların klinik olarak izlenmesi önerilmektedir. Bunun yanı sıra, CoQ10 ve kolesterolün aynı biyosentetik yol olan mevalonat yolunu paylaşması nedeniyle, HMG-CoA redüktaz inhibitörleri (statinler) ile birlikte kullanım sonrası serum CoQ10 düzeylerinde belirgin düşüşler gözlenmiştir. Bu durum, özellikle statin tedavisi alan bireylerde CoQ10 desteğinin önemini ortaya koymaktadır (Casagrande ve ark., 2018).

METODOLOJİ

Bu çalışma, MetS CoQ10'un terapötik potansiyelini inceleyen ulusal ve uluslararası literatürün kapsamlı bir değerlendirmesine dayanmaktadır. PubMed, Scopus ve Google Scholar gibi veri tabanlarında yapılan taramalarda "Coenzyme Q10", "ubiquinone", "ubiquinol", "metabolic syndrome", "hypertension", "oxidative stress", "insulin resistance" ve "inflammation" anahtar kelimeleri kullanılmıştır.

Bu konuda yayımlanmış randomize kontrollü çalışmalar, klinik denemeler, meta-analizler ve derleme makaleler incelenmiş, CoQ10'un MetS ile ilişkili oksidatif stres, insülin direnci ve inflamasyon üzerindeki etkilerini değerlendiren yayınlar dikkate alınmıştır. Bulgular, ilgili biyolojik mekanizmalar çerçevesinde sentezlenerek sunulmuştur.

TARTIŞMA ve SONUÇ

Hastalıklar Üzerindeki Etkisi

Hipertansiyon

CoQ10, arteriyel vazodilatasyonda rol oynayan nitrik oksit (NO) sentezini indükleme ve endotelyal fonksiyonları iyileştirme kapasitesi nedeniyle hipertansiyonla ilişkilendirilen önemli bir bileşiktir. Klinik çalışmalar, CoQ10 takviyesinin kan basıncını düşürücü etkiler gösterdiğini ve yüksek dozlarda dahi ciddi yan etkilere yol açmadığını ortaya koymuştur (Rosenfeldt ve ark., 2007 ve Young ve ark., 2007). Bu konuya yönelik olarak yayımlanan 12 randomize kontrollü çalışmayı (362 birey) içeren bir meta-analiz, CoQ10 takviyesinin sistolik ve diyastolik kan basıncında anlamlı düşüş sağladığını göstermiştir (Rosenfeldt ve ark., 2007).

Ayrıca, klinik gözlemler CoQ10'un hipertansiyonlu bireylerde etkinliğini desteklemektedir. Örneğin, sistolik hipertansiyonu olan hastalarda 120 mg/gün CoQ10 takviyesi ile 12 hafta süresince yapılan izlemde sistolik kan basıncında 17,8 mmHg, diyastolik kan basıncında ise 2,6 mmHg'lik anlamlı azalma rapor edilmiştir (Burke ve ark., 2001). Hipertansiyon ve koroner arter hastalığı birlikteliği olan bireylerde yapılan bir başka çalışmada ise sistolik basınçta 16 mmHg, diyastolik basınçta 9 mmHg düşüş gözlenmiş ve bu bulgular istatistiksel olarak anlamlı bulunmuştur (Singh ve ark., 1999). Daha küçük ölçekli araştırmalarda da benzer şekilde, kan basıncı üzerine olumlu etkilerin yanı sıra, hipertrigliseridemisi olan hastalarda C-reaktif protein ve kreatinin düzeylerinde azalma saptanmıştır (Cicero ve ark., 2005).

Her ne kadar CoQ10 doğrudan bir antihipertansif ilaç olarak tanımlanmasa da, hipertansiyon patofizyolojisinde rol oynayan bazı metabolik süreçleri olumlu yönde etkileyebilmektedir. Endotel ve vasküler düz kas hücrelerinde gevşemeyi artırarak periferik vasküler direnci azaltır. Ayrıca hipertansif bireylerde aşırı üretilen serbest radikallerle etkileşime girerek nitrik oksit ve süperoksit arasındaki zararlı reaksiyonu engeller; böylece NO biyoyararlanımını koruyarak vazodilatör etkinin devamlılığını sağlar. Bunun dışında, CoQ10'un kan viskozitesi, diyastolik fonksiyon, aldosteron sekresyonu ve renal sodyum tutulumu gibi mekanizmalar üzerinde de düzenleyici etkiler gösterebileceği belirtilmektedir (Kumar ve ark., 2009).

Obezite

Obezite, plazma CoQ10 düzeylerinde azalma ile ilişkilendirilebilmektedir. Bariatrik cerrahi sonrası yapılan çalışmalarda obez bireylerde plazma kolesterol düzeylerinde düzelme görülmesine rağmen, CoQ10 düzeylerinde anlamlı bir azalma rapor edilmiştir. Bu durumun, cerrahi sonrası lipid emiliminin azalmasına bağlı olabileceği öne sürülmektedir (Raygan ve ark., 2016). Ancak MetS'li bireylerde yapılan bazı çalışmalarda, plazma CoQ10 düzeylerinde belirgin bir değişim olmadığı bildirilmiştir (Bour ve ark., 2011).

Obez bireylerde yürütülen klinik araştırmalar, CoQ10 takviyesinin vücut ağırlığı üzerine umut verici etkiler gösterebileceğini ortaya koymuştur. Morbid obez bireylerde yalnızca enerji kısıtlaması uygulananlarla karşılaştırıldığında, enerji kısıtlamasına ek olarak CoQ10 takviyesi alanların iki ay sonunda daha fazla ağırlık kaybı yaşadığı belirlenmiştir (Sohet ve Delzenne, 2012).

Hayvan modellerinde ise bulgular kısmen farklıdır. Obez farelerde yapılan çalışmalarda, CoQ10 takviyesinin vücut ağırlığı üzerinde doğrudan bir etkisi gözlenmezken; serum lipid düzeylerini düşürdüğü, glukoz ve insülin metabolizmasını iyileştirdiği rapor edilmiştir (Moazen ve ark., 2015 ve Raizner, 2019). Yüksek yağlı diyetle beslenen obez farelerde ise CoQ10'un insülin duyarlılığını artırıcı ajanlarla birlikte uygulanması, vücut ağırlığında ve adipozitede artışı engellemiş; bu etki, adipoz dokuda lipid oksidasyonunun artışıyla ilişkilendirilmiştir (Hou ve ark., 2023). Ayrıca, adiposit farklılaşmasının azalması ve reaktif oksijen türlerinin baskılanması, CoQ10'un obeziteye karşı koruyucu potansiyelini destekleyen mekanizmalar olarak değerlendirilmektedir (Zila-Velasque ve ark., 2024).

Diyabet

Tip 2 diyabetli dislipidemik hastalarda yürütülen iki klinik müdahale çalışmasında CoQ10 takviyesinin HbA1c düzeylerinde anlamlı iyileşme sağladığı rapor edilmiştir (Mehmetoglu ve ark., 2011 ve Moazen ve ark., 2015). Ancak diğer bir çalışmada, CoQ10 desteğinin glisemik kontrol üzerinde belirgin bir etkisi olmadığı bildirilmiştir (Kolahdouz ve ark., 2013). Bu farklı sonuçlar, hasta profili, uygulanan dozlar ve çalışma süreleri gibi faktörlere bağlı olarak değişiklik gösterebilir.

Deneysel diyabet modellerinde elde edilen bulgular ise daha tutarlıdır. Diyabetik hayvanlarda yapılan çalışmalarda CoQ10 takviyesinin oksidatif stresi azalttığı, trigliserit, total kolesterol, LDL ve VLDL kolesterol düzeylerini düşürdüğü, buna karşılık HDL kolesterol düzeyini yükselttiği ve genel kan parametrelerinde iyileşme sağladığı gözlenmiştir (Gholami ve ark., 2019 ve Zahedi ve ark., 2014). Bu sonuçlar, CoQ10'un diyabetle ilişkili dislipidemi ve metabolik bozuklukların yönetiminde potansiyel bir destekleyici ajan olabileceğini göstermektedir.

İnflamasyon

İnflamasyon, endojen ya da eksojen faktörlerin dokulara zarar vermesi sonucu ortaya çıkan ve bozulan homeostazın yeniden sağlanmasına katkıda bulunan fizyolojik bir yanıttır. Bu süreçte tümör nekroz faktörü-α (TNF-α), interlökin-1 (IL-1) ve interlökin-6 (IL-6) gibi çeşitli proinflamatuar sitokinler üretilmektedir. CoQ10 takviyesinin inflamasyon üzerindeki etkileri incelendiğinde, interlökin-5, trombin, vitronektin, vitronektin reseptörü ve C-reaktif protein (CRP) gibi moleküller üzerinde düzenleyici etkiler gösterdiği saptanmıştır. Ayrıca CoQ10'un, IL-6 ve prostaglandin E2 gibi proinflamatuar mediyatörlerin üretimini azalttığı bildirilmiştir (Sifuentes-Franco ve ark., 2022).

Akut inflamasyon modelleri üzerine yapılan hayvan deneylerinde, CoQ10 takviyesi mortalite oranlarını ve oksidatif stresi azaltmış, aynı zamanda lipid peroksidasyonu üzerinde koruyucu bir etki göstermiştir. İlginç bir şekilde, CoQ10'un mikroRNA düzenleyici rolü de ortaya konmuştur. MikroRNA'lar, transkripsiyon sonrası gen ekspresyonunu düzenleyen ve hücre proliferasyonu, insülin sekresyonu, doğuştan gelen bağışıklık ve inflamasyon gibi süreçlerde kritik işlevlere sahip yaklaşık 22 nükleotidlik kodlamayan RNA'lar olup, CoQ10'un özellikle miRNA-146a üzerinde düzenleyici bir etkiye sahip olduğu rapor edilmiştir (Schmelzer ve ark., 2009).

CoQ10'un antiinflamatuar etkileri, diğer antioksidan bileşiklerle birlikte alındığında daha da güçlenmektedir. Yüksek yağlı ve kolesterol açısından zengin bir diyet ile birlikte CoQ10 ve E vitamini uygulanan deneklerde, serum CRP ve sitokin seviyelerinde belirgin azalmalar gözlenmiştir (Sangouni ve ark., 2022).

Yağ dokusunda inflamasyon sürecinde makrofaj infiltrasyonu ve fibroblast aktivasyonu, adipöz dokunun kronik iltihaplanmasını tetikleyen temel mekanizmalardandır (Casagrande ve ark., 2018). Ayrıca CoQ10, preadiposit farklılaşması sırasında enerji üretimi için gerekli ATP'nin sağlanmasına katkıda bulunur. Ancak obez bireylerde, artmış yağ depolanması ve mitokondriyal disfonksiyon nedeniyle CoQ10 düzeylerinin azaldığı görülmektedir (Mehmetoglu ve ark., 2011). Bu disfonksiyona, aşırı enerji alımı, reaktif oksijen türlerinin artışı, toksik lipid türlerinin üretimi, endoplazmik retikulum stresi, inflamatuar süreçler ve mitokondriyal fisyon gibi faktörler yol açabilmektedir (Sangouni ve ark., 2022).

Özetle, CoQ10 inflamasyonu baskılamada; adipogenez ve adiposit farklılaşmasını azaltma, yağ oksidasyonunu ve enerji harcamasını artırma yoluyla metabolik dengeye katkıda bulunabilir. Bu özellikleri, obezite ve MetS ile ilişkili inflamatuar süreçlerin yönetiminde CoQ10'u önemli bir nutrasötik aday haline getirmektedir (Casagrande ve ark., 2018).

Metabolik Sendrom Üzerine Etkileri

MetS, abdominal obezite, hiperglisemi, dislipidemi ve arteriyel hipertansiyon gibi birbirini tetikleyen risk faktörlerinin bir araya gelmesiyle karakterize kompleks bir klinik tablodur. MetS, kardiyovasküler olaylar ve Tip 2 diyabet gelişme riskini yaklaşık 2–6 kat artırmaktadır (Casagrande ve ark., 2018). Son yıllarda MetS ile birlikte karaciğer değişikliklerinin, özellikle de non-alkolik yağlı karaciğer hastalığının görülme sıklığında da artış rapor edilmiştir (Zila-Velasque ve ark., 2024).

Diyabetik hiperglisemi ve metabolik bozukluklar, antioksidan savunma sisteminin yetersiz aktivasyonu ve mitokondriyal fonksiyon kaybı ile ilişkilidir (Raygan ve ark., 2016). Diyabetik bireylerde düşük CoQ10 konsantrasyonlarının rapor edilmesi, mitokondriyal fonksiyon bozukluğu ile paralellik göstermektedir (Casagrande ve ark., 2018). Klinik çalışmalarda, 8 hafta boyunca günde 100 mg CoQ10 takviyesi verilen MetS, Tip 2 diyabet ve koroner arter hastalığı olan obez bireylerde insülin, HOMA-IR ve HOMA-B değerlerinde anlamlı iyileşmelerin yanı sıra plazmada toplam antioksidan kapasitenin arttığı gözlenmiştir (Masenga ve ark., 2023). Benzer şekilde, Tip 2 diyabetli kadınlarda yapılan 12 haftalık bir çalışmada, 100 mg/gün CoQ10 takviyesi açlık glikozu, HOMA-IR, toplam kolesterol, LDL kolesterol ve ferritin düzeylerini düşürmüş; HDL kolesterol seviyelerinde ise artış sağlamıştır (Gholami ve ark., 2018). Başka bir çalışmada da Tip 2 diyabetli bireylerde açlık glikoz düzeylerinde anlamlı düşüşler kaydedilmiştir (Zahedi ve ark., 2014). Bununla birlikte, CoQ10'un glisemik kontrol üzerindeki etkisini kesin olarak ortaya koymak için daha geniş ölçekli klinik araştırmalara ihtiyaç vardır.

MetS'de endotel disfonksiyonu ve arteriyel hipertansiyonun gelişiminde glukoz intoleransı ve oksidatif stres önemli rol oynamaktadır. CoQ10'un antihipertansif etkilerini değerlendiren meta-analizlerde, takviye sonrası sistolik ve diyastolik kan basıncında azalma eğilimi rapor edilmiştir (Rosenfeldt ve ark., 2007). Örneğin, 10 hafta süreyle günde iki kez 50 mg CoQ10 verilen hastalarda kan basıncında anlamlı düşüş gözlenmiştir (Tabrizi ve ark., 2018). Ancak bir çalışmada 12 hafta süren 100 mg/gün CoQ10 takviyesinin MetS hastalarında kan basıncı üzerinde anlamlı bir etki oluşturmadığı bildirilmiştir (Young ve ark., 2012). Bu farklı sonuçlar, CoQ10'un antihipertansif etkilerinin bireysel farklılıklar, hastalık evresi ve uygulanan dozlarla ilişkili olabileceğini göstermektedir.

Lipid metabolizması üzerine yapılan araştırmalar da benzer şekilde heterojen bulgular sunmaktadır. CoQ10'un yağ asidi oksidasyonunu ve PPARα aracılı lipolizi artırarak lipid profili üzerinde iyileştirici etkilere sahip olabileceği bildirilmiştir (Moazen ve ark., 2018). Bazı çalışmalarda toplam kolesterol ve LDL kolesterol seviyelerinde düşüş, HDL kolesterol seviyelerinde artış gözlenmiş (Kolahdouz ve ark., 2013); ancak başka araştırmalarda 8 haftalık takviyenin lipid parametreleri üzerinde belirgin bir etki göstermediği rapor edilmiştir (Moazen ve ark., 2018).

Sonuç olarak, CoQ10 yalnızca güçlü antioksidan özellikleriyle değil, aynı zamanda inflamatuar yanıtların modülasyonu, lipid metabolizmasının düzenlenmesi ve endotel fonksiyonunun iyileştirilmesi yoluyla da MetS tedavisinde potansiyel bir adjuvan olarak değerlendirilmektedir. Bununla birlikte, mevcut bulgular çelişkili olup, MetS tedavisinde ideal dozun belirlenmesi, uzun dönem güvenlilik ve etkinlik verilerinin ortaya konması için daha fazla randomize kontrollü çalışmaya ihtiyaç vardır.

KAYNAKLAR

Alcázar-Fabra, M., Navas, P., Brea-Calvo, G. (2016). Coenzyme Q biosynthesis and its role in the respiratory chain structure. Biochimica et Biophysica Acta (BBA)-Bioenergetics, 1857(8), 1073-1078.

Arenas-Jal, M., Suñé-Negre, J. M., García-Montoya, E. (2020). Coenzyme Q10 supplementation: Efficacy, safety, and formulation challenges. Comprehensive reviews in food science and food safety, 19(2), 574-594.

Bhagavan HN, Chopra RK. (2006). Coenzyme Q10: absorption, tissue uptake, metabolism and pharmacokinetics. Free Radic Res. 40(5): 445-53.

Bour S, Carmona MC, Galinier A. (2011). Coenzyme Q as an antiadipogenic factor. Antioxid Redox Signal.14:403–413.

Casagrande, D., Waib, P. H., Júnior, A. A. J. (2018). Mechanisms of action and effects of the administration of Coenzyme Q10 on metabolic syndrome. Journal of Nutrition & Intermediary Metabolism, 13, 26-32.

Cicero AF, Derosa G, Miconi A, (2005). Possible role of ubiquinone in the treatment of massive hypertriglyceridemia resistant to PUFA and fibrates. Biomed Pharmacother. 59: 312–317.

Cirilli, I., Damiani, E., Dludla, P. V., Hargreaves, I., Marcheggiani, F., Millichap, L. E., Tiano, L. (2021). Role of coenzyme Q10 in health and disease: An update on the last 10 years (2010–2020). Antioxidants, 10(8), 1325.

Dai, S., Tian, Z., Zhao, D., Liang, Y., Liu, M., Liu, Z., Yang, Y. (2022). Effects of coenzyme Q10 supplementation on biomarkers of oxidative stress in adults: A GRADE-assessed systematic review and updated meta-analysis of randomized controlled trials. Antioxidants, 11(7), 1360.

Earl S, Ford ES, Giles WH, Mokdad AH. (2005). Prevalence of the metabolic syndrome defined by the international diabetes federation among adults in the US. Diabetes Care 28: 2745-9.

Engin, A. (2024). The definition and prevalence of obesity and metabolic syndrome: correlative clinical evaluation based on phenotypes. Obesity and Lipotoxicity, 1-25.

Ercan, P., Sedef, E. L. (2010). Koenzim Q10'un beslenme ve sağlık açısından önemi ve biyoyararlılığı. TÜBAV Bilim Dergisi, 3(2), 192-200.

Gholami, M., Rezvanfar, M. R., Delavar, M., Abdollahi, M., Khosrowbeygi, A. (2019). Effects of coenzyme Q10 supplementation on serum values of gamma-glutamyl transferase, pseudocholinesterase, bilirubin, ferritin, and high-sensitivity C-reactive protein in women with type 2 diabetes. Experimental and Clinical Endocrinology & Diabetes, 127(05), 311-319.

Hou, S., Tian, Z., Zhao, D., Liang, Y., Dai, S., Ji, Q., Yang, Y. (2023). Efficacy and Optimal Dose of Coenzyme Q10 Supplementation on Inflammation-Related Biomarkers: A GRADE-Assessed Systematic Review and Updated Meta-Analysis of Randomized Controlled Trials. Molecular Nutrition & Food Research, 67(13), 2200800.

Ion, R. M., Sibianu, M., Hutanu, A., Beresescu, F. G., Sala, D. T., Flavius, M., Neagoe, R. M. (2023). A comprehensive summary of the current understanding of the relationship between severe obesity, metabolic syndrome, and inflammatory status. Journal of clinical medicine, 12(11), 3818.

Jakubiak, G. K., Osadnik, K., Lejawa, M., Osadnik, T., Goławski, M., Lewandowski, P., Pawlas, N. (2021). "Obesity and insulin resistance" is the component of the metabolic syndrome most strongly associated with oxidative stress. Antioxidants, 11(1), 79.

Kolahdouz, R. M., Hosseinzadeh-Attar, M. J., Eshraghian, M. R., Nakhjavani, M., Khorami, E., Esteghamati, A. (2013). The effect of coenzyme Q10 supplementation on metabolic status of type 2 diabetic patients. Minerva gastroenterologica e dietologica, 59(2), 231-236.

Kumar A, Kaur H, Devi P, (2009). Role of coenzyme Q10 (CoQ10) in cardiac disease, hypertension and Meniere-like syndrome. Pharmacol Ther.124:259–268.

Langsjoen PH, Langsjoen AM. (2014). Comparison study of plasma Coenzyme Q10 levels in healthy subjects supplemented with ubiquinol versus ubiquinone. Clin Pharmacol Drug Dev. 3(1): 13-7.

Masenga, S. K., Kabwe, L. S., Chakulya, M., Kirabo, A. (2023). Mechanisms of oxidative stress in metabolic syndrome. International journal of molecular sciences, 24(9), 7898.

Mehmetoglu, I., Yerlikaya, F. H., Kurban, S. (2011). Correlation between vitamin A, E, coenzyme Q10 and degree of insulin resistance in obese and non-obese subjects. Journal of clinical biochemistry and nutrition, 49(3), 159-163.

Moazen, M., Mazloom, Z., Ahmadi, A., Dabbaghmanesh, M. H., Roosta, S. (2015). Effect of coenzyme Q10 on glycaemic control, oxidative stress and adiponectin in type 2 diabetes. J Pak Med Assoc, 65(4), 404-408.

National Cholesterol Education Program (NCEP) (US). Expert Panel on Detection, & Treatment of High Blood Cholesterol in Adults. (2002). Third report of the National Cholesterol Education Program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III) (No. 2). National Cholesterol Education Program, National Heart, Lung, and Blood Institute, National Institutes of Health.

Neeland, I. J., Lim, S., Tchernof, A., Gastaldelli, A., Rangaswami, J., Ndumele, C. E., Després, J. P. (2024). Metabolic syndrome. Nature Reviews Disease Primers, 10(1), 77.

Oğuz A, Altuntaş Y, Karsidağ K, Güleç S, Temizhan A, Akalın AA, (2010). The prevalence of metabolic syndrome in Turkey. Obesity Reviews 11: 486-91.

Raizner, A. E. (2019). Coenzyme Q10. Methodist DeBakey cardiovascular journal, 15(3), 185.

Raygan, F., Rezavandi, Z., Tehrani, S. D., Farrokhian, A., Asemi, Z. (2016). The effects of coenzyme Q10 administration on glucose homeostasis parameters, lipid profiles, biomarkers of inflammation and oxidative stress in patients with metabolic syndrome. European journal of nutrition, 55(8), 2357-2364.

Rosenfeldt, F., Haas, S., Krum, H., Hadj, A., Ng, K., Leong, J.Y (2007). Coenzyme Q10 in the treatment of hypertension: a meta-analysis of the clinical trials. Journal of human hypertension, 21(4), 297-306.

Sangouni, A. A., Taghdir, M., Mirahmadi, J., Sepandi, M., Parastouei, K. (2022). Effects of curcumin and/or coenzyme Q10 supplementation on metabolic control in subjects with metabolic syndrome: a randomized clinical trial. Nutrition Journal, 21(1), 62.

Schmelzer C, Kitano M, Rimbach G. (2009). Effects of ubiquinol-10 on micro RNA146a expression in vitro and in vivo. Mediators Inflamm. 2009: 415-437.

Sifuentes-Franco, S., Sánchez-Macías, D. C., Carrillo-Ibarra, S., Rivera-Valdés, J. J., Zuñiga, L. Y., Sánchez-López, V. A. (2022, March). Antioxidant and anti-inflammatory effects of coenzyme Q10 supplementation on infectious diseases. In Healthcare (Vol. 10, No. 3, p. 487). MDPI.

Singh, R., Niaz, M., Rastogi, S., Shukla, P., Thakur, A. (1999). Effect of hydrosoluble coenzyme Q10 on blood pressures and insulin resistance in hypertensive patients with coronary artery disease. Journal of human hypertension, 13(3), 203-208.

Sohet, F. M., Delzenne, N. M. (2012). Is there a place for coenzyme Q in the management of metabolic disorders associated with obesity?. Nutrition reviews, 70(11), 631-641.

Tabrizi, R., Akbari, M., Sharifi, N., Lankarani, K. B., Moosazadeh, M., Kolahdooz, F., Asemi, Z. (2018). The effects of coenzyme Q10 supplementation on blood pressures among patients with metabolic diseases: a systematic review and meta-analysis of randomized controlled trials. High Blood Pressure & Cardiovascular Prevention, 25(1), 41-50.

Toprak, K., Ayaz, A. Koenzim Q10: Biyolojik Aktivitesi ve Sağlık Üzerine Etkisine Güncel Bakış. Hacettepe Üniversitesi Sağlık Bilimleri Fakültesi Dergisi, 6(2), 95-111.

Varela-López, A., Giampieri, F., Battino, M., Quiles, J.L. (2016). Coenzyme Q and its role in the dietary therapy against aging. Molecules, 21(3), 373.

Villalba, J.M., Parrado, C., Santos-Gonzalez, M., Alcain, F.J. (2010) Therapeutic use of coenzyme Q10 and coenzyme Q10-related compounds and formulations. Expert opinion on investigational drugs, 19(4), 535-554.

Young, J. M., Florkowski, C. M., Molyneux, S. L., McEwan, R. G., Frampton, C. M., Nicholls, M. G., George, P. M. (2012). A randomized, double-blind, placebo-controlled crossover study of coenzyme Q10 therapy in hypertensive patients with the metabolic syndrome. American journal of hypertension, 25(2), 261-270.

Zahedi, H., Eghtesadi, S., Seifirad, S., Rezaee, N., Shidfar, F., Heydari, I., Jazayeri, S. (2014). Effects of CoQ10 Supplementation on Lipid Profiles and Glycemic Control in Patients with Type 2 Diabetes: a randomized, double blind, placebo-controlled trial. Journal of Diabetes & Metabolic Disorders, 13(1), 81.

Zila-Velasque, J. P., Grados-Espinoza, P., Challapa-Mamani, M. R., Sánchez-Alcántara, F., Cedillo-Balcázar, J., Cs, A. D., Benites-Zapata, V. A. (2024). Prevalence of metabolic syndrome and its components according to altitude levels: a systematic review and meta-analysis. Scientific Reports, 14(1), 27581.

INTERMITTENT FASTING IN TYPE 2 DIABETES MANAGEMENT: GLYCEMIC CONTROL, FEASIBILITY, AND PERSONALIZATION

TİP 2 DİYABET YÖNETİMİNDE ARALIKLI ORUÇ: GLİSEMİK KONTROL, UYGULANABİLİRLİK VE BİREYSELLEŞTİRME

Tevfik KOÇAK

Gümüşhane University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Gümüşhane, Turkey

ORCID ID: https://orcid.org/0000-0002-4096-6796

Buse SARIKAYA

Amasya University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Amasya, Turkey

ORCID ID: https://orcid.org/0000-0001-8555-6662

Mehmet Arif İÇER

Amasya University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Amasya, Turkey

ORCID ID: https://orcid.org/0000-0002-1632-7484

ABSTRACT

Introduction and Purpose: Type 2 diabetes mellitus has emerged as a major global public health issue due to its rapidly increasing prevalence and the microvascular and macrovascular complications it causes. In addition to impairing quality of life, this chronic condition imposes a significant burden on healthcare systems. Achieving glycemic control is crucial for preventing complications and slowing disease progression. However, the treatment process is often complicated by interindividual variability, highlighting the need for personalized approaches to diabetes management. In recent years, intermittent fasting (IF) protocols have garnered attention for their potential benefits, including weight loss, enhanced insulin sensitivity, and improvements in various metabolic parameters. Different IF models are increasingly being studied for their ability to support glycemic control in individuals with type 2 diabetes and may also help reduce cardiometabolic risk factors. Nevertheless, the literature has yet to reach a clear consensus regarding the safety and efficacy of IF in this population. In particular, the risk of hypoglycemia in individuals using insulin and/or oral antidiabetic medications necessitates careful evaluation of these dietary interventions. Moreover, due to biological differences, lifestyle factors, and variable treatment responses among individuals, the personalization and long-term sustainability of IF protocols remain topics of ongoing debate.

Scope of the Review: This review comprehensively examines the effects of intermittent fasting models on blood glucose regulation, their feasibility, adaptability to individual needs, and sustainability in the management of type 2 diabetes.

Keywords: Glycemic Control, Intermittent Fasting, Type 2 Diabetes Management.

ÖZET

Giriş ve Amaç: Tip 2 diyabetes mellitus, hızla artan prevalansı ve yol açtığı mikrovasküler ve makrovasküler komplikasyonlar nedeniyle önemli bir küresel halk sağlığı sorunu olarak ortaya çıkmıştır. Yaşam kalitesini olumsuz etkilemesinin yanı sıra bu kronik durum, sağlık sistemleri üzerinde de ciddi bir yük oluşturmaktadır. Komplikasyonların önlenmesi ve hastalığın ilerleyişinin yavaşlatılması için glisemik kontrolün sağlanması kritik öneme sahiptir. Ancak, bireyler arası farklılıklar tedavi sürecini karmaşık hale getirmekte ve diyabet yönetiminde kişiselleştirilmiş yaklaşımların gerekliliğini ortaya koymaktadır. Son yıllarda, aralıklı oruç (AO) protokolleri; kilo kaybı, insülin duyarlılığında artış ve çeşitli metabolik parametrelerde iyileşme gibi potansiyel yararları nedeniyle dikkat çekmektedir. Farklı AO modellerinin tip 2 diyabetli bireylerde glisemik kontrolü destekleme potansiyeli artan şekilde araştırılmakta olup, aynı zamanda kardiyometabolik risk faktörlerini azaltmaya da katkıda bulunabileceği düşünülmektedir. Bununla birlikte, mevcut literatürde AO'nun bu hasta grubunda güvenilirliği ve etkinliği konusunda net bir uzlaşıya varılamamıştır. Özellikle insülin ve/veya oral antidiyabetik ilaç kullanan bireylerde hipoglisemi riskinin varlığı, bu beslenme yaklaşımlarının dikkatli bir şekilde değerlendirilmesini zorunlu kılmaktadır. Ayrıca, biyolojik farklılıklar, yaşam tarzı etkenleri ve tedaviye verilen yanıtların değişkenliği nedeniyle AO protokollerinin kişiselleştirilmesi ve uzun vadede sürdürülebilirliği halen tartışmalı konular arasında yer almaktadır.

Derlemenin Kapsamı: Bu derleme, aralıklı oruç modellerinin kan şekeri regülasyonu üzerindeki etkilerini, uygulanabilirliğini, bireysel gereksinimlere uyarlanabilirliğini ve tip 2 diyabet yönetiminde sürdürülebilirliğini kapsamlı bir şekilde incelemektedir.

Anahtar Kelimeler: Glisemik Kontrol, Aralıklı Oruç, Tip 2 Diyabet Yönetimi.

GİRİŞ

Tip 2 diabetes mellitus (DM), insülin eksikliği veya insülin etkisindeki defektler nedeniyle karbonhidrat, yağ ve proteinden yeterli düzeyde yararlanılamayan, sürekli tıbbi bakım gerektiren kronik bir metabolizma hastalığıdır (Günalay ve ark., 2016). Diabetes mellitus giderek artan sıklığı, kontrolsüz bırakıldığında mortalite ve morbiditeyi artıran komplikasyonları ve hem birey hem de toplum üzerinde oluşturduğu ekonomik yük nedeniyle önemli bir halk sağlığı sorunu olarak değerlendirilmektedir (Tümer & Çolak, 2012).

Son yıllarda sosyo-ekonomik düzeyin artması ve yaşam tarzı değişiklikleri sonucunda tip 2 diyabet prevalansı hızla yükselmektedir. Dünya genelinde 2017 yılı verilerine göre 18–99 yaş arası 451 milyon diyabetli birey bulunduğu, bu sayının 2045 yılında 693 milyona ulaşacağı öngörülmektedir (Yılmaz ve ark., 2019).

Tip 2 DM'nin, tanı konmadan yaklaşık 9–12 yıl önce başladığı kabul edilmektedir. Bu dönemde mikrovasküler komplikasyonlar genellikle belirlenemediğinden, tanı anında hastaların %15–20'sinde retinopati, %5–10'unda proteinüri saptanabilmektedir. Bu komplikasyonların ilerlemesinin önlenmesi ve yaşam kalitesinin artırılması için glisemik kontrolün sağlanması en etkin yöntem olarak kabul edilmektedir. Ancak kronik komplikasyonlar geliştikten sonra tedavi zorlaşmakta, sağlık harcamalarında diyabetli bireylerin payı hızla artmaktadır (Ersoy ve ark., 2006).

Obez bireylerde diyabet insidansı, obez olmayanlara göre 3–4 kat daha fazladır. Yapılan çalışmalar, aşırı kilonun ve obezitenin tip 2 DM ile güçlü bir şekilde ilişkili olduğunu ortaya koymaktadır. Kesitsel ve uzunlamasına araştırmalar, beden kitle indeksi (BKİ) ile tip 2 DM riski arasında pozitif bir ilişki olduğunu göstermektedir. Çoğu araştırmacı, özellikle yağ hücrelerinin insüline duyarsızlığı nedeniyle obez bireylerde insülin direncinin geliştiğini öne sürmektedir. Bu bağlamda, obeziteye bağlı kronik hastalıkların giderek yaygınlaşması küresel çapta bir sağlık stratejisinin gerekliliğini ortaya koymaktadır (Zang ve ark., 2022).

Son yıllarda enerji miktarından ziyade enerji alımının zamanlamasına odaklanan aralıklı oruç (intermittent fasting, IF) diyetlerinin; kilo kaybını teşvik ettiği, insülin direncini azalttığı, glisemik kontrolü iyileştirdiği ve kardiyometabolik hastalık riskini düşürdüğü gösterilmiştir. Bu etkilerinin yanı sıra, IF protokolleri özellikle obez bireyler arasında popüler hale gelmiştir. Ancak metabolik sendrom, prediyabet ve tip 2 DM'li kişilerde IF'nin etkilerini değerlendiren çalışmalar sınırlı olup, DM yönetiminde kullanımı ile ilgili literatür oldukça azdır (Sevindik & Uçar, 2024).

Tip 2 DM ve Glisemik Regülasyonun Önemi

DM, yaşam tarzı değişikliklerine bağlı olarak modern toplumda oldukça yaygın hale gelmiştir. İnsülin eksikliği, insülin direnci veya her ikisinin sonucu olarak gelişen kronik hiperglisemi ile karakterize metabolik bir hastalık grubudur. DM'nin öncülü olan prediyabet de en az tip 2 DM kadar önemli olup, ilerlemesini önlemek için yönetilmesi gerekmektedir (Ojo ve ark., 2022).

Tip 2 DM, obezite ile yakından ilişkili olup mikrovasküler, makrovasküler ve nöropatik komplikasyonların gelişimini sınırlamak için uzun süreli tıbbi müdahale gerektiren kronik bir hastalıktır. Bu komplikasyonların nedenleri arasında insülin direnci, yetersiz insülin sekresyonu ve uygunsuz glukagon salınımı bulunmaktadır (Furmli ve ark., 2018).

Glisemik kontrolün yetersizliği, akut komplikasyonlarla ölüme, kronik komplikasyonlarla ise yaşamı tehdit eden organ hasarına yol açabilmektedir. Bu nedenle diyabet tedavisinin temel amacı glisemik kontrolü sağlamak, komplikasyonları önlemek veya ilerlemesini yavaşlatmaktır. Yapılan çalışmalar, etkin glisemik kontrolün komplikasyonları önleyebileceğini veya geciktirebileceğini göstermektedir. Ancak ilaç tedavisine rağmen hem dünyada hem de Türkiye'de birçok diyabetli bireyde glisemik kontrolün sağlanamadığı bildirilmektedir (Avcı & Selçuk, 2016).

Glikoz homeostazının bozulması sonucu, hastalarda hastaneye yatış ve ölüm dahil olmak üzere ciddi komplikasyonlara yol açabilen yüksek serum glikoz seviyeleri gözlenmektedir. Diyet kalitesi ve miktarı diyabet patogenezinde merkezi rol oynamaktadır. Bu nedenle, enerji kısıtlaması ve özellikle aralıklı oruç (IF) gibi beslenme yaklaşımları araştırmacıların ilgisini çekmektedir (Saeed ve ark., 2021).

Aralıklı Oruç ve Metabolik Etkileri

Aralıklı oruç (IF), kilo kaybı ve insülin duyarlılığını artırma gibi metabolik faydaları bulunan, kalori miktarından çok alım zamanlamasına odaklanan bir beslenme modelidir (Sözer & Avuk, 2023). Özellikle 5:2 diyeti ve zaman kısıtlı beslenme (time-restricted eating, TRE) yöntemlerinin tip 2 DM'li bireylerde glisemik kontrolü iyileştirdiği bildirilmektedir (Çelik & Köksal, 2020). Kısa süreli kalori kısıtlaması ile elde edilen kilo kaybı, kan şekeri ve HbA1c seviyelerinin düşmesine, hatta tip 2 DM'nin remisyonuna katkı sağlayabilmektedir (Pammer ve ark., 2024).

Prediyabetin ilerlemesini önlemede ve tip 2 DM'nin yönetiminde kapsamlı yaşam tarzı değişiklikleri güvenli ve etkili bir yaklaşım olarak kabul edilmektedir. Bu bağlamda Akdeniz diyeti, çok düşük kalorili diyetler, düzenli egzersiz ve enerji kısıtlaması geleneksel olarak önerilmektedir (Ojo ve ark., 2022).

Aralıklı oruç, istenildiği kadar beslenme dönemleri ile kısıtlı enerji alımını içeren bir yöntem olarak tanımlanmakta; kan şekeri düşüşü, insülin duyarlılığının artışı, yağlanma azalması, inflamasyonun azalması, oksidatif stresin düşmesi ve yağ asidi oksidasyonunun artışı gibi çok sayıda metabolik fayda sağlamaktadır (Patel ve ark., 2024). Ayrıca IF'nin insülin ve leptin gibi hormonların sirkadiyen ritimlerini düzenlediği, tokluk ve açlık durumlarının bu hormon seviyelerindeki değişikliklerde rol oynadığı bildirilmektedir (Joaquim ve ark., 2022).

Aralıklı Oruç Modelleri

Aralıklı oruç, beslenme ve açlık dönemlerini içeren bir beslenme şekli olup farklı uygulama protokolleri mevcuttur. Bunlar arasında zaman kısıtlı beslenme (time-restricted eating, TRE), alternatif gün açlığı (alternate-day fasting, ADF), modifiye açlık (5:2 diyeti) ve Ramazan orucu gibi farklı uygulama biçimleri yer almaktadır. Her modelin etkisi bireylerin metabolik durumuna, genetik özelliklerine ve yaşam tarzlarına bağlı olarak değişebilmektedir (Gül & Akyüz, 2022).

Zaman Kısıtlı Beslenme (TRE)

Zaman kısıtlı beslenme, günün belirli saatlerinde açlık, belirli saatlerinde ise beslenmenin uygulandığı bir modeldir. Genellikle 4, 6, 8 veya 10 saatlik beslenme periyotları tercih edilir ve bu süre dışında bireyler kalori tüketmezler. Açlık dönemlerinde bol sıvı tüketimi teşvik edilir (Ezpeleta ve ark., 2024). Uygulanan protokole göre açlık süresi 20 saate kadar uzayabilmektedir. En sık kullanılan yöntemler 16:8, 18:6 ve 20:4 modelleridir (Sevindik & Uçar, 2024).

Erken zamanlı beslenme (ör. 18:6, 20:4), geç zamanlı beslenmeye kıyasla kan glukozu, açlık insülini, insülin direnci ve HbA1c üzerinde daha olumlu etkiler göstermektedir (Ezpeleta ve ark., 2024; Fanti ve ark., 2021). Sutton ve arkadaşlarının prediyabetli bireyler üzerinde yürüttükleri bir çalışmada, zaman kısıtlı beslenmenin vücut ağırlığı kaybı olmaksızın kardiyometabolik parametreler üzerinde olumlu etkiler sağladığı; açlık insülini, insülin direnci, sistolik ve diyastolik kan basıncında düşüşlere yol açtığı rapor edilmiştir (Çelik & Köksal, 2020). Ayrıca bu beslenme şeklinin HbA1c, inflamatuar belirteçler, açlık-tokluk hormonları ve kan basıncı üzerinde olumlu etkileri olduğu da belirtilmektedir (Çelik & Köksal, 2020).

Alternatif Gün Açlığı (ADF)

Alternatif gün açlığı, bir gün açlığın (enerjinin %0–25'inin alındığı) diğer gün ad libitum (enerji kısıtlaması olmaksızın) beslenmenin uygulandığı bir yöntemdir. Açlık ve beslenme periyotlarının süresi 20–40 saat arasında değişebilmektedir. Yapılan çalışmalarda ADF'nin HbA1c, açlık insülini, inflamatuar belirteçler, açlık-tokluk hormonları ve kan basıncı üzerinde olumlu etkiler sağladığı bildirilmektedir (Çelik & Köksal, 2020).

Modifiye Açlık (5:2 Diyeti)

5:2 diyeti, haftanın 5 günü ad libitum beslenme, 2 günü ise enerji kısıtlaması ile uygulanan bir modeldir. Açlık günlerinde günlük enerji ihtiyacının %20–25'i alınır. Açlık günleri ardışık veya ardışık olmayan günler şeklinde düzenlenebilir (Kalaycı & Altun, 2021).

Sürekli enerji kısıtlaması (continuous energy restriction, CR) ile 5:2 diyet karşılaştırıldığında; insülin, HOMA-IR, HbA1c, C-reaktif protein (CRP), total kolesterol (TK), trigliserid (TG), LDL, leptin, sistolik ve diyastolik kan basıncı değerlerinde benzer şekilde azalmalar elde edilmiştir. Ayrıca vücut ağırlığı ve vücut bileşiminde sağlanan olumlu değişimler de CR ile karşılaştırıldığında paralellik göstermektedir (Çelik & Köksal, 2020).

Ramazan Orucu

Ramazan orucu, zaman kısıtlı beslenmenin dini bir formu olarak kabul edilmektedir. Bu süreçte sahur ve iftar arasında besin alımı tamamen kısıtlanırken, iftar ile sahur arasında beslenme serbesttir. Coğrafi konuma bağlı olarak açlık süresi 10–20 saat arasında değişmektedir. Enerji kısıtlaması zorunlu olmasa da, öğün sayısının azalması nedeniyle vücut ağırlığında düşüş görülebilmektedir. Çeşitli çalışmalar Ramazan orucunun açlık glukozu, HOMA-IR, LDL, HDL ve trigliserid düzeyleri üzerinde olumlu etkiler sağladığını göstermektedir (Çelik & Köksal, 2020).

Uzamış Açlık

72 saate kadar sürebilen uzamış açlıkta enerji kaynaklarının büyük bölümü yağlardan sağlanmakta, hücresel düzeyde onarım süreçleri hızlanmakta ve otofaji mekanizmaları aktive olmaktadır. Bu durum diyabet ve metabolik bozuklukların yönetiminde potansiyel faydalar sağlayabilmektedir. Ancak, uzamış açlığın diyabet tedavisindeki uzun vadeli etkinliği konusunda daha fazla çalışmaya ihtiyaç vardır (Vendelbo ve ark., 2012).

Glisemik Regülasyon Üzerindeki Etkileri

Aralıklı oruç (AO) protokollerinin HbA1c, açlık insülini, inflamasyon ve oksidatif stres üzerinde olumlu etkiler gösterdiği, insülin duyarlılığını artırarak glisemik kontrolü iyileştirdiği ve kardiyometabolik riskleri azalttığı bildirilmektedir (Çelik & Köksal, 2020; Sevindik & Uçar, 2024; Soy & Ekici, 2024).

İnsülin Sinyal Yollarının Düzenlenmesi ve Glukoz-İnsülin Duyarlılığı

Bu oruç protokolleri, besin mevcudiyetine yanıt olarak metabolizmayı düzenleyen hücresel bir enerji sensörü olan AMP-aktive protein kinazı (AMPK) aktive etmektedir (Hardie, 2011; Long & Zierath, 2006). AMPK aktivasyonu, glukoz alımını artırmakta, yağ asidi oksidasyonunu desteklemekte ve karaciğerde glukoz üretimini baskılamaktadır (Towler & Hardie, 2007). Oruç, glukoz kullanımından yağ asidi ve keton kullanımına metabolik bir geçişi indükleyerek glukoz toleransını ve insülin duyarlılığını geliştirmektedir. Ayrıca, aralıklı oruç büyüme hormonu/insülin-benzeri büyüme faktörü-1 aksını düzenleyerek yaşlanmayı geciktirebilir, kanser riskini azaltabilir ve çeşitli sinyal yollarını etkileyerek oksidatif stres ile inflamasyonu azaltmaktadır (Ciastek ve ark., 2025).

Enerji alımının kısıtlanması, insülin seviyelerini düşürerek glisemik homeostazı iyileştirir ve insülin duyarlılığını artırır. Bu süreçte, glikozun depolanması ve kullanımında iskelet kası, karaciğer ve beyaz yağ dokusundaki reseptörler rol oynar. Obez bireylerde zaman kısıtlı beslenme (TRE) lipid oksidasyonunu artırır, plazma glikozunu düşürür ve insülin duyarlılığını geliştirir. Ayrıca glukagon salınımının artması, karaciğerde glikojen yıkımı ve keton cisimcikleri üretimini tetikler; bu döngü pankreas β-hücrelerinin dinlenmesini sağlayarak daha dengeli bir insülin yanıtına yol açar.

AO'nun insülin seviyelerini düşürerek insülin duyarlılığını artırabileceği ve glukoz metabolizmasını optimize edebileceği gösterilmiştir. İnsülin, glikozun depolanması ve kullanılmasında temel bir rol üstlenmekte olup etkilerini özellikle iskelet kası, karaciğer ve beyaz yağ dokusundaki reseptörler aracılığıyla göstermektedir (Petersen & Shulman, 2018). Aralıklı açlık ile enerji alımının azalması, uzun vadede insülin üretiminin düşmesine yol açarak glisemik homeostazda iyileşme sağlayabilir (Sevindik & Uçar, 2024). Ayrıca obez veya aşırı kilolu bireylerde zaman kısıtlı beslenmenin (TRE) lipid oksidasyonunu artırdığı, plazma glikoz seviyelerini düşürdüğü ve insülin duyarlılığını iyileştirdiği rapor edilmiştir (Rovira-Llopis ve ark., 2024).

HbA1c ve Açlık Glukozu

Araştırmalar, AO'nun HbA1c ve açlık glukoz seviyelerini düşürebildiğini göstermektedir. Carter ve ark. (2018) tarafından yürütülen çalışmada, 12 ay boyunca uygulanan modifiye açlık diyeti (5:2) ve sürekli enerji kısıtlı diyet karşılaştırılmış; her iki grupta da HbA1c düzeyleri azalırken, AO grubunda daha fazla kilo kaybı gözlenmiştir. Benzer şekilde Guo ve ark. (2024), 5:2 protokolünün HbA1c düzeylerinde anlamlı azalma sağladığını ve sürekli enerji kısıtlamasına kıyasla daha etkili olduğunu bildirmiştir.

İnflamasyon ve Oksidatif Stres

AO'nun antiinflamatuar ve antioksidan etkileri, diyabete bağlı komplikasyonların önlenmesinde rol oynayabilir. Enerji kısıtlaması ve açlık dönemleri otofajiyi aktive ederek mitokondriyal fonksiyonların korunmasına, DNA onarımına ve hücresel yenilenmeye katkıda bulunmaktadır (Devran & Saka, 2023). Sutton ve ark. (2018) tarafından yapılan bir çalışmada, erken zaman kısıtlı beslenme (6 saatlik beslenme penceresi, öğleden sonra 15.00'ten önce sonlanan akşam yemeği) prediyabetli erkeklerde kilo kaybı olmaksızın insülin duyarlılığını, inflamatuar belirteçleri ve oksidatif stresi iyileştirmiştir.

Sirkadiyen Ritim ve Metabolik Etkiler

Zaman kısıtlı beslenme, sirkadiyen ritimleri destekleyerek metabolik sağlığı olumlu etkileyebilir. Düzensiz yeme alışkanlıklarının metabolik sendrom riskini artırdığı gözlemsel çalışmalarla gösterilmiştir (Wilkinson ve ark., 2020). Bu bulgu, AO'nun biyolojik saat ile uyumlu bir beslenme modeli olarak önemini ortaya koymaktadır.

Bireyselleştirilmiş Yaklaşım mı, Sürdürülebilir Strateji mi?

AO'nun Tip 2 diyabet yönetiminde etkili bir strateji olduğu kabul edilmekle birlikte, farklı protokollerin uzun vadeli glisemik kontrol üzerindeki etkileri halen tartışmalıdır. Wang ve ark. (2021), AO'nun sürekli enerji kısıtlamalı diyetler ile benzer glisemik sonuçlar sağladığını, ancak kilo kaybında daha üstün olduğunu belirtmiştir. Bununla birlikte, uzun dönem uyum ve yaşam tarzına entegrasyonun başarının belirleyici unsurları olduğu vurgulanmaktadır.

Kişiselleştirilmiş beslenme stratejilerinin önemi, bireylerin postprandiyal glisemik tepkilerindeki farklılıklarla açıklanabilir. Wilkinson ve ark. (2020), metabolik sendromlu bireylerde kişiselleştirilmiş zaman kısıtlı beslenmenin glisemik kontrolü iyileştirdiğini rapor etmiştir. Bu nedenle, **aralıklı açlık protokollerinde bireyselleştirilmiş yaklaşımların kısa vadede etkili olduğu, ancak uzun vadede sürdürülebilir yaşam tarzı stratejilerine dönüştürülmesinin komplikasyonların önlenmesinde daha faydalı olabileceği** anlaşılmaktadır.

Aralıklı Oruç İle İlgili Potansiyel Riskler ve Yan Etkileri

Aralıklı oruç yöntemleri, hipoglisemi riski, besin ögeleri yetersizlikleri ve kas kaybı gibi olumsuz etkilerle ilişkilendirilebilmektedir. Bu nedenle özellikle diyabetli bireylerde söz konusu yöntemlerin uygulanması sırasında dikkatli bir izlem gereklidir. Ayrıca, antidiyabetik ilaçların dozaj ayarlamaları da önemli bir rol oynamaktadır.

Hipoglisemi

Aralıklı açlık diyetleriyle ilişkili en önemli risk hipoglisemidir. Özellikle insülin (hem bolus hem bazal) ve sülfonilüreler (kısa etkili meglitinidler dahil) kullanan hastalarda hipoglisemi görülme olasılığı yüksektir (Kalaycı & Altun, 2021). İnsülin ve sülfonilüreler dışındaki ilaç gruplarında ise aralıklı açlık sonrası hipoglisemi riski daha düşüktür. Bu nedenle, diyabetli bireylerde açlık dönemlerinde antidiyabetik ilaç ve insülin dozlarının gün ve miktar açısından yeniden düzenlenmesi gerekmektedir.

Yakın dönemde yapılan bir meta-analiz sonucuna göre, özellikle insülin kullanan tip 2 diyabetli (T2DM) bireylerde aralıklı açlık uygulamalarının güvenliği konusunda kesin bir yargıya varılamamıştır. Bununla birlikte, Corley ve ark. (2018) tarafından yapılan bir çalışmada, ardışık ve ardışık olmayan iki günlük aralıklı açlık protokolü uygulanan T2DM'li bireylerde hipoglisemi oranlarının kabul edilebilir düzeylerde olduğu bildirilmiştir. Ayrıca, uygun diyet tedavisi, hasta eğitimi ve antidiyabetik ilaçların titrasyonu ile hipoglisemi riskinin azaltılabileceği gösterilmiştir

Diyabetli bireylerde kademeli aralıklı açlık protokolü uygulanabilmektedir. Bu yaklaşıma göre, ilk dört hafta boyunca günlük kan glukoz izlemi eşliğinde 12 saat açlık – 12 saat besin alımı olacak şekilde bir plan yapılabilir. Kan glukoz regülasyonu sağlanabilirse açlık süresi 16 saate çıkarılarak "zaman kısıtlı beslenme" modeline (16:8) geçilebilir. Daha ileri dönemlerde ise, bireyin glukoz yanıtına göre erken zaman kısıtlı beslenme (18:6) veya periyodik açlık modelleri uygulanabilmektedir. Antidiyabetik ilaç kullanan hastalarda mutlaka doz ayarlamaları yapılmalıdır. Bu protokol, diyabetli bireylerde uygulanabilecek örnek bir aralıklı açlık modeli olarak değerlendirilmektedir (Soy & Ekici, 2024).

Besin Ögesi Eksiklikleri ve Kas Kaybı

Aralıklı açlık uygulamalarının bir diğer olası riski vitamin–mineral yetersizlikleri ile yetersiz protein alımına bağlı kas kaybıdır. Protein alımına dikkat edilmemesi durumunda özellikle kas kütlesinde kayıp meydana gelebilir. Bu nedenle, bireylerin haftada kaç gün açlık uyguladıkları ve beslenme günlerinde (ad libitum günlerde) tükettikleri besinlerin içeriği önemlidir. Gerektiğinde vitamin ve mineral desteği önerilebilmektedir (Veronese & Reginster, 2019). Bunun yanında, yetersiz enerji alımı ve sıvı tüketiminin de çeşitli riskler barındırdığı bildirilmektedir. Dehidrasyona bağlı gelişebilecek baş dönmesi, bulantı, uykusuzluk, senkop, düşme, migren tipi baş ağrıları, güçsüzlük ve aşırı açlık hissi gibi durumlar, diyabet hastası olsun ya da olmasın tüm bireylerde görülebilecek olumsuzluklar arasında yer almaktadır (Oakley, 2018).

SONUÇ

Bu çalışmada, aralıklı oruç (AO) ve uzamış açlık protokollerinin (özellikle 72 saatlik açlık) tip 2 diyabetli bireylerde glisemik regülasyon üzerindeki etkileri ele alınmıştır. Bulgular, bu tür diyet yaklaşımlarının glisemik kontrolü iyileştirebileceğini ve T2DM tedavi sürecine katkı sağlayabileceğini göstermektedir. Özellikle zaman kısıtlı beslenme (TRE) ve uzamış açlık uygulamalarının HbA1c düzeylerini düşürmede ve insülin duyarlılığını artırmada etkili olduğu bildirilmiştir.

Aralıklı oruç ve uzamış açlık, insülin düzeylerinde azalma sağlayarak insülin duyarlılığını artırmakta, bu da glukoz metabolizmasında iyileşmeye yol açmaktadır. 72 saatlik açlık protokollerinin, uzun süreli kalori kısıtlamalarıyla benzer şekilde kan glukozunu düşürdüğü ve metabolik parametreleri iyileştirdiği belirtilmektedir. Ayrıca bu tür protokoller inflamasyon ve oksidatif stresi azaltarak T2DM'nin ilerleyişinde rol oynayan mekanizmalar üzerinde olumlu etkilere sahip olabilir.

Bununla birlikte, bireyler arasında biyolojik yanıt farklılıklarının bulunması önemli bir sınırlılıktır. Bazı hastalar bu yöntemleri sürdürülebilir bulurken, bazıları için uygulama zorlukları mevcuttur. Ayrıca, insülin ve sülfonilüre kullanan hastalarda hipoglisemi riskinin artabileceği göz önünde bulundurulmalıdır.

Literatürde Ramazan orucu gibi dini oruçların da kısa süreli aralıklı açlığa benzer metabolik etkiler oluşturabildiği bildirilmektedir. Ancak, 72 saatlik açlık gibi daha uzun süreli protokollerin metabolik sendrom ve kardiyometabolik hastalıklar üzerindeki uzun vadeli etkilerini değerlendiren daha fazla çalışmaya ihtiyaç vardır.

Gelecekteki araştırmaların, farklı aralıklı oruç modellerinin (ör. 5:2 diyeti, alternatif gün orucu) daha geniş hasta gruplarında uygulanarak sürdürülebilirlik ve uzun vadeli glisemik kontrol üzerindeki etkileri incelemesi önerilmektedir. Ayrıca, kardiyometabolik sağlık göstergeleri üzerindeki etkiler, bireyler arası yanıt farklılıkları göz önünde bulundurularak değerlendirilmelidir.

Kaynakça

Avcı, D., & Selçuk, K. T. (2016). Tip 2 diyabetli hastalarda glisemik kontrol durumu ve etkileyen etmenler: Depresyonun rolü. *Gümüşhane Üniversitesi Sağlık Bilimleri Dergisi*, *5*(3), 70-79.

Carter, S., Clifton, P. M., & Keogh, J. B. (2018). Effect of intermittent compared with continuous energy restricted diet on glycemic control in patients with type 2 diabetes: a randomized noninferiority trial. *JAMA network open*, *1*(3), e180756-e180756.

Ciastek, B., Kapłon, K., & Domaszewski, P. (2025). A Comprehensive Perspective on the Biological Effects of Intermittent Fasting and Periodic Short-Term Fasting: A Promising Strategy for Optimizing Metabolic Health. *Nutrients*, *17*(13), 2061.

Corley, B., Carroll, R., Hall, R., Weatherall, M., Parry-Strong, A., & Krebs, J. (2018). Intermittent fasting in type 2 diabetes mellitus and the risk of hypoglycaemia: a randomized controlled trial. *Diabetic Medicine*, *35*(5), 588-594.

Çelik, Ö. M., & Köksal, E. (2020). Aralıklı açlık uygulamalarının vücut bileşimi ve biyokimyasal parametreler üzerine etkisi: Bir literatür derlemesi. *Mersin Üniversitesi Sağlık Bilimleri Dergisi*, *13*(2), 249-271.

Devran, B. S., & Saka, M. (2023). Aralıklı Açlık. *Başkent Üniversitesi Sağlık Bilimleri Fakültesi Dergisi*, *8*(1), 62-72.

Ersoy, C., Tuncel, E., Özdemir, B., Ertürk, E., & İmamoğlu, Ş. (2006). İnsülin kullanan tip 2 diabetes mellituslu hastalarda diyabet eğitimi ve metabolik kontrol. *Uludağ Üniversitesi Tıp Fakültesi Dergisi*, *32*(2), 43-47.

Ezpeleta, M., Cienfuegos, S., Lin, S., Pavlou, V., Gabel, K., Tussing-Humphreys, L., & Varady, K. A. (2024). Time-restricted eating: Watching the clock to treat obesity. *Cell Metab*, *36*(2), 301-314. https://doi.org/10.1016/j.cmet.2023.12.004

Fanti, M., Mishra, A., Longo, V. D., & Brandhorst, S. (2021). Time-Restricted Eating, Intermittent Fasting, and Fasting-Mimicking Diets in Weight Loss. *Curr Obes Rep*, *10*(2), 70-80. https://doi.org/10.1007/s13679-021-00424-2

Furmli, S., Elmasry, R., Ramos, M., & Fung, J. (2018). Therapeutic use of intermittent fasting for people with type 2 diabetes as an alternative to insulin. *BMJ Case Rep*, *2018*. https://doi.org/10.1136/bcr-2017-221854

Guo, L., Xi, Y., Jin, W., Yuan, H., Qin, G., Chen, S., Zhang, L., Liu, Y., Cheng, X., Liu, W., & Yu, D. (2024). A 5:2 Intermittent Fasting Meal Replacement Diet and Glycemic Control for Adults With Diabetes: The EARLY Randomized Clinical Trial. *JAMA Netw Open*, *7*(6), e2416786. https://doi.org/10.1001/jamanetworkopen.2024.16786

Gül, A., & Akyüz, E. Y. (2022). ARALIKLI AÇLIK VE METABOLİK ETKİLERİ. *Sağlık Akademisyenleri Dergisi*, *9*(1), 99-103.

Günalay, S., Taşkıran, E., Demir, B., Erdem, S., Mergen, H., & Akar, H. (2016). Tip 2 diyabetes mellitus hastalarında tedavi yöntemleri, glisemik kontrol ve diyabet komplikasyonları ile depresyon ve anksiyete riski arasındaki ilişki. *İstanbul Bilim Üniversitesi Florence Nightingale Tıp Dergisi*, *2*(1), 16-19.

Hardie, D. G. (2011). Sensing of energy and nutrients by AMP-activated protein kinase. *The American journal of clinical nutrition*, *93*(4), 891S-896S.

Joaquim, L., Faria, A., Loureiro, H., & Matafome, P. (2022). Benefits, mechanisms, and risks of intermittent fasting in metabolic syndrome and type 2 diabetes. *J Physiol Biochem*, *78*(2), 295-305. https://doi.org/10.1007/s13105-021-00839-4

Kalaycı, Z., & Altun, H. K. (2021). ARALIKLI AÇLIK DİYETLERİNİN GLUKOZ HOMEOSTAZI VE LİPİT METABOLİZMASI ÜZERİNE ETKİLERİ. *Bandırma Onyedi Eylül Üniversitesi Sağlık Bilimleri ve Araştırmaları Dergisi*, *3*(1), 52-63.

Long, Y. C., & Zierath, J. R. (2006). AMP-activated protein kinase signaling in metabolic regulation. *The Journal of clinical investigation*, *116*(7), 1776-1783.

Oakley, P. A. (2018). On the Side Effects of ‘Pain’and ‘Dehydration’in the Top 20 Selling Pharmaceuticals of 2017. *Journal of Pharmaceutical Research International*, *21*(6), 1-9.

Ojo, T. K., Joshua, O. O., Ogedegbe, O. J., Oluwole, O., Ademidun, A., & Jesuyajolu, D. (2022). Role of Intermittent Fasting in the Management of Prediabetes and Type 2 Diabetes Mellitus. *Cureus*, *14*(9), e28800. https://doi.org/10.7759/cureus.28800

Pammer, A., Obermayer, A., Stadler, J. T., Pferschy, P. N., Tripolt, N. J., Habisch, H., Madl, T., Sourij, H., & Marsche, G. (2024). Effects of dietary interventions and intermittent fasting on HDL function in obese individuals with T2DM: a randomized controlled trial. *Cardiovasc Diabetol*, *23*(1), 339. https://doi.org/10.1186/s12933-024-02426-5

Patel, S., Yan, Z., & Remedi, M. S. (2024). Intermittent fasting protects β-cell identity and function in a type-2 diabetes model. *Metabolism*, *153*, 155813. https://doi.org/10.1016/j.metabol.2024.155813

Petersen, M. C., & Shulman, G. I. (2018). Mechanisms of insulin action and insulin resistance. *Physiological reviews*.

Rovira-Llopis, S., Luna-Marco, C., Perea-Galera, L., Bañuls, C., Morillas, C., & Victor, V. M. (2024). Circadian alignment of food intake and glycaemic control by time-restricted eating: A systematic review and meta-analysis. *Rev Endocr Metab Disord*, *25*(2), 325-337. https://doi.org/10.1007/s11154-023-09853-x

Saeed, M., Ali, M., Zehra, T., Haider Zaidi, S. A., & Tariq, R. (2021). Intermittent Fasting: A User-Friendly Method for Type 2 Diabetes Mellitus. *Cureus*, *13*(11), e19348. https://doi.org/10.7759/cureus.19348

Sevindik, R., & Uçar, K. (2024). Tip 2 Diyabet Yönetiminde Potansiyel Beslenme Yaklaşımı: Aralıklı Açlık. *Gümüşhane Üniversitesi Sağlık Bilimleri Dergisi*, *13*(2), 966-973.

Soy, M., & Ekici, E. M. (2024). Tip 2 Diyabetes Mellitus Tedavisinde Yeni Bir Yaklaşım: Aralıklı Açlık Diyetleri. *Instıtute of Health Sciences Journal*, *9*(1), 83-86.

Sözer, H., & Avuk, H. S. (2023). YETİŞKİN KADINLARDA ARALIKLI AÇLIK DİYETİNİN ANTROPOMETRİK PARAMETRELERE ETKİSİ. *Karya Journal of Health Science*, *4*(2), 146-152.

Sutton, E. F., Beyl, R., Early, K. S., Cefalu, W. T., Ravussin, E., & Peterson, C. M. (2018). Early Time-Restricted Feeding Improves Insulin Sensitivity, Blood Pressure, and Oxidative Stress Even without Weight Loss in Men with Prediabetes. *Cell Metab*, *27*(6), 1212-1221.e1213. https://doi.org/10.1016/j.cmet.2018.04.010

Towler, M. C., & Hardie, D. G. (2007). AMP-activated protein kinase in metabolic control and insulin signaling. *Circulation research*, *100*(3), 328-341.

Tümer, G., & Çolak, R. (2012). Tip 2 diabetes mellitusda tıbbi beslenme tedavisi. *Journal of Experimental and Clinical Medicine*, *29*(1s), 12-15.

Vendelbo, M. H., Clasen, B. F., Treebak, J. T., Møller, L., Krusenstjerna-Hafstrøm, T., Madsen, M., Nielsen, T. S., Stødkilde-Jørgensen, H., Pedersen, S. B., Jørgensen, J. O., Goodyear, L. J., Wojtaszewski, J. F., Møller, N., & Jessen, N. (2012). Insulin resistance after a 72-h fast is associated with impaired AS160 phosphorylation and accumulation of lipid and glycogen in human skeletal muscle. *Am J Physiol Endocrinol Metab*, *302*(2), E190-200. https://doi.org/10.1152/ajpendo.00207.2011

Veronese, N., & Reginster, J.-Y. (2019). The effects of calorie restriction, intermittent fasting and vegetarian diets on bone health. *Aging clinical and experimental research*, *31*(6), 753-758.

Wang, X., Li, Q., Liu, Y., Jiang, H., & Chen, W. (2021). Intermittent fasting versus continuous energy-restricted diet for patients with type 2 diabetes mellitus and metabolic syndrome for glycemic control: A systematic review and meta-analysis of randomized controlled trials. *Diabetes Res Clin Pract*, *179*, 109003. https://doi.org/10.1016/j.diabres.2021.109003

Wilkinson, M. J., Manoogian, E. N. C., Zadourian, A., Lo, H., Fakhouri, S., Shoghi, A., Wang, X., Fleischer, J. G., Navlakha, S., Panda, S., & Taub, P. R. (2020). Ten-Hour Time-Restricted Eating Reduces Weight, Blood Pressure, and Atherogenic Lipids in Patients with Metabolic Syndrome. *Cell Metab*, *31*(1), 92-104.e105. https://doi.org/10.1016/j.cmet.2019.11.004

Yılmaz, F. T., Şahin, A. D., & Türesin, A. K. (2019). Tip 2 diyabetli bireylerde hastalığı kabul düzeyinin glisemik kontrol ile ilişkisi. *Cukurova Medical Journal*, *44*(4), 1284-1291.

Zang, B. Y., He, L. X., & Xue, L. (2022). Intermittent Fasting: Potential Bridge of Obesity and Diabetes to Health? *Nutrients*, *14*(5). https://doi.org/10.3390/nu14050981

COLORANTS: EFFECTS OF SYNTHETIC COLORANTS USED IN CANDIES ON CHILDREN'S HEALTH

RENKLENDİRİCİLER: ŞEKERLEMELERDE KULLANILAN SENTETİK RENKLENDİRİCİLERİN ÇOCUK SAĞLIĞI ÜZERİNE ETKİLERİ

PhD Student, Kübra TAŞBAŞI

Atatürk University, Graduate School Natural and Applied Sciences, Department of Food Engineering, Erzurum, Turkey

ORCID ID: https://orcid.org/0000-0003-4828-3671

Prof. Dr. Songül ÇAKMAKÇI

Atatürk University, Faculty of Agriculture, Department of Food Engineering, Erzurum, Turkey

ORCID ID: https://orcid.org/0000-0003-0334-5621

Abstract

Coloring food additives are added to various types of products to restore the natural color lost during food production and storage, enhance visual appeal by strengthening weak color, or compensate for natural color variations/provide a standard color. The use of these additives is strictly regulated in the European Union, the United States, and many countries worldwide. Owing to growing concerns about the safety of some commonly used legal food dyes, there is a trend to replace synthetic dyes with natural products. The most significant food safety concerns regarding food dyes are the lack of uniform regulation of legal food dyes worldwide, the potential link between artificial colors and hyperactive behavior, the replacement of synthetic colors with natural ones, and the presence of emerging harmful illegal dyes. The use of additives poses no risk to consumers if they comply with legal regulations and are used in limited quantities. Therefore, it is everyone's right to have concerns about food additives addressed on the basis of research and to address their concerns with factual information. While colorants are added to many foods today, their most common use is in the confectionery/candies industry. Natural colorants are often added to candies, especially those enjoyed by children, and artificial colorants are often added today as the trend toward processed foods increases. The relationship between artificial colorants and health has been a topic of debate for years, and research has focused on their effects on hyperactivity, allergies, cancer, and children's attention and activity levels. The purpose of this review is to increase consumer awareness by providing information about various concerns arising from the use of especially those used in candies.

Key Words: Food additive, Colorants, Artificial colorants, Candies, Food safety, Health

Özet

Renklendirici gıda katkı maddeleri, gıdaların üretim ve depolanmaları sırasında kaybolan doğal rengi yeniden kazandırmak veya zayıf olan rengi kuvvetlendirerek görsel çekiciliği artırmak veya doğal renk farklılıklarını telafi etmek/standart renk sağlamak amacıyla farklı ürün türlerine eklenmektedir. Bu katkı maddelerinin kullanımı Avrupa Birliği, Amerika Birleşik Devletleri ve dünya çapında birçok ülkede sıkı düzenlemelere tabidir. Yaygın olarak kullanılan bazı yasal gıda boyalarının güvenliği konusunda artan endişeler nedeniyle sentetik formların doğal ürünlerle değiştirilmesi eğilimi vardır. Gıda boyaları konusunda en önemli gıda güvenliği endişeleri; dünya çapında yasal gıda boyalarıyla ilgili tek tip düzenlemenin olmaması, yapay renklerin hiperaktif davranışla olası bağlantısı, sentetik renk maddelerinin doğal olanlarla değiştirilmesi ve yeni ortaya çıkan zararlı yasadışı boyaların varlığıdır. Katkı maddelerinin kullanımı, yasal düzenlemelere uygun olması halinde ve belirlenen miktarlardan fazla kullanılmaması durumunda tüketiciler için tehlike oluşturmamaktadır. Bu nedenle gıda katkı maddeleri ile ilgili endişelerin araştırma sonuçlarına dayandırılarak ve endişe kaynaklarının gerçek bilgiler ile giderilmesi her kesimin hakkıdır. Günümüzde renklendiricilerin birçok gıdaya eklenmesinin yanı sıra en yoğun kullanıldığı alan şekerleme endüstrisidir. Özellikle çocukların severek tükettiği şekerlemelere doğal renklendiriciler ve hazır gıdalara olan eğilimin arttığı günümüzde ise çoğunlukla yapay renklendiriciler ilave edilmektedir. Yapay renklendiricilerin sağlıkla ilişkisi yıllardır tartışma konusu olmuş ve hiperaktivite, alerji, kanser, çocukların dikkat ve aktiviteleri üzerindeki etkileri üzerine araştırmalar yoğunlaşmıştır. Bu derlemenin amacı, özellikle şekerlemelerde kullanılan renklendiricilerin kullanımından kaynaklanan çeşitli endişeler hakkında bilgi vererek tüketicileri bilinçlendirmektir.

Anahtar Kelimeler: Gıda katkı maddesi, Renklendiriciler, Yapay renklendiriciler, Şekerleme, Gıda güvenliği, Sağlık

GİRİŞ

Renk, gıdalarda tüketicinin ilk dikkatini çeken, seçimini, yeme isteğini doğrudan etkileyen en önemli duyusal özelliklerden olup genellikle ürünün pazarlanmasında önemli bir rol oynar (Akpunar, 2015; Çakmakçı, 2022; Silva vd., 2022). Tüketiciler her gıda maddesi için alışılmış renk istemekte, özellikle çocuklar albenili yiyecek ve içeceklere içgüdüsel olarak her zaman daha fazla ilgi duyarlar (Saleem 2013; Çakmakçı vd., 2025). Gıdaların rengi genellikle ürünün lezzeti, güvenliği ve besin değeri ile ilişkilendirilir (Sigurdson vd., 2017). Renk, gıda kalitesinin algılanmasını etkiler ve lezzetle ilgili olduğu algılandığından iştahı da uyarır (Downham ve Collins, 2000). Renk görsel çekiciliği arttırır ve bu nedenle de gıdalardaki renk kaybını/farklılıklarını önlemek için gıdalara yasalarla izin verilmiş olan ve belli miktarda renk maddesi katılabilir (Oplatowska Stachowiak ve Elliott, 2017; Çakmakçı, 2022). Renklendiricilerin kullanımı, renklendiricilerin şarap ve şekerlemelere eklendiği Eski Mısır dönemine (MÖ 1500) kadar uzanmaktadır (Downham ve Collins, 2000; Sigurdson ve ark., 2017). Eski Mısır yazıtlarında ilaçların renklendirilmesi anlatılırken, şarabın renklendirilmesi MÖ 400'de Romalılar tarafından tanımlanmıştır (Sigurdson vd., 2017).

Teknolojik işlem gören gıda maddelerinde renk kaybı olmakta, bu nedenle gıda üretim prosesine bağlı olarak doğal halde bulunan rengi arttırmak veya kaybolanı yerine koyarak gıdanın rengini korumak/cazip hale getirmek ve üründe standart renk oluşturmak için veya renksiz gıdalara renk kimliği kazandırmak ve işleme veya depolama sırasında oluşan kayıpları telafi etmek gibi çeşitli amaçlarla renklendiriciler kullanılır (Sigurdson vd., 2017; Çakmakçı, 2022; Marković vd., 2023).

Geçmişte gıda renklendiricileri safran, kırmızı biber, zerdeçal, pancar özü ve çeşitli çiçekler gibi doğal kaynaklardan elde edilmiş (Burrows, 2009; Sigurdson vd., 2017), "Mauveine" adı verilen mor bir pigment olan ilk sentetik renk maddesi ise 1856'da İngiliz kimyager Sir William Henry Perkin tarafından geliştirilmiş ve endüstriyel uygulamalar için binlerce yeni renklendirici bileşiğin sentezlenmesine yol açmıştır (Oplatowska-Stachowiak ve Elliott, 2017). Bu sentetik renklendiriciler, düşük üretim maliyetleri, yüksek renklendirici güçleri ve kimyasal kararlılıkları/yüksek stabiliteleri ve ayrıca ürüne istenmeyen bir tat vermeden güçlü bir renk katmaları nedeniyle gıda renklendiricileri olarak popülarite kazanmıştır (McCann vd., 2007, Potera, 2010; Barciela vd., 2023). Tüketici algısı ve talebi, sentetik renklendiricilerin doğal kaynaklardan elde edilenlerle değiştirilmesini sağlamıştır. Bu dönüşüm, tüketicilerin daha "doğal" ürünlere olan talebi, sentetik renklendiricilerin çocukların dikkati ve hiperaktivitesi ile olası bağlantıları ve hassas popülasyonlarda sentetik renklendiricilerin alerjenliği ile ilişkili olabilir (McCann vd., 2007, Potera, 2010; Marković et al., 2023; de Oliveira vd., 2024). Günümüzde kullanılan sentetik renklendiriciler uzun süreli güvenlik değerlendirmelerine ve sıkı düzenlemelere sahip olsa da gıda endüstrisi değişen pazar taleplerini ve yasal kısıtlamaları karşılamak için alternatifler aramaktadır (Sigurdson vd., 2017).

Doğal pigment uygulamaları, daha düşük stabilite, renklendirme gücünün zayıflığı, renk homojenliğinin sağlanamaması, gıda bileşenleriyle etkileşimler ve istenen renk tonlarını yakalayamama gibi nedenlerle sınırlı olabilir (Sigurdson vd., 2017; Silva vd., 2022). Doğal renklendiriciler, gıda bileşenleriyle veya aroma/koku maddeleriyle etkileşime girme, suya karşı kararsızlık gösterme ya da ışık ve sıcaklığa maruz kalındığında bozulma gibi bazı dezavantajlara sahip olmasına rağmen güvenilirlikleri, fonksiyonel özellikleri, biyolojik potansiyelleri ve sağlık açısından olumlu etkileri nedeniyle talep görmektedirler (Silva vd., 2022). Doğal renk maddeleri doğadan elde edilir ve daha basit ya da daha karmaşık ekstraksiyon işlemleriyle izole edilebilirken, sentetik renk maddeleri, doğada bulunmazlar ve kimyasal olarak sentezlenmektedir; toz, macun veya granül formda bulunabilmeleri ve suda çözünebilir olmaları gibi avantajlara sahiptirler (Silva vd., 2022). Orta ve uzun vadede çok sayıda yan etki ve toksisite (alerjik reaksiyonlar, davranışsal ve nörobilişsel etkiler), sentetik renklendiricilerin kullanımıyla ilişkilendirilmiştir; halbuki doğal olarak elde edilen benzerleri, bir sağlık destekleyicisi olarak nispeten yüksek kaliteli ve etkili bir katkı sağlamaktadır (Silva vd., 2022). Küçük çocuklar, hızlı büyüme hızları ve farklı gıda alım eğilimleri nedeniyle yetişkinlere göre daha fazla kimyasal maddeye maruz kalabilirler. Bu nedenle, maruziyet değerlendirmeleri bu yaş grubunda özellikle önemlidir (Martyn vd., 2013). Bu derlemede, gıdalarda kullanımına izin verilen sentetik ve doğal gıda renklendiricilerin sağlık üzerine etkilerine dikkat çekmek istenmiştir.

YASAL DÜZENLEMELER

Gıda renklendiricileri/boyaları, tüketici güvenliğini garanti altına almaktan sorumlu düzenleyici kuruluşlar tarafından test edilmiş/edilmektedir. Bununla birlikte, bu renklendiricilerin güvenliği tartışmalı olmaya devam etmektedir (Barciela vd., 2023). Gıda boyası düzenlemeleri dünya genelinde farklılık gösterdiğinden, tüm pigmentlerin evrensel olarak yasal olup olmadığı tartışılması güçtür. Latin Amerika ve Avrupa'daki birçok ülke, Codex Alimentarius veya Gıda ve Tarım Örgütü (FAO) / Dünya Sağlık Örgütü (WHO) Gıda Katkı Maddeleri Ortak Uzmanlar Komitesi'nin (JECFA) şartnamelerini benimsemiştir (Wrolstad ve Culver, 2012). Amerika Birleşik Devletleri, Kore ve Japonya gibi diğerleri ise gıda boyası katkı maddelerini bağımsız olarak düzenlemektedir (Wrolstad ve Culver, 2012).

Birçok sentetik bileşiğin insanlar için toksik ve zararlı olduğu gösterildiğinden, gelişmiş ülkelerde renklendiricilerin gıda katkı maddesi olarak kullanımı, ülkeden ülkeye değişen mevzuatlarla sıkı bir şekilde kontrol edilmektedir (Oplatowska-Stachowiak ve Elliott, 2017). Avrupa Gıda Güvenliği Ajansı (EFSA) ve Amerika Birleşik Devletleri Gıda ve İlaç Dairesi (FDA), gıda katkı maddeleri konusunda dünyadaki iki temel düzenleyici kurumdur. Bu kurumlar, güvenlik düzenlemelerini uygular, bilimsel verileri inceler, potansiyel toksisiteyi değerlendirir ve insanların gıda katkı maddelerine maruz kalma olasılığını tahmin eder. EFSA, sadece isimlendirmenin ötesinde, her gıda katkı maddesine "E" harfi ve bir sayıdan oluşan özel bir tanımlama kodu verir. Renklendiriciler E100'den (Kurkumin) E180'e (Litolrubin BK) kadar değişir. Yapay gıda renklendiricileri, (EC) 1333/2008 Yönetmeliği ile kısıtlanmıştır.

Türkiye'de gıda katkı maddelerinin kullanımını düzenleyen “Türk Gıda Kodeksi Gıda Katkı Maddeleri Yönetmeliği'ne göre, gıda etiketindeki içerik tablosunda gıdaya eklenen katkı maddesinin adını veya E kodunu işleviyle birlikte yazmak zorunludur. Herhangi bir karışıklığı önlemek için, gıda katkı maddelerini tanımlayan E kodu kullanılır ve gıda katkı maddelerinin kullanım sınırları uluslararası kuruluşlar tarafından belirlenen günlük alınabilir maksimum doz (Acceptable Daily Intake, ADI) değerlerine göre belirlenir (Baygut ve Bilici, 2022; Çakmakçı, 2022). ADI, "insanların tüm yaşamları boyunca herhangi bir sağlık riski oluşturmadan günlük olarak tüketebilecekleri bir maddenin miktarı" olarak tanımlanır. ADI değeri; mg/kg vücut ağırlığı/gün olarak ifade edilir (Martyn vd., 2013).

ŞEKERLEMELER

Dünya genelinde geniş bir ürün yelpazesi içeren şekerleme sektörünün çocuklar başta olmak üzere, her yaştan geniş bir tüketici kitlesi bulunmaktadır (Güneş vd., 2018). Tüketici tercihine göre geliştirilmiş çok fazla şekerleme çeşidi vardır. Sert, yumuşak ve dolgulu ve kaplamalı karışık şekerlemeler olduğu gibi helva, çiklet, lokum, çikolata vb. ürünler de şekerleme çeşitleridir (Elgün, 2013). Şekerleme ürünleri; şeker (sakkaroz) ve üzüm şekerinin (glukoz) veya sadece şekerin pişirilmesinden sonra sitrik asit, tartarik asit veya potasyum bitartarat ilave edilerek kesilmesi sonucu oluşan hamura, üretilecek ürünün çeşidine göre süt, süt tozu, jelatin, yağ ve aroma maddeleri gibi katkıların eklenerek şekillendirilip ambalajlanması sonucu elde edilen gıda maddeleridir. Şekerlemelerin ana yapısı karbonhidrattır. Glukoz; sakkarozun kristalizasyon riskini azaltmakta, işlenmesini ve şekil verilmesini kolaylaştırmaktadır. İstenen yapıyı sağlama ve işlemi kolaylaştırmak amacı ile lesitin, mono ve disakkaritler gibi emülgatörler kullanılmaktadır (Elgün, 2013).

Şekerleme tüketiminin diş çürümesi, Tip 2 diyabet, kardiyovasküler hastalıklar ve metabolik sendrom gibi sağlığa zararlı etkilerinden dolayı günümüzde şekerlemelere daha sağlıklı bir form kazandırmak için fonksiyonel şekerleme sektörü gelişmeye başlamıştır (Önder ve Aydar, 2022). Şekerleme üretiminde birçok faktör bulunmaktadır. Şekerleme üretiminde ürün kalitesini etkileyen önemli faktörler; formülasyon, işlem süresi ve sıcaklığı ile son ürünün nem içeriğidir (Yılmaz vd., 2019). Şekerleme ürünlerinin renklendirilmesinde kullanılan renklendiricilerin ürün bileşimi, katkı maddeleri ve işlem parametrelerine karşı stabil olmaları gerekir.

Amarant, Penso 4R, Allure Red AC, Sunset Yellow FCF, Tartrazin ve Karmoisin en sık kullanılan renklendiriciler olup bir araştırmada, şekerleme ürünlerinde yaygın olarak Karoten türevleri (β-karoten, E160a) ve Titanyum dioksit (E171) olmak üzere iki doğal gıda boyasına rastlandığı belirtilmiştir (AbuKhader vd., 2021).

Yapay renklendiriciler sağlık sorunlarının ortaya çıkmaması için belirlenmiş ADI değerinin bile altında kullanılmalıdır. Yetişkinlere kıyasla çocuklar daha fazla yiyecek tüketir, daha fazla su içer ve vücut ağırlığı birimi başına daha fazla hava solurlar. Dolayısıyla çocukların, gelecekte yetişkinlere göre yapay renklendiricilere ve bunların oluşturabilecekleri zararlara daha fazla maruz kalabilecekleri unutulmamalı ve beslenmelerine ve gıda içeriklerine dikkat edilmelidir. Bu nedenle sentetik renk maddeleri konusunda daha hassas olunmalı ve daha detaylı araştırmalar yapılmalıdır.

SAĞLIK ÜZERİNE ETKİLERİ

Gıda renklendiricilerini sağlık riskleri açısından değerlendiren çalışmalarda farklı görüşler ortaya çıkmış ve sağlığı olumlu yönde etkileyen renklendiriciler olduğuna dair çalışmalara da rastlanmıştır. Karotenoidin cildi koruduğu ve hücre gelişiminde önemli olan A vitamininin öncüsü olarak bilinen karotenin keşfiyle ortaya çıkmıştır (Solymosi vd., 2015). Kurkuminin antioksidan etkisinin olduğu, antikanseojenik, yaralar ve yanıklar konusunda terapötik özelliklere sahip olduğu belirtilmiştir (Baygut ve Bilici, 2022). Ancak günlük beslenmemizin bir parçası haline gelen bazı gıdalar renklendirilirken özellikle genotoksik veya kanserojen özelliklere sahip olabilecek sentetik olanlarla renklendirilir. Bu, halk sağlığı için bir risk teşkil edebilir. Özellikle çocuklar, son 50 yılda yaygınlaşan yapay gıda renklendiricilerinin ana tüketicileridir (Malabadi vd., 2022). Piyasadaki bazı gıdalar aşırı miktarda yapay renk katkısı içerebilmekte ve yapılan araştırmalara göre, alerjenite, çocukluk hiperaktivite sendromu, nörotoksisite, genotoksisite ve kanserojen etki gösterebilmektedir. Ayrıca gıda zehirlenmesinin başlıca nedenlerinden biri olabilmektedirler (Marković vd., 2023). Eritrosin, Karmoisin ve Tartrazin gibi gıda renklendiricilerinin karaciğer kanserine neden olabileceği belirtilmektedir (Malabadi vd., 2022).

Çok sayıdaki araştırma sonucuna göre (Silva vd., 2022), bazı sentetik renklendirici katkı maddeleri, çocuklarda hiperaktivite ve hatta mutajenik ve/veya kanserojen patolojilere neden olabilen alerjenik sağlık sorunlarına neden olabilmektedir. Bu nedenle, bazı gıda güvenliği çalışmaları, bazı sentetik gıda katkı maddelerinin yasaklanmasına neden olmuştur. Sentetik boyaların sağlık üzerindeki yan etkilerinin üstesinden gelmek için, bunların doğal gıda boyalarıyla değiştirilmesi sıklıkla başvurulan bir seçenektir. Örneğin, kırmızı renklendirici olarak Pancar Kırmızısı'ndan (E162) ve yeşil gıda boyası olarak klorofillerden (E140) elde edilenlerin kullanımı artırılmıştır. Bununla birlikte, doğal boyalar da gıda güvenliği çalışmalarının bir hedefi olup, bazı katkı maddeleri daha yüksek güvenlik garantilerine sahip olanlarla değiştirilmektedir. Son zamanlarda annatto, likopen üzerinde araştırmalar devam etmektedir (Silva vd., 2022).

Betanin, suda çözünen ve etanolde çözünmeyen, kırmızı veya koyu kırmızı (pH 4 ile 5 pH arasında parlak mavimsi kırmızıdır, pH arttıkça mavi-mor ve alkali seviyelerde hidrolizle bozunması sarı-kahverengi bir renk üretir). Bu gıda boyası özellikle dondurma ve aromalı süt ürünleri gibi çocuklara yönelik gıda ürünlerinde kullanılır. Tartrazin içeren bir karışıma maruz kalmanın 3 ve 8 - 9 yaş arası çocuklarda hiperaktiviteyi artırdığı, tartrazinin ürtikeri ve alerjik bir reaksiyonda histamin salınımının neden olduğu dudak, dil, boğaz ve boyun şişmesini tetiklediğinden şüphelenildiği belirtilmektedir (Silva vd., 2022). AbuKhader vd. (2021) de daha çok çocukların tükettikleri şekerleme ürünlerinde en çok bulunan sentetik renklendiricilerin Brilliant Blue FCF (E133) ve Allura Red AC (E129) olduğunu belirlemişlerdir.

Azo boyalarının yaklaşık %65'i meşrubat, reçel, şekerleme, turşu vb. ürünlerde gıda katkı maddesi olarak kullanılmaktadır. En yaygın kullanılan gıda azo boyaları Tartrazin (E102), Sunset Yellow (E110) olup her iki boya da EFSA ve FDA tarafından onaylanmıştır. Karmoizin (E122), Amaranth (E123), Ponceau 4R (E124), Allura Red AC (E129), Brillant Blue (E 133) ve HT Brown (E 155) de gıda işlemede yaygın olarak kullanılır (Barciela vd., 2023). Azo boyalarının popülaritesi, bol miktarda canlı renkle sonuçlanan kimyasal çok yönlülüklerine dayanmaktadır. Ayrıca, düşük maliyetlidirler, kolayca erişilebilirler, stabildirler, tutarlıdırlar ve herhangi bir tat veya hoş olmayan kokuya sahip değildirler (Barciela vd., 2023). Bununla birlikte, gıda azo boyalarının olumsuz sağlık etkileri olabilir (Monisha vd., 2023). ADI sınırlarının altında, yapay boyaların alımı güvenli olabilir. Ancak, daha yüksek dozlar, özellikle çocuklarda sağlık sorunlarına neden olabilir. Bildirilen olası sağlık sorunları arasında alerji, dikkat eksikliği hiperaktivite bozukluğu (DEHB), astım, anksiyete, sitotoksisite ve genotoksisite bulunmaktadır (Barciela vd., 2023).

de Oliveira vd. (2024), araştırma sonuçlarının, sentetik renk katkı maddelerinin bir dizi sağlık sorunuyla doğrudan bağlantılı olduğunu ve çocuklarda kanserojen, alerjenik, mutajenik, sitotoksik aktiviteler gibi patolojik durumlara yatkınlık ve ayrıca gastrointestinal ve solunum problemleri dahil olmak üzere patolojik durumlara yatkınlık ve tanı konmuş bozuklukları olan ve olmayan çocuklarda davranış değişiklikleri gibi daha büyük bir etkiye sahip olduğunu ortaya koyduğunu belirtmişlerdir. Otizm Spektrum Bozukluğu ve Dikkat Eksikliği Hiperaktivite Bozukluğu gibi hastalıkları olan çocuklarda sentetik boyalara maruz kalmanın, mevcut semptomları kötüleştirebileceği ve hastalığın yönetimini zorlaştırabileceği belirtilmiştir. Ayrıca, hastalığı olmayan çocuklarda bile sentetik boyaların, davranışsal, metabolik ve beslenme gelişimlerini etkileyerek sağlık riski oluşturabileceği belirtilmiştir. Bu nedenlerle ebeveynler, bakıcılar ve sağlık profesyonelleri için devletin de katkısıyla eğitim çalışmaları, sentetik boyaların tüketimiyle ilişkili potansiyel risklerin farkında olmaları ve çocukların bu katkı maddelerine maruziyetini azaltmak için önlemler almaları açısından önemlidir (de Oliveira vd., 2024).

Çoğu gıda boyası toksisite çalışmalarında herhangi bir olumsuz etkiye neden olmazken, boyalardaki olası kirleticiler konusunda bazı endişeler vardır. Ponzo 4R, Koşineal Red A, Sunset Yellow FCF / Orange Yellow S ve Tartrazinin kansere neden olduğu bilinen maddeler olan kirleticiler içerebilir. Kirleticilerin düşük seviyelerde bulunması ve bu seviyelerin güvenli olduğu varsayıldığından boyalarda bulunmasına izin verilir (Dey ve Nagababu, 2022). Gıda katkı maddeleri için sağlığa zararlıdır gibi kesin bir ifade doğru değildir. Bu konuda önemli olan kullanılan maddenin izin verilmiş olması ve dozudur. Dozdan sonra önemli etki ise doğru gıdada kullanımıdır (Çakmakçı, 2022).

Gıda boyaları ve diğer bazı katkı maddeleri, henüz tolerans geliştirmediğimiz çok küçük moleküllerden yapılır. Bu gıda katkı maddeleri, metabolizmadan sonra vücut proteinlerine veya gıda üretimi sırasında gıda proteinlerine bağlanabiliyorlarsa, immünolojik toleransın bozulmasının ana nedeni haline gelirler. Bu immünolojik reaktivitelere önemli ölçüde ancak gizlice katkıda bulundukları düşünülmektedir (Vojdani and Vojdani, 2015). Ek olarak, Tartrazin özellikle aspirin intoleransı olan hastalarda potansiyel bir astım ve ürtiker tetikleyicisi olarak belirtilmiştir. Bu reaksiyonlar Tartrazin ve diğer gıda renklendiricileri içeren gıdalar veya ürünler tüketildikten sonra meydana gelmiştir (Elhkim, 2007).

Kullanımı yaygın olan bazı renklendiriciler çocuklarda hiperaktivite semptomlarıyla Dikkat Eksikliği Hiperaktive Bozukluğu’na (DEHB) neden olabildiğini gösteren bir çalışmada bu bozukluğa sebep olabilecek renklendiricilerden en önemlilerinin Tartrazin (E102), Patent Blue V (E131), Brilliant Blue (E133), Allura Red (E129), Eritrosin (E127), Sunset Yellow (E110), Ponzo 4R (E124) ile Karminik asit, Karmin (E120) olduğu belirlenmiş, renklendiricilerin özellikle 3-9 yaş çocuklarda hiperaktivite gibi davranış bozukluklarına neden oldukları bildirilmiştir (Büyükdere ve Ayaz, 2016).

Lok vd. (2011), Çin'in Hong Kong eyaletinin üç bölgesinde 8 - 9 yaş aralığındaki öğrencilerin yapay renklere maruziyetlerini incelenmişler ve Sunset Yellow hariç, ortalama bir ilkokul öğrencisinin yapay renklere maruz kalma oranı, yaşlarına göre ADI'den önemli ölçüde düşük bulunmuştur. Verilere göre, 9 yaşındaki erkek çocukların günlük ortalama Sunset Yellow (E110) alımı, ADI eşiğinden %51 daha fazla bulunmuş olup bu yapay renklendiricinin yüksek seviyelerini içeren meşrubat ve jöle gibi ürünlerin artan tüketimi, öncelikle Sunset Yellow'un daha yüksek tüketilme sebebi olarak belirlenmiştir.

Kist-van vd. (2015) tarafından Hollanda, Amsterdam’da yürütülen bir çalışmada, süpermarketlerden, bakkallardan ve Türk ve Fas dükkanlarından alınan 550 ürünün 73'ü (%13), çoğunlukla şekerlemelerde (%33) ve (gazlı) içeceklerde (%31) yapay gıda renklendiricileri bulunduğu belirlenmiştir. En sık karşılaşılanların ise Brilliant Blue (E133), Patent Blue (E131) ve Indigotin (E132) olduğu görülmüştür. Ortalama alım miktarı 0,02-0,96 mg/kg/gün arasında değişmiş olup, bu miktar ADI'nin (5-15 mg/kg/gün) altındadır. Çocukların hiçbiri sarı, turuncu veya kırmızı yapay gıda boyası tüketmemiştir. Sonuçlar: Amsterdam'daki çocuklarda yapay gıda boyası tüketimi, kabul edilebilir günlük alımın (ADI) oldukça altındadır ve Brilliant Blue (E133), Patent Blue (E131), Indigotine (E132) ve Green S (E142) ile sınırlı olduğu belirtilmiştir.

Boussada vd. (2017), Tartrazinin hala ilaç, kozmetik ve gıda sektöründe en sık kullanılan renklendirici maddelerden biri olduğunu hem kemirgenlerde hem de insanlarda üreme sistemi işlevlerinde bazı bozukluklar dahil olmak üzere bir dizi zararlı sonucu olduğu tespit edildiğini belirtmiştir.

Bradman vd. (2022), ABD'de yaşayan çocukların ve yetişkinlerin sağlık ve beslenme durumunu belirlemek için ülke genelinde yaklaşık 5.000 kişiden oluşan bir örneğe anket uyguladı. Bunları

FDA ve WHO tarafından önerilen ADI değerlerini karşılaştırdılar. ABD'de gıdalarda genel kullanım için onaylanmış yedi FD&C (Federal Gıda, İlaç ve Kozmetik Yasası, FDA) renk katkı maddesi bulunduğunu ve bunların Brilliant Blue, Indigo Carmine, Fast Green, Eritrosin, Allura Red, Tartrazine ve Sunset Yellow olduğu ve tüketiciler için gıda renklerine yönelik en yüksek tahmini maruziyetler Allura Red, ardından Sunset Yellow ve Tartrazine olduğunu, en düşük maruziyetlerin Fast Green için bulunduğunu belirtmişlerdir. Genel olarak, çocukların Allura Red ve Erythrosine'e ve diğer beş gıda rengine yönelik tahmini maruziyetleri yetişkin kadınlara kıyasla daha yüksek bulunmuştur.

Ahmed vd. (2023), Suudi Arabistan'da 6 ila 17 yaş arasındaki okul çağındaki çocuklarda yapay gıda renklerinden Karmoisine (%32,3) ve Sunset Yellow (%30,1)'un en sık alınan, Eritrosin (%0,05) en az alınan renk maddesi olduğu ortaya çıkmıştır. İzin verilen renk maddelerinin çoğunun 6-11 yaş grubunda ADI değerini aştığı, 12-17 yaş grubunda ADI değerleri içinde olduğu, bunun da okul çocuklarının ortalama günlük yapay renklendirici tüketiminde yaşa bağlı azalmalar olduğunu gösterdiği belirtilmiştir (Ahmed vd., 2023).

Renklendiricilerin sağlık üzerine etkilerini gösteren bazı araştırma sonuçlarından derlenen bilgiler Tablo 1'de verilmiştir.

Tablo 1. Bazı renklendiricilerin sağlığa etkileri

Renklendirici	Sağlığa Etkisi	Kaynak
E 102 Tartrazin E110 Sunset Yellow E 127 Eritrosin E 129 Allura Red	Kanserojenik etki	Kobylewski ve Jacobson (2012)
E 129 Allura Red	Astım, rinit (saman nezlesi dahil) veya ürtikeri (kurdeşen) kötüleştirebilir veya tetikleyebilir	AbuKhader vd., 2021
E 102 Tartrazin E 110 Sunset Yellow E 120 Karminik asit, Karmin E 124 Ponzo 4R E 127 Eritrosin E 129 Allura Red E 131 Patent Blue V E 133 Brilliant Blue	Hiperaktivite, DEHB (Dikkat Eksikliği ve Hiperaktivite Bozukluğu),	Büyükdere ve Ayaz (2016),
E 133 Brilliant Blue FCF	Hiperaktivite ve deri döküntüleri	AbuKhader vd., 2021
E 102 Tartrazin	Üreme sisteminde bozukluk	Boussada vd (2017)
E 122 Karmoisin	Kanserojenik etki	Reza vd. (2019)
E 102 Tartrazin E 122 Karmoisin E 127 Eritrosin,	Karaciğer kanseri	Malabadi vd. (2022)

SONUÇ

Gıda ürünlerinde kullanılan renklendirici katkı maddeleri, tüketici tercihlerinde önemli bir rol oynamaktadır. Yapılan araştırmalar, katkı maddesi olarak renklendiricilerin hemen hemen bütün gıdalarda yer aldığını, özellikle çocukların çokça tükettiği ve renk yönünden zengin olan şekerlemelerde birçok sentetik renklendirici kullanıldığını göstermektedir. Renklendiricilerin gıdalarda kullanımı, olumlu etkilerin yanı sıra riskli etkileriyle ön plana çıkmaktadır. Bununla birlikte, sağlıklı, güvenli ve kaliteli ürün imajıyla yakından ilişkili olan doğal renklendiricilere olan tercihler, çok sayıda sentetik boyanın insan sağlığı üzerindeki yan etkilerinin tespit edilmesiyle keskin bir şekilde artmıştır. Dolayısıyla, gıda endüstrilerinin karşılaştığı zorluk göz önüne alındığında, zengin renkli pigmentlerin özellikleri nedeniyle ortaya çıkan teknolojik sınırlamaları aşmak için alternatifler geliştirilmelidir. Bu kısıtlamaların üstesinden gelmek için, yalnızca gıda renklendirici katkı maddelerinin kararlılığını ve depolama sırasındaki nihai çekiciliğini değil, aynı zamanda güvenliğini de artırmak için özel kaynaklar ve işlemler geliştirilmelidir. Nitekim, gıda boyalarının kullanımı, kısa ve uzun vadedeki tüm etkileri göz önünde bulundurularak ve yasal çerçeve dahilinde belirli sınırlar içinde ve belirli bir işlevi yerine getirecek şekilde gerçekleştirilmelidir. Bunun yanı sıra, tüketiciler sentetik boyaların neden olduğu istenmeyen ve zararlı etkiler konusunda güçlü bir algıya sahip olsalar da doğal pigmentlerin güçlü avantajı, sağlığı iyileştirici/koruyucu etkilerinin kesin olarak gösterilmesini gerektirmektedir. Özellikle çocukların tükettiği gıdalarda/özellikle çok tükettikleri şekerlemelerde renklendiricilerin riskli etkilerine karşın ebeveynlerin bilinçlendirilmesi gerektiği, üreticilerin ise sürekli olarak denetlenmesi gerektiği ortaya çıkmaktadır. Kısaca, yapay renklendiricilerin güvenliği, olası olumsuz ve toksik etkileri nedeniyle tartışmalıdır. Bu nedenlerle, tutarlı veriler, kullanımlarına alternatifler ve güvenilirliklerini sağlamak için bu renklendiriciler hakkında daha fazla araştırmaya ihtiyaç bulunduğu anlaşılmaktadır.

KAYNAKLAR

AbuKhader, M., Dhanalekshmi, U.M., Nazmi, A. (2021). Identification and prevalence of food colors in candies commonly consumed by children in Muscat, Oman. Int J Nutr Pharmacol Neurol Dis. 11, 128-36.

Ahmed, M.A., Al-Khalifa, A.S., Al-Nouri, D.M., El-din, M.F.S. (2023). Average daily intake of artificially food color additives by school children in Saudi Arabia. J King Saud Univ Sci 35(4), 102596. https://doi.org/10.1016/j.jksus.2023.102596

Akpunar, E. (2015). Türk Lokumu Üretiminde Kızılcık (Ergen) Meyvesinin Doğal Renklendirici Olarak Kullanılması ve Depolama Stabilitesinin Araştırılması, Yüksek Lisans Tezi, Afyon Kocatepe Üniversitesi Fen Bilimleri Enstitüsü, Afyon.

Barciela, P., Perez-Vazquez, A., Prieto, M.A. (2023). Azo dyes in the food industry: Features, classification, toxicity, alternatives, and regulation. Food Chem Toxicol 178, 113935. https://doi.org/10.1016/j.fct.2023.113935

Baygut, H., Bilici, S. (2022). Food color additives and health interaction. Süleyman Demirel Üniversitesi Sağlık Bilimleri Dergisi 13(1), 146-52. https://doi.org/10.22312/sdusbed.1010114

Boussada, M., Lamine, J.A., Elbini, I., Abidi, N., Lasram, M., El-Fazaa, S., El-Golli, N. (2017). Assessment of a sub-chronic consumption of tartrazine (E102) on sperm and oxidative stress features In wistar rats. Int Food Res J 24(4), 1473-1481.

Bradman, A., Castorina, R., Thilakaratne, R., Gillan, M., Pattabhiraman, T., Nirula, A., Marty, M., Miller, M.D. (2022). Dietary exposure to United States Food and Drug Administration-Approved Synthetic Food Colors in Children, Pregnant Women, and Women of Childbearing Age Living in the United States, Int J Environ Res Pub Health 19(15), 9661. https://doi.org/10.3390/ijerph19159661

Burrows A. (2009). Palette of our palates: a brief history of food coloring and its regulation. Compr Rev Food Sci Food Saf 8, 4394–408. https://doi.org/10.1111/j.1541-4337.2009.00089.x

Büyükdere, Y., Ayaz, A. (2016). Gıdalarda kullanılan renklendiricilerin sağlık yönü: dikkat eksikliği hiperaktivite bozukluğu. Beslenme ve Diyet Dergisi 44(2), 169-177.

Çakmakçı, S. (2022). Gıda Katkı Maddeleri (7. Bölüm), p171-194, In: Endüstriyel Gıda Üretim Teknikleri. Eds.: Şanlıbaba P., Güçer Y.), Nobel Yayınevi. ISBN: 978-625-417--615-9.

Çakmakçı, S., Çelik Taşbaşı, K., Salık, M.A. (2025). Probiotic viability, β-carotene and mineral contents, color, physicochemical and sensory properties of ice cream prepared with carrot (*Daucus carota* L.) puree and *Bifidobacterium animalis* subsp. *lactis* BB-12. Mljekarstvo, 75(2), 118-131. https://doi.org/10.15567/mljekarstvo.2025.0205

de Oliveira, Z.B., Silva da Costa, D.V., da Silva dos Santos, A.C., da Silva Júnior, A.Q., de Lima Silva, A., de Santana, R.C.F., Costa, I.C.G., de Sousa Ramos, S.F., Padilla, G., da Silva, S.K.R. (2024). Synthetic colors in food: A warning for children's health. Int J Environ Res Public Health, 21, 682. https://doi.org/10.3390/ijerph21060682

Dey, S., Nagababu, B.H. (2022). Applications of food color and bio-preservatives in the food and its effect on the human health. Food Chem Adv 1, 100019. https://doi.org/10.1016/j.focha.2022.100019

Downham, A., Collins, P. (2000). Colouring our foods in the last and next millennium. Int J Food Sci Technol 35,15–22. https://doi.org/10.1046/j.1365-2621.2000.00373.x

Elgün, A. (2013). Şeker, şekerlemeler ve şekerli ürünler. Uluslararası 2. Helal ve Sağlıklı Gıda Kongresi, 7-10 Kasım. Bildiri Kitapçığı, 77 96, Konya.

Elhkim, M.O., Héraud, F., Bemrah, N., Gauchard, F., Lorino, T., Lambré, C., Frémy, J.M., Poul, J.M. (2007). New considerations regarding the risk assessment on tartrazine. Regul Toxicol Pharmacol 47(3), 308–16. https://doi.org/10.1016/j.yrtph.2006.11.004

Güneş, R., Palabıyık, İ., Kurultay, Ş. (2018). dikkat. Gıda 43(6), 984-1001.

Kist-van Holthe, J., Altenburg, T., Bolakhrif, S., El Hamdi, L., Man, M.W., Tu, J., Chin, M.J., Paw, M.C.A. (2015). Consumption of artificial food colourings by school children in the Netherlands. Adv Pediatr Res 2, 5. https://doi.org/10.12715/apr.2015.2.5

Kobylewski, S., Jacobson, M.F. (2012). Toxicology of food dyes. Int J Occupat Environ Health 18(3), 220–46. https://doi.org/10.1179/1077352512Z.00000000034

Lok, K.Y.W., Chung, Y.W., Benzie, I.F.F., Woo. J. (2011). Synthetic colourings of some snack foods consumed by primary school children aged 8–9 years in Hong Kong. Food Addit Contam: Part B 4(3), 162–67. https://doi.org/10.1080/19393210.2011.585246

Malabadi, R.B., Kolkar, K.P., Chalannavar, R.K. (2022). Plant natural pigment colorants-health benefits: Toxicity of synthetic or artificial food colorants. Int J Innov Sci Res Rev 04(10), 3418-3429

Marković, T., Muhamedbegović, B., Šubarić, D., Ačkar, Đ. (2023). Potentıal harmful effects of artificial food colors on chıldren's health-revıew of literature. Food in Health and Disease, scientific-professional journal of nutrition and dietetics 12 (2), 74-83.

Martyn, D.M., McNulty, B.A., Nugent, A.P., Gibney, M.J. (2013). Food additives and preschool children. Prod Nutr Soc 72(1), 109–116. https://doi.org/10.1017/S0029665112002935

McCann, D., Barrett, A., Cooper, A., Crumpler, D., Dalen, L., Grimshaw, K. et al. (2007). Food additives and hyperactive behaviour in 3-year-old and 8/9-year-old children in the community: A randomised, double-blinded, placebo-controlled trial. Lancet 370, 95981560–67. https://doi.org/10.1016/S0140-6736(07)61306-3

Monisha, B., Sridharan, R., Kumar, P.S., Rangasamy, G., Krishnaswamy, V.G., Subhashree, S. (2023). Sensing of azo toxic dyes using nanomaterials and its health effects - A review. Chemosphere, 313, 137614. https://doi.org/10.1016/j.chemosphere.2022.137614

Oplatowska-Stachowiak, M., Elliott, C.T. (2017). Food colors: Existing and emerging food safety concerns, Crit Rev Food Sci Nutr 57(3), 524–548. https://doi.org/10.1080/10408398.2014.889652

Önder, H., Aydar, A.Y. (2022). Şekerleme üretiminde kullanılan hammaddeler ve fonksiyonel yumuşak şekerleme üretimi. Aydın Gastronomi, 6(1), 65-78. https://doi.org/10.17932/IAU.GASTRONOMY.2017.016/gastronomy_v06i1006

Potera C. (2010). The artificial food dye blues. Environ. Health Perspect 118,10428. http://dx.doi.org/10.1289/ehp.118-a428

Reza, S.A., Hasan, M., Hossain, K.I., Zubair, A., Bari, L., Abedin, Z., Khandaker, K.B.F., Haque, K.F., Islam, K., Ahmed, M.U., Hossain, K. (2019). Study of a common Azo Food Dye in Mice Model: Toxicity reports and its relation to carcinogenicity. Food Sci Nutr 7(2), 667–77. https://doi.org/10.1002/fsn3.906

Saleem, N., Umar, Z.N. ve Khan, S.I. (2013). Survey on the use of synthetic food colors in food samples procured from different educational institutes of Karachi city. J Tropical Life Sci 3(1), 1-7. http://dx.doi.org/10.11594/jtls.03.01.01

Sigurdson, G.T., Tang, P., Giusti, M.M. (2017). Natural colorants: Food colorants from natural sources. Annu Rev Food Sci Technol 8(1), 261–80. https://doi.org/10.1146/annurev-food-030216-025923

Silva, M.M., Reboredo, F.H., Lidon, F.C. (2022). Food colour additives: A synoptical overview on their chemical properties, applications in food products, and health side effects. Foods 11(3), 379. https://doi.org/10.3390/foods11030379

Solymosi, K., Latruffe, N., Morant-Manceau, A., Schoefs, B. (2015). Food colour additives of natural origin. In Colour additives for foods and beverages. Oxford: Woodhead Publishing, 3-34. https://doi.org/10.1016/B978-1-78242-011-8.00001-5

Türk Gıda Kodeksi Gıda Katkı Maddeleri Yönetmeliği (2023). https://www.resmigazete.gov.tr/eskiler/2023/10/20231013M1-1.htm

Türk Gıda Kodeksi Renklendiriciler Tebliği, TGK 2023.

Vojdani, A., Vojdani, C. (2015). Immune reactivity to food coloring. Altern Ther Health Med 21, 52-62.

Wrolstad, R.E, Culver, C.A. (2012). Alternatives to those artificial FD&C food colorants. Annu Rev Food Sci Technol 3, 59–77. https://doi.org/10.1146/annurev-food-022811-101118

Yılmaz, F.M., Yıldırım, E., Karakuş, M. (2019). Doğal renk maddesi katkılı sert şekerleme üretimi: Farklı karbonhidrat formülasyonlarının renk, camsı geçiş, higroskopite, karbonhidrat kompozisyonu ve duyusal özellikler üzerine etkileri. Gıda, 44(2), 357-368. https://doi.org/10.15237/gida.gd18117

THE IMPACT OF EXCESSIVE SCREEN TIME ON EATING HABITS

Delia-Lois Pătrăuțanu

Dr. Roxana Gheorghita

Faculty of Medicine and Biological Sciences, Stefan cel Mare University of Suceava, Romania

Abstract

In the context of the increasingly frequent use of digital devices, recent research draws attention to the negative effects of prolonged exposure to screens. Beyond the impact on physical and mental health, an increasingly important aspect of interest is the influence of these devices on eating behaviour. This paper is based on the analysis of the specialized literature and synthesizes the conclusions of relevant studies investigating this link. The studies examined highlight a clear association between the time spent in front of screens and the development of unhealthy eating habits. Eating in front of devices affects the perception of hunger and satiety, which favours overeating. Children who use screens for more than an hour a day are more likely to consume ultra-processed and high-calorie foods, with a reduced intake of fruits and vegetables. Online content, such as *"#whatieatinaday*" or advertisements with influencers, contribute to the formation of a distorted body image and can stimulate disordered eating behaviours. Also, prolonged exposure to screens is correlated with an unbalanced diet, an increased consumption of high-calorie snacks and sweetened beverages. These behaviours can lead to obesity, metabolic disorders and dental problems. In conclusion, the specialized literature shows that excessive exposure to screens negatively influences eating behaviour, favouring unhealthy choices and contributing to nutritional imbalances and important risks for physical and mental health. These conclusions emphasize the need for preventive measures and adapted educational programs.

Bibliography

1) Liu J, Riesch S, Tien J, Lipman T, Pinto-Martin J, O'Sullivan A. Screen Media Overuse and Associated Physical, Cognitive, and Emotional/Behavioral Outcomes in Children and Adolescents: An Integrative Review. J Pediatr Health Care. 2022 Mar-Apr;36(2):99-109. doi: 10.1016/j.pedhc.2021.06.003. Epub 2021 Jul 30. PMID: 34334279; PMCID: PMC10029815.

2) Wang, X., Li, Y. & Fan, H. The associations between screen time-based sedentary behavior and depression: a systematic review and meta-analysis. *BMC Public Health* **19**, 1524 (2019).

THE IMPACT OF REDUCTION OF FOOD WASTE ON SUSTAINABLE AGRICULTURE AND CLIMATE RESILIENCE

As. Prof. Dr. Fitnat Şule ŞAKAR

Haliç University Faculty of Health Sciences, Department of Nutrition and Dietetics, Istanbul, Turkey

ORCID ID: https://orcid.org/0000-0003-2640-492X

Yaren GÖKMEN YAZ

Istanbul Okan University Institute of Health Sciences, Department of Nutrition and Dietetics, Istanbul, Turkey

ORCID ID: https://orcid.org/0000-0002-5183-0755

ABSTRACT

Food waste is a complex global problem that significantly affects environmental, economic, and social sustainability. Approximately 1.3 billion tons of food is wasted each year worldwide, leading not only to economic losses but also to the inefficient consumption of natural resources and an increase in greenhouse gas emissions. The aim of this review is to evaluate the impacts of food waste reduction on sustainable agricultural practices and climate resilience through a comprehensive literature review.

A narrative review methodology was applied by examining current national and international literature published between 2010 and 2024. Scientific databases including PubMed, Scopus, Web of Science, and Google Scholar were scanned using keywords such as “food waste,” “sustainable agriculture,” “climate resilience,” “resource efficiency,” and “emissions reduction.” Particular attention was given to peer-reviewed studies involving technological tools (e.g., Global Farm Loss Tool), long-term agricultural impact analyses, and national policy reports. Data were synthesized thematically to assess the ecological, economic, and policy-related outcomes of food waste reduction.

The findings revealed that reducing food waste contributes positively to soil health, biodiversity, and water efficiency while also significantly decreasing greenhouse gas emissions. Tools like WWF’s Global Farm Loss Tool enable better tracking of post-harvest losses and guide intervention strategies. In Turkey, climate-related yield losses in cereal crops have been shown to threaten national food security. Studies also highlighted that improved consumer awareness and integrated agri-food policies are essential for reducing waste throughout the food supply chain.

This review underscores that reducing food waste is not only an environmentally conscious decision but also a strategic priority for achieving economic efficiency and social equity. Promoting circular agriculture, adopting smart technologies, and educating consumers are critical steps toward long-term sustainability.

In conclusion, food waste reduction plays a central role in strengthening the resilience of agricultural systems against climate change and should be incorporated into national and international development frameworks.

Key Words: Food Waste; Sustainable Agriculture; Climate Resilience; Environmental Sustainability; Resource Efficiency

ÖZET

Gıda israfı, çevresel, ekonomik ve sosyal sürdürülebilirliği önemli ölçüde etkileyen karmaşık bir küresel sorundur. Dünya çapında her yıl yaklaşık 1,3 milyar ton gıda israf edilmekte ve bu durum yalnızca ekonomik kayıplara değil, aynı zamanda doğal kaynakların verimsiz tüketimine ve sera gazı emisyonlarında artışa da yol açmaktadır. Bu incelemenin amacı, kapsamlı bir literatür taraması yoluyla gıda israfının azaltılmasının sürdürülebilir tarım uygulamaları ve iklim dayanıklılığı üzerindeki etkilerini değerlendirmektir.

2010-2024 yılları arasında yayınlanmış güncel ulusal ve uluslararası literatürü inceleyerek anlatısal bir inceleme metodolojisi uygulanmıştır. PubMed, Scopus, Web of Science ve Google Akademik gibi bilimsel veri tabanları, "gıda israfı", "sürdürülebilir tarım", "iklim dayanıklılığı", "kaynak verimliliği" ve "emisyon azaltımı" gibi anahtar kelimeler kullanılarak taranmıştır. Teknolojik araçları (örneğin, Küresel Çiftlik Kaybı Aracı), uzun vadeli tarımsal etki analizlerini ve ulusal politika raporlarını içeren hakemli çalışmalara özellikle dikkat edilmiştir. Veriler, gıda israfının azaltılmasının ekolojik, ekonomik ve politika ile ilgili sonuçlarını değerlendirmek için tematik olarak sentezlendi.

Bulgular, gıda israfının azaltılmasının toprak sağlığına, biyolojik çeşitliliğe ve su verimliliğine olumlu katkıda bulunurken aynı zamanda sera gazı emisyonlarını önemli ölçüde azalttığını ortaya koydu. WWF'nin Küresel Çiftlik Kaybı Aracı gibi araçlar, hasat sonrası kayıpların daha iyi izlenmesini sağlıyor ve müdahale stratejilerine rehberlik ediyor. Türkiye'de, tahıl ürünlerinde iklim kaynaklı verim kayıplarının ulusal gıda güvenliğini tehdit ettiği gösterilmiştir. Çalışmalar ayrıca, gıda tedarik zinciri boyunca israfı azaltmak için gelişmiş tüketici bilincinin ve entegre tarım-gıda politikalarının şart olduğunu vurgulamıştır.

Bu inceleme, gıda israfının azaltılmasının yalnızca çevreye duyarlı bir karar değil, aynı zamanda ekonomik verimlilik ve sosyal adalete ulaşmak için stratejik bir öncelik olduğunu vurgulamaktadır. Döngüsel tarımı teşvik etmek, akıllı teknolojileri benimsemek ve tüketicileri eğitmek, uzun vadeli sürdürülebilirliğe doğru kritik adımlardır.

Sonuç olarak, gıda israfının azaltılması, tarımsal sistemlerin iklim değişikliğine karşı dayanıklılığını güçlendirmede merkezi bir rol oynamaktadır ve ulusal ve uluslararası kalkınma çerçevelerine dahil edilmelidir.

Anahtar Kelimeler: Gıda İsrafı; Sürdürülebilir Tarım; İklim Dayanıklılığı; Çevresel Sürdürülebilirlik; Kaynak Verimliliği

GİRİŞ

Gıda israfı, günümüzün en önemli sürdürülebilirlik sorunlarından biri olarak küresel ölçekte çevresel, ekonomik ve sosyal alanlarda ciddi etkiler yaratmaktadır. Birleşmiş Milletler Gıda ve Tarım Örgütü (FAO, 2011) verilerine göre her yıl dünya genelinde üretilen gıdanın yaklaşık üçte biri, yani 1,3 milyar ton, tedarik zincirinin farklı aşamalarında kaybolmakta veya israf edilmektedir. Bu israf, yalnızca ekonomik olarak yılda yaklaşık 940 milyar ABD doları değerinde kayba karşılık gelmekte (Lipinski et al., 2013), aynı zamanda 250 km³ tatlı suyun, 1,4 milyar hektar tarım alanının ve milyonlarca ton gübrenin boşa kullanılmasına neden olmaktadır (Kummu et al., 2012). Çevresel açıdan, israf edilen gıdaların üretimi sırasında kullanılan enerji, su ve toprak kaynaklarının boşa harcanması, ekosistem üzerinde büyük bir yük oluşturmaktadır. FAO (2013) raporuna göre, gıda israfı tek başına küresel sera gazı emisyonlarının yaklaşık %8’inden sorumludur ve bu oran, gıda israfını dünya ülkeleri arasında karbon salımında üçüncü sıraya yerleştirmektedir. Ayrıca atık gıdaların çöp sahalarında ayrışmasıyla ortaya çıkan metan gazı, küresel ısınma potansiyeli karbondioksitten yaklaşık 25 kat daha yüksek olan güçlü bir sera gazıdır (Porter et al., 2016). Ekonomik açıdan, gıda israfı hem üretici hem de tüketici düzeyinde maliyet artışına yol açmaktadır. Gelişmiş ülkelerde israfın büyük bölümü tüketici aşamasında gerçekleşirken, gelişmekte olan ülkelerde yetersiz hasat teknikleri, depolama ve nakliye altyapısındaki eksiklikler nedeniyle üretim ve tedarik aşamalarında yoğunlaşmaktadır (FAO, 2019). Örneğin, Sahra Altı Afrika'da gıda kayıplarının %70'ten fazlası hasat sonrası dönemde meydana gelirken, Avrupa ve Kuzey Amerika'da israfın %50'si tüketici kaynaklıdır (Parfitt et al., 2010). Sosyal açıdan, gıda israfı ve gıda güvensizliği arasındaki çelişki dikkat çekicidir. Dünya genelinde yaklaşık 828 milyon insan yetersiz beslenme ile karşı karşıya iken (FAO, 2022), her yıl üretilen gıdanın üçte birinin çöpe gitmesi, gıda sistemlerindeki adaletsizliğin açık bir göstergesidir. İsraf edilen gıdanın yalnızca dörtte biri bile kurtarılabilseydi, dünyadaki açlık sorununun önemli ölçüde hafifletilebileceği belirtilmektedir (Gustavsson et al., 2011). Türkiye özelinde, TÜİK (2024) verilerine göre yıllık gıda israfı miktarı yaklaşık 18 milyon ton, kişi başına düşen israf miktarı ise 93 kilogramdır. İsrafın %40'ı hanehalkı kaynaklı olup, bu durum tüketici davranışlarının israf üzerindeki etkisini ortaya koymaktadır. Geri kalan israf, üretim, depolama, işleme ve dağıtım aşamalarında gerçekleşmektedir. Türkiye'de soğuk zincir altyapısının her bölgede yeterince gelişmemiş olması, özellikle sebze-meyve gibi hızlı bozulan ürünlerde kayıpların artmasına neden olmaktadır. Ayrıca, perakende sektöründe görsel kusurlu ürünlerin pazara sunulmaması da tüketim öncesi kayıpları artıran bir diğer faktördür (T.C. Tarım ve Orman Bakanlığı, 2021). İklim değişikliği bağlamında, Türkiye coğrafi konumu itibarıyla Akdeniz Havzası'nda yer almakta ve bu bölge, iklim değişikliğine karşı en kırılgan bölgelerden biri olarak tanımlanmaktadır (Türkeş et al., 2018). Kuraklık, ani sıcaklık değişimleri ve aşırı yağış gibi iklim olayları, tarımsal üretimde hem miktar hem de kalite kayıplarına neden olmaktadır. Gıda israfının azaltılması, mevcut tarımsal kaynakların daha verimli kullanılmasını sağlayarak bu olumsuz etkileri hafifletebilir ve tarım sistemlerinin iklim dayanıklılığını güçlendirebilir (Wheeler & von Braun, 2013; Vermeulen et al., 2012). Sonuç olarak, gıda israfı yalnızca çevresel bir problem değil, aynı zamanda ekonomik kaynakların verimsiz kullanımı ve sosyal adaletsizliklerin derinleşmesi anlamına gelen çok boyutlu bir sorundur. Bu nedenle israfın azaltılması, sürdürülebilir tarım uygulamaları ile iklim dayanıklılığı stratejilerinin merkezinde yer almalıdır.

YÖNTEM

Bu çalışma, anlatı temelli bir literatür taramasıdır. 2010–2024 yılları arasında yayımlanmış ulusal ve uluslararası literatür incelenmiştir. Araştırma sürecinde PubMed, Scopus, Web of Science ve Google Scholar veri tabanlarında 'food waste', 'sustainable agriculture', 'climate resilience', 'resource efficiency' ve 'emissions reduction' anahtar kelimeleri kullanılmıştır. Dahil etme kriterleri; hakemli dergilerde yayımlanmış olması, tarım ve iklim ilişkisini incelemesi ve gıda israfı azaltımına yönelik veri sağlamasıdır. Türkiye'ye ait istatistikler için FAO ve TÜİK veri setlerinden yararlanılmıştır.

GELİŞME

Avrupa ve Kuzey Amerika'da kişi başına yıllık gıda israfı 95–115 kg iken, Sahra Altı Afrika ve Güney/Güneydoğu Asya'da bu miktar 6–11 kg'dır (Kummu ve ark., 2012).

Gıda israfının çevresel etkileri yalnızca atığın kendisi ile sınırlı değildir; üretim aşamasında kullanılan su, enerji ve toprak gibi kaynakların da boşa harcanmasına yol açar (Porter ve ark., 2016). Küresel gıda israfı, toplam tatlı su kullanımının %24'ünü, tarım alanlarının %23'ünü ve gübre kullanımının %23'ünü boşa harcamaktadır (Kummu ve ark., 2012). Ayrıca israf edilen gıdalar, küresel sera gazı emisyonlarının yaklaşık %6'sına denk gelen 3,3 milyar ton CO_2 eşdeğeri emisyon üretmektedir (FAO, 2013).

İklim değişikliği, kuraklık, aşırı yağış, sıcaklık dalgalanmaları ve zararlı organizma artışları gibi faktörlerle tarımsal üretimi tehdit etmektedir (Wheeler & von Braun, 2013). Gıda israfının azaltılması, mevcut kaynakların daha verimli kullanımına imkân tanıyarak tarım sistemlerinin iklim şoklarına karşı dayanıklılığını artırabilir (Vermeulen ve ark., 2012).

Sosyoekonomik açıdan bakıldığında, gıda israfının önlenmesi hanehalkı giderlerini azaltmakta, üretici gelirlerini artırmakta ve kırsal kalkınmaya katkıda bulunmaktadır (Priefer ve ark., 2016). Döngüsel ekonomi yaklaşımı kapsamında, gıda atıklarının hayvan yemi, kompost veya biyogaz üretiminde kullanılması hem ekonomik hem de çevresel faydalar sağlamaktadır (Ellen MacArthur Foundation, 2013).

Gıda israfı yalnızca çevresel ve ekonomik bir mesele değil, aynı zamanda etik bir sorundur. Bir yanda milyonlarca insan açlıkla mücadele ederken, diğer yanda tüketilebilir gıdaların çöpe atılması, gıda adaletsizliğini derinleştirmektedir. Bu durum, Birleşmiş Milletler'in sürdürülebilir kalkınma hedeflerinden biri olan "Açlığa Son" ilkesiyle doğrudan çelişmektedir. Gıda israfının azaltılması, sosyal eşitsizliklerin giderilmesi ve gıda hakkının savunulması açısından da hayati öneme sahiptir

Tablo 1. Ülkelere Göre Gıda İsrafı ve Politika Önlemleri

Bölge/Ülke	Yıllık Gıda İsrafı (Milyon Ton)	Kişi Başına İsraf (kg)	Politika/Program Örneği
Avrupa Birliği	88	173	AB Farm to Fork Stratejisi
ABD	60	185	USDA-EPA Food Loss and Waste 2030
Çin	35	25	Clear Your Plate Kampanyası
Türkiye	18	93	Gıdanı Koru Kampanyası
Sahra Altı Afrika	6	10	Yerel Depolama ve Taşıma İyileştirmeleri

TARTIŞMA

Bu çalışmanın bulguları, gıda israfının azaltılmasının sürdürülebilir tarım ve iklim dayanıklılığı üzerinde belirgin olumlu etkiler yarattığını ortaya koymaktadır. Elde edilen sonuçlar, mevcut literatürdeki birçok çalışma ile paralellik göstermektedir. FAO (2019) raporunda, gıda kayıplarının %25 oranında azaltılmasının tarım sektörünün sera gazı emisyonlarında %8'e varan bir düşüş sağlayabileceği belirtilmektedir. Benzer şekilde Kummu ve ark. (2012), gıda israfının küresel tatlı su kullanımının %24'ünü, tarım alanlarının %23'ünü ve gübre kullanımının %23'ünü boşa harcadığını ortaya koymuştur. Bu bulgular, çalışmamızda vurgulanan "israfın azaltılmasının ekolojik kaynak verimliliğini artıracağı" sonucunu desteklemektedir.

Türkiye bağlamında, "Gıdanı Koru" kampanyası gibi farkındalık artırma girişimleri israfın önlenmesine yönelik önemli bir adım olsa da, uygulamaların henüz tedarik zincirinin tüm halkalarını kapsayacak düzeyde olmadığı görülmektedir. Avrupa Birliği'nin "Farm to Fork" stratejisi, üretimden tüketime kadar tüm aşamalarda israfı önlemeye yönelik somut ve ölçülebilir hedefler içerirken (European Commission, 2020), Türkiye'de benzer stratejilerin yasal zemine oturtulması ve sektörler arası koordinasyonun güçlendirilmesi gerekmektedir.

Çalışma ayrıca, teknolojik çözümlerin önemini ortaya koymaktadır. WWF tarafından geliştirilen Global Farm Loss Tool gibi dijital izleme araçları, çiftlik düzeyinde kayıpların ölçülmesini ve müdahale stratejilerinin belirlenmesini kolaylaştırmaktadır (WWF, 2020). Türkiye'de bu tür araçların yaygınlaştırılması, özellikle hasat sonrası kayıpların azaltılması açısından kritik bir rol oynayabilir. Soğuk zincir altyapısının geliştirilmesi, lojistik süreçlerin iyileştirilmesi ve üretici eğitimi ile entegre edilmesi, tarımsal verimliliğin artmasına ve israfın azalmasına katkı sağlayacaktır.

Bunun yanı sıra, tüketici davranışları da israfın boyutunu doğrudan etkilemektedir. WRAP (2021) verilerine göre, gelişmiş ülkelerde gıda israfının yarısından fazlası hanehalkı düzeyinde gerçekleşmektedir. Türkiye'de TÜİK (2024) verileri, hanehalkı kaynaklı israfın toplam israfın %40'ına ulaştığını göstermektedir. Bu durum, farkındalık kampanyalarının sadece üretici ve perakendeci boyutunda değil, tüketici alışkanlıklarını değiştirecek şekilde kurgulanması gerektiğini göstermektedir.

Son olarak, gıda israfının sosyal etkileri de göz ardı edilmemelidir. Dünya genelinde 828 milyon insan yetersiz beslenme ile karşı karşıya iken (FAO, 2022), israf edilen gıdanın yalnızca dörtte birinin kurtarılması bile açlık sorununu önemli ölçüde hafifletebilir. Bu bağlamda, gıda bağış ağlarının güçlendirilmesi, fazla gıdanın ihtiyaç sahiplerine ulaştırılması ve yasal düzenlemelerle bu sürecin kolaylaştırılması hem sosyal adalet hem de çevresel sürdürülebilirlik açısından fayda sağlayacaktır.

SONUÇ VE ÖNERİLER

Bu çalışma, gıda israfının azaltılmasının sürdürülebilir tarım uygulamaları ve iklim dayanıklılığı üzerinde çok boyutlu etkiler yarattığını ortaya koymaktadır. Bulgular, israfın azaltılmasının yalnızca çevresel faydalar sağlamakla kalmadığını; aynı zamanda ekonomik verimliliği artırdığını, doğal kaynakların korunmasına katkıda bulunduğunu ve sosyal eşitliği desteklediğini göstermektedir.

Politika ve Yasal Düzenleme Önerileri:

o Ulusal Gıda İsrafı Azaltma Stratejisi: Üretimden tüketime tüm aşamaları kapsayan, ölçülebilir hedeflere sahip ve yasal zemine oturtulmuş bir ulusal strateji geliştirilmelidir.
o Bağış Teşvikleri: Perakende ve gıda hizmeti sektörlerinde satılamayan ancak güvenli gıdaların bağışını teşvik eden vergi indirimleri ve lojistik destek mekanizmaları oluşturulmalıdır.
o Görsel Kusurlu Ürünlerin Pazara Girişi: Estetik standartlara uymayan ancak güvenli gıdaların satışının teşvik edilmesi ile üretim aşamasında kayıplar azaltılabilir.

Teknolojik ve Operasyonel Öneriler

o Dijital İzleme Sistemleri: Global Farm Loss Tool gibi teknolojiler Türkiye'de yaygınlaştırılarak üretim ve dağıtım aşamalarında kayıplar izlenebilir.
o Soğuk Zincir Altyapısı: Özellikle sebze-meyve gibi kısa ömürlü ürünlerde soğuk zincir yatırımları artırılmalıdır.
o Lojistik Optimizasyonu: Taşıma sürelerini ve bozulma riskini azaltacak rota planlamaları ve depolama sistemleri geliştirilmelidir.

Toplumsal ve Eğitim Odaklı Öneriler

o Farkındalık Kampanyaları: Hanehalkı düzeyinde israfı azaltmaya yönelik ulusal medya kampanyaları ve sosyal medya projeleri yürütülmelidir.
o
Müfredat Entegrasyonu: İlköğretimden itibaren gıda israfı ve sürdürülebilir tüketim alışkanlıkları eğitim programlarına dahil edilmelidir.
o
Yerel Yönetim Projeleri: Belediyeler, fazla gıdanın bağış ağlarına aktarılmasını kolaylaştıracak altyapılar oluşturmalıdır.

Uluslararası İşbirliği

o Bilgi ve Teknoloji Paylaşımı: Diğer ülkelerde başarıyla uygulanmış israf azaltma programlarının Türkiye'ye adapte edilmesi için işbirlikleri yapılmalıdır.

o

Küresel Sürdürülebilirlik Hedefleri ile Uyum: Gıda israfının azaltılması, Birleşmiş Milletler Sürdürülebilir Kalkınma Hedefleri'nin (SKH 12.3) bir parçası olarak ulusal kalkınma planlarına entegre edilmelidir.

Sonuç olarak, gıda israfı ile mücadele, yalnızca çevreyi koruma çabası değil, aynı zamanda ekonomik kalkınma, sosyal adalet ve iklim değişikliğine uyum stratejilerinin temel unsurlarından biridir. Türkiye'de atılacak adımların hem yerel hem de küresel düzeyde önemli katkılar sağlayacağı açıktır.

KAYNAKLAR

Ellen MacArthur Foundation. (2013). *Towards the circular economy: Economic and business rationale for an accelerated transition*. Ellen MacArthur Foundation.

European Commission. (2020). *Farm to Fork Strategy – For a fair, healthy and environmentally-friendly food system*. Publications Office of the European Union.

Food and Agriculture Organization of the United Nations. (2011). *Global food losses and food waste – Extent, causes and prevention*. FAO.

Food and Agriculture Organization of the United Nations. (2013). *Food wastage footprint: Impacts on natural resources*. FAO.

Food and Agriculture Organization of the United Nations. (2019). *The state of food and agriculture 2019: Moving forward on food loss and waste reduction*. FAO.

Food and Agriculture Organization of the United Nations. (2022). *The state of food security and nutrition in the world 2022*. FAO.

Garrone, P., Melacini, M., & Perego, A. (2014). Opening the black box of food waste reduction. *Food Policy, 46,* 129–139. https://doi.org/10.1016/j.foodpol.2014.03.014

Gustavsson, J., Cederberg, C., & Sonesson, U. (2011). *Global food losses and food waste: Extent, causes and prevention*. FAO.

Kitinoja, L., & Barrett, D. M. (2015). Extension of small-scale postharvest horticultural technology for reducing losses in developing countries. *Acta Horticulturae, 1119,* 263–278. https://doi.org/10.17660/ActaHortic.2016.1119.35

Kummu, M., de Moel, H., Porkka, M., Siebert, S., Varis, O., & Ward, P. J. (2012). Lost food, wasted resources: Global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use. *Science of the Total Environment, 438*, 477–489. https://doi.org/10.1016/j.scitotenv.2012.08.092

Lipinski, B., Hanson, C., Lomax, J., Kitinoja, L., Waite, R., & Searchinger, T. (2013). *Reducing food loss and waste*. World Resources Institute.

Parfitt, J., Barthel, M., & Macnaughton, S. (2010). Food waste within food supply chains: Quantification and potential for change to 2050. *Philosophical Transactions of the Royal Society B: Biological Sciences, 365*(1554), 3065–3081. https://doi.org/10.1098/rstb.2010.0126

Porter, S. D., Reay, D. S., Higgins, P., & Smith, P. (2016). Mitigation potential of carbon capture and storage in the food sector. *Nature Climate Change, 6*(1), 1–6. https://doi.org/10.1038/nclimate2870

Priefer, C., Jörissen, J., & Bräutigam, K. R. (2016). Food waste prevention in Europe – A cause-driven approach to identify the most relevant leverage points for action. *Resources, Conservation and Recycling*, *109*, 155–165. https://doi.org/10.1016/j.resconrec.2016.03.004

Republic of Türkiye Ministry of Agriculture and Forestry. (2021). *Gıdanı Koru Kampanyası*. https://www.gidanikoru.com

Türkeş, M., Sümer, U. M., & Kılıç, G. (2018). Climate change, drought, and agriculture in Turkey: Impacts and adaptation. *Turkish Journal of Agriculture and Forestry*, *42*, 1–13. https://doi.org/10.3906/tar-1806-21

Vermeulen, S. J., Campbell, B. M., & Ingram, J. S. (2012). Climate change and food systems. *Annual Review of Environment and Resources*, *37*, 195–222. https://doi.org/10.1146/annurev-environ-020411-130608

Wheeler, T., & von Braun, J. (2013). Climate change impacts on global food security. *Science, 341*(6145), 508–513. https://doi.org/10.1126/science.1239402

World Wide Fund for Nature. (2020). *Global farm loss tool – Measuring on-farm food loss*. WWF.

WRAP. (2021). *Food surplus and waste in the UK – Key facts*. Waste and Resources Action Programme.

TOXICOLOGICAL AND BIOLOGICAL CHARACTERIZATION OF THE VENOMS OF THE MOST DANGEROUS VIPER SPECIES IN MOROCCO

PhD Student Noureddine HAMMANI

Pasteur Institute of Morocco, Venom and Toxin Laboratory, Place Louis Pasteur, Casablanca 20250, Morocco

University Hassan II, Casablanca, Faculty of Medicine and Pharmacy, Morocco

ORCID ID: https://orcid.org/0009-0005-6337-2578

PhD Student Khawla AMMOUCH1

Mohammed V University of Rabat, Faculty of Dental Medicine, Morocco

Pasteur Institute of Morocco, Venom and Toxin Laboratory, Place Louis Pasteur, Casablanca 20250, Morocco

ORCID number: 0009-0003-8596-9055

PhD Student Nihal MESMOUDI

Mohammed V University of Rabat, Faculty of Dental Medicine, Morocco

Pasteur Institute of Morocco, Venom and Toxin Laboratory, Place Louis Pasteur, Casablanca 20250, Morocco

Prof. Abdellah MOUSTAGHFIR

Mohammed V University of Rabat, Faculty of Dental Medicine, Morocco

Ennaji HANANE

University Hassan II, Casablanca, Faculty of Medicine and Pharmacy, Morocco

Samir IBENMOUSSA

University Hassan II, Casablanca, Faculty of Medicine and Pharmacy, Morocco

Dr. Naoual OUKKACHE

Pasteur Institute of Morocco, Venom and Toxin Laboratory, Place Louis Pasteur, Casablanca 20250, Morocco

Morocco is one of the most biodiverse countries in the Mediterranean region, particularly regarding its snake fauna. The country is home to eight venomous snake species, seven of which belong to the *Viperidae* family, responsible for approximately 80% of viper envenomation cases. According to the Moroccan Poison Control and Pharmacovigilance Centre, *Cerastes cerastes* (the Sahara horned viper) and *Daboia mauritanica* are considered among the most dangerous species, being the most frequently implicated in reported envenomation cases in the Kingdom. These vipers cause a wide

range of local and systemic symptoms, including oedema, blistering, dermonecrosis, myotoxicity, and hemorrhagic diathesis, often associated with defibrinogenation and thrombocytopenia. Current treatment guidelines address the clinical manifestations of viper envenomation as a single clinical syndrome, without distinguishing between the specific effects of different species. However, for more effective clinical management, a detailed characterization of the toxicological and biological profiles of each viper species is essential.

In this context, we investigated the lethality, as well as the hemorrhagic, oedematous, and myotoxic activities of *C. cerastes* and *D. mauritanica* venoms. Our results show that the median intraperitoneal lethal doses (LD_{50}) for *C. cerastes* and *D. mauritanica* venoms are 36.30 µg/mouse and 48.64 µg/mouse, respectively. The minimum hemorrhagic doses (MHD) were 0.35 µg/mouse for *C. cerastes* and 1.74 µg/mouse for *D. mauritanica*, while the minimum oedematous doses (MED) were 1.37 µg/mouse and 3.05 µg/mouse, respectively. These findings indicate that *C. cerastes* venom is more toxic and hemorrhagic, and induces death significantly faster than *D. mauritanica* venom.

The LD_{50} values and associated pathophysiological data obtained in this study can support the development of a specific antivenom targeting bites from these two medically significant viper species in Morocco.

Keywords: Viper, Envenomation, *In vivo* toxicity, Hemorrhage, Oedema, Pathophysiology.

KNOWLEDGE, LIFESTYLE HABITS, AND THE ROLE OF NUTRITIONAL ELEMENTS IN TYPE 2 DIABETES MANAGEMENT: A CROSS-SECTIONAL STUDY AMONG IRAQI PATIENTS

Ali Hussein

Tikrit University - College of Pharmacy - Department of Pharmaceutical Chemistry - Tikrit-Iraq

Mustafa AL-Obaidi

Tikrit University - College of Pharmacy - Department of Pharmaceutical Chemistry - Tikrit-Iraq

Majd Ahmed Jumaah

Tikrit University - College of Pharmacy - Department of Pharmaceutical Chemistry - Tikrit-Iraq

Omar Salih Hassan

Tikrit University - College of Pharmacy - Department of Pharmaceutical Chemistry - Tikrit-Iraq

Abstract

Type 2 diabetes is a rapidly growing disease, with increasing associated complications and healthcare costs. Lifestyle and medical nutrition therapy are the cornerstones of type 2 diabetes prevention and treatment, and the American Diabetes Association has made several recommendations on medical nutrition therapy for diabetes; these recommendations emphasize the importance of reducing major and minor vascular complications in diabetic patients. Four types of diets were reviewed for their effects on diabetes: the Mediterranean diet, the low-carbohydrate/high-protein diet, the plant-based diet, and the vegan diet. In this research, survey data were collected on January 18, 2023 by posting a Google form on social media, WhatsApp, Telegram, and the link sent to all files. All the questionnaire questions were directed to groups of diabetic patients, three questions were about distinctive things for example (age, healthy diet, and exercise), and the remaining questions (11) were about their knowledge and information about type 2 diabetes, and the study ended on February 25, 2023, and the researchers selected 123 questionnaires from different Iraqi governorates. (49_43) 30.9% have diabetes in a year, 71.5% females and 28.5% males. 42% do not exercise and 57% exercise, 4.1% use a healthy diet and exercise, 38% use metformin, 26% use amaryl, 43% use daunil, 28% use empagliflozin. This study shows that young Iraqi participants (aged 40-50 years) have good knowledge about the causes and symptoms of type 2 diabetes but have poor knowledge about the importance of healthy diet and exercise in maintaining blood sugar levels. Elements such as chromium, magnesium, and zinc contribute to improved insulin sensitivity and glucose regulation. Additionally, dietary fiber and omega-3 fatty acids support glycemic control and reduce inflammation. Incorporating these nutrients through a balanced diet may enhance diabetes management and reduce the risk of complications.

Keywords: Diabetes, health care costs, Metabolism, Treatments and Medications Diabetes.