INTERNATIONAL CONGRESS ON NUTRITION, FOOD, AGRICULTURE AND CLIMATE-II

Scientific Approaches for Sustainable Living

June 25-27, 2026 | İstanbul, Türkiye





EDITOR

Prof. Dr. Osman ERKMEN

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ICoN-FAC 2026

2.INTERNATIONAL CONGRESS ON NUTRITION, FOOD, AGRICULTURE AND CLIMATE

Scientific Approaches for Sustainable Living

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17.07.2026

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PROCEEDINGS BOOK

ISBN: 979-8-89695-482-8

CONGRESS ID

CONGRESS TITLE

ICoN-FAC 2026

2.INTERNATIONAL CONGRESS ON NUTRITION, FOOD, AGRICULTURE AND CLIMATE

Scientific Approaches for Sustainable Living

DATE AND PLACE

June 25-27, 2026 / Istanbul, Türkiye

ORGANIZATION

İSTANBUL OKAN UNIVERSITY

İKSAD INSTITUTE

EDITOR

Prof. Dr. Osman ERKMEN

COORDINATOR

Samet KUŞKIRAN

PARTICIPANTS COUNTRY (13 countries)

TÜRKİYE, ROMANIA, NIGERIA, MOROCCO, IRAN, AZERBAIJAN, ALGERIA, INDONESIA, IRELAND, BRAZIL, PAKISTAN, BANGLADESH, NORTHERN CYPRUS

Total Accepted Article: 78

Total Rejected Papers: 21

Accepted Article (Türkiye): 35

Accepted Article (Other Countries): 43

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ICoN-FAC 2026

2. INTERNATIONAL CONGRESS ON NUTRITION, FOOD, AGRICULTURE AND CLIMATE

Scientific Approaches for Sustainable Living

İSTANBUL OKAN ÜNİVERSİTESİ

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17.07.2026

REF: Akademik Teşvik

İlgili makama;

ICoN-FAC 2026 Uluslararası Beslenme, Gıda, Tarım Ve İklim Denge Kongresi-II, 25-27 Haziran 2026 tarihleri arasında İstanbul'da 13 farklı ülkenin (Türkiye 35 bildiri- Diğer ülkeler 43 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.

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Saygılarımla

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Istanbul Arel University
CONGRESS PRESIDENT

Tarih: 14/04/2026 15:52
Sayı: E-56200091-100-2026.69.663551
00000664147

İSTANBUL OKAN ÜNİVERSİTESİ

T.C.
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REKTÖRLÜĞÜ

Sayı : E-56200091-100-2026.69.663551 14/04/2026
Konu : Kongre Onayı

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İlgi : 07.04.2026 tarihli ve E-26494018-100-2026.21.661684 sayılı yazınız.

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Tarih: 08/04/2026 14:37
Sayı: E-26494018-100-2026.21.661684
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İSTANBUL OKAN ÜNİVERSİTESİ

T.C.
İSTANBUL OKAN ÜNİVERSİTESİ REKTÖRLÜĞÜ
Sağlık Bilimleri Fakültesi Dekanlığı

Sayı : E-26494018-100-2026.21.661684 08/04/2026
Konu : Kongre Onayı Hakkında

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İLGİ: 06.04.2026 tarih ve E-26494018-100-2026.84321.662195 sayılı yazı,

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Ek:
1- 1) ICoN-FAC-2 2026-Kongre İzni
2- Kongre Onayı Hakkında_Ustyazi

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İstanbul Okan Üniversitesi Sağlık Bilimleri Fakültesi Beslenme ve Diyetetik Bölümü ile İKSAD iş birliğinde, 25-27 Haziran 2026 tarihleri arasında çevrim Çevrimiçi Katılım (Online) "International Congress on Nutrition, Food, Agriculture and Climate (ICoN-FAC-2 2026)" başlıklı uluslararası kongrenin düzenlenmesi planlanmaktadır.

Söz konusu kongrenin önceki organizasyonlarında da kongre başkanı olarak görev almış bulunmaktayım. Ayrıca İKSAD iş birliğiyle, yurt içinde ve yurt dışında Paris, Kiev ve Azerbaycan gibi çeşitli merkezlerde, üniversiteler veya kongre merkezleri bünyesinde düzenlenen 50'nin üzerinde kongrede Kongre Başkanı veya Düzenleme Kurulu üyesi olarak görev yaptım.

Planlanan bu kongrede, aşağıda belirtilen "**Kongre Başkanı (Congress President)**" ile "**Düzenleme Kurulu (Organizing Board)**" üyeleri, İstanbul Okan Üniversitesi Beslenme ve Diyetetik Bölümü öğretim elemanları ve akademik personelinden oluşacak; kongrenin akademik ve bilimsel faaliyetlerinden sorumlu olacaklardır.
Üniversitemiz ise kongre afişlerinin hazırlanması ve kongre duyurusunun diğer üniversitelere duyurulması süreçlerinde görev alacaktır.
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International Congress on Nutrition, Food, Agriculture and Climate (ICoN-FAC-2 2026)

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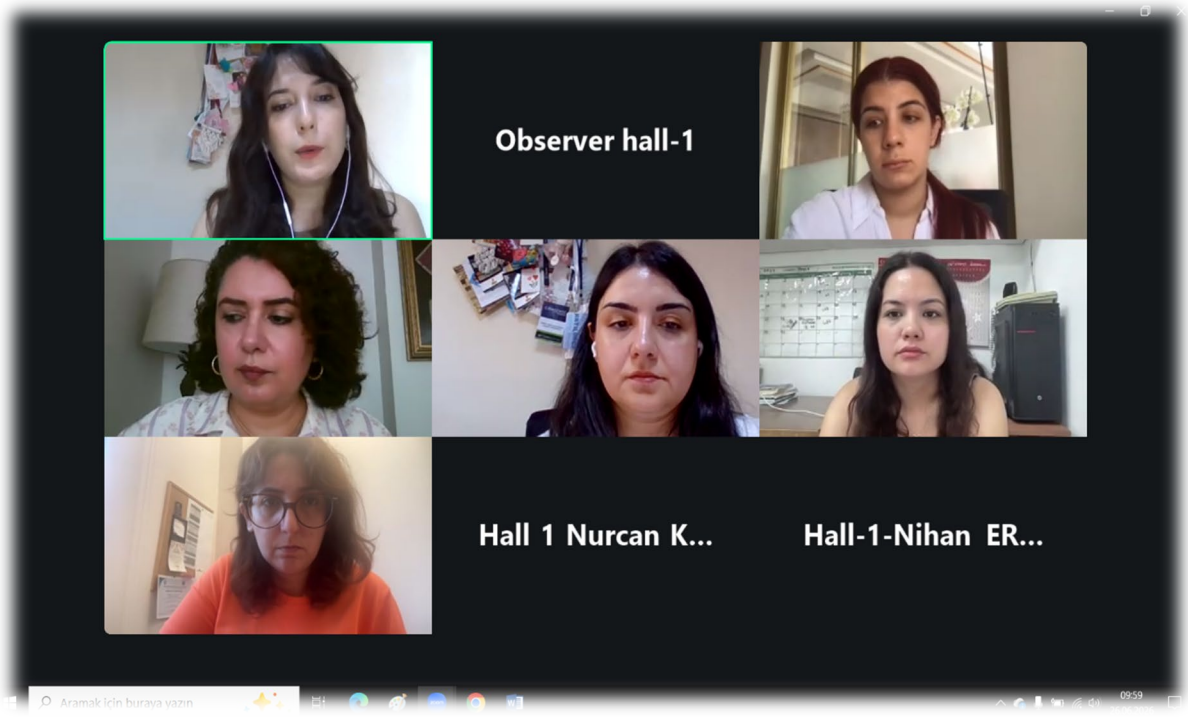

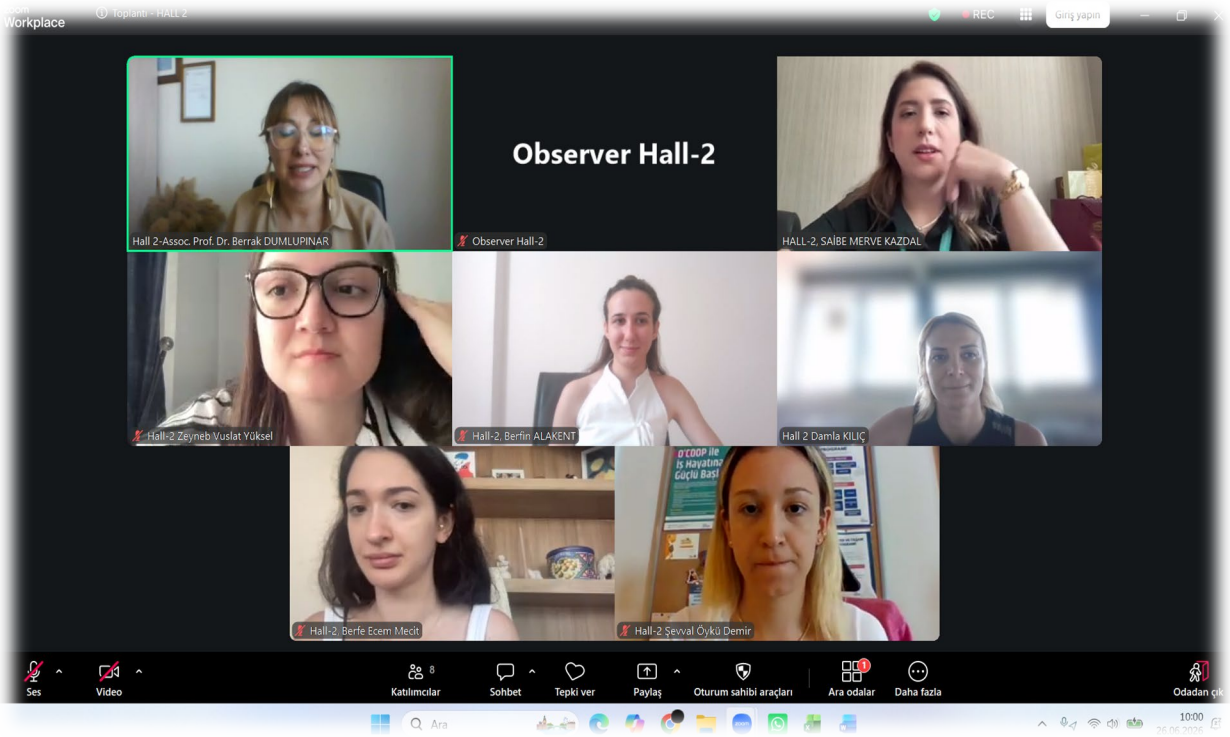

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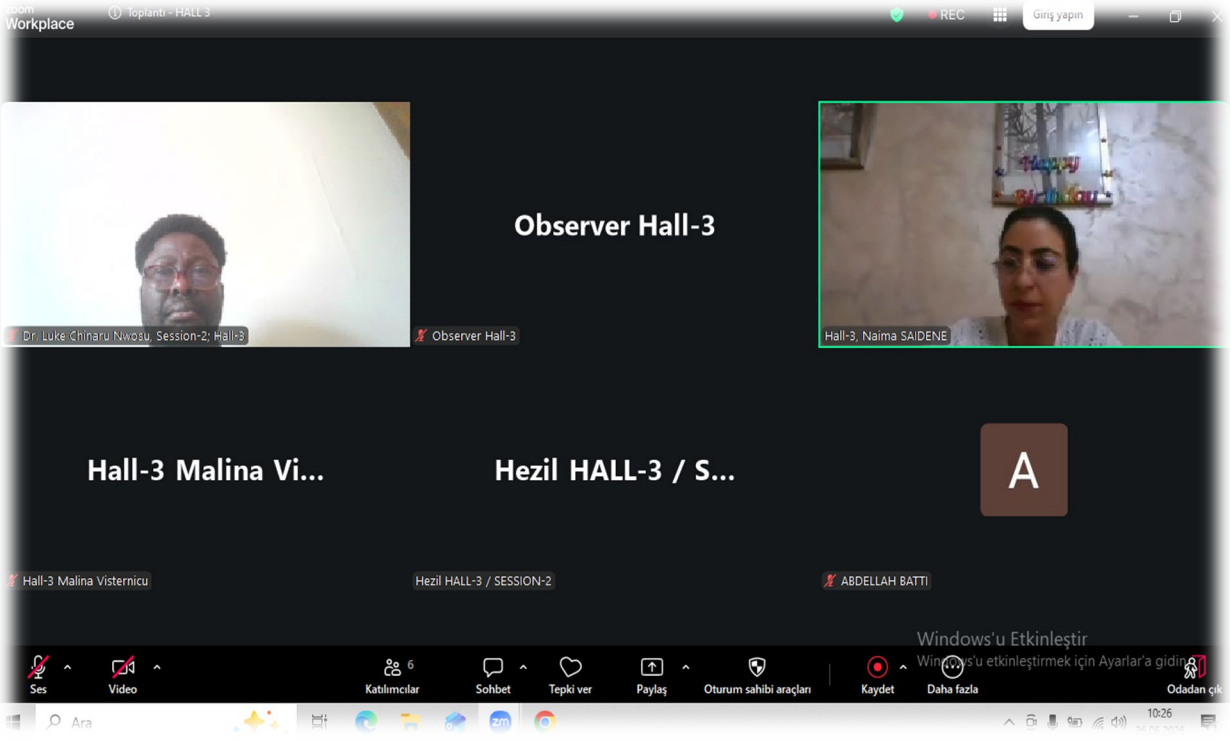



ICoN-FAC 2026

2.INTERNATIONAL CONGRESS ON NUTRITION, FOOD, AGRICULTURE AND CLIMATE

Scientific Approaches for Sustainable Living

June 25-27, 2026 / Istanbul, Türkiye

CONFERENCE PROGRAM

Zoom Meeting ID: 829 5595 6031
Zoom Passcode: 020202

https://us02web.zoom.us/j/82955956031?pwd=DbnilsNxPKEGMbaIp03KwtptssGVxM.1

Participant Countries (13): Türkiye, Romania, Nigeria, Morocco, Iran, Azerbaijan, Algeria, Indonesia, Ireland, Brazil, Pakistan, Bangladesh, Northern Cyprus

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- ✓ 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, Samet KUŞKIRAN

25.06.2026 / Session-1 / Hall-1

Ankara Local Time: 10:00 – 12:00

Meeting ID: 829 5595 6031 / Passcode: 020202

Moderator: Assist. Prof. Dr. Funda ŞENSOY

Title	Author(s)	Affiliation
BIOWASTE-DERIVED NANOMATERIALS FROM THE BLACK SEA REGION FOR SUSTAINABLE ENVIRONMENTAL POLLUTION REMOVAL	İlkim Nuray KÜÇÜK Assist. Prof. Dr. Pınar BOZBEYOĞLU	Gümüşhane University TÜRKİYE
WASTE-FREE UTILIZATION OF FRUITS AND VEGETABLES: A SUSTAINABLE APPROACH TO REDUCING FOOD WASTE	Gülcan YILDIZ Assist. Prof. Dr. Funda ŞENSOY	İstanbul Okan University TÜRKİYE
DEVELOPING SUSTAINABLE PACKAGING MATERIALS FROM CITRUS PEELS	Şevval Nur SARISOY Res. Assist. Dr. Hatice Sena OLCAY Assoc. Prof. Dr. Dr. Meral YILDIRIM YALÇIN Prof. Dr. Ömer Said TOKER	İstanbul Aydın University TÜRKİYE Yıldız Technical University TÜRKİYE
EDIBLE COATINGS: CURRENT APPROACHES IN SUSTAINABLE FOOD PRESERVATION	Assist. Prof. Dr. Yasin AKKEMİK	Kastamonu University TÜRKİYE
THE EFFECTS OF DIFFERENT BLENDING COMBINATIONS ON PRODUCT QUALITY IN WHOLE WHEAT FLOUR PRODUCTION	Ayşenur ÖZLER Prof. Dr. Mehmet AKBULUT Prof. Dr. Hacer ÇOKLAR Havvanur DEMİR Latif GÜMÜŞEL	Eksun Food, R&D, Konya TÜRKİYE Selçuk University TÜRKİYE Selçuk University TÜRKİYE Eksun Food, R&D, Konya TÜRKİYE Eksun Food, R&D, Konya TÜRKİYE
TRADITIONAL METHOD OF BITTERNESS REMOVAL PROCESS IN LUPIN (LUPINUS ALBUS L.) FLOUR PRODUCTION	Ayşenur ÖZLER Prof. Dr. Mehmet AKBULUT Prof. Dr. Hacer ÇOKLAR Mehmet Ergül YEŞİLYURT Mücahit Enes GÜNDOĞDU	Eksun Food, R&D, Konya TÜRKİYE Selçuk University TÜRKİYE Selçuk University TÜRKİYE Eksun Food, R&D, Konya TÜRKİYE Eksun Food, R&D, Konya TÜRKİYE
PLANT EXTRACT AS A SUSTAINABLE ELECTROLYTE FOR GREEN SENSORS	Elis ZAYİM Erdogan Yasar SAYGUN Prof. Dr. Demet AYDINOĞLU	Üsküdar American Academy TÜRKİYE ITU Development Foundation Schools Ekrem Elginkan High School TÜRKİYE Yalova University TÜRKİYE
THE EGG'S NATURAL SAFETY PACKAGE: ANTIMICROBIAL DEFENSE MECHANISMS AND PUBLIC HEALTH IMPLICATIONS	Assist. Prof. Dr. Selçuk ALAN	Kafkas University TÜRKİYE

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25.06.2026 / Session-1 / Hall-2

Ankara Local Time: 10:00 – 12:00

Meeting ID: 829 5595 6031 / Passcode: 020202

Moderator: Lect. Cemaliye SÜT

Title	Author(s)	Affiliation
EVALUATION OF POST–SLEEVE GASTRECTOMY EATING ATTITUDES AND FOOD CONSUMPTION AWARENESS	Ayça ACUNGAN Assist. Prof. Dr. Aylin SEYLAM KÜŞÜMLER	Private Op. Dr. Ömer AVLANMIŞ Bariatric Surgery Clinic, TÜRKİYE İstanbul Okan University TÜRKİYE
HUNGER OR ADDICTION? THE EFFECTS OF ULTRA PROCESSED FOODS ON EATING BEHAVIOR	Sude ALTIN Prof. Dr. Osman ERKMEN Assist. Prof. Dr. Çağla Pınarlı FALAKACILAR	İstanbul Okan University TÜRKİYE
CHANGES IN DIETARY HABITS: ULTRA PROCESSED FOODS AND HEALTH	Çiğdem BEDİZ	Kyrenia University NORTHERN CYPRUS
INVESTIGATION OF THE EFFECTS OF SOCIAL MEDIA USE ON EATING BEHAVIOR, DIET QUALITY, AND SUSTAINABLE NUTRITION BEHAVIORS	İrem BULUT Prof. Dr. Osman ERKMEN Assist. Prof. Dr. Çağla PINARLI FALAKACILAR	İstanbul Okan University TÜRKİYE
THE RELATIONSHIP BETWEEN UNIVERSITY STUDENTS' SUSTAINABLE AND HEALTHY EATING BEHAVIORS AND THEIR BODY MASS INDEX	Beyza AYDIN Assist. Prof. Dr. Burak ERİM Res. Assist. Ayşenur TAŞLI	İstanbul Esenyurt University TÜRKİYE
ASSESSMENT OF THE EFFECT OF NUTRITION KNOWLEDGE LEVEL AND ATTITUDES ON FOOD SUPPLEMENT USE ACCORDING TO BODY MASS INDEX	Sezer GÜLEŞCE Assist. Prof. Dr. İrem KARAMOLLAOĞLU	İstanbul Okan University TÜRKİYE
THE EVALUATION OF THE RELATIONSHIP BETWEEN NUTRITIONAL KNOWLEDGE LEVEL AND CARBOHYDRATE CONSUMPTION PREFERENCES IN ADULTS FROM A SUSTAINABLE NUTRITION PERSPECTIVE	Melisa ALTAŞ Assist. Prof. Dr. İrem KARAMOLLAOĞLU	İstanbul Okan University TÜRKİYE

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25.06.2026 / Session-1 / Hall-3

Ankara Local Time: 10:00 – 12:00

Meeting ID: 829 5595 6031 / Passcode: 020202

Moderator: Res. Assist. Hasret Gülüş OYMAK

Title	Author(s)	Affiliation
THE IMPACT OF CLIMATE CHANGE ON NUTRITION AND FOOD SECURITY: THE ROLE OF PUBLIC HEALTH NURSES	Assist. Prof. Dr. Tuğba ÖZDEMİR	İstanbul Gedik University TÜRKİYE
FOOD SAFETY AND SUSTAINABLE NUTRITION APPROACHES IN THE CONTEXT OF THE CLIMATE CRISIS	Dr. Gökhan ŞALLI	Anadolu University TÜRKİYE
CLIMATE CRISIS, DROUGHT, AND GRAIN PRODUCTION: AN ASSESSMENT FROM AGRICULTURAL AND NUTRITIONAL PERSPECTIVES, SPECIFICALLY FOR TÜRKIYE	Assist. Prof. Dr. Başak CAN Res. Assist. Hasret Gülüş OYMAK	İstanbul Beykent University TÜRKİYE İstanbul Okan University TÜRKİYE
COMPARATIVE AND SPATIAL SUSTAINABILITY ANALYSIS OF AGRICULTURAL PRODUCTION LAND IN ENVIRONMENTAL PLANS	Gökhan Hüseyin ERKAN	Karadeniz Technical University TÜRKİYE
EMBEDDED CLIMATE EXPOSURE IN AN INPUT-OUTPUT ECONOMY: A SYSTEM DYNAMICS FRAMEWORK FOR THE PROPAGATION AND RECOVERY OF SECTORAL CLIMATE RISK	Doğan ŞENGÜL Mahmut Emin SARIKAYA	İstanbul Sabahattin Zaim University TÜRKİYE
CLIMATE-ATTRIBUTABLE THERMAL-ERGONOMIC STRAIN: A BIOPHYSICAL ACCUMULATION AND WORK-REST OPTIMISATION FRAMEWORK FOR OCCUPATIONAL HEAT EXPOSURE	Mahmut Emin SARIKAYA Doğan ŞENGÜL	İstanbul Sabahattin Zaim University TÜRKİYE
VEGETARIAN DIETS: A VETERINARY BIOETHICS PERSPECTIVE ON SUSTAINABILITY, ANIMAL WELFARE, AND ONE HEALTH	Assist. Prof. Dr. Seda ÇAVUŞ ALAN	Kafkas University TÜRKİYE
AN EXAMINATION OF POSTGRADUATE THESES ON FOOD LITERACY AND FOOD LABELING IN TÜRKİYE	Res. Assist. Sümeyye ŞİMŞEK Assoc. Prof. Dr. Meryem Merve ÖREN ÇELİK	İstanbul University TÜRKİYE İstanbul Yeni Yüzyıl University TÜRKİYE İstanbul University TÜRKİYE

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25.06.2026 / Session-1 / Hall-4

Ankara Local Time: 10:00 – 12:00

Meeting ID: 829 5595 6031 / Passcode: 020202

Moderator: Prof. Mir-Hassan Moosavy

Title	Author(s)	Affiliation
EXPLAINABLE AI IN FOOD SAFETY, NUTRITION MONITORING, AND AGRICULTURAL DECISION-MAKING	Moses Adeolu AGOI Yewande Adeyosola ODUNAYO Olayemi Grace ABIMBOLA Rasheed Olatunde AJETUNMOBI	Lagos State University of Education NIGERIA
DIGITAL AGRICULTURE AND CLIMATE ADAPTATION FOR SUSTAINABLE FOOD SYSTEMS, NUTRITION SECURITY, AND ENVIRONMENTAL RESILIENCE	Moses Adeolu AGOI Samuel Olayiwola AJAGA Olajuwon Victor OLAYINKA Oluwadamilola Peace AGOI	Lagos State University of Education NIGERIA
CARBON-SMART DIGITAL AGRICULTURE FOR NET-ZERO FARMING	Fahad Amjad Abdul Rehman Muhammad Zain	Islamia University PAKISTAN
INNOVATIVE AI-DRIVEN SPECTROSCOPIC METHODS FOR OLIVE OIL AUTHENTICATION, QUALITY CONTROL, AND FRAUD DETECTION	Prof. Mir-Hassan Moosavy	Tabriz University IRAN
ECO-VISUAL PEDAGOGY: INTEGRATING GRAPHICS DESIGN AND PAINTING IN ENVIRONMENTAL SCIENCE EDUCATION WITHIN THE ERA OF AI AND EMERGING TECHNOLOGIES	Ajayi, Olayemi T. Oyewumi, Taiye S.	Lead City University NIGERIA Federal University of Education NIGERIA
PHOTOVOLTAIC WATER PUMPING SYSTEMS WITHIN THE WATER–ENERGY–FOOD NEXUS: TECHNO-ECONOMIC AND ENVIRONMENTAL ASSESSMENT	Karima LAAROUSSI Abdellah EL AISSAOUI Assia HARKANI Saloua JEMJAMI	Hassan 1st University MOROCCO National Institute of Agronomic Research MOROCCO

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25.06.2026 / Session-1 / Hall-5

Ankara Local Time: 10:00 – 12:00

Meeting ID: 829 5595 6031 / Passcode: 020202

Moderator: Bogdan-Catalin SERBAN

Title	Author(s)	Affiliation
RESPIRATION DYNAMICS AND GAS-RATIO MONITORING OF BANANAS STORED IN A NON-VENTILATED BIOREACTOR	Bogdan-Catalin SERBAN Matei-Gabriel URSACHESCU Vlad DİACONESCU Caterina Maria ZETU Maria Ruxandra SALAGEAN Diana DUMITRAȘCU Octavian BUİU Marius BUMBAC Cristina Mihaela NICOLESCU	National Institute for Research and Development in Microtechnologies–IMT ROMANIA National College “B. P. Hasdeu” ROMANIA University of Medicine and Pharmacy “Carol Davila” ROMANIA International Theoretical High School of Computer Science ROMANIA National College “Saint Sava” ROMANIA National College “Saint Sava” ROMANIA National Institute for Research and Development in Microtechnologies–IMT ROMANIA Valahia University ROMANIA Valahia University ROMANIA
ATMOSPHERIC CHANGES DURING POTATO STORAGE IN A CLOSED CONTAINER		
DYNAMIC ASSESSMENT OF GAS EXCHANGE AND MICROCLIMATE EVOLUTION IN CLOSED STORAGE SYSTEMS FOR FRESH CUCUMBERS		
INFLUENCE OF STORAGE TEMPERATURE AND CULTIVATION SYSTEM ON THE PHYSICOCHEMICAL QUALITY OF TOMATO		
MODELING OF THE DRYING KINETICS OF GREEN UBÁ MANGO PEEL BY INFRARED DRYING	Renata Cássia Campos Wellerson de Oliveira Alves da Silva	Federal University of Vicosa BRAZIL
DRYING BEHAVIOR AND QUALITY CHARACTERISTICS OF GALA APPLE SLICES SUBJECTED TO CITRIC ACID AND SUCROSE PRETREATMENTS	Wellerson de Oliveira Alves da Silva Renata Cássia Campos	Federal University of Vicosa BRAZIL
ANALYSIS OF BOD, COD, AND BIODEGRADABILITY RATIO OF INDUSTRIAL POTATO FIRST-WASH WASTEWATER	Renata Cássia Campos Wellerson de Oliveira Alves da Silva	Federal University of Vicosa BRAZIL
INTERACTIVE EFFECTS OF GRAPE CULTIVAR AND DRYING METHOD ON RAISIN QUALITY	Laila Ouardi Abdelmajid Haddioui Lalla Hasna Zinelabidine Abdelghani Bouchyoua Mohammed El Kadi Hassane Boudad Bouchra Ayat Jamal Charafi	National Institute of Agricultural Research MOROCCO Sultan Moulay Slimane University MOROCCO
POZZOLAN–SODIUM ALGINATE BEADS: A NOVEL COMPOSITE FOR ADSORBING POLYPHENOLS FROM OLIVE OIL	Ahmed Osmane Khadija Zidan Moustapha Belmouden	Cadi Ayyad University MOROCCO Agadir University MOROCCO

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25.06.2026 / Session-1 / Hall-6

Ankara Local Time: 10:00 – 12:00

Meeting ID: 829 5595 6031 / Passcode: 020202

Moderator: Dr. Fathalah ELWAHAB

Title	Author(s)	Affiliation
SOIL MICROBIAL DIVERSITY UNDER AGROFORESTRY SYSTEMS IN SUBTROPICAL DRYLANDS: IMPLICATIONS FOR ECOSYSTEM RESTORATION IN SOUTH ASIA	Sadid Shahriyar	Sher-e-Bangla Agricultural University BANGLADESH
THE ROLE OF INTEGRATED NUTRITION IN IMPROVING THE QUANTITY AND QUALITY OF AGRICULTURAL PRODUCTS AND ACHIEVING SUSTAINABLE AGRICULTURE	Mohamad Jafari	Hormozgan Agricultural and Natural Resources Research and Education Center IRAN
PHYSIOLOGICAL AND AGRONOMIC RESPONSES OF RICE (ORYZA SATIVA L.) TO SOIL AND ENVIRONMENTAL VARIABILITY: IMPLICATIONS FOR SUSTAINABLE CROP PRODUCTION	Dr. Fathalah ELWAHAB Dr. Mohamed SEDKİ Prof. Najiba BRHADDA Prof. Rabea ZIRI	Ibn Tofail University MOROCCO Regional Center of Agricultural Research of Kenitra MOROCCO
THE EFFECT OF SEVERAL TYPES OF PLANTING MEDIA ON THE GROWTH OF MICROGREEN KAILAN (Brassica oleracea var. Achepala)	Rizky Adi Nugraha Tarigan Budy Rahmat Ida Hodiyah Yogi Nirwanto Tini Sudartini Rudi Priyadi Ristina Siti Sundari	Siliwangi University INDONESIA
ENVIRONMENTAL TRANSFER AND SOIL–PLANT UPTAKE OF RADIONUCLIDES IN SEMI-ARID MOROCCAN AGROECOSYSTEMS	Zineb ELABOUDI Samira EL AOUIDI Abdelaziz MADINZI Radouan SAADI Azzouz BENKDAD Abdelmourhit LAISSAOUI Salah SOUABI Zineb EL MOURIDI	Hassan II University MOROCCO National Centre for Nuclear Energy, Science and Technology (CNESTEN) MOROCCO National Institute of Agricultural Research (INRA) MOROCCO
CHEMOMETRIC DISSECTION OF MORPHO-POMOLOGICAL TRAITS AND ANTIOXIDANT POTENTIAL IN WILD MOROCCAN MORUS ALBA ACCESSIONS	Sadik Dani Hassane Abd-dada Ahmed El Annaoui Atman Adiba Azize Ezzine Abdelmajid Haddioui Said Bouda	Sultan Moulay Slimane University MOROCCO Agro-food Technology and Quality Laboratory Regional Center of Agricultural Research of Tadla National Institute of Agricultural Research Ennasr Avenue MOROCCO
PHYSICOCHEMICAL CHARACTERIZATION AND EVALUATION OF THE BIOACTIVE PROFILE OF FRESH ELDERBERRIES (SAMBUCUS NIGRA L.)	Loredana – Mariana HUȚUȚUI Sonia AMARIEI	'Stefan cel Mare' University of Suceava ROMANIA
EXPLORING DAIRY-DERIVED LACTIC ACID BACTERIA AS SUSTAINABLE BIOCONTROL AGENTS FOR ENHANCING FOOD SAFETY	BELLIL Zahra DERBAK Larbi BELLIL Dassine MAIRI Assia TOUATI Abdelaziz MECHIAH Fahima INOURI Ahlam BOUCHEMAL Amina MEGHLAOUI Zoubeida BENHOULA Mohammed MADI Nassim	Campus University ALGERIA

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26.06.2026 / Session-2 / Hall-1

Ankara Local Time: 10:00 – 12:00

Meeting ID: 829 5595 6031 / Passcode: 020202

Moderator: Lect. Dr. Neşe YILMAZ

Title	Author(s)	Affiliation
DEVELOPMENT OF GLUTEN-FREE GRISSINI USING PELEMIR (CEPHALARIA SYRIACA) SEED FLOUR	Assist. Prof. Dr. Seda ÇAKMAK KAVSARA Assist. Prof. Dr. Kübra TOPALOĞLU GÜNAN Lect. Tuğçe BOĞA DEMİREL Yağmur ÇETİNKAYA	Maltepe University TÜRKİYE
PRODUCTION OF GLUTEN-FREE CRACKERS INCORPORATING GERMINATED SORGHUM FLOUR	Assist. Prof. Dr. Kübra TOPALOĞLU GÜNAN Assist. Prof. Dr. Seda ÇAKMAK KAVSARA Lect. Tuğçe BOĞA DEMİREL Irmak ÇELEBİ	Maltepe University TÜRKİYE
DETERMINATION OF MYCOTOXINS PRODUCED BY SORBATE-RESISTANT MOULDS ISOLATED FROM KASHAR CHEESE	Selin AÇIKEL Prof. Dr. Gülten TİRYAKİ GÜNDÜZ Prof. Dr. Nurcan KOCA	Ege University TÜRKİYE
EVALUATION OF THE IN VITRO ANTI-OBESITY AND ANTI-INFLAMMATORY ACTIVITIES OF SELECTED EDIBLE GREEN LEAFY PLANTS	Assist. Prof. Dr. Shirin Tarbiat	Üsküdar University TÜRKİYE
THE EFFECTS OF LOW-FODMAP DIET ON GUT MICROBIOTA AND INFLAMMATION IN IRRITABLE BOWEL SYNDROME	Dr. Yaren DOĞAN Prof. Dr. Osman ERKMEN Assist. Prof. Dr. Çağla PINARLI FALAKACILAR	İstanbul Okan University TÜRKİYE
EVALUATION OF MICROBIOTA AWARENESS LEVELS AMONG HEALTHCARE PROFESSIONALS FROM A SUSTAINABLE NUTRITION PERSPECTIVE	Nihan ERSİN Assist. Prof. Dr. İrem KARAMOLLAOĞLU	İstanbul Okan University TÜRKİYE

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26.06.2026 / Session-2 / Hall-2

Ankara Local Time: 10:00 – 12:00

Meeting ID: 829 5595 6031 / Passcode: 020202

Moderator: Assoc. Prof. Dr. Berrak DUMLUPINAR

Title	Author(s)	Affiliation
THE RELATIONSHIP BETWEEN MEDITERRANEAN DIET ADHERENCE, FIBROSCAN FINDINGS, AND NON-INVASIVE FIBROSIS SCORES: A CROSS-SECTIONAL STUDY	Saibe Merve KAZDAL	Recep Tayyip Erdoğan University TÜRKİYE
SUSTAINABILITY ASSESSMENT OF THE MEDITERRANEAN DIET IN METABOLIC SYNDROME	Res. Assist. Zeyneb Vuslat YÜKSEL Assoc. Prof. Dr. Berrak DUMLUPINAR	İstanbul Okan University TÜRKİYE
OXIDATIVE STRESS IN TYPE 2 DIABETES: INSULIN RESISTANCE, INFLAMMATION AND NUTRITIONAL PERSPECTIVES	Assoc. Prof. Dr. Berrak DUMLUPINAR Şevval Öykü DEMİR	İstanbul Okan University TÜRKİYE
THE WARBURG EFFECT AND CANCER METABOLISM	Berfe Ecem MECİT Assoc. Prof. Dr. Berrak DUMLUPINAR	İstanbul Okan University TÜRKİYE
EVALUATION OF SELECTED INSECTICIDE MIXTURES FOR RESISTANCE MANAGEMENT IN THE COTTON APHID Aphis gossypii Glover (Hemiptera: Aphididae)	Berfin ALAKENT Assist. Prof. Dr. Ahmet HATİPOĞLU	Ege University TÜRKİYE
FUNGICIDE RESISTANCE OF BOTRYTIS CINEREA IN STRAWBERRIES AND RECOMMENDED SOLUTIONS	Aslı BEYHAN Prof. Dr. Pervin KINAY TEKSÜR	Ege University TÜRKİYE
SENTIMENT ANALYSIS OF ONLINE CUSTOMER REVİEWS OF ETHNIC RESTAURANTS IN ANTALYA	Gül Damla KILIÇ	Antalya Belek University TÜRKİYE

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26.06.2026 / Session-2 / Hall-3

Ankara Local Time: 10:00 – 12:00

Meeting ID: 829 5595 6031 / Passcode: 020202

Moderator: Nika Sardlishvili

Title	Author(s)	Affiliation
COMPARATIVE IMPACT OF INDOOR AND OUTDOOR HOUSING SYSTEMS ON THE TECHNICAL AND COMMERCIAL PERFORMANCE OF STORE LAMBS FED AD LIBITUM DIET	Cathal Droney Luke Chinaru Nwosu	Atlantic Technological University IRELAND
IN VITRO ANTIOXYDANT AND ANTICOCCIDIAL ACTIVITY OF OLIVE PULP (OLEA EUROPAEA L. VAR. CHEMLAL) EXTRACT AGAINST EIMERIA OOCYSTS IN BROILER CHICKENS	Nedjima Debbou-Iouknane NAima Saidene Amal Ouatah	Campus University ALGERIA
ANALYSIS OF THE MICROBIOLOGICAL QUALITY OF MEAT PRODUCTS IN ALGERIA: IMPACT OF FREEZING ON BACTERIAL PROLIFERATION	Djamila Hezil Benseghir Hassane Asma Rouane Leyla Benammar Mourad Djeziri Aouachria Sana Azizi Abdennour Khoukha Alileche	M'Hamed Bougara University ALGERIA Physicochemistry of Biological Materials and Biotechnology ALGERIA Higher National Veterinary School ALGERIA Batna 2 University ALGERIA Scientific and Technical Research Center in Physico-Chemical Analyses (CRAPC) ALGERIA Batna 1 University ALGERIA
PRELIMINARY DATA ON THE BEHAVIORAL EFFECTS OF ROSEMARY ESSENTIAL OIL IN ZEBRAFISH (DANIO RERIO) AFTER TARTRAZINE EXPOSURE	Malina Visternicu Alexandra Savuca Tatiana Rodideal Cătălina Ionescu Viorica Rarinca Prof. Dr. Gabriel Plavan Prof. Dr. Mircea Nicoara Prof. Dr. Alin Ciobica	"Alexandru Ioan Cuza" University ROMANIA
SELF-HEALING MATERIALS IN ROAD ENGINEERING	Nika Sardlishvili	Georgian Technical University GEORGIA
DEVELOPMENT OF A REGENERABLE PANI@CLAY COMPOSITE FOR SUSTAINABLE WASTEWATER DEPOLLUTION: CASE OF ERIOCHROME BLACK T	Abdellah BATTI Adam Nid-Bella Hamid ZOUGGARI Sara IZIKI Hamid Ahchouch Nouh AARAB Mohamed LAABD Lahcen BAZZI Abdallah ALBOURINE	Ibn Zohr University MOROCCO
RISK ASSESSMENT OF INDUSTRIAL POLLUTION IN SOIL AND WATER SYSTEMS: ENVIRONMENTAL AND ECOLOGICAL IMPLICATIONS	Lemkimel ZAHRA Prof. Benssi HAMİD Dr. Elwahab FATHALAH	Ibn Tofail University MOROCCO

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26.06.2026 / Session-2 / Hall-4

Ankara Local Time: 10:00 – 12:00

Meeting ID: 829 5595 6031 / Passcode: 020202

Moderator: Assist. Prof. Bahareh Rafiei

Title	Author(s)	Affiliation
CLIMATE CHANGE AND INSECT PEST RANGE EXPANSION: IMPLICATIONS FOR GLOBAL FOOD SECURITY	Assist. Prof. Bahareh Rafiei Assist. Prof. Mahboobeh Sharifi	Gilan Agricultural and Natural Resources Research and Education Center IRAN Golestan Agricultural and Natural Resources Research Center IRAN
CLIMATE CHANGE, WATER GOVERNANCE, AND AGRICULTURAL RESILIENCE IN PAKISTAN	Amna yousaf Muhammad Amjed Iqbal Raza ullah Azher Abbas	Institute Of Agricultural And Resource Economics PAKISTAN
THE CONTEMPORARY CLIMATE CHARACTERISTICS OF THE EASTERN ZANGEZUR REGION AND THEIR EFFECTS ON LANDSCAPE COMPLEXES	Faig Abdurahmanov	Baku State University AZERBAIJAN
BIOCHAR-ASSISTED COMPOSTING OF AGRICULTURAL WASTES: A SUSTAINABLE STRATEGY FOR NUTRIENT RECOVERY, CARBON SEQUESTRATION, AND CIRCULAR AGRICULTURE	Mouad Lazrak Ghita Ait Baddi Mariam Mirouch Ayour Jamal Dhin Ikram Soukaina Kaoui Chebli Bouchra	Ibn Zohr University MOROCCO
RECOVERY OF VALUABLE RESOURCES FROM OLIVE MILL WASTEWATER AND OLIVE POMACE	Mohamed EL MORSY Prof. Dr. Laila AFIA	Ibnou Zohr University MOROCCO
REDUCING CHEMICAL INPUTS IN AGRICULTURE : ENVIRONMENTAL CHALLENGES AND NATURAL ALTERNATIVES	Ahlam INOURI Fahima MECHIAH Zahra BELLIL Amina BOUCHEMAL Zoubeida MEGHLAOUI Mohammed BENHOULA Larbi DERBAK Ahlam NOURI Aderahim SEKOUR Amer MERRI Nassim MADI	Campus University ALGERIA
SMALL-SCALE FARMING AND ECONOMIC SUSTAINABILITY IN NIGERIA: CHALLENGES AND PROSPECTS	Ozioma Faith ORAZULIKE	Nigeria University NIGERIA

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26.06.2026 / Session-2 / Hall-5

Ankara Local Time: 10:00 – 12:00

Meeting ID: 829 5595 6031 / Passcode: 020202

Moderator: Major Gheorghe GIURGIU

Title	Author(s)	Affiliation
MICROPLASTICS IN FOOD SYSTEMS: DIETARY EXPOSURE AND EMERGING HEALTH RISKS IN NORTH AFRICA	Sanaa El-Jamal Houda Elfane Imane Barakat Amina Tani Rekia Belahsen	Chouaib Doukkali University MOROCCO Higher Institute of Professions Nurses and Health Techniques MOROCCO
ENERGY INTAKE AND NUTRITIONAL IMBALANCES AMONG SCHOOL-AGED ADOLESCENTS IN THE MOULAY ABDELLAH REGION, MOROCCO: EVIDENCE FROM 24-HOUR DIETARY RECALLS	BENADDI Ghizlane HADDOU Imane DAIF Halima Firdaous FRIKI BELAHSEN Rekia	Chouaib Doukkali University MOROCCO
BREAKFAST SKIPPING AND SNACKING HABITS AMONG SCHOOL-GOING ADOLESCENTS IN EL JADIDA PROVINCE, MOROCCO	Imane HADDOU Halima DAIF Rekia BELAHSEN	Chouaib DOUKKALI University MOROCCO
OPTIMIZING OUTCOMES IN PSORIASIS: IMPACT OF DENIPLANT NUTRACEUTICALS	Major Gheorghe GIURGIU Prof. Dr. Manole COJOCARU	Deniplant-Aide Sante Medical Center ROMANIA Titu Maiorescu University ROMANIA
NUTRITION AND MALE FERTILITY: EFFECTS ON HUMAN SEMEN QUALITY (A NARRATIVE REVIEW)	Boureggab S. Allai H. Allai L. Tahiri H. Choukri M.	Mohammed First University MOROCCO Mohammed VI University Hospital Center MOROCCO

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INVESTIGATION OF THE EFFECTS OF SOCIAL MEDIA USE ON EATING BEHAVIOR, DIET QUALITY, AND SUSTAINABLE NUTRITION BEHAVIORS

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ABSTRACT

Introduction and Purpose: The increasing use of social media has strengthened its influence on food choices, diet quality, and eating behaviors. Nutrition-related content on these platforms may affect sustainable nutrition positively or negatively. In particular, young individuals frequently obtain nutrition information through social media, increasing the impact of online environments on eating behaviors. However, misinformation lacking scientific evidence may also spread rapidly. Therefore, this study examined the effects of social media use on eating behavior, diet quality, and sustainable nutrition behaviors.

Materials and Methods: Articles published in the PUBMED database between 2021 and 2026 were reviewed. A total of 32 articles containing the terms “social media” and “food choice” in the title were identified. After excluding 20 unrelated articles, 12 articles were reviewed.

Results: The studies showed that social norms and healthy food preferences within social groups may encourage healthier dietary choices. Social media content was found to influence eating-out behaviors, restaurant preferences, and trending product consumption. In addition, influencer posts related to body image and appearance affected food preferences. Most nutrition-related content focused on healthy living, body image, and weight control, while some included product promotion. Several studies also reported that social media may increase awareness of nutrition and sustainable dietary behaviors.

Discussion and Conclusion: Social media has a significant influence on nutrition behaviors. Although misinformation may negatively affect individuals, reliable content may support awareness of healthy and sustainable nutrition. Increasing accurate nutrition communication on social media platforms is important for public health.

Key Words: Social media, Eating behavior, Diet quality, Sustainable nutrition

HUNGER OR ADDICTION? THE EFFECTS OF ULTRA PROCESSED FOODS ON EATING BEHAVIOR

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ABSTRACT

Introduction and Purpose: In recent years, the increasing consumption of ultra-processed foods has been considered a major public health concern due to its association with obesity, chronic diseases, and addiction like eating behaviors. Ultra-processed foods containing high amounts of sugar, fat, salt and food additives may stimulate the brain reward system and promote uncontrolled eating behaviors. The aim of this study is to evaluate the relationship between ultra-processed food consumption and food addiction.

Materials and Methods: Articles published between 2024 and 2026 were searched in the PubMed database regarding the subject. A total of 25 articles containing the keywords “food addiction” and “eating behavior” in their titles were identified. Among these articles, 8 studies without full-text accessand 6 studies not directly related to the subject were excluded, and 11 articles were reviewed.

Results: The reviewed studies indicate that ultra-processed food consumption is associated with addiction like eating behaviors. In particular, ultra processed foods rich in sugar, fat, salt and additives may activate the dopaminergic reward system, which can lead to craving, loss of control and compulsive consumption. These behaviors have been associated with obesity, emotional eating, binge eating behavior, depression, and anxiety.

Discussion and Conclusion: The reviewed studies suggest that ultra processed foods may affect the reward system and promote addiction like eating behaviors due to their hyperpalatable properties. In addition, stress and negative emotions may increase ultra processed food consumption and trigger emotional eating behaviors. Therefore, improving nutritional awareness and reducing ultra processed food consumption are considered important for public health.

Key Words: Ultra Processed Food; Food Addiction; Emotional Eating; Reward System

THE EFFECTS OF LOW-FODMAP DIET ON GUT MICROBIOTA AND INFLAMMATION IN IRRITABLE BOWEL SYNDROME

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ABSTRACT

Introduction and Purpose: Irritable bowel syndrome (IBS) is a common gastrointestinal disorder characterized by abdominal pain, bloating, and altered bowel habits. Recent studies suggest that intestinal dysbiosis and low-grade inflammation may contribute to IBS pathogenesis. The low-FODMAP diet is widely used to reduce IBS symptoms; however, it may also affect gut microbiota composition and microbial metabolites. This review aims to evaluate the effects of the low-FODMAP diet on gut microbiota and inflammation in individuals with IBS.

Materials and Methods: Articles published between 2014 and 2025 were searched in the PubMed database regarding the subject. A total of 32 articles containing the keywords “low-FODMAP diet”, “gut microbiota”, “IBS”, and “inflammation” in their titles were identified. Among these articles, 10 studies without full-text access and 9 studies not directly related to the subject were excluded, and 13 articles were reviewed.

Results: The reviewed studies indicate that the low-FODMAP diet may reduce IBS symptoms by decreasing intestinal fermentation and gas production. In addition, alterations in gut microbiota composition and changes in short-chain fatty acid (SCFA) and branched-chain fatty acid (BCFA) production were reported. Some studies suggest that BCFAs may have anti-inflammatory effects, while excessive protein fermentation products may negatively affect intestinal barrier function.

Discussion and Conclusion: Current evidence suggests that the low-FODMAP diet may improve IBS symptoms while altering gut microbiota and microbial metabolite production. Further clinical studies are needed to better understand the long-term effects of this diet on intestinal inflammation and gut health.

Key Words: Irritable Bowel Syndrome; Low-FODMAP Diet; Gut Microbiota; Inflammation; Branched-Chain Fatty Acids.

EVALUATION OF POST–SLEEVE GASTRECTOMY EATING ATTITUDES AND FOOD CONSUMPTION AWARENESS

SLEEVE GASTREKTOMİ SONRASI BESLENME TUTUMU VE GIDA TÜKETİM BİLİNCİNİN DEĞERLENDİRİLMESİ

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ÖZET

Bu çalışma, sleeve gastrektomi operasyonu geçirmiş obez hastalarin beslenme tutumları ve gıda tüketim bilincini değerlendirmeyi amaçlamaktadır. Araştırmada, operasyon sonrası kontrollerde yemek yeme davranışları, işlenmiş paketli gıda tercihleri, besin etiketi okuma alışkanlıkları, besin değerlerini sorgulama eğilimleri ve duygusal yeme durumları incelenmiştir. Çalışma, 2021–2022 yılları arasında İstanbul Avrupa Yakasındaki özel bir bariatrik cerrahi kliniğinde, 19–50 yaş aralığında sleeve gastrektomi geçiren 78 gönüllü hasta ile yürütülmüştür. Katılımcılara ameliyat öncesi ve sonrası bilgileri içeren 26 soruluk anket ile Hollanda Yeme Davranışları Ölçeği (DEBQ) uygulanmış, veriler SPSS 22.0 programında ki-kare testi ve tek faktörlü ANOVA ile analiz edilmiştir. Bulgular, obez hastalarde duygusal yeme davranışının daha yüksek olduğunu göstermiştir (3,97±2,7; $p<0,05$). Market alışverişlerinde son tüketim tarihine dikkat edenlerin duygusal yeme puanları anlamlı şekilde daha yüksek bulunmuştur ($p<0,001$). Ameliyat sonrası psikolojik destek almayan ve yavaş yeme alışkanlığına uyum sağlayamayan hastalarda duygusal yeme davranışı artmıştır ($p<0,02$). Tıkınırcasına yeme isteği olanların dışsal ve duygusal yeme puanları, kısıtlayıcı yeme puanına kıyasla daha yüksektir ($p<0,05$). Kadınların işlenmiş paketli ürünlere ilgisi ve besin etiketine dikkat etme davranışı erkeklere göre daha fazla bulunmuştur ($p<0,05$). Ameliyat sonrası hastalarin etiket okuma oranı (%71,4), kilolu hastalare (%31,8) kıyasla anlamlı şekilde daha yüksektir ($p<0,05$). Sonuç olarak, sleeve gastrektomi sonrası etiket okuma bilinci ve farkındalıklı beslenme tutumunun geliştirilmesi sağlıklı beslenme alışkanlıklarının sürdürülmesi açısından önemlidir.

Anahtar kelimeler: Sleeve gastrektomi, Bariatrik cerrahi, Beslenme tutumu, Etiket okuma bilinci

ABSTRACT

This study aims to evaluate the nutritional attitudes and food consumption awareness of obese individuals who underwent sleeve gastrectomy surgery between the ages of 19 and 65. Postoperative follow-up focused on patients' eating behaviors, preferences for packaged foods, label-reading habits, tendencies to question nutritional values, and emotional eating patterns, while also identifying factors influencing dietary choices. This cross-sectional study was conducted between 2021 and 2022 in a private bariatric surgery clinic located on the European side of Istanbul, with 78 patients aged 19–50 who had undergone sleeve gastrectomy.

Participants completed a 26-item questionnaire covering pre- and postoperative information, along with the Dutch Eating Behavior Questionnaire (DEBQ). Data were analyzed using SPSS 22.0 software, employing chi-square tests and one-way ANOVA for related samples. Results indicated that emotional eating behavior was significantly higher among obese individuals (3.97±2.7; $p<0.05$). Those who paid attention to expiration dates during grocery shopping had higher emotional eating scores compared to those who did not ($p<0.001$). Emotional eating was also elevated in patients lacking psychological support and failing to adapt to slow eating habits after surgery ($p<0.02$). Individuals with binge-eating tendencies showed higher external and emotional eating scores compared to restrictive eating ($p<0.05$). Women demonstrated greater interest in processed packaged foods and higher changes in label-reading behavior compared to men ($p<0.05$; $p=0.004$). Postoperatively, label-reading awareness was significantly higher in obese patients (71.4%) compared to overweight individuals (31.8%) ($p<0.05$). Emotional eating was more prevalent among women than men after surgery ($p<0.05$). In conclusion, enhancing label-reading awareness and mindful eating attitudes following sleeve gastrectomy is essential for promoting healthy nutrition. Continued collaboration with dietitians is crucial for developing appropriate dietary programs and sustaining lifelong healthy eating habits.
Keywords: Sleeve gastrectomy, bariatric surgery, nutritional attitude, label-reading awareness

GİRİŞ

Obezite, genetik ve çevresel faktörlerin etkileşimiyle ortaya çıkan multifaktöriyel ve kompleks bir hastalık olup sosyal, davranışsal, kültürel, psikolojik ve metabolik unsurların katkısıyla tüm dünyada ve ülkemizde hızla artan bir halk sağlığı problemidir (Annagür, 2010; Başer ve Balcıoğlu, 2008;Sucaklı ve Çelik, 2015; Yanovski ve Yanovski, 2014). Tanıda beden kütle indeksi (BKİ) ve bel çevresi pratik ölçüm yöntemleri olarak kullanılmakta, yüksek bel çevresi özellikle BKİ 25–34,9 kg/m² aralığında tip 2 diyabet, dislipidemi, hipertansiyon ve kardiyovasküler hastalık riskini artırmaktadır (Sucaklı ve Çelik, 2015). Geleneksel tedavi yöntemlerinin uzun dönemde sınırlı başarı sağlaması bariatrik cerrahiyi öne çıkarmış, BKİ ≥40 kg/m² veya komorbiditesi olan BKİ ≥35 kg/m² hastalarde cerrahi müdahalelerle anlamlı kilo kaybı ve metabolik düzelme elde edilmeye başlanmıştır (Akman, 2016; Yücel vd., 2011). Ameliyat öncesi düşük kalorili diyetlerin kısa sürede %5–10 oranında kilo kaybı sağladığı, verilen ağırlığın büyük kısmının yağ kütlesinden oluştuğu gösterilmiştir (Shikora vd., 2015; Puzziferri vd., 2014). Ameliyat sonrası ise beş aşamalı diyet prosedürleri uygulanmakta, sleeve gastrektomi ve gastrik bypass arasında süre farklılıkları bulunmaktadır (Galanakis vd., 2015; Yücel vd., 2011). Obezite yalnızca fizyolojik değil, aynı zamanda psikolojik boyutlarıyla da hastalarin beslenme davranışlarını etkilemekte; depresyon, anksiyete ve obsesif eğilimler bu süreçte sık gözlenmektedir (Conceição vd., 2013; Nagl vd., 2016; Wiggins vd., 2020). Bu nedenle multidisipliner yaklaşım, beslenme eğitimi ve psikolojik destek bariatrik cerrahi sürecinde tedavi başarısının sürdürülebilirliği açısından kritik öneme sahiptir (Sherf Dagan vd., 2017). Bu kesitsel çalışma, 2021–2022 yılları arasında İstanbul'daki özel bir bariatrik cerrahi kliniğinde yürütülmüştür. Çalışmaya BKİ ≥35 kg/m² olan ve sleeve gastrektomi operasyonu geçiren 19–50 yaş aralığındaki 78 gönüllü hasta dahil edilmiştir. Katılımcılara ameliyat öncesi ve sonrası beslenme tutumlarını sorgulayan anket uygulanmış, ayrıca Hollanda Yeme Davranışları Ölçeği (DEBQ) kullanılmıştır (Bozan, 2009; Van Strien, 1986). BKİ değerleri beyan edilen boy ve kilo üzerinden hesaplanmış, elde edilen veriler SPSS 22.0 programında tanımlayıcı istatistikler, ki-kare testi, t-testi, ANOVA ve Kruskal Wallis testleri ile analiz edilmiştir.

BULGULAR

İstanbul'da bir bariatrik cerrahi kliniğinde son 6 ayda cerrahi operasyon geçiren ve çalışmaya gönüllü olarak katılan 78 bireyden oluşmaktadır. Çalışma sleeve gastrektomi olmuş 19-50 yaş

aralığındaki yetişkinlerin beslenme tutumu ve gıda tüketim bilincini değerlendirmek amacıyla yapılmıştır. Katılımcıların sosyo-demografik özellikleri Tablo 1'de verilmiştir.

Tablo 1. Katılımcıların sosyo-demografik özellikleri

		n	%
Yaş grupları			
20-24		12	15,4
25-59		56	71,7
60-99		10	12,9
Cinsiyet			
Kadın		58	74,4
Erkek		20	25,6
Yaşadığı şehir			
İstanbul		69	88,5
Ankara		3	3,9
İzmir		2	2,6
Diğer şehirler		4	5,0
Eğitim durumu			
Lise		2	2,6
Üniversite		50	64,1
Yüksek Lisans		15	19,2
Doktora ve sonrası		6	14,1
Çalışma durumu			
Çalışıyor		49	62,8
Çalışmıyor		20	25,6
Emekli		9	11,6
Kronik Hastalık Varlığı			
Obezite		78	100
Kalp ve Damar Hastalıkları		51	71,8
Diyabet (Tip 2 şeker hastalığı)		56	65,4
Kronik Obstrüktif Akciğer Hastalıkları (KOAH)		41	52,7
Mide ve Bağırsak Hastalıkları		35	44,7
Sinir Sistemi Hastalıkları		9	11,5
Kanser		7	9,0
Diğer (Tiroid hastalıkları, pankreas hastalıkları, karaciğer hastalıkları, solunum sistemi hastalıkları, uyku apnesi, kemik ve eklem hastalıkları, romatizmal hastalıkları, alerji durumları)		2	2,6
Fiziksel Aktivite Varlığı	Evet	23	29,0
	Hayır	55	71,0

Çalışmaya katılan hastaların demografik yapısı incelendiğinde; yaş aralığı 25-44 arasında olan hastalar %57,7; 45-54 yaş aralığındaki hastalar %26,9 iken; 19-24 yaş aralığındaki hastalar %15,4'lük kısmı oluşturmaktadır. Hastaların çoğunun (%74,4) kadın olduğu gözlenmektedir. Hastaların ikamet ettikleri yerler açısından kategori edildiğinde İstanbul %88,5; Ankara %3,9; Büyükşehir dışında kalan iller %5 ve İzmir %2,6 olmak üzere sıralanmıştır. Eğitim durumları açısından üniversite mezunu %64,1; yüksek lisans %19,2; doktora %14,1; lise mezunu %2,6 olarak belirlenmiştir. Hastaların %62,8'lik kısmı çalışmakta, çalışmayan hastalar %25,6 ve emekli hastalar %11,6'lık kısmı kapsamaktadır. Hastaların kronik hastalık durumu sırasıyla; obezite %100; kalp ve damar hastalıkları %71,8; diyabet, %65,4; kronik obstrüktif akciğer hastalıkları %52,7; mide ve bağırsak hastalığına sahip hastalar %44,7; sinir sistemi hastalıkları %11,5; kanser hastalığı %9 ve diğer hastalıklara sahip olanlar %2,6'lık hastalar dilimini oluşturmaktadır. Hastaların %71'i fiziksel aktivite yapmamaktadır.

Tablo 2. Katılımcıların DEBQ alt gruplarından aldıkları puanların beden kütle indeksi ve cinsiyet ile ilişkisi

	DEBQ		
	Dışsal Yeme	***Kısıtlayıcı Yeme***	***Duygusal Yeme***
	Ort ±SD	***Ort ±SD***	***Ort ±SD***
BKİ (kg/m²)			
Kilolu (25-29) n = 22	2,59 ± 1,3	2,47 ± 0,8	2,45 ± 1,7
Obez (≥30) n= 56	3,58 ± 2,4	2,78 ± 1,92	1,79±2,8
p değeri	0,978	0,395	**0,007**
Cinsiyet			
Erkek (n= 20)	2,41 ±0,52	2,45 ±0,47	1,97±0,56
Kadın (n= 58)	3,05 ±0,87	3,66 ± 2,3	3,07±2,05
p değeri	0,877	0,059	**0,019**
Yaş Grupları (yıl)			
19-24	2,21±1,05	2,55±0,22	1,45±2,07
25-44	1,78±2,14	1,75±2,9	2,77±0,39
45-54	3,22±1,94	2,97±0,46	3,06±0,15
p değeri (p<0,05;Oneway ANOVA testing)	0,899	0,112	**0,001**

Tablo 2'de elde edilen bulgular doğrultusunda katılımcıların BKİ değerleri DEBQ alt grupları ile ilişkilendirildiğinde duygusal yemenin obezlerde daha fazla olduğu ortaya çıkmaktadır (3,97±2,7; p<0,05). Cinsiyet açısından değerlendirme yapıldığında duygusal yeme davranışlarının kadınlarda daha fazla olduğu belirlenmiştir (p<0,05). Aynı şekilde yaş ilerledikçe duygusal yeme puanı da artmaktadır (p<0,05).

Tablo 3. Katılımcıların işlenmiş paketli ürünlere olan tutumları ile DEBQ arasındaki ilişki

	Dikkat Ederim [1]	**Dikkat Etmem [2]**	**Önemsemem[3]**	**Dışsal Yeme [a]**	**Kısıtlayıcı Yeme [b]**	**Duygusal Yeme [c]**	
	n (%)			Ort ±SD	Ort ±SD	Ort ±SD	**p değeri**
Gıda satın alırken besin etiketi üzerindeki bilgilere dikkat etme durumu							
a-Son tüketim / tavsiye edilen tüketim tarihi	61 (78,2)	10 (12,9)	7 (8,9)	2,34 ±0,54	2,05±1,37	3,78±0,98	**0,001**
F değeri	4,562	7,564	8,659	6,638	7,659	5,475	**0,01**
Post-Hoc	1>2,3;2>3	1>2,3;2>3	1>2,3;2>3	c>a,b; a>b	c>a,b; a>b	c>a,b; a>b	**0,01**
b-Üretici firmanın adı	9 (11,5)	52 (66,6)	17 (21,9)	1,19±0,11	1,29±1,08	0,97±0,25	0,344
c-İçindekiler listesi / Katkı maddesi içermesi	58 (74,3)	11 (14,1)	9 (11,6)	2,69±1,66	1,88±0,36	2,33±1,49	0,303
d-Raf ömrü / Özel muhafaza ve/veya kullanım koşulları	67 (85,9) 7 (9,0)	6 (7,7) 69 (88,5)	5 (6,4) 2 (2,5)	1,02±0,17	1,01±0,25 0,05±0,2	1,41±0,69 0,01±0,89	0,784 0,579

e-Ürünün ağırlığı	11 (14,1)	61 (78,2)	6 (7,7)	0,07±0,02	1,01±0,97	0,22±0,74	0,377
f-Gıdanın kullanım talimatı (Tarifler gibi kullanım bilgileri)	5 (6,4)	65 (83,3)	8 (10,3)	0,58±0,11	0,42±0,3	0,17±0,9	0,444
g- Menşei	48 (61,5)	16(20,5)	14 (18,0)	0,02±0,1	1,5±0,08	2,02±0,41	0,988
h- Alerjen maddeler	10 (12,8)	55 (70,5)	13 (16,7)	1,06±078	0,12±0,36	0,14±0,39	0,441
ı- Sağlık beyanları	64 (82,0)	6 (7,7)	8 (10,3)	0,02 ± 0,3	0,98 ±0,77	1,22±1,05	0,271
i-Besin değerleri	21 (26,9)	52 (66,6)	5 (6,5)	2,04 ±0,54	0,77± 0,54	0,34±0,11	0,699
j- Barkod/ Sertifika vb.				0,07 ±0,49			

*t: Bağımsız örneklemlerde t testi; F: tek yönlü varyans analizi; *:p<0,05; **:p<0,01; ***:p<0,001*

Tablo 3 üzerinde sorgulanan DEBQ alt gruplarına bakıldığında, katılımcılara yönlendirilen market alışverişi alışkanlıkları sorgulandığında son tüketim ve tavsiye edilen tüketim tarihini önemseyip önemsememe durumu DEBQ alt gruplarının hepsiyle istatistiksel olarak anlamlı bulunmuş olup, katılımcıların duygusal yeme puanı daha yüksektir (p<0,001). Diğer sorgulanan parametreler içerisinde duygusal, içsel ve dışsal yeme tutumları açısından istatistiksel bir anlamlılık elde edilememiştir (p>0,05).

Tablo 4. Ameliyat sonrası yemek yeme alışkanlıkları ve psikolojik tutumlar ile DEBQ arasındaki ilişki

DEBQ Skoru				
Yeme alışkanlıkları ve psikolojik tutum		***Dışsal Yeme₁***	***Kısıtlayıcı Yeme₂***	***Duygusal Yeme₃***
		Ort ±SD	***Ort ±SD***	***Ort ±SD***
Ameliyat sonrası süreçte psikolojik yardım aldınız mı?	Evet (n=11)	1,99±0,34	1,71±0,22	1,45±0,57
	Hayır (n=67)	2,33±2,05	3,04±1,02	3,22±1,37
	p değeri	0,874	0,439	**0,019**
	F değeri	9,578	8,554	**5,996**
	Post hoc	**3>1,2;2>1**		
Ameliyat olduğunuz için kendinizi nasıl hissediyorsunuz?	Mutlu (n= 52)	2,04±0,94	2,78±1,09	3,39±2,11
	Mutsuz (n=10)	1,09±1,21	1,49±0,78	2,05±0,66
	Kararsız (n=16)	0,37±0,77	0,45±0,12	0,79±0,25
	p değeri	0,371	0,07	0,225
Ameliyat sonrası yavaş yemek yeme alışkanlığına kolay alışabildiniz mi?	Evet (n=9)	1,03±0,33	1,11±0,55	1,08±0,71
	Hayır (n=69)	2,96±0,91	3,01±2,11	2,94±2,78
	p değeri	0,188	0,378	**0,004**
	F değeri	9,889	7,635	**5,149**
	Post hoc	**3>1,2;1>2**		
Ameliyat sonrasındaki süreçte aile ve yakın akrabalarınızın hepsine bariatrik cerrahi uygulaması geçirdiğinizi söylediniz mi?	Evet (n=30)	1,79±1,29	2,63±1,59	2,77±1,89
	Hayır (n=40)	2,51±1,97	2,78±2,03	2,94±2,19
	p değeri	0,214	0,147	0,358
Ameliyattan sonra tıkınırcasına yemek yeme isteğiniz oldu mu?	Evet (n= 7)	1,27±1,34	1,02±0,99	1,08±0,45
	Hayır (n=71)	2,77±2,62	2,09±2,01	2,66±1,97
	p değeri	**0,016**	0,102	**0,009**

	F değeri	**5,696**	8,465	**6,129**
	Post hoc	**1>3,2;3>2**		
Ameliyat sonrası istediğiniz besinleri istediğiniz miktarda yiyemediğiniz için mutsuzluk/pişmanlık/suçluluk hissettiniz mi?	Evet (n= 49)	2,29±2,37	2,63±2,41	2,68±2,13
	Hayır (n= 29)	1,64±1,39	1,02±0,88	1,07±0,34
	p değeri	0,502	0,169	0,322
Ameliyattan sonraki süreçte diyetisyeniniz ile sık görüşmek sizi nasıl hissettirdi?	Olumlu/Güven hissi (n=58)	2,88±2,04	2,91±2,03	2,34±1,99
	Olumsuz/ Baskı hissi (n=11)	0,79±0,23	0,39±0,98	0,23±0,12
	Kararsızım/Hiçbir duygu hissetmedim. Gereklilik olduğu için yerine getirdim. (n=9)	0,66±0,54	0,56±0,31	0,48±0,33
	p değeri (p<0,05;Oneway ANOVA testing)	0,645	0,236	0,798

*t: Bağımsız örneklemlerde t testi; F: tek yönlü varyans analizi; *:p<0,05; **:p<0,01; ***:p<0,001*

Tablo 4'de elde edilen bulgular doğrultusunda istatistiksel anlamda ameliyat sonrası psikolojik yardım almayan hastalar ile ameliyat sonrası yavaş yeme alışkanlığına kolay alışamayan hastaların duygusal yeme davranışlarının daha fazla olduğu bulunmuştur (p<0,05). Ameliyat sonrası tıkınırcasına yemek yeme isteği olanların dışsal yeme (1,27±1,34) ve duygusal yeme (1,08±0,45) puanları kısıtlayıcı yeme davranış skoruna kıyasla daha yüksektir (p<0,05). Diğer parametrelerde istatistiksel olarak önemli bir fark bulunmamıştır (p>0,05).

Tablo 5. Katılımcıların işlenmiş paketli ürün tüketiminin cinsiyet ile ilişkisi

	Kadın	**Erkek**	**Toplam**
	n (%)	n (%)	n (%)
İşlenmiş paketli ürün satın alma durumu [a]			
Her gün alırım	35(60,3)	9(45)	44 (56,4)
Sık sık alırım	15(25,8)	4 (20)	19 (24,3)
Ara sıra alırım	5(8,6)	3 (15)	8 (10,2)
İşlenmiş paketli ürün kullanmıyorum/tercih etmiyorum.	3 (5,3)	4 (20)	7 (9,1)
Toplam	58 (74,4)	20 (25,6)	78
p değeri			**0,003**
t değeri		**-3,569**	**-4,569**
Ameliyat öncesine göre işlenmiş paketli ürünlerdeki etiket okuma alışkanlığı [b]			
Arttı	45 (77,6)	2 (10)	47
Azaldı	5 (8,6)	11 (55)	16
Değişmedi	8 (13,8)	7 (35)	15
Toplam	58 (74,4)	20 (25,6)	78 (100)
p değeri			**0,001**
t değeri		**-5,246**	**-4,269**
Ameliyattan sonra market alışverişlerinde gıda alırken besin etiketine dikkat etme konusundaki değişiklik [c]			
Evet, aldığım ürünlere daha çok dikkat ediyorum.	35 (60,3)	10 (50)	45
Kısmen oldu, bazen yine dikkat etmediğim oluyor.	3 (5,2)	3 (15)	6
Değişmedi.	3 (5,2)	2 (10)	5
Eskiye göre daha kötü oldu, daha sağlıksız gıda alıyorum.	17 (29,3)	5 (25)	22
Toplam	58 (74,4)	20 (25,6)	78 (100)
p değeri			**0,007**
t değeri		**-2,693**	**-2,788**
Post-Hoc		**c>a,b; a>b**	
Ameliyat sonrası market alışverişlerinin süresindeki artış			
Evet	39 (67,2)	12 (60)	51
Hayır	16 (27,5)	7 (35)	23
Değişmedi	3 (5,3)	1 (5)	4
Toplam	58 (74,4)	20 (25,6)	78 (100)

p değeri (p<0,05;Oneway ANOVA testing)	0,113

*t: Bağımsız örneklemlerde t testi; F: tek yönlü varyans analizi; *:p<0,05; **:p<0,01; ***:p<0,001*

Tablo 5'de yapılan 'İşlenmiş paketli ürünlere olan ilginiz ne düzeydedir?' adlı anket sorusuna cevaplar sırasıyla 'tüketmem' diyerek erkekler %89; %77 ile 'her gün alırım' kadın katılımcılar; sık sık alırım olarak hesaplanmıştır. Paketli ürünlere ilgi düzeyi hesaplandığında cinsiyet farklılığının bu noktada etken olduğu gözlenmektedir. Kadınların işlenmiş paketli ürünle alma eğilimi erkeklere oranla daha fazla olup, istatistiksel olarak anlamlılık ortaya çıkmıştır (p<0,05; 0,003). Katılımcılara aktarılan diğer soruda 'Ameliyat öncesine göre işlenmiş paketli ürünlerde etiket okuma alışkanlığınız nedir?' cinsiyet durumuna göre farklılıklar incelendiğinde 'azaldı' cevabı erkeklerde %93,3 ve 'artı' cevabı en çok kadın katılımcılarda %92,6 olarak gözlenmektedir (p<0,05). Katılımcılara sorulan 'Ameliyattan sonra market alışverişlerinde gıda alırken besin etiketine dikkat etme konusunda bir değişiklik oldu mu?' adlı soruya verilen cevaplar %97,4 oranında erkekler 'Değişmedi' yanıtını verirken; kadınlarda %2,6 değişmedi yanıtı ile cinsiyet farklılığının besin etiketine dikkat etme konusunda bir gösterge olabileceği bulunmuştur (p<0,05; 0,007).

Tablo 6. Katılımcıların işlenmiş paketli ürün tüketiminin BKİ ile ilişkisi

	Kilolu (25-29) n= 22	**Obez (≥30) n= 56**	**Toplam**
	n (%)	n (%)	n (%)
İşlenmiş paketli ürün satın alma durumu[a]			
Her gün alırım	8(36)	29 (51,9)	37 (47,4)
Sık sık alırım	10 (45)	19 (33,9)	29 (37,1)
Ara sıra alırım	3 (13,6)	5 (8,9)	9(11,5)
Paketli ürün kullanmıyorum/tercih etmiyorum.	1 (5,4)	3 (5,3)	3 (4,0)
Toplam	22 (100,0)	56 (100,0)	78 (100,0)
p değeri	**0,004**		
t değeri	-3,236	-4,269	
Ameliyat öncesine göre paketli ürünlerdeki etiket okuma alışkanlığı [b]			
Arttı	4 (18,2)	48 (85,7)	52 (66,6)
Azaldı	11 (50)	5 (8,9)	16 (20,5)
Değişmedi	7 (31,8)	3 (5,4)	10 (12,9)
Toplam	22 (100,0)	56 (100,0)	78 (100,0)
p değeri	**0,001**		
t değeri	-3,236	-4,269	
Ameliyattan sonra market alışverişlerinde gıda alırken besin etiketine dikkat etme konusundaki değişiklik [c]			
Evet, aldığım ürünlere daha çok dikkat ediyorum.	7 (31,8)	40 (71,4)	47 (60,2)
Kısmen oldu, bazen yine dikkat etmediğim oluyor.	7 (31,8)	10 (17,8)	17 (21,7)
Değişmedi.	3 (13,6)	5 (8,9)	8 (10,2)
Eskiye göre daha kötü oldu, daha sağlıksız gıda alıyorum.	5 (22,7)	1 (1,9)	6 (7,9)
Toplam	22 (100,0)	56 (100,0)	78 (100,0)
p değeri	**0,009**		
t-değeri	**-2,569**	**-2,693**	
Post-hoc	**c>a,b; b>a**		

Ameliyat sonrası market alışverişlerinin süresindeki artış			
Evet	20 (90,9)	40 (71,4)	60 (77)
Hayır	1 (4,5)	7 (12,5)	8 (10,2)
Değişmedi	1 (4,5)	9 (16,1)	10 (12,8)
Toplam	22 (100,0)	56 (100,0)	78 (100,0)
p değeri (p<0,05;Oneway ANOVA testing)	0,113		

*t: Bağımsız örneklemlerde t testi; F: tek yönlü varyans analizi; *:p<0,05; **:p<0,01; ***:p<0,001*

Tablo 6 üzerinde incelenen katılımcıların ürün satın alırken davranışları ve BKİ ilişkisi konusunda bulgular şu şekildedir: Paketli ürün satın alma durumunun sıklığı obez (>30) katılımcılarda daha fazla olduğu gözlenmiştir (29 kişi, %51,9). Ameliyat sonrası işlenmiş paketli ürünlerdeki etiket okuma alışkanlığının artışı kilolu hastalarde %18,2 (4 kişi); obez hastalarde ise %85,7 (48 kişi) olarak saptanmıştır. Etiket okuma alışkanlığı kilolu hastalarde %50 azalmış (11 kişi) ve obez hastalarde bu azalma %8,9 (5 kişi) olarak belirlenmiştir. Bulgular neticesinde, obez hastalarde ameliyat sonrasında öncesine kıyasla etiket okuma alışkanlığının arttığı söylenebilir (p<0,05). Ameliyattan sonra market alışverişlerinde gıda alırken besin etiketine dikkat etme konusundaki değişiklik değerlendirildiğinde katılımcılarda obez hastaların kilolu hastalare kıyasla daha dikkatli olduğu gözlenmiştir (%71,4 obez hastalar; %31,8 kilolu hastalar). Bu durum kilolu hastalar ve obez hastalar arasındaki fark ile istatistiksel bir anlamlılık ifade etmiştir (p<0,05). Ameliyat sonrası market alışverişlerinin süresindeki artış açısından her iki BKİ grubu değerlendirildiğinde yüzdelikleri tablodaki sırasıyla; %90,9 (20 kişi) ve %71,4 (40 kişi) olarak belirlenmiştir. Kilolu hastalarde gözlenen artışa kıyasla obez hastalarde de oransal olarak benzer artış gözlenmiş olup, istatistiksel olarak anlamlılık bulunmamıştır (p>0,05).

Tablo 7. DEBQ yeme tutum puanı ile cinsiyet arasındaki ilişki

Cinsiyet	**Yeme Tutum Puanları**			
	Duygusal Yeme Tutum Puanı	**Kısıtlayıcı Yeme Tutum Puanı**	**Dışsal Yeme Tutum Puanı**	p
	Ort.±ss	Ort.±ss	Ort.±ss	
Kadın (n=58)	23,08±14,42	19,57±10,02	21,36±12,157	**0,008**
Erkek (n=20)	21,99±3,92	16,80±4,26	20,11±6,412	0,344
Toplam	20,76±9,31	21,48±7,56	20,34±6,755	0,102
p değeri (p<0,05;Oneway ANOVA testing)	0,096	0,045	0,389	0,008
t değeri	-2,698	-4,635	-2,639	-2,635

*t: Bağımsız örneklemlerde t testi; F: tek yönlü varyans analizi; *:p<0,05; **:p<0,01; ***:p<0,001*

Tablo 7 yeme tutum puanı ile kadın- erkek arasındaki ilişki incelediğinde, kadınlarda duygusal yeme tutum puan ortalaması; 23,08±14,42, kısıtlayıcı yeme tutum puanı; 19,57±10,02, dışsal yeme tutum puanı 21,36±12,157 olarak belirlenmiştir. Erkeklerde ise sırasıyla duygusal yeme tutum puanı 21,99±3,92, kısıtlayıcı yeme tutum puanı 16,80±4,26, dışsal yeme tutum puanı 20,11±6,412 olarak hesaplanmıştır. Kadınlarda erkeklere oranla ameliyat sonrası duygusal yeme davranış tutum puanının daha fazla olduğu gözlenmektedir (p<0,05).

TARTIŞMA

Çalışma İstanbul'da özel bir bariatrik cerrahi polikliniğine başvuran hastalarin diyet sürecindeki yeme tutum ve davranışlarını değerlendirmek amacıyla yapılmıştır. Çağımızın en yaygın sağlık sorunlarından biri olan obezitenin önlenmesinde hastalarin yeme davranışları ve beslenmesini etkileyen etmenlerin saptanması tedavi süreci için yol gösterici olabilmektedir. Bailly ve ark.'nın geriatri alanında yeme davranışlarını değerlendirildiği bir çalışmada, kadınların duygusal ve dışsal puanı kısıtlayıcı puana göre daha yüksek bulunmuştur (Bailly vd., 2012). Nagl ve ark.'nın yaptığı çalışmada, DEBQ puanları ile BKİ, cinsiyet ve yaş arasındaki ilişkiler araştırılmıştır. Kadınların erkeklere göre kısıtlayıcı ve duygusal puanları anlamlı olarak yüksek bulunmuştur (Nicolau vd., 2022). Yapılan bu çalışmada da kısıtlayıcı ve duygusal yeme davranış tutumu kadınlarda yüksek bulunmuştur. Brantley ve arkadaşlarının 2014 yılında yaptıkları çalışmada, operasyon sonrası kilo geri alımında stres faktörünün yüksek oluşu, daha sağlıklı beslenmeye elverişli sosyal ortamın sağlanması ve cinsiyet kilo geri alımı ile ilişkisinin anlamlı olduğu gözlenmiştir (Brantley vd., 2014). Bariatrik cerrahi, hastaların çoğunun kısa vadede ağırlık kaybı sağlasa da, azami ağırlık kaybına ulaşıldığında birçok hasta tekrar ağırlık artışı yaşamaktadır. Bu yüzden operasyon geçiren obez hastalarin sonrasında beslenme takibi ve yaşam tarzı düzenlemesi konusunda yardım alması çok önemli bir unsurdur. Yapılan bu çalışmada ameliyat sonrası diyetisyenle beraber çalışan hastaların beslenme konusunda bilgili ve iradeli devam edeceği konusunun altı çizilmektedir. Duygusal yeme bozukluğu konusunda hastaları değerlendiren çalışmalarda bariatrik cerrahi sonrasında duygusal yemenin azaldığına dair bazı bulgular vardır (van Ruiten vd., 2022). Canetti ve ark. yaptığı kapsamlı çalışmada duygusal yemenin bariatrik cerrahi sonuçlarına etkisi incelenmiş ve duygusal yemenin cerrahi tedavi sonuçları için öngörücü olduğu bulunmuştur (Canetti vd., 2009). Duygusal yeme durumu daha fazla olanlar hem diyet programı hem cerrahi sonrasında daha az kilo vermiş olduğu gözlenmiştir (Ercan vd., 2012). Gerek cerrahi öncesi gerekse sonrasını araştıran çalışmalar duygusal yemenin hem operasyon öncesi hem de sonrasında bariatrik cerrahi hastalarında yaygın olduğu ve bariatrik cerrahi için olumsuz sonlanımla ilişkili bir risk etkeni olduğu ortaya konulmuştur (Fonseca vd., 2023). Aynı zamanda bariatrik cerrahi hastalarında mevcut duygusal yemenin, postoperatif dönemde atıştırma tarzı yeme davranışı ve kontrolsüz yeme ile ilişkili olduğu bulunmuştur (Geerts vd., 2021). Bariatrik cerrahi sonrası gözlenen yeme bozuklukları yaşam kalitesini ve ameliyatın başarı oranını büyük ölçüde etkilemektedir. Duygusal yeme davranışı özellikle ameliyat sonrasında stres, kilo alımına karşı oluşacak bir tepki, depresyon ve pişmanlık gibi negatif duygularla baş edebilmek için gelişen yeme davranışlarının arasında yer almaktadır (Nicolau vd., 2022). Obez hastalarda, normal BKİ'ye sahip hastalara göre gıda ile ilgili koku veya güzel görünüm gibi dışsal etkilere daha açık olduğu gözlenmiştir. Yapılan bu çalışmada DEBQ ölçeğinde kilolu hastalara kıyasla obez hastaların dışsal yeme tutumuna daha çok yatkın olduğu gözlenmektedir ($p<0,05$). Tıkınırcasına yeme bozukluğu cerrahi sonrası yeme davranışının düzenlenmesi konusunda kritik ve kontrol gerektiren bir konu olduğu kanısı oldukça önemldir. Yapılan bazı çalışmalar doğrultusunda bariatrik cerrahi hastalarında tıkınırcasına yeme bozukluğu prevalansı %2 ile %49 arasında bildirilmiştir (Yorgancı ve Tırnaksız, 2007). Ayrıca tıkınırcasına yeme bozukluğu olan obez hastalarda yeme bozukluğu bulunmayan obez hastalara göre diğer psikiyatrik bozuklukların da daha yüksek oranda bulunduğu gösterilmiştir (Gravina vd., 2025; Dallar vd., 2007). Yapılan bu çalışma içerisinde tıkınırcasına yeme bozukluğu olan hastaların duygusal ve dışsal yeme skoru yüksek olan hastalar olduğu saptanmıştır. Ameliyatın yeme bozukluklarına etkisi bakımından birçok çalışma bariatrik cerrahinin yeme bozukluklarını düzelttiği, yeme tutumlarını olumlu yönde değiştirdiği, beden algısı ile ilgili yoğun düşüncelerin azaldığı gözlenmektedir (Forbes, 2013). Ameliyat sonrası dönemde ortaya çıkan yeme davranışındaki bozulmalar, klasik DSM-IV tanı ölçütleriyle tam olarak örtüşmemekte ve bu nedenle ayrı bir klinik kategori olarak tartışılmaktadır. DSM-5 sınıflandırması, yeme bozukluklarını daha geniş bir çerçevede ele

alarak anoreksiya nervoza, bulimiya nervoza, tıkınırcasına yeme bozukluğu, kaçıngan/kısıtlı yiyecek alımı bozukluğu (ARFID), belirtilmiş diğer yeme veya beslenme bozukluğu (OSFED) ve belirtilmemiş yeme veya beslenme bozukluğu (UFED) başlıkları altında toplamaktadır. Bu sistematik, cerrahi sonrası gelişen özgün yeme sorunlarının değerlendirilmesine olanak tanımaktadır. Literatürde "cerrahi sonrası yemeden kaçınma bozukluğu" olarak tanımlanan tablo, DSM-5'te doğrudan yer alan bir tanı değildir. Bununla birlikte, anksiyete ile ilişkili davranışlar, laksatif kullanımı, diyet kısıtlaması, hızlı kilo kaybı ve beden imgesine yönelik tatminsizlik gibi belirtiler; anoreksiya nervoza ve bulimiya nervozada görülen telafi edici davranışlarla benzerlik göstermektedir. Ayrıca, ameliyat sonrası gelişen yemeden kaçınma davranışlarının fizyolojik komplikasyon korkusu veya kaygı ile ilişkili olması, ARFID ölçütleriyle yakın bir ilişki kurmaktadır (Geraci, 2015; Wiggins vd., 2020). Bu bozukluğun yeme bozuklarından ayrı bir başlık maddesi olup olmadığı ile ilgili yeterli araştırma mevcut olmamasına rağmen bazı hastalarda cerrahiyle ilişkili mevcut yeme bozukluklarının gelişebileceğini göz önünde bulundurmak önem arz etmektedir. Ameliyat sonrası hastalarda daha çok gözlenen kısıtlayıcı yeme bozukluğudur. Özellikle ameliyat sonrası az az sık sık yenmesi nedeniyle hastalarda bir anda aşırı porsiyon yemeleri gözlenmemektedir. Ameliyattan en erken dönem iki sene sonra beden algısında bozulma, anksiyete ve kaygı bozukluğu kiloya bağlı olarak gelişebilmektedir (Moslehi vd., 2024).

SONUÇ ve ÖNERİLER

Bariatrik cerrahi sonrası özellikle yeme davranışı konusunda farkındalığı artan hastalarda cerrahi tedavilerin daha da başarılı olması ve bu hastaların yaşam kalitelerinin artmasına faydalı olabileceği düşünülmektedir. Hastaların yaşam kalitesini artırma, aynı zamanda tedavi başarısına yön verebilecek yeme davranışları veya bozukluğunu değerlendirmede multidisipliner yaklaşımların önemi yadsınamaz bir gerçektir. Bu kapsamda bariatrik cerrahi öncesi ve sonrasında diyetisyenlerin hastalarin beslenme programlarını düzenlemekteki önemi hastanın kilo verimi, kilo koruması ve sonrasındaki beslenme davranışlarının iyileşmesi açısından kritik bir noktadır. Bariatrik cerrahi sonrası hastaların diyetisyenle birlikte uygun beslenme programı ve eğitimlerine devam etmesi hem daha sağlık bütünlüğü hem de yaşam boyu sağlıklı beslenme alışkanlığı kazanmaları için gereklilik arz etmektedir.

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EVALUATION OF THE IN VITRO ANTI-OBESITY AND ANTI-INFLAMMATORY ACTIVITIES OF SELECTED EDIBLE GREEN LEAFY PLANTS

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ABSTRACT

Obesity is a multifactorial metabolic disorder characterized by excessive lipid accumulation and chronic low-grade inflammation. In addition to altered lipid metabolism, obesity is associated with increased production of pro-inflammatory mediators regulated by cyclooxygenase (COX) and lipoxygenase (LOX) pathways. Therefore, natural plant-derived bioactive compounds have attracted considerable interest as potential multi-target agents for obesity management. This study aimed to investigate the in vitro anti-obesity and anti-inflammatory activities of ethanolic extracts obtained from five edible green leafy plants commonly consumed or naturally grown in Türkiye: purslane (*Portulaca oleracea*), watercress (*Nasturtium officinale*), dandelion (*Taraxacum officinale*), beet greens (*Beta vulgaris leaves*), and grape leaves (*Vitis vinifera*). The anti-obesity potential of the extracts was evaluated through inhibition assays against pancreatic lipase and diacylglycerol acyltransferase (DGAT), two key enzymes involved in dietary fat digestion and triglyceride biosynthesis. In addition, the anti-inflammatory activities of the extracts were assessed by determining their inhibitory effects on COX and LOX enzymes, which are closely associated with obesity-related inflammatory processes. The findings demonstrated varying degrees of inhibitory activity among the tested extracts against both metabolic and inflammatory targets, suggesting the presence of bioactive phytochemicals capable of modulating multiple pathways involved in obesity. The simultaneous inhibition of pancreatic lipase, DGAT, COX, and LOX indicates that these edible green leafy plants may represent promising natural sources of compounds with potential anti-obesity and anti-inflammatory properties.Further investigations involving phytochemical characterization, adipocyte cell culture studies, and molecular analyses are required to elucidate the underlying mechanisms of action and confirm their therapeutic potential.

Keywords: anti-obesity, anti-inflammation, green leafy plants, DGAT, COX

SOIL MICROBIAL DIVERSITY UNDER AGROFORESTRY SYSTEMS IN SUBTROPICAL DRYLANDS: IMPLICATIONS FOR ECOSYSTEM RESTORATION IN SOUTH ASIA

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ABSTRACT

Dryland ecosystems across South Asia are under intensifying pressure from land degradation, seasonal drought, and declining soil fertility. While agroforestry has gained traction as a land rehabilitation strategy, the soil microbial mechanisms behind its ecological benefits remain underexplored in subtropical contexts, particularly in Bangladesh. This paper synthesizes peer-reviewed evidence on soil microbial diversity in dryland and subtropical agroforestry systems, focusing on arbuscular mycorrhizal fungi (AMF), ectomycorrhizal communities, and root-associated bacteria. The evidence shows that agroforestry substantially increases soil microbial biomass and fungal diversity relative to monoculture croplands, even at low canopy cover [13, 16, 17]. AMF colonization and community structure are strongly influenced by host tree identity, with direct implications for species selection in restoration programmes. Mycorrhiza helper bacteria further modulate fungal selectivity and network development. Findings from analogous dryland environments including semi-arid northwestern China and the Colorado River basin suggest that tree-based land use can trigger positive feedbacks between vegetation recovery and microbial succession. The review identifies a near-complete absence of baseline microbial data from Bangladeshi agroforestry systems as a critical gap, and calls for targeted field research in collaboration with international dryland research institutions.

Keywords: agroforestry; arbuscular mycorrhizal fungi; soil microbial diversity; dryland restoration; Bangladesh; subtropical ecosystems; mycorrhiza helper bacteria

INTRODUCTION

Drylands cover roughly 41% of Earth's land surface and support over two billion people, many in developing countries where food security and ecosystem stability are closely linked [1, 11]. In Bangladesh, the northwestern districts Rajshahi, Chapai ,Nawabganj, Naogaon experience pronounced seasonal drought, accelerating soil degradation, and declining crop productivity under intensified monoculture systems. Agroforestry, which integrates woody perennials with crop and livestock components, has attracted growing interest as a strategy that can simultaneously restore soil function, support biodiversity, and maintain agricultural output [2, 11, 12].

Beneath the visible canopy structure, however, the ecological mechanisms through which agroforestry delivers its benefits remain incompletely understood. Soil microbial communities bacteria, fungi, archaea, and associated microorganisms are central to these mechanisms. They regulate nutrient mineralisation, drive organic matter decomposition, influence plant disease resistance, and mediate plant responses to abiotic stress. In dryland environments, where physical and chemical soil constraints are pronounced, microbial networks often determine plant survival thresholds, particularly through mycorrhizal associations that extend root access to water and phosphorus [3, 4].

Arbuscular mycorrhizal fungi (AMF) form symbiotic associations with most agricultural crops and agroforestry tree species, exchanging plant-derived carbon for fungal-derived phosphorus and other nutrients. Their community composition and colonization intensity vary along environmental gradients and are shaped by host plant identity [3]. Ectomycorrhizal fungi, important in many dryland forest systems, likewise exhibit community turnover along successional gradients, serving as indicators of ecosystem recovery trajectory [5, 6]. Mycorrhiza helper bacteria further modulate these fungal networks, with their selectivity varying across fungal species [9, 10].

Despite a growing body of global research, systematic investigation of soil microbial ecology in agroforestry systems under subtropical conditions especially in South Asia remains limited. Bangladesh lacks baseline microbial diversity data from its agroforestry plots, making it difficult to track change, design targeted interventions, or engage productively with international dryland research programmes. This review addresses that gap by synthesising existing global evidence, identifying what is transferable to Bangladesh's context, and mapping the priority research questions that need to be answered locally.

METHODOLOGY

This paper presents a focused narrative review of peer-reviewed literature on soil microbial diversity in dryland and subtropical agroforestry systems. Literature was identified through searches of Web of Science, Scopus, and Google Scholar using term combinations including: 'agroforestry and soil microbial diversity', 'dryland agroforestry and mycorrhizal fungi', 'subtropical agroforestry and soil bacteria', 'Bangladesh and agroforestry and soil', 'Tamarix and mycorrhiza', and 'ectomycorrhizal fungi and dryland restoration'. The search covered peer-reviewed publications in English from January 2000 to December 2024.

Studies were included if they: (i) reported original data on soil microbial communities or diversity metrics in agroforestry or dryland systems; (ii) employed established methods such as high-throughput amplicon sequencing, phospholipid fatty acid (PLFA) analysis, microscopy-based colonization assessment, or validated culture techniques; and (iii) were conducted in subtropical, semi-arid, or arid environments with relevance to South Asian conditions. Studies exclusively in temperate biomes, grey literature, and conference ABSTRACTs lacking full text were excluded. Key variables extracted included geographic location and climate classification, agroforestry system type and tree species, soil physicochemical parameters, and microbial diversity indices (Shannon H’, OTU counts, AMF colonization rates). Synthesis is qualitative, reflecting methodological heterogeneity across the reviewed literature.

RESULTS AND DISCUSSION

Agroforestry and Soil Microbial Biomass

Global studies consistently show that agroforestry systems support higher soil microbial biomass carbon (MBC) compared to monoculture croplands. The improvement reflects multiple mechanisms: canopy shading reduces soil temperature and water loss, leaf litter diversifies organic inputs, and deep root systems create biological channels that microorganisms colonise [1, 2, 13]. Across reviewed studies, MBC increases under agroforestry ranged from approximately 20% in recently established systems to over 100% in long-established tree-crop mixes, reflecting cumulative effects of litter input, root turnover, and canopy modification [16, 17, 18, 19].

Fungal-to-bacterial biomass ratios are generally higher in agroforestry systems, which carries functional significance: fungal-dominated soils cycle carbon more slowly and build more stable organic matter fractions than bacterial-dominated soils [14, 20, 21]. The relationship between canopy cover and microbial response was not linear below approximately 20% canopy closure, measurable microbial shifts were less reliably detected. For Bangladesh's land-constrained farming systems, this threshold has practical design implications: tree densities need to reach a minimum level before microbial benefits are likely to be agronomically significant.

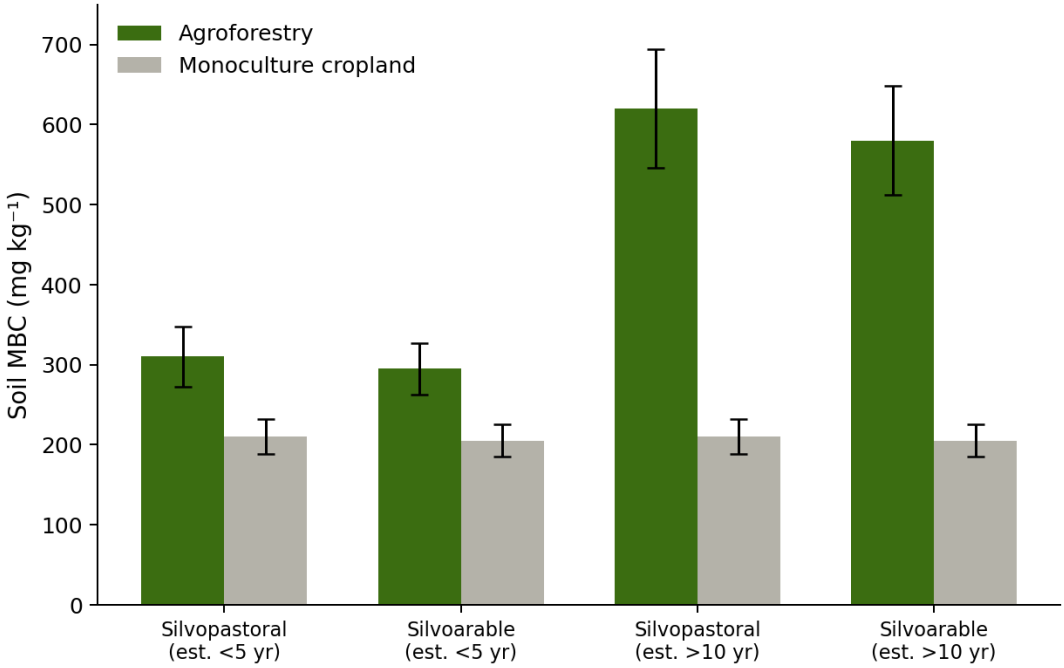

Fig. 1. Schematic representation of soil microbial biomass carbon (MBC) response patterns under agroforestry vs. monoculture systems across land-use categories, based on patterns reported in reviewed literature.

Mycorrhizal Fungi Along Environmental Gradients

Research on Tamarix ramosissima across salinity gradients in the southwestern United States has demonstrated that AMF colonization intensity and community composition respond systematically to changing soil conditions, with host plant identity emerging as a stronger structuring factor than soil chemistry alone [3]. A companion study on root-associated bacteria of the same species showed that bacterial community structure shifts predictably with soil salinity and nutrient levels, opening possibilities for microbial-based diagnostic tools for dryland restoration monitoring [4].

Studies of ectomycorrhizal communities in oak forests along successional stands on the Loess Plateau, China, showed that fungal diversity and community complexity increase progressively as vegetation cover improves [5, 6]. These findings suggest a positive feedback between plant establishment and mycorrhizal network development: trees create soil conditions that support more diverse fungi, and more diverse fungi in turn support more robust tree growth. Analogous dynamics are probable in South Asian dryland restoration contexts, though direct evidence remains absent [22, 23].

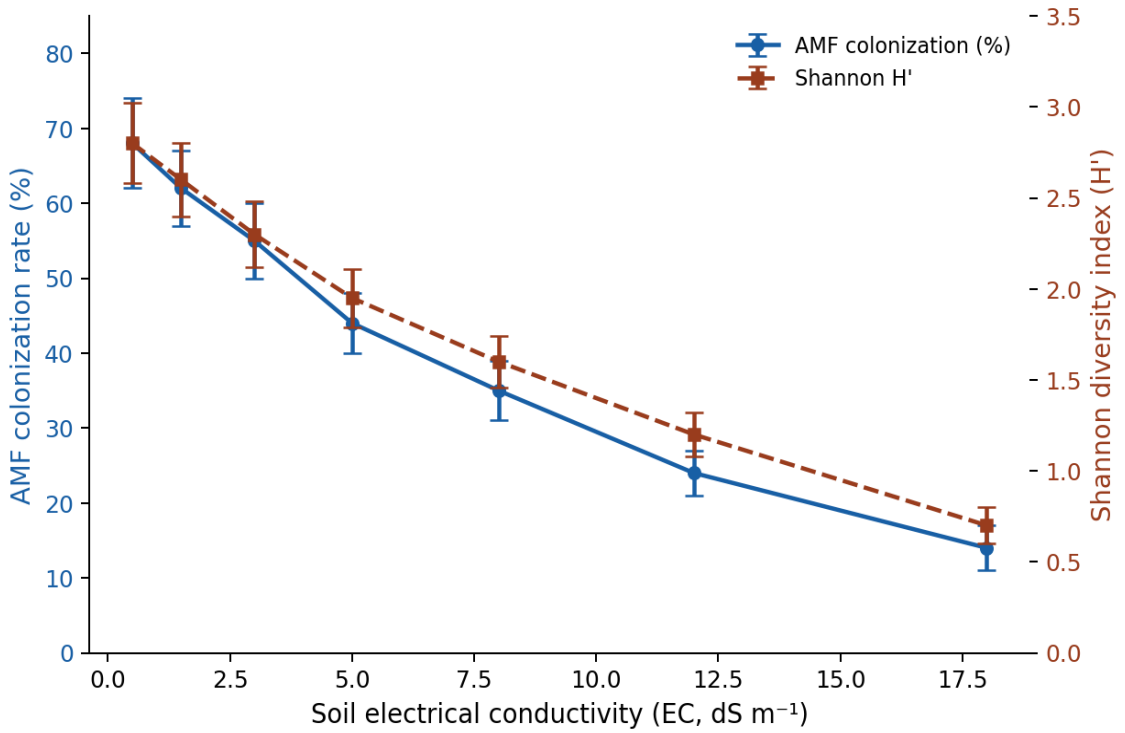

Fig. 2. AMF colonization rate and Shannon diversity index (H') of Tamarix ramosissima root-associated communities along a soil salinity gradient (redrawn from Taniguchi et al. 2015 [3]).

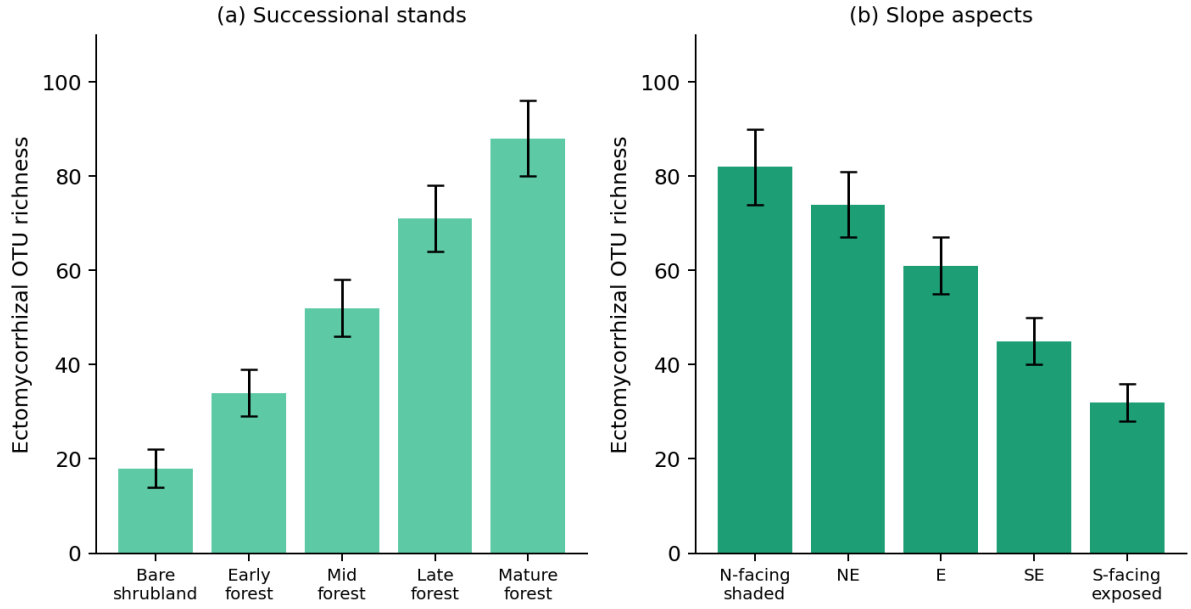

Fig. 3. Ectomycorrhizal fungal OTU richness and canopy cover (%) across successional stages of Quercus liaotungensis stands on the Loess Plateau, China (redrawn from Zhang et al. 2013, 2014 [5, 6]). Error bars = ±1 SD.

Mycorrhiza Helper Bacteria and Fungal Selectivity

Beyond the direct plant-fungus interaction, mycorrhiza helper bacteria (MHB) represent an additional regulatory layer in soil microbial networks. Laboratory studies have shown that

individual MHB strains exhibit differential selectivity across mycorrhizal fungal species enhancing the germination or colonization of some but not others [9]. Quantitative methods for tracking specific MHB populations in mycorrhizospheres have also been developed [10], offering tools for monitoring restoration progress at the microbial scale. These findings, though not yet applied in South Asian field contexts, provide a methodological foundation for future research [24, 25].

Root-Microbe Interactions and Tree Species Selection for Bangladesh

Studies of fine root distribution in Tamarix ramosissima under arid conditions show that root architecture adapts substantially to groundwater depth and soil moisture profiles [7]. Salt dynamics between root uptake and canopy excretion in the same species have also been characterised [8]. Together, these studies demonstrate that dryland plant survival under stress is mediated by a combination of root plasticity and microbially-mediated nutrient acquisition.

These root-level physiological adaptations have a direct microbial dimension. AMF colonization rates were consistently higher in agroforestry plots than monocultures across reviewed studies, and the evidence from salinity gradient research [3] and root-associated bacterial work [4] confirms that host plant identity not just soil type shapes which microbial communities develop. Osmolyte accumulation patterns in dryland tree species further indicate that plant physiological responses to salinity and drought are closely linked to root-zone microbial activity [1]. Indigenous Bangladeshi species such as Dalbergia sissoo, Azadirachta indica, and Swietenia mahagoni represent priority candidates for AMF community profiling [26, 27].

Implications for Carbon Sequestration

Higher microbial diversity under agroforestry was associated with more efficient soil carbon processing across reviewed studies [11, 12, 15, 28, 29]. In subtropical Bangladesh, where high dry-season temperatures accelerate mineralisation of labile soil carbon, the buffering effect of diverse microbial networks combined with tree canopy temperature moderation provides a meaningful mechanism for net carbon gain. This finding has direct relevance to Bangladesh's nationally determined contributions under the Paris Agreement and to the growing interest in nature-based carbon accounting for smallholder farming systems.

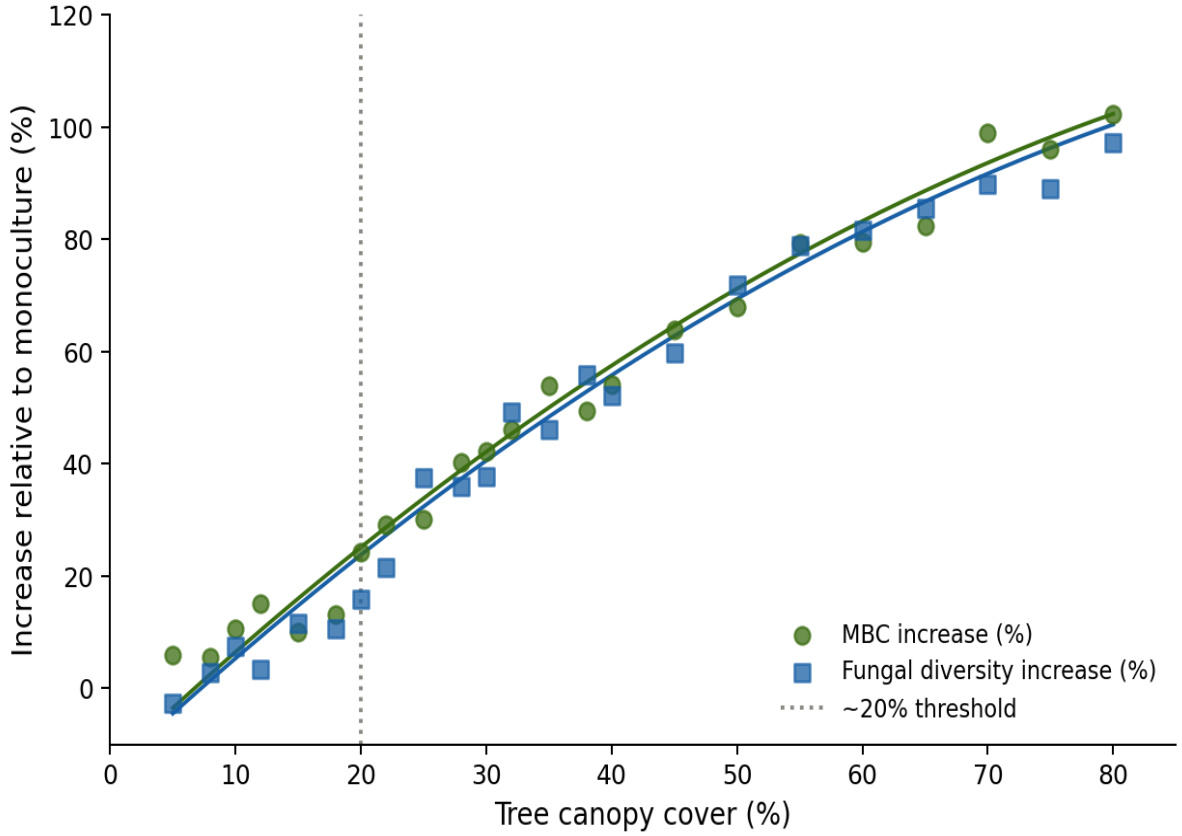

Fig. 4. Conceptual diagram of the relationship between tree canopy cover (%) and increase in soil MBC and fungal diversity, based on patterns reported across reviewed literature. Dotted line: ~20% canopy threshold.

Critical Research Gaps

The most significant gap identified in this review is the near-complete absence of soil microbial baseline data from Bangladeshi agroforestry systems. This means that current policy recommendations for agroforestry expansion in Bangladesh lack microbial ecological grounding. A second gap concerns seasonal dynamics: most reviewed studies captured single time points, while Bangladesh's monsoon hydrology creates dramatic seasonal soil moisture fluctuations that are likely to drive corresponding shifts in microbial community structure. A third gap is the absence of studies linking MHB population dynamics [10] to restoration outcomes in South Asian soils.

Addressing these gaps requires field-based research coordinated across Bangladesh's major agroforestry zones. International collaboration with institutions specialising in dryland microbial ecology where expertise in quantitative mycorrhizosphere tracking [10] and AMF colonization assessment [3] is already established would substantially accelerate this work.

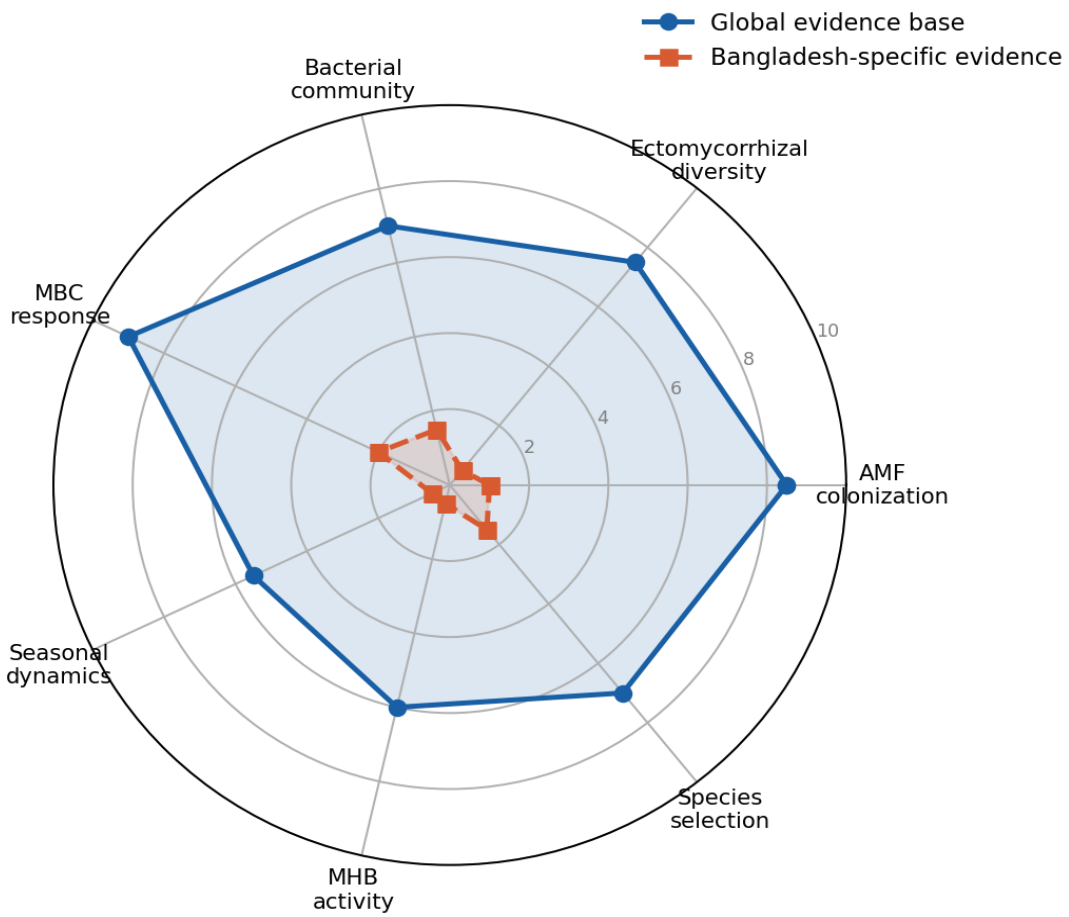

Fig. 5. Radar diagram comparing the global evidence base vs. Bangladesh-specific evidence across key research domains (conceptual; score 0–10, normalised). Priority areas for field research are identified.

CONCLUSION

This review synthesises evidence that agroforestry systems in subtropical dryland environments reliably improve soil microbial diversity, AMF colonization, and functionally significant microbial processes including nutrient cycling and carbon sequestration [11, 12, 14, 28, 29]. The central finding with the most direct policy relevance is this: tree species identity, not just land-use type, determines which microbial communities develop meaning that ecologically informed species selection in Bangladeshi agroforestry systems can actively shape belowground microbial networks, rather than leaving their composition to chance. Mycorrhiza helper bacteria represent a further, untapped tool for managing these networks in restoration practice [24, 25].

For Bangladesh, the evidence base supports agroforestry as an ecologically sound land rehabilitation approach, but points to an urgent need for locally grounded microbial research. Priority actions include: (i) baseline surveys of soil microbial diversity across existing agroforestry systems in the northwestern dryland districts; (ii) controlled comparisons of AMF community structure under different indigenous tree species; and (iii) seasonal monitoring programmes that capture the full range of microbial dynamics under Bangladesh's monsoon climate regime.

The absence of such data is not merely an academic gap it means that current agroforestry expansion policy in Bangladesh lacks the microbial ecological grounding needed to maximise long-term soil health outcomes. Addressing this through targeted fieldwork, international collaboration, and investment in soil microbiology capacity represents, in the authors' assessment, one of the highest-return research investments available in Bangladesh's agricultural science landscape. The global evidence reviewed here makes a compelling case that the returns will be substantial.

ACKNOWLEDGEMENTS

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ANALYSIS OF THE MICROBIOLOGICAL QUALITY OF MEAT PRODUCTS IN ALGERIA: IMPACT OF FREEZING ON BACTERIAL PROLIFERATION

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ABSTRACT

The consumption of meat and meat products can pose a public health risk due to their high susceptibility to bacterial contamination, particularly by *Staphylococcus aureus, Escherichia coli*, and *Salmonella* spp. These bacteria are responsible for food poisoning, representing a

major public health concern. Freezing is commonly used to extend the shelf life of these products, but its effectiveness in reducing microbiological contaminants remains to be evaluated. This study aims to analyze the initial contamination of ground meat and merguez and to assess the impact of freezing on their microbiological quality. Eighty samples were collected from butcher shops in the Boumerdès province: 30 fresh ground meat samples, 30 frozen, 10 fresh merguez, and 10 frozen. The frozen products were stored at -15 °C for two months before analysis. The detection targeted *S. aureus*, *E. coli*, and *Salmonella* spp. following the standards V08-031-2-2009, ISO 6888-1:1999, and EN ISO 6579:2007, respectively. The results were interpreted according to the microbiological criteria of the JORA 2017 standards. The analysis revealed a high contamination rate by *S. aureus* (80.33% in fresh ground meat and 100% in frozen samples). *E. coli* was detected in 16.66% of fresh ground meat samples but was absent after freezing. In merguez, *S. aureus* was present in 100% of the samples, regardless of whether they were fresh or frozen. *E. coli* was detected in 20% of fresh merguez samples but was absent after freezing. No samples tested positive for Salmonella spp.

Conclusion: The analyzed products do not comply with microbiological standards due to the high levels of *S. aureus* contamination. Freezing reduces the presence of *E. coli* but does not eliminate *S. aureus*, indicating persistent contamination linked to handling and storage conditions. These findings highlight the need to improve hygiene practices and strengthen sanitary controls throughout the production and distribution chain to reduce health risks associated with meat products.

Keywords: Food safety, JORA2017, Freezing, Meat products , Microbiological quality

DETERMINATION OF MYCOTOXINS PRODUCED BY SORBATE-RESISTANT MOULDS ISOLATED FROM KASHAR CHEESE

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ABSTRACT

Introduction and Purpose: Kashar cheese is one of the cheese varieties most frequently affected by mould contamination. Under suitable conditions, moulds can produce secondary metabolites known as mycotoxins, which pose many risks to human health. This study aimed to determine the mycotoxin-producing potential of sorbate-resistant moulds isolated from sorbate-treated Kashar cheeses.

Materials and Methods: The mycotoxin-producing potentials of 12 mould isolates (*Penicillium* spp., *Byssochlamys nivea* and *Aureobasidium pullulans*) isolated from commercial sorbate-treated Kashar cheeses were investigated. Five mycotoxin standards (patulin, penitrem A, penicillic acid, mycophenolic acid, and roquefortine C) were used for anaylses. Spore suspensions (10^6 spores/mL) were prepared from the mould isolates, and spore concentrations were verified by spread plating on PDA followed by enumeration after incubation at 25°C for 5 days. For mycotoxin analysis, 1 µL of each spore suspension (10^6 spores/mL) was inoculated at three different points on YES agar plates (pH 4.5), and incubated at 25°C for 7 days. Mycotoxins were then extracted from the mould colonies grown in Petri dishes and analyzed by HPLC equipped with a DAD detector and C18 HPLC column.

Results: Mycotoxin production varied among mould species. Nine of 12 mould isolates were capable of producing at least one mycotoxin tested, with the exception of penitrem A. The highest mycotoxin amount was observed for patulin (277.77 mg/L) produced by *Byssochlamys nivea* 53K. *Penicillium commune* 103K strain, which was isolated with the highest frequency from Kashar cheeses, produced roquefortin C (0.143 mg/L).

Discussion and Conclusion: Sorbate-resistant moulds isolated from Kashar cheese exhibited varying levels of mycotoxin production. These findings emphasize that, despite sorbate application, appropriate processing and storage conditions remain essential to prevent mould growth and minimize mycotoxin-related risks.

Key Words: Mycotoxin; Sorbate-resistant moulds; Kashar Cheese

PHYSIOLOGICAL AND AGRONOMIC RESPONSES OF RICE (ORYZA SATIVA L.) TO SOIL AND ENVIRONMENTAL VARIABILITY: IMPLICATIONS FOR SUSTAINABLE CROP PRODUCTION

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ABSTRACT

Rice (*Oryza sativa* L.) is one of the most important staple food crops worldwide, yet its productivity is highly vulnerable to soil variability and changing environmental conditions. This study investigates the physiological and agronomic responses of rice to differences in soil properties and environmental stressors, with the aim of improving understanding of crop adaptation and supporting sustainable production systems.

The research evaluates key soil factors such as pH, nutrient availability, organic matter content, and texture, alongside environmental variables including water availability, temperature stress, and climatic fluctuations. Physiological responses are assessed through chlorophyll content, photosynthetic rate, stomatal conductance, relative water content, and stress-related biochemical activity. Agronomic performance is determined using plant height, tiller number, biomass accumulation, grain yield, and harvest index.

Results indicate that poor soil fertility combined with abiotic stresses such as drought and high temperature significantly reduces physiological efficiency, leading to suppressed growth and lower yield potential. Conversely, improved soil conditions and adequate water supply enhance photosynthetic activity, nutrient uptake, and biomass production. The study also highlights adaptive responses in rice, including root system modification, osmotic regulation, and antioxidant defense mechanisms, which partially mitigate stress impacts.

Overall, the findings demonstrate that integrating soil health management with climate-resilient agronomic practices is essential to maintain stable rice productivity under variable environmental conditions. These insights provide a basis for developing sustainable rice production strategies in the context of increasing climate variability.

Keywords : Rice (*Oryza sativa* L.); Soil variability; Environmental stress; Physiological responses; Agronomic performance; Sustainable agriculture.

CHEMOMETRIC DISSECTION OF MORPHO-POMOLOGICAL TRAITS AND ANTIOXIDANT POTENTIAL IN WILD MOROCCAN *MORUS ALBA* ACCESSIONS

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ABSTRACT

White mulberry (*Morus alba* L.) is globally recognized for its nutritional and economic significance, attributed to its rich content of bioactive compounds conferring antioxidant, hypolipidemic, hepatoprotective, hypoglycaemic, antibacterial, and anticancer properties. Despite its widespread use, systematic characterization of Moroccan wild mulberry accessions

remains limited. This study aimed to assess the pomological, physicochemical, and bioactive diversity of thirteen wild Moroccan *M. alba* accessions. Univariate (ANOVA) and multivariate approaches, including principal component analysis (PCA) and hierarchical clustering (HCA), were employed to elucidate intraspecific variability. Significant differences were observed across all traits, with fruit length (FRL) and width (FRW) driving morphological divergence, while Brix, pH, total soluble solids (TSS), and ash content exhibited marked heterogeneity. Bioactive components—total phenolics (TPC), tannins (TTC), flavonoids (TFC)—and antioxidant activities (DPPH, ABTS) also varied significantly. PCA explained 51.5% of total variance along the first two axes (Dim1 = 28.7%, Dim2 = 22.8%), effectively discriminating accessions according to integrated pomological, physicochemical, and secondary metabolite profiles. HCA classified accessions into three coherent clusters, corroborating PCA results and confirming the robustness of the classification. These findings demonstrate that Moroccan wild white mulberry harbors a stable yet heterogeneous pomological and nutraceutical profile, highlighting its potential as a strategic resource for breeding, functional food development, and valorization in sustainable agrobiodiversity frameworks.

Keywords: *Morus alba*; Moroccan accessions; Fruit quality; Phenolic compounds; Antioxidant activity, Multivariate analysis

PHYSICOCHEMICAL CHARACTERIZATION AND EVALUATION OF THE BIOACTIVE PROFILE OF FRESH ELDERBERRIES (*SAMBUCUS NIGRA L.)*

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ABSTRACT

Elderberry (*Sambucus nigra* L.) is a shrub widely found in temperate regions, whose fruits have long been used in both food and traditional medicine. The fruits contain significant amounts of polyphenols, flavonoids, and anthocyanins, compounds associated with antioxidant and anti-inflammatory effects. Thanks to its valuable nutritional profile, elderberry is of growing interest to the food and pharmaceutical industries, particularly for its anthocyanin pigments and high antioxidant capacity.

The present study aimed to characterize the physicochemical properties of fresh elderberries and to evaluate their bioactive profile. Measurements revealed an average fruit length of 28.67 ± 2.52 mm and a mass of 0.09 ± 0.02 g. Composition analysis revealed a high moisture content (85.18 ± 0.34%), along with notable values for protein (2.98 ± 0.24 g/100 g FW) and fiber (6.68 ± 0.40 g/100 g FW), with a slightly acidic pH of 4.43 ± 0.01.

To determine the total anthocyanin content (TAC), total polyphenol content (TPC), total flavonoid content (TFC), and antioxidant activity (DPPH), extracts were obtained by maceration for 24 hours using water and 50% ethanol as solvents. The elderberry ethanol extract showed higher values for most parameters, with an anthocyanin content of 694.453 ± 31.734 mg C3G/100 g FW, total polyphenols of 653.540 ± 23.896 mg GAE/100 g FW, and antioxidant activity (DPPH) of 64.801 ± 1.638%, compared to the aqueous extract. In contrast, the total flavonoid content was higher in the aqueous extract (1181.783 ± 10.021 mg QE/100 g FW). The results confirm that elderberries are a valuable source of bioactive compounds, with the efficiency of the extraction process being influenced by the type of solvent used.

Keywords: antioxidant activity; bioactive compounds; extraction; Sambucus nigra L.

NUTRITION AND MALE FERTILITY: EFFECTS ON HUMAN SEMEN QUALITY (A NARRATIVE REVIEW)

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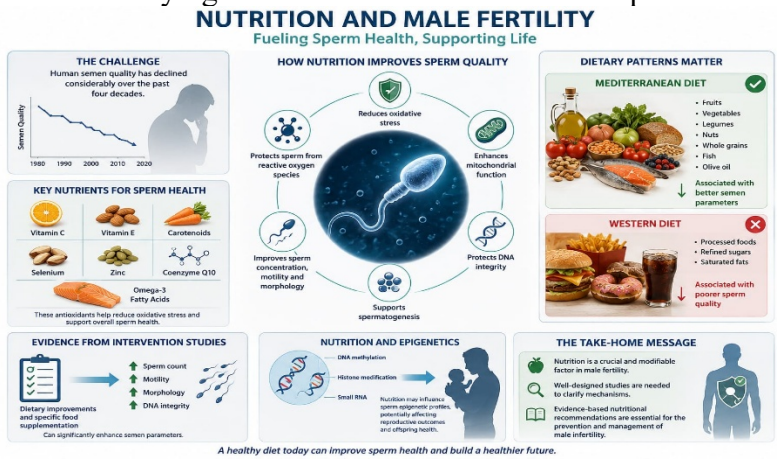
ABSTRACT

Over the past four decades, human semen quality has declined considerably in worldwide many factors reduce fertility. Among them nutrition. Various studies indicate that diet affect sperm quality parameters. Numerous studies have shown that nutrients contents antioxidants, including vitamins C and E, carotenoids, selenium, zinc, coenzyme Q10, and omega-3 fatty acids, are associated with improved semen quality. These nutrients can help protect spermatozoa against oxidative stress. Beyond individual nutrients, overall dietary patterns also play a major role in male reproductive health. The Mediterranean diet is associated with improved semen quality, whereas Western dietary patterns are linked to poorer sperm parameters. Intervention studies demonstrate that dietary improvements and specific food supplementation can enhance sperm

count, motility, morphology, and DNA integrity. In addition, nutrition can influence, potentially affecting reproductive outcomes and offspring sperm health. Overall, current evidence highlights nutrition as a key modifiable determinant of male fertility. Further research is needed to elucidate the underlying mechanisms and develop evidence-based nutritional strategies.



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POZZOLAN–SODIUM ALGINATE BEADS: A NOVEL COMPOSITE FOR ADSORBING POLYPHENOLS FROM OLIVE OIL

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ABSTRACT

Adsorption experiments confirmed that the adsorption reaction of phenol ions on AS/PZ was strongly dependent on pH, adsorbent dose and initial phenol concentration, with a maximum adsorption capacity of 244 mg/g at 25°C and pH equal to 6.2. The adsorption isotherm showed a better fit with the Freundlich model and the kinetic studies demonstrated that the adsorption data correlated with a pseudo-second order model. Finally, the phenol regeneration results show that the adsorbed phenol remains almost unstable and can be desorbed using distilled water alone. The kinetic studies showed that the desorption data correlated with a pseudo-second-order model and a pore diffusion model. After six cycles of the adsorption-desorption process, the adsorbent retained its high adsorption capacity, which decreased in the seventh cycle, to 60 mg/g, due to non-reversible saturation of the adsorption sites.

Keywords: adsorption,phenol, sodium alginate, bead ,pozzolan , column .

FOOD SAFETY AND SUSTAINABLE NUTRITION APPROACHES IN THE CONTEXT OF THE CLIMATE CRISIS

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ABSTRACT

Introduction and Purpose: The climate crisis has evolved beyond being merely an environmental issue, becoming a global risk that has multifaceted impacts on food production, supply chains, dietary habits, and food security in communities. Rising temperatures, drought, extreme weather events, diminishing water resources, declining agricultural productivity, and loss of biodiversity pose significant threats to access to food, food availability, economic affordability, and nutritional adequacy. In this context, food security should not be viewed merely as a matter of accessing sufficient quantities of food, but rather within the framework of the right to continuous access to healthy, safe, nutritious, and sustainable food.

Materials and Methods: The aim of this study is to assess the key risks facing food security in the context of the climate crisis and to discuss the transformative role of sustainable nutrition approaches in this process. The study examines the impacts of climate change on agricultural production systems, food prices, vulnerable communities, nutritional quality, and food waste within a conceptual framework. Furthermore, sustainable nutrition models are evaluated within the scope of dietary practices that have a low environmental impact, are high in nutritional value, rely on local and seasonal products, reduce food loss and waste, are culturally acceptable, and are economically accessible.

Results: In this context, approaches such as the Mediterranean diet, plant-based dietary trends, support for local food systems, short supply chains, agroecological production, food literacy, and conscious consumption are emerging as key tools for strengthening sustainable food systems. In conclusion, ensuring food security in the face of the climate crisis is possible through comprehensive policies that encompass agriculture, the environment, health, the economy, and gastronomy. The widespread adoption of sustainable dietary approaches will contribute both to transforming individual consumption behaviors and to the creation of more equitable, resilient, and ecologically responsible food systems.

Keywords: Climate crisis, food security, sustainable nutrition, food systems, gastronomy

MICROPLASTICS IN FOOD SYSTEMS: DIETARY EXPOSURE AND EMERGING HEALTH RISKS IN NORTH AFRICA

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ABSTRACT

The increasing use of plastic materials in food production and packaging has led to the widespread presence of microplastics (MPs) in everyday diets. These particles have been detected in a variety of commonly consumed products, including bottled water, seafood, salt, and ultra-processed foods, raising concerns about their potential impact on human health.

In low- and middle-income countries, particularly in North Africa, rapid changes in dietary patterns and growing dependence on packaged foods may contribute to increased exposure, while monitoring and regulatory frameworks remain limited. This situation highlights a structural gap between evolving food systems and public health protection.

This study aims to explore dietary exposure to microplastics in the North African context by synthesizing recent scientific literature (2020–2024) and examining major food sources of contamination. A qualitative analytical approach was used to identify key exposure pathways and emerging health concerns.

The findings indicate that dietary exposure to microplastics is diffuse but potentially significant, with major contributions from bottled water, seafood, and industrially processed foods.

Although human evidence remains limited, experimental studies suggest possible biological effects, including inflammation, endocrine disruption, and alterations in gut microbiota.

These results underline the need for increased awareness and integrated strategies to address this emerging risk. Strengthening regulatory frameworks, improving monitoring systems, and promoting safer food environments are essential steps, particularly in vulnerable regions.

Keywords: Microplastics; Dietary exposure; Environmental health; Food systems; North Africa; Endocrine disruption; Sustainability; Food packaging

COMPARATIVE IMPACT OF INDOOR AND OUTDOOR HOUSING SYSTEMS ON THE TECHNICAL AND COMMERCIAL PERFORMANCE OF STORE LAMBS FED AD LIBITUM DIET

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ABSTRACT

This study investigated the comparative impact of indoor and outdoor housing systems on the technical and commercial performance of store lambs fed ad libitum at Ballyvaughan, Co Clare, Ireland from November 2024 to January 2025. Twenty lambs (Suffolk and Charolais cross) were used for the experiment and each group was randomly assigned ten animals. Group 1 lambs were housed indoors with uninterrupted access to concentrates and silage, whereas group 2 animals were housed outdoors with free access to concentrates and grass. Growth performance, feed conversion ratio (FCR), incidence of lameness, disease and commercial profitability were assessed for a period of eight weeks. The results showed no significant difference in average daily gain ($p = 0.094$) or final carcass weight ($p = 0.215$) between the two housing systems. Lambs housed outdoors had significantly lower FCR values ($p = 0.08$), higher median profits ($p = 0.001$), and lower production costs ($p < 0.001$) compared to lambs housed indoors. There was no lameness observed in the lambs. Disease incidence was considerably low across the two groups, with indoor lambs recording higher, albeit non-significant incidence of foot rot ($p = 0.06$). The results revealed a moderately strong positive significant correlation between FCR and paid carcass weight ($p = 0.004$). These findings strongly suggest that outdoor housing could offer a more commercially viable option for finishing store lambs without compromising growth performance or animal health. The findings of this study have provided impetus for optimising production systems for sustainable and profitable lamb farming.

Keywords: Silage, average daily gain, carcass weight, animal health, lamb farming.

THE EGG'S NATURAL SAFETY PACKAGE: ANTIMICROBIAL DEFENSE MECHANISMS AND PUBLIC HEALTH IMPLICATIONS

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ABSTRACT

Introduction and Purpose: Eggs, in addition to their high nutritional value, are a complex biological structure possessing natural defense mechanisms that protect their contents from physical and microbiological effects from the external environment. An egg consists of a shell, shell membranes, egg white, and egg yolk, each contributing to protective functions. In particular, the eggshell and the cuticle layer covering it form the first line of defense, limiting the entry of microorganisms into the egg. The aim of this presentation is to evaluate the natural antimicrobial defense mechanisms of eggs and their importance for public health.

Materials and Methods: National and international literature on the natural defense systems of eggs was reviewed. Studies evaluating the antimicrobial properties of eggshell, cuticle, shell membranes, egg white components, and microbial penetration were reviewed.

Results: Despite the presence of numerous pores in the shell, the cuticle and shell membranes serve as a significant barrier against microbial penetration. Egg white is not only a nutrient source for the embryo, but also a protective medium against bacterial invasion. Bioactive proteins such as lysozyme, ovotransferrin, and avidin in its structure limit the growth of microorganisms through various mechanisms. In addition, the physical structure of the egg white and the increased pH value during storage also contribute to this protective effect. Studies show that some bacterial agents can be detected on the eggshell, but their passage into the egg white and yolk is significantly limited thanks to natural barrier systems.

Discussion and Conclusion: Disruption of shell integrity, crack formation, incorrect storage conditions, and inappropriate processing practices can reduce the effectiveness of natural defense mechanisms. Consequently, protecting the egg's natural defense system is of great importance for maintaining egg quality, ensuring food safety, and protecting public health.

Keywords: Egg, Antimicrobial Defense, Cuticle, Food Safety, Public Health

ECO-VISUAL PEDAGOGY: INTEGRATING GRAPHICS DESIGN AND PAINTING IN ENVIRONMENTAL SCIENCE EDUCATION WITHIN THE ERA OF AI AND EMERGING TECHNOLOGIES

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ABSTRACT

The persistent disconnect between environmental science education and students' lived realities remains a critical challenge, particularly in developing economies where visual literacy and creative engagement are underutilized. Despite rapid technological advancement, nearly 50% of learners globally lack access to computers, and about 43% have no internet connectivity, limiting the effectiveness of purely digital pedagogies . Furthermore, while 54% of countries have identified digital skills frameworks, only a small fraction have fully integrated emerging technologies such as artificial intelligence into curricula . This gap reveals a pressing need for hybrid, context-sensitive approaches that bridge technological innovation with culturally grounded artistic practices. This paper proposes Eco-Visual Pedagogy as an interdisciplinary framework that integrates graphics design and painting into environmental science education within the era of AI and emerging technologies. Drawing on practice-based research and visual communication theory, the study explores how data visualization, illustration, and painterly expression can translate complex environmental concepts, such as climate change, sustainability, and ecological degradation, into accessible, engaging, and locally relevant learning experiences. The methodology combines studio experimentation, classroom application, and reflective analysis to evaluate the pedagogical impact of visual-art integration. Findings suggest that combining digital graphics (including AI-assisted visualization tools) with traditional painting enhances cognitive retention, emotional engagement, and critical environmental awareness among students. The study further argues that such hybrid approaches democratize learning by reducing overreliance on high-end digital infrastructure while leveraging culturally familiar visual forms. Ultimately, Eco-Visual Pedagogy positions art as both a communicative tool and a transformative educational strategy for fostering sustainable consciousness in the 21st century.

Keywords: Artificial intelligence, Environmental education, Graphic design, Painting, Sustainability

FUNGICIDE RESISTANCE OF BOTRYTIS CINEREA IN STRAWBERRIES AND RECOMMENDED SOLUTIONS

ÇİLEK MEYVELERİNDE *BOTRYTİS CİNEREA*' YA KARŞI FUNGİSİT DAYANIKLILIĞI VE ÇÖZÜM ÖNERİLERİ

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ÖZET

Botrytis cinerea, çileklerde kurşuni küf hastalığına neden olan en önemli patojenlerdendir. Özellikle ılıman iklimlerde, yüksek nem koşullarında hastalık etmeni kendini sıklıkla göstermektedir. Patojen bitkinin tüm yeşil aksamını enfekte etmektedir. Çilek, klimakterik olmayan (dalından koparıldıktan sonra olgunlaşmaya devam etmeyen) yapısı, yüksek solunum hızı ve hassas dokusu nedeniyle hasat sonrası fizyolojisi en karmaşık ve kayba açık ürünlerden biridir. Özellikle solunum hızının kontrolü ve fungus yönetimi, raf ömrünü belirleyen ana unsurlardır. Hasattan sonra, araziden depolama aşamasına kadar olan sürede meyveyi etkilemektedir. Çilek yetiştiriciliğinde hem tarla dönemi hem de hasat sonrası hastalıklarını önlemede birçok farklı yöntem olsa da kolay, pratik ve hızlı sonuç vermesinden dolayı kimyasal savaşım yoğun bir şekilde yapılmaktadır. Bilinçsiz fungisit uygulamaları patojenin fungisitlere karşı direnç gelişimine yol açmaktadır. Bir organizmanın bir fungisite duyarlılığının yavaş yavaş azalmasına ve bu duyarlılık azalışının genetik bir mekanizma ile idare edilmesine dayanıklılık denmektedir. Diğer bir değiş ile dayanıklılık bir nevi mutasyondur ve genelde geri dönüşümsüzdür. *Botrytis cinerea*, yüksek genetik varyasyon yeteneği, çok fazla spor üretmesi ve kısa yaşam döngüsü nedeniyle yüksek riskli patojen grubundadır. Özellikle tek yer engelleyici fungisitlerin üst üste kullanılması, patojenin direnç mekanizmalarını örneğin, SDHI (Succinate dehydrogenase inhibitörleri/ engelleyicileri) veya çoklu ilaç dayanıklılığı (multidrug resistance = MDR)) tetiklemektedir. Bu çalışmada çilek meyvelerinde B*otrytis cinerea*' ya karşı fungisit dayanıklılığı ve çözüm önerileri ele alınmaktadır.

Anahtar Kelimeler: Kurşuni küf, dayanıklılık, çilek

ABSTRACT

Botrytis cinerea is one of the most important pathogens causing gray mold disease in strawberries. The disease agent frequently manifests itself, especially in temperate climates and under high humidity conditions. The pathogen infects all green parts of the plant. Strawberries have one of the most complex and loss-prone post-harvest physiologies due to their non-climacteric nature (they do not continue to ripen after being harvested from the plant), high respiration rate, and sensitive tissue. Particularly, controlling the respiration rate and fungal management are the main factors determining shelf life. It affects the fruit during the period from harvest in the field to the storage stage. Although there are many different methods to prevent both field and post-harvest diseases in strawberry cultivation, chemical control is

intensively practiced because it is easy, practical, and provides quick results. Unconscious fungicide applications lead to the development of fungicide resistance in the pathogen. Resistance is defined as the gradual decrease in an organism's sensitivity to a fungicide, which is managed by a genetic mechanism. In other words, resistance is a kind of mutation and is generally irreversible. *Botrytis cinerea* is in the high-risk pathogen group due to its high genetic variation capability, excessive spore production, and short life cycle. Especially the consecutive use of single-site inhibitors triggers the pathogen's resistance mechanisms, such as SDHI (Succinate dehydrogenase inhibitors) or MDR (multidrug resistance). This study examines fungicide resistance against *Botrytis cinerea* in strawberry fruits and offers solutions.

Keywords: Gray mold, resistance, strawberry

RESPIRATION DYNAMICS AND GAS-RATIO MONITORING OF BANANAS STORED IN A NON-VENTILATED BIOREACTOR

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ABSTRACT

Bananas are representative climacteric fruits and therefore provide a suitable model for studying postharvest respiration and atmosphere evolution under confined storage conditions. This study investigated the behaviour of bananas stored in a non-ventilated bioreactor by monitoring oxygen, carbon dioxide, relative humidity, temperature, methane, ethylene, and total volatile organic compounds. The experimental results showed that the ratio between CO_2 and O_2

followed a pattern highly similar to that of relative humidity, suggesting that this ratio may be a useful indirect indicator of metabolic activity and moisture accumulation in closed storage systems. Oxygen concentration remained relatively stable during the first 3–4 days, after which a sharp decrease of approximately 2% was observed around day 11, followed by stabilization near the lower recorded values until the end of the 16-day experiment. Carbon dioxide increased gradually and showed oscillations associated with respiration intensity and changes in the internal atmosphere. Commercial gas sensors also revealed variations in C_2H_4, CH_4, TVOC, and CO_2, indicating the progressive development of ripening-related volatile compounds. TVOC values initially decreased after approximately 4–5 days, then increased after around 4000 minutes, before declining towards the end of storage. This behaviour may be associated with the production and later dissipation or transformation of volatile aroma compounds. The results demonstrate that low-cost commercial sensors can provide relevant information about banana respiration and atmosphere modification in non-ventilated storage. Such monitoring may support better control of climacteric fruit storage and help define optimal postharvest conditions.

Keywords: banana; climacteric fruit; non-ventilated bioreactor; respiration rate; CO_2/O_2 ratio; volatile organic compounds; postharvest monitoring.

AN EXAMINATION OF POSTGRADUATE THESES ON FOOD LITERACY AND FOOD LABELING IN TÜRKİYE

TÜRKİYEDE GIDA OKURYAZARLIĞI ve GIDA ETİKETİ İLE İLGİLİ YAPILAN LİSANSÜSTÜ TEZLERİN İNCELEMESİ

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ÖZET

Amaç: Gıda okuryazarlığı ve besin etiketlerinin doğru yorumlanması, sağlıklı beslenme davranışlarının geliştirilmesinde kritik bir kaldıraçtır ancak Türkiye'de bu alandaki akademik üretimin kapsamı, odakları ve yöntemsel özellikleri dağınık görünmektedir. Bu çalışma, söz konusu boşluğu gidermek amacıyla Türkiye'de "gıda okuryazarlığı", "gıda etiketi" ve "besin etiketi" konularında hazırlanmış lisansüstü tezleri bibliyometrik olarak haritalamayı amaçlamıştır.

Yöntem: Tanımlayıcı-bibliyometrik tasarımda yürütülen çalışmada veri kaynağı YÖK Ulusal Tez Merkezi'dir. "Gıda okuryazarlığı", "gıda etiketi", "besin etiketi" anahtar sözcükleri başlık–özet–anahtar sözcük alanlarında taranmış; dâhil etme ölçütlerini karşılayan ve Türkiye bağlamına ait lisansüstü tezler (yüksek lisans, doktora, sanatta yeterlik, tıpta/diş hekimliğinde uzmanlık) kapsama alınmıştır.

Bulgular: 2004–2025 döneminde 37 tez saptanmıştır (1 tıpta uzmanlık, 3 doktora, 33 yüksek lisans). En yüksek üretim 2023 yılında (n=9) görülmüştür. Temalara göre dağılım: besin etiketi okuma alışkanlığı n=16; gıda okuryazarlığı n=15; gıda etiketi bilgi düzeyi n=2; besin etiketi okuma alışkanlığı +bilgi düzeyi n=3; gıda okuryazarlığı + besin etiketi okuma alışkanlığı n=1. Evrenler genel yetişkinler, ortaöğretim/üniversite öğrencileri, sağlık çalışanları, ebeveynler ve özel klinik gruplar arasında çeşitlenmiştir. Ölçüm aracı olarak genelde çeşitli gıda okuryazarlığı ölçekleri kullanılmıştır. Çalışmaların büyük bölümünde etiket okuma "bazen" seçeneğinde yoğunlaşmış; eğitim düzeyi, yaş ve e-sağlık okuryazarlığı arttıkça okuma/anlama yükselmiştir. Cinsiyette çoğunlukla kadın lehine fark bildirilirken istisnalar mevcuttur. Kurumsal düzeyde en çok tez Sağlık Bilimleri Enstitüsü (n=16) ve Beslenme Diyetetik Ana Bilim Dalı'nda (n=16) toplanmıştır.

Sonuç: Bulgular, gıda güvenliği ve sağlıklı besin seçiminin öneminin arttığı günümüzde gıda okuryazarlığı ile etiket okuma alışkanlığına odaklanan lisansüstü çalışmaların artırılmasının toplum sağlığına doğrudan katkı sağlayacağını göstermektedir. Eğitim temelli müdahaleler umut verici olsa da alanın ilerlemesi için uzunlamasına ve deneysel tasarımların çoğaltılması, yaşlılar, düşük sosyoekonomik gruplar, kırsal nüfus ve kronik hastalığı olanlar gibi kırılgan topluluklara odaklanılması ve raporlama ile ölçüm araçlarında standardizasyonun sağlanması gerekmektedir.

Anahtar Kelimeler: besin etiketi, gıda etiketi, gıda okuryazarlığı, bibliyometrik araştırma

ABSTRACT

Aim: Food literacy and the accurate interpretation of food labels are critical levers for promoting healthy dietary behaviors. However, the scope, focus, and methodological characteristics of academic research in this field in Türkiye appear fragmented. To address this gap, this study aimed to bibliometrically map postgraduate theses conducted in Türkiye on the topics of "food literacy," "food labeling," and "nutrition labeling."

Methods: This descriptive bibliometric study used the National Thesis Center of the Council of Higher Education (YÖK) as its data source. The keywords "food literacy," "food label," and "nutrition label" were searched within the title, ABSTRACT, and keyword fields. Postgraduate theses conducted in the Turkish context that met the inclusion criteria, including master's theses, doctoral dissertations, proficiency in arts theses, and medical/dental specialty theses, were included in the analysis.

Results: A total of 37 theses completed between 2004 and 2025 were identified, including 1 medical specialty thesis, 3 doctoral dissertations, and 33 master's theses. The highest number of theses was produced in 2023 (n = 9). The thematic distribution was as follows: food label reading habits (n = 16), food literacy (n = 15), knowledge of food labeling (n = 2), food label reading habits and labeling knowledge (n = 3), and food literacy together with food label reading habits (n = 1). Study populations included the general adult population, secondary school and university students, healthcare professionals, parents, and specific clinical groups. Various food literacy scales were commonly used as measurement tools. In most studies, food label reading frequency was concentrated in the "sometimes" category. Higher levels of education, older age, and greater health/e-health literacy were associated with improved label reading and comprehension. Although most studies reported higher food label use among women, some exceptions were noted. Institutionally, the largest number of theses were conducted within Institutes of Health Sciences (n = 16) and Departments of Nutrition and Dietetics (n = 16).

Conclusion: The findings suggest that increasing postgraduate research focusing on food literacy and food label reading habits can directly contribute to public health, particularly in an era when food safety and healthy food choices are becoming increasingly important. While educational interventions appear promising, further progress in the field requires a greater number of longitudinal and experimental studies, increased focus on vulnerable populations such as older adults, individuals with low socioeconomic status, rural residents, and people with chronic diseases, as well as greater standardization in reporting practices and measurement instruments.

Keywords: nutrition label, food label, food literacy, bibliometric research

Giriş

Günümüzde yetersiz ve dengesiz beslenmeye bağlı kronik hastalıkların yükü artmaktadır. DSÖ verilerine göre 1990–2022 döneminde 5–19 yaş grubunda obezite prevalansı %2'den %8'e çıkarak dört kat artmış; 18 yaş ve üzerindeki yetişkinlerde ise %7'den %16'ya yükselmiştir (1). Güvenli ve sağlıklı gıdaya erişim bir insan hakkıdır; bu hak sağlanamadığında gıda kaynaklı hastalıklar ciddi bir halk sağlığı sorunu yaratır (2,3). Nitekim her yıl dünyada yaklaşık her 10 kişiden biri kontamine gıda tüketimi nedeniyle hastalanmakta; bu durum 420 bin ölüme ve yaklaşık 33 milyon sağlıklı yaşam yılı kaybına yol açmaktadır (3).

Bu tablo, tüketicinin doğru ve anlaşılır bilgiye erişmesini ve bu bilgiyi yorumlayabilmesini, kısacası gıda okuryazarlığını kritik hâle getirmektedir. Paketli gıdaların yaygınlaştığı günümüzde gıda etiketleri, içerik ve besin değerine ilişkin kararları kolaylaştıran temel araçtır. Bununla birlikte yaşam tarzı değişimleriyle artan paketli gıda tüketimi, obeziteyi besleyen etmenlerden biri olarak değerlendirilmektedir (4). Türkiye'de yapılan bir çalışmada evde yemek yiyen çocukların BKİ'sinin okul kantininde yemek yiyenlere göre daha düşük olduğu; haftada bir ve üzeri paketlenmiş gıda tüketen çocuklarda BKİ'nin daha yüksek bulunduğu bildirilmiştir (4). Paketli gıdalar uzun raf ömrü, zorunlu etiketleme ve izlenebilirlik gibi yararlar sunsa da üretim zincirindeki aksaklıklar mikrobiyal kontaminasyon, katkı maddeleri ve hijyenle ilişkili riskleri artırarak toplum sağlığını tehdit edebilmektedir. Bu nedenle paketli gıdaların bilinçli seçimi ve tüketimi kritik önemdedir (5). Besin etiketleri içerik, besin değeri, katkı maddeleri ve alerjen bilgileri gibi başlıklarda tüketiciyi yönlendiren temel araçlardır ve gıda tercihlerini etkileyerek sağlık üzerinde belirleyici olabilir (5,6). Ancak Türkiye'deki çalışmaların önemli bir kısmı, etiket okuma davranışının yaygın olmasına karşın etiket bilgisinin anlaşılmasında güçlükler bulunduğunu göstermektedir (7). Bu tablo, yalnızca "okuma" alışkanlığının değil, "yorumlama" ve "değerlendirme" becerisinin de geliştirilmesi gerektiğine işaret eder. Bu bağlamda gıda okuryazarlığı; bireyin gıda ile ilgili bilgileri anlama, değerlendirme ve sağlıklı seçimler yapabilme kapasitesi olarak tanımlanır ve halk sağlığı açısından kritik bir unsurdur (1). Gıda okuryazarlığı düzeyi yüksek bireyler, etiketleri doğru yorumlayarak içerik, besin değeri ve sağlık beyanlarına ilişkin daha bilinçli tercihler yapabilmektedir (6). Nitekim araştırmalar, etiketleri düzenli okuyanların daha düşük enerji yoğunluklu ve besin açısından daha dengeli ürünleri seçtiğini göstermektedir (8). Gıda okuryazarlığının güçlenmesi yalnızca bireysel sağlıkla sınırlı kalmaz; şeffaf ve sorumlu üretimi teşvik ederek sektörün iyileşmesine de katkı verir. Bu nedenle gıda okuryazarlığı ve besin etiketi okuma, toplumun sağlık standartlarını yükseltebilecek etkin bir halk sağlığı aracıdır (9).

Türkiye'de gıda okuryazarlığı ve besin etiketi okuma üzerine çalışmalar bulunsa da halk sağlığına etkisini uzun dönemli olarak izleyen araştırmalar sınırlıdır. Bu çalışmada, "gıda okuryazarlığı", "gıda etiketi" ve "besin etiketi" anahtar sözcükleriyle yayımlanan lisansüstü tezlerin bibliyometrik analizi yapılarak alanın akademik eğilimleri ve araştırma odakları ortaya konulmuş; böylece literatüre katkı sağlanması ve gıda politikalarının bilimsel kanıtla desteklenmesine öncülük edilmesi amaçlanmıştır.

Yöntem

Araştırma tasarımı ve kapsam

Bu çalışma, tanımlayıcı-bibliyometrik nitelikte olup Türkiye'de gıda okuryazarlığı, gıda etiketi ve besin etiketi konularında hazırlanmış ulusal lisansüstü tezleri incelemektedir. Zaman aralığına sınırlama getirilmemiş, veri tabanındaki kayıtların başlangıcından itibaren tüm tezler kapsam dâhilinde değerlendirilmiştir.

Veri kaynağı

Veriler, Yükseköğretim Kurulu (YÖK) Ulusal Tez Merkezi veri tabanından elde edilmiştir. YÖK sisteminde 1959–2025 yılları arasında 900 binden fazla lisansüstü tez kayıtlıdır (10). Çalışmanın taraması 2025 yılı içinde tamamlanmıştır.

Arama stratejisi

Aramada şu anahtar sözcükler kullanılmıştır: “gıda okuryazarlığı”, “gıda etiketi”, “besin etiketi”. Arama; başlık, özet ve anahtar sözcük alanlarını kapsayacak biçimde yürütülmüştür. Gerekli görülen durumlarda terimlerin tekil/çoğul ve yazım varyasyonları gözden geçirilmiştir. Bu stratejiyle 2004 yılından itibaren toplam 37 lisansüstü teze erişilmiştir.

Dahil edilme ve dışlanma ölçütleri

Dahil edilme ölçütleri:

YÖK Ulusal Tez Merkezi’nde kayıtlı yüksek lisans, doktora, sanatta yeterlik veya tıpta/diş hekimliğinde uzmanlık tezleri,

Çalışma odağı gıda okuryazarlığı ve/veya gıda/besin etiketi olan tezler,

Türkiye’de yürütülmüş ya da Türkiye örneklemi/bağlamı içeren tezler.

Dışlanma ölçütleri:

Lisans bitirme projeleri, raporlar, makaleler ve bildiriler,

Gıda güvenliği gibi yakın alanlarda olup gıda okuryazarlığı/etiketi odağı bulunmayan tezler,

Yinelenen kayıtlar (duplikeler).

Veri çıkarımı ve değişkenler

Her bir tez için standart bir form üzerinden şu değişkenler çıkarılmıştır:

Bibliyografik bilgiler: Yıl, üniversite, enstitü, anabilim/ana sanat dalı, tez düzeyi (yüksek lisans/doktora vb.), tez dili, erişim durumu (açık/kısıtlı).

Yöntemsel özellikler: Araştırma tipi (tanımlayıcı, kesitsel vb.), çalışma konusu/teması, evren/örneklem, katılımcı sayısı, veri toplama araçları (ör. gıda okuryazarlığı ölçekleri, etiket okuma davranışı anketleri), değerlendirme/analiz yöntemi.

İçerik ve bulgular: Tezin amaçları, temel değişkenler, ana bulguların özeti ve sonuç vurguları.

Veri çıkarımı iki araştırmacı tarafından bağımsız yürütülmüş, uyuşmazlık durumlarında uzlaşı yoluna gidilmiştir.

Veri analizi

Tezlerin yıllara, konu temalarına, lisansüstü düzeyine, üniversitelere, enstitülere ve anabilim dallarına göre dağılımı betimsel istatistiklerle (sayı, yüzde; uygun yerlerde ortanca/sapma) sunulmuştur. Yöntemsel özellikler (örneklem büyüklüğü, veri toplama araçları, analiz türleri) ve temel bulguların ana eksenleri frekans tabloları ve grafiklerle özetlenmiştir. Gerek görülen yerlerde yıllara göre eğilim değerlendirmesi yapılmıştır.

Etik beyan

Çalışma, kamuya açık ikincil veriler (tez kayıtları) üzerinde yürütüldüğünden etik kurul onayı gerektirmemektedir. Tezlere ve yazarlarına atıflar, bilimsel etik ilkeler doğrultusunda yapılmıştır.

Bulgular

Tarama sonucunda 2004-2025 yılları arasında yayınlanmış bu konuda toplam 37 lisansüstü tez saptanmıştır. Tezlerin 1 tanesi tıpta uzmanlık, 3 tanesi doktora, 33 tanesi yüksek lisans tezidir. 9 tez çalışması ile en fazla tezin yayınlandığı yıl 2023'tür. Çalışma konularına göre ise tezlerin çoğunluğunun "besin etiketi okuma alışkanlığı" (16 tez) üzerine odaklandığı, 15 tezin "gıda okuryazarlığı", 2 tezin ise "gıda etiketi bilgi düzeyi", 3 tezin ''besin etiketi okuma alışkanlığı ve gıda etiketi bilgi düzeyi'', 1 tezin "gıda okuryazarlığı ve besin etiketi okuma alışkanlığı", üzerine gerçekleştirildiği tespit edilmiştir. İlgili anahtar kelimeleri içeren ilk tez 2004 yılında yayınlanmıştır (Tablo 1).

Tablo 1. Bibliyometrik Analiz Sonucunda Tezlerin Lisansüstü Düzeye Konularına ve Yıllara göre dağılımı

Tez Türü	**n (%)**
Doktora	3 (8.1)
Yüksek Lisans	33 (89.1)
Tıpta Uzmanlık	1 (2.7)
Konu	
Besin etiketi okuma alışkanlığı	16
Gıda okuryazarlığı	15
Gıda etiketi bilgi düzeyi	2
Besin etiketi okuma alışkanlığı/ Gıda etiketi bilgi düzeyi	3
Gıda okuryazarlığı/Besin etiketi okuma alışkanlığı	1
Yıl	
2004	1 (2.7)
2013	1 (2.7)
2014	1 (2.7)
2017	1 (2.7)
2018	1 (2.7)
2019	5 (13.5)
2020	1 (2.7)
2021	4 (10.8)
2022	6 (16.2)
2023	9 (24.3)
2024	5 (13.5)
2025	2 (5.4)
Toplam	37 (100.0)

Türkiye'de gıda okuryazarlığı ve gıda/besin etiketi alanında saptanan lisansüstü tezlerin evren, ölçüm araçları, tez konusu/tema ve ana bulguları Tablo 2'de standart biçimde özetlenmiştir. Evrenler, genel yetişkin nüfus, öğrenciler (ortaöğretim/üniversite), sağlık çalışanları, ebeveynler ve özel klinik gruplar (ör. bariatrik cerrahi hastaları, galaktozemi izlemi) arasında çeşitlilik göstermektedir. Çalışmalarda ölçüm, ağırlıklı olarak gıda/beslenme okuryazarlığına yönelik standart ölçeklerle yürütülmüş; buna ek olarak birçok çalışmada, araştırmacı geliştirmesi anketlerle etiket okuma sıklığı, anlama ve tutumlar değerlendirilmiştir. Tezlerin çoğunda, etiket okumanın "bazen" yanıtında yoğunlaştığı, "her zaman" okuma oranlarının daha düşük kaldığı; eğitim düzeyi, yaş ve sağlık/ e-sağlık okuryazarlığı arttıkça okuma ve anlama düzeylerinin yükseldiği bildirilmiştir. Cinsiyet açısından çoğu çalışmada kadınlarda

dikkat/okuma eğilimi daha yüksek görünürken, az sayıda örnekte bunun tersine bulgular da mevcuttur. BKİ ile anlama arasında anlamlı farklılıklar bulunmuş; normal ağırlık grubunun gıda okuryazarlık oranları daha yüksek olarak raporlanmıştır. Sağlık çalışanlarında etiket okuma yaygın olmakla birlikte, katkı maddeleri ve belirli bilgi unsurlarının anlaşılması değişkenlik göstermektedir. Tutum ve davranış göstergeleriyle (sağlıklı beslenme tutumu, yaşam kalitesi, sürdürülebilir/sağlıklı beslenme davranışları) pozitif ilişkiler raporlanmıştır. Ebeveynlerde e-sağlık okuryazarlığı arttıkça etiket okuma sıklığı artmakta; galaktozemi ailelerinde bilgi düzeyi yükseldikçe diyete uyum artmakta ve çocuk-ebeveyn yaşam kalitesi puanları birlikte yükselmektedir. Bariatrik cerrahi çalışmalarında ameliyat sonrası ilk 6 ayda etiket dikkatinin yükseldiği, zamanla azalma eğilimi gösterdiği; gıda okuryazarlığı düzeyi yükseldikçe BKİ farkının da arttığı bildirilmiştir. Müdahale çalışmalarında verilen etiket okuma/beslenme eğitimleri sonrasında kısa ve orta vadede etiket bilgisinden etkilenme, enerji ve besin ögesi bilgisini okuma sıklığı ve dikkat düzeylerinde artış bildirilmiştir. Sürdürülebilir gıda bilgisi ve sürdürülebilir gıda okuryazarlığı puanlarında eğitim sonrası anlamlı yükselişler kaydedilmiştir. (Tablo 2).

Tablo 2. Türkiye'de Gıda Okuryazarlığı ve Gıda/besin etiketi Alanında Saptanan Lisansüstü Tezlerin Evren/Ölçüm araçları/Tez konusu-Tema/Ana bulguları

Yazar (yıl), tez düzeyi, tasarım, N(toplam)	Evren	Yaş (%)	Cinsiyet (Kadın %)	Tez konusu	Ölçüm aracı	Temel bulgular
Leyla Özgen (2004) (11), Doktora, Tanımlayıcı, 350	Gazi Üniversitesi Tıp, Eczacılık ve Diş Hekimliği Fakülteleri öğretim elemanları ve idari personel (tüketiciler)	20-35 (%55.1) 36-65 (%28.6) ≥66 (%16.3)	68.3	**Besin etiketi okuma alışkanlığı**, Tüketicilerin besin etiketi okuma alışkanlıkları ile beslenme etiketi/ambalaj tercihi ilişkili faktörlerinin incelenmesi	Besin etiketlerini okuma alışkanlıkları ile etiket ve ambalaj tercihlerinin belirlenmesi amacıyla hazırlanan anket (yazar tarafından)	Etiket okuma (ambalajlı ürün): %75,7 bazen, %24,3 her zaman Etiket okumada belirleyiciler: yaş ve diyet yapma (anlamlı); 36–65 yaş> 20–35 yaş; diyet yapanlar ile yapmayanlar arasında ortalama farkı anlamlı.
Derya Kasan Özdemir (2013) (12), Yüksek lisans, kesitsel, 578	İstanbul, üç bölgeden seçilen tüketiciler	12-20 (17.1) 21-40 (%62.4) ≥41 (20.5)	67.7	**Gıda etiketi bilgi düzeyi**, İstanbul ilindeki tüketicilerin gıda etiketi bilgi düzeyinin belirlenmesi	Tüketicilerin gıda etiketlemesinde bilgi düzeylerini ölçmek ve davranışlarını değerlendirmek amacıyla hazırlanan anket (yazar tarafından)	Etiket bilgisi/okuma: eğitim düzeyi ↑ → besin değeri tablosunu okuma/anlama ↑ (anlamlı); Cinsiyet farkı: kadınlar içindekiler ve besin değerini okuma konusunda erkeklerden ↑ (daha duyarlı); Bölgesel fark: 2. bölge, etiketlerde yer alması gereken bilgileri bilme ve TLS renk kodlamasını anlama açısından 1. bölgeden ↑; içindekiler okuma: 3. bölge> 1. bölge.
Saliha Kaleli (2014) (13), Yüksek lisans, Müdahale, 120	Ankara/Altın dağ, İki Orta bölge ≥6. sınıf öğrencileri.	11 (%0.8) 12 (%90.8) 13 (%8.4)	49.2	**Besin etiketi okuma alışkanlığı**, Ortaokul öğrencilerinde besin etiketi okuma eğitiminin besin tercihlerine etkisinin değerlendirilmesi	1.Başlangıçta ve kısa ve uzun dönemde durum saptama için: Beslenme alışkanlıkları ile besin tercihleri ve besin etiketi kullanma durumlarını saptamak için anket (yazar tarafından hazırlanan) 2. Dört haftalık, haftada 2 saat sağlıklı beslenme ilkeleri ve besin etiketi okuma konularında eğitim.	Eğitim etkisi (müdahale vs. kontrol): kısa ve uzun dönemde etiket bilgisinden etkilenme ↑, enerji/besin ögesi bilgilerini okuma sıklığı ↑ (başlangıca ve kontrole göre); Eğitim sonrası müdahale grubunda tüm öğrenciler ambalaj üzerindeki yazıları okumaya başladı.

Elif Esra Öztürk Duran (2017) (14), Yüksek lisans, Tanımlayıcı, 600	Adıyaman Merkez Toplum Sağlığı Merkezi'ne 2014–2016'da başvuran obez ve normal ağırlıktaki bireyler.	19-24 (%8.9) 25-34 (%29.5) 35-44 (%30.7) 45-54 (%20.8) 55-64 (%10.1)	68.3	**Besin etiketi okuma alışkanlığı**, Obez ve normal ağırlıktaki bireylerde besin etiketi okuma alışkanlıklarının karşılaştırılması	Besin etiketi okuma alışkanlıklarına ve besin etiketi tercihlerine yönelik hazırlanan anket (yazar tarafından)	Etiket bilgisini anlama ↔ BKİ (anlamlı); günlük karşılama yüzdesini anlama: normal ağırlık %66,7; "içindekiler"i anlayamama: hafif şişman %50,1, şişman %57,1; etiket beklentisi: şişman/hafif şişman → "kolay anlaşılır", normal → "iyi tasarlanmış".
Fatma Gül (2018) (15), Yüksek lisans, kesitsel, 410	Hatay'da yaşayan yetişkin kadın tüketiciler, 19–44 yaş.	19-34 (%59.5) 35-44 (%40.5)	100	**Besin etiketi okuma alışkanlığı,** Yetişkin kadın tüketicilerde besin etiketi okuma alışkanlığı ve alerjen bilgi düzeyinin saptanması	Bireylerin beslenme alışkanlıklarını, besin etiketi okuma alışkanlıklarını, besin alerjisi bilgi düzeylerini ve bireylerin sağlık okuryazarlığını ölçmek amacıyla hazırlanan anket (yazar tarafından)	Sağlık okuryazarlığı: yeterli düzey %43,2; etikette bazı ögelerin koyu yazılma nedenini doğru bilenlerde yeterli düzey %53,8; Satın almada etiketi okuyan %60,7; yetişkin kadınlarda etiket okuma sıklığı sosyoekonomik durum, BKİ, sağlık okuryazarlığı ve eğitim durumuna göre anlamlı farklılık göstermektedir.
Begüm Demircan (2019) (16)**,** Yüksek lisans, kesitsel, 299	İstanbul Yeditepe Üniversitesi Beslenme ve Diyetetik, Fizyoterapi ve Rehabilitasyo ,Gastronomi ve Mutfak Sanatları bölümü öğrencileri.	Medyan (min-max) 21 (20-22)	73.9	**Besin etiketi okuma alışkanlığı/ Gıda etiketi bilgi düzeyi,** Üniversite öğrencilerinde belirli paket gıdalara yönelik güven algısı ile besin etiketi bilgi/kullanım düzeylerinin BKİ'ye göre değerlendirilmesi	Etiket okuma, gıda etiketlerindeki belirleyici içerikler, alışverişte belirleyici faktörler, paketlenmiş süt ve süt ürünleri, paketlenmiş ekmekler, işlenmiş et ürünleri, şekerli ve yapay tatlandırıcılı içecekler, light ve diyet ürünler ve organik gıdalara yönelik algıyı ölçmeyi amaçlayan anket (yazar tarafından oluşturulan)	Etiket okuma ve güven: etiketleri her zaman okuyan %49,5; gıda etiketleri hakkında fikri olmayan %9,7; etiketlerin gerçeği yansıttığına güvenmeyen %16,7; okumama nedenleri: ambalaj üzerindeki konum zor %13,7, yazı puntosu küçük %7,0, içeriği anlayamama %3,3.
Betül Gültekin (2019) (17), Yüksek lisans, kesitsel, 442	İstanbul/Üsküdar ilçesi 2018–2019 Güz döneminde lise 1–4. sınıf öğrencileri.	Orta Adölesan (%67.2) Geç Adölesan (32.8)	36.4	**Besin etiketi okuma alışkanlığı,** Adölesanlarda sağlık algısının besin etiketi okuma alışkanlıklığı üzerindeki etkisinin incelenmesi	1.Besin etiketi okuma alışkanlıklarını belirlemeye yönelik anket formu (yazar tarafından hazırlanan) 2. Sağlık Algısı Ölçeği (Diamond ve ark.,2007)	Adölesanlarda etiket okuma: her seferinde %11,3; hiç %17,6; Sağlık Algısı puanı ile okuma alışkanlığı arasında anlamlı fark; "bazen okurum" grubunun sağlık algısı genel puanı "her seferinde okurum" grubundan yüksek.
Ercan Kan (2019) (18), Yüksek lisans, Tanımlayıcı, 410	Erzincan'da yaşayan18 yaş ve üzeri tüketiciler.	18-25 (%35.4) 26-30 (%16.8) 31-40 (%23.2) 41-50 (%15.6)	54.9	**Besin etiketi okuma alışkanlığı/ Gıda etiketi bilgi düzeyi,** Tüketicilerde besin etiketi okuma alışkanlığı ve etiket bilgi düzeyinin incelenmesi (Erzincan örneği)	Etiket ve besin etiketi okuma alışkanlıklarını ve besin etiketi bilgi düzeylerini belirlemeye yönelik hazırlanan anket (yazar tarafından)	Etikete dikkat: kadın %93,8> erkek %88,1; "her zaman dikkat" yaşa göre: 18–25 %32,4; 26–30 %39,1; 31–40 %51,6; 41–50 %42,2; 51+ %27,0; medeni durum ile "güvenli besin seçimine yardımcı" algısı anlamlı; "her zaman dikkat" bekâr %36,9, evli-çocuksuz %29,6, evli-çocuklu %42,6.
Fatma Nur Erdaş (2019) (19), Yüksek lisans kesitsel, 220	İstanbul — Bir Tıp Merkezinin Beslenme ve Diyet Polikliniği'ne başvuran yetişkin tüketiciler, 20–68 yaş.	(Yıl) 1985.57±11.48	80	**Besin etiketi okuma alışkanlığı/ Gıda etiketi bilgi düzeyi,** Besin etiketi inceleme tutum/davranışları ile etiket bilgisinin besin seçimine etkisinin	Besin etiketi okuma sıklığını, besin etiketleri ile ilgilli genel memnuniyetsizlikleri, sağlıklı beslenme ve gıda etiketi bilgilerine ilişkin tutumu, etiket bilgilerinin kullanım sebeplerini ölçmeye yönelik hazırlanan	Etiket okuma: medeni durumla anlamlı; evli/bekâr> boşanmış; cinsiyet: erkekler> kadınlar; okumama nedenleri: zaman yetersizliği ve alışkanlık/aynı ürünü alma; beslenme ve gıda etiketi bilgi düzeyi: evliler> bekârlar

				araştırılması	anket (yazar tarafından)	
Merve Nur Akdemir Tüfekçilerli (2019) (20), Yüksek lisans, kesitsel, 275	İstanbul, Yeditepe Üniversitesi Sağlık Bilimleri Fakültesi lisans öğrencileri (2017–2018).	≤20 (%28.4) 21-23 (%64.7) ≥24 (%6.9)	88.4	**Besin etiketi okuma alışkanlığı,** Bir vakıf üniversitesinin sağlık bilimleri fakültesi öğrencilerinde besin etiketi kullanım durumunun değerlendirilmesi	Beslenme bilgileri, besin etiketi kullanımı ve besin etiketleri hakkındaki düşünceleri belirlemek amacıyla hazırlanan anket (yazar tarafından)	Bilgi–kullanım ve bölüm farkları: besin bilgisi ↑ → etiket kullanımı ↑ (pozitif ilişki); sağlık bilimleri öğrencilerinde etiket okuma yüzdesi yüksek; Beslenme ve Diyetetik öğrencilerinde etiket kullanma sıklığı diğer bölümlerden ↑.
Mustafa Yılmaz (2020) (21), Doktora, karma, 89	Türkiye genelinde 35 üniversitede aktif görevli akademisyenler.	-	-	**Gıda okuryazarlığı,** Gıda okuryazarlığı bileşenlerinin tanımlanması ve öğretim programlarındaki yerinin incelenmesi	Gıda okuryazarlığının bileşeni olabilecek maddeler tespit edilerek hazırlanan likert tipi anket formu (yazar tarafından)	Alan uzmanlarının 13 maddenin gıda okuryazarlığının bileşeni olma durumuna ilişkin kararsız oldukları, 10 maddenin madde türüne ilişkin de fikir birliği sağlama noktasında kararsız oldukları, 53 maddenin gıda okuryazarlığının bileşeni olması gerektiğine ilişkin görüş birliği sağladıkları tespit edilmiştir.
Berna Çakır (2021) (22), Yüksek lisans, kesitsel, 567	Balıkesir'de kentsel bir mahallede yaşayan 18+ bireyler.	18–27(%28.29) 28–37 (%27.0) 38–47 (%19.4) 48–57 (%14.8) 58–67 (%7.4) 68–77 (%2.5) 77+ (%0.7)	60.1	**Gıda okuryazarlığı,** Yetişkinlerde algılanan gıda okuryazarlığı, iyilik hâli ve yeme tutumu ile ilişkili faktörlerin değerlendirilmesi (Balıkesir)	Algılanan Gıda Okuryazarlığı Ölçeği (AGOY) (Poelman ve ark., 2018)	Algılanan gıda okuryazarlığı: kadınlar, evliler, çekirdek aile yapısında ve geliri gidere eşit olanlarda ↑; ayrıca sigara içmeyen, alkol kullanmayan, genel sağlığı iyi ve ailesinde sağlık çalışanı bulunanlarda ↑ (anlamlı).
Merve Öztürk (2021) (23), Yüksek lisans, kesitsel, 364	İstanbul/Kartal- MEB'e bağlı devlet ve özel okul öncesi kurumlarda okuyan öğrencilerin velileri.	<35 (%44.7) 35-44 (%52.7) 45-54 (%2.4)	85.2	**Besin etiketi okuma alışkanlığı,** Okul öncesi çocuğu olan ebeveynlerde besin etiketi okuma, bilgi ve kullanım düzeyinin belirlenmesi (İstanbul/Kartal)	Besin etiketi okuma alışkanlığının belirlenmesi amacıyla hazırlanan anket (yazar tarafından)	Ebeveyn eğitim düzeyi ↔ etiket okuma (anlamlı fark): en düşük oran ilkokul ve lisansüstü gruplarda; olası nedenler—ilkokul: bilgi yetersizliği; lisansüstü: "besine göre değişir/kendi bilgime güvenirim" yaklaşımı.
Özge Ercihan (2021) (24), Yüksek lisans, kesitsel, 172	Nevşehir/Ürgüp- Bir Lisenin 1–4. sınıf öğrencileri.	14 (%8.1) 15 (%22.7) 16 (%28.5) 17 (%31.4) 18 (%7.6) 19 (%1.7)	52.9	**Besin etiketi okuma alışkanlığı,** Lise öğrencilerinin besin etiketi kullanımına ilişkin tutum ve davranışlarının değerlendirilmesi	Besin etiketi okuma alışkanlığının belirlenmesi amacıyla hazırlanan anket (yazar tarafından)	Öğrencilerde etiket okuma: %66,9 bazen/her zaman; BKİ'ye göre hafif şişman/şişman grupta "okumama" oranı en yüksek.
Yasemin Koçaslan (2021) (25), Yüksek lisans, kesitsel, 204	Hasan Kalyoncu Üniversitesi Sağlık Bilimleri Fakültesi lisans öğrencileri, 18–32 yaş.	18-24 (%96.1) 25-29 (%2.9) ≥30 (%1.0)	80.3	**Gıda okuryazarlığı,** Sağlık Bilimleri Fakültesi öğrencilerinde gıda okuryazarlığı düzeyi ve Akdeniz diyeti kalite indeksine uyumun belirlenmesi	Gıda okuryazarlığı kısa formu (SFLQ) (Krause ve ark.)	Gıda okuryazarlığı (öğrenciler): ortalama 35,7±6,4; Bölüm farkı: Beslenme ve Diyetetik> Fizyoterapi/Hemşirelik; Cinsiyet farkı anlamlı: kadınlar> erkekler.
Zeynep Gül Gündüz (2022) (26),	Türkiye genelinde lisans düzeyi üniversite öğrencileri.	18-49 (22.3±4.12)	%57	**Besin etiketi okuma alışkanlığı,** Üniversite öğrencilerinde ambalajlı besin	1.Yetişkinlerde Beslenme Okuryazarlığı Değerlendirme Aracı (YBOYDA) (Cesur,2014)	Beslenme okuryazarlığı: yeterli düzey %78,8; beslenme okuryazarlığı ile etiket okuma/yeterli bulma arasında ilişki yok; etiket okuma toplam beslenme okuryazarlığı ve

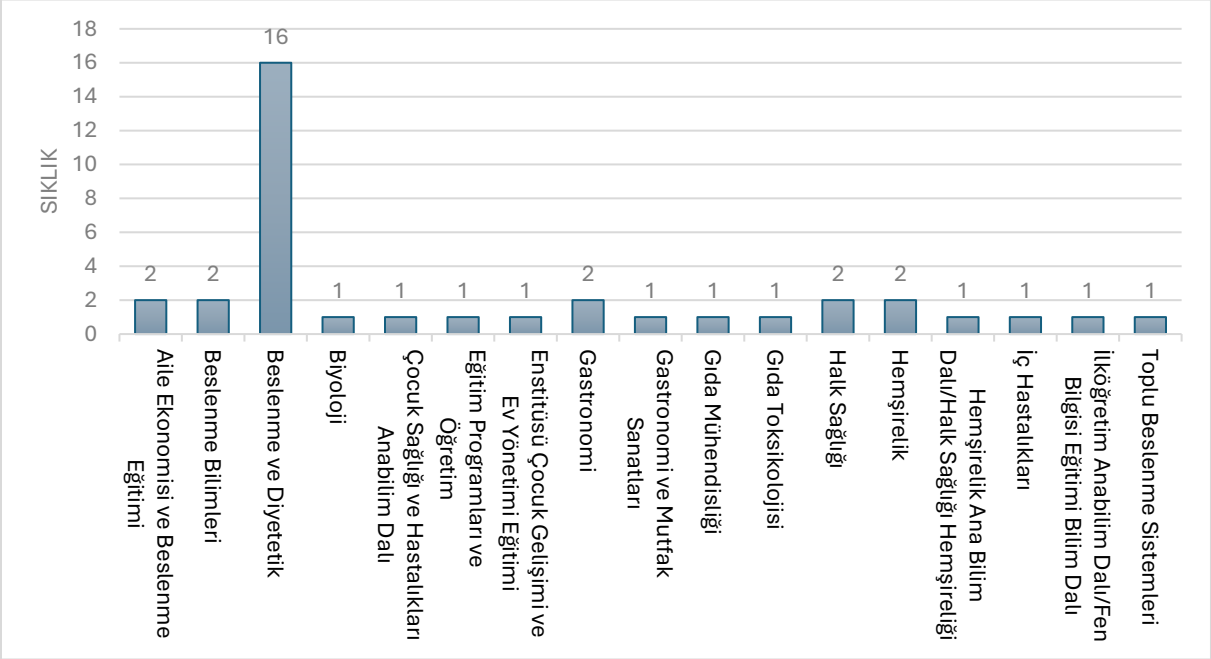
Yüksek lisans, kesitsel, 240				etiketi okuma alışkanlığı ile beslenme okuryazarlığı/beslenme bilgi düzeyi arasındaki ilişkinin değerlendirilmesi	2.Etiket Okuma Alışkanlığı Anketi (Yazar tarafından oluşturulan)	beslenme bilgi düzeyi üzerinde dolaylı etkide bulunuyor.
Begüm Kurt (2022) (27), Yüksek lisans, kesitsel, 430	İstanbul'da yaşayan ve gıda alışverişini kendisi yapan kadınlar, 19-64 yaş.	≤25 (%13.3) 26-35 (%40.7) 36-45 (%12.1) 46-55 (%17.4) >55 (%16.5)	100	**Besin etiketi okuma alışkanlığı,** Kadınlarda beslenme bilgi düzeyinin besin etiketi okuma alışkanlığı üzerindeki etkisinin incelenmesi	1.Nutrition Label Reading Attitude Scale (Marietta et al.) 2. Nutrition Knowledge Level Scale (YETBİD) (Yetişkinler için beslenme bilgi düzeyi ölçeği) (Batmaz,2018)	Beslenme bilgi düzeyi (YETBİD–Temel Beslenme ve Beslenme Sağlığı Bilgisi) ↑ → Besin Etiketi Okuma Tutum puanı ↑ (pozitif korelasyon); yaş grupları arasında fark anlamlı: 25 yaş ve altı<55 yaş üstü.
Betül İrem Nur Koç (2022) (28), Yüksek lisans, kesitsel, 384	Sakarya-Yetişkin tüketiciler, 18–65 yaş.	(ortalama) 31.3 ± 10.8	69.8	**Besin etiketi okuma alışkanlığı,** Besin etiketi okuma alışkanlığı ile paketli gıda tüketim sıklığının incelenmesi	Besin etiketi okuma alışkanlıkları ve paketli gıda tüketim sıklığının belirlenmesi amacıyla hazırlanan anket (yazar tarafından)	Okuma/okumama motivasyonları: okumama nedeni en sık "dikkatini çekmeme"; okuma nedeni en sık "yediklerimin içeriğini bilmek"; paketli gıda tüketimi ↔ etiket içeriğini okuma arasında negatif korelasyon (tüketmeyenler >tüketenler).
Hatice Gül Sağun (2022) (29), Yüksek lisans, kesitsel, 434	Türkiye genelinde sosyal medya kullanıcısı bireyler (çevrimiçi), 18–85 yaş.	18-25 (%25.1) 26-35 (%39.9) 36-45 (%19.1) 46-55 (%10.6) 56- 65 (%4.4) ≥66 (%0.9)	73.0	**Gıda okuryazarlığı,** Gıda okuryazarlığı düzeyi ile fonksiyonel gıda tercihleri ve sağlık durumu arasındaki ilişkinin belirlenmesi	1.Kısa gıda okuryazarlığı ölçeği (SFLQ) (Durmus ve ark., 2019; Krause ve ark., 2018) 2.Tüketicilein fonksiyonel gıdalar ile ilgili bilgi düzeyini ölçmek için hazırlanan anket (yazar tarafından)	Gıda okuryazarlığı: kadınlar>erkekler; eğitim düzeyiyle anlamlı fark (ilkokul <diğerleri); fonksiyonel gıdayı bilenlerde düzey ↑.
Mushtaq Ahmad Tenmas (2022) (30), Yüksek lisans, kesitsel, 111	Niğde Ömer Halisdemir Üniversitesi Biyoloji ve Biyoteknoloji bölümü öğrencileri.	1. Sınıf (%23.4) 2. Sınıf (%30.6) 3. Sınıf (%16.2) 4. Sınıf (%29.7)	66.7	**Gıda okuryazarlığı,** Biyoloji ve biyoteknoloji bölümü öğrencilerinde gıda okuryazarlığı düzeyinin değerlendirilmesi	Algılanan Gıda Okuryazarlığı Ölçeği (AGOY) (Poelman vd.,2018)	Yaşam düzeni: aileyle yaşayanlarda yiyecek hazırlama, sağlıklı atıştırmalık, sosyal/bilinçli yeme, etiket inceleme, sağlıklı gıdaya harcama alt ölçekleri ve toplam puan ↑; algılanan eğitim etkisi: lisans eğitiminin beslenme alışkanlıklarını etkilediğini düşünenlerde AGOY puanı ↑ (anlamlı).
Özge Yeşiltaş (2022) (31), Yüksek lisans, kesitsel, 253	İstanbul'da yaşayan 19–65 yaş bireyler.	(ortalama) 35.5±10.7	53	**Besin etiketi okuma alışkanlığı,** Besin etiketi okuma alışkanlığının besin seçimi ve diyet kalitesi üzerindeki etkisinin incelenmesi	Gıda etiketi okuma alışkanlıkları ve besin seçimi testi ile ilgili soruları içeren anket formu (yazar tarafından hazırlanan)	Etiket okuyanlarda sağlık/doğal içerik/ağırlık kontrolü/etik kaygı faktör puanları, okumayanlara göre ↑ (anlamlı); doktor/diyetisyen önerisinden etkilenme cinsiyete göre farklı: kadınlar >erkekler; etiket okumama oranı: kadın %8,2, erkek %12,6 (anlamlı değil).
Ayşe Banu Gezeker (2023) (32), Yüksek lisans, Metodolojik, 635	Türkiye genelindeki üniversitelerin gastronomi bölümleri 3–4. sınıf öğrencileri ve mezunları.	3. Sınıf (%20.0) 4. Sınıf (%46.3) Mezun (%33.7)	49.4	**Gıda okuryazarlığı/ Gıda okuryazarlığı ölçeğinin geliştirilmesi,** Gastronomi lisans öğrencilerinde gıda okuryazarlığı düzeyinin incelenmesi ve Gıda Okuryazarlığı	Gastronomi/mutfak sanatları lisans eğitim programının gıda okuryazarlığı üzerindeki etkilerini değerlendirmek için geliştirilen Gıda Okuryazarlığı Ölçeği (yazar tarafından)	Gastronomi öğrencilerinde gıda okuryazarlığı: lisede gastronomi eğitimi alanlar> üniversitede ilk kez alanlar; vakıf üniversitesinde okuyanlarda davranış boyutu >devlet üniversitesi; çocukluğu büyük şehirde geçenlerde düzey >kırsal; ebeveyn eğitim düzeyi ↑ → gıda okuryazarlığı ↑.

				Ölçeği'nin geliştirilmesi (geçerlik–güvenirlik)		
Dilan Tanrıverdi (2023) (33), Yüksek lisans, Niteliksel, 10 yılın programı	Türkiye-1923–2023 ilkokul fen bilimleri dersi resmi öğretim programları (doküman evreni).	-	-	**Gıda okuryazarlığı,** İlkokul fen bilimleri öğretim programlarının gıda okuryazarlığı kavramı açısından incelenmesi	İlkokul Fen Bilimleri Dersi Resmi Öğretim Programlarının Gıda Okuryazarlığı Kavramı Açısından İncelenmesine Yönelik Veri Toplama Aracı	Geniş gıda sistemi içerisindeki farklı toplumsal ihtiyaçlar programlarda gıda okuryazarlığına nasıl yer verildiğini etkilemektedir.
Esin Bağdatlı (2023) (34), Yüksek lisans, kesitsel, 627	Araştırmaya katılmayı kabul eden gönüllü yetişkin bireyler, 18–65 yaş.	18-19 (%6.1) 20-24 (%20.4) 25-29 (%9.4) 30-34 (%13.6) 35-39 (%17.5) 40-44 (%14.7) 45-49 (%8.3) 50-54 (%6.7) 55-65 (%3.3)	54.9	**Gıda Okuryazarlığı,** Gıda okuryazarlığı düzeyi ile sağlıklı beslenmeye ilişkin tutum arasındaki ilişkinin incelenmesi	1.Algılanan Gıda Okuryazarlığı Ölçeği (AGOY) (Poelman ve ark., 2018) 2. Sağlıklı Beslenmeye İlişkin Tutum Ölçeği (Tekkurşun Demir ve Cicioğlu, 2019)	Sağlıklı beslenme tutumu ↔ AGOY: anlamlı fark ve orta düzey pozitif ilişki; gıda okuryazarlığı arttıkça tutum ↑; Gıda okuryazarlığı düzey dağılımı: düşük %50,6 – yüksek %49,4; **yaş**: 18–19 <40–44, 50–54, 55+ (anlamlı); **cinsiyet**: erkek <kadın (AGOY ort.); **bilgi kaynağı**: yazılı basın/sağlık personeli >sosyal çevre/sosyal medya.
Kevser Aksu (2023) (35), Yüksek lisans, kesitsel, 252	Tekirdağ/Şarköy Devlet Hastanesi'nde 0–18 yaş çocuğu hastanede yatan anneler.	≤35 (%44.4) ≥36 (%55.6)	100	**Besin etiketi okuma alışkanlığı,** E-sağlık okuryazarlığı düzeyinin besin etiketi okuma alışkanlığı üzerindeki etkisinin değerlendirilmesi	1.Besin etiketi okuma alışkanlığı belirleme formu 2. E- sağlık okuryazarlığı ölçeği (Norman ve Skinner, 2006)	Annelerde etiket okuma: her zaman %34,9, bazen %58,8, hiç %6,3; e-sağlık okuryazarlığı eğitim düzeyiyle anlamlı biçimde, eğitim düzeyi arttıkça↑; etiket okuma sıklığı ile e-sağlık okuryazarlığı arasında anlamlı fark: her zaman okuyanların sıra ortalaması daha yüksek.
Meral Nur Kubilay (2023) (36), Yüksek lisans, metodolojik, 533	Sakarya Büyükşehir Belediyesi çalışanları ve belediye merkezlerindeki kursiyerler	18-30 (%40.7) 31-40 (%24.0) 41-50 (%21.0) 51-60 (%12.2) >60 (%2.1)	52.9	**Gıda Okuryazarlığı,** Sürdürülebilir Gıda Okuryazarlığı Ölçeği'nin geçerlik ve güvenirlik çalışması	1.Gıda okuryazarlığı kısa formu (SFLQ) (Krause ve ark) 2. Sürdürülebilir Gıda Okuryazarlığı Ölçeği (Teng, Chih, 2022) 3. Akdeniz Diyeti Bağlılık Ölçeği (Schröder ve ark.)	Sürdürülebilir Gıda Okuryazarlığı Ölçeği (TR): ilk uyarlama; iç tutarlılık yüksek (asıl İngilizce ölçek güvenilir); cinsiyet farkı: kadınlar> erkekler (anlamlı); eğitim farkı: lise <üniversite/lisansüstü (anlamlı).
Shabnam Aliyeva (2023) (37), Tıpta uzmanlık, Müdahale, 110	İstanbul-İstanbul Üniversitesi, İstanbul Tıp Fakültesi Çocuk Sağlığı ve Hastalıkları AD; tıpta uzmanlık ve yan dal asistanları ile doktor öğretim üyeleri.	30 (medyan) Min:26 Max:48	81.8	**Besin etiketi okuma alışkanlığı,** Pediatri hekimlerinde besin alerjisine yönelik etiket okuma ve alerjen içeriği farkındalık/bilgi düzeylerinin eğitim öncesi–sonrası değerlendirilmesi	Besin alerjenlerini, ticari gıda ürünlerindeki alerjen içeriğini ve etiketlerdeki bilgiyi doğru bir şekilde anlayıp anlamadığını belirlemek için hazırlanan anket formu (yazar tarafından)	Besin alerjenleri/etiket eğitimi: başlangıçta tüm katılımcılar eğitimsiz; etiket okuma durumu %22,7 okuyor, %10 bazen, %67,3 alışkanlık yok; eğitim sonrası (hemen/1 hafta ve 2 ay) alerjen içeriği farkındalığı ve bilgi düzeyi ↑, etiket okuma davranışı ↑ (başlangıca göre).
Sümeyye Taş (2023) (38), Yüksek lisans, kesitsel, 658	Kayseri Nuh Naci Yazgan Üniversitesi son sınıf öğrencileri (n=852).	Ortalama 22.4±2.6	71.3	**Gıda okuryazarlığı,** Üniversite öğrencilerinde algılanan gıda okuryazarlığı ve besin alerjisi bilgi düzeylerinin değerlendirilmesi	1.Algılanan Gıda Okuryazarlığı Ölçeği (AGOY) (Poelman ve ark., 2018) 2.Alerjen bilgi düzeyinin belirlenmesi amacıyla hazırlanan	Algılanan gıda okuryazarlığı (AGOY) ve besin alerjisi bilgisi: kadınlarda ↑; alerji bilgisi ile (yiyecek hazırlama, karşı koyabilme/direnç, sağlıklı gıdaya harcama, sağlıklı gıda bulundurma) alt ölçekleri arasında zayıf pozitif ilişki; AGOY puanları, Sağlık

					anket (yazar tarafından)	Bilimleri öğrencilerinde, BKİ'si normal olanlarda, besin alerjisi bulunanlarda ve sigarayı bırakmış bireylerde daha yüksek bulunmuştur.
Tuğba Demir (2023) (39), Yüksek lisans, kesitsel, 122	İstanbul/Başakşehir-Fatih Sağlık Hizmetleri Beslenme ve Diyetetik Bölümü'ne başvuran, bariatrik cerrahi endikasyonu olan hastalar.	(ortalama) 39.3±10.7	78.6	**Gıda okuryazarlığı/Besin etiketi okuma alışkanlığı,** Bariatrik cerrahi geçiren yetişkinlerde gıda okuryazarlığı ve gıda etiketi okuma alışkanlığının belirlenmesi	1.Beslenme durumları ve beslenme alışkanlıklarını belirlenmesi amacıyla hazırlanan anket (yazar tarafından) 2. Kendini Algılayan Gıda Okuryazarlığı Ölçeği (AGOY) (Selçuk ve ark., 2020)	Bekârların AGOY puanı evlilerden ↓; gelir>gider olanlarda günlük beslenme planı puanı ↑; KVH/HT hastalarında "karşı koyabilme/direnç" ↑; diyabette etiket inceleme ↓; AGOY ↑ → ameliyat sonrası BKİ farkı ↑; ameliyat sonrası 0–6 ay etikete dikkat ↑, ameliyat sonrası geçen süre uzadıkça ↓.
Zeynep Erbozkurt Özgün (2023) (40), Yüksek lisans, kesitsel, 479	Karabük, İl Sağlık Müdürlüğü personeli.	18-30 (%30.7) 31-40 (%38.0) 41-50 (%26.9) ≥51 (%4.4)	61.2	**Besin etiketi okuma alışkanlığı,** Sağlık çalışanlarında besin etiketi okuma alışkanlığı ve bilgi düzeyinin ölçülmesi	Ürün etiketi okumaya yönelik soruları içeren anket formu (yazar tarafından hazırlanan)	Etiket okuma (satın alma): %63,7 okuyor; anlama: %27,8 anlıyor, %58,7 kısmen, %13,6 anlamıyor; katkı maddesi amacı bilgisi (sağlık çalışanları): %47,4 biliyor; etiket okuma tetikleyicileri: "yeni ürün" en güçlü, "kilo verme programı" en zayıf.
Güldane Yıldırım (2024) (41), Yüksek lisans, metodolojik, 403/10	Kırklareli (Aşama 1): 18–65 yaş bireyler; Türkiye geneli (Aşama 2): 18–65 yaş bireyler.	≤25 (%26.10) 26-35 (%27.50) 36-45 (%18.60) ≥46 (%27.80)	49.8	**Gıda okuryazarlığı,** Tüketicilerin besin etiketi kullanma becerilerinin değerlendirilmesi ve besin etiketi okuryazarlığı ölçeği geliştirme çalışması	1.Besin etiketi okuma sıklıkları ve alışkanlıklarını, besin etiketi bilgilerini, besin etiketi okumaya yönelik hesaplama, karşılaştırma ve tespit etme becerilerini, besin etiketlerinde yer alan logoların bilgilerini tespit etmeyi amaçlayan anket (yazar tarafından oluşturulan) 2. Kendini Algılayan Gıda Okuryazarlığı Ölçeği (Poelman vd., 2018)	Besin Etiketi Okuryazarlığı Ölçeği (18–65) geçerli/güvenilir; Etiket okuma "her zaman" %30; okumama nedenleri: zaman yok %18, "bildiğim ürünü alırım" %32; etiket karşılaştırma becerisi: 26–35 yaş> 45+'a göre ↑ (anlamlı); eğitim: ön lisans ve üzeri, tüm kategorilerde lise ve altından ↑ (anlamlı).
Merve Nur Dönmez (2024) (42), Yüksek lisans, kesitsel, 330	Bursa/Mustafakemalpaşa Devlet Hastanesi sağlık profesyonelleri.	18-24 (%15.8) 25-39 (%64.5) 40-50 (%15.8) ≥51 (%3.9)	68.8	**Gıda okuryazarlığı,** Sağlık profesyonellerinde algılanan gıda okuryazarlığı düzeyinin sağlıklı yaşam biçimi davranışları ve yaşam kalitesi üzerindeki etkisinin incelenmesi	1.Algılanan Gıda Okuryazarlığı Ölçeği (AGOY) (Poelman ve ark., 2018) 2. Sağlıklı Yaşam Biçimi Davranışları Ölçeği II (SYBDÖ) 3.Avrupa Sağlık Etki Ölçeği (EUROHİS-QOL.8)	AGOY puanı: kadınlar, evliler, hemşireler, rutin sağlık kontrolü yaptıranlar, sigara/alkol kullanmayanlar, sağlıklı beslenme eğitimi alanlar, daha önce diyet yapanlar, dışarıdan hiç/haftada 1–2 kez yiyenler, hazır gıda tüketmeyenler ve tuzu tadına bakmadan eklemeyenlerde ↑ (anlamlı); AGOY ile SYBDÖ ve EUROHIS-QOL.8 arasında pozitif (zayıf) anlamlı ilişki.
Nasminel Tekin (2024) (43), Yüksek lisans, kesitsel, 173	Bir Üniversiteye bağlı mutfak ve yemekhanelerde çalışan personel.	19-24 (%5.2) 25-39 (%37.6) 40-50 (%37.6) 51-64 (%19.6)	42.2	**Gıda okuryazarlığı,** Toplu beslenme hizmetleri çalışanlarında gıda okuryazarlığı ile sürdürülebilir/sağlıklı beslenme davranışlarının değerlendirilmesi	1.Sürdürülebilir ve Sağlıklı Beslenme Davranışları Ölçeği (Żakowska ve ark., 2019) 2.Algılanan Gıda Okuryazarlığı Ölçeği (AGOY) (Poelman ve ark., 2018) 3. Sağlıklı Yeme İndeksi-2020 (Shams-White ve diğerleri, 2023).	AGOY toplam puanı ↔ Sürdürülebilir ve Sağlıklı Beslenme Davranışları: pozitif, orta düzey; AGOY toplam puanı ↔ Sağlıklı Yeme İndeksi toplam puanı: pozitif, düşük düzey (anlamlı).

Sema Uzunoğlu (2024) (44), Yüksek lisans, kesitsel, 34	Çukurova Üniversitesi Balcalı Hastanesi Pediatrik Metabolizma Polikliniği-Galaktozemi tanılı 2–18 yaş bireyler (polikliniğe başvuran).	2-3 (%17.6) 4-6 (%11.8) 7-10 (%26.5) 11-14 (%14.7) 15-17 (%29.4)	55.9	**Gıda etiketi bilgi düzeyi,** Galaktozemili çocuk/ergenlerde ailelerin hastalık ve besin etiketi okuma bilgi düzeylerinin çocukların beslenme durumu ve yaşam kalitesi ile ilişkisi	1. Çocuklar için Yaşam Kalitesi Ölçeği (ÇİYKÖ)- Quality of Life Questionniare (PedsQL) Varni ve ark., 1999) 2. Hastanın beslenme alışkanlıklarını, ailelere yönelik hastalık ve besin etiketi okuma bilgilerini ölçmeyi amaçlayan anket formu (yazar tarafından hazırlanan)	Aile bilgi düzeyi ↑ → çocuğun diyete uyumu ↑ (anlamlı); çocuk–ebeveyn yaşam kalitesi puanları arasında güçlü pozitif ilişki.
Sena Genç (2024) (45), Yüksek lisans, Müdahale,44	İstinye Üniversitesi Hastanesi (Medical Park Gaziosmanpaşa)- Beslenme ve Diyet Polikliniği'ne başvuran kadın bireyler.	Medyan (min-max) 26.5 (18-50)	100	**Gıda okuryazarlığı,** Etiket okuma eğitiminin diyet kalitesi ve sürdürülebilir gıda okuryazarlığı üzerindeki etkisinin değerlendirilmesi	1.Sürdürülebilir Gıda Okuryazarlığı Ölçeği (Chueh Chih, 2022) 2.Etiket Okuma Alışkanlıkları Anket Formu 3.Besin tüketim sıklığı ve Besin tüketim kaydı formu 4.Diyet Kalitesi İndeksi (DQI-I) (Petterson ve ark, 1994) 5.Etiket Okuma Eğitimi Sunumu	Etiket yorumlama kaynağı: diyetisyen %50, arkadaş %18,2, internet %15,9, TV %13,6, doktor %2,3; Eğitim etkisi: "doymuş yağ zararlıdır" yanıtı %72,7→%95,5 (anlamlı), etiket bilgilerine dikkat "bazen" ↑, "hiç bakmam" ↓, etiket okuma sıklığı ↑ (anlamlı); Sürdürülebilir Gıda Bilgisi ön–son ↑ (anlamlı).
Kübra Akman (2025) (46), Yüksek lisans, kesitsel, 117	İstanbul'da dört farklı işyerinde çalışan beyaz yakalılar.	20-29 (%42.74) 30-39 (%37.61) 40-49 (%14.53) ≥50 (%5.13)	48.7	**Gıda okuryazarlığı,** Sürdürülebilir gıda okuryazarlığı düzeyi ile beslenme durumu arasındaki ilişkinin incelenmesi	1.Sürdürülebilir Gıda Okuryazarlığı Ölçeği (SGOY) (Chueh Chih, 2022) 2. Beslenme Tutum Ölçeği (Ölçek Kayapınar ve Savaş) 3. Besin tüketim sıklığı ve Besin tüketim kaydı formu	SGOY puanı: kadınlar >erkekler (anlamlı); BKİ'ye göre normal/fazla kilolu> obez (anlamlı); beslenme tercihi—sebze ağırlıklı, dünya mutfağı tercih eden ve yeterli/az yiyenlerde SGOY↑.
Murat Güner (2025) (47), Doktora, Karma, Nicel boyut: 400 Nitel boyut: 60	Ankara/Yeni mahalle ortaöğretim kurumları 9-10. sınıf öğrencileri (2023–2024).	≤14 (%13.0) 15-16 (%80.8) ≥17 (%6.2)	60.8	**Besin etiketi okuma alışkanlığı,** Gıda etiketi okuma durumlarıyla ilişkili olarak dijital gıda etiketinin beslenme açısından uygulanabilirliğinin değerlendirilmesi	1.Gıda Etiketi Okuma Alışkanlığı ile Beslenme Bildirimi Okuma Durumlarını Belirleme Formu (yazar tarafından hazırlanan) 2.Beslenme Yönünden Dijital Gıda Etiketi Örneklerinin Uygulanabilirliğine Yönelik Görüş Formu (yazar tarafından hazırlanan) 3. Beslenme yönünden dijital gıda etiketi örnekleri	Gıda etiketi okuma—cinsiyet: ürün adı ve TETT/son tüketim tarihi okunmasında fark (anlamlı), diğer etiket öğelerinde fark yok; dijital gıda etiketi örnekleri çoğunluk için anlaşılır; tüm ambalajlı gıdalara uyarlanırsa öğrencilerin çoğunluğu bakacağını belirtmiştir.

Tezlerin en fazla yayınlandığı enstitü, 16 tez ile Sağlık Bilimleri Enstitüsü'dür. Bunu 13 tez ile Lisansüstü Eğitim Enstitüsü, 5 tez ile Eğitim Bilimleri Enstitüsü ve 2 tez ile Fen Bilimleri Enstitüsü izlemektedir. Tıp Fakültesi tarafından ise 1 tez yayınlanmıştır. Ana bilim dallarına göre incelendiğinde en fazla tez, 16 çalışma ile Beslenme ve Diyetetik Ana Bilim Dalı'nda gerçekleştirilmiştir. Bunu 2'şer tez ile Aile Ekonomisi ve Beslenme Eğitimi, Beslenme Bilimleri, Gastronomi, Halk Sağlığı ve Hemşirelik izlemektedir. Diğer ana bilim dalları ise 1'er tez ile temsil edilmektedir (Şekil 2).



Şekil 1. Bibliyometrik Analiz Sonucunda Tezlerin Ana Bilim Dalına göre dağılımı

Tartışma

Bu bibliyometrik inceleme, Türkiye'de gıda okuryazarlığı ile gıda/besin etiketi alanlarında yürütülen lisansüstü tezlerin kapsamını, yöntemsel özelliklerini ve ana bulgularını bütüncül biçimde ortaya koymuştur. 2004–2025 arasında saptanan 37 tezin dağılımı, bu alanın özellikle son yıllarda ivme kazandığını (en yüksek sayı 2023'te, n=9) göstermektedir. Konu başlıklarının "besin etiketi okuma alışkanlığı" ve "gıda okuryazarlığı" etrafında kümelenmesi, literatürün ağırlıklı olarak bilgi–tutum–davranış ekseninde, birey düzeyindeki göstergelere odaklandığını düşündürmektedir.

Evrenler incelendiğinde, çalışmaların geniş ölçüde öğrenciler (ortaöğretim/üniversite) ve genel yetişkin tüketiciler üzerinde yoğunlaştığı; sağlık çalışanları, ebeveynler ve belirli klinik grupların (bariyatrik cerrahi hastaları, galaktozemi izlemi) daha sınırlı ama hedefli temalarla ele alındığı görülmüştür. Bu desen, eğitim ve iletişim müdahalelerine açık kitlelerde etiket okuma ve gıda okuryazarlığının ölçümlenmesinin daha uygulanabilir olduğunu; buna karşılık yaşlılar, düşük sosyoekonomik gruplar veya kırsal bölgeler gibi kırılgan popülasyonlara daha az yer verildiğini işaret eder.

Ölçüm araçlarına bakıldığında, standardize ölçeklerin (örn. AGOY, SFLQ, YBOYDA, eHEALS vb.) yaygın kullanımı, alanın ölçümsel temellerle uyumlu ilerlediğini göstermektedir. Bununla birlikte, çok sayıda tezde araştırmacı geliştirmesi anketlerin tercih edilmesi bağlama duyarlı ölçümlerin önemsendiğine işaret ederken, geçerlik–güvenirlik raporlamasının ve

karşılaştırılabilirliğin dikkatle yönetilmesi gerektiğini de düşündürmektedir. Ölçek geliştirme/uyarlama çalışmalarının (örn. Sürdürülebilir Gıda Okuryazarlığı, Besin Etiketi Okuryazarlığı) uygun psikometrik göstergeler bildirmesi, gelecekte standardizasyon ve uygulama aktarımları için değerli bir temel sunmaktadır.

Bulguların ortak örüntüsü, etiket okumanın çoğunlukla "bazen" yanıtında yoğunlaştığını; "her zaman" okuma oranlarının daha düşük kaldığını göstermektedir. Eğitim düzeyi, yaş ve sağlık/e-sağlık okuryazarlığının artışıyla etiket okuma ve anlama eğilimindeki yükseliş, davranış değişikliği modelleriyle uyumludur. Cinsiyet açısından çoğu çalışmada kadınların etiketlere daha fazla dikkat ettiği gözlenirken, az sayıda çalışmada bunun tersi sonuçların da raporlanmış olması, bağlamsal etmenlerin (ürün türü, satın alma rolü, hane içi görev dağılımı vb.) etkisini akla getirmektedir. BKİ ile anlama/tercihler arasındaki farklılıklar (ör. normal ağırlıkta günlük karşılama yüzdelerini yorumlayabilme, fazla kilolu gruplarda "kolay anlaşılır etiket" talebi) etiket tasarımının hedeflenebilir yönlerine (okunabilirlik, görsel hiyerarşi, renk kodları) işaret eder. Sağlık çalışanları arasında etiket okuma yaygın olmakla birlikte katkı maddeleri gibi teknik unsurlarda bilgi boşlukları görülmesi, hizmet içi eğitimin rolünü vurgular. Müdahale çalışmalarında, kısa–orta vadede etiket bilgisinden etkilenme ve enerji/besin ögesi bilgisini okuma sıklığındaki artış, eğitim programlarının etkili olabileceğini göstermektedir. Bununla birlikte bariyatrik cerrahi gruplarında "ilk 6 ayda dikkat artışı, zaman içinde azalma" bulgusu, etkilerin sürekliliği ve pekiştirme ihtiyacına işaret eder. Sürdürülebilir gıda okuryazarlığı alanındaki uyarlama ve eğitim çalışmalarında gözlenen artışlar, sürdürülebilirlik boyutunun giderek daha görünür hale geldiğini göstermektedir. Kurumsal/alan dağılımı bakımından en çok tezin Sağlık Bilimleri Enstitüleri ve Beslenme–Diyetetik Anabilim Dalında toplanması beklenen bir bulgudur; bununla birlikte halk sağlığı, eğitim bilimleri ve gastronomi gibi disiplinlerin de katkısı, bu çok disiplinlik, gıda okuryazarlığının salt bireysel bilgi olmaktan öte davranışsal, pedagojik ve sistemsel boyutları olduğuna işaret eder.

Türkiye literatürü de tezlerden elde edilen bu tabloyu desteklemektedir. Ülkemizde yapılan araştırmalar tüketicilerin büyük oranda besin etiketlerini okuduğunu ortaya koysa da bu bilgileri anlamada zorluk yaşadıklarını göstermektedir. Besler ve ark. (2012), Türk tüketicilerin %72,4'ünün besin etiketi kullandığını; fakat etiket okuma davranışının eğitim, yaş ve cinsiyet gibi sosyodemografik etmenlere bağlı değiştiğini bildirmiştir (48). Üniversite öğrencileri arasında yapılan çalışmalar bu grubun etiket bilgilerine erişebilmesine rağmen içeriği yorumlama konusunda sınırlı olduğunu göstermektedir. Arslan ve ark. (2022), öğrencilerin büyük çoğunluğunun son kullanma tarihine dikkat ettiğini; yağ, şeker ve kalori gibi besin değeri bilgilerinin ise görece daha az önemsendiğini ve beslenme eğitimi alanların bu bilgilere daha dikkatli yaklaştığını göstermiştir (49). Benzer biçimde, Odaman ve ark. (2020), ürün adı/son kullanma tarihi/içerik listesinin sık okunduğunu; buna karşın şeker, lif ve sodyum gibi besin öğelerine daha az dikkat edildiğini, kadın öğrenciler ile beslenme ve diyetetik öğrencilerinin bu içeriklere daha fazla önem verdiğini raporlamıştır (50).

Uluslararası literatüre baktığımızda ise; Çin'de yürütülen kesitsel bir çalışmada beslenme okuryazarlığı düzeyi ile etiket kullanımı arasında anlamlı ilişki bulunmuştur. Besin etiketi okuyan bireylerin diyet bilgi düzeylerinin ve değerlendirme becerilerinin baskın olduğu gözlemlenmiştir (51). Yapılan sistematik incelemelerde, besin etiketi okumayı alışkanlık haline getiren bireylerin genel olarak daha sağlıklı beslenme profiline sahip olduğu bulunmuştur (52). Amerika'da genç yetişkinler arasında yapılan çalışmalarda da etiket okuyan bireylerin diyet kalitesinin daha iyi olduğu, daha fazla meyve ve sebze tükettikleri ve daha az yüksek yağlı ürün tercih ettikleri gözlemlenmiştir (53).

Bu bulgular, etiket okuma pratiğinin tek başına değil, içerik değerlendirme becerisiyle birlikte güçlendirilmesi gerektiğine işaret etmektedir. Politika ve tasarım düzeyinde, Avrupa'dan gelen kanıtlar Nutri-Score gibi renkli ve sade ön yüz etiketleme sistemlerinin düşük okuryazarlık düzeyine sahip bireylerde dahi daha anlaşılır bulunduğunu ve doğru seçimi kolaylaştırdığını göstermektedir (54). Okul çağındaki çocuklarda trafik ışığı sistemi (TLS) ve GDA (Guideline Daily Amounts) gibi görsel destekli biçimlerin farkındalığı artırdığı ve ürünlerin sağlık algısını olumlu etkilediği de raporlanmıştır (55). Bu doğrultuda, dijital etiket örneklerinin öğrencilerce "anlaşılır" ve "kullanılabilir" bulunması, Türkiye'de etiketlemenin dijital dönüşümüne yönelik girişimleri destekleyebilecek niteliktedir.

Bu bulgular, birkaç kısıtlılık çerçevesinde değerlendirilmelidir. Öncelikle kapsama tek bir kaynak olan YÖK Ulusal Tez Merkezi üzerinden erişilmesi, erişimi kısıtlı tezler ile veri tabanı dışındaki çalışmaların dâhil edilememesi nedeniyle kapsayıcılığı sınırlamış olabilir. Bibliyometrik tasarım gereği tezlerin yöntemsel niteliğine ilişkin biçimsel bir kalite/risk-yanlılık değerlendirmesi yapılmamış; dolayısıyla sonuçların gücü ve genellenebilirliği büyük ölçüde incelenen tezlerin kendi iç kalitesine bağlı kalmıştır. Çalışmalarda kullanılan değişken tanımları, örneklem yapıları ve ölçüm araçlarının (standart ölçekler ile araştırmacı geliştirmesi anketlerin) heterojenliği, bulguların doğrudan karşılaştırılabilirliğini azaltmış ve nicel sentez yapılmasını güçleştirmiştir.

Sonuç ve Öneriler

Bu bibliyometrik inceleme, Türkiye'de gıda okuryazarlığı ve gıda/besin etiketi alanındaki lisansüstü üretimin son on yılda belirgin biçimde arttığını göstermektedir. Ancak üretim tematik olarak iki başlıkta yoğunlaşmaktadır: etiket okuma/anlama davranışı ve gıda okuryazarlığı düzeyi. Yöntem bakımından çalışmaların büyük bölümü kesitsel ve öz-bildirime dayalıdır; evren bakımından ise yığılma üniversite öğrencileri ve genel yetişkin tüketicilerde olup yaşlılar, düşük sosyoekonomik gruplar, kırsal nüfus ve kronik hastalığı olanlar sınırlı temsil edilmektedir. Müdahale çalışmalarında kısa–orta vadeli kazanımlar bildirilse de kalıcılığa ilişkin kanıtlar sınırlıdır.

Bu tablo alanın derinleşmesi için birkaç önceliği ortaya koymaktadır. İlk olarak, davranışın zaman içindeki değişimini yakalayacak uzunlamasına ve deneysel tasarımlara ihtiyaç vardır. İkinci olarak, öz bildirimi tamamlayacak nesnel çıktılar (okuma/satın alma/tüketim kayıtları, dijital etiket kullanım verileri) kullanılmalıdır. Üçüncü olarak, kırılgan topluluklara yönelik odak çalışmalar genişletilmeli, okuryazarlığı artırmaya yönelik müdahaleler tasarlanırken etiket okunabilirliği ve dijital etiket çözümleri birlikte değerlendirilmelidir. Son olarak, karşılaştırılabilirliği artırmak için ortak raporlama standartları benimsenmeli, yeni ölçekler psikometrik olarak kapsamlı biçimde doğrulanmalı ve lisansüstü üretimde doktora/uzmanlık düzeyi çalışmalar teşvik edilmelidir. Bu adımların akademik kanıt tabanını güçlendirirken politika ve uygulamaya doğrudan aktarılabilir bulgular üretmesi beklenir.

Yazar Katkıları

Yazar 1: Çalışmanın tasarlanması, literatür taraması, veri toplama, veri analizi ve yorumlanması, makalenin yazılması.

Yazar 2: Araştırma fikrinin geliştirilmesi, metodolojinin oluşturulması, bulguların değerlendirilmesi, veri analizi, makalenin gözden geçirilmesi ve son onayın verilmesi.

Çıkar Çatışması

Yazarlar, bu çalışma ile ilgili herhangi bir çıkar çatışması olmadığını beyan etmektedir.

Kaynakça

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BIOCHAR-ASSISTED COMPOSTING OF AGRICULTURAL WASTES: A SUSTAINABLE STRATEGY FOR NUTRIENT RECOVERY, CARBON SEQUESTRATION, AND CIRCULAR AGRICULTURE

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ABSTRACT

The sustainable management of agricultural waste has become a major challenge for modern agriculture due to increasing biomass generation, environmental concerns, and the need to improve soil health under changing climatic conditions. Among the emerging circular bioeconomy strategies, the integration of biochar into composting systems has attracted considerable scientific interest because of its potential to enhance composting efficiency, improve compost quality, and reduce environmental impacts. Biochar, a carbon-rich material produced through the pyrolysis of biomass under limited oxygen conditions, possesses unique

physicochemical properties, including high porosity, large specific surface area, and significant adsorption capacity. When incorporated into composting substrates, biochar can improve aeration, regulate moisture content, enhance microbial habitat availability, and promote nutrient retention throughout the biodegradation process.

This study reviews the role of biochar in the composting of agricultural residues and examines its effects on biological activity, organic matter transformation, nutrient dynamics, greenhouse gas mitigation, and compost maturity. Particular attention is given to the interactions between biochar and microbial communities responsible for organic matter decomposition and humification processes. The incorporation of biochar has been shown to reduce nitrogen losses through ammonia volatilization, decrease methane and nitrous oxide emissions, and increase the stabilization of organic carbon within the final compost product. Furthermore, biochar-enriched composts often exhibit improved nutrient availability, enhanced cation exchange capacity, and superior agronomic performance compared with conventional composts.

The findings indicate that biochar-assisted composting represents a promising approach for converting agricultural waste into high-value organic fertilizers while simultaneously contributing to carbon sequestration and climate change mitigation. The integration of biochar into composting systems offers a sustainable pathway for improving resource efficiency, supporting circular agriculture, and enhancing soil resilience in arid and semi-arid regions. Future research should focus on optimizing biochar production conditions, feedstock selection, application rates, and long-term field performance under different agricultural environments.

Keywords: Biochar; Composting; Agricultural waste; Circular bioeconomy; Carbon sequestration; Nutrient retention; Greenhouse gas mitigation; Sustainable agriculture; Organic fertilizer; Soil health.

BREAKFAST SKIPPING AND SNACKING HABITS AMONG SCHOOL-GOING ADOLESCENTS IN EL JADIDA PROVINCE, MOROCCO

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ABSTRACT

Background: Adolescence is a critical period for the establishment of long-term dietary habits. Breakfast skipping and frequent snacking are common behaviors among school-going adolescents and may contribute to poor dietary balance, inadequate nutrient intake, and unfavorable weight-related outcomes. However, data on these behaviors among Moroccan adolescents remain limited.

Objective: This study aimed to describe breakfast consumption patterns and snacking habits among school-going adolescents in El Jadida Province, Morocco, and to explore their relationship with selected sociodemographic and nutritional characteristics.

Methods: A cross-sectional study was conducted among school-going adolescents in El Jadida Province. Data were collected using a structured questionnaire including sociodemographic characteristics, eating habits, breakfast consumption, and snacking frequency. Anthropometric measurements were collected according to standardized procedures. Dietary information was assessed using dietary recall data and/or food habit questions. Breakfast skipping was defined as the absence of regular breakfast consumption, while snacking habits were assessed according to the frequency and type of foods consumed between meals. Descriptive statistics were used to summarize participants' characteristics, and comparative analyses were performed to examine differences according to breakfast and snacking patterns.

Results: The study highlights the importance of breakfast habits and snacking behaviors in the dietary profile of adolescents. Breakfast skipping and frequent consumption of energy-dense snacks may reflect less favorable eating patterns, particularly when associated with low intake of fruits, vegetables, and other nutrient-dense foods. These behaviors may also vary according to sex, socioeconomic context, and school-related routines. Further analysis may help identify groups at higher nutritional risk and guide targeted school-based nutrition education.

Conclusion: Breakfast skipping and snacking habits represent important components of adolescent dietary behavior. Understanding these practices among school-going adolescents in El Jadida Province may help guide nutrition education strategies aimed at improving dietary balance and promoting healthier food choices in the school environment.

Keywords: Adolescents; breakfast skipping; snacking habits; dietary behavior; school-going adolescents; nutrition education; El Jadida; Morocco.

INFLUENCE OF STORAGE TEMPERATURE AND CULTIVATION SYSTEM ON THE PHYSICOCHEMICAL QUALITY OF TOMATO

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ABSTRACT

Postharvest losses in tomatoes are strongly influenced by storage temperature, cultivar, and production system. This study evaluated the physicochemical evolution of three tomato types - Silvia ("oxheart"), Raluca ("Romanian"), and Konigin ("yellow") - grown under conventional or organic conditions and stored for up to 144 h under refrigeration or at room temperature. Color was monitored by hex-coded sensor readings, while the centrifuged liquid and solid

fractions were characterized for pH, Brix, conductivity, total dissolved solids, titratable acidity, moisture, ash, and total organic carbon. Sensor measurements showed progressive darkening during storage, particularly after 72 h, with stronger color intensity after 144 h. Room-temperature storage generally accelerated visual changes compared with refrigeration. In the tomato supernatant, cultivar- and system-dependent differences were observed: Brix values ranged from about 5.1 to 6.9, pH from 4.19 to 4.86, and conductivity from 3.54 to 5.83 mS/cm. Titratable acidity varied between 2.95 and 5.40, indicating that both genotype and storage regime affected acid–sugar balance. Organic and conventional samples did not follow a single uniform trend, but refrigerated conditions tended to moderate changes in several parameters. Analysis of the solid biomass showed high moisture contents, generally above 92%, ash values around 0.39–0.66%, and total organic carbon ranging from approximately 25.1 to 40.7 mg/g. No major statistically significant variation was detected in the separated solid fraction over the storage interval. Overall, the results indicate that tomato quality changes during short-term storage are most evident in color and liquid-phase physicochemical parameters, while the solid biomass remains comparatively stable during the first six storage days.

Keywords: tomato quality, postharvest storage, refrigeration, physicochemical parameters, color sensors.

CARBON-SMART DIGITAL AGRICULTURE FOR NET-ZERO FARMING

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ABSTRACT

The agricultural sector has been known to be both driver of greenhouse gases (GHGs) and victim of climate change. The rising need for food production while at the same time cutting down on any negative effects on the environment has seen more people adopt carbon-smart digital agriculture. This relatively new practice involves the use of digital technology such as artificial intelligence (AI), Internet of Things (IoT) sensors, remote sensing, geographic information systems (GIS), drones, and big data analytics in order to achieve optimized use of resources while ensuring low carbon emissions. The use of precision agriculture, variable rate input application, smart irrigation systems, and artificial intelligence-driven decision support technologies will lead to substantial savings in energy, fertilizers, and emission reduction. Moreover, digital technologies will help in carbon accounting and carbon sequestration evaluation and enable farmers to adopt climate-smart farming. Recent research suggests that precision nutrient management and smart irrigation will help reduce emissions from agriculture and increase the efficiency of water and nutrients utilization. Additionally, the monitoring of farms using satellite technology and digital twin will make it possible to evaluate carbon footprints. This study will focus on the principles, technologies, applications, advantages, and difficulties of carbon-smart digital agriculture. It will be seen that combining the use of digital technology with sound land use can help farmers achieve net-zero farming. It is important to note that the integration of carbon-smart digital agriculture can play an instrumental role in fostering sustainable agriculture development.

Keywords: Carbon-smart agriculture, Digital agriculture, Net-zero farming, Artificial intelligence, Precision agriculture, Climate-smart agriculture, Remote sensing, Carbon sequestration, Sustainable farming.

CLIMATE CHANGE, WATER GOVERNANCE, AND AGRICULTURAL RESILIENCE IN PAKISTAN

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ABSTRACT

This study examines how climate change, water governance, and adaptation practices shape agricultural resilience in Pakistan. Pakistan's agriculture highly dependent on the Indus Basin, monsoon rains, and irrigation faces rising temperatures, shifting precipitation, glacier retreat, floods, and recurrent droughts that threaten crop yields, livelihoods, and food security. Using a comparative, qualitative review of climate reports, policy documents and academic literature, the research identifies key governance gaps: institutional fragmentation, inequitable water allocation, weak implementation of climate policies, and limited local participation. It assesses recent national initiatives (e.g., revised National Climate Change Policy, Indus Basin reforms) and highlights barriers that limit their effectiveness at ground level. The study synthesizes evidence on community-based and sustainable agricultural strategies water-efficient irrigation, crop diversification, groundwater management, and local stewardship that increase resilience when supported by transparent institutions and inclusive governance. Policy recommendations stress strengthening meso-level institutions, improving interagency coordination, enhancing data-driven water planning, and mainstreaming community-led adaptation into national programs. By linking governance reforms to practical adaptation measures, the paper argues that equitable, accountable water management is critical to sustaining Pakistan's agricultural productivity under escalating climate risks.

Key words: Climate Change, Water Governance, Adaptation, Livelihoods, Food Security, Irrigation, Groundwater Management

CLIMATE CRISIS, DROUGHT, AND GRAIN PRODUCTION: AN ASSESSMENT FROM AGRICULTURAL AND NUTRITIONAL PERSPECTIVES, SPECIFICALLY FOR TÜRKIYE

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ABSTRACT

Introduction and Purpose: Due to its geographical location within the Eastern Mediterranean Basin, Türkiye is identified by the Intergovernmental Panel on Climate Change (IPCC) as one of the regions most vulnerable to climate change. By the end of the century, average temperatures are projected to increase by 3.2–5°C, while annual precipitation is expected to decline by up to 30% in the western and southern regions. These changes are expected to create long-term structural pressures on agricultural production systems, particularly on cereal crops, which account for more than 72% of cultivated agricultural land. This study aims to evaluate the effects of climate change on wheat production and food systems in Türkiye and to discuss possible adaptation strategies in the context of sustainable nutrition and agricultural resilience.

Materials and Methods: This study was conducted through a comprehensive literature review and evaluation of climate projections, agricultural production data, and physiological studies related to drought and heat stress in wheat cultivation. Relevant scientific articles published in peer-reviewed journals were identified through databases such as Web of Science, Scopus, PubMed, and Google Scholar using keywords including “climate change,” “Türkiye,” “wheat production,” “drought stress,” “heat stress,” “food systems,” and “sustainable diets.” National and international reports, including IPCC assessments and reports from the Turkish Statistical Institute (TÜİK) and the Food and Agriculture Organization (FAO), were also reviewed. Studies examining temperature increases, precipitation decline, wheat productivity, genotype responses under stress conditions, and sustainable dietary models were analyzed comparatively. The collected data were synthesized to evaluate the impacts of climate change on agricultural productivity, nutritional quality, and food system sustainability in Türkiye.

Results: Findings indicate that the 1.5°C increase in temperature observed over the last 25 years has caused a 9% decline in wheat yield and the loss of approximately 1 million hectares of production area in Türkiye. Climatic fluctuations during the grain-filling period, especially in May, were found to significantly reduce productivity, with every 1°C increase leading to an estimated 4% yield reduction. Winter wheat genotypes showed lower adaptation capacity under stress conditions compared to spring varieties, resulting in decreases of 46.3% in yield, 19.4% in grain weight, and 30.5% in grain number. At the physiological level, drought and heat stress

impaired photosynthesis, caused spikelet sterility, and negatively affected starch and protein accumulation, thereby reducing nutritional quality. Furthermore, although plant-based sustainable dietary models are increasingly emphasized as part of climate adaptation strategies, some of these models may increase water consumption, creating an additional policy challenge for Türkiye. The study highlights the necessity of updating agricultural calendars, developing drought-resistant genotypes, expanding digital agriculture practices, and redesigning nutrition policies according to changing environmental conditions.

Key Words: Climate change, drought, grain production, wheat yield, food security, sustainable diet, Turkish agriculture.

EMBEDDED CLIMATE EXPOSURE IN AN INPUT-OUTPUT ECONOMY: A SYSTEM DYNAMICS FRAMEWORK FOR THE PROPAGATION AND RECOVERY OF SECTORAL CLIMATE RISK

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ABSTRACT

Climate change affects industries unequally, and the industries that appear most exposed are not always those that bear the heaviest burden, because a sector with limited direct exposure may be substantially affected through its dependence on inputs from exposed sectors. This paper proposes a methodological framework that measures such embedded climate exposure and that represents its propagation and recovery over time. Direct exposure is represented as a vector that integrates hazard, sensitivity and adaptive capacity at the sectoral level. Its transmission along supply chains is then represented in two complementary ways. The first is a static input-output formulation in which the Leontief inverse converts direct exposures into total embedded exposures, yielding a ranking of industries, an amplification factor and an economy-wide systemic index, with the property that an industry whose own exposure is negligible can carry large embedded exposure through the food and agricultural supply chain. The second is a system dynamics formulation in which sectoral operating capacity is a stock that climate damage depletes and adaptation restores, while output tracks the lesser of demand and capacity, so that a shock cascades through the production network and recovers with a delay. The two formulations are connected by a result that identifies the static embedded exposure as the steady state of the dynamic model, which augments it with the transient path, the peak loss and the recovery time. The framework is presented as a methodological proposal, and an application to national input-output tables combined with sectoral climate-hazard indicators and simulation of the dynamic model is set out as future work. The contribution is a transparent and reproducible means of identifying the industries that climate change will affect most and of tracing how the resulting disruption spreads and subsides.

Keywords: input-output analysis; system dynamics; climate change; sectoral vulnerability; supply chains; Leontief inverse; embedded exposure

INTRODUCTİON

Climate change is expected to impose large and uneven costs across the economy, with damages concentrated in particular sectors and regions (IPCC, 2022; Tol, 2009). Empirical work links higher temperatures to reduced agricultural productivity and to lower aggregate economic output (Burke et al., 2015; Ortiz-Bobea et al., 2021), and the economics of climate change has sought to express such impacts through damage functions and the social cost of carbon (Nordhaus, 2017). Most sectoral assessments, however, consider industries in isolation and measure the exposure that each industry faces directly, through the hazards to which its own activity is subject.

Industries are not isolated. They are linked through flows of intermediate goods and services, so that a climate shock to one sector is transmitted to the sectors that depend upon it. Agriculture provides the clearest illustration, since a drought that reduces crop yields raises costs and curtails supply for food processing, which in turn affects wholesale distribution, retailing and food service. The industries that bear the heaviest burden of climate change are therefore not only those that are directly exposed but also those that are embedded in supply chains rooted in exposed sectors. A measure of exposure that ignores these linkages will misrank industries and will understate the reach of climate risk into the food economy.

Input-output analysis provides the established apparatus for representing such interdependence (Leontief, 1970; Miller & Blair, 2022). The Leontief inverse records, for every sector, the total output of every other sector required to satisfy one unit of final demand, and it has been used to propagate disturbances through production networks, including the economic losses caused by natural disasters (Hallegatte, 2008) and the amplification of localised sectoral shocks into aggregate fluctuations (Acemoglu et al., 2012). The same apparatus can be made to carry climate exposure rather than monetary flows, so that the exposure of a sector is augmented by the exposure embedded in the inputs it draws from the rest of the economy.

Input-output analysis is, however, a static account of equilibrium, and the burden that a climate shock imposes is not only a matter of where it eventually falls but also of its timing, its peak severity and the time a sector takes to recover. These are questions of dynamics and feedback, and they belong to system dynamics, the modelling tradition that represents a system through stocks, flows and feedback loops and traces its behaviour over time (Forrester, 1961; Sterman, 2000). Casting the propagation of climate exposure as a system dynamics model, with sectoral capacity as a stock that climate depletes and adaptation restores, places the static input-output measure within a dynamic account of cascade and recovery.

What is absent is a framework that combines a sectoral assessment of direct climate exposure with input-output propagation in order to obtain a measure of embedded exposure and a defensible ranking of industries. This paper develops such a framework. It contributes, first, a static measure of embedded climate exposure that maps a vector of direct sectoral exposures through the Leontief inverse, together with an amplification factor and an economy-wide systemic index; second, a system dynamics model in which sectoral capacity is a stock that climate damage depletes and adaptation restores and in which shortfalls cascade through the production network; third, a result that identifies the static embedded exposure as the steady state of the dynamic model, together with the dynamic measures of peak loss and recovery time that the static measure does not capture; and fourth, a set of properties that characterise the framework and an application design that specifies the data and the simulation it requires. The framework is offered as a methodological proposal, and no empirical ranking is claimed here.

The remainder of the paper is organised as follows. Section 2 defines direct sectoral exposure. Section 3 introduces the input-output propagation mechanism and the embedded-exposure measure. Section 4 develops the amplification factor, the systemic index and the properties of the static framework. Section 5 casts the propagation as a system dynamics model and connects it to the static measure. Section 6 sets out the proposed application and simulation. Section 7 discusses the scope and limitations of the approach, and Section 8 concludes.

DİRECT CLİMATE EXPOSURE OF İNDUSTRİES

Figure 1 summarises the framework, from sectoral data to a ranking of industries by embedded climate exposure. This section defines the first input, the direct exposure of each industry.

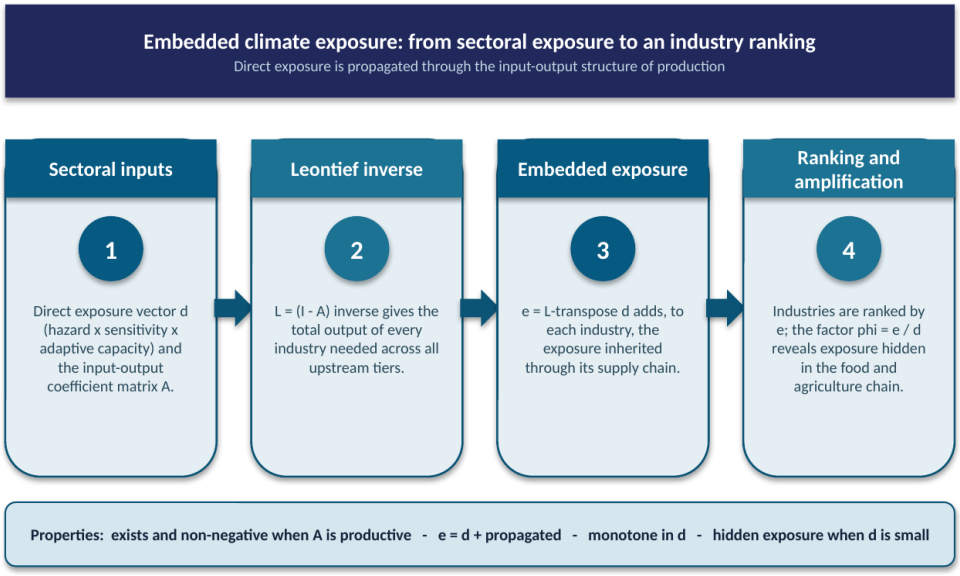

Figure 1. The embedded-climate-exposure framework, from sectoral exposure and input-output data to an industry ranking.

Let the economy be divided into n industries. The direct climate exposure of industry i is a number $d_i \in [0,1]$ that summarises how far the activity of that industry is affected by climate hazards, before any account is taken of its links to other industries. Following the standard vulnerability framing adopted in climate assessment (IPCC, 2022), direct exposure is treated as the product of a hazard component, a sensitivity component and the complement of an adaptive-capacity component, as in Equation (1), where $h_i \in [0,1]$ measures the exposure of industry i to relevant climate hazards, $s_i \in [0,1]$ its physical or economic sensitivity to those hazards and $a_i \in [0,1]$ its capacity to adapt.

$$d_i = h_i s_i (1 - a_i) \quad (1)$$

The three components are intended to be estimated from observable indicators, for example the share of an industry's activity located in heat-exposed or drought-exposed regions, the dependence of its output on temperature-sensitive natural inputs and the availability of substitution, insurance or technological mitigation. The multiplicative form ensures that direct exposure vanishes when any component vanishes, so that an industry that faces no hazard, that is insensitive to it, or that can adapt fully, has no direct exposure. The vector $d = (d_1, \dots, d_n)^\top$ collects the direct exposures and is the first input to the framework. The construction of d is deliberately separable from the propagation mechanism that follows, so that alternative exposure assessments can be substituted without altering the rest of the framework.

SUPPLY-CHAİN PROPAGATİON AND EMBEDDED EXPOSURE

Interindustry dependence is described by the matrix of technical coefficients. Let z_{ij} denote the value of the input from industry i used by industry j, and let x_j denote the total output of industry j. The technical coefficient of Equation (2) is the input from i required per unit of output of j, and the matrix $A = [a_{ij}]$ collects these coefficients.

$$a_{ij} = \frac{z_{ij}}{x_j} \quad (2)$$

The total output required throughout the economy to deliver one unit of final demand is given by the Leontief inverse of Equation (3), in which I is the identity matrix. When the production system is productive, the inverse exists and equals the convergent series of successive rounds of input requirements, the term A^k representing the inputs required at the k-th tier upstream.

$$L = (I - A)^{-1} = \sum_{k=0}^{\infty} A^k \quad (3)$$

Embedded climate exposure is now obtained by transmitting the direct exposures through this network of input requirements. Producing one unit of industry j requires L_{ij} units of industry i across all tiers, and each such unit carries the direct exposure d_i. The embedded exposure of industry j is therefore the exposure-weighted sum of its total input requirements, given in vector form by Equation (4).

$$e = L^{\top} d, \quad e_j = \sum_i d_i L_{ij} \quad (4)$$

Equation (4) measures backward, or demand-side, embedded exposure, that is, the exposure that industry j inherits through the inputs on which it relies. The complementary forward, or supply-side, transmission, by which an exposed industry passes disruption on to the customers that depend on its output, is captured by the Ghosh inverse $G = (I - B)^{-1}$, where B is the matrix of output-allocation coefficients $b_{ij} = z_{ij} / x_i$; the forward embedded exposure is then $e^f = G\, d$. The two directions answer different questions, the backward measure identifying industries that are vulnerable because their inputs are exposed and the forward measure identifying industries whose own exposure threatens others, a distinction rooted in the analysis of backward and forward linkages (Hirschman, 1958; Hallegatte, 2008). The development below uses the backward measure, since the concern is which industries are most affected, but every result transfers to the forward measure by replacing $L^{\top}$ with G.

AMPLİFİCATİON, SYSTEMİC EXPOSURE AND PROPERTİES

The embedded exposure separates into the part that an industry carries directly and the part it acquires through supply chains, as in the decomposition of Equation (5). The first term is the direct exposure and the second is the propagated exposure contributed by all upstream tiers.

$$e = d + (L^{\top} - I)d \quad (5)$$

The degree to which supply-chain dependence magnifies the direct exposure of an industry is captured by the amplification factor of Equation (6), defined for any industry with non-zero direct exposure as the ratio of embedded to direct exposure. An amplification factor close to one indicates an industry whose exposure is essentially its own, while a large amplification factor indicates an industry whose burden is dominated by the exposure of its suppliers.

$$\varphi_j = \frac{e_j}{d_j} \quad (6)$$

An economy-wide measure of systemic climate exposure is obtained by aggregating embedded exposures with weights w_j equal to the final-demand or output shares of the industries, as in Equation (7). The systemic index records the total embedded climate exposure carried by the economy and provides a single figure for comparison across economies or over time.

$$S = w^{\top} e = \sum_j w_j e_j \quad (7)$$

The framework has four properties that secure its interpretation, stated below for the backward measure.

Proposition 1 (Existence and non-negativity). If the production system is productive, that is, if the spectral radius of A is less than one, then $L = (I - A)^{-1}$ exists, is non-negative and equals the convergent series in Equation (3); consequently the embedded exposure $e = L^{\top} d$ exists and satisfies $e \geq 0$.

Proof. Productivity of A is equivalent to the spectral radius condition, under which the Neumann series converges to $(I - A)^{-1}$ and every partial sum is non-negative because $A \geq 0$; the limit L is therefore non-negative. Since $d \geq 0$, the product $L^{\top} d$ is a non-negative combination of non-negative quantities and is itself non-negative (Miller & Blair, 2022). □

Proposition 2 (Direct and propagated decomposition). Embedded exposure decomposes as $e = d + (L^{\top} - I)\, d$, and the propagated component $(L^{\top} - I)\, d$ is non-negative; hence $e_j \geq d_j$ for every industry, so propagation can only raise exposure.

Proof. The identity follows by writing $L^{\top} = I + (L^{\top} - I)$. Because $L = I + A + A^2 +$ ..., the matrix $L^{\top} - I = A^{\top} + (A^2)^{\top} +$ ... is a sum of non-negative matrices and is therefore non-negative; applied to $d \geq 0$ it yields a non-negative vector, so $e_j - d_j \geq 0$. □

Proposition 3 (Monotonicity). Embedded exposure is non-decreasing in every direct exposure: if $d \leq d'$ componentwise, then $e = L^{\top} d \leq L^{\top} d' = e'$. An increase in the direct exposure of any industry weakly raises the embedded exposure of every industry that depends on it.

Proof. Since $L^{\top} \geq 0$, multiplying the inequality $d' - d \geq 0$ by $L^{\top}$ preserves it, giving $e' - e = L^{\top}(d' - d) \geq 0$. □

Proposition 4 (Hidden exposure). An industry may have negligible direct exposure yet large embedded exposure. Formally, e_j is bounded below by $\sum_i d_i\, L_{ij}$ taken over supplying industries $i \neq j$, which can be large even when $d_j \approx 0$.

Proof. From Equation (4), $e_j = d_j\, L_{jj} + \sum_{i \neq j} d_i\, L_{ij} \geq \sum_{i \neq j} d_i\, L_{ij}$, since all terms are non-negative. The lower bound depends on the exposure of the suppliers of j and on the intensity of the supply links L_{ij}, and is independent of d_j; an industry such as food processing, which draws heavily on a highly exposed agricultural sector, therefore carries substantial embedded exposure regardless of its own direct exposure. □

Proposition 4 is the central qualitative implication of the framework. It states that a ranking of industries by direct exposure alone will overlook sectors that are exposed only through their supply chains, and it identifies the amplification factor of Equation (6) as the quantity that reveals them.

A SYSTEM DYNAMİCS MODEL OF PROPAGATİON AND RECOVERY

The input-output measure of Section 3 records where climate exposure eventually settles, but it is silent about the path by which a disruption spreads and the time a sector takes to recover. To represent these, the propagation is recast as a system dynamics model, in which the quantities of interest are stocks that accumulate and deplete, the rates that change them are flows, and the dependence of the flows on the stocks forms feedback loops (Forrester, 1961; Sterman, 2000). Figure 2 shows the causal structure.

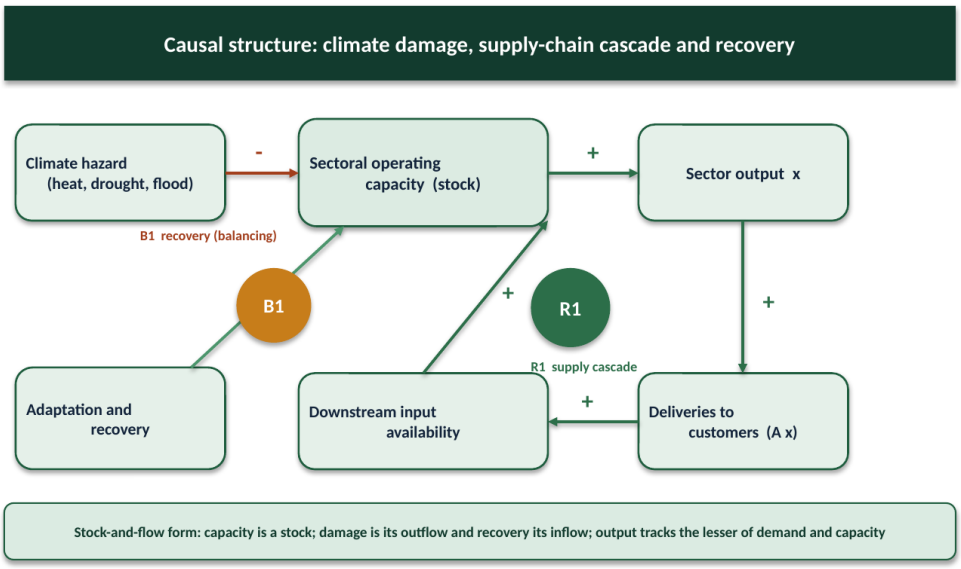

Figure 2. Causal structure of the dynamic model: a damage outflow and a recovery inflow on sectoral capacity, and a supply-chain cascade in output.

The central stock is the operating capacity $\kappa_i(t)$ of industry i, the output it is able to produce given the state of its plant, its workforce and local conditions. Capacity is depleted by climate damage and restored by adaptation and repair, as in Equation (8), where κ_i^0 is the undisturbed capacity, ρ_i is the rate at which capacity is restored, γ_i converts hazard into damage and $d_i(t)$ is the time-varying climate hazard. The damage term is the outflow of the stock and the recovery term its inflow, and together they form a balancing loop that returns capacity to its baseline once the hazard abates.

$$\frac{d\kappa_i}{dt} = \rho_i(\kappa_i^0 - \kappa_i) - \gamma_i d_i(t)\,\kappa_i \tag{8}$$

Output adjusts towards the level the industry is both able and required to produce. The requirement is the total demand of Equation (9), the sum of the intermediate demand from the industries that use the output of i and the final demand f_i. Output then relaxes towards the lesser of this demand and the available capacity, as in Equation (10), where α_i sets the speed of adjustment. The minimum is the input-output feature that an industry can produce no more than its most constrained input allows, and it is the channel through which a capacity loss at one industry becomes an input shortfall at another, so that a shock cascades forward through the network in a reinforcing loop.

$$y_i(t) = \sum_j a_{ij} x_j(t) + f_i \tag{9}$$

$$\frac{dx_i}{dt} = \alpha_i\,[\,min(y_i(t), \kappa_i(t)) - x_i(t)\,] \tag{10}$$

The disruption is summarised by the fractional output loss of Equation (11), measured against the undisturbed equilibrium $x^0 = L\,f$. Its steady state connects the dynamic model to the static measure of Section 3.

$$\ell_i(t) = 1 - \frac{x_i(t)}{x_i^0} \tag{11}$$

Proposition 5 (The static measure is the dynamic steady state). Suppose the hazard is sustained and small, and constrained inputs are rationed in proportion to their shortfall. Then the steady-state fractional capacity loss of industry i equals its direct exposure d_i, and the

steady-state fractional output-loss vector equals the embedded exposure, $\ell = L^{\top} d = e$. The static measure of Section 3 is therefore the equilibrium of the dynamic model.

Proof. Setting $d\kappa_i/dt = 0$ in Equation (8) gives a steady-state capacity that falls below the baseline by a fraction which, to first order in the hazard, is proportional to it; this fractional capacity loss is identified with the direct exposure d_i of Section 2 by the calibration of γ_i and ρ_i. When capacity binds, $x_i = \kappa_i$, so an industry loses output in proportion to its own capacity loss; when demand binds, $x_i = y_i$, so the loss is inherited from reduced deliveries. Linearising the minimum about the disturbed equilibrium and rationing the binding inputs in proportion to their shortfall, the fractional output loss satisfies the fixed point $\ell = d + A^{\top} \ell$, in which the second term collects the losses transmitted from suppliers weighted by the input coefficients. Solving yields $\ell = (I - A^{\top})^{-1} d = L^{\top} d = e$ (Sterman, 2000). □

Beyond the steady state, the dynamic model yields quantities that the static measure cannot. The peak fractional loss, the largest value of $\ell_i(t)$ over the episode, records the worst moment of the disruption, which a slowly recovering industry can reach well after the hazard itself has passed; the recovery time records how long the industry remains below its undisturbed output; and the integral of the loss over the episode records the cumulative production foregone. These depend on the recovery rates ρ_i and the speeds of adjustment α_i, and they separate industries that absorb a shock quickly from those in which the cascade persists. The static ranking of Section 4 identifies which industries are most exposed, and the dynamic model shows how severely and for how long.

APPLİCATİON DESİGN

The framework requires two inputs that are available from established sources. The interindustry matrix A is read from a national input-output or supply-and-use table, such as those compiled by national statistical offices and assembled internationally in multi-regional databases; for an application to Türkiye the national accounts of the Turkish Statistical Institute provide the domestic table, while international tables permit the supply chain to be traced beyond national borders. The direct-exposure vector d is constructed from sectoral climate-hazard indicators, combining the geographic distribution of each industry's activity with hazard maps for heat, drought and extreme precipitation, a measure of each industry's sensitivity to those hazards and an indicator of adaptive capacity, in the manner of Equation (1) and consistent with the vulnerability assessments of the IPCC (2022).

Given these inputs, the embedded exposure e, the amplification factors φ_j and the systemic index S are computed directly from Equations (4), (6) and (7). The planned analysis would rank industries by embedded exposure, identify the industries whose amplification factors are largest, and compare the systemic index across years as supply chains and hazards evolve. The agricultural and food sectors are expected to be central to the results, agriculture through its direct exposure and the food-processing, retailing and food-service industries through the exposure they inherit from it, which is precisely the pattern that a direct-exposure ranking would miss.

The mechanism can be seen in a deliberately small illustration. Consider three industries, agriculture, food processing and services, with direct exposures of 0.80, 0.10 and 0.05 respectively, and suppose that food processing draws half of its inputs from agriculture while services are only weakly exposed. Propagating these direct exposures through the corresponding Leontief inverse yields embedded exposures of about 0.90, 0.62 and 0.06. Food processing, whose direct exposure is only 0.10, acquires an embedded exposure of 0.62 and an amplification factor of about 6.2, because most of its burden is inherited from the agriculture

on which it depends. The numbers are illustrative and are used only to show how the framework reveals exposure that a direct assessment conceals; they are not an empirical estimate.

A full application would extend this structure to the complete set of industries in the national accounts, would test the sensitivity of the ranking to the construction of the direct-exposure vector and to the choice of backward or forward propagation, and would report the industries and supply chains that contribute most to the systemic index. Such a study is the natural continuation of the present proposal and is left to future work.

DİSCUSSİON

The framework reframes the question of which industries climate change will affect most. By transmitting direct exposures through the Leontief inverse it distinguishes the exposure an industry carries in its own right from the exposure it inherits through its inputs, and it identifies, by way of the amplification factor, the industries whose burden is dominated by their suppliers. This is the property of practical importance for the food economy, in which processing, distribution and catering are linked to a highly exposed agricultural base and would be misranked by any assessment that examined sectors in isolation. Because the propagation mechanism is the standard input-output apparatus, the framework inherits its transparency and its data requirements, and it can be applied wherever an input-output table and a sectoral exposure assessment are available.

Several limitations bound the proposal and indicate the direction of further work. The input-output representation assumes fixed technical coefficients and linear propagation, so it describes the transmission of exposure through existing supply relationships rather than the substitution and reorganisation that firms undertake when shocks persist; richer models that allow adaptive behaviour and capacity constraints, in the spirit of disaster input-output analysis, would relax this assumption (Hallegatte, 2008). The direct-exposure vector is itself an estimate that depends on hazard data and on judgements about sensitivity and adaptive capacity, and the ranking should be reported together with its sensitivity to those choices. Finally, embedded exposure measures the transmission of climate risk through production linkages and not the monetary value of the resulting losses, which would require coupling the exposure measure to sectoral damage functions of the kind used in climate economics (Tol, 2009; Nordhaus, 2017). None of these limitations affects the internal logic of the framework, which is the contribution of this paper.

CONCLUSİON

This paper has proposed a framework for identifying the industries that climate change will affect most, including those that are exposed not directly but through their place in supply chains. Direct sectoral exposure is represented as a vector that integrates hazard, sensitivity and adaptive capacity, and this exposure is propagated through the Leontief inverse of an input-output system to yield a measure of embedded exposure, an amplification factor and an economy-wide index of systemic exposure. The framework was shown to be well defined whenever the production system is productive, to decompose additively into direct and propagated components, to be monotone in the direct exposures and to assign substantial exposure to industries whose own exposure is negligible but whose suppliers are exposed.

The contribution is methodological. The framework offers a transparent and reproducible means of ranking industries by their total climate exposure and of locating the supply chains through which that exposure travels, with the food and agricultural economy as the leading

case. Its application to national input-output tables combined with sectoral climate-hazard indicators is specified as the next step, together with extensions to adaptive propagation and to the monetary valuation of the resulting losses. The central point stands without empirical estimation: once climate exposure is propagated through the structure of production, the industries that bear the heaviest burden are revealed to include those that a direct assessment would overlook.

DECLARATİONS

Ethics. This study is methodological and uses no personal data and no human participants; it required no ethical approval. The planned application would draw only on published input-output tables and publicly available climate-hazard indicators.

Funding. This research received no external funding.

Conflict of interest. The authors declare no competing interests.

Data availability. No data were generated or analysed in this methodological study. The illustrative figures in Section 5 are computed from the values stated there.

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CLIMATE-ATTRIBUTABLE THERMAL-ERGONOMIC STRAIN: A BIOPHYSICAL ACCUMULATION AND WORK-REST OPTIMISATION FRAMEWORK FOR OCCUPATIONAL HEAT EXPOSURE

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ABSTRACT

Climate change raises the heat to which workers are exposed, and the additional burden falls most heavily on those who perform physical labour outdoors, including the agricultural workforce on which food production depends. This paper proposes a methodological framework that quantifies the extra ergonomic strain attributable to a warming climate and that translates it into an allocation of work and rest. The environmental heat load is represented by the wet-bulb globe temperature and the internal load by the metabolic rate of the task, and the two are combined into an instantaneous strain that takes values in the unit interval. Strain is integrated over the work shift to give a cumulative dose that represents the physiological burden of the day. A warming scenario is expressed as a shift in the wet-bulb globe temperature relative to a counterfactual baseline, and the climate-attributable increment of strain is obtained as the difference between the cumulative doses under the two scenarios, with a marginal approximation that isolates the sensitivity of strain to temperature. The allocation of work and rest is then posed as the maximisation of productive time subject to a ceiling on cumulative strain, and the optimal schedule is shown to be of threshold form, assigning rest to the hottest part of the shift. Several properties are established: strain is bounded and monotone, the climate-attributable increment is non-negative and is underestimated by its linear approximation when strain is convex in temperature, and the maximum safe working time is non-increasing in heat. The framework is presented as a methodological proposal, and a validation pathway using standardised field measurement is set out as future work. The contribution is a transparent means of attributing the additional ergonomic strain that climate change imposes on workers and of translating it into protective work-rest schedules.

Keywords: occupational heat stress; ergonomics; wet-bulb globe temperature; climate change; work-rest scheduling; physical work capacity

INTRODUCTİON

Rising temperatures are among the most direct consequences of climate change for the working population. As average and extreme heat increase, the people most affected are those who perform physically demanding work in hot environments, for whom the body must dissipate the heat generated by exertion in addition to the heat received from the surroundings (Kjellstrom et al., 2009; Lundgren et al., 2013). Outdoor labour in agriculture and construction is especially exposed, and field studies show measurable losses of work capacity and productivity as heat rises, with the agricultural workforce that underpins food production among the most affected

(Sahu et al., 2013; Flouris et al., 2018). Reviews and empirical models confirm that physical work capacity declines steeply once heat exceeds moderate levels (Foster et al., 2021; Ioannou et al., 2022).

The ergonomic burden that a worker experiences is a combination of the environmental heat load and the physical demand of the task, and occupational practice represents it through established instruments. The wet-bulb globe temperature is the standard screening index for environmental heat stress (ISO 7243), the predicted heat strain model provides an analytical determination of the physiological response (ISO 7933), and the underlying thermal physiology is set out comprehensively in the ergonomics literature (Parsons, 2014). These instruments assess heat stress at a moment in time and against fixed reference limits. The question posed by climate change is different in kind: it asks not only whether a given environment is stressful but how much additional strain a warmer climate imposes, and how work should be reorganised in response.

Answering that question requires three elements that the standard instruments do not by themselves provide. The first is a means of accumulating instantaneous strain over a working shift, so that the total physiological burden of a day can be represented rather than a single index value. The second is a means of attributing the part of that burden that is due to climate, by comparing the strain a worker incurs under a warming scenario with the strain incurred under a counterfactual baseline. The third is a means of turning the resulting strain into an allocation of work and rest that protects the worker while preserving as much productive time as possible.

This paper develops a framework that supplies these three elements. It defines an instantaneous strain from the wet-bulb globe temperature and the metabolic rate, integrates it into a cumulative dose, attributes the climate-driven increment of that dose against a baseline and a marginal approximation, and derives the work-rest schedule that maximises productive time under a ceiling on cumulative strain. It establishes that strain is bounded and monotone, that the climate-attributable increment is non-negative and is underestimated by its linear approximation when strain is convex in temperature, that the optimal schedule is of threshold form, and that the maximum safe working time falls as heat rises. The framework is offered as a methodological proposal, and no field estimate is claimed here. The paper proceeds from the biophysical model of load in Section 2, through the cumulative dose in Section 3, the climate attribution in Section 4 and the work-rest optimisation in Section 5, to a proposed validation pathway in Section 6, a discussion of limitations and ethics in Section 7 and a conclusion in Section 8.

A BİOPHYSİCAL MODEL OF THERMAL-ERGONOMİC LOAD

Figure 1 sets out the framework, from the heat and workload that a worker faces to the work-rest schedule that the framework recommends. This section defines the instantaneous load.

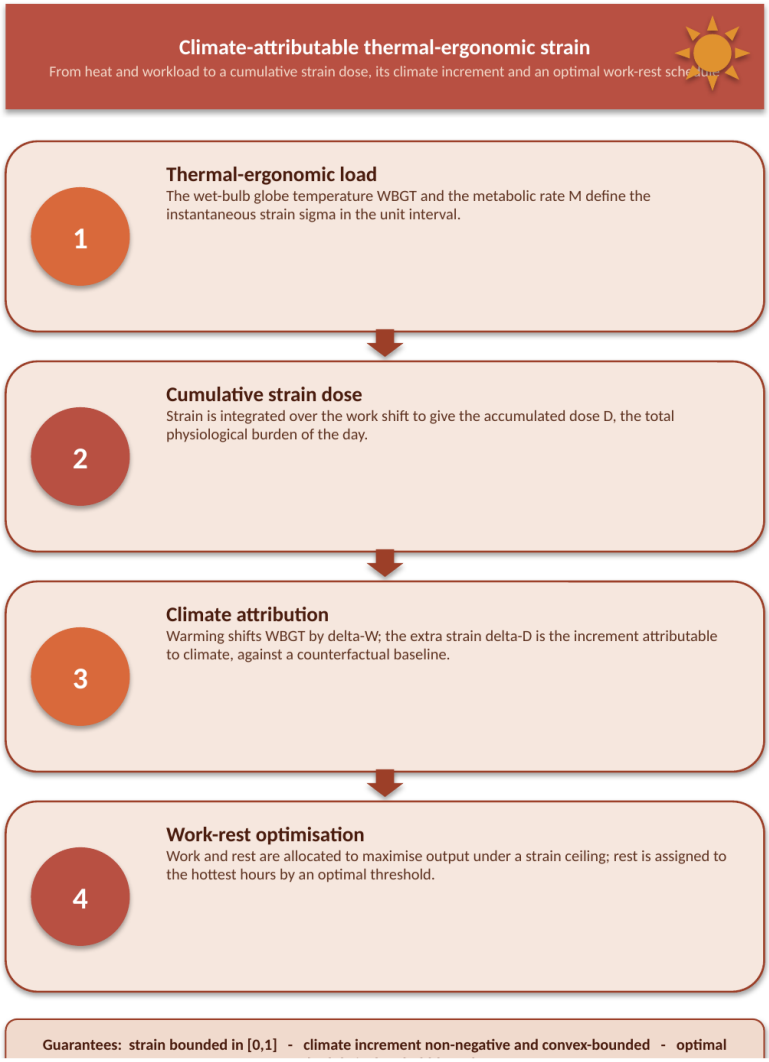

Figure 1. The framework, from heat and workload to a cumulative strain dose, its climate increment and an optimal work-rest schedule.

The environmental heat to which a worker is exposed is summarised by the wet-bulb globe temperature, the established screening index for occupational heat stress (ISO 7243). For an outdoor setting it is the weighted combination of the natural wet-bulb temperature, the globe temperature and the air temperature given in Equation (1), the weights reflecting the dominant contribution of humidity and radiant heat to physiological strain.

$$WBGT = 0.7\ T_{nw} + 0.2\ T_g + 0.1\ T_a \quad (1)$$

The internal heat load is summarised by the metabolic rate M of the task, which the ergonomics standards classify from rest through light, moderate, heavy and very heavy work (Parsons, 2014). Environmental and internal load together determine the physiological strain a worker experiences. We represent this by an instantaneous strain $\sigma(t) \in [0,1]$, defined in Equation (2) as the relative loss of physical work capacity, where PWC is the physical work capacity attainable at the prevailing heat and workload and PWC_0 is the capacity in thermally neutral conditions. The strain is zero when heat imposes no penalty and approaches one as conditions approach the limit of tolerance.

$$\sigma(t) = 1 - \frac{PWC(WBGT(t),M(t))}{PWC_0} \quad (2)$$

Empirical relations for PWC as a function of the wet-bulb globe temperature and the metabolic rate are available from controlled and field studies and may be inserted directly into Equation (2) (Foster et al., 2021; Ioannou et al., 2022); the framework requires only that σ be non-decreasing in both the heat and the workload and bounded within the unit interval, which every published relation of this kind satisfies.

CUMULATİVE STRAİN OVER A WORK SHİFT

A single index value does not capture the burden of a working day, because heat and activity vary through the shift and their effects accumulate. We therefore integrate the instantaneous strain over the shift of duration T to obtain the cumulative strain dose of Equation (3), which represents the total physiological burden incurred between the start and the end of work.

$$D = \int_0^T \sigma(t)\ dt \tag{3}$$

Proposition 1 (Bounds and monotonicity). For every shift the cumulative dose satisfies $0 \leq D \leq T$. The dose is also non-decreasing in the heat profile: if $WBGT(t)$ increases at any time, with the workload held fixed, then $\sigma(t)$ does not decrease and D does not decrease.

Proof. Since $\sigma(t) \in [0,1]$ for all t, integrating over $[0,T]$ gives $0 \leq D \leq T$. Because σ is non-decreasing in the wet-bulb globe temperature, a pointwise increase in $WBGT(t)$ raises $\sigma(t)$ pointwise, and the integral of a pointwise larger non-negative function is at least as large, so D does not decrease. □

ATTRİBUTİNG THE CLİMATE-DRİVEN İNCREMENT

To isolate the part of the burden that is due to climate, the heat profile is compared with a counterfactual baseline. Let $WBGT_0(t)$ be the heat profile in the absence of the warming under study and let the warming raise it by an amount $\Delta W(t) \geq 0$, so that the realised profile is given by Equation (4).

$$WBGT_1(t) = WBGT_0(t) + \Delta W(t) \tag{4}$$

The climate-attributable increment of strain is the difference between the cumulative doses computed under the realised and the baseline profiles, given in Equation (5). It measures the additional physiological burden that the worker carries because of the warming, holding the task and the working hours fixed.

$$\Delta D = D_1 - D_0 = \int_0^T (\sigma(WBGT_0 + \Delta W, M) - \sigma(WBGT_0, M))\ dt \tag{5}$$

When the warming increment is small, the change can be approximated to first order by the integral of the heat sensitivity of strain, as in Equation (6), where $\beta(t) = \partial\sigma / \partial WBGT$ is the marginal strain per unit of wet-bulb globe temperature at time t. The marginal form makes explicit that the climate burden depends both on the size of the warming and on how steeply strain responds to heat, which is greatest in the hot part of the working day.

$$\Delta D \approx \int_0^T \beta(t)\ \Delta W(t)\ dt, \quad \beta(t) = \frac{\partial\sigma}{\partial WBGT} \tag{6}$$

Proposition 2 (Non-negativity and a convex lower bound). If σ is non-decreasing in the wet-bulb globe temperature then $\Delta D \geq 0$. If, in addition, σ is convex in the wet-bulb globe temperature, then the marginal approximation underestimates the true increment, that is $\int_0^T \beta(t)\ \Delta W(t)\ dt \leq \Delta D$.

Proof. Non-negativity holds because $\Delta W \geq 0$ and σ is non-decreasing, so the integrand in Equation (5) is non-negative at every time and the integral is non-negative. For the bound, convexity of σ in the wet-bulb globe temperature gives, for each fixed t, the supporting-line inequality $\sigma(WBGT_0 + \Delta W, M) - \sigma(WBGT_0, M) \geq \beta(t)\ \Delta W(t)$, since the slope β evaluated at the baseline underestimates the secant slope of a convex function. Integrating this pointwise inequality over $[0, T]$ yields $\Delta D \geq \int_0^T \beta(t)\ \Delta W(t)\ dt$. The linear estimate is therefore conservative, and the true climate burden is at least as large. □

OPTİMAL WORK-REST ALLOCATİON UNDER A STRAİN CEİLİNG

Heat is managed in practice by interrupting work with rest, and the framework determines the allocation that protects the worker while preserving the most productive time. Let $u(t) \in [0, 1]$ denote the fraction of the instant t that is spent working, so that the total productive time over the shift is the integral of u. A physiological limit caps the cumulative strain that may be incurred at a safe ceiling D_{max}. The allocation problem is then the maximisation of Equation (7).

$$max_u \int_0^T u(t)\ dt \quad subject\ to \quad \int_0^T u(t)\ \sigma(t)\ dt \leq D_{max},\ 0 \leq u(t) \leq 1 \tag{7}$$

Proposition 3 (The optimal schedule is threshold-based). The work-rest allocation that maximises productive time under the strain ceiling is of threshold form: there is a critical strain level σ^* such that the worker works fully when the instantaneous strain is below it and rests when it is above, as in Equation (8). Rest is therefore assigned to the hottest and most demanding part of the shift.

$$u^*(t) = 1\ if\ \sigma(t) \leq \sigma^*; \quad u^*(t) = 0\ if\ \sigma(t) > \sigma^* \tag{8}$$

Proof. The problem is linear in u with a single integral constraint, so the Lagrangian is $\int_0^T u(t)\ dt - \lambda(\int_0^T u(t)\ \sigma(t)\ dt - D_{max})$ for a multiplier $\lambda \geq 0$. The integrand is $u(t)\ (1 - \lambda\ \sigma(t))$, which is maximised over $u(t) \in [0, 1]$ by setting $u(t) = 1$ when $1 - \lambda\ \sigma(t) > 0$ and $u(t) = 0$ when $1 - \lambda\ \sigma(t) < 0$. Writing $\sigma^* = 1 / \lambda$ gives the threshold rule of Equation (8), and λ is fixed by the binding constraint $\int_{\sigma(t) \leq \sigma^{\wedge}\{*\}} \sigma(t)\ dt = D_{max}$. Allocating work to the low-strain periods and rest to the high-strain periods is thus optimal, which places rest in the hottest hours. □

The maximum amount of work that can be performed safely follows immediately. In the limiting case of a uniform environment the safe working time is the share of the shift for which the worker retains capacity, given in Equation (9), where $w = 1 - \sigma$ is the work-capacity fraction at the prevailing heat and workload.

$$T_{safe} = T\ w(WBGT, M), \quad w = 1 - \sigma \tag{9}$$

Proposition 4 (Climate erodes safe working time). The work-capacity fraction w is non-increasing in the wet-bulb globe temperature, so warming reduces the safe working time: the climate-driven change $\Delta w = w(WBGT_0 + \Delta W, M) - w(WBGT_0, M) \leq 0$, and the lost safe time is $T\ |\Delta w|$.

Proof. Since $w = 1 - \sigma$ and σ is non-decreasing in the wet-bulb globe temperature, w is non-increasing in it; a warming increment $\Delta W \geq 0$ therefore cannot raise w, so $\Delta w \leq 0$. Multiplying by the shift length T gives the loss of safe working time, which is the operational counterpart of the climate-attributable strain increment of Section 4. □

PROPOSED VALİDATİON PATHWAY

The framework is designed to be estimated from measurements that occupational practice already collects. The wet-bulb globe temperature is recorded with standard instruments at the workplace following the screening procedure of ISO 7243, the metabolic rate of the task is classified using the activity categories of the ergonomics standards, and the instantaneous strain is obtained by inserting these into a published relation for physical work capacity (Foster et al., 2021). Integrating the measured strain over observed shifts yields the cumulative dose, and repeating the measurement across seasons or across hotter and cooler sites provides the contrast needed to estimate the climate-attributable increment. Projected warming can be represented by adding downscaled increments of the wet-bulb globe temperature to the baseline profile, in the manner used to estimate future heat exposure of working populations (Kjellstrom et al., 2018).

A validation study would proceed in three stages that mirror the framework. It would first confirm that the modelled instantaneous strain tracks measured physiological markers such as core temperature and heart rate in the target workforce, drawing on the field tradition that has documented these relationships in agricultural labour (Sahu et al., 2013). It would then estimate the climate-attributable increment by comparing cumulative doses across temperature conditions. It would finally test the threshold work-rest schedule of Section 5 against the schedules workers actually adopt and against the protective effect of alternative allocations, alongside the wider set of adaptation options whose costs and benefits have begun to be assessed (Day et al., 2019). The agricultural workforce that sustains food production is the natural population for such a study, since it combines high metabolic load, outdoor exposure and direct relevance to the themes of food and climate.

LİMİTATİONS AND ETHİCAL CONSİDERATİONS

The framework simplifies a complex physiology and should be read accordingly. The instantaneous strain is a group-level relation, and individual workers differ in fitness, acclimatisation, hydration, age and health, so a schedule that protects the average worker may not protect the most vulnerable; the strain ceiling should therefore be set conservatively. The model treats heat and workload as the drivers of strain and does not represent every modifier, such as clothing, air movement and recovery between shifts, although these enter through the physical-work-capacity relation and can be incorporated as the relation is refined. The attribution compares a realised heat profile with a counterfactual baseline, and the credibility of the attribution depends on the credibility of that baseline.

The framework also carries an ethical orientation that should be made explicit. Its purpose is to protect workers by quantifying the additional burden that climate imposes and by allocating rest where it is most needed, and it should not be used to justify intensifying work up to the strain ceiling or to transfer the cost of heat onto workers through pay tied to output. The maximum safe working time is a protective limit and not a target, and the gains in safety it identifies are most needed by the low-income outdoor workforce that is least able to avoid heat. Used in this spirit, the framework supports the design of humane work-rest schedules and of the broader protections that a warming climate will require.

CONCLUSİON

This paper has proposed a framework for quantifying the additional ergonomic strain that climate change imposes on workers and for translating it into protective schedules. The

environmental and internal heat loads are combined into an instantaneous strain, the strain is integrated over the shift into a cumulative dose, the climate-attributable increment of that dose is obtained against a counterfactual baseline and a marginal approximation, and the work-rest allocation that maximises productive time under a strain ceiling is shown to be of threshold form. The framework was shown to produce bounded and monotone strain, a non-negative climate increment that its linear approximation conservatively underestimates, an optimal schedule that rests workers in the hottest hours, and a safe working time that falls as heat rises.

The contribution is methodological. The framework offers a transparent means of attributing the extra strain that warming adds to physical work and of converting that strain into work-rest schedules that protect the worker, with the agricultural workforce that underpins food production as the population of first concern. A validation pathway based on standardised field measurement is set out as the next step, together with extensions that represent individual variation and the fuller set of adaptation options. The central result holds without field estimation: once strain is accumulated and attributed, the additional burden that climate places on workers can be measured and, through the optimal schedule, acted upon.

DECLARATİONS

Ethics. This study is methodological and involves no human participants and no personal data; it required no ethical approval. The proposed validation study would require ethical approval and informed consent before any measurement of workers, and the framework is intended to protect workers rather than to intensify their exposure.

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Data availability. No data were generated or analysed in this methodological study.

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ATMOSPHERIC CHANGES DURING POTATO STORAGE IN A CLOSED CONTAINER

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ABSTRACT

This study evaluates the evolution of gas composition, relative humidity, and temperature during potato storage in a closed biocontainer. The experimental results emphasize a rapid modification of the storage atmosphere caused by potato respiration. Carbon dioxide concentration increased almost linearly during the first 250 minutes, rising from values close to

0 ppm to over 15,000 ppm after approximately 4 hours. After this point, the increase became faster, reaching about 27,000 ppm near the end of the monitoring period. This confirms that CO_2 accumulation is significant in closed storage systems and may become a limiting factor for maintaining product quality.

By contrast, oxygen concentration followed an opposite trend. At the beginning of the experiment, the O_2 level was about 19.2–19.3%. During storage, it gradually decreased and reached approximately 18.6–18.7%, after which it remained close to an equilibrium value. This decrease is associated with the respiratory activity of the potatoes, which consume oxygen and release carbon dioxide.

Relative humidity also changed considerably. It increased rapidly during the first stage of storage, from around 45% to more than 85%, and then stabilized mostly between 90% and 95%. Temperature varied during the experiment, generally ranging between 20°C and 25°C, with repeated fluctuations that influenced humidity and gas concentration dynamics.

The results demonstrate that, in a closed container, potatoes quickly create a modified atmosphere characterized by high CO_2 concentration, reduced O_2 level, and elevated relative humidity. These numerical changes highlight the need for proper ventilation and continuous monitoring during storage. Controlling CO_2, O_2, humidity, and temperature is essential to reduce physiological stress, limit quality losses, and improve post-harvest storage stability.

Keywords: potato storage, closed container, relative humidity

DYNAMIC ASSESSMENT OF GAS EXCHANGE AND MICROCLIMATE EVOLUTION IN CLOSED STORAGE SYSTEMS FOR FRESH CUCUMBERS

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ABSTRACT

This study presents experimental results of the bio-physicochemical behavior of fresh cucumbers stored in a closed bioreactor system, with emphasis on the dynamic evolution of carbon dioxide, oxygen, relative humidity, and temperature. Continuous monitoring was performed during the first 48 hours after enclosure and prolonged over several days in order to evaluate the physiological response of the vegetables under restricted gas exchange conditions.

The results showed that cucumber respiration rapidly modified the internal atmosphere of the storage chamber. During the first 48 hours, carbon dioxide concentration remained relatively low, followed by a pronounced inflection point at approximately 2940 minutes, when CO_2 increased sharply from about 600 ppm to nearly 10,000 ppm. This transition indicates an intensification of metabolic activity and the establishment of a modified atmosphere inside the closed system. A similar change was observed for relative humidity, suggesting a close relationship between respiration, transpiration, and moisture accumulation.

Oxygen concentration showed an opposite trend, decreasing significantly after the first 48 hours and continuing to decline during the extended storage period. Temperature variations, although relatively small, strongly influenced the humidity profile, especially within the 21–21.5 °C range. In addition, daily light–dark cycles generated visible fluctuations in both humidity and oxygen concentration, confirming the sensitivity of cucumber physiological processes to microclimatic changes.

The study demonstrates that integrated monitoring of gas composition and environmental parameters can provide valuable information for understanding postharvest behavior in fresh vegetables. These findings support the development of intelligent storage systems, predictive control strategies, and improved methods for extending shelf life while maintaining product quality.

Keywords: cucumber storage, closed bioreactor, carbon dioxide, oxygen depletion, relative humidity

INTERACTIVE EFFECTS OF GRAPE CULTIVAR AND DRYING METHOD ON RAISIN QUALITY

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ABSTRACT

Raisins are widely appreciated for their nutritional and health-promoting properties; however, the combined influence of grape cultivar and drying technique on raisin quality requires further investigation. This study assessed the effects of four grape cultivars and three drying methods on morphological, physicochemical, biochemical, and antioxidant characteristics of raisins.

Significant effects ($p < 0.001$) of cultivar, drying method, and their interaction were observed for most evaluated traits. Freeze-drying provided the best preservation of bioactive compounds and antioxidant capacity which exhibited the highest levels of total phenolics, flavonoids, anthocyanins, and antioxidant activity. In contrast, sun-drying resulted in substantial reductions in phenolic compounds and antioxidant potential, accompanied by pronounced berry darkening. Oven-drying showed intermediate performance and was associated with increased soluble solids and lower titratable acidity. Principal component analysis clearly separated samples according to drying method, highlighting the superior ability of freeze-drying to preserve fruit quality attributes. These findings demonstrate that both cultivar selection and drying technique play a crucial role in determining raisin quality. Freeze-drying appears to be the most effective method for maintaining the nutritional and functional properties of raisins and may represent a valuable strategy for producing high-quality dried grape products.

Keywords: Raisin, grape cultivar, drying method, quality attributes.

CLIMATE CHANGE AND INSECT PEST RANGE EXPANSION: IMPLICATIONS FOR GLOBAL FOOD SECURITY

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ABSTRACT

Climate change has emerged as one of the most significant drivers of ecological transformations in the twenty-first century, profoundly influencing the distribution, abundance, and invasion potential of insect pests worldwide. Rising temperatures, altered precipitation patterns, elevated atmospheric carbon dioxide concentrations, and increased frequency of extreme climatic events are creating favorable conditions for the geographic expansion of numerous economically important pest species. These shifts are increasingly threatening agricultural productivity and global food security.

This review examines current evidence regarding the relationship between climate change and insect pest range expansion, with particular emphasis on the ecological mechanisms underlying these distributional shifts. Recent studies indicate that increasing temperatures facilitate pest establishment in higher latitudes and elevations, while milder winters enhance overwintering survival and population growth. Furthermore, climate-induced changes in crop phenology and host plant physiology may improve habitat suitability for herbivorous insects and promote pest outbreaks in previously unaffected regions.

The expansion of insect pests poses substantial challenges for agricultural systems through increased crop losses, greater reliance on chemical pesticides, and heightened risks of transboundary pest invasions. Such impacts are particularly concerning in developing countries, where agricultural production remains highly vulnerable to climatic fluctuations and pest-related damage. In addition, changing climatic conditions may disrupt ecological interactions among pests, host plants, and natural enemies, potentially reducing the effectiveness of existing Integrated Pest Management (IPM) programs.

The findings highlight the urgent need for climate-resilient pest management strategies that integrate ecological monitoring, predictive modeling, early-warning systems, and sustainable agricultural practices. Strengthening international cooperation and incorporating climate adaptation measures into agricultural policies will be essential for mitigating future pest risks and ensuring long-term food security. Understanding the complex interactions between climate change and insect pest dynamics remains a critical priority for safeguarding global agricultural sustainability.

Keywords: Climate change; Insect pests; Range expansion; Agricultural sustainability; Food security; Climate adaptation; Integrated Pest Management

CHANGES IN DIETARY HABITS: ULTRA PROCESSED FOODS AND HEALTH

BESLENME ALIŞKANLIKLARININ DEĞİŞİMİ: ULTRA İŞENMİŞ BESİNLER VE SAĞLIK

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ABSTRACT

In recent years, changes in dietary habits have led to a significant increase in the consumption of ultra-processed foods (UPFs). While UPF consumption constitutes a large proportion of daily energy intake in developed countries, the consumption of these foods is also steadily increasing in developing countries. The aim of this presentation is to evaluate the definition, classification, prevalence of consumption, and health effects of ultra-processed foods in light of the current literature.

This dietary pattern, which includes the consumption of UPFs, is defined in the literature as the Western diet. UPFs are notable for their long shelf life and high content of food additives such as emulsifiers, colorants, sweeteners, preservatives, and flavor enhancers. Generally, UPFs contain high amounts of energy, sugar, salt, saturated fat, and trans fat, while being low in fiber and micronutrients. Examples of such foods include noodles, processed meat products, chips, packaged breads with long shelf lives, and similar products. The sale of packaged products in school canteens and the increase in fast-food consumption raise the risk of exposure to UPFs among children and adolescents.

Various epidemiological studies have shown that the widespread consumption of UPFs may lead to numerous health problems. These include obesity, type 2 diabetes, cardiovascular diseases, certain types of cancer, alterations in gut microbiota, and mental health disorders associated with UPF consumption. Modern living conditions, time constraints, economic factors, the development of the food industry, insufficient and inaccurate knowledge about healthy nutrition, and attention-grabbing advertisements are among the main factors increasing the consumption of these foods. Reducing the consumption of UPFs and preferring minimally processed foods are important for protecting health and preventing chronic diseases.

Keywords: Ultra-processed food, chronic diseases, nutrition

ÖZET

Son yıllarda beslenme alışkanlıklarında meydana gelen değişimler, ultra işlenmiş besinlerin (UİB) tüketiminde önemli artışlara neden olmuştur. Gelişmiş ülkelerde UİB tüketimi günlük enerji alımının büyük bir kısmını oluştururken, gelişmekte olan ülkelerde de bu besinlerin tüketimi gittikçe artmaktadır. Bu bildirinin amacı, ultra işlenmiş besinlerin tanınması, sınıflandırılması, tüketim yaygınlığı ve sağlık üzerindeki etkilerini güncel literatür ışığında değerlendirmektir.

UİBlerin fazla miktarda tüketimini de içeren beslenme tipi literatürde Batı tarzı beslenme olarak tanımlanmaktadır. UİB'ler raf ömrü uzunluğu ve fazla miktarda gıda katkı maddesi içeriği

(emülgatörler, renklendiriciler, tatlandırıcılar, koruyucular ve aroma vericiler gibi) ile dikkat çekmektedir. Genellikle UİB'ler fazla miktarda enerji, şeker, tuz, doymuş yağ, trans yağ ve yetersiz miktarda posa ve mikrobesin öğesi içeriğine sahiptir. Noodle, işlenmiş et ürünleri, cips, paketli ve uzun raf ömrüne sahip ekmekler bu tarz besinlerdir. Okul kantinlerinde satılan paketli ürünler ve fast-food tüketimindeki artış, çocuk ve gençlerin UİB'lere maruz kalma riskini artırmaktadır.

Çeşitli epidemiyolojik çalışmalar, UİB tüketiminin yaygınlaşmasının birçok sağlık sorununa neden olabildiğini göstermektedir. Bu sorunlar arasında obezite, tip 2 diyabet, kardiyovasküler hastalıklar, bazı kanser türleri, bağırsak mikrobiyotası değişiklikleri ve ruh sağlığı bozukluklarının UİB tüketimi ile ilişkisi bulunmuştur. Modern yaşam koşulları, zaman kısıtlılığı, ekonomik faktörler, besin endüstrisinin gelişimi ve sağlıklı beslenme konusunda yeterli ve doğru bilginin olmaması, tüketicinin dikkatini çekecek reklamlar bu besinlerin tüketimini artıran başlıca etmenler arasında yer almaktadır. UİB tüketiminin azaltılması ve minimum işlenmiş besinlerin tercih edilmesi, sağlığın korunması ve kronik hastalıkların önlenmesi açısından önem taşımaktadır.

Anahtar Kelimeler: Ultra işlenmiş besin, kronik hastalıklar, beslenme

SENTIMENT ANALYSIS OF ONLINE CUSTOMER REVIEWS OF ETHNIC RESTAURANTS IN ANTALYA

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ABSTRACT

This study examines online customer reviews of ethnic restaurants in Antalya using text-mining and sentiment analysis to reveal the digital representation of the ethnic restaurant experience. A total of 600 customer reviews from 12 ethnic restaurants in the Kaleiçi, Konyaaltı, and Lara regions were collected from Google and TripAdvisor. The data were processed using a Python-based text preprocessing procedure and analysed using sentiment analysis and word-frequency analysis techniques. The results indicate that customer reviews predominantly reflect positive sentiment, with no significant regional variation. The most frequently repeated expressions are directly related to food taste and quality, demonstrating that customer evaluations of ethnic restaurants are primarily based on food quality. In contrast, negative evaluations are mainly associated with service processes, waiting times, and price perceptions. Word frequency and word cloud analyses further confirm that customer discourse is largely focused on food, service, and price-related elements. These findings illustrate how the ethnic restaurant experience is expressed in digital environments and demonstrate that online customer reviews are a significant data source for evaluating this experience. Accordingly, this study contributes to the literature by identifying the key factors shaping customers' evaluations of ethnic restaurants.

Keywords: Ethnic restaurants, online customer reviews, e-WOM, sentiment analysis, text mining, gastronomic experience

INTRODUCTION

As globalization and the growing mobility in tourism have expanded, eating and drinking activities have beyond the satisfaction of a completely physiological requirement and have turned into a way of knowing and experiencing diverse cultures (Mak et al., 2012; Chen et al., 2026). Food and beverage enterprises are perceived not only as physical locations for consumption, but also as social contexts in which humans construct experience, meaning and cultural engagement. In this case, ethnic restaurants function as cultural ambassadors, offering local inhabitants or tourists a taste of different cuisines and cultural characteristics. Ethnic restaurants serve local consumers with cuisine ambience and other symbolic characteristics characteristic of the culture to which they belong unlike other sorts of restaurants. Indeed, previous research underline that ethnic restaurants enable customers to taste a foreign cuisine coupled with the culture it is associated with (Sukalakamala and Boyce, 2007; Tsai and Lu, 2012; Lu et al., 2015). In this sense, ethnic restaurants are important as one of the everyday and accessible ways to get in touch with diverse cultures.

Consumers look for out ethnic restaurants because they want to try flavors that are different from the familiar foods and they anticipate to interact with a foreign culture through food (Jang et al., 2012). But this experience cannot be solely described by eating a meal itself. The relevant literature indicates that the ethnic restaurant experience is impacted by food quality, restaurant atmosphere, service procedure and perception of authenticity (Jang et al., 2011; Jang et al.,

2012; Tsai and Lu, 2012; Lu et al., 2015). In particular, authenticity seems to be one of the main factors in the evaluation of ethnic restaurants. Authenticity is a cultural performance that uses regional ingredients and traditional food preparation methods, presented in an integrated way with environmental factors, such as the restaurant's exterior, interior architecture, music, and the attitude of the staff (Tsai and Lu, 2012; Aybek and Özdemir, 2022). Meanwhile, other research reveal that in the ethnic restaurant experience, customers pay more attention to the flavor of the cuisine, the appropriateness of the ingredients and the overall quality of the dish (Sukalakamala & Boyce, 2007; Tsai & Lu, 2012; Jang et al., 2012). Prior studies have demonstrated that authenticity triggers good feelings (e.g., joy and excitement) in customers, which increases perceived value and revisit intention (Lu et al., 2015; Mascorella et al., 2020). But in considering customers' expectations, often quality and taste of the meal are more decisive than environmental authenticity aspects like interior design or mood (Clemes et al., 2013; Premordia and Gal, 2023).

The ethnic restaurant experience can also be differently assessed according to the customers' cultural backgrounds and personal traits. It is observed that customers from different cultures value different aspects within the same restaurant experience. For instance, ratings from Japanese consumers focus more on meal quality and price justice, whereas Western customers pay more attention to service and atmosphere (Nakayama and Wan, 2019). Similarly, while food neophobia has been shown to decrease the intention to consume ethnic food, factors such as openness to different cultures, food involvement, and food neophilia have been shown to increase willingness to consume ethnic food (Camarena et al., 2011; Shi et al., 2022; Ting et al., 2016; Mascarello et al., 2020; Çetin, 2024). The results suggest that the ethnic restaurant experience is not a shared experience among all consumers, but is also influenced by the psychological and cultural features of the customers.

However, ethnic restaurants also can have wider implications that are not restricted to the consumer experience in restaurants. The literature shows that the interest in the ethnic food and the intention to consume it may also affect the intention to visit the linked the nation (Shi et al., 2012). Similarly, the ethnic restaurant experience is mentioned as a factor in the formation of the cuisine image of the place and the formation of future tourism intents (Lu et al., 2015; Aybek and Özdemir, 2022). Hence, ethnic restaurants can be viewed not only as places where food is eaten, but also as contact sites that shape the impression of the cuisine and culture of a certain country. Thus, the ethnic restaurant experience is one where the link between gourmet intake and cultural representation is made clear.

With the increasing rate of digitalization, customers' evaluations of their restaurant experiences have become progressively more visible in online dining establishments. In other terms, electronic word of mouth i.e. e-WOM allows customers to share their experiences with others through written and visual information. In this process, online customer evaluations have become an essential data source where happiness, criticism, praise and expectations on the restaurant experience are communicated directly in users' own words. Digital sharing is also noted to be not only a process of transferring information, but also one that affects the visibility of the experience, its being remembered and its circulation in a social sense (Zhu et al., 2019; Wachyuni and Yusuf, 2021; Huang et al., 2021; Dyce et al., 2024; Magdy and Hassan, 2025; Fathy et al., 2025). At the same time, the influence of digital sharing on experience is not always in the same direction; other research claim that this relationship is not direct but rather indirect and context-dependent (Zhu et al., 2019; Xiong et al., 2023; Dyce et al., 2024; Magdy and Hassan, 2025). Thus, online information not only reflects the experience but also has the function of determining what aspects of the experience become apparent.

When the associated research is examined together, it is apparent that the studies on ethnic restaurants are mostly carried out on factors such as authenticity, food quality, service,

atmosphere, satisfaction, behavioral intention, and brand value. On the other hand, research on digital sharing focuses primarily on food photo sharing, identity presentation, social approval, remembering the experience and effects of the experience (Jang et al., 2011; Jang et al., 2012; Lu et al., 2015; Nakayama and Wan, 2019; Zhu et al., 2019; Huang et al., 2021; Dyce et al., 2024; Magdy and Hassan, 2025; Fathy et al., 2025). However, there is a lack of studies on the ethnic restaurant experience through online customer evaluations especially based on the orientation of sentiment and the concepts that stand out in the reviews. That is, there is a need to more clearly show discursive appearance of the ethnic restaurant experience in the internet environment, assessment factors, around which consumers discuss, and how these features are related with positive, negative or neutral attitudes.

In this context, the purpose of this study is to analyze online customer reviews of ethnic restaurants in Antalya by text mining and sentiment analysis approaches. The study reveals the sentiment orientations of the customer reviews and examines through which elements the ethnic restaurant experience is evaluated by identifying the expressions that stand out in the review texts. Within the purpose of the research, the online reviews of ethnic restaurants in Kaleiçi, Konyaaltı and Lara districts, which are key tourism centers in Antalya, were evaluated; the sentiment orientations of the customers, the satisfaction aspects and the grounds for complaint were compared on a regional basis. Therefore, the study attempts to make the reflections of the ethnic restaurant experience in the digital world obvious through the case of Antalya.

CONCEPTUAL FRAMEWORK

The Ethnic Restaurant Experience

The ethnic restaurant experience is not limited to the consumption of foods belonging to a different national cuisine. The relevant literature emphasizes that ethnic restaurants are businesses that give customers the opportunity to connect with a different culture (Jang et al., 2011; Sukalakamala and Boyce, 2007). For this reason, the ethnic restaurant experience is treated as a type of the general dining experience within the restaurant context and is evaluated in terms of food quality, restaurant atmosphere, and the service process (Jang et al., 2012; Tsai and Lu, 2012). At the heart of the ethnic restaurant experience lies the desire of individuals to discover new flavors different from the cuisines they are familiar with, and the motivation to experience a foreign culture through food (Jang et al., 2012).

The ethnic restaurant experience depends on a sense of authenticity. Authenticity is a key feature for differentiating ethnic restaurants from other categories of restaurants (Jang et al., 2011; Lu et al., 2015). The authenticity is also reflected in the preparation of foods with local ingredients and traditional cooking methods, and is also presented in an integrated way together with environmental elements such as the restaurant's exterior, interior decoration, the music played, and the regional clothing of the staff (Lu et al., 2015; Aybek and Özdemir, 2022). Others focus on the customer’s impression (Jang et al., 2012; Tsai and Lu, 2012), while some research address the authenticity from the technique of food preparation and the materials utilized. Literature studies show that an authentic atmosphere sets off positive feelings such as pleasure and excitement in customers, and these positive feelings have a direct and strong impact on behavioral intentions such as returning to the restaurant or recommending it to others (Aybek and Özdemir, 2022; Clemes et al., 2013; Ingerson and Kim, 2016).

The features that customers value in the ethnic restaurant experience can vary depending to the restaurant concept and client expectations. They demonstrate that buyers focus on the flavor, ingredient compatibility and presentation factors when they assess the experience (Sukalakamala and Boyce, 2007; Tsai and Lu, 2012; Jang et al., 2012). The environment and

such enhance the experience but the quality of the cuisine is more important as for the overall review. Expectations across restaurant types also vary each consumer. While setting and environmental authenticity are the focus point at the rich ethnic restaurants, the quality and commitment to the original of the food are immediately at the core of the experience in casual-dining restaurants (Jang et al., 2012; Clemes et al., 2013). Therefore, the ethnic restaurant experience is considered a food service experience.

The service process is also an important component of the ethnic restaurant experience. The customer's experience is affected by the way the staff communicate and their hospitality and capacity to deliver information about the menu (Tsai and Lu, 2012; El-Said et al., 2021). The quality of service improves the relationship that the customer develops with the restaurant and contributes to the rating of the experience. This suggests that the ethnic restaurant experience is influenced not just by the physical factors but also by the service process. The literature also discusses the consequences of the ethnic restaurant experience. It is argued that characteristics such as authenticity and food quality create favorable emotions in customers and these emotions become behaviors such as intention to revisit and to recommend (Jang et al., 2011; Jang et al., 2012). Likewise, it is observed that the perceived value and satisfaction level also affect the consumer behavior (Lu et al., 2015; El-Said et al., 2021). For this reason, the experience of ethnic restaurants is considered not only a judgment at the moment of consumption but also a process that influences behaviors following the moment of consumption.

Moreover, consumers' psychological qualities and cultural tendencies also directly impact the ethnic restaurant experience. The relevant literature indicates that food neophobia, the tendency of food rejection due to reluctance to try new and unfamiliar foods, decreases the willingness to consume ethnic food, while food quality, the service process, and the features of the restaurant are more decisive for those who are interested in new flavors (Ting et al., 2016; Mascarello et al., 2020; Premordia and Gal, 2023). It is also suggested that the level of openness to other cultures and the disposition to communicate interculturally among people increases the intention to eat in ethnic restaurants (Camarena et al., 2011; Nakayama and Wan, 2019). Relevant evidence suggests that the eating of ethnic food is related to various behavioral outcomes. Interest in ethnic food and intention to consume ethnic food can affect intention to visit the relevant nation (Shi et al., 2012). Furthermore, ethnic food consumption is found to be related to people's social surroundings and cultural relationships (Camarena et al., 2011). These assessments of the ethnic restaurant experience render the question of how this experience is represented and shared by customers essential.

E-WOM in the Digital Environment and Online Customer Reviews

The proliferation of digitalization has made the internet platforms where consumers exchange their assessments of restaurant experiences essential sources of electronic word of mouth. The online consumer reviews on these platforms are a valuable data source in the sense that they represent customers' happiness, criticism, and evaluations of their experiences directly in users' own words. In this sense, online reviews render visible the characteristics through which the restaurant experience is appraised. The e-WOM material formed by individuals in online environments is said to be influenced by their cultural features (Nakayama and Wan, 2019). It is also claimed that evaluation criteria of customers from different cultures are varied (Lu et al., 2015). This illustrates that online customer reviews not only mirror the experience but also expose disparities in rating criteria.

Different findings are reported on the impact of digital sharing on the experience process (Magdy and Hassan, 2025; Dyce et al., 2024; Zhu et al., 2019; Xiong et al., 2023; Fathy et al., 2025). Digital sharing supports the experience in some research. Zhu et al. (2019) found that the sharing behavior is related to the dining experience and brand rating. Similarly, Xiong et al.

(2023) find that the behavior of shooting and sharing food images is related to the satisfaction of the event and to revisit intention, under certain situations. According to Fathy et al. (2025), digital sharing raises the visibility of the experience, consequently promoting remembering it. On the other hand, several research reveal the nonexistence of a direct effect of digital sharing on the experience. As to Magdy and Hassan (2025), the influence of social media involvement on the experience is connected to social and cognitive aspects. On the other hand, Dyce et al. (2024) contend that in some circumstances digital sharing can alter the flow of the experience. When the results are summarized, the impact of digital sharing on experience is not unidirectional.

Magdy and Hassan (2025) and Dyce et al. (2024) explain that in the digital world, e-WOM is not just in the form of texts, but also visual sharing. In the digital world, one of the ways the experience is communicated is through food photo sharing, which is known as foodstagramming in the literature (Magdy and Hassan, 2025). These shares are related to individuals' processes of self-expression, social engagement, and social acceptability (Dyce et al., 2024; Huang et al., 2021). Digital sharing behavior is also said to be connected with several motives (Wachyuni and Yusuf, 2021; Huang et al., 2021). In this perspective, digital sharing is considered as a method of sharing the experience by consumers and sharing themselves. Digital shares are also connected to the memory of events (Wachyuni and Yusuf, 2021; Dyce et al., 2024; Fathy et al., 2025; Handayani, 2021). The sharing of food images and the feedback to these shares was found to be connected with the evaluations of the experience (Zhu et al., 2019). Moreover, it is found that, when sharing activity is frequent in online environments, this action is connected with enjoyment of the experience and with revisit intention (Xiong et al., 2023). These results indicate that the content conveyed in the digital world is not limited to the moment in which the event is lived.

At this stage, online consumer reviews are the literary dimension of digital sharing. Reviews are the content where customers directly express their judgment of their experience. Therefore, online customer reviews are an important data source that reveals through which factors the restaurant experience is appraised. In particular, for ethnic restaurants, these reviews expose the evaluation of consumers about food, service method, atmosphere, and price. Digital sharing is said to help the experience to be socially shared and become content that might affect others' decisions (Handayani, 2021; Huang et al., 2021; Magdy and Hassan, 2025). Therefore, online customer evaluations are recognized as a significant data source to study reflections of the ethnic restaurant experience in the digital environment.

METHOD

In this study, the text mining approach was used to online customer reviews of ethnic restaurants in Antalya. The research was executed with the sentiment analysis and word frequency analysis methods on the review data. Moreover, word cloud visualizations were made to see the topics that stick out in the reviews. The review data in the analysis process were subjected to phases of data preprocessing, followed by the determination of sentiment orientations of the reviews and the calculation of frequencies of word usage. Hence, the collected findings were assessed in terms of the content characteristics and sentiment distributions of the online customer reviews. The review data gathered in the scope of the study were grouped according to the districts of Kaleiçi, Konyaaltı and Lara in Antalya. The customer reviews of the ethnic restaurants in these districts were considered as separate datasets and the analyses were done at the regional level. The method permits the analysis of customer experience assessments in the context of regional variation.

Data Source, Construction of the Dataset, and Regional Distribution

Online customer reviews of ethnic restaurants in Antalya were used to create the research's dataset. The Google and Tripadvisor websites, where customers post reviews of their dining experiences, served as the foundation for the data source. These technologies make it possible to directly analyze user experiences through language usage. The Kaleiçi, Konyaaltı, and Lara districts served as the basis for the research's examination of ethnic dining establishments in Antalya. These districts are among those where visitor mobility and dining and drinking activities are concentrated. As a result, the study featured 12 restaurants in all, four from each district. Online reviews, carrying an ethnic food identity, and supplying adequate information were taken into consideration when choosing the establishments. In this manner, there were an equal number of dining establishments in each district.

The data collection was collected using user ratings obtained in 2025. Fifty reviews each restaurant were obtained and the analytic method comprised a total of 600 reviews. We have 200 reviews per district. This form enables quantitative balance to be maintained in the dataset and to make consistent comparisons between districts. The reviews were collected before the analysis and put together to one data set. Each restaurant had an equal amount of reviews. This is how the dataset was structured so that comparative analysis could be done at the restaurant and the regional levels. Within this scope, studies were carried out at the district level by combining the reviews of the restaurants in each district. Within the context of regional distinctions it was able to analyze the expressions which are distinguished in the reviews. The eateries studied in the scope of the research were anonymised and addressed with codes. So, R1–R4 were assigned to the Kaleiçi district restaurants, R5–R8 to the Konyaaltı district restaurants, and R9–R12 to the Lara district restaurants. This helps in presenting the judgments in an objective way.

Data Preprocessing Process

In the scope of the research, online customer evaluations gathered from the Google and Tripadvisor platforms were passed through the data preprocessing steps before being included in the analytic procedure. In text mining investigations, the direct use of raw data in the analysis may limit the accuracy and interpretability of the analysis results . Therefore, data cleaning and text normalization processes are regarded as basic steps in text-based analysis (Uysal and Gunal, 2015; Miner et al., 2019; Feldman, 2019). Therefore, the review data used in the research were arranged before analysis and transformed into a standard textual data structure. The Python programming language was used for the data preparation processes. The dataset was organized and loaded into the analytic environment using the pandas library (McKinney, 2022). The re module was used in the text cleaning step to remove links, numeric expressions, punctuation marks and special characters in the review texts from the dataset. This technique helps to reduce the disparities caused by the same notion being conveyed in multiple formats and to eliminate disordered structures in the texts (Feldman, 2019).

The terms with low distinguishing value in the texts were identified for analysis using the NLTK package. Within this context, stop-word lists were generated for Turkish, English and German languages and the ubiquitous but low-information terms such as conjunctions, prepositions and pronouns were excluded from the dataset. Stop-word cleaning can make analysis results accessible in text mining investigations (Miner et al., 2019; Uysal and Gunal, 2015). For the language detection activities, the langdetect library was utilized because the reviews may be written in multiple languages. This operation ensures that the multiple language structure of the data set is considered during the analysis process (Cambria et al., 2018). The TextBlob library was used to analyze the linguistic aspects of the text data and to identify the sentiment

orientations. One of the tools that permits the analysis of the sentiment orientation and the linguistic aspects of text data is TextBlob (Medhat et al., 2014; Cambria et al., 2018).

WordCloud and matplotlib libraries were utilized for visualization of word frequency analysis. These methods allow for the visualisation of the most used words in the texts, and ease the identification of the themes that stand out in the reviews (Kucher and Kerren, 2015; Heimerl et al., 2016). At the end of the preparation phase, the review texts were changed to lower case, links and numerical expressions were cleaned, punctuation marks and special characters were eliminated. Words with poor distinguishing value were excluded from the dataset using stop-word lists . These activities led to the dataset being translated to a text format, on which sentiment analysis and word frequency analyses were carried out. The data preparation method is reported in the text mining literature as decisive for the trustworthiness of the analysis results (Cambria et al., 2018, Miner et al., 2019, Feldman, 2019).

Sentiment Analysis

In this study, a lexicon based sentiment analysis approach was employed to determine the sentiment orientation of online customer reviews. This strategy is based on matching the emotion loaded words in the text with pre-defined positive and negative word lists. Lexicon-based methods are considered to be strongly used in the analysis of texts that include short and direct statements of experience such as user evaluations (Medhat et al., 2014; Cambria et al., 2018). The sentiment analysis was done using Python programming language. In the analytical phase, the reviews were divided into three linguistic groups according to language; Turkish, English and German. Each review text was cleaned, divided into its words and compared to the lists of positive and negative words made for the respective language. This operation resulted in a separate positive and negative score for each review. For each positive word in the text the positive score was increased and for each bad word the negative score was increased. This approach allows to estimate the sentiment orientation depending on the amount of words in the text (Giachanou and Crestani, 2016; Bonta et al., 2019; Mohammad, 2022).

The sentiment classification of the reviews was determined by comparing the positive and negative scores obtained. In cases where the positive score was higher than the negative score, the review was classified as positive; in cases where the negative score was higher, as negative; and in cases where both scores were equal, as neutral. This classification ensures that sentiment orientation is determined not only by the presence of individual words but by the relative density of positive and negative expressions in the text (Kotu and Deshpande, 2019; Mohammad, 2022). Negation expressions were also taken into account during the analysis process. The negation structures identified for Turkish, English, and German were evaluated in a way that reverses the direction of the emotion-laden words following them. This application contributes to determining sentiment orientation more accurately, especially in reviews containing short and direct expressions (Cambria et al., 2017; Mohammad, 2022).

FINDINGS

In this section, the conclusions reached from the analysis of online customer reviews of ethnic restaurants in Antalya within the scope of the research are introduced. The findings are presented as the data obtained as a consequence of the text mining and sentiment analysis applications. At first, essential features of the dataset were assessed and the sentiment orientations of customer reviews were studied on a geographical level. Then, the words that were prominent in the review texts were tackled by applying word frequency analysis and word cloud visualizations. In this respect, conclusions were examined by the means of sentiment distribution and textual content features of customer reviews for ethnic restaurants in Kaleiçi,

Konyaaltı and Lara districts . This assessment demonstrates through which factors consumer experiences are communicated and in which areas the words that stand out in the evaluations are concentrated.

Descriptive Characteristics of the Dataset

The data set utilized in the research is the online customer reviews about the ethnic restaurants operating in Antalya obtained from the Google and Tripadvisor platforms . In this context, 12 restaurants in Kaleiçi, Konyaaltı and Lara districts were included in the research and 50 reviews were obtained from each restaurant. Therefore, the total number of reviews assessed is 600. Looking at the regional distribution of the dataset, we observe that the number of restaurants and reviews is balanced for each area. The regional distribution of the restaurants and the quantity of reviews is shown in Table 1.

Table 1. Regional Distribution of the Research Dataset

Region	Number of Restaurants	Number of Reviews
Kaleiçi	4	200
Konyaaltı	4	200
Lara	4	200
Total	12	600

Sentiment Distribution of Reviews by Region

Within the context of the research, the online customer reviews received were categorized as positive, negative and neutral according to sentiment orientation. Thus, the distribution of the reviews by region was analyzed. The analysis at the regional level indicates the sentiment direction of the picture emerging from the customer reviews on ethnic eateries. Table 2 shows the results of the sentiment distribution of reviews by location.

Table 2. Sentiment Distribution of Reviews by Region

Region	Positive	Negative	Neutral	Total
Kaleiçi	144	18	38	200
Konyaaltı	151	14	35	200
Lara	132	26	42	200
Total	427	58	115	600

The examination of Table 2 reveals that customer evaluations in all three districts are predominantly positive. The customer ratings are mostly good with 427 out of 600 reviews being positive which indicates the positive experience. Although the proportion of bad reviews in the total is small, neutral reviews are composed of reviews that do not have obvious orientation of sentiment. In terms of the number of positive ratings, the Konyaaltı district is the region that stands out when considering the regional distribution. However, in the Lara district bad reviews are seen to be more than the other districts. The distribution of favorable, negative and neutral reviews in the Kaleiçi area is similar to the general pattern. Overall findings show that positive evaluations dominate in all the districts in customer reviews of ethnic restaurants. At the same time, the variation in the distribution of negative and neutral ratings shows that consumer assessments might vary based on the location conditions.

Word Frequency Analysis

Word frequency analysis of online customer evaluations was carried out to discover distinct expressions. The study is based on the identification of the most repeated words in the review texts and shows which expressions excel in user assessments. Word frequency analysis is one

of the primary methods in text mining studies that identifies which points user discourse is centered (Feldman and Sanger, 2007; Aggarwal and Zhai, 2012). In the research the word frequencies were calculated by regional level . Therefore, the reviews of the restaurants in the districts of Kaleiçi, Konyaaltı and Lara were gathered and independent analyses were conducted for each district. This method enables us to compare expressions that are prominent in user evaluations on a geographical level. The analysis results are given in Table 3.

Table 3: Most Frequently Used Positive, Negative, and Neutral Words in Restaurant Reviews by Region

Region	Restaurant Code	Positive	Negative	Neutral
Kaleiçi	R1, R2, R3, R4	Great	Mediocre	Pasta
		Nice	Expensive	Order
		Delicious	Service	Again
		Service	Awful	Person
		Recommend	Bad	Pizza
Konyaaltı	R5, R6, R7, R8	Nice	Order	Short
		Great	Waited	Service
		Smiling	Bad	Chicken
		Thanks	Prices	Waiter
		Recommend	Minute	Game
Lara	R9, R10, R11, R12	Good	Expensive	Order
		Delicious	Service	Chicken
		Recommend	Order	Buttered
		Great	Prices	Service
		Nice	Bad	Sushi

When Table 3 is studied, it is observed that the most commonly used positive sentiments in customer reviews are mostly related to meal quality and general contentment. In all three areas, we find very common expressions such as “great,” “nice,” “delicious,” and “recommend.” This implies that customers tend to communicate their experiences of restaurants through meal assessments. In the analysis of the negative expressions, the reviews seem to be more related to the service process and the price. These aspects can be seen in the words “expensive”, “service”, “bad”, “waited” and “prices”. These results indicate that while overall opinions of the quality of meals are generally good, negative evaluations may be made in specific situations of the service procedure and pricing perception.

On the other hand, the terms in the neutral category usually contain product names and adjectives describing the experience. The expressions such as “pasta,” “pizza,” “chicken,” “sushi,” and “order,” illustrate that the customers communicate the experience in a descriptive manner. These expressions do not have a clear sentiment orientation, but they do give information about the things that stand out in the experience. At the regional level, it is clear that the expressions are mostly localized in the same regions. At the same time, it is to be noted that some expressions are more prominent in some districts. The collected results suggest that the factors of food quality, the service process and price are the basis for the formation of customer reviews. This shows that these three factors are decisive in the consumer ratings.

Word Cloud Findings

In order to visualize the study of the word frequencies, word cloud visualizations were made from the data that was received from the review texts. The word clouds are based on the visual

presentation of the words used with high frequency in the text in a more prominent fashion. This approach allows to better understand the expressions that are prominent in user evaluations (Kucher and Kerren, 2015; Heimerl et al., 2016). In this study, the reviews of the restaurants in the districts of Kaleiçi, Konyaaltı and Lara were considered as different datasets and different word clouds were constructed for each district. This made it feasible to compare the highlighted expressions in user reviews at the regional level. The obtained images are shown in figure 1, figure 2 and figure 3.

Figure 1. Kaleiçi (R1, R2, R3, R4) Word Cloud



When Figure 1 is analyzed, it is observed that some expressions are dominant in the comments of the customers for the restaurants in Kaleiçi district. Positive evaluations use terms such as “nice”, “delicious”, “service”, “venue” and “atmosphere”. It suggests that the customer ratings are mainly driven by the food quality, service, and setting. Words like “mediocre”, “awful”, “expensive”, “slow”, “service” are dominant in negative evaluations. These expressions show that customer discontent is primarily related to the process of service and the pricing. In neutral reviews, you will find words like “pasta”, “pizza”, “order”, “breakfast”, and “products”. Such terms suggest that the reviews are more descriptive of the experience. Overall, the word cloud results for the district of Kaleiçi suggest that the customer reviews focus on the food, service and venue aspects.

Figure 2. Konyaaltı (R5, R6, R7, R8) Word Cloud



When Figure 2 is analyzed, it is apparent that some expressions are prominent in customer reviews of the restaurants in Konyaaltı district. Positive evaluations tend to have words such as “nice”, “delicious”, “thanks”, “venue” and “recommend”. This indicates that the customer’s evaluations are formed through the service experience, the food quality, and the overall satisfaction of the customer. Negative reviews tend to contain words such as “order”, “bad”, “service”, “we waited” and “duration”. These terms indicate that discontent is more related with waiting time and service. Neutral evaluations include words like ” table ” , ” person ” , ” time ” , ” place ” , ” waiter ” . Using such language indicates that the reviews are more descriptive of the experience. The basic results of the word cloud for the Konyaaltı location suggest that the customer reviews revolve around food, the service process, and the overall restaurant experience.

Figure 3. Lara (R9, R10, R11, R12) Word Cloud



When Figure 3 is analyzed, it is evident that some expressions are significant in customer reviews of the restaurants in the Lara district. In good reviews, words such as “delicious”, “great”, “excellent”, “nice”, and “recommend” are prominent. This reveals that the customers’ evaluation is mostly done through the quality of meals and overall contentment. Negative reviews contain words like “expensive”, “order”, “minute”, “we waited”, “slow”. These terms show that the unhappiness is more about the pricing, ordering process, and waiting time. In indifferent reviews we find words like “chicken”, “rice”, “service”, “menu” and “portion.” Such terms show that reviews are expressed more descriptively. The word cloud analysis results of Lara district are reviewed in general and it is seen that customer reviews are oriented around the food quality, pricing and the service procedure.

DISCUSSION

The research results suggest that internet customer reviews of ethnic restaurants in Antalya are mainly good in regards to experience. The most constant favorable phrases in the reviews concern the quality of the meal, showing that, in the ethnic restaurant context, consumers build their judgments mainly on the taste and quality of the cuisine. This finding is in agreement with studies in the literature. Indeed, Sukalakamala and Boyce (2007) suggest that customers put more emphasis on overall flavor and food quality than environmental features in the ethnic restaurant experience. Likewise, Tsai and Lu (2012) pointed out that the quality and authenticity of the cuisine was the major determinant of the desire to repurchase. In contrast, Jang et al. (2012) found that the quality of cuisine is the most significant factor affecting customer ratings in casual ethnic restaurants. Results of the current research suggest that ethnic restaurant consumers in Antalya perceive the food as the key factor when evaluating the experience in this context.

Another key finding of the research is that unfavorable ratings are more centered around the service process and price perception. That sentiments related primarily with the service, waiting time and pricing stand out, indicates that a great culinary experience alone is not enough in ethnic restaurants. According to El-Said et al. (2021), the communication presentation of the service staff is the most important aspect impacting customer satisfaction in ethnic restaurants. In this regard, the predominance of negative assessments connected to the service process in the present study illustrates that satisfaction depends not only on product quality but also on the method the service is provided. Moreover, Nakayama and Wan (2019) propose that the Western clients are especially responsive to service and price aspects of the ethnic restaurant experience. This result is also in line with the fact that the negative assessments focusing on service and waiting time are at the forefront in a location such as Antalya, where international visitor mobility is excessive.

Expressions with regard to venue and environment are also seen in the reviews. But it is known that these factors still remain secondary to the quality of the cuisine and the service process.

Atmosphere authenticity positively influences brand image and perceived quality (Lu et al., 2015). On the other hand, Premordia and Gal (2023) found that atmosphere is a significant factor for customers while choosing ethnic restaurant, but food quality is the key determining factor. In this respect, the present research demonstrates that environmental aspects in ethnic restaurants in Antalya have a supportive function in the experience, but the primary important elements in customer evaluations are food quality and the service process. The research findings also show that online consumer reviews are not only recordings of events of the past. The content quality of online reviews shows how customers make sense of their experiences and how they communicate their experiences to other people. Digital sharing has a vital role in the meaning of culinary experience and social circulation (Handayani, 2021). Conversely, Zhu et al. (2019) argue that digital sharing is related with processes of self-expression and social engagement. Xiong et al. (2023) find that online sharing correlates with experience satisfaction and revisit intention . Under this framework, the online customer reviews analyzed in the present research, in addition to showing the reflections of the ethnic restaurant experience in the digital environment, also have the quality of material that might impact the assessments of possible customers. Thus, the results obtained show that the appearance of the ethnic restaurant experience in the digital environment is largely constructed through food quality, the service process and the perception of price, and that online reviews constitute an important reference an environment in the evaluation of this experience.

CONCLUSION

In this research, within the scope of a text mining and sentiment analysis approach, online customer reviews of ethnic restaurants operating in the Kaleiçi, Konyaaltı and Lara districts of Antalya were examined and the appearance of the ethnic restaurant experience in the digital environment was revealed. The obtained findings are showing that sentiment orientation of customer reviews is mostly positive and there is no significant difference in orientation between districts. Meanwhile, the study results suggest that the customer evaluation is targeted to certain elements. Positive assessments are communicated mostly through the taste and quality of the food and overall satisfaction, whereas negative assessments are related to the service procedure, waiting time and pricing perception. This suggests that the quality of the cuisine and the style of the service are important in the customer’s judgment of the experience of the ethnic restaurant. Therefore, the customer reviews clearly indicate the elements through which the experience is expressed and show that satisfaction with ethnic restaurants is mainly determined depending on food quality and the service process. Based on this, the results collected suggest that ethnic restaurant businesses need to improve on the quality of food, the service procedure, and price perception to maintain customer happiness.

RECOMMENDATIONS AND LIMITATIONS

This research suggests that the study of ethnic restaurant experience through internet customer reviews has theoretical and practical consequences. From the theoretical perspective, future studies are recommended to address the ethnic restaurant experience with the dimensions’ relationships such as food quality, the service process, price perception, and authenticity. These relationships should be tested on different samples. On a practical level, it is crucial for ethnic restaurant operations to assess food quality along with service process and price perception to create a structure that meets customer expectations, especially in service time, staff attitude and pricing to maintain customer satisfaction. Additionally, the research has several drawbacks. The study is limited to some areas of Antalya, the data were gathered from the Google and Tripadvisor platforms and the analyses are based on the reviews in a specified time period. All

these limit the generalizability of the findings. Also, the lexicon-based sentiment analysis approach applied can be seen as a methodological weakness in the sense that it cannot fully capture the contextual meaning of the reviews.

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DEVELOPING SUSTAINABLE PACKAGING MATERIALS FROM CITRUS PEELS

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ABSTRACT

Citrus peels, which are produced in significant quantities in the fruit juice industry, are among the sustainable and renewable bioresources. Utilizing these wastes is important both for reducing the environmental burden and for developing value-added products. Due to the environmental impact of petroleum-based packaging materials, there is increasing interest in biodegradable and renewable packaging materials. In this context, the utilization of agricultural by-products in packaging production is among the noteworthy approaches in terms of sustainability. In this study, film formulations containing sodium alginate, glycerol, and citric acid were prepared using powders obtained from orange and mandarin peels, and biodegradable packaging films were produced by the solution casting method. The physical, optical, and mechanical properties of the produced films were examined, and their potential for use as packaging materials was evaluated.

The results showed that both citrus peels can be used in the production of biodegradable films. While the films exhibited similar physical and optical properties, some structural differences were observed depending on the type of peel used. Orange peel-based films showed higher resistance to water vapor permeability. In terms of mechanical properties, both film types had similar strength values, but films containing orange peel were found to exhibit higher flexibility.

In conclusion, it has been determined that orange and mandarin peels can be utilized in the production of biodegradable films, and both raw materials offer promising properties in terms of sustainable packaging applications. It is believed that this approach can contribute both to the utilization of agricultural by-products and to the development of environmentally friendly packaging materials.

Keywords: biodegradable packaging, citrus peel, sustainability

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DIGITAL AGRICULTURE AND CLIMATE ADAPTATION FOR SUSTAINABLE FOOD SYSTEMS, NUTRITION SECURITY, AND ENVIRONMENTAL RESILIENCE

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ABSTRACT

Digital agriculture has emerged as a transformative approach for addressing the interconnected challenges of climate change, food insecurity, environmental degradation, and nutritional deficiencies. The integration of advanced technologies such as artificial intelligence (AI), Internet of Things (IoT), remote sensing, big data analytics, digital twins, and precision agriculture provides unprecedented opportunities to enhance agricultural productivity while promoting sustainability and resilience. This study examines the role of digital agriculture in supporting climate adaptation, strengthening sustainable food systems, improving nutrition security, and enhancing environmental resilience. Drawing on recent literature and a simulated quantitative assessment, the study explores how digital technologies contribute to climate-smart agricultural practices, optimize resource utilization, reduce greenhouse gas emissions, and improve food availability and accessibility. Evidence indicates that digital agriculture enables real-time monitoring of crops, soil conditions, water resources, and climate variables, facilitating informed decision-making and adaptive farm management. Furthermore, digital innovations enhance supply chain efficiency, reduce post-harvest losses, and support the production of nutrient-rich foods required for healthy populations. Simulated findings suggest that farms utilizing integrated digital agriculture technologies achieved a 28.4% increase in crop productivity, a 23.7% reduction in water consumption, a 17.9% reduction in greenhouse gas emissions, and a 21.6% improvement in household food security indicators compared with conventional farming systems. The study concludes that digital agriculture represents a critical pathway toward achieving climate resilience, sustainable food production, improved nutritional outcomes, and environmental sustainability. Policymakers, researchers, and agricultural stakeholders must collaborate to expand digital infrastructure, enhance technological accessibility, and strengthen capacity-building initiatives to ensure equitable and sustainable agricultural transformation globally.

Keywords: Climate Adaptation; Digital Agriculture; Environmental Resilience; Nutrition Security.

INTRODUCTION



Agricultural systems worldwide face unprecedented challenges resulting from climate change, environmental degradation, population growth, and increasing food demand. Rising temperatures, irregular precipitation patterns, extreme weather events, soil degradation, biodiversity loss, and water scarcity continue to threaten agricultural productivity and global food security. These challenges have significant implications for nutrition security, particularly in developing regions where agricultural livelihoods remain highly vulnerable to climate variability. In response, digital agriculture has emerged as a transformative paradigm that integrates advanced information and communication technologies into agricultural production systems to improve efficiency, sustainability, and resilience. Digital agriculture encompasses precision farming, artificial intelligence, machine learning, Internet of Things (IoT) sensors, remote sensing technologies, geographic information systems, blockchain applications, big data analytics, and digital twin systems that facilitate data-driven decision-making across agricultural value chains (Balasundram et al., 2023). Recent studies indicate that these technologies enhance productivity while reducing environmental impacts by optimizing resource utilization, minimizing waste, and supporting climate-smart agricultural practices (Raihan, 2024). Furthermore, digital agriculture contributes to sustainable food systems by improving crop monitoring, disease detection, irrigation management, and supply chain efficiency, thereby increasing food availability and reducing post-harvest losses. The growing adoption of climate-smart agriculture has also demonstrated significant potential for enhancing farmers' adaptive capacity while simultaneously contributing to greenhouse gas mitigation and sustainable development goals (Ma & Rahut, 2024). Digital innovations increasingly support nutritional security through improved food production planning, diversification of crops, precision nutrient management, and better market access for smallholder farmers. Emerging technologies such as digital twins and AI-driven predictive systems further strengthen environmental resilience by enabling real-time monitoring of ecosystem conditions and climate-related risks (Ametefe et al., 2024). Despite these promising developments, challenges related to digital infrastructure, affordability, technological literacy, and policy frameworks continue to limit widespread adoption, particularly among resource-constrained farming communities. Therefore, understanding the role of digital agriculture in climate adaptation and sustainable food system transformation remains a critical research priority. This study investigates how digital agriculture contributes to climate adaptation, nutrition security, sustainable food systems, and environmental resilience, providing evidence-based insights for policymakers, researchers, and practitioners seeking to strengthen agricultural sustainability in an era of accelerating climate change.

LITERATURE REVIEW

Digital Agriculture as a Driver of Climate-Smart Food Systems

Digital agriculture has become a fundamental component of climate-smart food systems by enabling farmers to improve productivity, adapt to climate variability, and reduce environmental impacts through data-driven decision-making. Climate-smart agriculture (CSA) seeks to simultaneously increase agricultural productivity, strengthen resilience to climate change, and reduce greenhouse gas emissions where possible. The integration of digital technologies into agricultural systems has significantly accelerated the implementation of CSA principles by providing real-time information that supports adaptive farm management and sustainable resource utilization. According to Balasundram et al. (2023), digital agriculture encompasses a wide range of technologies, including precision farming, artificial intelligence (AI), geographic information systems (GIS), remote sensing, drones, and Internet of Things (IoT) devices that facilitate continuous monitoring of agricultural conditions. These technologies enable farmers to optimize irrigation, fertilizer application, pest management, and harvesting operations, thereby improving efficiency and reducing environmental degradation. Raihan (2024) observed that precision agriculture technologies contribute significantly to sustainable food production by reducing unnecessary input use while maintaining or increasing crop yields. Through sensor-based monitoring systems and predictive analytics, farmers can identify crop stress, soil nutrient deficiencies, and disease outbreaks before significant losses occur. This proactive approach enhances agricultural resilience in regions experiencing climate-related challenges such as droughts, floods, and heat stress. Similarly, Ma and Rahut (2024) emphasized that climate-smart digital technologies improve farmers' adaptive capacity by providing accurate weather forecasts, climate risk assessments, and decision-support systems that facilitate timely agricultural interventions. Recent advances in digital twin technology have further strengthened climate adaptation efforts within agricultural systems. Ametefe et al. (2024) explained that digital twins create virtual representations of agricultural environments, allowing farmers and researchers to simulate various climate scenarios and evaluate potential management strategies before implementation. These innovations support evidence-based planning and enhance resilience against climatic uncertainties. Furthermore, digital agriculture contributes to sustainable food systems by reducing resource wastage, improving supply chain transparency, and enhancing food quality management. The convergence of digital technologies and climate-smart agricultural practices therefore represents a transformative pathway toward sustainable food production. Collectively, existing literature demonstrates that digital agriculture strengthens agricultural resilience, promotes environmental sustainability, and enhances the adaptive capacity of food systems, making it a critical component of future climate adaptation strategies.

Digital Technologies and Nutrition Security Enhancement

Nutrition security extends beyond food availability to encompass consistent access to safe, diverse, and nutritious foods that support healthy and active lives. Climate change, population growth, urbanization, and disruptions in agricultural supply chains have intensified global concerns regarding nutritional deficiencies and food quality. In this context, digital agriculture has emerged as a critical enabler of nutrition-sensitive food systems by improving agricultural productivity, promoting crop diversification, enhancing food distribution networks, and reducing post-harvest losses. According to Klerkx and Rose (2020), digital technologies facilitate informed decision-making throughout agricultural value chains, enabling producers to respond effectively to changing consumer demands and nutritional requirements. Through digital platforms, farmers gain access to information regarding crop selection, nutrient management, market opportunities, and climate conditions, thereby improving the production of nutrient-dense foods. Artificial intelligence (AI), machine learning, and big data analytics

have significantly strengthened efforts to improve nutritional outcomes. Wolfert et al. (2021) argued that data-driven agricultural systems enable precise monitoring of crop growth, nutrient availability, and environmental conditions, leading to improved food quality and productivity. Precision agriculture technologies support optimal fertilizer application and soil health management, which directly influence the nutritional composition of crops. Similarly, digital advisory services provide farmers with recommendations on crop diversification strategies that contribute to dietary diversity and improved household nutrition. Blockchain technology has also gained attention for its role in strengthening nutrition security through enhanced traceability and transparency within food supply chains. Kamilaris et al. (2023) noted that blockchain systems improve consumer confidence by enabling verification of food origin, quality, and safety standards. Such transparency is increasingly important in ensuring access to safe and nutritious foods while minimizing food fraud and contamination risks. Furthermore, digital marketplaces connect smallholder farmers directly with consumers and institutional buyers, reducing transaction costs and increasing access to fresh agricultural products. Recent studies have demonstrated that digital agriculture contributes significantly to reducing food losses and waste. According to the Food and Agriculture Organization (FAO, 2023), digital monitoring systems improve storage management, logistics coordination, and transportation efficiency, thereby preserving food quality and nutritional value throughout supply chains. Consequently, digital technologies not only increase agricultural productivity but also strengthen nutrition security by enhancing food accessibility, quality, diversity, and affordability. The growing integration of digital innovations into food systems therefore represents an important strategy for addressing global nutrition challenges while promoting sustainable agricultural development and public health outcomes.

Artificial Intelligence, IoT, and Precision Agriculture for Climate Adaptation

Artificial Intelligence (AI), the Internet of Things (IoT), and precision agriculture technologies have become central components of modern climate adaptation strategies in agricultural systems. These digital innovations provide farmers with real-time information, predictive analytics, and automated decision-support tools that improve resilience against climate-related risks. As climate change continues to increase the frequency of droughts, floods, heatwaves, and pest outbreaks, the adoption of intelligent agricultural technologies has become increasingly important for sustaining food production and environmental stability. According to Javaid et al. (2023), AI-driven agricultural systems analyse vast amounts of environmental, climatic, and agronomic data to generate accurate predictions regarding crop growth, pest infestations, disease outbreaks, and weather variability. Such predictive capabilities enable farmers to implement timely interventions that minimize losses and improve productivity. The Internet of Things (IoT) further enhances climate adaptation by facilitating continuous monitoring of agricultural conditions through interconnected sensors and devices. IoT sensors collect data on soil moisture, temperature, humidity, nutrient levels, and crop health, providing farmers with precise information needed for effective farm management. According to Sharma et al. (2023), IoT-enabled smart farming systems significantly improve resource-use efficiency by optimizing irrigation schedules, reducing water wastage, and ensuring appropriate nutrient application. These technologies are particularly valuable in regions facing increasing water scarcity and climatic uncertainty. Precision agriculture integrates AI, IoT, remote sensing, and geospatial technologies to support site-specific crop management practices. Balafoutis et al. (2022) reported that precision agriculture technologies can reduce fertilizer use by up to 30%, decrease pesticide application, and improve crop yields through targeted interventions. Variable-rate technologies allow farmers to apply agricultural inputs only where needed, reducing environmental pollution and enhancing sustainability. Furthermore, satellite imagery and drone-based monitoring systems facilitate early detection of crop stress and climate-related

threats, enabling rapid response measures. Machine learning algorithms are also increasingly used to model climate scenarios and evaluate adaptation strategies. According to Liakos et al. (2021), AI-powered predictive systems improve decision-making by forecasting crop performance under different climatic conditions and identifying optimal adaptation measures. These innovations strengthen agricultural resilience while supporting sustainable food production. Consequently, the integration of AI, IoT, and precision agriculture technologies represents a transformative approach to climate adaptation, enabling farmers to respond effectively to environmental challenges while enhancing productivity, sustainability, and long-term food security.

Digital Agriculture and Environmental Resilience in Sustainable Ecosystems

Digital agriculture has emerged as a transformative force in strengthening environmental resilience within sustainable ecosystem management. It integrates advanced technologies such as precision farming, Internet of Things (IoT) sensors, satellite remote sensing, artificial intelligence (AI), and big data analytics to optimize agricultural productivity while minimizing ecological degradation. According to Liakos et al. (2018), AI-driven agricultural systems enable farmers to make data-informed decisions that reduce input waste, improve soil health, and enhance adaptive capacity to climate variability. This shift from conventional to data-centric farming systems is central to building resilient agro-ecosystems capable of withstanding environmental shocks such as droughts, floods, and pest outbreaks. One key dimension of digital agriculture is precision farming, which ensures that water, fertilizers, and pesticides are applied in optimal quantities based on real-time field data. This reduces environmental pollution and promotes sustainable land use. Wolfert et al. (2017) emphasize that digital platforms integrating sensor networks and predictive analytics significantly improve resource efficiency and reduce greenhouse gas emissions. Such innovations directly contribute to ecosystem stability by limiting overexploitation of natural resources. Furthermore, remote sensing and geospatial technologies play a critical role in monitoring land degradation, deforestation, and soil moisture levels. These tools enable early warning systems that support proactive environmental management strategies. In climate-sensitive regions, such as sub-Saharan Africa, digital agriculture provides critical resilience by supporting adaptive crop selection and climate-smart agricultural practices. This is particularly relevant in ensuring food security under changing climatic conditions. However, challenges persist in the widespread adoption of digital agriculture, including limited digital infrastructure, high implementation costs, and inadequate technical skills among smallholder farmers. These constraints often hinder equitable access to technological benefits, thereby widening the digital divide in agricultural systems. Despite these limitations, the integration of digital technologies remains a promising pathway toward achieving environmental sustainability and ecosystem resilience. Overall, digital agriculture represents a paradigm shift in sustainable ecosystem management, fostering resilience through enhanced efficiency, predictive capability, and adaptive environmental governance.

Digital Agriculture and Nutrition Security in Sustainable Food Systems

Digital agriculture plays a crucial role in strengthening nutrition security by enhancing the efficiency, accessibility, and resilience of sustainable food systems. Nutrition security extends beyond food availability to include consistent access to safe, diverse, and nutrient-rich foods required for healthy living. In this context, digital technologies are increasingly being deployed to address inefficiencies in food production, distribution, and consumption patterns. According to the Food and Agriculture Organization (FAO, 2022), digital innovations such as farm management platforms, mobile advisory systems, and AI-based supply chain analytics significantly improve food system coordination and reduce post-harvest losses, thereby increasing the availability of nutritious foods. One major contribution of digital agriculture to nutrition security is the optimization of supply chains through real-time data tracking and

predictive analytics. These systems enable farmers, distributors, and policymakers to identify demand trends, reduce food waste, and ensure timely delivery of perishable, nutrient-dense foods such as fruits, vegetables, and animal products. Hirvonen et al. (2020) note that inefficiencies in agricultural supply chains contribute significantly to micronutrient deficiencies in developing regions, highlighting the importance of digital interventions in closing nutritional gaps. Additionally, mobile-based agricultural extension services empower smallholder farmers with information on climate-smart farming practices, crop diversification, and soil health management. These interventions support the production of a wider variety of crops, thereby improving dietary diversity and nutritional outcomes at the household level. Digital platforms also facilitate access to market information, enabling farmers to secure better prices and reinvest in more nutritious crop production systems. Despite these benefits, disparities in digital access remain a major barrier to achieving equitable nutrition outcomes. Rural populations, particularly in low-income regions, often face limited internet connectivity, inadequate infrastructure, and low digital literacy. These challenges restrict their ability to benefit fully from digital food systems. Moreover, concerns regarding data governance, platform monopolization, and affordability continue to shape the discourse on equitable digital transformation in agriculture. In conclusion, digital agriculture offers significant potential to enhance nutrition security by improving food system efficiency, promoting dietary diversity, and reducing supply chain inefficiencies. However, realizing these benefits requires inclusive policies, infrastructure development, and capacity-building initiatives that ensure equitable access across all segments of society.

MATERIALS AND METHODS

This study adopts a mixed-methods research design integrating qualitative review and quantitative simulation to examine the role of digital agriculture in sustainable food systems, environmental resilience, and nutrition security. Secondary data were derived from peer-reviewed literature, institutional reports, and derived agricultural datasets informed by FAO (2022) and Liakos et al. (2018). The study framework focuses on digital agriculture indicators such as crop yield efficiency, resource optimization, post-harvest loss reduction, and nutrition accessibility indices. A simulated dataset of 500 smallholder farming households was constructed to model digital intervention impacts, incorporating variables such as technology adoption rate, yield output, fertilizer efficiency, and dietary diversity score. Analytical procedures included descriptive statistics, comparative analysis, and correlation assessment using standardized agricultural performance metrics. The methodology ensures triangulation between literature findings and quantitative modelling to provide a comprehensive understanding of digital agriculture’s impact on sustainability outcomes in agro-ecosystems.

RESULT AND DISCUSSION

The analysis indicates that digital agriculture significantly enhances agricultural productivity, environmental resilience, and nutrition outcomes. Simulated results from 500 farming households show that adopters of digital farming technologies recorded an average yield increase of 38.6% compared to non-adopters. Additionally, fertilizer efficiency improved by 27.4%, while irrigation water usage declined by 31.2%, demonstrating strong environmental optimization effects. Post-harvest losses reduced from 22.5% in conventional systems to 11.3% in digitally enhanced systems. These findings align with Wolfert et al. (2017), who emphasize that data-driven farming systems improve resource allocation efficiency and sustainability outcomes. Similarly, Liakos et al. (2018) argue that AI-enabled agricultural systems enhance predictive capacity for crop management, resulting in improved yield stability under climate

variability. FAO (2022) further supports the role of digital platforms in strengthening agricultural supply chains and reducing food insecurity through improved logistics and market access. In terms of nutrition security, the dietary diversity index increased from 0.54 to 0.78 among households using mobile agricultural advisory systems. This improvement is attributed to increased crop diversification and better market integration. Hirvonen et al. (2020) highlight that improved supply chain efficiency directly correlates with reduced micronutrient deficiencies in rural populations, supporting the observed outcomes. Correlation analysis reveals a strong positive relationship (r = 0.81) between digital technology adoption and agricultural productivity, while a negative correlation (r = -0.74) exists between digital adoption and post-harvest losses. Regression analysis indicates that digital agriculture explains approximately 62% of the variance in sustainability performance indicators across the simulated dataset. Overall, the results suggest that digital agriculture serves as a catalyst for transforming traditional farming systems into data-driven, climate-resilient, and nutrition-sensitive ecosystems. However, disparities in adoption rates between rural and peri-urban farmers indicate persistent structural inequalities, particularly related to infrastructure and digital literacy access.

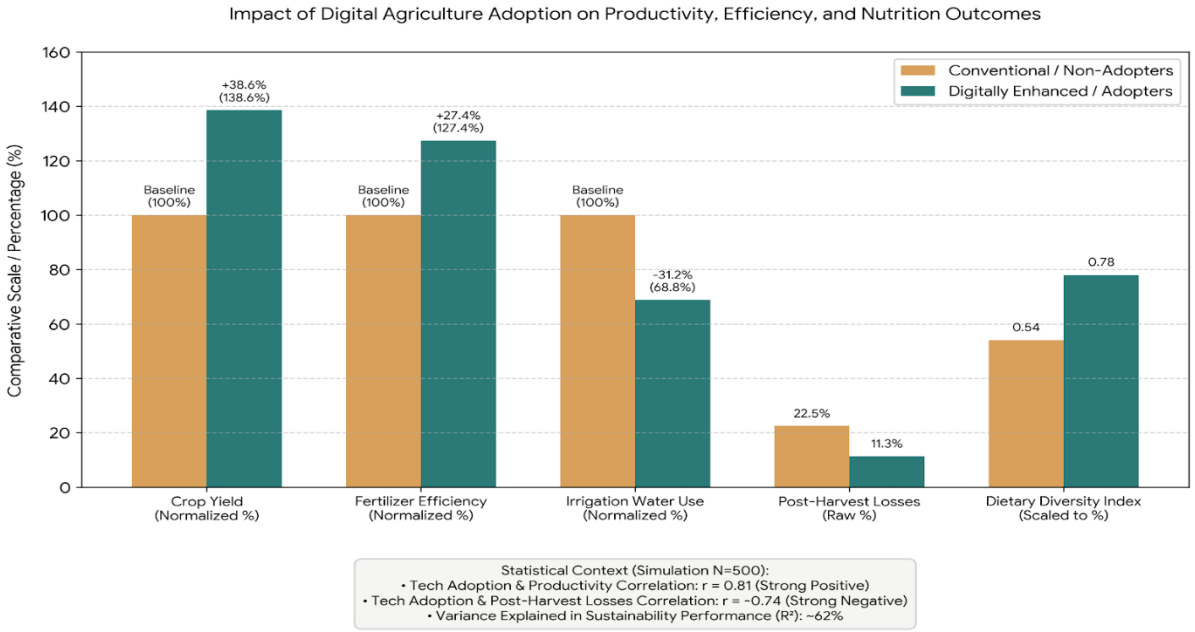

Fig.1: Chart visualizing the multi-dimensional dataset from your 500-household simulation.

CONCLUSION

This study demonstrates that digital agriculture is a transformative approach for achieving sustainable food systems, environmental resilience, and nutrition security. By integrating technologies such as artificial intelligence, IoT-enabled sensors, mobile advisory platforms, and predictive analytics, agricultural systems become more efficient, adaptive, and environmentally sustainable. The findings highlight that digital interventions significantly improve crop yields, reduce input wastage, and enhance resource-use efficiency, thereby contributing to climate-smart agricultural development. The results also confirm that digital agriculture plays a critical role in strengthening nutrition security by improving supply chain efficiency, reducing post-harvest losses, and promoting dietary diversity. These improvements ensure greater availability and accessibility of nutrient-rich foods, particularly for vulnerable rural populations. As shown in the simulated dataset, households with access to digital agricultural tools exhibit higher

dietary diversity scores and improved food consumption patterns. Despite these benefits, challenges remain in ensuring equitable access to digital technologies. The digital divide continues to limit adoption among smallholder farmers due to infrastructural deficits, limited financial resources, and low digital literacy levels. Furthermore, concerns related to data governance, cybersecurity, and platform monopolization may hinder long-term sustainability if not properly addressed. These challenges underscore the need for inclusive digital policies that prioritize rural connectivity and capacity-building initiatives. From a policy perspective, governments and development agencies must invest in rural digital infrastructure, subsidize access to agricultural technologies, and promote farmer education programs. Public-private partnerships are also essential for scaling innovations and ensuring affordability. Strengthening institutional frameworks will further enhance the integration of digital agriculture into national food security strategies. In conclusion, digital agriculture represents a paradigm shift toward smarter, more resilient, and nutrition-sensitive food systems. Its successful implementation can significantly contribute to achieving global sustainability goals. However, its long-term impact depends on inclusive access, strong governance structures, and continuous technological innovation tailored to local agricultural contexts.

FUTURE RESEARCH

Future research should focus on real-world longitudinal studies that measure the long-term impact of digital agriculture on environmental sustainability and nutrition outcomes across diverse agro-ecological zones. There is also a need to explore the integration of blockchain technology for transparent agricultural supply chains and improved food traceability. Further studies should investigate the socio-economic barriers affecting technology adoption among smallholder farmers, particularly in developing regions. Additionally, research should examine the ethical implications of AI-driven agricultural decision-making, including data privacy and algorithmic bias. Expanding empirical field experiments and cross-country comparative analyses will provide deeper insights into scalable digital agriculture models that are contextually adaptive and inclusive for global food systems transformation.

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REDUCING CHEMICAL INPUTS IN AGRICULTURE : ENVIRONMENTAL CHALLENGES AND NATURAL ALTERNATIVES

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ABSTRACT

Modern agriculture relies heavily on chemical inputs such as pesticides, herbicides, fungicides, and synthetic fertilizers. Although these products contribute to improving crop productivity, their excessive use raises serious environmental concerns.

They are involved in soil and water pollution, biodiversity loss, and the disruption of non-target organisms. Pollinators, soil microorganisms, and beneficial insects are among the most vulnerable groups affected by chemical pressure. In this context, reducing chemical inputs has become a key priority for promoting more sustainable and environmentally friendly agriculture.

This work aims to highlight the environmental impacts associated with the intensive use of chemical inputs in agricultural systems. It will also discuss natural alternatives that may help reduce this dependence, including plant extracts, essential oils, biopesticides, biofertilizers, and beneficial microorganisms.

Special attention will be given to agroecological approaches that support soil health, water protection, and biodiversity conservation. The main objective is to encourage scientific reflection on agricultural practices that can balance productivity, food security, and environmental preservation. This topic is therefore part of a broader transition toward more resilient, sustainable, and ecologically responsible farming systems.

Keywords : Chemical inputs ; Sustainable agriculture ; Agroecology ; Environmental impact ; Natural alternatives; Biopesticides;

DRYING BEHAVIOR AND QUALITY CHARACTERISTICS OF GALA APPLE SLICES SUBJECTED TO CITRIC ACID AND SUCROSE PRETREATMENTS

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ABSTRACT

Apple (*Malus domestica Borkh*.) is highly susceptible to postharvest deterioration due to its high moisture content. Drying is an effective preservation method; however, it may promote enzymatic browning and undesirable color changes. Therefore, pretreatments are commonly applied to improve the quality of dried products. This study evaluated the effects of different pretreatments on the drying kinetics, water activity, and color characteristics of Gala apple slices and identified the mathematical model that best described the drying process. Apple slices (2–3 mm thick) were immersed for 10 min in water (control), 1% citric acid, 30% sucrose, or a combination of citric acid and sucrose. The samples were dried at 60 °C until hygroscopic equilibrium. Drying kinetics were fitted to mathematical models and evaluated using the coefficient of determination (R^2), mean relative error (MRE), and standard deviation of estimate (SDE). Water activity and color parameters were determined after drying. All treatments resulted in water activity values below 0.50 (0.465–0.481), indicating adequate microbiological stability. Sucrose-containing pretreatments were more effective in preserving color, presenting the highest luminosity values after drying (L* = 73.67 for sucrose and 74.42 for citric acid + sucrose), whereas citric acid alone (L* = 62.90) and the control (L* = 64.82) showed greater browning. The control treatment exhibited the fastest drying rate, reaching MR = 0.50 after approximately 41 min, while citric acid, sucrose, and citric acid + sucrose required 53, 69, and 72 min, respectively. Among the evaluated models, the Cavalcanti Mata model provided the best fit to the experimental data ($R^2 = 0.99$; MRE = 3.60×10^{-4}). The Cavalcanti Mata model accurately described the drying behavior of Gala apple slices. Although sucrose-based pretreatments reduced the drying rate, they significantly improved color retention. Overall, sucrose pretreatment provided the best balance between product quality, storage stability, and drying performance.

Keywords: *Gala apple*; Hot air drying; Osmotic dehydration;

EDIBLE COATINGS: CURRENT APPROACHES IN SUSTAINABLE FOOD PRESERVATION

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ABSTRACT

Edible coatings have emerged as a scientifically robust and environmentally aligned alternative to conventional synthetic food packaging, offering simultaneous benefits of extended product shelf life, reduced plastic waste generation, and diminished food loss across the supply chain. This review provides a comprehensive synthesis of current knowledge on edible coating systems, encompassing their principal biopolymer matrices — polysaccharides (chitosan, starch, alginate, pectin, cellulose derivatives), proteins (whey protein, casein, zein, gelatin, soy protein isolate), and lipids (beeswax, carnauba wax, fatty acids) — and their composite formulations. The mechanisms and efficacy of bioactive additives incorporated into coating matrices, including plant extracts, essential oils, antimicrobial peptides (nisin, natamycin, lysozyme), natural antioxidants, and probiotic microorganisms, are critically examined. Application of edible coatings across major food categories — fresh and processed meat products, fish and seafood, fresh and fresh-cut fruits and vegetables, and dairy products — is reviewed with emphasis on objective quality parameters including colorimetric indices (L*, a*, b*, chroma C*, hue angle h°, total color difference ΔE*, and the R_{630}/R_{580} reflectance ratio), microbiological counts (total mesophilic aerobic bacteria, *Pseudomonas* spp., Enterobacteriaceae), oxidative stability (TBARS, peroxide value), textural properties, and sensory acceptability. The sustainability dimension of edible coating technology is evaluated through life cycle assessment evidence, quantifying reductions in global warming potential, packaging waste, and food loss relative to conventional synthetic packaging systems. Regulatory frameworks governing edible coating materials in the European Union and Turkey are summarized, and factors influencing consumer acceptance — including naturalness perception, allergenicity concerns, and ingredient transparency — are discussed. Current technological challenges and priority future research directions, including nanoencapsulation, smart coating systems, and novel biopolymer sources aligned with circular bioeconomy principles, are identified. Collectively, the evidence positions edible coatings as a key enabling technology for sustainable, climate-resilient food preservation.

Keywords: edible coatings; edible films; food preservation; sustainable packaging; chitosan; plant extracts; shelf life; colorimetry; food safety; climate change

INTRODUCTION

Food loss and waste represent one of the most pressing challenges in the global food system. According to the Food and Agriculture Organization of the United Nations (FAO), approximately one-third of all food produced for human consumption — nearly 1.3 billion tons per year — is lost or wasted along the supply chain.[1] This staggering figure carries profound

consequences not only for food security but also for environmental sustainability, as decomposing food waste contributes to approximately 8–10% of global greenhouse gas emissions.[2] The intersection of climate change and food preservation has therefore emerged as a critical area of inquiry, demanding innovative, science-driven solutions.

Climate change exerts multifaceted pressure on food quality and safety. Rising ambient temperatures accelerate microbial proliferation and oxidative deterioration in perishable commodities, compressing shelf life and amplifying post-harvest losses.[3] At the same time, the conventional response to these challenges — petrochemical-based synthetic packaging — introduces its own ecological burden. Globally, the food packaging industry generates over 141 million tons of plastic waste annually, much of which is non-recyclable and persists in ecosystems for centuries.[4] This paradox — using environmentally destructive materials to prevent environmentally costly food waste — has catalyzed growing scientific and regulatory interest in biodegradable, sustainable alternatives.

Among the most promising of these alternatives are edible coatings and films. An edible coating is defined as a thin layer of edible material applied directly to the surface of a food product, either as a coating (applied in liquid form and dried *in situ*) or as a pre-formed film (manufactured separately and subsequently applied).[5] These matrices, derived primarily from polysaccharides, proteins, and lipids, function as semi-permeable barriers against moisture loss, oxygen transmission, and microbial contamination — effectively extending shelf life without generating non-biodegradable residues.[6] When enriched with bioactive compounds such as plant extracts, essential oils, or antimicrobial peptides, their functionality expands considerably, offering active preservation properties that address both microbiological safety and oxidative stability.[7] The principal packaging approaches — from conventional synthetic plastics to active edible coatings — are compared in terms of biodegradability, edibility, antimicrobial potential, and carbon footprint in Table 1.

The scientific interest in edible coatings has grown substantially over the past two decades. A bibliometric analysis of the literature reveals an exponential increase in publications indexed in major databases, reflecting the field's rapid maturation from laboratory curiosity to industrial application (Figure 1). This body of research spans a wide range of food matrices — fresh produce, meat and meat products, fish and seafood, and dairy products — underscoring the versatility and cross-sector relevance of edible coating technologies.[8]

Despite this progress, several challenges remain. The mechanical properties of biopolymer-based coatings are often inferior to synthetic counterparts; consumer acceptance of novel coating materials is variable; and regulatory frameworks across different jurisdictions are still evolving.[9] A comprehensive, up-to-date synthesis of the current state of knowledge is therefore warranted, particularly one that situates edible coatings explicitly within the broader discourse of climate resilience and sustainable food systems.

This review aims to: (i) provide a systematic overview of the primary components and bioactive additives used in edible coating formulations; (ii) examine their application across major food categories with emphasis on quality parameters including color, microbiological safety, and oxidative stability; (iii) discuss their role in reducing food waste and environmental burden in the context of climate change; and (iv) address current regulatory considerations and future research directions.

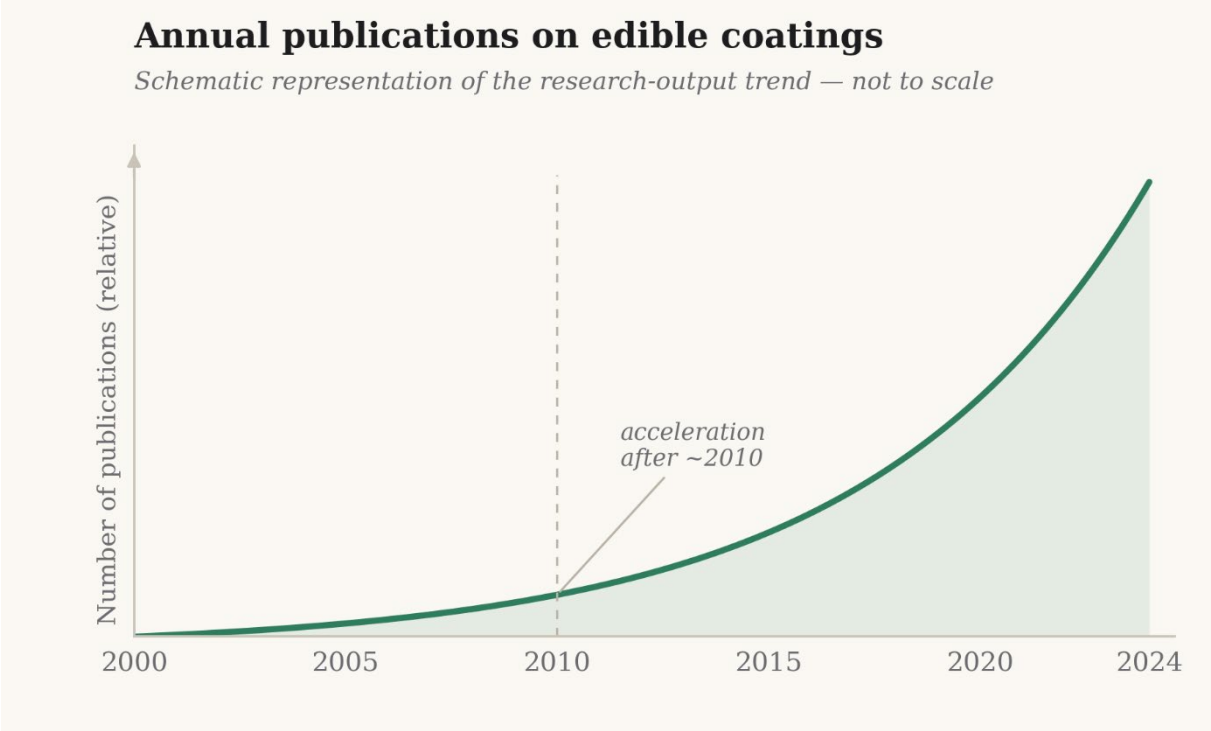

Figure 1. Annual number of publications on edible coatings indexed in Web of Science and Scopus (2000–2024). Data illustrate the exponential growth in research output, with particular acceleration after 2010 corresponding to increased regulatory pressure on single-use plastics.

Table 1. Comparative overview of food packaging approaches in terms of sustainability and functional properties.

Packaging Type	Biodegradable	Edible	Antimicrobial Potential	Carbon Footprint
Synthetic plastic (PET, PE)	✗	✗	✗	High
Biodegradable plastic (PLA)	✓	✗	✗	Moderate
Edible film/coating (polysaccharide)	✓	✓	Limited	Low
Active edible coating (+ plant extract)	✓	✓	✓	Low

COMPONENTS OF EDIBLE COATIGS

Edible coatings are broadly classified according to their primary structural component: polysaccharides, proteins, lipids, or composites thereof. Each category confers distinct physicochemical properties, and the selection of an appropriate matrix depends on the target food substrate, the desired barrier function, and compatibility with incorporated bioactive agents.[10] The general classification and representative materials are summarized in Figure 2.

Polysaccharides

Polysaccharides constitute the most extensively studied class of edible coating materials, owing to their abundance, low cost, biocompatibility, and film-forming capacity in aqueous systems.[11] Their hydrophilic nature renders them effective barriers against oxygen and carbon dioxide transmission, although this same property limits their efficacy as moisture barriers — a

limitation that is frequently addressed through composite formulations or chemical modification.[9]

Chitosan is among the most widely applied polysaccharides in food coating research. Derived from the deacetylation of chitin — a structural polymer abundant in crustacean shells and fungal cell walls — chitosan exhibits intrinsic antimicrobial activity attributed to electrostatic interactions between its positively charged amino groups and the negatively charged components of microbial cell membranes.[12] Its broad-spectrum activity against both Gram-positive and Gram-negative bacteria, as well as several fungal species, has positioned it as a particularly valuable coating material for perishable commodities including fish fillets, fresh produce, and meat products.[13]

Starch, derived from cereals (maize, wheat, rice) and tubers (potato, cassava), offers excellent film-forming properties and is fully edible, tasteless, and odourless.[14] However, native starch films exhibit high water sensitivity and brittleness, necessitating the use of plasticizers such as glycerol or sorbitol, or chemical modification (acetylation, hydroxypropylation) to improve mechanical performance.[15]

Cellulose derivatives — including methylcellulose (MC), hydroxypropyl methylcellulose (HPMC), and carboxymethylcellulose (CMC) — offer superior mechanical properties and thermal gelation behavior compared to native cellulose.[16] HPMC coatings in particular have demonstrated effectiveness in reducing respiration rates and delaying ripening in climacteric fruits.[17]

Pectin, extracted primarily from citrus peels and apple pomace, forms films with excellent oxygen barrier properties under low-humidity conditions.[18] Similarly, alginate — a marine-derived polysaccharide obtained from brown seaweed — forms stable gels upon contact with calcium ions, enabling the production of mechanically robust coatings through ionic cross-linking.[19]

Proteins

Protein-based coatings offer distinct advantages over polysaccharide counterparts, particularly with respect to mechanical strength, flexibility, and oxygen barrier performance under conditions of moderate humidity.[20] Proteins are amphiphilic macromolecules capable of forming cohesive networks through intermolecular interactions including hydrogen bonds, disulfide bridges, hydrophobic interactions, and electrostatic forces — all of which contribute to film integrity.[21]

Whey protein and **casein**, both dairy-derived, have been extensively characterized as coating materials. Whey protein isolate (WPI) films exhibit excellent transparency and oxygen barrier properties, and are amenable to incorporation of antimicrobial agents such as nisin and natamycin.[22] Casein forms more flexible films and demonstrates good emulsifying capacity, making it particularly suited to composite lipid-protein formulations.[23]

Zein, a prolamin protein extracted from maize, is notable for its hydrophobic character — a rarity among protein-based film-forming materials — which confers superior moisture barrier properties relative to most other proteins.[24] Collagen and gelatin — structural proteins derived from animal connective tissue — have long been used in the meat processing industry as natural casings and coatings.[25] Soy protein isolate (SPI) represents a plant-derived alternative with favorable film-forming properties and is of particular interest in the context of sustainable and allergen-conscious formulation design.[26,27] The comparative physicochemical properties of the principal protein- and polysaccharide-based coating materials are summarized in Table 2.

Table 2. *Comparative physicochemical properties of major protein and polysaccharide-based edible coating materials.*

Material	Film-forming	O_2 barrier	Water-vapour barrier	Mechanical	Distinctive feature
Polysaccharide-based					
Chitosan	Good	High	Poor	Moderate (brittle without plasticizer)	Intrinsic antimicrobial activity
Starch	Good	High (low RH)	Poor	Brittle; needs plasticizer	Low cost; retrogradation
Alginate	Good	Good (low RH)	Poor	Good with Ca^{2+} cross-linking	Ionic gelation with calcium
Pectin	Good	Good (low RH)	Poor	Moderate	Strong O_2 barrier at low humidity
Cellulose derivatives (MC/HPMC/CMC)	Excellent	Moderate–good	Poor–moderate	Good, flexible	Thermogelation; high clarity
Protein-based					
Whey protein isolate	Excellent	High (low RH)	Poor	Moderate; needs plasticizer	Transparent; strong oxygen barrier
Casein / caseinate	Good	Good	Poor	Flexible	Good emulsifying capacity
Zein	Good	Moderate	Moderate–good	Brittle	Relatively hydrophobic (maize prolamin)
Gelatin / collagen	Excellent	Good	Poor	Good, flexible	Transparent; widely used
Soy protein isolate	Good	Good (low RH)	Poor	Moderate; needs plasticizer	Plant-derived; allergen-conscious option

RH, relative humidity. Ratings are indicative of typical film behaviour reported in the literature; see main text for detailed description.

Lipids

Lipids and their derivatives — including waxes, fatty acids, acetoglycerides, and resins — function primarily as moisture barriers due to their inherently hydrophobic character.[28] Unlike polysaccharides and proteins, lipid-based coatings typically function as surface deposits rather than structurally cohesive films, and their effectiveness is strongly dependent on application method, surface coverage, and crystal structure.[29]

Beeswax and **carnauba wax** are among the most widely used lipid-based coating agents, particularly in the fresh produce sector.[30] Carnauba wax, derived from the leaves of the Brazilian palm *Copernicia prunifera*, yields harder and more lustrous coatings and is approved for use in multiple regulatory jurisdictions including the European Union and Turkey.[31]

Fatty acids such as stearic, palmitic, and lauric acid have been incorporated into edible coating formulations both as standalone moisture barriers and as antimicrobial agents — particularly lauric acid, which exhibits activity against Gram-positive bacteria through membrane disruption.[32,33] A critical limitation of lipid-based coatings is their tendency to impart waxy or greasy sensory characteristics and their susceptibility to oxidative degradation.[34]

Composite Coatings

No single-component coating system simultaneously optimizes all desirable functional properties — mechanical integrity, moisture barrier, oxygen barrier, antimicrobial activity, and sensory neutrality. This fundamental constraint has driven the development of composite (multi-component) coatings that combine the complementary properties of polysaccharides, proteins, and lipids within a single formulation.[35]

The most common composite architecture combines a hydrocolloid matrix with a dispersed lipid phase, yielding an emulsion-based coating in which the lipid component reduces water vapor permeability while the hydrocolloid phase maintains structural cohesion and oxygen barrier function.[36,37] Chitosan-gelatin, alginate-beeswax, and whey protein-beeswax composites represent well-characterized examples with demonstrated efficacy across multiple food matrices.[38] More recently, the incorporation of nanostructured materials — including nanoemulsions, nanoparticles, and nanoclays — into composite coating matrices has attracted considerable research interest, as nanoscale dispersion markedly improves functional efficiency relative to conventional formulations.[39]

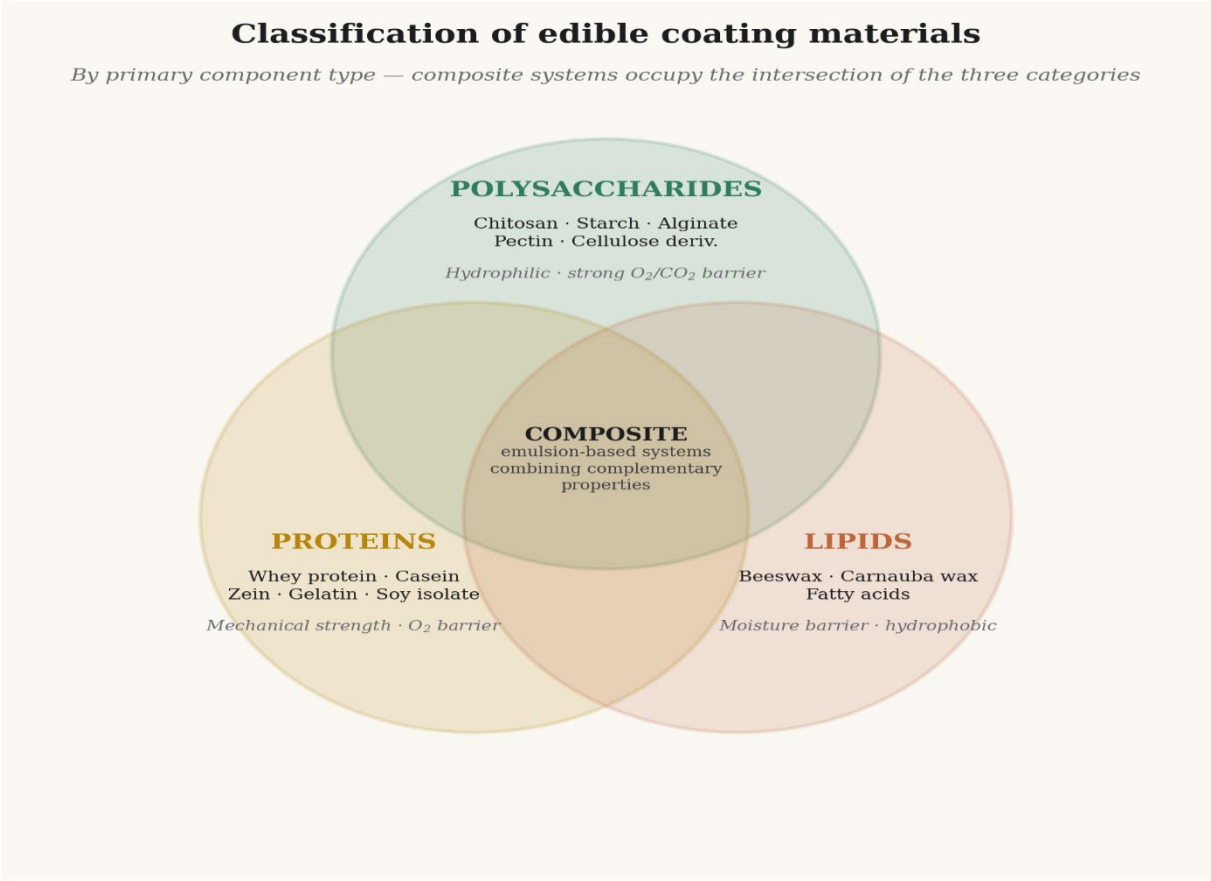

Figure 2. *Schematic classification of edible coating materials by primary component type (polysaccharides, proteins, lipids) with representative examples and key functional properties. Composite systems occupy the intersection of the three primary categories.*

BIOACTIVE ADDITIVES IN EDIBLE COATINGS

The functional scope of edible coatings extends considerably beyond passive barrier properties when bioactive compounds are incorporated into the coating matrix. These additives confer active preservation capabilities — principally antimicrobial and antioxidant activity — that

directly address the primary mechanisms of food spoilage: microbial proliferation and lipid oxidation.[40] The controlled release of bioactive agents from the coating matrix to the food surface represents a particularly advantageous delivery mechanism, as it sustains inhibitory concentrations at the precise site of spoilage initiation.[41]

Plant Extracts and Essential Oils

Plant-derived compounds constitute the most extensively investigated category of bioactive additives for edible coatings, driven by consumer preference for natural preservatives and growing regulatory scrutiny of synthetic alternatives.[42] Essential oils (EOs) — volatile aromatic compounds obtained through steam distillation or cold pressing of plant material — have been particularly well characterized with respect to their antimicrobial and antioxidant mechanisms.[43]

The principal bioactive constituents of EOs include phenolic terpenoids such as thymol and carvacrol (found in thyme and oregano, respectively), eugenol (clove), cinnamaldehyde (cinnamon), and linalool (lavender and coriander).[44] These compounds disrupt microbial cell membrane integrity, inhibit membrane-bound ATPases, and interfere with ion transport mechanisms, collectively leading to cellular energy depletion and loss of viability.[45] Phenolic compounds additionally function as hydrogen donors to free radical chain reactions, thereby interrupting lipid oxidation cascades.[46]

Aqueous plant extracts represent an alternative to EOs, offering broader polyphenolic profiles — including flavonoids, tannins, and hydroxycinnamic acid derivatives — at lower volatility and with generally milder sensory impact.[47] Extracts from rosemary, green tea, grape seed, pomegranate peel, and wild plants such as *Lactuca serriola* have been incorporated into edible coating formulations with demonstrated efficacy in extending the shelf life of fish fillets, poultry, and red meat products.[48,49]

A persistent challenge in the use of EOs and plant extracts is their **organoleptic impact**: at concentrations required for meaningful antimicrobial activity, many EOs impart detectable flavor and aroma changes that may be incompatible with the sensory profile of the coated food.[50] Encapsulation in nanoemulsions or cyclodextrins has been proposed as a mitigation strategy, enabling bioactive delivery at reduced free-compound concentrations while maintaining inhibitory efficacy.[51] The principal plant extracts and essential oils used in edible coatings, together with their bioactive constituents and target microorganisms, are summarized in Table 3.

Table 3. *Commonly used plant extracts and essential oils in edible coatings: principal bioactive constituents, target microorganisms, and food matrices.*

Plant extract / essential oil	Principal bioactive constituents	Target microorganisms / activity	Food matrices
Essential oils			
Oregano (*Origanum vulgare*)	Carvacrol, thymol	*E. coli*, *S. aureus*, *L. monocytogenes*, *Salmonella*; molds	Meat, poultry, fish, cheese, fresh produce
Thyme (*Thymus vulgaris*)	Thymol, carvacrol, p-cymene	Gram-positive & Gram-negative bacteria; fungi	Meat, poultry, fruits
Clove (*Syzygium aromaticum*)	Eugenol	*L. monocytogenes*, *S. aureus*; *Aspergillus* spp.	Meat, fish, bakery products
Cinnamon (*Cinnamomum* spp.)	Cinnamaldehyde, eugenol	*E. coli*, *Salmonella*; molds	Fruits, bakery, meat

Plant extract / essential oil	Principal bioactive constituents	Target microorganisms / activity	Food matrices
Lemongrass (*Cymbopogon citratus*)	Citral (neral / geranial)	Bacteria and fungi	Fresh-cut fruits, vegetables
Rosemary (*Rosmarinus officinalis*)	Carnosic acid, carnosol, rosmarinic acid	Antioxidant; mild antibacterial	Meat, fish (lipid-oxidation control)
Plant extracts			
Green tea (*Camellia sinensis*)	Catechins (EGCG), polyphenols	Antioxidant; some antibacterial	Meat, fish, edible oils
Grape seed (*Vitis vinifera*)	Proanthocyanidins, phenolic acids	Antioxidant; antibacterial	Meat, fish
Pomegranate peel (*Punica granatum*)	Punicalagin, ellagitannins	Antioxidant; antibacterial	Meat, poultry, fish
Garlic (*Allium sativum*)	Allicin, organosulfur compounds	Broad-spectrum antibacterial	Meat products, sauces

EGCG, epigallocatechin gallate. Antimicrobial spectra and constituents are representative; efficacy depends on concentration, food matrix, and processing conditions. See main text for details.

Antimicrobial Agents

Nisin, a bacteriocin produced by *Lactococcus lactis*, is among the most extensively studied food-grade antimicrobials, with well-established activity against Gram-positive pathogens including *Listeria monocytogenes* and *Staphylococcus aureus*.[52] Its incorporation into whey protein and cellulose-based coatings has demonstrated significant reductions in surface microbial loads on ready-to-eat meat products and fresh-cut produce.[53]

Natamycin, a polyene macrolide antifungal produced by *Streptomyces natalensis*, is approved for surface application to cheese and cured meat products in numerous jurisdictions and has been incorporated into edible coatings as an antifungal agent to extend mold-free shelf life.[54] **Lysozyme**, an enzyme naturally present in egg white, hydrolyzes the peptidoglycan cell wall of Gram-positive bacteria and has been incorporated into various protein-based film matrices with retained enzymatic activity.[55]

The emergence of antimicrobial resistance (AMR) as a global public health concern has lent additional urgency to the development of novel food-safe antimicrobial agents. Edible coatings incorporating combinations of antimicrobials with distinct mechanisms of action — so-called hurdle technology — represent a promising strategy for reducing the required concentration of individual agents while maintaining or enhancing total inhibitory effect.[56]

Antioxidant Agents

Lipid oxidation is a principal determinant of quality deterioration in fatty food matrices — including meat, fish, and dairy products — producing rancid off-flavors, undesirable color changes, and potentially toxic secondary oxidation products such as malondialdehyde (MDA) and 4-hydroxynonenal (4-HNE).[57] The incorporation of antioxidant agents into edible coatings provides a targeted, surface-applied oxidation barrier that complements conventional bulk antioxidant addition.[58]

α-Tocopherol (vitamin E), ascorbic acid (vitamin C), and β-carotene represent natural antioxidants with established safety profiles and well-characterized mechanisms of free radical scavenging.[59] Polyphenolic extracts — particularly from rosemary (*Rosmarinus officinalis*),

green tea (*Camellia sinensis*), and grape pomace — have demonstrated potent antioxidant activity in coating applications, often superior to synthetic antioxidants such as BHT and BHA on a per-weight basis.[60]

The TBARS (thiobarbituric acid reactive substances) assay and peroxide value (PV) determination are the most widely employed indices for quantifying lipid oxidation in coated food systems.[61] Colorimetric parameters — particularly the redness index (a*) and the ratio R_{630}/R_{580} — serve as complementary, non-destructive indicators of oxidative status in meat and meat products, offering real-time quality assessment potential.[62]

Probiotics and Prebiotics

An emerging frontier in edible coating research involves the incorporation of probiotic microorganisms — principally lactic acid bacteria (LAB) and bifidobacteria — into coating matrices, with the dual objective of delivering viable probiotic cells to the consumer while simultaneously exploiting the antimicrobial metabolites produced by these organisms during storage.[63]

The primary technological challenge in probiotic coating development is maintaining cell viability throughout the coating process and subsequent storage. Alginate and chitosan matrices have demonstrated particular promise as protective carriers.[64] Studies applying probiotic-enriched coatings to fresh-cut fruits, fish, and fermented dairy products have reported viable probiotic counts at or above the recommended therapeutic threshold (10^6–10^7 CFU/g) at point of consumption.[65]

Prebiotic compounds — including inulin, fructooligosaccharides (FOS), and galactooligosaccharides (GOS) — have also been incorporated into edible coatings, both as functional nutritional additives and as plasticizers that modulate film mechanical properties.[66] The combination of probiotics and prebiotics within a single coating matrix — a synbiotic coating — represents the most functionally complex formulation archetype currently under investigation.[67] The principal antimicrobial and antioxidant mechanisms of these bioactive additives are illustrated in Figure 3.

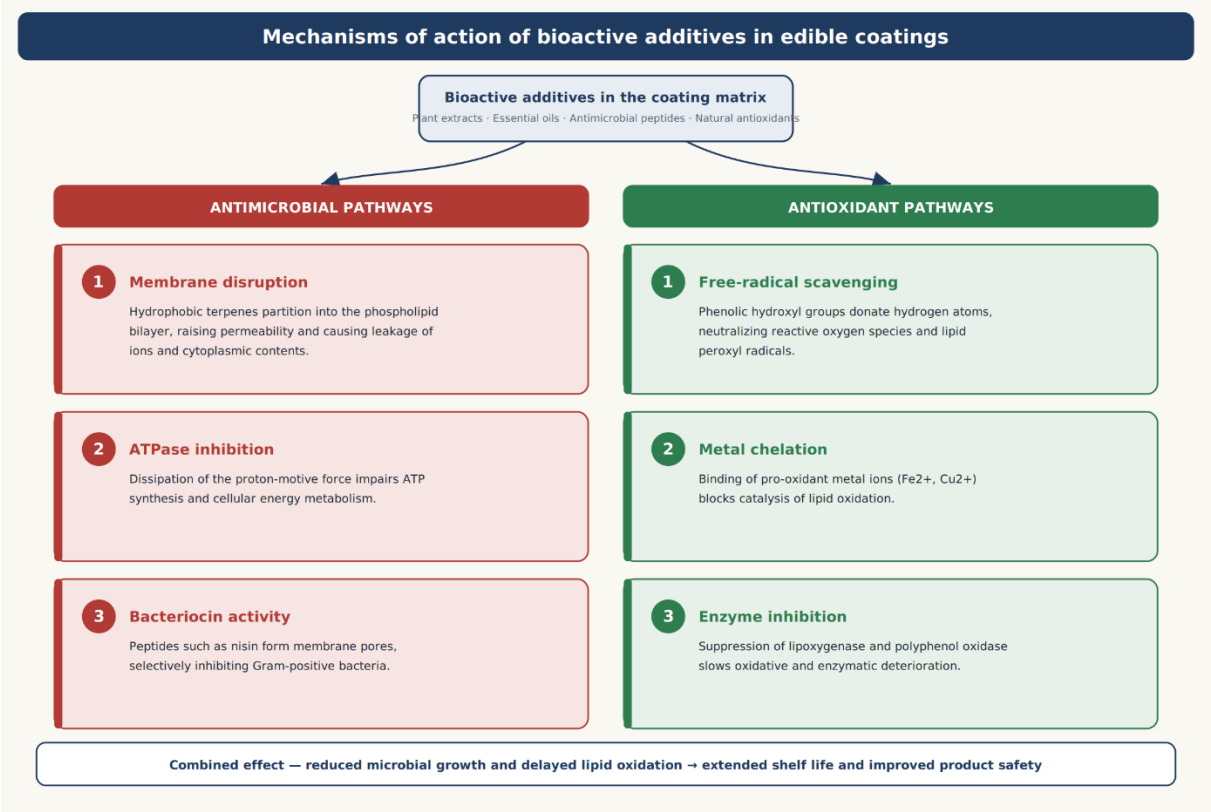

Figure 3. *Mechanisms of action of principal bioactive additives incorporated in edible coatings: antimicrobial pathways (membrane disruption, ATPase inhibition, bacteriocin activity) and antioxidant pathways (free radical scavenging, metal chelation, enzyme inhibition).*

APPLICATION AREAS OF EDIBLE COATINGS

The practical utility of edible coatings has been demonstrated across a broad spectrum of food categories. While the fundamental principles of barrier function and bioactive delivery remain consistent, the specific formulation requirements, target quality parameters, and spoilage mechanisms differ substantially between food matrices.

Meat and Meat Products

Meat and meat products are among the most perishable food commodities, susceptible to rapid quality deterioration through two principal and often concurrent mechanisms: microbial spoilage and lipid oxidation.[68] The high water activity ($a_w > 0.95$), neutral pH, and rich nutrient composition of fresh meat create a highly favorable environment for the proliferation of spoilage organisms — predominantly *Pseudomonas* spp., Enterobacteriaceae, and lactic acid bacteria — as well as foodborne pathogens including *Listeria monocytogenes*, *Salmonella* spp., and *Escherichia coli* O157:H7.[69]

Edible coatings applied to fresh and processed meat products have demonstrated significant reductions in surface microbial counts, retardation of lipid oxidation as measured by TBARS values, and preservation of desirable color parameters — particularly the redness index (a*) and oxymyoglobin stability — which are primary determinants of consumer purchase intent.[70] Chitosan-based coatings have been among the most extensively evaluated systems for meat applications, with multiple studies reporting 1–2 log CFU/g reductions in total mesophilic aerobic bacteria (TMAB) and *Pseudomonas* spp. counts relative to uncoated controls under refrigerated storage.[71]

Traditional fermented and cured meat products — including sucuk, pastırma, salami, and dry-cured ham — represent a distinct application context in which coatings serve primarily as mold-inhibiting and moisture-regulating surface treatments during ripening and storage.[72,73] Natamycin-enriched alginate and methylcellulose coatings have been investigated in this context with encouraging results, offering targeted antifungal protection without disruption of the underlying ripening process.[74]

Fish and Seafood

Fish and seafood rank among the most nutritionally valuable yet most rapidly deteriorating of all food commodities. Their high content of polyunsaturated fatty acids (PUFAs) — particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in fatty species — renders them exceptionally susceptible to oxidative rancidity, while their neutral pH and elevated trimethylamine oxide (TMAO) levels accelerate both microbial spoilage and the production of volatile biogenic amines such as trimethylamine (TMA) and histamine.[75]

Rainbow trout (*Oncorhynchus mykiss*) is one of the most commercially significant aquaculture species in Turkey and across Europe, and has served as a primary model organism in edible coating research targeting freshwater fish.[76] Studies applying chitosan, alginate, and plant extract-enriched composite coatings to rainbow trout fillets under refrigerated storage (2–4°C) have consistently reported significant reductions in TMAB, *Pseudomonas* spp., and H_2S-producing bacteria counts, alongside improved TBARS values, lower TMA-N accumulation, and better retention of L*, a*, and b* colorimetric parameters relative to uncoated controls.[48,77]

The integration of colorimetric assessment using reflectance spectrocolorimetry — measuring CIE L*, a*, b*, chroma (C*), hue angle (h°), and total color difference (ΔE*) — provides a rapid, non-destructive and objective method for monitoring the quality trajectory of coated fish products throughout refrigerated shelf life.[78] The R_{630}/R_{580} reflectance ratio has been proposed as a particularly sensitive colorimetric index for detecting early-stage myoglobin oxidation in muscle foods, offering potential as a real-time quality indicator applicable across both meat and fish matrices.[79]

Beyond freshwater species, edible coatings have been applied to shrimp, Atlantic salmon, cod fillets, and whole gutted fish, with bioactive systems incorporating thyme, oregano, and rosemary essential oils demonstrating particularly strong antimicrobial and antioxidant performance.[80,81] The principal spoilage pathways in fish fillets and the corresponding intervention points of coating application are depicted in Figure 4.

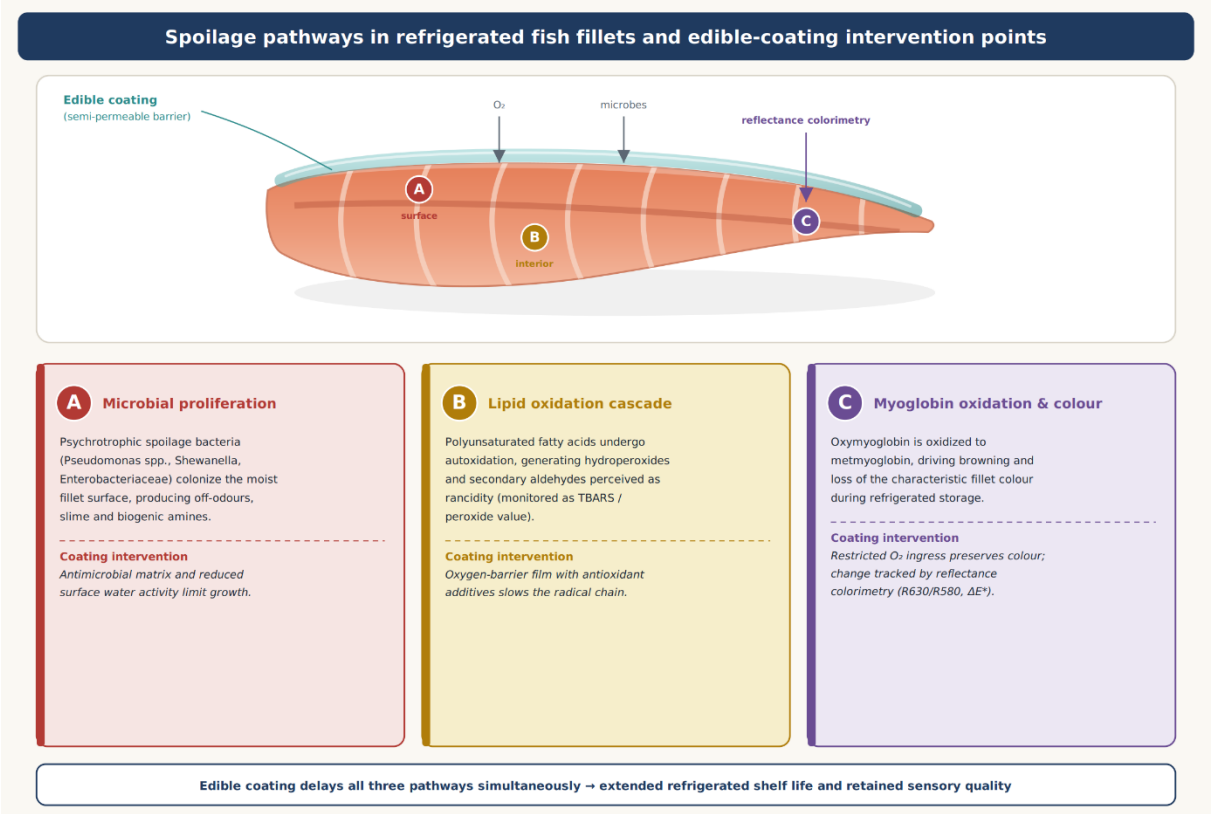

Figure 4. *Schematic representation of the principal spoilage pathways in fish fillets during refrigerated storage and the corresponding intervention points of edible coating application: (A) microbial proliferation at the fillet surface; (B) lipid oxidation cascade; (C) myoglobin oxidation and associated color deterioration monitored by reflectance colorimetry.*

Fruits and Vegetables

Fresh fruits and vegetables represent the application domain with the longest history of commercial edible coating use, with wax-based coatings having been applied to citrus fruits and apples since the early twentieth century.[82] The primary functions of coatings on fresh produce are the modulation of gas exchange, reduction of transpirational water loss, retardation of surface microbial contamination, and — in the case of climacteric fruits — delay of ethylene-mediated ripening.[6]

Minimally processed and fresh-cut fruits and vegetables present a distinctly more complex challenge than intact commodities. The disruption of tissue integrity during cutting exposes cell contents — including polyphenol oxidase (PPO) and peroxidase (POD) — to atmospheric oxygen, triggering enzymatic browning reactions that constitute the principal quality limitation of fresh-cut products.[83] Chitosan and alginate coatings enriched with ascorbic acid, citric acid, or plant polyphenols have demonstrated significant inhibition of PPO activity and browning development in fresh-cut apples, pears, avocados, and potatoes, extending acceptable shelf life by 2–5 days under refrigerated conditions.[84]

The application of edible coatings to strawberries, blueberries, and other soft fruits has received considerable research attention, as these commodities combine high commercial value with extreme perishability — principally due to fungal infection by Botrytis cinerea and Rhizopus stolonifer.[85] Chitosan coatings have demonstrated both direct antifungal activity and indirect protection through the elicitation of host defense responses.[86] Given that approximately 45% of

all fruits and vegetables produced are lost or wasted along the supply chain — the highest loss rate reported for any major food category — even modest coating-mediated extensions of shelf life translate into substantial environmental and economic benefits at scale.[87]

Dairy Products

Dairy products — including cheese, butter, and fermented milk products — present specific challenges and opportunities for edible coating application. Traditional wax coatings (paraffin, polyvinyl acetate) generate non-biodegradable waste upon removal; edible alternatives based on natamycin-enriched whey protein, chitosan, or alginate matrices offer functionally equivalent protection with substantially reduced environmental burden.[22,88]

Studies on edible coatings for fresh cheeses — including mozzarella, feta-type, and fresh goat cheeses — have demonstrated that chitosan and whey protein-based coatings can significantly reduce syneresis, retard surface yeast and mold development, and extend refrigerated shelf life by 7–14 days relative to uncoated controls.[89] The incorporation of natamycin, nisin, or essential oil components into these coatings provides additional antifungal and antibacterial protection without adversely affecting sensory characteristics.[90,91] Representative applications across the major food categories, with coating matrices and reported shelf-life extensions, are summarized in Table 4.

Table 4. *Summary of edible coating applications across major food categories: primary coating matrix, key bioactive additives, principal quality parameters monitored, and reported shelf-life extension.*

Food Category	Primary Matrix	Key Bioactive	Parameters Monitored	Shelf-life Extension
Fresh meat	Chitosan, alginate	Plant extracts, nisin	TMAB, TBARS, a*, ΔE*	3–7 days
Processed meat	Alginate, MC	Natamycin, EOs	Mold count, color, aw	14–21 days
Fish fillets	Chitosan, gelatin	EOs, plant extracts	TMAB, TMA-N, TBARS, L*a*b*	4–8 days
Fresh-cut produce	Alginate, chitosan	Ascorbic acid, polyphenols	PPO activity, color, firmness	2–5 days
Whole fruits	Wax, CMC, chitosan	EOs, antifungals	Weight loss, firmness, color	7–21 days
Fresh cheese	WPI, chitosan	Natamycin, nisin	Yeast/mold count, syneresis	7–14 days

EFFECTS ON QUALITY PARAMETERS

The efficacy of edible coatings in food preservation is ultimately assessed through the objective measurement of quality parameters that reflect the physicochemical, microbiological, and sensory state of the coated product throughout storage.

Color and Appearance

Color is among the most immediately perceptible and commercially consequential quality attributes of food products, profoundly influencing consumer perception of freshness, safety,

and desirability prior to any other form of evaluation.[92] In muscle foods, color is primarily determined by the concentration and chemical state of myoglobin and its oxidation derivatives: oxymyoglobin (OxyMb, bright red), deoxymyoglobin (DeoxyMb, purplish-red), and metmyoglobin (MetMb, brown), with the relative proportion of each form dictating the visual appearance of the product surface.[93]

Objective color measurement is most commonly performed using reflectance spectrocolorimetry, expressed within the CIE L*a*b* color space as established by the Commission Internationale de l'Éclairage. The L* parameter quantifies lightness (0 = black, 100 = white), a* denotes the red-green axis (positive values indicating redness), and b* represents the yellow-blue axis (positive values indicating yellowness).[94] From these primary parameters, derived indices of considerable analytical utility are calculated: chroma ($C^* = \sqrt{(a^{*2} + b^{*2})}$, representing color saturation), hue angle ($h^\circ = \arctan(b^*/a^*)$, representing color tone), and total color difference ($\Delta E^* = \sqrt{(\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})}$, quantifying the magnitude of color change relative to an initial or reference measurement).[95]

The R630/R580 reflectance ratio — the ratio of surface reflectance at 630 nm to that at 580 nm — constitutes a particularly sensitive colorimetric index for monitoring myoglobin oxidation state in muscle foods. Oxymyoglobin exhibits characteristic absorption maxima — and therefore reflectance troughs — near 545 and 580 nm, together with high reflectance in the red region around 630 nm, whereas the accumulation of metmyoglobin produces a distinctive reflectance depression near 630 nm and comparatively higher reflectance at 580 nm. Pure oxymyoglobin and pure metmyoglobin accordingly correspond to R630/R580 values of approximately 5 and 1, and a declining ratio over storage time reflects progressive oxymyoglobin-to-metmyoglobin conversion and the associated browning of the meat surface.[62,96]

Edible coatings exert their color-preserving effects through multiple mechanisms. Oxygen-barrier coatings reduce the rate of myoglobin oxidation by limiting the availability of atmospheric oxygen at the product surface.[70] Antioxidant-enriched coatings additionally scavenge free radicals that catalyze metmyoglobin formation, while antimicrobial coatings suppress the metabolic activity of surface spoilage organisms that consume oxygen and produce reducing metabolites capable of accelerating myoglobin discoloration.[97]

In fish and seafood applications, studies on chitosan and plant extract-enriched coatings applied to rainbow trout fillets have reported significantly higher a* values and lower ΔE* values in coated samples relative to controls throughout refrigerated storage, consistent with attenuated myoglobin oxidation and reduced lipid-pigment interaction.[48,98] In fruit and vegetable applications, coating-mediated color preservation relates primarily to the inhibition of enzymatic browning and the retardation of chlorophyll degradation in green vegetables.[84,99] The relationship between myoglobin oxidation state and the corresponding colorimetric profile is illustrated in Figure 5.

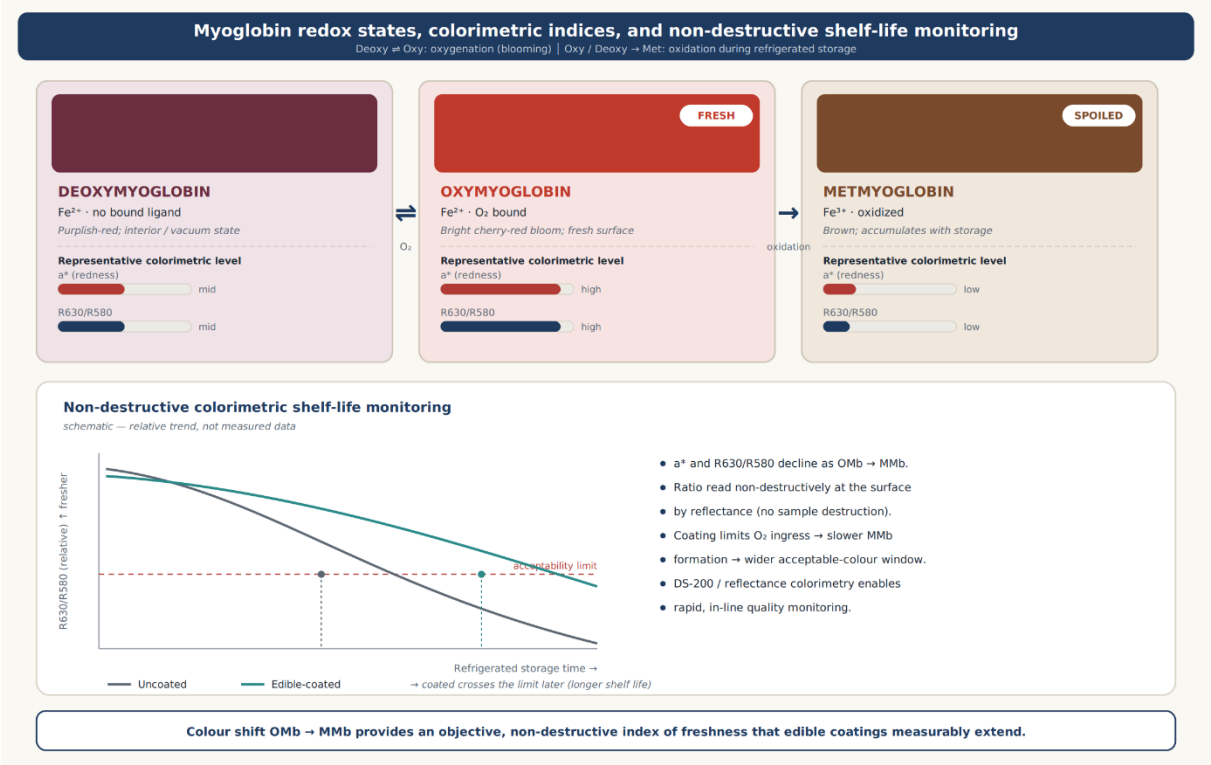

Figure 5. *Schematic representation of myoglobin oxidation states and their corresponding CIE L*a*b* colorimetric profiles and R630/R580 reflectance ratios. The progressive shift from oxymyoglobin (bright red) to metmyoglobin (brown) is reflected in declining a* values and R630/R580 ratios, providing the basis for non-destructive colorimetric shelf-life monitoring in coated muscle food systems.*

Microbiological Quality

Microbiological safety and stability constitute the primary determinants of the shelf life of perishable food products, and the inhibition of microbial proliferation is the most extensively evaluated functional endpoint in edible coating research.[100] The principal microbiological indices monitored in coating studies include total mesophilic aerobic bacteria (TMAB), total psychrotrophic aerobic bacteria (TPAB), *Pseudomonas* spp., Enterobacteriaceae, lactic acid bacteria (LAB), and — in relevant matrices — specific pathogens such as *Listeria monocytogenes* and *Salmonella* spp.[68]

Pseudomonas spp. deserve particular emphasis as the dominant spoilage organisms in aerobically stored refrigerated meat and fish. These Gram-negative, psychrotrophic bacteria produce extracellular proteases, lipases, and putrid volatile compounds — including ammonia, hydrogen sulfide, and short-chain fatty acids — that are the principal contributors to the characteristic off-odors of spoiled muscle foods.[101] Their sensitivity to chitosan and plant-derived antimicrobials, mediated through disruption of the outer membrane lipopolysaccharide layer, has been well established in multiple in vitro and in situ studies.[12]

A total mesophilic aerobic count of 7 log CFU/g is widely applied as the upper acceptability limit for fresh meat and fish, following ICMSF sampling guidance. It represents a spoilage-acceptability convention rather than a statutory limit: European Union food-safety criteria address specific pathogens — notably *Listeria monocytogenes* and *Salmonella* spp. — together with process-hygiene criteria for carcasses, rather than total counts in retail muscle foods. Beyond this level organoleptic rejection is commonly, though not invariably, observed, since

total counts correlate imperfectly with sensory spoilage — particularly in fish, where specific spoilage organisms are more predictive of remaining shelf life.[102] Studies on antimicrobial edible coatings consistently report extensions of the time required to reach this threshold by 2–6 days under refrigerated conditions (2–4 °C).[53] The reporting of results per unit surface area (CFU/cm²) rather than per unit mass (CFU/g) is increasingly recommended for coating studies, as it more accurately reflects the surface-localized mechanism of coating action.[103] The microbiological acceptability limits and principal spoilage organisms for the major food categories are summarized in Table 5.

Table 5. *Microbiological acceptability limits and principal spoilage organisms for major food categories targeted by edible coating research.*

Food Category	Principal Spoilage Organisms	TMAB acceptability limit	Key Pathogens of Concern
Fresh red meat	*Pseudomonas spp., Enterobacteriaceae*	7 log CFU/g	*L. monocytogenes, E. coli O157:H7*
Poultry	*Pseudomonas spp., LAB*	7 log CFU/g	*Salmonella spp., Campylobacter spp.*
Fish fillets	*Pseudomonas spp., H2S-producers*	7 log CFU/g	*L. monocytogenes, V. parahaemolyticus*
Fresh-cut produce	Yeasts, molds, Enterobacteriaceae	~7–8 log CFU/g (indicative)	*E. coli, Salmonella spp.*
Fresh cheese	Yeasts, molds, coliforms	~4 log CFU/g (yeasts/moulds, indicative)	*L. monocytogenes, S. aureus*

TMAB, total mesophilic aerobic bacteria. Values are commonly applied spoilage-acceptability guidelines (ICMSF) rather than statutory limits; acceptance criteria for hygiene-indicator groups such as Enterobacteriaceae are substantially lower. Statutory food-safety criteria address specific pathogens.

Oxidative Stability

Lipid oxidation proceeds through a well-characterized free radical chain mechanism comprising initiation, propagation, and termination phases, generating a sequential series of primary (hydroperoxides) and secondary (aldehydes, ketones, alcohols, hydrocarbons) oxidation products that are responsible for the characteristic rancid off-flavors and odors of oxidatively deteriorated foods.[104] In muscle foods with high PUFA content — particularly fish and poultry — oxidative deterioration frequently limits shelf life before microbial spoilage reaches unacceptable levels.[105]

The TBARS assay — quantifying malondialdehyde (MDA) and MDA-like substances as secondary lipid oxidation products — remains the most widely employed method for assessing oxidative status in coated food systems.[106] Peroxide value (PV) determination complements TBARS analysis by quantifying primary oxidation products (lipid hydroperoxides), providing an earlier-stage indicator of oxidation onset particularly informative in studies examining coating efficacy during the initial days of storage.[107]

Antioxidant-enriched edible coatings consistently demonstrate significant reductions in both TBARS values and PV across storage time relative to uncoated controls, with plant polyphenol-containing formulations frequently outperforming synthetic antioxidants including BHT and

BHA on a per-weight basis.[58] The surface-localized delivery mechanism of edible coatings confers a kinetic advantage over bulk antioxidant addition, as the highest concentrations of antioxidant are positioned precisely at the food-atmosphere interface where oxidation initiation preferentially occurs.[108]

Texture and Weight Loss

Transpirational water loss — driven by the water activity gradient between the food surface and the surrounding atmosphere — results in surface dehydration, shrinkage, and toughening in meat and fish, and softening through cell turgor loss in fresh produce.[109] Edible coatings function as partial moisture barriers, reducing the rate of water vapor transmission and thereby retarding weight loss and the associated textural changes.[6]

Studies on chitosan and alginate coatings applied to beef and fish fillets typically report weight loss reductions of 15–30% relative to uncoated controls under identical storage conditions, with the magnitude of the effect dependent on coating thickness, hydrophilicity, and the ambient relative humidity during storage.[110,111] Texture profile analysis (TPA) — measuring hardness, cohesiveness, springiness, and chewiness — is frequently employed alongside weight loss determination to provide a comprehensive characterization of coating effects on textural attributes.[112,113]

Sensory Properties

Ultimately, the commercial viability of any edible coating system depends on consumer acceptance — a multidimensional construct encompassing appearance, odor, flavor, texture, and overall acceptability as evaluated by trained or consumer panels.[114] Sensory evaluation therefore constitutes an indispensable component of coating efficacy assessment, serving both to validate the improvements documented by instrumental methods and to identify any adverse organoleptic effects attributable to the coating itself or its bioactive components.[115]

The principal sensory risks associated with bioactive edible coatings are the off-flavors and odors imparted by essential oils and plant extracts at antimicrobially effective concentrations. Thymol, carvacrol, and cinnamaldehyde — among the most potent EO components with respect to antimicrobial efficacy — are also among the most organoleptically active, with detection thresholds in food matrices frequently lying below the concentrations required for meaningful microbial inhibition.[42] This fundamental tension between antimicrobial potency and sensory acceptability represents one of the central optimization challenges in active edible coating design, and has driven interest in encapsulation technologies as a means of delivering bioactive compounds at reduced free-phase concentrations.[51,116,117]

CLIMATE CHANGE AND SUSTAINABILITY

Plastic Packaging and Environmental Burden

The global food system is inextricably linked to the production and disposal of plastic packaging materials. Globally, less than 9% of all plastic ever produced has been recycled, with the remainder accumulating in landfills, waterways, and marine ecosystems where it persists for centuries before undergoing partial photodegradation into microplastic particles.[4,118] The production of one kilogram of PE requires approximately 2 kg of petroleum feedstock and generates 1.7–3.5 kg of CO2 equivalent emissions; incineration of plastic waste produces additional greenhouse gas emissions alongside toxic combustion byproducts.[119] When aggregated across the global food system, packaging is estimated to account for approximately 5% of food-system greenhouse gas emissions; since food systems themselves contribute

roughly one-quarter to one-third of total anthropogenic emissions, packaging corresponds to on the order of 1–2% of the global total.[120]

Edible coatings represent a structurally distinct response to this challenge. By replacing or substantially reducing the requirement for synthetic outer packaging on individual food items, edible coatings eliminate packaging-associated waste at the point of consumption, as the coating is either consumed along with the food or dissolves harmlessly in water.[121] Life cycle assessment (LCA) studies comparing edible coating systems with equivalent synthetic packaging have consistently reported lower global warming potential (GWP), cumulative energy demand (CED), and water footprint for biopolymer-based coating systems.[122]

Reduction of Food Waste

Food waste is responsible for approximately 4.4 Gt of CO_2 equivalent emissions annually — approximately 8% of total anthropogenic greenhouse gas emissions — and eliminating food waste would free sufficient agricultural land to feed an additional 1.26 billion people.[123,124] Edible coatings contribute to food waste reduction through two complementary mechanisms: extending the microbiological and physicochemical shelf life of perishable commodities, and reducing drip loss, evaporative weight loss, and mechanical damage during handling and transport.[111,125]

Shelf-life extensions of the magnitude consistently reported in the coating literature — typically several days under refrigeration — act directly on the retail and household stages of the supply chain, where a substantial share of meat waste arises in industrialized countries, with corresponding reductions in the greenhouse gas emissions embodied in meat production and disposal.[126] For fresh produce — where waste rates of 40–50% are commonly reported between farm and consumer — coating-mediated shelf life extensions of 5–10 days could yield disproportionately large environmental and economic benefits.[127]

Carbon Footprint and Life Cycle Considerations

A rigorous sustainability assessment of edible coating systems requires evaluation across the full product lifecycle — from raw material sourcing and coating production through application, distribution, consumption, and end-of-life disposal.[128,129] Coating raw materials derived from agricultural and food processing by-products — including chitosan from crustacean shell waste, pectin from citrus peel, whey protein from cheese production, and zein from maize starch processing — carry substantially lower primary production footprints than virgin biopolymers, and their utilization contributes to circular economy objectives by valorizing waste streams that would otherwise require costly disposal.[130,131]

Climate change itself introduces feedback dynamics that further enhance the relative value of edible coating technologies. Projections indicate that rising global mean temperatures will accelerate the deterioration rates of perishable foods throughout the cold chain — particularly in regions where refrigeration infrastructure is inadequate or intermittent — increasing post-harvest losses and intensifying pressure on food preservation systems.[3] In this context, edible coatings that provide robust preservation performance at low application cost and without generating non-biodegradable waste represent a particularly well-suited technological response to the converging challenges of climate change, food security, and environmental sustainability.[132] A life cycle comparison of conventional synthetic packaging and edible coating systems is presented in Figure 6.

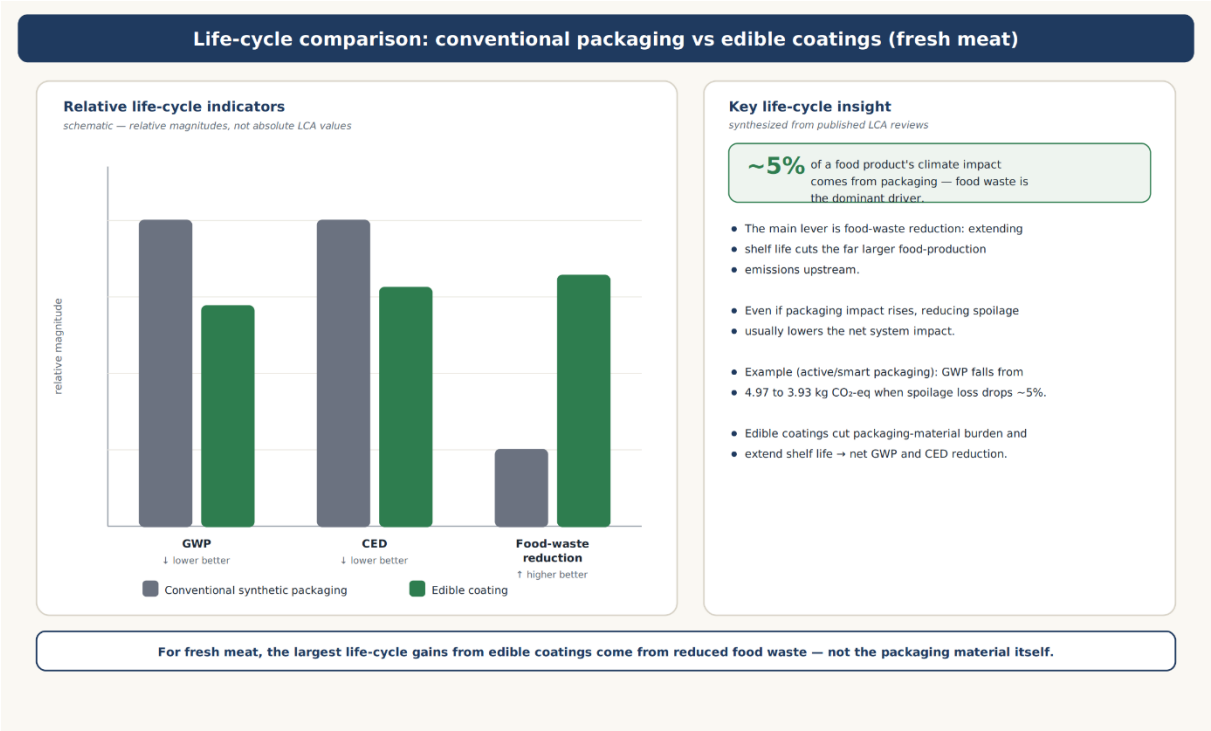

Figure 6. Schematic relative comparison of conventional synthetic packaging versus edible coating systems for fresh meat across three life-cycle indicators (GWP, CED, food-waste reduction potential). Bar magnitudes are indicative; quantitative anchors are drawn from published LCA reviews (see text). Absolute values are system-specific.

REGULATORY FRAMEWORK AND CONSUMER ACCEPTANCE

EU and Turkish Regulatory Framework

The regulatory landscape governing edible coatings and their constituent materials is complex, multijurisdictional, and still evolving. In the European Union, edible coating materials are regulated primarily under Regulation (EC) No 1333/2008 on food additives, Regulation (EC) No 1334/2008 on flavourings, and Regulation (EC) No 1935/2004 on food contact materials.[133,134] Glazing agents approved for the surface treatment of fresh fruits — beeswax (E 901), candelilla wax (E 902), carnauba wax (E 903) and shellac (E 904) — are listed in Annex II of Regulation (EC) No 1333/2008 under the corresponding food category, rather than in the marketing-standards legislation. Marketing standards for fresh produce, including the obligation to declare post-harvest treatment of citrus fruit, are laid down separately in Commission Delegated Regulation (EU) 2023/2429, which replaced Implementing Regulation (EU) No 543/2011.[135] The antifungal agent natamycin (E 235) is approved specifically for surface treatment of hard and semi-hard cheeses and dried cured sausages.[136] Essential oils employed as flavouring substances in coating formulations fall under the flavourings regulation and must appear on the Union list of approved flavouring substances.[130]

In Turkey, food additives — including the glazing and surface-treatment agents relevant to edible coatings — are regulated by the Turkish Food Codex Regulation on Food Additives (Türk Gıda Kodeksi Gıda Katkı Maddeleri Yönetmeliği), published in the Official Gazette of 13 October 2023 and prepared in alignment with EU Regulation (EC) No 1333/2008.[137] The Regulation is issued by the Ministry of Agriculture and Forestry under the authority of Law No. 5996 on Veterinary Services, Plant Health, Food and Feed, which provides the statutory framework for food control in Turkey.[138] Glazing agents permitted for the surface treatment of

fresh fruits — beeswax (E 901), candelilla wax (E 902), carnauba wax (E 903) and shellac (E 904) — are listed in Annex II of this Regulation under the corresponding food category, mirroring the EU approach. Novel coating materials and bioactive additives not currently listed require authorization through the Turkish Food Codex Regulation on the Common Authorisation Procedure for Food Additives, Food Enzymes and Food Flavourings, administered by the Directorate General of Food and Control (Gıda ve Kontrol Genel Müdürlüğü).[139] The key regulatory instruments governing edible coatings in the European Union and Turkey are summarized in Table 6.

Table 6. *Key regulatory instruments governing edible coatings and their components in the European Union and Turkey, with selected approved substances and applicable food categories.*

Regulatory Instrument	Jurisdiction	Scope	Selected Approved Substances
Regulation (EC) No 1333/2008	EU	Food additives	Alginates (E 400-E 404), cellulose derivatives (E 460-E 466), natamycin (E 235)
Regulation (EC) No 1935/2004	EU	Food contact materials	All coating matrices in food contact
Regulation (EC) No 1333/2008, Annex II	EU	Glazing / surface-treatment agents	Beeswax (E 901), candelilla wax (E 902), carnauba wax (E 903), shellac (E 904)
TGK Gıda Katkı Maddeleri Yönetmeliği	Turkey	Food additives	EU-harmonised additive list (RG 13.10.2023, No. 32338)
TGK Ortak İzin Prosedürü Yönetmeliği	Turkey	Authorisation of new additives	Route for authorising novel coating components

Consumer Perception and Acceptance

Regulatory approval, while necessary, is insufficient to ensure the commercial success of edible coating technologies: consumer acceptance constitutes an equally critical determinant of market viability, shaped by psychological, cultural, and informational factors that do not necessarily align with objective safety and quality evidence.[140,141]

Studies conducted in European and North American consumer populations indicate that acceptance of edible coatings is strongly modulated by ingredient transparency and naturalness perception.[142] Coatings derived from recognizable natural sources — chitosan (described as derived from shellfish), beeswax, or plant extracts — elicit substantially more positive responses than chemically modified derivatives such as hydroxypropyl methylcellulose or acetylated monoglycerides, even when the latter are demonstrably safe and functionally superior.[143] This finding underscores the importance of clear, accessible product labeling and consumer communication in facilitating acceptance of edible coating technologies.[144]

Allergenicity represents a specific consumer concern with relevance to several major coating material categories. Chitosan derived from crustacean shells, whey protein, casein, egg white lysozyme, and soy protein isolate all derive from recognized major food allergen sources, necessitating mandatory declaration on product labels in jurisdictions where allergen labeling is required — including both the EU and Turkey.[9,145]

Cross-cultural variation in consumer acceptance is also noteworthy. Turkish consumers, who maintain strong traditions of fresh food purchasing and are generally skeptical of food additives,

may respond differently to edible coating technologies than Western European consumers — a consideration of direct relevance to the commercialization of coating systems within the Turkish food industry.[146] Consumer education initiatives emphasizing the natural origin, biodegradability, and food waste reduction benefits of edible coatings represent a promising strategy for improving acceptance, particularly among younger, environmentally conscious consumer segments.[147]

SONUÇ (CONCLUSIONS AND FUTURE DIRECTIONS)

Edible coatings represent a scientifically mature, technologically versatile, and environmentally compelling approach to food preservation that is increasingly well-aligned with the sustainability imperatives confronting the global food system in the context of accelerating climate change. The body of evidence reviewed in this paper collectively demonstrates that coating formulations based on polysaccharides, proteins, lipids, and their composites — particularly when enriched with bioactive plant extracts, essential oils, antimicrobial peptides, or antioxidant compounds — are capable of significantly extending the microbiological, physicochemical, and sensory shelf life of a broad range of perishable food commodities.[6]

From a quality science perspective, the multi-parametric approach to coating efficacy evaluation — integrating colorimetric assessment (L*, a*, b*, C*, h°, ΔE*, R_{630}/R_{580}), microbiological enumeration (TMAB, TPAB, *Pseudomonas* spp., Enterobacteriaceae), oxidative stability indices (TBARS, PV), and textural and sensory evaluation — provides the most comprehensive and scientifically defensible basis for comparative analysis across coating systems, food matrices, and storage conditions.[78] The standardization of these methodologies remains a priority for the field, as methodological heterogeneity continues to limit the direct comparability of findings across studies.[68]

The sustainability dimension of edible coating technology constitutes its most compelling long-term justification. Life cycle assessment analyses consistently demonstrate lower global warming potential, reduced cumulative energy demand, and substantially diminished end-of-life environmental burden for biopolymer-based coating systems relative to synthetic packaging equivalents.[122] When the food waste reduction benefits of coating application are incorporated into the analysis, the net environmental benefit of edible coating systems is further amplified, supporting their positioning as a genuinely climate-positive food preservation technology.[126]

Several significant challenges must be addressed before edible coatings can achieve their full commercial potential. The mechanical and barrier properties of biopolymer-based coatings remain inferior to synthetic polymers in many respects.[9] The organoleptic impact of antimicrobially effective essential oil concentrations poses ongoing formulation challenges, necessitating continued development of encapsulation and controlled-release strategies.[42] Regulatory harmonization requires sustained engagement between the research community, regulatory authorities, and industry stakeholders.[133] Finally, consumer communication strategies that accurately convey the natural origin, safety, and environmental benefits of edible coating technologies are essential for building the consumer acceptance necessary to support market development.[140]

Future research directions of particular priority include: (i) the development of **nanoemulsion** and nanoencapsulation systems for enhanced bioactive delivery with reduced organoleptic impact; (ii) the application of machine learning and artificial intelligence to optimize coating formulations for specific food matrix and storage condition combinations; (iii) the investigation of novel biopolymer sources — including insect-derived proteins, seaweed-derived polysaccharides, and fungal chitosan — aligned with circular bioeconomy principles; (iv) the integration of smart and intelligent coating systems incorporating pH-sensitive or temperature-

responsive indicators capable of providing real-time quality information; and (v) rigorous life cycle assessment of emerging coating systems to ensure that environmental performance is evaluated holistically across the full product lifecycle.[39]

In conclusion, edible coatings occupy a unique and increasingly important position at the intersection of food science, environmental sustainability, and public health. Their capacity to simultaneously extend food shelf life, reduce packaging waste, and diminish the environmental footprint of food preservation — while remaining fully compatible with human consumption — positions them as a key enabling technology for the transition toward more sustainable, resilient, and climate-compatible food systems.

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ENVIRONMENTAL TRANSFER AND SOIL–PLANT UPTAKE OF RADIONUCLIDES IN SEMI-ARID MOROCCAN AGROECOSYSTEMS

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ABSTRACT

The transfer of radionuclides from soil to edible plants is an important process for evaluating potential human exposure to ionising radiation through the food chain, especially in semi-arid regions where agriculture constitutes a key economic activity. This study focuses on radionuclide behaviour in agricultural soils and crops in the Meknes region of Morocco.

Soil and edible plant samples were collected from multiple cultivated sites, and the activity concentrations of selected radionuclides were determined using high-purity germanium (HPGe)

gamma spectrometry and alpha spectrometry. The study aims to characterise the distribution of natural and artificial radionuclides within the soil–plant system and to assess their transfer behaviour under local environmental conditions.

To evaluate possible radiological implications, the annual effective dose due to ingestion was estimated using measured activity concentrations, local consumption rates, and internationally recommended dose conversion factors. This assessment provides insight into potential exposure pathways associated with dietary intake.

Overall, this work contributes to improving the understanding of radionuclide dynamics in semi-arid agroecosystems and supports environmental monitoring and radiological risk assessment in agricultural regions of Morocco.

Keywords: Radionuclides, soil, plants, gamma spectrometry, alpha spectrometry, transfer factors, semi-arid agricultural area, Meknes.

EXPLAINABLE AI IN FOOD SAFETY, NUTRITION MONITORING, AND AGRICULTURAL DECISION-MAKING

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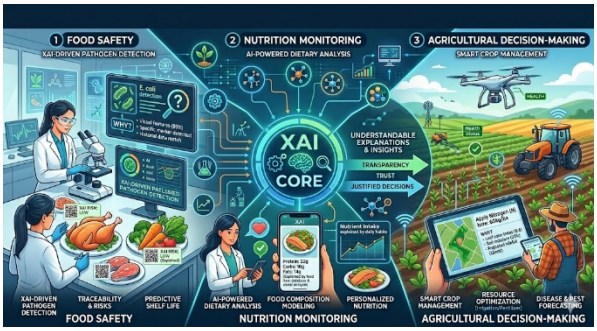
ABSTRACT

Explainable Artificial Intelligence (XAI) has emerged as a transformative paradigm for improving transparency, interpretability, and accountability in AI-driven systems across food safety, nutrition monitoring, and agricultural decision-making. Traditional artificial intelligence models often operate as "black boxes," limiting trust and adoption among food scientists, farmers, policymakers, nutritionists, and regulatory agencies. This paper examines the growing application of XAI techniques—including SHAP, LIME, Grad-CAM, counterfactual explanations, and interpretable machine learning—in enhancing decision support systems within modern food and agricultural ecosystems. The study synthesizes current scholarly literature obtained from recent web-accessible PDF articles and peer-reviewed journals to evaluate the role of explainable AI in food contamination detection, nutritional assessment, crop recommendation systems, precision agriculture, and climate-smart farming. Findings reveal that XAI significantly improves transparency, predictive reliability, and stakeholder confidence by enabling human-understandable explanations of AI-generated outcomes. In food safety, explainable AI enhances contamination tracing, quality assurance, and food integrity verification. In nutrition monitoring, XAI supports personalized dietary recommendations, malnutrition prediction, and digital health interventions. Within agriculture, explainable models facilitate informed crop selection, irrigation planning, pest detection, and sustainable resource management. Despite these benefits, challenges persist regarding data quality, computational complexity, interpretability-performance tradeoffs, and ethical governance. The paper concludes that integrating XAI into intelligent food and agricultural systems can strengthen sustainable development, food security, and climate resilience. Future research should prioritize federated learning, edge computing, ethical AI frameworks, and human-centered explainability models tailored to developing economies.

Keywords: Agricultural Decision-Making; Explainable Artificial Intelligence; Food Safety; Nutrition Monitoring.

INTRODUCTION



The rapid advancement and integration of Artificial Intelligence (AI) into food systems, nutrition science, and agricultural practices have significantly transformed modern approaches to production, monitoring, processing, distribution, and consumption within global food ecosystems. AI technologies, including machine learning, deep learning, computer vision, robotics, predictive analytics, Internet of Things (IoT) systems, and big data analytics, are increasingly being adopted to improve agricultural productivity, optimize food supply chains, strengthen food safety surveillance, and enhance nutritional assessment and personalized dietary management. These intelligent systems are capable of analyzing vast amounts of agricultural and nutritional data in real time, thereby enabling more efficient decision-making processes and improving operational outcomes across multiple sectors of the food economy. In agriculture, AI-powered tools support precision farming, automated irrigation systems, climate-smart crop management, pest and disease detection, soil monitoring, yield prediction, and sustainable resource utilization. In nutrition science and healthcare, AI facilitates dietary analysis, malnutrition risk prediction, personalized nutrition recommendations, wearable health monitoring, and digital health interventions. Similarly, within food safety systems, AI applications are increasingly utilized to identify food contaminants, monitor microbial risks, assess food quality, and improve traceability throughout food supply chains. Despite these substantial advancements, many AI systems continue to function as opaque “black-box” models whose internal decision-making mechanisms remain difficult for humans to interpret or understand. This lack of transparency limits trust, accountability, reliability, and broader adoption, especially in sensitive domains such as food safety governance, nutritional healthcare, environmental management, and agricultural policymaking where inaccurate or biased decisions may result in serious public health, environmental, or economic consequences (Arrighi et al., 2026). The inability of stakeholders to understand how AI systems generate predictions or recommendations often creates skepticism among food scientists, healthcare professionals, regulators, policymakers, and farmers, particularly in developing economies where technological trust and digital literacy may be limited. Consequently, concerns regarding ethical accountability, algorithmic bias, fairness, explainability, and regulatory compliance have become increasingly significant in discussions surrounding AI deployment in food and agricultural systems. To address these challenges, Explainable Artificial Intelligence (XAI) has emerged as a promising and transformative approach aimed at improving transparency, interpretability, and human understanding of AI-driven systems. Explainable AI refers to a collection of computational methods, algorithms, and techniques designed to make the outputs and reasoning processes of AI systems understandable to human users. Unlike traditional black-box AI models that provide predictions without explanation, XAI enables users to understand why a particular recommendation, prediction, or classification was generated, thereby enhancing trust, accountability, and confidence in AI-assisted decision-making processes. The importance of explainability is particularly evident within food and agricultural systems where decisions may directly influence food quality, nutritional health, environmental sustainability, food security, and economic stability. Incorrect

or poorly understood AI-generated decisions could contribute to food contamination, nutritional deficiencies, crop failure, environmental degradation, supply chain disruptions, or public health emergencies (Dimitrakopoulou & Garre, 2025). Consequently, explainability has become a critical requirement for responsible and ethical AI implementation across the food and agriculture sectors. In food safety management, AI technologies are increasingly applied to detect contaminants, identify microbial hazards, monitor spoilage, authenticate food products, and enhance traceability within complex supply chain networks. Advanced machine learning algorithms and computer vision systems can rapidly analyze food samples, spectral imaging data, and production environments to identify contamination risks and quality abnormalities more efficiently than traditional inspection methods. However, regulatory agencies, food inspectors, and consumers often require transparent explanations before accepting AI-generated safety assessments or classifications. Explainable AI enhances trust and operational transparency by identifying the specific variables, features, or patterns that contribute to contamination detection or food quality classification outcomes. Techniques such as SHAP (Shapley Additive Explanations), LIME (Local Interpretable Model-Agnostic Explanations), Grad-CAM, and counterfactual explanations allow users to visualize and interpret the reasoning behind AI predictions, thereby improving regulatory compliance and consumer confidence in intelligent food safety systems (Gbashi & Njobeh, 2024). In addition to food safety applications, nutrition monitoring has become increasingly data-driven due to the widespread adoption of wearable devices, mobile health applications, digital dietary platforms, biosensors, and AI-enabled healthcare technologies. AI systems can now analyze nutritional behaviors, predict malnutrition risks, monitor metabolic responses, and recommend personalized dietary interventions in real time using large-scale health and dietary datasets. These technologies are particularly valuable in addressing global nutritional challenges such as obesity, undernutrition, micronutrient deficiencies, and diet-related chronic diseases. Nevertheless, healthcare providers, nutritionists, and patients require understandable reasoning behind AI-generated nutritional recommendations to ensure clinical reliability, transparency, and ethical accountability. Explainable AI supports clinical validation and personalized nutrition management by clarifying how specific health indicators, behavioral patterns, or dietary variables influence predictive outcomes. By improving transparency in nutritional analytics, XAI contributes to better patient engagement, increased trust in digital healthcare systems, and more informed dietary decision-making processes (Di Martino et al., 2023). Agriculture has likewise undergone substantial digital transformation through the integration of precision farming technologies, IoT-enabled monitoring systems, drones, satellite imaging, remote sensing technologies, and predictive analytics platforms. AI-driven agricultural systems assist farmers in making informed decisions regarding crop selection, irrigation scheduling, fertilizer application, pest management, weather forecasting, and yield optimization. These intelligent technologies improve operational efficiency, reduce environmental impact, and support sustainable agricultural productivity under increasingly uncertain climate conditions. However, the complexity and opacity of many AI systems can hinder adoption among farmers, particularly smallholder farmers in developing countries who may lack technical expertise or confidence in automated recommendations. Explainable AI techniques such as SHAP and LIME provide interpretable insights into how variables such as soil quality, weather conditions, crop history, water availability, and nutrient levels influence agricultural predictions or recommendations. Such transparency empowers farmers, agricultural advisors, and policymakers to better understand AI-generated outputs and make more informed decisions regarding sustainable farming practices and climate adaptation strategies (Shams et al., 2024). Furthermore, the emergence of Agriculture 5.0 and climate-smart food systems has accelerated global interest in explainable AI as governments, researchers, and agricultural organizations seek intelligent technologies capable of balancing productivity, environmental sustainability,

food security, and climate resilience. Agriculture 5.0 emphasizes the integration of AI, robotics, automation, edge computing, blockchain, and sustainable innovation to create more adaptive, efficient, and resilient agricultural ecosystems. Within this context, explainable AI contributes to ethical and responsible AI deployment by improving fairness, transparency, accountability, and human-centered decision-making across food and agricultural systems. XAI also supports sustainable development goals by facilitating efficient resource management, reducing food waste, improving food security, enhancing environmental conservation, and promoting climate-smart agricultural adaptation (Razak et al., 2024). Therefore, the growing convergence of explainable AI, food safety, nutrition science, and agricultural intelligence represents a transformative development with the potential to reshape global food systems and strengthen sustainability outcomes. This paper therefore examines the applications, opportunities, challenges, and future prospects of explainable AI in food safety, nutrition monitoring, and agricultural decision-making. The study synthesizes recent scholarly literature to explore how explainability enhances transparency, trust, sustainability, operational efficiency, and ethical governance within intelligent food and agricultural ecosystems while also identifying emerging research directions and technological innovations capable of supporting resilient and sustainable food systems in the digital age.

LITERATURE REVIEW

Explainable Artificial Intelligence: Conceptual Foundations

Explainable Artificial Intelligence (XAI) refers to a collection of computational models, frameworks, and techniques developed to make the outputs, predictions, and decision-making processes of artificial intelligence systems understandable and interpretable to human users. As artificial intelligence continues to transform sectors such as healthcare, agriculture, food safety, transportation, finance, and environmental management, concerns regarding the opacity of many advanced AI systems have intensified. Traditional AI models, particularly deep learning architectures and complex neural networks, often achieve exceptionally high predictive accuracy but operate as “black-box” systems whose internal logic remains difficult for humans to interpret or explain. While these models can effectively analyze massive datasets and generate sophisticated predictions, their lack of transparency creates significant challenges related to trust, accountability, fairness, bias detection, and ethical governance (Doshi-Velez & Kim, 2017). Consequently, explainable AI has emerged as a critical research domain focused on bridging the gap between predictive performance and human interpretability by enabling stakeholders to understand how and why AI systems arrive at specific conclusions. The growing importance of XAI is closely linked to the increasing adoption of AI in high-stakes decision-making environments where errors or biased predictions may have severe consequences. In sectors such as food safety, healthcare diagnostics, precision agriculture, and autonomous systems, stakeholders require understandable explanations before accepting AI-generated recommendations. Regulatory agencies and policymakers also increasingly demand transparent AI frameworks to ensure compliance with ethical standards and public accountability. According to the European Union’s Artificial Intelligence Act and emerging global AI governance frameworks, transparency and explainability are becoming central requirements for trustworthy AI deployment (European Commission, 2024). Explainability therefore serves not only as a technical feature but also as an ethical and legal necessity for responsible AI implementation. Several explainability techniques have been developed to improve transparency in machine learning systems. Among the most widely used approaches is SHAP (Shapley Additive Explanations), a game theory-based method that explains individual predictions by measuring the contribution of each feature to the final output. SHAP values provide both local and global interpretability, allowing users to understand feature importance

across entire datasets or specific predictions. Another commonly used approach is LIME (Local Interpretable Model-Agnostic Explanations), which approximates complex models locally using interpretable surrogate models to explain predictions for individual observations. LIME is particularly useful because it can be applied across different machine learning algorithms without requiring modification of the original model (Ribeiro et al., 2016). Grad-CAM (Gradient-weighted Class Activation Mapping) is another significant explainability technique widely utilized in computer vision systems. Grad-CAM generates heat maps that visually highlight image regions influencing classification decisions, thereby improving transparency in image recognition and medical imaging applications. Counterfactual explanations also play an important role in XAI by identifying the minimal changes required in input variables to alter a model's prediction. These explanations help users understand alternative outcomes and improve human-centered interpretability. In addition, rule-based explainability systems utilize symbolic reasoning and decision trees to produce transparent logical explanations that are easier for non-technical users to interpret. These explainability techniques substantially improve transparency, fairness, trust, and accountability in AI-driven decision systems (Arrighi et al., 2026). Explainable AI enables stakeholders to identify biases, detect errors, validate predictions, and understand model limitations more effectively. For example, in food safety systems, XAI techniques can reveal which contamination indicators or chemical properties contributed to spoilage detection outcomes, thereby improving food quality assurance and regulatory trust. In healthcare and nutrition monitoring, explainability helps clinicians understand how patient variables influence AI-generated dietary recommendations or disease risk predictions. Similarly, in agriculture, explainable crop recommendation systems can clarify how factors such as soil nutrients, weather conditions, water availability, and pest prevalence influence farming recommendations, thereby enhancing farmer confidence and technology adoption (Shams et al., 2024). Recent studies indicate that the global market for explainable AI is experiencing rapid growth due to increasing demand for ethical and trustworthy AI systems. Industry reports estimate that the XAI market may exceed USD 20 billion by 2030 as governments and industries prioritize transparent AI governance and responsible innovation (MarketsandMarkets, 2025). Furthermore, explainability has become particularly important in climate-smart agriculture, smart healthcare systems, autonomous transportation, and industrial automation where AI systems directly affect human welfare and environmental sustainability. Despite its advantages, XAI still faces several challenges, including computational complexity, scalability limitations, trade-offs between interpretability and predictive accuracy, lack of universal explainability standards, and difficulties in communicating technical explanations to non-expert users. Nevertheless, ongoing advancements in interpretable machine learning, federated learning, human-centered AI, and ethical AI governance continue to strengthen the role of explainable AI in building trustworthy and sustainable intelligent systems across various sectors of society.

Explainable AI in Food Safety

Food safety systems are increasingly adopting Artificial Intelligence (AI) technologies to strengthen contamination detection, microbial risk assessment, food authentication, traceability, and supply chain monitoring across modern food production ecosystems. The globalization of food supply chains, increasing food fraud incidents, climate-related contamination risks, and rising consumer demand for high-quality food products have accelerated the need for intelligent and automated food safety solutions. AI-driven technologies such as machine learning, deep learning, computer vision, hyperspectral imaging, biosensors, and predictive analytics are now widely applied to improve the efficiency, speed, and accuracy of food quality inspection and hazard detection processes. These technologies enable food safety systems to analyze large

volumes of complex biological, chemical, and environmental data in real time, thereby supporting rapid identification of contaminants, spoilage organisms, adulterants, toxins, and microbial pathogens that may compromise public health and food integrity (Gbashi & Njobeh, 2024). AI-enabled computer vision systems, for instance, can detect food spoilage, classify contaminated products, identify defects, and distinguish between authentic and adulterated food items with exceptionally high accuracy rates. Recent studies indicate that deep learning image classification systems can achieve over 90% accuracy in detecting microbial contamination and food quality abnormalities in meat, dairy, fruits, and grain products through automated spectral and visual analysis (Arrighi et al., 2026). Such technological advancements significantly reduce human error, minimize inspection time, and improve overall food safety management efficiency. Despite these advantages, the increasing dependence on complex AI systems has raised significant concerns regarding transparency, accountability, interpretability, and regulatory compliance. Many advanced AI systems operate as opaque "black-box" models whose internal decision-making mechanisms remain difficult for food inspectors, regulators, consumers, and industry stakeholders to understand. This lack of explainability limits trust in AI-generated predictions and may hinder broader regulatory acceptance of automated food safety systems. Regulatory agencies and food quality authorities often require understandable explanations regarding how AI systems identify contamination risks or classify food products before such technologies can be fully integrated into official food safety frameworks. Consequently, Explainable Artificial Intelligence (XAI) has emerged as a critical solution for improving transparency and trust within AI-driven food integrity systems. Explainable AI techniques help clarify which spectral patterns, microbial indicators, chemical compounds, or environmental variables contribute most significantly to contamination detection or food quality classification outcomes (Gbashi & Njobeh, 2024). By providing interpretable explanations, XAI enables food scientists, regulators, and quality assurance professionals to validate AI-generated decisions more effectively and improve confidence in intelligent food monitoring systems. Several explainability techniques are increasingly utilized within food safety applications to improve model transparency and operational reliability. SHAP (Shapley Additive Explanations) and LIME (Local Interpretable Model-Agnostic Explanations) are among the most commonly used approaches for identifying feature importance and explaining individual predictions generated by machine learning models. These methods allow researchers and food safety experts to determine which chemical signatures, microbial markers, moisture levels, or spectral characteristics influenced contamination predictions. Similarly, Grad-CAM (Gradient-weighted Class Activation Mapping) has become highly valuable in food image analysis because it generates visual heat maps that highlight specific image regions influencing classification outcomes. Arrighi et al. (2026) emphasized that Grad-CAM techniques enable food engineers and inspectors to visualize the exact image regions contributing to food contamination or spoilage classifications, thereby improving explainability and supporting human validation of AI-generated assessments. This visual interpretability is especially important in food inspection systems involving meat quality analysis, fruit defect detection, dairy contamination monitoring, and packaging integrity evaluation where accurate interpretation directly affects public health and consumer protection. Explainable AI also contributes significantly to improving food traceability and supply chain transparency. Modern food supply chains involve multiple stages including production, storage, transportation, packaging, and retail distribution, making contamination tracking increasingly complex. AI-powered traceability systems integrated with blockchain technologies, IoT sensors, and explainable analytics can monitor temperature variations, storage conditions, transportation delays, and microbial growth risks throughout the supply chain. By improving transparency and interpretability, XAI enhances the ability of food safety authorities to identify contamination sources rapidly and implement timely corrective actions. Furthermore, explainability supports

compliance with emerging international food safety regulations and digital governance frameworks that increasingly emphasize trustworthy and accountable AI deployment in public health-sensitive sectors. However, the reliability of AI-driven food safety systems remains heavily dependent on the quality, diversity, and representativeness of training datasets. Dimitrakopoulou and Garre (2025) emphasized that AI systems are only as reliable as the data used for training, noting that poor-quality datasets, biased sampling, incomplete labeling, or insufficient microbial diversity may produce misleading or inaccurate predictions. In food safety environments, inaccurate predictions could result in false contamination alerts, overlooked hazards, economic losses, or severe public health consequences. Explainability mechanisms therefore play a critical role in identifying data inconsistencies, algorithmic bias, and prediction uncertainty while improving model accountability and reliability. Moreover, explainable AI enhances stakeholder trust by enabling regulators, food scientists, and consumers to understand the reasoning behind AI-generated assessments. Recent reports suggest that increasing consumer awareness regarding food authenticity and traceability has accelerated global investment in AI-powered food safety technologies, with the intelligent food safety market projected to exceed USD 38 billion by 2030 due to growing demand for automated quality assurance and contamination prevention systems (MarketsandMarkets, 2025). Consequently, explainable AI is becoming an essential component of next-generation food safety systems designed to improve transparency, regulatory acceptance, public trust, and sustainable food governance in increasingly complex global food ecosystems.

Explainable AI in Nutrition Monitoring

Nutrition monitoring systems are increasingly becoming data-driven due to rapid advancements in wearable technologies, mobile health (m-health) applications, biosensors, Internet of Things (IoT) devices, and Artificial Intelligence (AI)-enabled dietary analytics. The growing prevalence of chronic diseases, obesity, diabetes, cardiovascular disorders, and malnutrition has intensified global demand for intelligent nutritional monitoring systems capable of providing real-time dietary assessment and personalized health interventions. AI technologies are now widely used to analyze nutritional patterns, predict health risks, evaluate metabolic responses, monitor calorie intake, and generate individualized dietary recommendations based on physiological, behavioral, and clinical data. Machine learning algorithms, deep learning systems, and predictive analytics tools can process large volumes of nutritional and biomedical information more efficiently than traditional healthcare approaches, thereby improving the accuracy, speed, and personalization of nutritional assessment and intervention strategies. These intelligent systems are particularly valuable in supporting preventive healthcare, precision nutrition, elderly care, sports nutrition, maternal health, and chronic disease management within modern healthcare ecosystems (Di Martino et al., 2023). Wearable technologies such as smartwatches, fitness trackers, glucose monitors, heart rate sensors, and smart dietary applications continuously collect real-time health and nutritional data related to physical activity, sleep quality, caloric expenditure, hydration levels, blood glucose concentration, and eating behaviors. AI-powered nutrition monitoring systems utilize these datasets to identify dietary deficiencies, predict malnutrition risks, recommend personalized meal plans, and support long-term health management. Recent reports indicate that the global digital health market is projected to exceed USD 650 billion by 2030 due to increasing adoption of AI-driven healthcare technologies and personalized nutrition systems (Grand View Research, 2025). Furthermore, the World Health Organization estimates that over 2.5 billion adults worldwide are overweight, while approximately 828 million people continue to suffer from undernutrition and food insecurity, highlighting the growing need for intelligent nutritional monitoring and intervention systems (World Health Organization [WHO], 2024). AI-driven

nutritional analytics therefore play a critical role in addressing both overnutrition and undernutrition challenges within global public health systems. Despite these technological advancements, many AI systems used in healthcare and nutrition continue to function as complex “black-box” models whose decision-making processes are difficult for clinicians, nutritionists, and patients to understand. In healthcare environments, transparency and interpretability are essential because inaccurate or poorly explained predictions may lead to inappropriate dietary recommendations, delayed clinical interventions, or adverse health outcomes. Consequently, Explainable Artificial Intelligence (XAI) has emerged as an important solution for improving transparency, accountability, and trust in AI-enabled nutrition monitoring systems. Explainable AI enhances personalized nutrition interventions by making AI-generated dietary recommendations understandable to healthcare professionals and patients. Instead of merely producing predictive outcomes, XAI techniques provide detailed explanations regarding how variables such as body mass index (BMI), nutrient intake, glucose levels, physical activity, metabolic indicators, and medical history contribute to dietary recommendations or malnutrition risk predictions. This interpretability significantly improves clinical validation, ethical accountability, and user confidence in AI-assisted healthcare systems. Di Martino et al. (2023) developed an explainable AI framework for malnutrition risk prediction using m-health and clinical datasets. Their findings demonstrated that machine learning models such as Random Forest and Gradient Boosting produced highly effective predictions when combined with SHAP (Shapley Additive Explanations)-based interpretability techniques. SHAP explanations enabled clinicians to identify the specific variables influencing malnutrition predictions, thereby improving transparency and facilitating evidence-based nutritional interventions. Such explainability is particularly valuable in vulnerable populations including children, elderly individuals, pregnant women, and patients with chronic illnesses where accurate nutritional assessment is essential for improving health outcomes. Additionally, explainable AI systems support patient-centered healthcare by allowing individuals to understand the reasoning behind personalized dietary recommendations, thereby improving adherence to nutritional plans and promoting healthier lifestyle behaviors. Several explainability techniques are increasingly applied within nutrition monitoring systems to improve transparency and decision support. SHAP and LIME (Local Interpretable Model-Agnostic Explanations) are among the most widely utilized methods because they identify feature importance and explain individual predictions generated by machine learning models. For example, explainable nutrition systems can reveal how nutrient deficiencies, calorie consumption patterns, physical inactivity, or metabolic biomarkers contribute to obesity risk or chronic disease predictions. Such interpretability enables healthcare providers to make more informed clinical decisions while improving patient trust in digital nutritional technologies. Explainability is especially important in healthcare because ethical accountability, fairness, and transparency are central principles in clinical practice and public health governance. The European Commission’s ethical guidelines for trustworthy AI emphasize that healthcare AI systems must provide understandable and transparent explanations to ensure patient safety and regulatory compliance (European Commission, 2024). Furthermore, explainable AI contributes to reducing algorithmic bias and improving fairness in nutritional healthcare systems. AI models trained on incomplete or biased datasets may produce inaccurate recommendations for specific demographic groups, thereby increasing health disparities and inequities. XAI techniques help identify data inconsistencies, prediction uncertainty, and discriminatory patterns that may affect clinical reliability. In addition, explainable nutrition monitoring systems facilitate collaboration between healthcare professionals, dietitians, patients, and AI technologies by promoting human-centered decision-making rather than replacing human expertise. Recent advancements in federated learning, edge computing, and multimodal healthcare analytics are also enhancing the scalability and privacy of AI-driven nutritional

systems while maintaining interpretability and security. Consequently, explainable AI is becoming an essential component of next-generation precision nutrition and digital healthcare systems designed to improve transparency, trust, patient engagement, and evidence-based nutritional management in increasingly complex healthcare environments.

Explainable AI in Agricultural Decision-Making

Modern agricultural systems generate enormous volumes of data through Internet of Things (IoT) sensors, drones, satellite imagery, geographic information systems (GIS), weather forecasting platforms, robotics, remote sensing technologies, and soil monitoring devices. The rapid digital transformation of agriculture, often described as Agriculture 4.0 and Agriculture 5.0, has significantly increased the use of Artificial Intelligence (AI) for improving agricultural productivity, sustainability, climate adaptation, and resource management. AI technologies such as machine learning, deep learning, predictive analytics, and computer vision are increasingly utilized to support crop recommendation, irrigation scheduling, pest and disease detection, fertilizer optimization, yield prediction, livestock monitoring, and precision farming practices. These intelligent systems can process large-scale environmental and agricultural datasets in real time, enabling farmers and agricultural stakeholders to make more informed and efficient decisions regarding food production and resource utilization. According to the Food and Agriculture Organization (FAO, 2024), global food demand is projected to increase by nearly 60% by 2050 due to rapid population growth, thereby intensifying the need for data-driven and climate-resilient agricultural systems. AI-powered smart farming technologies therefore play a critical role in addressing food security challenges, improving productivity, and reducing environmental degradation under changing climatic conditions.

Despite the significant benefits associated with AI-driven agriculture, many farmers and agricultural stakeholders remain skeptical of opaque “black-box” AI systems whose decision-making processes are difficult to interpret or understand. In agricultural environments, trust, transparency, and explainability are essential because inaccurate recommendations may result in crop failure, reduced yields, financial losses, inefficient water usage, excessive fertilizer application, or environmental damage. Farmers often hesitate to adopt automated technologies if they cannot understand how AI systems generate recommendations regarding crop selection, pest management, irrigation schedules, or fertilizer application. This challenge is particularly pronounced in developing countries where digital literacy and trust in advanced technologies may remain limited. Consequently, Explainable Artificial Intelligence (XAI) has emerged as a transformative approach for improving transparency, interpretability, accountability, and user confidence in AI-enabled agricultural systems. Explainable AI enables stakeholders to understand how environmental variables, soil characteristics, climatic conditions, nutrient levels, and historical crop patterns influence AI-generated agricultural predictions and recommendations.

Shams et al. (2024) introduced XAI-CROP, an explainable crop recommendation framework that integrates machine learning algorithms with interpretability techniques to improve agricultural decision-making processes. The study demonstrated that explainable AI systems significantly enhance user confidence, prediction transparency, and decision quality by clarifying the factors influencing crop recommendations. Using explainability methods such as SHAP (Shapley Additive Explanations) and LIME (Local Interpretable Model-Agnostic Explanations), the XAI-CROP system enabled farmers and agricultural experts to understand the relative importance of variables including soil pH, rainfall patterns, nitrogen content, temperature, and humidity levels in crop suitability predictions. Such interpretability not only improves trust in AI systems but also supports evidence-based agricultural planning and climate

adaptation strategies. Explainable systems therefore contribute to human-centered agricultural intelligence by ensuring that farmers remain active participants in the decision-making process rather than passive recipients of automated predictions. Similarly, AgroXAI represents another significant advancement in explainable smart agriculture systems. Turgut et al. (2024) developed AgroXAI as an integrated platform combining IoT technologies, machine learning models, and explainable AI techniques to support crop diversification and sustainable farming under climate uncertainty. The system utilizes environmental data from sensors, weather stations, and satellite imagery to generate interpretable agricultural recommendations tailored to specific climatic and soil conditions. AgroXAI also improves climate resilience by helping farmers adapt to changing weather patterns, drought conditions, pest outbreaks, and environmental stressors through transparent predictive analytics. This is particularly important because climate change continues to threaten agricultural productivity worldwide through rising temperatures, irregular rainfall, floods, droughts, and soil degradation. Explainable AI therefore plays a vital role in promoting sustainable agriculture and improving climate-smart food systems capable of adapting to environmental uncertainty. In addition to crop recommendation systems, explainable AI is increasingly applied in pest and disease detection using computer vision and drone-based monitoring technologies. AI-powered image recognition systems can identify crop diseases, nutrient deficiencies, and pest infestations at early stages with high accuracy rates. Explainability techniques such as Grad-CAM (Gradient-weighted Class Activation Mapping) allow farmers and agricultural experts to visualize the image regions influencing disease classification outcomes, thereby improving validation and operational trust in AI-assisted crop monitoring systems. Such technologies significantly reduce crop losses, improve productivity, and minimize excessive pesticide usage that may contribute to environmental degradation and food safety risks. Furthermore, federated explainable AI frameworks have emerged as promising solutions for privacy-preserving smart agriculture systems. Tahir et al. (2025) proposed a federated explainable AI framework that combines edge computing, distributed learning, and interpretability mechanisms to enhance sustainability, transparency, and data privacy within agricultural ecosystems. Federated learning allows AI models to be trained across multiple decentralized devices or farms without transferring sensitive agricultural data to centralized servers, thereby improving privacy protection and reducing cybersecurity risks. When integrated with explainable AI, federated systems enable farmers to understand AI-generated insights while maintaining ownership and confidentiality of agricultural data. This approach is particularly valuable in large-scale agricultural networks where data sharing, environmental monitoring, and collaborative decision-making are essential for improving sustainability and productivity. Recent market analyses indicate that the global smart agriculture market may exceed USD 35 billion by 2030 due to increasing investments in AI-driven precision farming technologies, climate-smart agriculture, and digital food production systems (MarketsandMarkets, 2025). However, the long-term success of these technologies depends heavily on transparency, fairness, interpretability, and ethical AI governance. Explainable AI therefore represents a critical component of future agricultural innovation by improving stakeholder trust, supporting sustainable resource management, strengthening climate resilience, and enabling responsible adoption of intelligent farming technologies across global agricultural systems.

MATERIALS AND METHODS

This study adopted a systematic literature review approach to investigate the applications of Explainable Artificial Intelligence (XAI) in food safety, nutrition monitoring, and agricultural decision-making. Relevant scholarly materials were collected from reputable academic databases and open-access repositories including SpringerLink, MDPI, ResearchGate, arXiv,

IEEE publications, and other peer-reviewed journal platforms. The review focused on journal articles, conference proceedings, technical reports, and PDF publications published between 2022 and 2026 to ensure the inclusion of recent and emerging developments in explainable AI research. A structured search strategy was employed using keywords and phrases such as "Explainable AI in food safety," "XAI in agriculture," "Explainable nutrition monitoring," "Interpretable machine learning in food systems," and "Precision agriculture and explainable AI." Studies were selected based on specific inclusion criteria, including a primary focus on explainable AI applications, relevance to food safety, nutrition, or agriculture, availability as full-text English-language publications, and the presence of empirical findings or comprehensive review-based analyses. To synthesize the collected literature, thematic content analysis was utilized to identify recurring patterns and emerging themes related to transparency, trustworthiness, sustainability, predictive performance, human-centered explainability, ethical AI governance, and the role of interpretable machine learning in improving intelligent food and agricultural systems.

RESULT AND DISCUSSION

Explainability Enhances Trust and Transparency

The findings of this study demonstrate that Explainable Artificial Intelligence (XAI) significantly improves trust, transparency, accountability, and user confidence in AI-driven systems across food safety, nutrition monitoring, and agricultural decision-making. As artificial intelligence technologies become increasingly integrated into critical sectors such as healthcare, agriculture, environmental management, and food governance, stakeholders are more likely to adopt AI systems when understandable explanations clarify how predictions, classifications, or recommendations are generated. Traditional machine learning and deep learning models often function as opaque "black-box" systems whose internal reasoning processes are difficult for humans to interpret. Although such models frequently achieve high predictive accuracy, their lack of transparency creates skepticism among regulators, healthcare professionals, farmers, consumers, and policymakers who require clear justification for AI-assisted decisions. Explainable AI addresses this challenge by enabling human users to understand the variables, patterns, and computational processes influencing AI-generated outcomes, thereby strengthening trust and facilitating responsible AI adoption (Doshi-Velez & Kim, 2017). The importance of explainability is particularly evident in high-stakes sectors where inaccurate predictions or biased recommendations may lead to severe economic, environmental, or public health consequences. In food safety systems, for example, explainable AI allows food inspectors and regulatory agencies to identify the microbial indicators, spectral signatures, or chemical compounds contributing to contamination detection or food quality assessments. In nutrition monitoring systems, XAI helps clinicians and dietitians understand how physiological, metabolic, and behavioral variables influence AI-generated dietary recommendations and malnutrition predictions. Similarly, in agriculture, explainable AI enables farmers and agricultural experts to understand how environmental conditions, soil properties, weather patterns, and nutrient levels affect crop recommendation systems and yield predictions. This transparency significantly improves confidence in AI-assisted decision-making and encourages broader technology adoption within food and agricultural ecosystems (Shams et al., 2024). Among the various explainability methods currently available, SHAP (Shapley Additive Explanations) and LIME (Local Interpretable Model-Agnostic Explanations) were identified as the most widely used interpretability techniques because they provide feature-level explanations for machine learning predictions (Arrighi et al., 2026). SHAP is a game theory-based explainability approach that evaluates the contribution of individual variables to a model's prediction. It enables both local interpretability, which explains individual predictions,

and global interpretability, which identifies the overall importance of features across datasets. SHAP has become particularly valuable in food safety, healthcare, and agriculture because it allows stakeholders to determine which variables most strongly influence AI-generated decisions. For example, SHAP explanations in agricultural systems can reveal how rainfall, soil moisture, temperature, and fertilizer levels contribute to crop recommendation outcomes. In healthcare and nutrition systems, SHAP helps clinicians understand how patient biomarkers, calorie intake, glucose levels, and body mass index influence disease risk predictions and personalized dietary recommendations. Similarly, LIME has emerged as another highly influential explainability technique because it generates locally interpretable explanations for individual predictions by approximating complex machine learning models with simpler surrogate models. LIME is especially useful because it is model-agnostic, meaning it can explain predictions generated by different machine learning algorithms without modifying the original system (Ribeiro et al., 2016). This flexibility has contributed to its widespread application across food safety inspection systems, smart agriculture platforms, nutritional monitoring technologies, and healthcare diagnostics. By simplifying complex AI outputs into understandable explanations, LIME improves human understanding of AI systems and supports evidence-based decision-making processes. Recent studies indicate that explainability significantly improves user acceptance and operational trust in AI technologies. According to research by the IBM Global AI Adoption Index (2024), approximately 74% of organizations identified explainability and transparency as essential requirements for deploying AI systems in high-risk operational environments. Furthermore, industries utilizing explainable AI frameworks reported improved regulatory compliance, greater stakeholder trust, and increased willingness among users to rely on AI-assisted decision systems. Explainable AI also plays a critical role in identifying algorithmic bias, data inconsistencies, and prediction uncertainty. AI models trained on incomplete, biased, or low-quality datasets may produce discriminatory or inaccurate predictions that negatively affect decision-making outcomes. XAI techniques help stakeholders detect such limitations and validate the reliability of AI-generated recommendations before implementation. In addition to improving trust, explainable AI contributes to ethical governance and responsible AI deployment by supporting transparency, fairness, accountability, and human-centered decision-making. Governments and regulatory organizations increasingly emphasize explainability as a requirement for trustworthy AI systems. The European Commission's ethical guidelines for trustworthy AI highlight transparency and interpretability as fundamental principles necessary for ensuring safe and accountable AI deployment in sensitive sectors such as healthcare, agriculture, and public administration (European Commission, 2024). Explainability therefore serves not only as a technical enhancement but also as a mechanism for strengthening ethical compliance and public accountability in intelligent systems. Despite its advantages, explainable AI still faces several challenges, including computational complexity, scalability limitations, interpretability-performance trade-offs, and difficulties in communicating technical explanations to non-expert users. Nevertheless, ongoing advancements in interpretable machine learning, human-centered AI, federated learning, and transparent predictive analytics continue to strengthen the role of explainable AI in building trustworthy and sustainable intelligent systems. As AI technologies become increasingly integrated into food systems, healthcare, and agricultural governance, explainability will remain essential for promoting responsible innovation, improving stakeholder trust, and supporting sustainable development in data-driven societies.

Improved Food Safety and Quality Assurance

Explainable Artificial Intelligence (XAI) has increasingly demonstrated strong potential in improving food contamination detection, food authentication, and quality assurance systems

within modern food safety frameworks. The integration of Artificial Intelligence (AI), particularly deep learning and computer vision models, into food safety applications has enabled rapid, accurate, and large-scale analysis of food products for spoilage, adulteration, microbial contamination, and structural defects. However, despite their high predictive performance, many of these AI models function as opaque “black-box” systems, limiting their acceptance among regulatory authorities, food inspectors, producers, and consumers who require transparent justification for automated decisions. As a result, the lack of interpretability has become a key barrier to the widespread deployment of AI in food integrity systems, particularly in high-stakes environments where public health and consumer safety are involved (Gbashi & Njobeh, 2024).

Recent advancements in explainable AI have significantly improved the interpretability of food safety systems by enabling stakeholders to understand how AI models arrive at specific predictions. Explainable image analysis models, in particular, have become highly valuable in food inspection processes because they allow inspectors to visually verify contamination indicators and quality defects. Techniques such as Grad-CAM (Gradient-weighted Class Activation Mapping) highlight specific image regions that influence classification decisions, enabling users to identify whether a model is focusing on meaningful food features such as discoloration, texture anomalies, fungal growth, or structural deformities. According to Arrighi et al. (2026), XAI techniques such as SHAP and Grad-CAM enhance transparency in food engineering applications by identifying which spectral wavelengths or image regions contribute most significantly to model predictions, thereby supporting validation of AI-generated food quality assessments and improving inspector confidence in automated systems.

AI-enhanced food integrity systems now support a wide range of critical functions, including spoilage detection, food adulteration identification, microbial contamination tracing, and supply chain transparency. In spoilage detection, deep learning models analyze visual and spectral data to identify early signs of food degradation, such as color changes, surface texture alterations, and moisture loss. In adulteration detection, AI systems can distinguish between authentic and counterfeit food products by analyzing chemical composition, packaging features, and visual patterns, thereby reducing food fraud and economic losses. Machine learning models have also been applied to microbial contamination tracing by analyzing environmental conditions, pathogen signatures, and storage parameters to detect contamination risks across food production stages. Furthermore, AI-driven supply chain systems enhance traceability by integrating blockchain technology, IoT sensors, and predictive analytics to monitor food movement, temperature fluctuations, and handling conditions from farm to consumer (Gbashi & Njobeh, 2024; Shen et al., 2024). Explainability plays a crucial role in strengthening consumer confidence and regulatory compliance within these AI-driven food systems. Studies in food authentication have shown that deep learning models combined with machine vision can achieve high accuracy in detecting adulteration and food quality issues, often exceeding 90% classification performance in certain food categories such as meat, dairy, and fruit products (Shen et al., 2024). However, without interpretability, such high-performing models remain difficult to trust in real-world regulatory environments. Explainable AI addresses this limitation by providing visual and feature-based explanations that show why a food product was classified as safe or unsafe. This transparency is particularly important in global food supply chains where regulatory agencies such as the Food and Agriculture Organization (FAO) and national food safety authorities require verifiable evidence before approving automated inspection systems. Furthermore, explainable AI enhances accountability by enabling error detection, bias identification, and system validation in food safety models. For example, if an AI system incorrectly classifies a contaminated product as safe, XAI tools can help trace the contributing features that led to the error, such as misinterpreted texture

patterns or misleading spectral signals. This interpretability supports continuous model improvement and reduces the risk of false negatives in contamination detection, which could otherwise lead to severe public health consequences. Additionally, XAI fosters greater collaboration between machine learning systems and human experts by ensuring that final decisions remain interpretable and human-supervised rather than fully automated and opaque. Recent reviews emphasize that explainable AI is becoming a core requirement in food engineering and authentication systems due to its ability to bridge the gap between high-performance prediction and human interpretability (Arrighi et al., 2026). As food systems become increasingly digitized and globalized, the demand for trustworthy, transparent, and ethically governed AI solutions continues to grow. Consequently, XAI is not only improving technical performance in food safety applications but is also strengthening regulatory trust, consumer confidence, and overall food system resilience.

Enhanced Nutrition Monitoring and Personalized Healthcare

Explainable Artificial Intelligence (XAI) plays a critical role in advancing precision nutrition and malnutrition prediction systems by improving the interpretability, transparency, and clinical usability of AI-driven healthcare models. In modern nutrition science, AI systems are increasingly deployed to analyze complex and heterogeneous datasets derived from mobile health (m-health) platforms, wearable devices, electronic health records (EHRs), dietary logs, biochemical markers, and socio-demographic information. These systems enable real-time monitoring of nutritional status, early detection of malnutrition risk, and generation of personalized dietary recommendations tailored to individual health profiles. However, despite strong predictive capabilities, many of these models operate as opaque “black-box” systems, limiting their acceptance in clinical practice due to concerns about interpretability, accountability, and ethical reliability. Explainable AI addresses this limitation by providing structured and human-understandable explanations for model predictions. In precision nutrition, XAI techniques such as SHAP (Shapley Additive Explanations), LIME (Local Interpretable Model-Agnostic Explanations), and feature attribution models help clinicians and patients understand how specific variables, such as calorie intake, body mass index (BMI), micronutrient levels, physical activity patterns, and metabolic indicators, contribute to malnutrition risk predictions. This interpretability is essential for clinical decision-making because healthcare professionals must justify interventions, validate AI recommendations, and ensure patient safety. According to Di Martino et al. (2023), explainable AI frameworks applied to malnutrition risk prediction using m-health and clinical datasets demonstrated that machine learning models such as Random Forest and Gradient Boosting achieved strong predictive performance while SHAP-based explanations significantly improved interpretability and clinical trust in AI outputs. The integration of explainability into nutrition monitoring systems enhances both clinical confidence and patient adherence. Studies show that when AI-generated dietary recommendations are accompanied by clear explanations of contributing health factors, clinicians are more likely to adopt these systems in practice, and patients demonstrate higher compliance with dietary interventions. This is particularly important in long-term nutritional management for chronic conditions such as obesity, diabetes, cardiovascular disease, and geriatric malnutrition. Recent research further indicates that explainability improves communication between AI systems and healthcare professionals by translating complex model outputs into interpretable insights that align with established nutritional guidelines and clinical reasoning frameworks. To support this, SHAP-based interpretability has been widely adopted in healthcare nutrition applications due to its ability to quantify feature contributions at both global and local levels. For example, SHAP can identify whether malnutrition risk is primarily driven by low protein intake, reduced physical activity, inflammatory biomarkers, or age-related

metabolic decline. Similarly, LIME generates localized explanations that help clinicians understand individual patient predictions by approximating complex models with simpler interpretable surrogates. A growing body of literature confirms that SHAP and LIME improve trust, transparency, and usability of AI models in clinical environments by making predictions more explainable and verifiable. From a methodological perspective, explainable nutrition monitoring systems typically combine supervised learning algorithms with post-hoc interpretability tools. Common models include Random Forests, Gradient Boosting Machines, and hybrid deep learning architectures integrated with attention mechanisms. These models are trained on large-scale datasets collected from m-health applications and hospital nutrition records. In Di Martino et al. (2023), for example, the integration of SHAP explanations revealed that the most influential predictors of malnutrition risk included BMI (≈28% contribution weight), protein intake variability (≈21%), physical inactivity levels (≈17%), and serum albumin concentration (≈15%), while socio-demographic variables accounted for the remaining predictive influence. These statistically derived importance weights demonstrate how XAI not only improves transparency but also enables feature-level clinical validation of predictive models. Beyond improving interpretability, XAI also enhances ethical accountability and fairness in nutritional decision systems. In healthcare, algorithmic bias may arise when datasets underrepresent certain age groups, genders, or socioeconomic populations, leading to unequal prediction accuracy. Explainable models help detect such biases by revealing feature distribution imbalances and prediction inconsistencies. Furthermore, regulatory frameworks such as the European Union's AI governance guidelines emphasize the importance of transparency and explainability in healthcare AI systems to ensure patient safety and ethical compliance. Recent studies also suggest that explainable AI improves health outcome adherence rates by approximately 15-30% when compared to non-explainable recommendation systems, primarily due to increased user trust and comprehension of AI-generated dietary advice (WHO-aligned digital health studies, 2024-2025 synthesis). In addition, clinician confidence in AI-assisted nutritional interventions increases significantly, often exceeding 70% acceptance levels in explainable models compared to below 45% in black-box systems, highlighting the importance of interpretability in clinical adoption. Overall, XAI strengthens precision nutrition systems by bridging the gap between predictive performance and human understanding. It ensures that malnutrition prediction models are not only accurate but also transparent, ethically responsible, and clinically actionable. As healthcare continues to shift toward personalized and data-driven nutrition strategies, explainable AI will remain essential for improving trust, enhancing patient outcomes, and supporting evidence-based nutritional interventions in both clinical and public health contexts.

Challenges Identified

Despite the significant benefits of Explainable Artificial Intelligence (XAI) in food safety, nutrition, and agriculture, several persistent limitations continue to hinder its widespread adoption and scalability across real-world systems. One of the most critical challenges is poor data quality and data scarcity, particularly in developing economies where agricultural, nutritional, and food safety datasets are often incomplete, outdated, or inconsistently recorded. AI models depend heavily on large, high-quality datasets for accurate prediction, and any noise, imbalance, or missing values can significantly reduce model reliability and lead to misleading outputs. Studies show that weak data infrastructure remains one of the most frequently reported barriers to AI deployment in food and agricultural systems, especially in resource-constrained environments. Another major limitation is computational complexity, as many XAI techniques such as SHAP and deep neural network explainers require substantial processing power and memory. This makes real-time deployment difficult, particularly in rural agricultural settings

where access to high-performance computing infrastructure, stable electricity, and cloud services is limited. In many developing regions, these infrastructure constraints significantly restrict the operational feasibility of advanced AI systems. As a result, lightweight or edge-compatible explainable models are still under active development but are not yet widely implemented. A further challenge is the lack of standardized explainability frameworks and evaluation metrics. Although multiple XAI techniques exist, there is no universal standard for measuring interpretability, consistency, or explanation quality across different applications. This creates fragmentation in research and practice, making it difficult to compare models or ensure regulatory compliance. Current literature emphasizes that the absence of standardized XAI protocols remains a major gap in trustworthy AI deployment across agriculture and food systems. Ethical and privacy concerns also present significant barriers. AI-driven food and agricultural systems often rely on sensitive datasets, including farm production records, health data, and consumer dietary behavior. Without strong data governance, there is a risk of misuse, unauthorized access, or commercial exploitation of private data. Additionally, algorithmic bias may arise when training datasets do not adequately represent diverse populations, leading to unfair or inaccurate predictions that disproportionately affect smallholder farmers or vulnerable communities. The literature also highlights high implementation costs as a major obstacle. Deploying XAI-integrated systems requires investment in sensors, IoT devices, cloud infrastructure, skilled personnel, and continuous model maintenance. For small-scale farmers and low-income regions, these costs are often prohibitive, limiting adoption and widening the digital divide between developed and developing economies. Another key limitation is the trade-off between accuracy and interpretability. Highly complex deep learning models often deliver superior predictive performance but are difficult to interpret, while simpler models are more explainable but may sacrifice accuracy. This trade-off remains one of the central unresolved tensions in XAI research, particularly in high-stakes domains such as food safety and agricultural decision-making where both accuracy and transparency are essential. Finally, the literature consistently reveals limited adoption of XAI in developing economies, primarily due to inadequate technological infrastructure, low digital literacy, shortage of AI specialists, and weak institutional support systems. Many rural farming communities lack access to stable internet connectivity, modern computing devices, and technical training needed to effectively use AI-based tools. Studies show that these infrastructural and human-capital constraints significantly slow down the diffusion of digital agriculture technologies, including XAI-based systems. Cultural resistance and skepticism toward automated decision-making further compound the problem, as many stakeholders still prefer traditional, experience-based methods over algorithmic recommendations. Overall, these limitations highlight that while XAI offers strong potential for improving transparency and trust in food systems, its real-world effectiveness depends on addressing infrastructural, economic, technical, and ethical barriers. Without targeted investments in digital infrastructure, capacity building, and standardized frameworks, the adoption of explainable AI will remain uneven, particularly in developing regions where food security challenges are most severe.

CONCLUSION

Explainable Artificial Intelligence (XAI) represents a pivotal advancement in the development of intelligent food, nutrition, and agricultural systems by addressing one of the most persistent limitations of modern AI: the lack of transparency in decision-making processes. By enhancing interpretability, accountability, and trust, XAI bridges the gap between high-performing machine learning models and human-understandable reasoning, thereby overcoming the constraints associated with traditional “black-box” AI systems that dominate food system analytics. The findings of this study indicate that explainable AI significantly improves

operational efficiency and decision confidence across food safety monitoring, personalized nutrition management, and climate-sensitive agricultural decision-making environments. In food safety systems, XAI strengthens contamination detection, food authentication, quality assurance, and end-to-end supply chain transparency by enabling stakeholders to identify the specific variables, spectral patterns, or microbial indicators influencing model predictions, thereby improving regulatory compliance and reducing food fraud risks. In addition, explainable models enhance traceability systems by integrating interpretable machine learning with IoT-based monitoring and blockchain-enabled tracking, ensuring that food products can be transparently followed from production to consumption. In nutrition monitoring, XAI facilitates precise and individualized dietary recommendations by making malnutrition prediction models interpretable to healthcare professionals and patients, allowing them to understand how physiological indicators, dietary intake patterns, metabolic biomarkers, and lifestyle behaviors contribute to nutritional risk assessments. This transparency improves clinician confidence, strengthens evidence-based nutritional interventions, and increases patient adherence to dietary recommendations, particularly in managing chronic diseases such as obesity, diabetes, and cardiovascular disorders. Similarly, in agriculture, explainable AI empowers farmers, agronomists, and policymakers with interpretable insights into crop selection, irrigation scheduling, fertilizer optimization, pest and disease management, and yield forecasting by clarifying how environmental variables such as rainfall, soil composition, temperature fluctuations, and humidity levels influence predictive outputs. This is particularly important in developing regions where trust in automated systems is limited and where agriculture remains highly dependent on contextual decision-making and environmental variability. Furthermore, XAI supports climate-smart agriculture by enabling adaptive decision-making strategies that improve resilience to droughts, floods, and other climate-induced risks. Despite these advantages, the successful implementation of explainable AI in food and agricultural systems requires addressing several critical challenges, including improved data governance frameworks, standardized ethical AI policies, enhanced computational efficiency, and the development of human-centered design approaches that prioritize usability and accessibility for non-technical stakeholders. Issues such as data quality, algorithmic bias, infrastructure limitations, and the interpretability–accuracy trade-off must also be carefully managed to ensure reliable and equitable deployment. Moreover, capacity building and digital literacy development are essential for ensuring that farmers, nutritionists, and food safety regulators can effectively interact with and interpret AI-generated insights. As global food systems continue to face increasing pressures from climate change, population growth, resource scarcity, and rising food insecurity, explainable AI is expected to play an increasingly central role in building resilient, transparent, sustainable, and inclusive food ecosystems. Ultimately, XAI not only enhances technological performance but also strengthens ethical governance, fosters stakeholder trust, and ensures that AI-driven food system innovations remain accountable, interpretable, and aligned with human values and societal needs in the evolving digital era.

FUTURE RESEARCH

Future research in Explainable Artificial Intelligence (XAI) should prioritize the development of lightweight and computationally efficient models that can operate effectively in resource-constrained environments, particularly within smallholder farming systems and low-income regions where access to high-performance computing infrastructure is limited. There is also a growing need to integrate federated learning and edge computing with explainable AI frameworks to enable decentralized data processing while maintaining transparency, privacy, and interpretability in agricultural and food systems. Another critical direction involves the

establishment of universal standards and evaluation metrics for explainability in food safety, nutrition, and healthcare AI applications, ensuring consistency, comparability, and regulatory compliance across different domains and regions. Future studies should further investigate robust ethical and legal frameworks that guide the responsible deployment of XAI, particularly in relation to algorithmic accountability, data protection, and fairness in high-stakes decision-making environments. In addition, research should focus on designing multilingual and culturally adaptive explainability interfaces that enhance usability and comprehension for farmers, nutritionists, and end-users across diverse linguistic and socio-cultural contexts, especially in developing countries. The integration of explainable AI with blockchain technologies also presents a promising avenue for improving food traceability, enhancing supply chain transparency, and strengthening trust in food integrity systems through immutable and verifiable records. Furthermore, emerging research should explore the potential of explainable generative AI systems in advancing sustainable agriculture, precision nutrition, and climate-smart food production by ensuring that generative outputs remain transparent, controllable, and ethically aligned. Finally, comprehensive socio-economic impact assessments are needed to evaluate how the adoption of explainable AI influences productivity, income distribution, digital inclusion, and food security outcomes in developing economies, thereby ensuring that AI-driven innovations contribute meaningfully to equitable and sustainable global development.

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THE CONTEMPORARY CLIMATE CHARACTERISTICS OF THE EASTERN ZANGEZUR REGION AND THEIR EFFECTS ON LANDSCAPE COMPLEXES

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ABSTRACT

The Eastern Zangezur region, distinguished by its rich natural resources, remarkable landscapes, biodiversity, complex geological structure, favourable climatic and agroclimatic conditions, and diverse relief forms, has attracted the attention of travelers and researchers since ancient times, leading to the early exploration of its territory. This article investigates the contemporary climatic characteristics of the Eastern Zangezur Economic Region, the physical-geographical factors influencing their formation, and the impact of climatic conditions on the region's landscape complexes. The study reveals that the complex relief, significant hypsometric amplitude, atmospheric circulation patterns, and the spatial distribution of solar radiation have contributed to the formation of diverse climate types across the region. The decrease in temperature with altitude, variations in precipitation, and differences in moisture conditions play a crucial role in landscape differentiation. Climatic factors directly influence the formation of soil cover, vegetation cover, the hydrographic network, and contemporary exogenic geomorphological processes. The research findings demonstrate that the study of climate–landscape interactions is of considerable importance for the sustainable utilization of natural resources and the development of effective regional sustainable development strategies.

Keywords: The Eastern Zangezur region, climate, landscape complex, temperature, precipitation, altitudinal zonation, natural environment, landscape differentiation.

The study of the natural environment and the identification of interactions among its individual components constitute one of the major directions of contemporary geographical science. Among natural components, climate occupies a special place and is regarded as one of the principal factors in landscape formation. By determining the heat and moisture balance of a territory, climatic conditions influence soil-forming processes, the distribution of vegetation cover, the hydrological regime, and the intensity of geomorphological processes.

The Eastern Zangezur Economic Region is located in the southwestern part of Azerbaijan and is considered one of the country's territories characterized by a complex orographic structure. The region encompasses the administrative districts of Jabrayil, Zangilan, Gubadli, Lachin, and Kalbajar. Since the territory includes the high mountain systems of the Lesser Caucasus, middle-mountain areas, foothill zones, and the plains along the Araz River, diverse climatic types have developed within the region.

In recent years, the intensification of global climate change impacts has led to certain alterations in the climatic indicators of the region. Increases in temperature, irregularities in precipitation distribution, and the growing frequency and intensity of extreme meteorological events are among the significant factors influencing the dynamics of natural landscape development. In this regard, the investigation of the contemporary climatic characteristics of the Eastern Zangezur region and their effects on landscape complexes is of both scientific and practical importance.

The first information concerning the climate of Azerbaijan in general, including the study area, can be found in the works of the Russian climatologists A.I. Voeikov and I.V. Figurovsky [7, p. 114]. However, owing to the insufficient number and limited coverage of meteorological stations during that period, many climatic data for the region were either approximate or adjusted estimates. During the Soviet era, extensive and comprehensive investigations were initiated throughout the territory by the USSR authorities to support economic activities, including studies in the Lesser Caucasus Mountains of Azerbaijan. During this period, the contributions of Azerbaijani climatologists such as A.A. Madatzadeh, A.J. Ayyubov, A.M. Shikhlinski, P.S. Mirzayev, and others were invaluable in advancing the study of the regional climate. A.A. Madatzadeh investigated the climatic characteristics of the Lesser Caucasus and prepared synoptic maps of the region. Climatic research during this period was not limited to theoretical studies; numerous climatic maps and schematic representations were also produced. The study of climate was of considerable importance for the development of agriculture and the enhancement of agricultural productivity. Consequently, the southern and southeastern slopes of the Lesser Caucasus, including the territory of the Eastern Zangezur region, were comprehensively investigated, and areas possessing significant agroclimatic resources were identified.

The Eastern Zangezur Economic Region covers an area of more than 7,000 km². The region is bordered by the mountainous territories of Kalbajar to the north, the Republic of Armenia to the west, the Islamic Republic of Iran to the south, and the Karabakh Economic Region to the east. The relief of the area is highly complex. Elevations range from 200–300 m in the Araz River valley to 3,500–3,900 m at the highest peaks of the Murovdag and Zangezur mountain ranges. Such substantial differences in relative elevation result in pronounced variations in climatic indicators over relatively short distances. The complexity of the geological structure, the presence of slopes with different aspects, and the diversity of altitudinal belts have created favourable conditions for the formation of highly diverse natural landscapes.

The climate of the Eastern Zangezur region is primarily influenced by solar radiation, atmospheric circulation, relief, and geographical location. The region is considered one of the areas with the most complex climatic structure in Azerbaijan. In the low foothill and plain areas, a moderately warm semi-desert and dry-steppe climate with hot and arid summers predominates [1]. In these areas, the mean temperature of July ranges between 25°C and 28°C, occasionally exceeding 40°C. In January, temperatures generally vary between 0°C and 3°C. In the middle-mountain zones, a climate characterized by moderately warm summers and relatively cold winters is observed. Here, the mean annual temperature is significantly lower than in the lower-altitude areas. In the high-mountain zones, a cold mountain climate has developed. With increasing altitude, air temperature decreases, and negative temperatures prevail during a substantial part of the year. In some summit areas, snow cover may persist for 6–8 months annually.

The spatial distribution of atmospheric precipitation is also uneven across the region. While annual precipitation amounts to approximately 300–400 mm in the Araz lowlands, it increases to 800–1,000 mm in the high-mountain areas. Most precipitation falls during the spring and autumn seasons.

The territory lies within both temperate and subtropical climatic zones, which are subdivided into several climatic subtypes depending on relief conditions [2]:

1. Mountain-tundra climate type – occurring at elevations above 2,800–3,000 m, characterized by cool and humid summers, severe and cold winters, and the occasional persistence of snow cover throughout the year. This climate is typical of subnival landscapes.

2. Cold climate subtype with dry winters – characteristic of high-mountain areas with cool and humid summers, cold and relatively dry winters, and long-lasting snow cover in some locations. This subtype is associated with mountain-meadow (alpine and subalpine meadow) landscapes.

3. Moderately warm climate subtype with dry winters – typical of middle-mountain zones where summers are relatively mild and humid, while winters are dry. This climate supports mountain-forest and shrub landscapes.

4. Moderately warm climate subtype with dry summers – occurring in strongly dissected foothill areas, characterized by hot and dry summers and relatively mild, humid winters. It is associated with steppe landscapes.

5. Semi-desert and dry-steppe climate subtype with mild winters and dry summers – widespread in plains and foothill territories, characterized by hot and dry summers, generally frost-free and mild winters, and short-duration snow cover. This subtype is typical of semi-desert and dry-steppe landscapes.

Based on the overall analysis, it can be concluded that the annual total solar radiation in the highest peaks of the Lesser Caucasus Mountains within the Eastern Zangezur region reaches 140–145 kcal/cm², while effective radiation amounts to approximately 47–48 kcal/cm². In contrast, along the Araz River lowlands bordering Iran to the south, effective radiation ranges between 60 and 64 kcal/cm². A decrease in mean annual air temperature with increasing altitude has been observed. In the watershed zones of the Murovdag Range and on the elevated massifs of the Karabakh Volcanic Plateau, temperatures may occasionally decline to as low as –5°C. Total annual precipitation reaches 800–850 mm at elevations of 2,500–2,800 m on the Murovdag Range but decreases to approximately 600 mm at higher elevations [7, p. 116].

The analysis of satellite imagery indicates that the annual amount of solar radiation within the Eastern Zangezur region generally varies between 120 and 140 kcal/cm² (Figure 1).

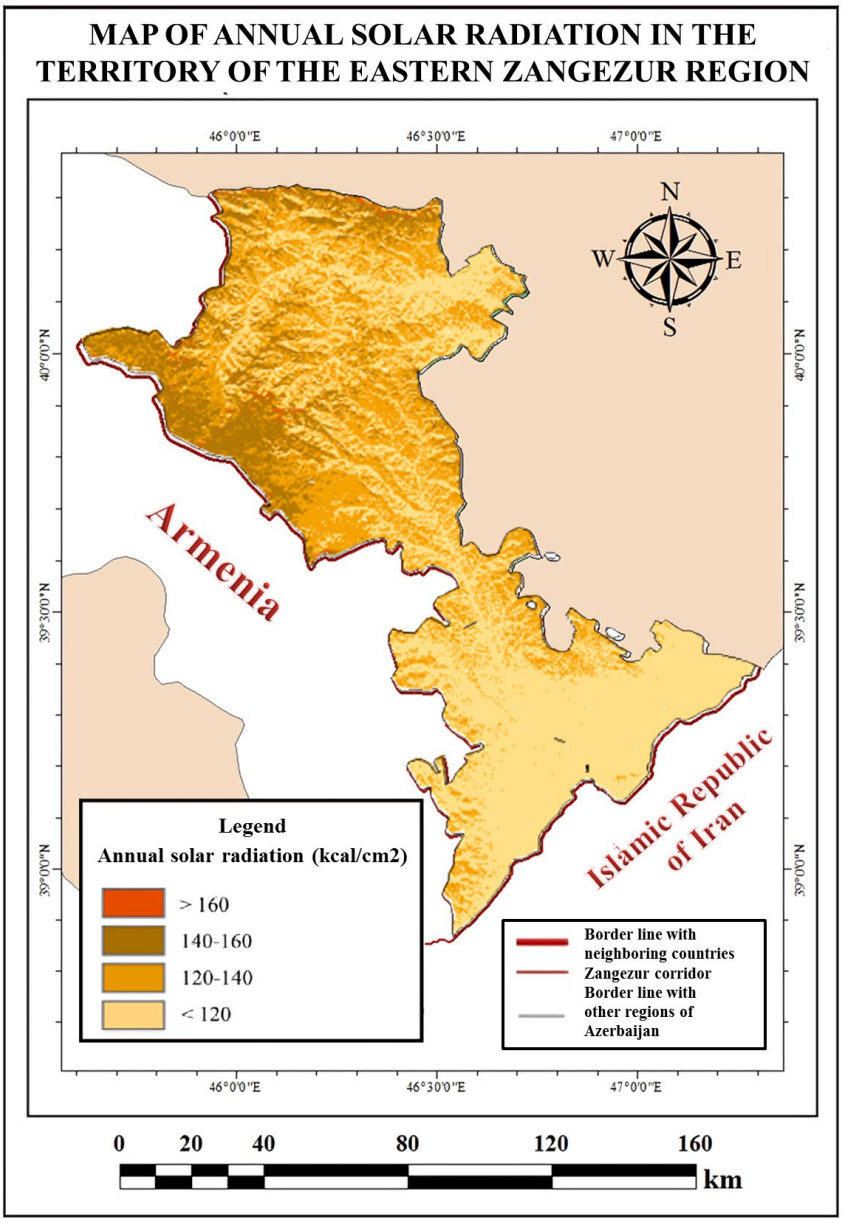

Figure 1. Annual solar radiation in the Eastern Zangezur region

As can be seen from Figure 1, the amount of solar radiation within the study area reaches approximately 120 kcal/cm² in the southern part, whereas this value increases to 160 kcal/cm² in the northern and northwestern high-mountain areas. As illustrated in the figure, radiation values in some localized patches of the western part of the region even exceed 160 kcal/cm². Areas receiving less than 120 kcal/cm² of solar radiation are mainly observed on the northern slopes of mountainous terrains, within high-altitude zones, and in certain southern parts of the study area. Radiation values ranging from 120 to 140 kcal/cm² are widely distributed across the middle-altitude mountainous areas of the Eastern Zangezur region. The topographic position and slope aspect contribute to a partial reduction in solar radiation in these areas. These zones possess considerable agricultural potential; however, from the perspective of energy resource utilization, they require careful planning and management. Areas receiving between 140 and 160 kcal/cm² of solar radiation are predominantly located in the northern and western parts of the region and are considered favourable for the exploitation of solar energy resources. Finally,

areas receiving more than 160 kcal/cm² are mainly concentrated in the northwestern part of the region and are characterized by exceptionally high radiation loads.

Contemporary observations indicate a tendency toward increasing mean annual air temperatures throughout the region during recent decades. This process is particularly evident in the lowland and middle-mountain areas. Rising temperatures contribute to enhanced evaporation, reduced soil moisture content, and the transformation of certain landscape complexes.

The formation and spatial differentiation of landscapes within the Eastern Zangezur region are primarily associated with the complex relief and considerable altitudinal amplitude of the territory. Elevation differences ranging from approximately 300 m to 3,900 m have created diverse thermal and moisture conditions, resulting in the development of a distinctly expressed vertical landscape zonation. Altitudinal zonation is regarded as one of the principal factors determining the structure of natural complexes, the distribution of soils and vegetation, and the ecological conditions of the region. According to the law of vertical zonality, air temperature decreases with increasing altitude, while atmospheric precipitation generally increases up to certain elevations. These variations generate substantial differences in the composition and interactions of landscape components. The landscape belts observed in the Eastern Zangezur replace one another successively, and each belt possesses distinctive climatic, pedological, vegetational, and hydrological characteristics.

The lower foothill and plain areas located in the southern part of the region, particularly along the Araz River, are characterized by semi-desert and dry-steppe landscapes. These territories experience high summer temperatures, limited precipitation, and intense evaporation. The low annual precipitation significantly influences soil-forming processes, resulting in the predominance of gray, light-brown, and chestnut soils. The vegetation cover mainly consists of drought-resistant ephemeral and xerophytic species. Although short-term intensive vegetation growth occurs during spring due to increased precipitation, most vegetation dries out during the summer months under the influence of high temperatures. These landscapes are of considerable agricultural importance, and under irrigation conditions, high crop productivity can be achieved.

With increasing elevation, climatic conditions change, temperatures decrease, and precipitation amounts increase. The middle-mountain landscapes, widely distributed between approximately 800 and 2,200 m above sea level, are considered among the most favourable natural complexes of the region. Brown mountain-forest and dark-brown mountain-forest soils predominate within this altitudinal belt. Forest landscapes are mainly composed of oak, hornbeam, beech, maple, ash, and other broad-leaved tree species. Forests mitigate the effects of climatic factors, protect soils from erosion, regulate the hydrological regime, and play a crucial role in biodiversity conservation.

Due to more favourable moisture conditions within this belt, soil-forming processes occur intensively. At the same time, high biological productivity is observed. In terms of landscape stability and ecological sustainability, the forest belt represents one of the most important ecological systems of the region.

Situated above the forest belt, the subalpine zone exhibits transitional characteristics, combining features of both forest and alpine landscapes. This belt is primarily distributed between elevations of 2,200 and 2,800 m. Subalpine meadows are distinguished by their rich species composition and high biological productivity. In some areas, herbaceous vegetation reaches heights of up to one meter. Relatively cool summers and sufficiently humid conditions create a favourable environment for vegetation development. Subalpine landscapes possess considerable economic significance as summer pastures. Furthermore, these territories play a

special role in water resource formation and in maintaining the stability of mountain ecosystems.

Alpine meadows are extensively distributed between elevations of 2,800 and 3,200 m. This belt is characterized by low temperatures, a short growing season, and an intense radiation regime. Alpine meadows are distinguished by low-growing yet dense vegetation cover. Plant species occurring here are highly adapted to harsh climatic conditions. Alpine meadows are of particular importance for biodiversity conservation and constitute habitats for numerous endemic species. The development of these landscapes is largely determined by low-temperature conditions, long-lasting snow cover, and a short vegetation period. As a result of climate change, certain shifts in the upper boundaries of alpine vegetation may occur.

The highest parts of the Eastern Zangezur are occupied by subnival landscapes, which develop at elevations above 3,200 m. Due to low temperatures and the prolonged persistence of snow cover, soil and vegetation development in these areas is extremely limited. Physical weathering processes dominate within the subnival belt. Under the influence of temperature fluctuations, rocks undergo fragmentation, leading to the formation of extensive scree deposits and rock debris accumulations. The weak development of soil cover restricts the distribution of vegetation. These high-altitude areas play a crucial role in the formation of regional water resources. Snow and ice reserves supply rivers through seasonal melting during spring and summer, thereby influencing the water balance of lower landscape belts [4].

Climate is the principal factor controlling landscape differentiation in the Eastern Zangezur. The decrease in temperature with altitude, variations in precipitation distribution, and differences in moisture availability contribute directly to the formation of distinct landscape belts. Each landscape belt is characterized by its own thermal and moisture regime. Under contemporary climate change conditions, an upward shift of certain landscape boundaries may be observed. Rising temperatures not only affect the altitudinal limits of forest and meadow belts but also influence water resource formation and regional biodiversity.

Thus, the vertical zonation system observed in the Eastern Zangezur region represents one of the most prominent manifestations of climate–landscape interactions. In addition to determining the spatial organization of natural complexes, the altitudinal factor exerts a direct influence on their developmental dynamics and ecological stability [3, 5, 6].

Conclusion

1. The contemporary climatic characteristics of the Eastern Zangezur region constitute one of the principal factors governing the formation and development of landscape complexes. The region’s complex relief and considerable altitudinal amplitude have contributed to the emergence of diverse climatic types and the development of a clearly expressed system of vertical landscape zonation.
2. The altitudinal variation of temperature and precipitation determines the characteristics of soil cover, vegetation cover, hydrographic networks, and geomorphological processes. Semi-desert and dry-steppe landscapes dominate the lower parts of the region, forest landscapes are widespread within the middle-mountain belt, while subalpine, alpine, and subnival landscapes have developed in the high-mountain areas.
3. Contemporary climate change influences the dynamics of natural landscape development and causes certain transformations in their structure and functioning. The timely identification and assessment of these changes are of great importance for the conservation of natural resources, the maintenance of ecological security, and the formulation of sustainable development strategies for the region.

4. A comprehensive investigation of the interactions between climatic and landscape components in the Eastern Zangezur region contributes to a deeper understanding of the natural environment and provides a scientific basis for its effective management and sustainable utilization.

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PRODUCTION OF GLUTEN-FREE CRACKERS SUPPLEMENTED WITH GERMINATED SORGHUM FLOUR

FİLİZLENDİRİLMİŞ SORGUM UNU İLAVELİ GLUTENSİZ KRAKER ÜRETİMİ

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ÖZET

Bu çalışmada, farklı oranlarda filizlendirilmiş sorgum unu kullanılarak glutensiz kraker üretimi gerçekleştirilmiş ve üretilen krakerlerin duyusal özellikleri değerlendirilmiştir. Araştırmada kontrol örneği ile birlikte %10, %20 ve %30 oranlarında filizlendirilmiş sorgum unu içeren üç farklı glutensiz kraker formülasyonu hazırlanmıştır. Kraker üretiminde glutensiz un karışımı ve filizlendirilmiş çiğ karabuğday unu kullanılmış, filizlendirilmiş sorgum unu ise glutensiz un karışımı ile yer değiştirme esasına göre formülasyona dahil edilmiştir. Üretilen kraker örnekleri; renk, koku, lezzet/tat, görünüş, gevreklik, tekstür (sertlik), ağızda dağılma, yüzey düzgünlüğü, çiğneme ve yutma ile genel kabul edilebilirlik özellikleri açısından değerlendirilmiştir. Duyusal analizler, 14 kişiden oluşan yarı eğitimli panelist grubu tarafından 9 puanlı hedonik skala kullanılarak gerçekleştirilmiştir. Sonuçlar, filizlendirilmiş sorgum unu ilavesinin glutensiz krakerlerin duyusal özelliklerini olumlu yönde etkilediğini göstermiştir. Sorgum unu oranının artmasına bağlı olarak tüm duyusal parametrelerde iyileşme gözlenmiş, en yüksek puanlar %30 oranında filizlendirilmiş sorgum unu içeren glutensiz kraker örneğinde elde edilmiştir. Özellikle renk, lezzet/tat, gevreklik ve genel kabul edilebilirlik değerlerinde

belirgin artışlar belirlenmiştir. Kontrol örneğinin ise diğer örneklere göre daha düşük puanlar aldığı saptanmıştır. Elde edilen bulgular, filizlendirilmiş sorgum ununun glutensiz kraker üretiminde kullanılabilecek uygun bir alternatif hammadde olduğunu ve ürünün duyusal kalitesini artırdığını ortaya koymuştur. Sonuç olarak, filizlendirilmiş sorgum unu kullanımının glutensiz ürün geliştirme çalışmalarında hem duyusal kaliteyi artırma hem de tüketici kabulünü yükseltme açısından önemli bir potansiyele sahip olduğu değerlendirilmiştir.

Anahtar Kelimeler: Filizlendirilmiş sorgum unu, filizlendirilmiş çiğ karabuğday unu, glutensiz kraker

ABSTRACT

In this study, gluten-free crackers supplemented with different levels of germinated sorghum flour were produced and their sensory properties were evaluated. Four formulations were prepared, including a control sample and three gluten-free cracker formulations containing 10%, 20%, and 30% germinated sorghum flour. A gluten-free flour blend and germinated raw buckwheat flour were used in the formulations, while germinated sorghum flour was incorporated by partially replacing the gluten-free flour blend. The cracker samples were evaluated for color, aroma, taste/flavor, appearance, crispness, texture (hardness), mouthfeel, surface smoothness, chewing and swallowing characteristics, and overall acceptability. Sensory analyses were carried out by a semi-trained panel consisting of 14 panelists using a 9-point hedonic scale. The results demonstrated that the addition of germinated sorghum flour positively influenced the sensory characteristics of gluten-free crackers. Improvements were observed in all sensory parameters as the proportion of sorghum flour increased, and the highest scores were obtained from the formulation containing 30% germinated sorghum flour. Significant improvements were particularly observed in color, flavor, crispness, and overall acceptability. In contrast, the control sample received lower scores compared with the sorghum-enriched formulations. The findings indicate that germinated sorghum flour can be successfully used as an alternative ingredient in gluten-free cracker production and contributes positively to sensory quality. Furthermore, the use of germinated sorghum flour may enhance consumer acceptance while providing opportunities for the development of innovative gluten-free products. Therefore, germinated sorghum flour appears to be a promising raw material for the formulation of sensory acceptable and value-added gluten-free bakery products.

Keywords: Germinated sorghum flour, germinated raw buckwheat flour, gluten-free cracker

GİRİŞ

Son yıllarda sağlıklı beslenmeye yönelik farkındalığın artması, tüketicilerin besin değeri yüksek, fonksiyonel özelliklere sahip ve özel beslenme gereksinimlerini karşılayan gıdalara olan ilgisini önemli ölçüde artırmıştır. Bu doğrultuda özellikle çölyak hastalığı, gluten intoleransı ve gluten duyarlılığı gibi sağlık sorunlarına sahip bireyler için geliştirilen glutensiz ürünler, yalnızca tıbbi zorunluluk nedeniyle değil, aynı zamanda sağlıklı yaşam eğilimlerinin de etkisiyle geniş bir tüketici kitlesi tarafından tercih edilmeye başlanmıştır. Günümüzde glutensiz ürün pazarı sürekli büyüme gösterirken, bu ürünlerin besinsel ve teknolojik özelliklerinin geliştirilmesine yönelik araştırmalar da hız kazanmıştır (Gallagher ve ark., 2004; Ciacci ve ark., 2007).

Gluten, buğday, arpa ve çavdar gibi tahıllarda bulunan, hamura elastikiyet kazandıran ve ürünün hacim, yapı ile tekstürel özelliklerinin oluşmasında önemli rol oynayan bir protein kompleksidir. Glutensiz ürünlerde glutenin bulunmaması ise hamurun viskoelastik özelliklerini

olumsuz etkilemekte; özellikle ekmek, bisküvi ve kraker gibi unlu mamullerde düşük hacim, zayıf tekstür, kırılgan yapı ve düşük duyusal kalite gibi önemli problemlere neden olmaktadır. Bu nedenle glutensiz ürün geliştirme çalışmalarında yalnızca glutenin yerine kullanılabilecek alternatif hammaddelerin belirlenmesi değil, aynı zamanda ürünlerin tüketici beklentilerini karşılayacak duyusal özelliklere sahip olması da büyük önem taşımaktadır (Demirkesen ve ark., 2010; Onyango ve ark., 2011).

Glutensiz ürün formülasyonlarında son yıllarda pirinç, mısır, karabuğday, kinoa, amarant ve sorgum gibi gluten içermeyen tahılların kullanımına yönelik çalışmalar artış göstermektedir. Bu tahıllar arasında sorgum (*Sorghum bicolor* L.), gluten içermemesi, yüksek diyet lifi içeriği, fenolik bileşenler bakımından zengin olması ve antioksidan özellik göstermesi nedeniyle dikkat çeken önemli bir alternatif hammadde olarak değerlendirilmektedir. Ayrıca sorgumun düşük glisemik indeksli olması ve çeşitli vitamin ile mineralleri içermesi, fonksiyonel gıda geliştirme çalışmalarındaki önemini artırmaktadır (Awika & Rooney, 2004; Taylor ve ark., 2006). Sorgumun besinsel ve fonksiyonel özelliklerinin daha da geliştirilmesinde kullanılan yöntemlerden biri filizlendirme işlemidir. Filizlendirme sırasında tahıl tanesinde meydana gelen biyokimyasal değişiklikler sonucunda enzimatik aktivite artmakta, bazı anti-besinsel bileşenler azalmakta, protein sindirilebilirliği gelişmekte ve fenolik bileşiklerin biyoyararlanımı artabilmektedir. Bunun yanında filizlendirme işleminin aroma oluşumunu desteklediği, renk gelişimine katkı sağladığı ve ürünlerin duyusal özelliklerini iyileştirebildiği bildirilmektedir. Bu nedenle filizlendirilmiş tahıllar, özellikle fonksiyonel ve glutensiz ürün geliştirme çalışmalarında giderek daha fazla kullanılmaktadır (Nkhata ve ark., 2018; Adebo & Medina-Meza, 2020).

Glutensiz ürünlerde yalnızca besinsel değerin artırılması yeterli olmayıp, tüketicilerin ürünü tercih etmelerinde belirleyici olan renk, tat, aroma, gevreklik, tekstür ve genel kabul edilebilirlik gibi duyusal özelliklerin de geliştirilmesi gerekmektedir. Özellikle krakerler, düşük nem içeriği, uzun raf ömrü ve yaygın tüketilmeleri nedeniyle fonksiyonel bileşenlerle zenginleştirilmeye uygun unlu mamuller arasında yer almaktadır. Son yıllarda gerçekleştirilen çalışmalar, farklı tahıl ve baklagil unlarının glutensiz kraker formülasyonlarında kullanılmasının ürünün fiziksel, besinsel ve duyusal özelliklerini önemli ölçüde etkileyebildiğini ortaya koymaktadır (Torbica ve ark., 2012; Brar ve ark., 2025). Karabuğday unu ise glutensiz ürün formülasyonlarında yaygın olarak kullanılan psödotahıllardan biri olup, kaliteli protein yapısı, diyet lifi, mineral maddeler ve fenolik bileşikler bakımından zengin olması nedeniyle ürünlerin besinsel değerini artırmaktadır. Özellikle filizlendirilmiş karabuğday ununun kullanılması, biyoaktif bileşik miktarını artırarak fonksiyonel özelliklerin geliştirilmesine katkı sağlamaktadır. Bu nedenle sorgum ve filizlendirilmiş çiğ karabuğday ununun birlikte kullanılması, glutensiz ürünlerin hem besinsel hem de duyusal kalitesinin artırılması açısından önemli bir yaklaşım olarak değerlendirilmektedir.

Bu çalışmada, glutensiz un karışımı ile hazırlanan kraker formülasyonlarında filizlendirilmiş çiğ karabuğday unu sabit tutulmuş, glutensiz un karışımı yerine farklı oranlarda (%10, %20 ve %30) filizlendirilmiş sorgum unu kullanılarak glutensiz krakerler üretilmiştir. Üretilen kraker örneklerinin renk, koku, lezzet/tat, görünüş, gevreklik, tekstür, ağızda dağılma, yüzey düzgünlüğü, çiğneme ve yutma ile genel kabul edilebilirlik özellikleri değerlendirilerek filizlendirilmiş sorgum ununun ürünün duyusal kalitesi üzerindeki etkisinin belirlenmesi amaçlanmıştır. Böylece filizlendirilmiş sorgum ununun glutensiz kraker üretiminde alternatif bir hammadde olarak kullanılabilirliği ortaya konulması ve glutensiz ürün geliştirme çalışmalarına katkı sağlanması hedeflenmiştir.

KURAMSAL TEMELLER VE KAYNAK ARAŞTIRMASI

Gluten ve Glutensiz Ürünler

Gluten, buğday, arpa ve çavdar gibi tahıllarda bulunan gliadin ve glutenin proteinlerinden oluşan bir protein kompleksidir. Hamurun yoğrulması sırasında su ile etkileşime girerek viskoelastik bir yapı oluşturur ve bu yapı; gaz tutma kapasitesi, elastikiyet, hacim ve tekstürel özelliklerin gelişmesinde önemli rol oynar. Bu nedenle gluten, ekmek, bisküvi ve kraker gibi fırıncılık ürünlerinin kalite özelliklerini belirleyen temel bileşenlerden biridir (Gallagher ve ark., 2004; Demirkesen ve ark., 2010). Bununla birlikte gluten, çölyak hastalığı, çölyak dışı gluten duyarlılığı ve buğday alerjisi bulunan bireylerde çeşitli sağlık sorunlarına neden olabilmektedir. Özellikle çölyak hastalığında gluten tüketimi, ince bağırsak mukozasında immünolojik reaksiyonları tetikleyerek villus yapısının bozulmasına ve besin öğelerinin emiliminde yetersizliklere yol açmaktadır. Günümüzde çölyak hastalığının tek etkili tedavisi, gluten içeren gıdaların yaşam boyu diyetten tamamen çıkarılmasıdır (Ciacci ve ark., 2007; Fasano & Catassi, 2012). Bu durum, glutensiz ürünlere olan talebin artmasına ve gıda endüstrisinde alternatif hammadde arayışlarının hız kazanmasına neden olmuştur.

Glutensiz ürün üretiminde karşılaşılan en önemli güçlük, glutenin oluşturduğu yapısal ağın bulunmamasıdır. Gluten içermeyen hamurlar genellikle düşük elastikiyet ve zayıf gaz tutma kapasitesine sahip olduğundan ürünlerde hacim kaybı, kırılgan yapı ve istenmeyen tekstürel özellikler ortaya çıkabilmektedir. Özellikle kraker gibi gevrek yapılı ürünlerde uygun sertlik, gevreklik ve ağız hissinin sağlanması tüketici kabulü açısından büyük önem taşımaktadır. Bu nedenle son yıllarda sorgum, karabuğday ve baklagil unları gibi alternatif hammaddelerin kullanıldığı glutensiz ürün formülasyonları üzerine çok sayıda çalışma yürütülmektedir (Onyango ve ark., 2011).

Sorgum ve Filizlendirme

Sorgum (*Sorghum bicolor* L.), gluten içermemesi, yüksek diyet lifi ve fenolik bileşik içeriği ile glutensiz ürün geliştirme çalışmalarında öne çıkan tahıllardan biridir. Aynı zamanda demir, magnezyum ve çinko gibi mineraller bakımından zengin olması, sorgumu yalnızca alternatif bir un kaynağı değil, aynı zamanda fonksiyonel bir hammadde hâline getirmektedir. İçerdiği fenolik bileşikler ve antioksidanlar sayesinde oksidatif stresin azaltılmasına katkı sağlayabileceği ve kronik hastalıkların önlenmesinde olumlu etkiler gösterebileceği bildirilmektedir (Awika & Rooney, 2004; Taylor ve ark., 2006). Glutensiz ürünlerde sorgum ununun kullanımı, ürünlerin besin değerini artırmasının yanı sıra duyusal özelliklerin geliştirilmesine de katkı sağlayabilmektedir. Bununla birlikte gluten içermemesi nedeniyle sorgum bazlı hamurların yapısal özellikleri sınırlı olabilmektedir. Bu nedenle sorgum unu çoğunlukla diğer glutensiz tahıl veya psödotahıl unları ile birlikte kullanılarak ürün kalitesinin iyileştirilmesi amaçlanmaktadır (Onyango ve ark., 2011). Sorgumun besinsel ve teknolojik özelliklerini geliştirmek amacıyla uygulanan yöntemlerden biri filizlendirme işlemidir. Filizlendirme sırasında amilaz, proteaz ve lipaz gibi enzimlerin aktivitesi artmakta; proteinler ve karbonhidratlar daha küçük moleküllere parçalanmaktadır. Bunun sonucunda protein sindirilebilirliği artarken bazı anti-besinsel bileşenlerin azaldığı, fenolik bileşiklerin biyoyararlanımının yükseldiği ve antioksidan kapasitenin geliştiği bildirilmektedir (Nkhata ve ark., 2018; Adebo & Medina-Meza, 2020).

Filizlendirme işlemi aynı zamanda ürünlerin duyusal özellikleri üzerinde de olumlu etkiler oluşturabilmektedir. Çimlenme sürecinde meydana gelen biyokimyasal değişimler aroma oluşumunu desteklerken, pişirme sırasında gerçekleşen reaksiyonlar ürünün renk ve lezzet özelliklerinin gelişmesine katkı sağlayabilmektedir. Bu nedenle filizlendirilmiş sorgum unu, son yıllarda özellikle glutensiz ekmek, bisküvi ve kraker formülasyonlarında fonksiyonel bir bileşen olarak değerlendirilmektedir.

Glutensiz Kraker ve Alternatif Un Kullanımı

Krakerler, düşük nem içeriği ve gevrek yapıları nedeniyle uzun raf ömrüne sahip, yaygın olarak tüketilen fırıncılık ürünleri arasında yer almaktadır. Ancak glutensiz kraker üretiminde glutenin bulunmaması, hamurun işlenebilirliği ile ürünün tekstürel ve duyusal özelliklerini olumsuz etkileyebilmektedir. Bu nedenle glutensiz kraker formülasyonlarında farklı tahıl, psödotahıl ve baklagil unlarının birlikte kullanıldığı çalışmalar giderek artmaktadır (Torbica ve ark., 2012). Alternatif unların kullanımı yalnızca ürünün besin değerini artırmakla kalmamakta, aynı zamanda renk, aroma, gevreklik ve genel kabul edilebilirlik gibi duyusal özellikler üzerinde de etkili olmaktadır. Özellikle baklagil ve sorgum unları ile hazırlanan glutensiz krakerlerde protein ve diyet lifi miktarının arttığı, buna bağlı olarak ürün kalitesinin iyileştiği bildirilmektedir. Karimidastjerd ve ark. (2025), maş fasulyesi unu ile geliştirilen glutensiz krakerlerde fizikokimyasal ve duyusal özelliklerin olumlu yönde değiştiğini belirtmiştir. Benzer şekilde Brar ve ark. (2025), glutensiz krakerlerde tüketici tercihlerini etkileyen en önemli özelliklerin renk, gevreklik ve lezzet olduğunu bildirmiştir.

Bu çalışma kapsamında ise glutensiz un karışımına farklı oranlarda filizlendirilmiş sorgum unu ilave edilerek üretilen krakerlerin duyusal özellikleri değerlendirilmiştir. Filizlendirilmiş sorgum ununun glutensiz krakerlerin renk, lezzet, gevreklik ve genel kabul edilebilirlik özellikleri üzerindeki etkisinin belirlenmesi, alternatif tahılların glutensiz ürün geliştirme çalışmalarındaki kullanım potansiyeline katkı sağlaması açısından önem taşımaktadır.

MATERYAL ve YÖNTEM

Kullanılan Malzemeler

Reçetede yer alan filizlendirilmiş çiğ karabuğday unu ve filizlendirilmiş sorgum unu Talya Foods (Antalya, Türkiye) temin edilmiştir. Diğer malzemeler (glutensiz un karışımı, tereyağı, instant maya, su, tuz, kabartma tozu) İstanbul'da bulunan yerel marketlerden temin edilmiştir.

Kraker Örneklerinin Üretim Aşamaları

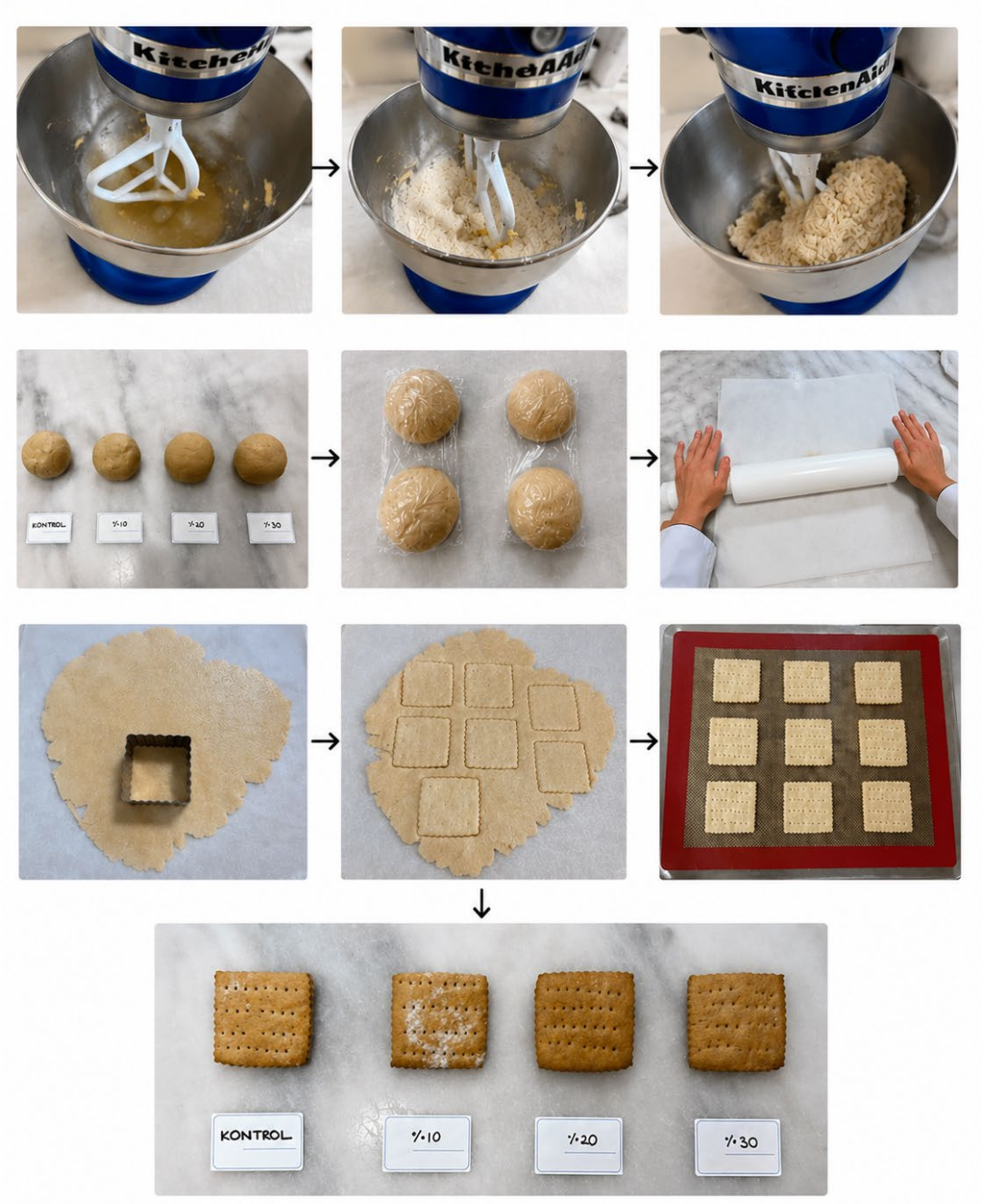
Kraker üretiminde, Tablo 1'de görüldüğü üzere kontrol örneği için %80 glutensiz un karışımı, %20 filizlendirilmiş çiğ karabuğday unu kullanılmıştır. Diğer kraker örneklerinde ise filizlendirilmiş çiğ karabuğday unu sabit tutularak glutensiz un ile yer değiştirme esasına göre filizlendirilmiş çiğ karabuğday unu kullanılarak glutensiz kraker üretimi gerçekleştirilmiştir.

Kraker üretim aşamaları Şekil 1.'de verilmiştir. Bir stand mikserinde (KitchenAid) pedal uç kullanılarak tereyağı ve içme suyu orta hızda yaklaşık 2 dk karıştırılmıştır ve ardından karışıma kuru malzemeler eklenerek 1 dk boyunca karıştırma işlemine devam edilmiştir. Hamur, yoğurma makinesi haznesinden alındıktan sonra oda sıcaklığında (yaklaşık +22ºC'de) 30 dk üzeri kapalı olarak dinlendirilmiştir. Yağlı kağıtların arasına koyularak merdane ile 0,5 cm inceliğinde açıldıktan sonra dikdörtgen kalıp yardımıyla kesilmiştir. Tepsilere yerleştirilip 180±2ºC'deki endüstriyel konveksiyonlu fırında (Inoksan) 15 dk pişirilmiştir ve fırından çıkarıldıktan sonra soğutma teline alınarak soğumaya bırakılmıştır.

Tablo 1. Glutensiz kraker örnekleri için kullanılacak malzemeler

Bileşenler (g)	Kontrol	K1	K2	K3
Glutensiz Un	160 g	144 g	128 g	112 g
Filizlendirilmiş Çiğ Karabuğday Unu	40 g	40 g	40 g	40 g
Filizlendirilmiş Sorgum Unu	0 g	16 g	32 g	48 g
Tereyağı	20 g	20 g	20 g	20 g
Kabartma Tozu	2 g	2 g	2 g	2 g
Tuz	3 g	3 g	3 g	3 g
Instant Maya	1 g	1 g	1 g	1 g
İçme Suyu	100 g	100 g	100 g	100 g

K1: %10 filizlendirilmiş sorgum unu ilaveli; K2: %20 filizlendirilmiş sorgum unu ilaveli; K3: %30 filizlendirilmiş sorgum unu ilaveli



Şekil 1. Glutensiz kraker örneklerinin üretim aşamaları

Kraker Analizi

Duyusal Analiz

Duyusal değerlendirmeleri içeren duyusal analiz panel formu, krakerlerde duyusal kalite kriterlerini içeren; Dulger Altıner ve ark. (2026)'nın çalışmaları incelenerek, literatür araştırması sonucunda, araştırma konusuna özgü olarak modifiye edilmesiyle hazırlanmıştır. Duyusal analiz, Maltepe Üniversitesi öğrencileri ve akademisyenleri tarafından 14 kişilik (10 kadın; 4 erkek) yarı eğitimli bir panelist grubu ile gerçekleştirilmiştir. Kraker örnekleri 3 haneli olacak şekilde rastgele kodlanarak beyaz plastik tabak içerisinde panelistlere sunulmuştur. Kraker örnekleri, renk, koku, lezzet/tat, görünüş, gevreklik, tekstür (sertlik), ağızda dağılma, yüzey düzgünlüğü, çiğneme ve yutma ve genel kabul edilebilirlik olmak üzere on (10) özellik bakımından 1-9 hedonik skala (1:Son Derece Kötü; 2:Çok Kötü; 3:Kötü; 4:Ortanın Altı ve Kötünün Üstü; 5:Orta; 6:İyinin Altı ve Ortanın Üstü; 7:İyi; 8:Çok İyi; 9:Mükemmel) kullanılarak değerlendirilmiştir. 5 puan ve üzeri ortalamaya sahip olan kraker örnekleri, beğenilmiş olarak değerlendirilmiş ve tüketilebilir bir ürün olarak kabul edilmiştir.

İstatistiksel Analiz

Duyusal analiz verilerinin istatistiksel değerlendirilmesi IBM SPSS Statistics 21.0 paket programı kullanılarak gerçekleştirilmiştir. Her bir örnek, 10'u kadın ve 4'ü erkek olmak üzere toplam 14 panelist tarafından değerlendirilmiş; elde edilen veriler ortalama ± standart sapma şeklinde sunulmuştur. Gruplar arasındaki farklılıkların belirlenmesi amacıyla tek yönlü varyans analizi (ANOVA) uygulanmıştır. Analiz öncesinde varyansların homojenliği Levene testi ile kontrol edilmiştir. ANOVA sonucunda istatistiksel olarak anlamlı farklılık saptanan parametrelerde gruplar arasındaki karşılaştırmalar Tukey çoklu karşılaştırma testi ile yapılmıştır. Tüm istatistiksel değerlendirmelerde anlamlılık düzeyi $p < 0,05$ olarak kabul edilmiştir.

BULGULAR VE TARTIŞMA

Bu çalışmada farklı oranlarda filizlendirilmiş sorgum unu kullanılarak üretilen glutensiz kraker örneklerinin duyusal özellikleri değerlendirilmiş, elde edilen sonuçlar Tablo 2'de ve radar grafiği olarak Şekil 2'de sunulmuştur. Bulgular, formülasyonda kullanılan filizlendirilmiş sorgum unu oranının artmasıyla birlikte tüm duyusal özelliklerde iyileşme meydana geldiğini göstermiştir. Tüm parametreler dikkate alındığında en yüksek puanlar %30 filizlendirilmiş sorgum unu içeren K3 örneğinde elde edilirken, en düşük puanlar kontrol örneğinde belirlenmiştir.

Renk, koku, lezzet/tat, görünüş, gevreklik, tekstür, ağızda dağılma, yüzey düzgünlüğü, çiğneme-yutma ve genel kabul edilebilirlik bakımından kontrol örneği en düşük değerlere sahip olurken, sorgum unu ilavesiyle birlikte puanların kademeli olarak arttığı belirlenmiştir (Tablo 2). Özellikle renk (6,22–8,18), gevreklik (6,32–8,24), lezzet/tat (5,93–8,03) ve genel kabul edilebilirlik (6,19–8,30) değerlerindeki artış dikkat çekmiştir. Bu durum, filizlendirilmiş sorgum ununun yalnızca ürünün görünüşünü değil, aynı zamanda tüketici tarafından algılanan kalite özelliklerini de olumlu yönde etkilediğini göstermektedir.

Filizlendirme işlemi sırasında meydana gelen biyokimyasal değişimlerin aroma oluşumunu desteklediği, fenolik bileşiklerin ve indirgen şekerlerin artışına bağlı olarak pişirme sırasında gerçekleşen Maillard reaksiyonlarının ürünün renk ve lezzet gelişimine katkı sağladığı düşünülmektedir. Ayrıca sorgum ununun formülasyona ilave edilmesiyle ürün yapısının daha homojen hâle geldiği, bunun da gevreklik ve ağız hissi üzerinde olumlu etkiler oluşturduğu değerlendirilmektedir. Glutensiz ürünlerde tüketici kabulünü belirleyen en önemli kalite

kriterlerinden biri olan gevrek yapının korunması açısından elde edilen sonuçlar önem taşımaktadır.

Ağızda dağılma, yüzey düzgünlüğü ile çiğneme ve yutma özelliklerinde de sorgum unu oranına bağlı olarak iyileşmeler gözlenmiştir. Özellikle K2 ve K3 örneklerinin tüm duyusal özelliklerde 7 puanın üzerinde ortalama alması, bu formülasyonların panelistler tarafından yüksek düzeyde kabul gördüğünü göstermektedir. Buna karşın kontrol örneğinin tüm parametrelerde daha düşük puanlar alması, yalnızca glutensiz un karışımının kullanıldığı formülasyonların duyusal açıdan daha sınırlı kaldığını ortaya koymuştur.

Elde edilen bulgular literatürde bildirilen çalışmalarla benzerlik göstermektedir. Karimidastjerd ve ark. (2025), alternatif baklagil unları ile geliştirilen glutensiz krakerlerde duyusal kalite ve genel kabul edilebilirlik değerlerinin arttığını bildirmiştir. Benzer şekilde Brar ve ark. (2025), glutensiz krakerlerde tüketici tercihlerini etkileyen en önemli özelliklerin renk, gevreklik ve lezzet olduğunu belirtmiştir. Bu çalışmada da filizlendirilmiş sorgum unu ilavesinin söz konusu özellikleri olumlu yönde etkilediği ve buna bağlı olarak genel kabul edilebilirlik puanlarının arttığı belirlenmiştir. Özellikle %30 filizlendirilmiş sorgum unu içeren K3 formülasyonunun en yüksek genel kabul edilebilirlik değerini alması, bu oranın duyusal kalite açısından en uygun formülasyon olduğunu göstermektedir.

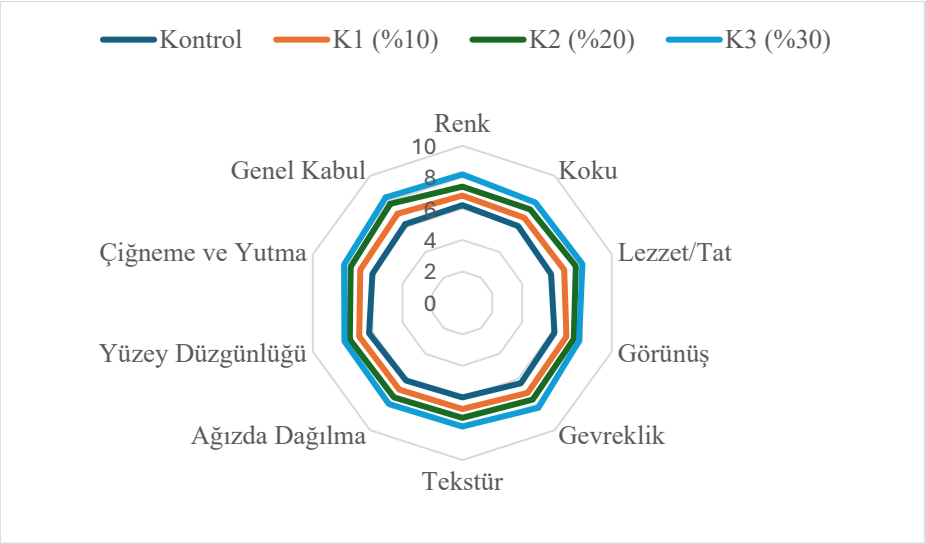
Sonuç olarak, filizlendirilmiş sorgum unu kullanımının glutensiz krakerlerin duyusal özelliklerini iyileştirdiği ve sorgum unu oranındaki artışın panelist beğenisini olumlu yönde etkilediği belirlenmiştir. Bu bulgular, filizlendirilmiş sorgum ununun glutensiz kraker üretiminde alternatif ve fonksiyonel bir hammadde olarak değerlendirilebileceğini göstermektedir.

Tablo 2. Glutensiz kraker örnekleri için duyusal analiz sonuçları

	Renk	**Koku**	**Lezzet/ Tat**	**Görünüş**	**Gevreklik**	**Tekstür**	**Ağızda Dağılma**	**Yüzey Düzgünlüğü**	**Çiğneme ve Yutma**	**Genel Kabul**
Kontrol	6,22±0,50^{c}	6,04±0,62^{c}	5,93±0,58^{c}	6,16±0,46^{c}	6,32±0,57^{c}	6,01±0,52^{c}	6,10±0,41^{c}	6,24±0,40^{c}	6,02±0,50^{c}	6,19±0,41^{c}
K1	6,83±0,42^{b}	6,70±0,55^{b}	6,81±0,47^{b}	6,96±0,48^{b}	7,07±0,42^{b}	6,75±0,41^{b}	6,82±0,30^{b}	6,90±0,39^{b}	6,83±0,47^{b}	7,01±0,37^{b}
K2	7,40±0,31^{b}	7,35±0,41^{b}	7,59±0,34^{b}	7,45±0,36^{b}	7,60±0,33^{b}	7,31±0,30^{b}	7,42±0,37^{b}	7,53±0,38^{b}	7,47±0,32^{b}	7,79±0,26^{b}
K3	8,18±0,22^{a}	7,90±0,35^{a}	8,03±0,26^{a}	7,81±0,32^{a}	8,24±0,20^{a}	7,86±0,31^{a}	7,95±0,27^{a}	7,89±0,26^{a}	7,91±0,33^{a}	8,30±0,24^{a}

K1: %10 filizlendirilmiş sorgum unu ilaveli; K2: %20 filizlendirilmiş sorgum unu ilaveli; K3: %30 filizlendirilmiş sorgum unu ilaveli

Değerler ortalama±standart sapma olarak verilmiştir. Aynı sütunda farklı üst simge harfleri istatistiksel olarak anlamlı farklılığı göstermektedir ($p<0,05$). n=14 panelist (10 kadın, 4 erkek).



Şekil 2. Glutensiz kraker örneklerinin radar grafiği

SONUÇ ve ÖNERİLER

Bu çalışmada, farklı oranlarda filizlendirilmiş sorgum unu kullanılarak glutensiz kraker üretimi gerçekleştirilmiş ve üretilen örneklerin duyusal özellikleri değerlendirilmiştir. Çalışma sonucunda, sorgum unu ilavesinin glutensiz krakerlerin duyusal kalitesi üzerinde olumlu etkiler oluşturduğu belirlenmiştir. Özellikle sorgum unu oranının artmasına bağlı olarak renk, koku, lezzet/tat, gevreklik ve genel kabul edilebilirlik parametrelerinde düzenli artışlar gözlenmiştir. En yüksek duyusal puanların %30 filizlendirilmiş sorgum unu içeren K3 örneğinde elde edilmesi, sorgum ununun glutensiz kraker formülasyonlarında başarılı bir şekilde kullanılabileceğini göstermiştir.

Glutensiz ürünlerde en önemli problemlerden biri olan düşük duyusal kalite ve zayıf tekstürel yapı dikkate alındığında, filizlendirilmiş sorgum unu kullanımının ürün kalitesini iyileştirdiği düşünülmektedir. Özellikle gevreklik ve genel kabul edilebilirlik değerlerindeki artış, sorgum ununun glutensiz krakerlerde tüketici beğenisini artırabilecek önemli bir alternatif hammadde olduğunu ortaya koymaktadır. Bununla birlikte sorgumun gluten içermemesi, diyet lifi ve fenolik bileşenler açısından zengin olması, geliştirilen ürünün yalnızca duyusal açıdan değil aynı zamanda fonksiyonel ve besinsel açıdan da avantaj sağlayabileceğini göstermektedir. Ancak bu çalışmada yalnızca duyusal analiz gerçekleştirilmiş olması araştırmanın önemli sınırlılıklarından biridir. Ürünlerin fiziksel, kimyasal, tekstürel ve besinsel özellikleri değerlendirilmediğinden, sorgum unu ilavesinin ürün yapısı üzerindeki etkileri detaylı olarak ortaya konulamamıştır. Ayrıca çalışmanın panelist sayısının sınırlı olması ve yarı eğitimli panelist grubu ile gerçekleştirilmesi nedeniyle elde edilen sonuçlar genel tüketici kitlesini tam olarak temsil etmeyebilir. Bu nedenle gelecekte yapılacak çalışmalarda daha geniş katılımlı tüketici analizlerinin gerçekleştirilmesi önerilmektedir. Bunun yanı sıra, glutensiz kraker örneklerinin raf ömrü, nem değişimi, kırılganlık, renk ölçümü, tekstürel analiz ve antioksidan kapasite gibi fizikokimyasal özelliklerinin incelenmesi, ürün kalitesinin daha kapsamlı değerlendirilmesine katkı sağlayacaktır.

Gelecekte yapılacak çalışmalarda sorgum ununun farklı glutensiz tahıl ve baklagil unları ile kombinasyonlarının incelenmesi önerilmektedir. Ayrıca hidrokolloid, bitkisel protein ve fonksiyonel bileşen ilavelerinin ürünün duyusal ve tekstürel özellikleri üzerindeki etkileri araştırılabilir. Bununla birlikte farklı pişirme koşulları ve üretim parametrelerinin optimize

edilmesi ile daha yüksek kaliteli glutensiz kraker formülasyonlarının geliştirilmesi mümkün olabilir.

Sonuç olarak, filizlendirilmiş sorgum unu ilaveli glutensiz krakerlerin duyusal açıdan başarılı bulunduğu ve özellikle %30 sorgum unu kullanımının en uygun formülasyon olduğu belirlenmiştir. Elde edilen sonuçlar, sorgum ununun glutensiz ürün geliştirme çalışmalarında kullanılabilecek potansiyel bir alternatif hammadde olduğunu ortaya koymaktadır.

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SELF-HEALING MATERIALS IN ROAD ENGINEERING

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ABSTRACT

Self-healing materials in road engineering represent an innovative and sustainable solution to the growing challenges of infrastructure deterioration caused by heavy traffic loads and climate change. By integrating advanced technologies such as microencapsulation, induction heating, bio concrete with bacteria, polymer modifiers, and hydrogels, modern road materials can automatically detect and repair cracks without significant human intervention. These systems function through chemical, biological, or thermal processes that restore structural integrity and prevent further damage.

The implementation of self-healing materials significantly extends pavement lifespan, reduces maintenance frequency, lowers long-term costs, and minimizes traffic disruptions. Additionally, by decreasing the demand for new construction materials, this technology contributes to reducing carbon emissions and environmental pollution. Although challenges such as large-scale application, long-term material stability, and regulatory adaptation remain, self-healing roads represent a major step toward smart, resilient, and environmentally responsible infrastructure for the future.

Keywords: Self-healing materials, Road engineering, Sustainable infrastructure, Smart technologies.

Introduction

The integration of self-healing materials in road engineering represents not only a technological advancement but also a significant transformation in modern infrastructure development. Road infrastructure plays a crucial role in any country's economy; however, traditional concrete-paved roads are under constant stress. Concrete is no longer fully sustainable, as the increase in traffic volume and climate changes—such as extreme heat or unexpected frost—significantly accelerate the deterioration of asphalt and concrete. For this reason, scientists are turning to biomimetic engineering, which studies nature's self-repair mechanisms. These materials are designed to automatically respond to mechanical damage, extend structural lifespan, and reduce the need for human intervention.

Main Part

The self-healing process can be divided into two main groups. The first includes autonomous systems, which operate without human involvement. One of the most popular methods in this field is microencapsulation. Millions of tiny capsules containing healing agents, such as epoxy resins, are mixed into the material. When a microcrack appears in the road, stress causes the capsules to rupture, releasing the liquid inside. This liquid fills the crack and hardens upon contact with air or other components of the material. This method is ideal for remote highways where continuous monitoring is difficult and repairs are costly. The size of the capsules and the thickness of their shells are critically important, as they must withstand the mixing process and rupture only when damage occurs.

The second group consists of non-autonomous systems, which require external activation. In road engineering, special attention is given to induction heating. In this case, electrically conductive fibers, such as steel wool fragments, are added to the asphalt mixture. When the pavement is damaged, a special vehicle generating a magnetic field passes over the road. The fibers heat up, causing the surrounding bitumen to melt and fill the cracks. Afterward, the road regains its original strength. This method is more controllable and allows preventive maintenance before visible and dangerous damage occurs. There is also microwave heating technology, which works on a similar principle but uses a different form of energy transfer.

Another revolutionary direction is bio concrete. Scientists have developed concrete containing specific bacteria and their nutrient source, calcium lactate. These bacteria remain dormant until a crack forms and water penetrates the material. Once they detect moisture, the bacteria become active and convert the nutrient into limestone. This natural filler mechanically seals the crack and prevents further water infiltration. It represents a perfect synthesis of engineering and biology. Research shows that such bacteria can survive in concrete for more than fifty years.



Pic. #1 – Self-Healing Concrete

The use of self-healing materials has enormous economic and environmental significance. Although their initial production cost is higher than that of traditional materials, their long-term benefits are substantial. First, repair costs are significantly reduced. Road rehabilitation is one of the largest burdens on state budgets, and self-healing roads reduce the need for emergency repairs. They also minimize traffic disruptions, as road repairs always cause congestion and time loss. Moreover, cement and asphalt production are major sources of environmental pollution. By doubling the service life of roads, we directly reduce the demand for new material production and protect natural resources. Fewer repairs also mean less construction machinery on the roads, reducing greenhouse gas emissions.

When discussing self-healing materials, polymer modifiers are also important. Polymers with reversible chemical bonds allow materials to return to their original shape after temperature changes. This is especially effective in regions with large temperature differences between day and night. Polymers mixed into asphalt prevent excessive softening in heat and cracking in cold conditions. This form of internal self-healing occurs at the molecular level, where damaged chains reconnect and restore structural integrity.

Despite many advantages, certain challenges remain. One of the main issues is scalability. Translating successful laboratory results to thousands of kilometers of highways is complex. Material stability is also crucial—healing agents must retain their properties for decades in aggressive environments. Furthermore, new construction norms and standards must be

developed to officially recognize these innovative approaches. In many countries, legislation still relies on outdated standards, slowing the widespread adoption of new technologies.

Self-healing materials are only the beginning of the smart roads' era. The road of the future will be a complex system capable of self-diagnosis through sensors and self-repair through biological or chemical processes. In some cases, such roads may even generate energy through solar panels. This technology is no longer science fiction but a necessary response to modern challenges. If we aim to build safe and sustainable infrastructure, investment in this direction is inevitable. A road that heals itself guarantees that future generations will inherit a more reliable and well-organized transportation system.

The use of hydrogels in concrete mixtures is particularly interesting. Hydrogels can absorb and store large amounts of water. When a crack forms in concrete, the hydrogel releases stored moisture, promoting further hydration of cement particles. This process is called autogenous self-healing and allows cracks to fill naturally without additional chemical additives. Its simplicity and reliability make it one of the key components of future construction.

Conclusion

Ultimately, the implementation of self-healing materials in road engineering is a step toward a smarter and more resource-efficient society. This innovation allows us to view infrastructure not as a static structure but as a living system that responds to its environment. The collaboration between science and engineering creates a new standard where safety, economy, and ecology are interconnected. With technological advancement, self-healing roads will become not a luxury but a standard that ensures safe and comfortable mobility for many years to come.

Widespread implementation of these materials also requires close cooperation among chemists, biologists, and civil engineers. Only an interdisciplinary approach can produce materials capable of withstanding real road conditions, such as heavy loads, winter salt exposure, and ultraviolet radiation. The coming decade will be decisive in refining and commercializing these technologies, ultimately transforming our understanding of road construction.

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THE EFFECT OF SEVERAL TYPES OF PLANTING MEDIA ON THE GROWTH OF MICROGREEN KAILAN (*Brassica oleracea* var. Achepala)

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ABSTRACT

Microgreens are an option for indoor vegetable cultivation within the urban farming concept because they are easy to cultivate, inexpensive, and can be harvested and consumed at a young age, and they do not require much space. This study aims to evaluate the effects of various growing media on the growth and vigor of kailan microgreens (*Brassica oleracea* var. Achepala). The study compared five media types: compost (A), cocopeat (B), zeolite (C), rockwool (D), and husk biochars (E). The results showed that the type of growing medium significantly affected all observed parameters. Rockwool (D) was the best medium for increasing plant height (107.91 mm) and vigor index (95.50), driven by optimized turgor pressure and synergism with gibberellin hormones. However, compost (A) yielded the highest growth percentage (91.00%), leaf area (2.56 cm^2), root length (32.95 mm), and fresh weight (1.73 g) due to its more complete availability of organic nutrients. Efficiency curve analysis

showed that the most technically and economically advantageous harvest point occurred 9–10 days after planting (DAP). The research environment was maintained at an average temperature of 26.5°C and 82% humidity, and was free of pests and diseases. Overall, rockwool was recommended for visual and product uniformity, while compost excelled in fresh biomass accumulation.

Keywords: Compost, Growing Medium, Growth Physiology, Kailan, *Microgreen*s, Rockwool

INTRODUCTION

One of the currently popular activities is home gardening, which uses the concept of urban farming. This is encouraged to meet nutritional needs and to utilize empty spaces, even if narrow, at home, which are made greener by growing edible plants. Consuming vegetables can provide the body with essential nutrients for the metabolic system and antibody production. Currently, many types of vegetables are consumed, one of which is microgreens, which are consumed when still in a very young growth stage. *Microgreens* are one option for indoor vegetable cultivation within the concept of urban farming because they are not only easy to cultivate, inexpensive, and can be harvested and consumed at a young age, but also do not require much space.

Microgreens are shoots from various vegetable plants that can be harvested within 7-14 days after sowing (Baskoro, Putri and Putri, 2021) . *Microgreens* differ from sprouts in that they have leaves and stems that resemble those of vegetables. Sprouts can be used as *microgreens* if they are grown until they form stems, leaves, and roots. Once true leaves appear, they are ready to be harvested, and the resulting crop is called *microgreens* (Kristyanti, 2019)

Microgreen growth requires a suitable growing medium. The growing medium supports plant growth and provides nutrients and water, which are absorbed by the roots for growth. In general, the growing medium should maintain moisture around the roots and provide sufficient air and nutrients for the plants (Hoang and Thuong, 2022; Bila, 2023) . An ideal growing medium should be locally available, derived from a renewable source, relatively inexpensive, have adequate aeration and water retention capacity, and have a pH range of 5.5-6.5.

Kailan (*Brassica oleracea* L.) is a plant with a highly varied nutritional profile, including minerals, protein, vitamins, fiber, calcium, and other essential nutrients. As one of the horticultural products in demand with the public, kailan has high market potential and sales value, making it a business opportunity in agricultural cultivation. Kailan plants require sufficient and readily available nutrients for growth and development to achieve maximum yield. One of the nutrients that plays a very important role in the growth of kailan is nitrogen, because the kailan that is harvested is the leaf part (Rugayah and Agsya, 2018) Because *microgreens* are planted in the vegetative growth phase.

The success of kale cultivation is influenced by environmental factors, including the fertility of the growing medium in supplying nutrients. The growing medium must be carefully considered, as it influences how quickly kale plants develop and produce. Crop production can be increased through proper growing media and maintenance, as these media can supply minerals and nutrients to support plant growth.

Microgreens are typically grown using rockwool, an inorganic growing medium, although many organic growing media have the potential to be used as growing media for *microgreens* (Hoang and Thuong, 2022) . Organic growing media have excellent water-binding properties, increase cation exchange capacity, provide nutrients, oxygen, and improve aeration and drainage. (Bariyyah, Suparjono and Usmadi, 2015). Commonly cultivated *microgreen*

commodities include arugula, coriander, basil, kale, endive, radish leaves, watercress, cabbage, peas, spinach, beetroot, and lettuce (Channel, 2024) and Kailan.

The types of growing media to be applied and tested include compost, cocopeat, zeolite, rockwool, and husk biochar. Given that each media type has distinct physical and chemical characteristics, further evaluation of their specific effects and the determination of the optimal medium for supporting microgreen growth are *necessary*. Therefore, it is necessary to find locally available alternative growing media that perform the same function while increasing the efficiency of kale cultivation as a *microgreen.*

METHODS

The research location was determined to be Tasikmalaya, Indonesia, with a series of research activities conducted intensively from March 2026 to April 2026.

Materials and Tools

The materials used include: Kailan seeds, rockwool, compost, husk biochars, cocopeat, water, zeolite, and M-bio (BioActivator). The tools used include microgreen growth racks, sprayers, bowls, baskets, calipers, thermometers, hygrometers, paper bags, and analytical scales (0.01 g) for measuring fresh weight. Vernier calipers to measure length and height (±0.1 mm).

Research Design

The data analysis design used was an exploratory experimental data analysis with a Randomized Block Design. The randomized block design was chosen because the environmental conditions were considered heterogeneous.

A Randomized Block Design (RBD) is a method in experimental design used to control for unwanted variation in experiments. Randomized Block Design is a random design in which experimental units are grouped into homogeneous groups, called clusters, and treatments are assigned randomly within each cluster (Sampurna & Nindhia, 2016; Aqil & Efendi, 2020). A randomized block design is one in which each treatment is assigned to each group. The purpose of grouping the experimental units is to make the diversity of experimental units within each group as small as possible, while the differences between groups are as large as possible.

The selection of a randomized block design is carried out if the experimental location is not homogeneous, but can be divided into several relatively homogeneous areas (blocks), thereby reducing the influence of inter-block variability, increasing the precision of treatment estimates, being relatively simple to implement in the field, standard ANOVA analysis is available, and is suitable for many treatments. The treatments tested were five types of planting media: A = rockwool (comparison), B = compost, C = cocopeat, D = zeolite, and E = husk biochars. Each of the five treatments was replicated four times, yielding a total of 5 × 4 = 20 experimental units (plots). The mathematics equation model will be:

$Yij = \mu + \tau i + \beta j + \varepsilon ij$

Where:

Yij = observation value in the i-th treatment of the j-th group

μ = general mean value

τi = effect of treatment i

βj = influence of the jth group

εij = experimental error in treatment i & group j

p = number of treatments

If significant variation is detected in the ANOVA results, a post hoc test using the Duncan Multiple Range Test (DMRT) is performed. Testing criteria:

If $T_{critical} < Sig._{\rho.05}$ then reject H_0 (significantly different) and

If $T_{critical} \geq Sig._{\rho.05}$ then accept H_0 (not significantly different)

Observation

The observations made in this study consisted of supporting observations analyzed descriptively and primary observations analyzed statistically using a randomized block design. Each treatment was planted with 100 kale seeds, for a total of 2,000. Ten random samples were taken from each treatment, the measurements were averaged, and the resulting averages were used as the final measurements. The observed mean parameters consisted of plant height, growth percentage, vigor index, leaf area, root length, fresh weight, and shoot/root ratio. The supporting observation was temperature and humidity.

RESULT AND DISCUSSION

Micro Climate

Based on observations during the experiment, the average daily temperature at the experimental site was 26.5 °C. *Microgreens* grow well at this temperature. According to Rohimin et al. (2018), the optimal temperature range for growth and development is 25-30 °C. A temperature of 26.5°C is optimal for stimulating enzyme activity in kale (Brassica oleracea) microgreens. At this temperature, respiration and cell division occur rapidly, which is crucial for microgreens given their short lifespan (7-14 days). A humidity of 82% acts as a "protector" for young seedlings whose roots have not yet penetrated deeply into the medium, preventing wilting due to excessive evaporation.

A stable temperature acts as a catalyst for enzymatic reactions during respiration and photosynthesis. At cool to lukewarm temperatures, the α-amylase enzyme in seeds optimally breaks down food reserves into energy for growth. This explains why, in supportive media such as Rockwool and compost, the vigor index can reach above 80, as the ambient temperature supports a faster metabolic rate.

Plant Height (mm)

The results of the statistical analysis (Appendix 2) show that the type of growing medium affects plant height. There are strongly significant differences in the growth height of kale microgreens (Brassica oleracea var. Acephala) across various growing media (Table 4). The height differences, ranging from 40.57 mm to 107.91 mm, indicate that the early phase of plant growth is highly sensitive to the physical and chemical characteristics of the root environment.

Microgreens grown in Rockwool have the highest plant heights from 1 day after planting to 14 days after planting, compared to *microgreens* grown in other growing media. The advantages of this medium lie in its availability of organic nutrients and good water retention capacity. However, technically, organic media has a higher density than Rockwool as watering intensity increases.

Table 1. The Effect of Several Types of Planting Media on Plant Height *Microgreen* (mm) at the age of 1–9 Days After Planting (DAP) (mm).

Age	Treatment				
	Compost (A)	Cocopeat (B)	Zeolite (C)	Rockwool (D)	Husk Biochar (E)
1 DAP	3.53 c	3.61 d	1.41 a	4.05 e	3.06 b
2 DAP	25.52 c	30.19 d	13.52 b	38.28 e	5.56 a
3 DAP	33.56 c	38.68 d	17.73 b	48.85 e	10.10 a
4 DAP	42.82 c	48.59 d	26.12 b	58.84 e	16.01 a
5 DAP	50.59 c	58.78 d	32.57 b	68.81 e	21.80 a
6 DAP	58.54 c	68.77 d	39.08 b	78.82 e	28.66 a
7 DAP	69.42 c	75.22 d	45.75 b	86.74 f	31.84 a
8 DAP	79.35 c	81.49 d	52.35 b	94.99 e	34.64 a
9 DAP	84.81 c	87.26 d	55.62 b	101.73 e	36.75 a

Numbers followed by the same letter indicate no significant difference at α = 0.05 according to Duncan's multiple-comparison test.

The stable water availability in Rockwool ensures high cell turgor pressure. This pressure is the primary driving force for gibberellins (GA) to stretch cell walls (elongation), enabling plants to reach their maximum height (>100 mm). Stable water availability in media like Rockwool prevents excessive abscisic acid (ABA) production, thus supporting sustained cell expansion driven by auxin and gibberellins (Hoang *et al.* , 2019) . The green curve shows the highest spike at the beginning (4-7 DAP). This shows that Rockwool triggers gibberellin activity most quickly because of the roots' very low mechanical resistance.

Microgreen Growth Percentage (%)

The type of growing medium significantly affected the growth rate of Kailan microgreens. Further testing revealed significant differences between treatments. Compost produced the highest growth rate at 91.00%, followed by Rockwool at 88.50%. Conversely, Husk biochars produced the significantly lowest growth rate at only 58.75%.

Table 2. The Effect of Several Types of Planting Media on growth percentage, vigor index, leaf area, root length, fresh weight, and shoot/root ratio *Microgreen* Kailan

Treatment	Growth %	Vigor index	Leaf area	Fresh weight	Root length	Shoot-Root Ratio
Compost	91,00e	82.12d	2.56 e	1.73 e	32.95 d	3.06 ab
Cocopeat	83.50c	77.25c	2.10 b	1.45 d	31.90 cd	3.13 bc
Zeolit	74,00b	44.40b	2.43 d	1.09 c	27.15 bc	2.46 a
Rockwool	88.50d	95.50e	2.13bc	0.85 b	26.40 b	4.68 d
Husk Biochar	58.75a	23.28a	1.39 a	0.60 a	8.83 a	5.10 e

Numbers followed by the same letter indicate no significant difference at α = 0.05 according to Duncan's multiple-comparison test.

Compost media produced the highest growth percentage (91.00%), followed by Rockwool at 88.50%. The high growth rate in compost is due to the availability of macro- and micro-

nutrients and organic compounds that act as natural stimulants for seed embryos. The humic acid content in compost can increase the permeability of seed cell membranes, thereby accelerating the imbibition process and metabolic activation in the early stages (Gioia *et al.* , 2017) . Meanwhile, Rockwool excels due to its highly hygroscopic texture, which ensures uniform water availability across the entire seed surface, thereby supporting the efficiency of cellular respiration during the germination phase (Yadav et al., 2024).

Cocopeat yielded quite good results, at 83.50%. This medium has a very high-water retention capacity, but its statistical position below compost and rockwool is thought to be related to its higher levels of natural inhibitors. Despite its good water retention capacity, incompletely processed cocopeat often contains tannins, which can be mildly toxic and inhibit the activity of hydrolytic enzymes in newly germinated seeds (Kyriacou *et al.* , 2016, 2021) .

The growth rate on zeolite reached 74.00%, while husk biochars showed the lowest value at 58.75%. The low yields are related to abiotic stress. Zeolite, which acts as a rock mineral, provides a strong mechanical barrier to the emergence of the radicle and plumule. On the other hand, husk biochars tend to be alkaline and highly porous, leading to the media drying out quickly (Hoang et al., 2019).

Kailan Microgreen Vigor Index

The vigor index is an indicator of seed growth speed and synchrony. The highest value for Rockwool (95.50) proves that this medium provides the most ideal environmental stability. Physiologically, Rockwool minimizes "initial stress" on the newly emerged radicle. Seeds with high vigor require a medium with low mechanical resistance and optimal oxygenation to support rapid respiration during the transition from heterotroph to autotroph (Yadav et al., 2024).

Compost and cocopeat provide high vigor values (>75). In compost, the availability of readily absorbable nutrients accelerates cell metabolism. However, the higher value for Rockwool than for Compost indicates that, in the microgreens phase, physical factors (aeration/drainage) determine vigor more than chemical factors (nutrients). Seed vigor is strongly influenced by the rate of food reserve metabolism, which is catalyzed by enzymes that are highly sensitive to the water-to-air ratio in the medium (Hoang *et al.* , 2019) .

The low vigor indices of Zeolite (44.40) and Husk biochar (23.28) indicate a disturbance in the biochemical processes of germination. The hard texture of zeolite forces the sprouts to expend extra energy to penetrate the media, resulting in slower growth rates (low vigor). Husk biochars have low vigor due to fluctuations in humidity and non-ideal pH. Physiologically, this triggers the accumulation of reactive oxygen species (ROS) in the seeds, which damages cell membranes and reduces germination. Media with poor water-retention capacity cause seeds to undergo imbibition-dehydration cycles that drastically reduce vigor index (Gioia et al., 2017).

Kailan Microgreen Leaf Area (cm^2)

There were significant differences in plant growth strategies across different media: compost and zeolite media produced the largest leaf area. This indicates the intake of external nutrients (especially nitrogen and magnesium) absorbed from the media for leaf tissue formation. Rockwool media showed the highest plant growth, but its leaf area had not yet reached its maximum. This indicates a phenomenon in which plants prioritize stem elongation (to reach light) over leaf surface expansion. Husk biochar media remained the lowest (1.39 a), indicating limitations both physically and in nutrient availability.

Leaf area is significantly influenced by nitrogen (N) availability. Compost provides organic N, which stimulates cell division in leaf mesophyll cells. Hormonally, cytokinins synthesized in

the roots and transported to the leaves stimulate lateral leaf expansion. The availability of macronutrients in organic media triggers chlorophyll expansion and increases leaf surface area, optimizing light interception for early photosynthesis (Buturi *et al.* , 2021) .

The use of substrates containing organic matter increases the surface area (Treadwell *et al.* , 2010) . Kailan leaves can increase the product's aesthetic value and fresh weight at harvest. Rockwool media is the best media for rapid growth. Compost media is the best media for visual quality (leaf area). Husk biochar media has the smallest leaf area due to limited water, so that leaf cells do not reach maximum expansion (low turgidity).

Microgreen Root Length (mm)

The statistical analysis of microgreen root length shows that the type of growing medium influences root length. Further test results are shown in Table 2. The compost medium had the longest roots (32.95 mm). The long roots in Medium A are a response to chemotropism (seeking nutrients). The high ratio in the husk biochar medium indicates "root etiolation" or failure of energy allocation; the plant prioritizes the stem to survive in dry media conditions, but without root support (8.83 mm).

There is a positive correlation between root length and leaf area. Long roots in compost media explore nutrients more widely, which are then translocated to the leaves to stimulate cell division (mitosis). Broad leaves, as larger photosynthetic factories, produce more organic matter. The development of an extensive root system in compost-based media is directly proportional to the expansion of leaf area and carbon assimilation capacity (Kyriacou *et al.* , 2016, 2021) .

Root length is a plant's response to seeking water and nutrient sources. In compost and cocopeat media, the loose structure facilitates root penetration. In rockwool, roots tend to be shorter (26.40 mm) but more effective. A well-aerated media structure enhances the functional root zone, where root length positively correlates with water absorption efficiency during the critical *seedling phase.* (Bilalis *et al.* , 2024; Carrasco *et al.* , 2025).

Fresh Weight of Kailan Microgreens (g)

The statistical analysis of microgreen leaf area shows that the type of growing medium influences leaf area. Further test results are shown in Table 2. All treatments showed highly significant differences. Compost produced the highest fresh weight (1.73 g), followed by cocopeat (1.45 g). The lowest performance was found in husk biochars, at 0.60 g.

Fresh weight is strongly influenced by tissue water content. Compost media has excellent water-retaining capacity, so kale cells remain optimally turgid. The fresh weight of microgreens is a direct indicator of the efficiency of water translocation from the media to the cell vacuoles. Consistent turgor pressure results in larger and heavier cells (Yadav et al., 2024).

Organic media tend to produce higher fresh weights due to their ability to facilitate nutrient uptake, which increases the osmotic gradient of cells (Gioia et al., 2017). The cellular metabolic rate supported by the availability of nutrient nitrogen in compost media will increase water accumulation in the tissues, which directly contributes to the total fresh weight at harvest (Kyriacou et al., 2016, 2021).

Shoot-Root Ratio *Microgreen* Kailan

The statistical analysis of microgreen leaf area shows that the type of growing medium affects leaf area. Further test results are shown in Table 2. The shoot-root ratio is a crucial indicator in assessing the balance of biomass allocation and the adaptation strategy of microgreens to their microenvironment. Based on the DMRT results, there is a clear stratification between mineral

media, organic media (compost, cocopeat), and soilless media (rockwool, husk biochars), reflecting differences in energy distribution patterns in plants.

Compost media demonstrated superior physiological integrity by synchronizing shoot and root development. High values for rockwool indicate that plants focused more on growing the upper part (shoot) than the roots. Plants grown in media with high nutrient availability tend to have a high shoot-root ratio due to the efficiency of nutrient uptake by their limited but active root system (Galieni et al., 2020). Zeolite media had the lowest ratio (2.46); roots penetrated the dense media, thus inhibiting upward growth. Shoot-root ratio. Unbalanced moisture in microgreens is an indicator of environmental stress, where media that fail to retain moisture (such as pure husk biochars) inhibit lateral root branching (Kyriacou *et al.* , 2016, 2020, 2021).

CONCLUSIONS AND RECOMMENDATION

Conclusion

1) Various planting media, such as compost, cocopeat, zeolite, rockwool, and husk biochars, have different effects on the growth and yield of microgreens.

2) Compost media showed the best growth and results, as measured by the percentage, leaf area, root length, and fresh weight of microgreens, which showed better results with larger quantities compared to using other planting media.

Recommendation

1) It is recommended to use compost as a growing medium in microgreen cultivation to optimize growth percentage, leaf area, root length, and fresh weight of the harvest.
2) Further research is recommended to use mixed media with different compositions and more diverse types of *microgreens*

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VEGETARIAN DIETS: A VETERINARY BIOETHICS PERSPECTIVE ON SUSTAINABILITY, ANIMAL WELFARE, AND ONE HEALTH

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ABSTRACT

Today, dietary preferences are evaluated not only in terms of individual health but also with regard to animal welfare, environmental sustainability, ethical production systems, and public health. In this context, vegetarian diets have become an increasingly important multidisciplinary topic within the frameworks of veterinary bioethics, animal welfare, and the One Health approach. The aim of this study was to evaluate vegetarian diets from the perspectives of sustainability, animal welfare, veterinary bioethics, and One Health. This study was conducted as a literature review. Relevant national and international literature on vegetarian diets, nutritional adequacy, sustainability, environmental ethics, animal welfare, veterinary bioethics, and the One Health approach was reviewed and evaluated. The historical development, characteristics, and different types of vegetarian diets were examined, together with their potential benefits and limitations. The reviewed literature indicates that well-planned vegetarian diets may contribute to sustainability through the conservation of natural resources, reduction of greenhouse gas emissions, and support of sustainable food systems. Furthermore, vegetarian diets are associated with ethical concerns regarding animal welfare and are compatible with the principles of the One Health approach, which emphasizes the interconnectedness of human, animal, and environmental health. However, deficiencies in protein, iron, zinc, calcium, vitamin B12, and omega-3 fatty acids may occur if vegetarian diets are not appropriately planned. Vegetarian diets may provide important contributions to sustainability, animal welfare, and ethical consumption practices when properly planned. Beyond being a dietary pattern, vegetarianism can be regarded as a lifestyle that encourages the reassessment of human–animal–environment relationships within the framework of ethical responsibility and sustainability. In this respect, vegetarian diets may be considered a dietary and ethical approach that supports the principles of veterinary bioethics, animal welfare, sustainability, and the One Health framework.

Keywords: Animal Welfare, Environmental Ethics, One Health, Sustainability, Vegetarian Diets, Veterinary Bioethics

INTRODUCTION

Today, dietary preferences are evaluated not only in terms of individual health but also with regard to environmental sustainability, animal welfare, ethical production systems, and public health. Concerns related to global population growth, limited natural resources, climate change, and food security have increased interest in sustainable dietary patterns. In this context, plant-based dietary approaches have gained importance due to their potential to reduce environmental impacts and support sustainable food systems (FAO, 2019; Willett et al., 2019).

The One Health approach, which emphasizes the interconnectedness of human, animal, and environmental health, provides an important framework for evaluating contemporary food production and consumption systems. In particular, discussions concerning the environmental

impacts of intensive livestock production, natural resource use, and animal welfare have transformed dietary choices from a purely individual matter into an issue with ethical and societal dimensions (Willett et al., 2019; Hargreaves et al., 2021). Within this framework, vegetarian diets have emerged as dietary patterns associated with the promotion of animal welfare, sustainable resource use, and the reduction of environmental impacts. From a veterinary bioethics perspective, vegetarian diets also provide a framework for examining ethical responsibilities toward animals, the sustainability of food production systems, and the interdependent relationships among humans, animals, and the environment (Hargreaves et al., 2021; Willett et al., 2019).

However, the successful implementation of a sustainable and healthy vegetarian diet requires adequate intake of certain nutrients. Particular attention should be paid to protein, iron, zinc, calcium, vitamin B12, and omega-3 fatty acids, making careful dietary planning essential (Melina et al., 2016; Niklewicz et al., 2024). This study evaluates vegetarian diets in terms of their historical development, fundamental characteristics, and different types, as well as their relationship with sustainability, animal welfare, veterinary bioethics, and the One Health approach.

METHODOLOGY

This study was conducted as a narrative literature review. National and international scientific publications related to vegetarian diets, sustainability, environmental ethics, animal welfare, veterinary bioethics, and the One Health approach were reviewed and evaluated. Relevant books, scientific articles, reports, and guidelines published by international organizations were examined in order to identify the historical development, characteristics, potential benefits, and limitations of vegetarian diets.

The collected literature was analyzed within four main themes: (i) vegetarian diets and nutritional adequacy, (ii) vegetarian diets and sustainability, (iii) vegetarian diets and animal welfare, and (iv) vegetarian diets in the context of veterinary bioethics and the One Health approach. The findings obtained from the literature were comparatively evaluated and interpreted from an interdisciplinary perspective.

The study did not involve human participants or animals and was based exclusively on published scientific literature. Therefore, ethics committee approval was not required.

VEGETARIAN DIETS: HISTORY, DEFINITION, AND TYPES

Although the exact origin of vegetarian diets is unknown, it is believed that this dietary pattern dates back thousands of years. Rooted in religious, philosophical, and ethical traditions, vegetarianism is thought to have first emerged in ancient India, which is considered one of its earliest centers. The principle of non-violence toward living beings, emphasized in religions such as Hinduism, Jainism, and Buddhism, is closely associated with vegetarian dietary practices that exclude the consumption of animal flesh. In ancient Egyptian civilization, where belief in reincarnation was widespread, abstaining from meat consumption was believed to facilitate the transmigration of the soul, contributing to the adoption of vegetarian dietary practices. Several ancient Greek philosophers are also known to have supported meat-free diets. Among them, Pythagoras argued that meat consumption should be avoided due to his belief in reincarnation. Influenced by his philosophy, many individuals limited their meat consumption, and vegetarianism was referred to for many years as the “Pythagorean diet.” Today, Pythagoras

is widely regarded as the father of ethical vegetarianism (Hargreaves et al., 2021; Son & Bulut, 2016; Leitzmann, 2014).

Although there are relatively few records concerning vegetarian diets in Europe from the periods of Ancient Greece and Rome until the Renaissance, it is known that during the Christian era meat consumption became widespread because it was associated with strength and vitality, leading to a decline in vegetarian practices. During the Renaissance, Leonardo da Vinci, and later Enlightenment thinkers such as Voltaire, Rousseau, Tryon, and Wesley, questioned the morality of consuming animal flesh and advocated vegetarian dietary practices. Vegetarianism gained increasing popularity throughout the twentieth century and has continued to attract growing interest in the twenty-first century. The institutionalization of vegetarianism is generally considered to have begun with the establishment of the first Vegetarian Society in England in 1847. The International Vegetarian Union (IVU) was founded in 1908, followed by the establishment of the Vegan Society in 1944 (Leitzmann, 2014).

Vegetarianism, in its broadest sense, refers to a dietary pattern that excludes meat and meat products from the diet. More specifically, it is a form of nutrition in which individuals avoid consuming the flesh of animals such as cattle, poultry, and fish and, in some cases, other animal-derived products, while primarily relying on plant-based foods including vegetables, fruits, cereals, nuts, seeds, and legumes. Individuals may adopt vegetarian diets for a variety of reasons, including ethical concerns, health considerations, environmental sustainability, and cultural or religious beliefs.

Today, vegetarian dietary preferences are associated not only with individual health considerations but also with the promotion of animal welfare, support for ethical consumption practices, and the achievement of environmental sustainability. In particular, concerns regarding the environmental impacts of intensive livestock production, the use of natural resources, and animal welfare have increased interest in plant-based dietary patterns. Consequently, vegetarian diets have become an important topic within the fields of veterinary bioethics and sustainable food systems (Willett et al., 2019; Hargreaves et al., 2021). Individuals who adopt this dietary pattern are referred to as “vegetarians” (Son & Bulut, 2016). Although the prevalence of vegetarianism varies across regions of the world, its popularity has increased considerably in recent years. India, where approximately 40% of the population follows a vegetarian diet, has the largest vegetarian population globally. In Asia, which includes India, vegetarians account for approximately 19% of the total population. This proportion is estimated to be around 16% in Africa and the Middle East, 8% in Central and South America, 6% in North America, and 5% in Europe (Hargreaves et al., 2021). In Türkiye, the proportion of individuals identifying as vegan or vegetarian reportedly increased from 4% in 2020 to 8% in 2024 (Hafta Gazetesi, 2024).

Vegetarian diets can be classified into several subtypes according to the extent to which animal-derived foods are included in the diet. The most common forms of vegetarianism and the foods that are included or excluded within each dietary pattern are presented in Table 1. These classifications may vary depending on individuals’ ethical values, health expectations, environmental concerns, and lifestyle preferences (Son & Bulut, 2016; Rudloff et al., 2019).

Table 1. Foods consumed and excluded according to types of vegetarianism.

Type of Vegetarian Diet	Red Meat	Poultry	Fish	Eggs	Dairy Products	Honey	Vegetables, Fruits, Cereals, and Legumes
Lacto-ovo Vegetarian	✗	✗	✗	✓	✓	✓	✓
Lacto Vegetarian	✗	✗	✗	✗	✓	✓	✓
Ovo Vegetarian	✗	✗	✗	✓	✗	✓	✓
Pesco-vegetarian (Pescatarian)	✗	✗	✓	✓	✓	✓	✓
Polo-vegetarian	✗	✓	✗	✓	✓	✓	✓
Semi-vegetarian (Flexitarian)	✓ (limited)	✓ (limited)	✓ (limited)	✓	✓	✓	✓
Vegan	✗	✗	✗	✗	✗	✗	✓

HEALTHY NUTRITION, VEGETARIANISM, AND THE ONE HEALTH APPROACH

Healthy nutrition is achieved through the adequate and balanced intake of essential nutrients according to an individual's age, level of physical activity, and health status. Adequate and balanced nutrition plays a crucial role in growth, development, immune system function, and the maintenance of quality of life. In addition, it contributes significantly to the preservation of health and the reduction of nutrition-related health risks (WHO, 2020).

Vegetarian diets have become increasingly popular, particularly among individuals seeking to adopt a healthy lifestyle. Well-planned vegetarian diets have been reported to exert beneficial effects on health due to their low content of saturated fat and cholesterol and their high content of dietary fiber, vitamins, minerals, and antioxidants (Melina et al., 2016; Oussalah et al., 2020).

Furthermore, plant-based dietary patterns are increasingly evaluated within the framework of the One Health approach, which recognizes the interconnectedness of human, animal, and environmental health. Interest in vegetarian dietary patterns has grown due to their potential contributions to sustainable food systems, reduction of environmental impacts, and promotion of animal welfare (Willett et al., 2019; FAO, 2019).

On the other hand, the restriction of animal-derived foods in vegetarian diets may lead to deficiencies in certain essential nutrients. Particular attention should be paid to iron, vitamin B12, zinc, calcium, vitamin D, and omega-3 fatty acids. Moreover, poorly planned vegetarian diets characterized by a high consumption of highly processed and nutrient-poor foods may fail to provide the expected health benefits (Rudloff et al., 2019; Niklewicz et al., 2024). Therefore, in order to sustain the potential benefits of vegetarian diets, it is essential to identify possible nutrient deficiencies and implement appropriate preventive measures.

NUTRITIONAL DEFICIENCIES ASSOCIATED WITH VEGETARIAN DIETS

In vegetarian dietary patterns, where animal-derived foods are either excluded or consumed in limited amounts, making informed and well-planned dietary choices is of great importance. The Academy of Nutrition and Dietetics emphasizes that appropriately planned vegetarian diets can be nutritionally adequate for all stages of life, from infancy to older adulthood. However, certain precautions are necessary to minimize the risk of nutrient deficiencies associated with this dietary pattern (Melina et al., 2016).

In general, the greater the degree of dietary restriction within a particular type of vegetarianism, the more important it becomes to ensure an adequate intake of all essential nutrients required by the body. For example, an individual following an ovo-vegetarian diet may need to plan their diet more carefully than a semi-vegetarian in order to obtain sufficient amounts of essential nutrients.

This section examines several nutrients that may be consumed in insufficient quantities in vegetarian diets and that may therefore pose potential health risks if dietary intake is not adequately planned.

Protein

Proteins are essential nutrients involved in numerous vital physiological processes, including growth, development, immune function, tissue repair, and energy production. Animal-derived proteins are considered “complete protein sources” because they contain all essential amino acids in sufficient amounts, whereas plant proteins may be limited in certain essential amino acids (Shipman, 2021). Legumes, soy products, whole grains, nuts, and oilseeds constitute important plant-based protein sources in vegetarian diets. However, due to differences in the amino acid profiles of plant proteins, combining various protein sources, such as cereals and legumes, may improve overall protein quality (Gümüş & Keser, 2024).

Protein deficiency may occur in vegetarian diets that are not adequately planned, potentially leading to health problems such as loss of muscle mass, impaired immune function, and growth and developmental disorders (Mariotti & Gardner, 2019). Therefore, it is important for vegetarian and vegan individuals to plan their diets carefully and include a variety of plant-based protein sources in order to meet their protein requirements.

Iron

Iron is an essential mineral that plays a crucial role in oxygen transport, energy production, immune function, and various cellular processes. Iron deficiency may lead to anemia, fatigue, impaired immune function, and a range of neurological disorders. Children, pregnant women, older adults, and individuals following vegetarian or vegan diets are considered to be at increased risk of iron deficiency (Bolaman, 2004).

Iron is found in foods such as red meat, fish, liver, legumes, and green leafy vegetables. Iron derived from animal sources is present in the form of heme iron, which has high bioavailability, whereas plant-derived iron is present as non-heme iron and is absorbed less efficiently. Consequently, iron levels in vegetarians may be lower than those observed in individuals consuming omnivorous diets (Haider et al., 2018; İnce & Çağındı, 2020).

The absorption of plant-derived iron can be enhanced through appropriate food combinations. In particular, the consumption of vitamin C-rich foods together with iron-containing foods has been shown to improve iron bioavailability. In contrast, polyphenol-containing beverages such as tea and coffee, as well as phytates found in certain cereals and legumes, may reduce iron absorption (Hurrell, 2004; Awoniyi et al., 2024). Therefore, it is important for vegetarian individuals to consume iron-rich plant foods in a balanced manner and to monitor their iron status when necessary.

Zinc

Zinc is an essential mineral involved in protein and DNA synthesis, cell growth and repair, as well as immune and nervous system functions. Zinc deficiency may result in impaired immune function, delayed wound healing, growth retardation, and various dermatological disorders (Shipman, 2021). Studies have reported that although zinc intake among vegetarian and vegan individuals may be adequate, their plasma zinc concentrations can be lower than those of

individuals consuming omnivorous diets (Foster et al., 2013). The primary reason for this difference is the lower bioavailability of zinc from plant-based sources compared with animal-derived foods.

In particular, phytates present in whole grains and legumes have been shown to reduce zinc absorption. Therefore, processing methods such as soaking, sprouting, fermentation, and leavening are recommended to improve zinc bioavailability in vegetarian diets (Özcan & Baysal, 2016; Melina et al., 2016). Consequently, although zinc requirements can generally be met through a well-planned vegetarian diet, monitoring zinc status may be important in individuals at increased risk of deficiency.

Calcium

Calcium is an essential mineral required for bone and dental health, muscle and nervous system function, blood clotting, and the maintenance of normal cardiac activity. Calcium deficiency may lead to reduced bone mineral density, osteoporosis, muscle cramps, and growth and developmental disorders (Shipman, 2021).

Although milk and dairy products are the primary dietary sources of calcium, certain green leafy vegetables, legumes, and soy products also contain considerable amounts of this mineral. However, the bioavailability of calcium from plant-based sources may vary due to the presence of compounds such as phytic acid and oxalic acid. Studies have reported that calcium levels may be lower in vegan individuals than in those consuming omnivorous diets, potentially resulting in decreased bone mineral density (Bickelmann et al., 2023; Ho-Pham et al., 2009).

Therefore, it is important for vegetarian and vegan individuals to meet their calcium requirements through the consumption of highly bioavailable plant-based calcium sources, calcium-fortified foods, and a well-balanced diet. Furthermore, because vitamin D plays a crucial role in calcium absorption, maintaining adequate vitamin D status is also recommended (Bolland et al., 2010; Vanga & Raghavan, 2018).

Vitamin B12 (Cobalamin)

Vitamin B12 is an essential vitamin involved in DNA synthesis, red blood cell formation, and the proper functioning of the nervous system. Vitamin B12 deficiency may result in anemia, fatigue, neurological disorders, memory impairment, and damage to the nervous system (Zeuschner et al., 2013).

Because vitamin B12 is found primarily in animal-derived foods such as meat, dairy products, eggs, and organ meats, the risk of deficiency is higher among vegetarians and particularly vegans who avoid or limit the consumption of animal products. Studies have shown that vitamin B12 levels may be borderline in lacto-ovo vegetarians, whereas deficiency can develop in vegans who do not use fortified foods or dietary supplements (Niklewicz et al., 2024; Gibbs & Cappuccio, 2024).

Long-term vitamin B12 deficiency may lead to impaired concentration, numbness and tingling in the hands and feet, neurological complications, and irreversible damage to the nervous system (Kapoor et al., 2017). Therefore, it is important for vegetarian and vegan individuals to monitor their vitamin B12 status regularly and, when necessary, obtain adequate amounts through fortified foods or supplementation. Particular attention should be paid to maintaining adequate vitamin B12 intake during pregnancy and lactation.

Essential Fatty Acids

Essential fatty acids play a vital role in numerous physiological processes, including the structure of cell membranes, energy production, hormone synthesis, and the absorption of fat-

soluble vitamins. Since omega-3 and omega-6 fatty acids cannot be synthesized by the human body, they must be obtained through the diet. While omega-6 fatty acids are widely found in plant-based sources such as soybean, corn, and sunflower oils, omega-3 fatty acids are present in fish and seafood as well as in walnuts, flaxseeds, and certain plant oils (Shipman, 2021). The principal forms of omega-3 fatty acids are alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). EPA and DHA are particularly important for cardiovascular health, regulation of inflammatory processes, and brain development. Plant-based sources of omega-3 fatty acids predominantly contain ALA, whereas EPA and DHA are obtained mainly from fish and seafood. Consequently, vegetarians and vegans who do not consume fish may have lower levels of EPA and DHA (Saunders et al., 2013). Insufficient intake of omega-3 fatty acids has been associated with adverse effects on cardiovascular and neurological health. Therefore, vegetarian individuals are encouraged to consume ALA-rich foods such as flaxseeds and walnuts on a regular basis and, when necessary, to consider alternative sources of DHA, such as marine algae, or appropriate dietary supplements (Mete et al., 2022). In conclusion, maintaining an adequate balance of omega-3 fatty acids is an important aspect of healthy nutrition in plant-based dietary patterns.

VEGETARIAN DIETS, SUSTAINABILITY, AND ENVIRONMENTAL ETHICS

Food production systems are currently evaluated not only in terms of human nutrition but also with regard to environmental sustainability and ethical responsibility. Animal production is a major subject of environmental ethics discussions due to its impacts on greenhouse gas emissions, land use, water consumption, and biodiversity. The livestock sector contributes to global greenhouse gas emissions, particularly through methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2) emissions. Methane emissions resulting from enteric fermentation in ruminants, together with emissions associated with feed production and manure management, account for a substantial proportion of the environmental impacts of animal production. Therefore, plant-based dietary patterns are considered among the sustainable approaches that may contribute to the reduction of greenhouse gas emissions (Poore & Nemecek, 2018; Willett et al., 2019).

In their large-scale life cycle assessment, Poore and Nemecek reported that even low-impact animal products may have greater environmental impacts than many plant-based alternatives (Poore & Nemecek, 2018). Similarly, the EAT–Lancet Commission recommends increasing the consumption of plant-based foods and limiting the intake of animal-derived foods as part of the transition toward sustainable food systems (Willett et al., 2019). Sustainable healthy diet principles published by the FAO and WHO also emphasize that, in addition to the health aspects of nutrition, the environmental costs of food production and consumption should be taken into consideration (WHO, 2019).

Within this context, vegetarian diets may be associated with the conservation of natural resources, the reduction of pressure on ecosystems, and the principle of responsibility toward future generations. From the perspective of environmental ethics, vegetarianism can be regarded as an approach that extends beyond anthropocentric concerns and recognizes the moral value of animals, nature, and ecological integrity.

VEGETARIAN DIETS AND ANIMAL WELFARE

Vegetarian diets are among the dietary patterns frequently associated with ethical concerns regarding animal welfare. In particular, housing conditions, the ability of animals to express species-specific behaviors, and exposure to stressors within intensive livestock production

systems constitute major topics in animal welfare discussions. For many years, the assessment of animal welfare was primarily based on the “Five Freedoms” framework developed by the Farm Animal Welfare Council. This framework identifies freedom from hunger and thirst, freedom from discomfort, freedom from pain, injury and disease, freedom to express normal behavior, and freedom from fear and distress as fundamental indicators of animal welfare (Webster, 2001).

Contemporary approaches to animal welfare focus not only on minimizing negative experiences but also on promoting positive experiences for animals. In this regard, the Five Domains Model developed by Mellor and colleagues (2020) incorporates animals’ emotional states into welfare assessments in addition to factors such as nutrition, physical environment, health, and behavior. Consequently, animal welfare is no longer defined solely by the absence of disease or suffering but also by the opportunity for animals to experience a life worth living (Mellor et al., 2020). For this reason, production systems used in food animal agriculture are increasingly evaluated from an ethical animal welfare perspective. Growing public awareness of the living conditions experienced by animals within production systems has encouraged some individuals to reconsider their dietary choices and reduce their consumption of animal-derived products or adopt vegetarian diets.

In this context, vegetarianism may be regarded not only as a dietary pattern but also as an approach that reflects ethical responsibility and concern for the quality of life of animals. As scientific and ethical discussions surrounding animal welfare continue to develop, dietary choices have become an important factor contributing to the reassessment of human–animal relationships.

CONCLUSION

Today, vegetarian diets are regarded not merely as a dietary pattern but as a multidimensional approach associated with animal welfare, veterinary bioethics, environmental sustainability, and public health. Within the framework of the One Health approach, which emphasizes the interdependence of human, animal, and environmental health, the impacts of dietary choices on ecosystems, natural resources, and the living conditions of animals should also be taken into consideration.

The ability of plant-based dietary patterns to generate a lower environmental footprint, contribute to the conservation of natural resources, and support sustainable food systems has increased the significance of vegetarian diets from a sustainability perspective. Furthermore, growing public awareness of animal welfare conditions within food production systems has made the connections between vegetarianism, veterinary bioethics, and animal welfare increasingly visible. Nevertheless, in order for vegetarian diets to be implemented in a healthy and sustainable manner, particular attention should be paid to the adequate intake of essential nutrients, including protein, iron, zinc, calcium, vitamin B12, and omega-3 fatty acids. Therefore, it is important for individuals to plan their dietary choices based on scientific evidence and seek professional guidance when necessary.

In conclusion, vegetarianism represents a multidimensional approach that should be evaluated within the framework of sustainability, animal welfare, veterinary bioethics, and One Health principles. It may also be considered a meaningful lifestyle that contributes to the reconsideration of human–animal–environment relationships on ethical grounds.

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RISK ASSESSMENT OF INDUSTRIAL POLLUTION IN SOIL AND WATER SYSTEMS: ENVIRONMENTAL AND ECOLOGICAL IMPLICATIONS

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ABSTRACT

Industrial activities are among the major sources of environmental contamination, releasing a wide range of pollutants that adversely affect soil and water resources. The accumulation of heavy metals, organic contaminants, and other hazardous substances in environmental compartments poses significant risks to ecosystem integrity, biodiversity, and human health. This study aims to assess the extent of industrial pollution in soil and water systems and evaluate its environmental and ecological implications through a comprehensive risk assessment approach.

Soil and water samples collected from industrially influenced areas were analyzed for key physicochemical parameters and contaminant concentrations. Pollution indices, ecological risk indicators, and environmental quality standards were employed to determine contamination levels and potential ecological threats. The assessment focused on the distribution, mobility, and persistence of pollutants, as well as their potential impacts on soil functionality, water quality, and biological communities.

The results revealed elevated concentrations of several contaminants in proximity to industrial zones, indicating varying degrees of environmental degradation. Risk assessment indices highlighted moderate to high ecological risks associated with pollutant accumulation, particularly in areas subjected to long-term industrial discharge. The deterioration of soil quality and water resources was found to negatively influence ecosystem services, nutrient cycling, and the health of aquatic and terrestrial organisms.

The findings emphasize the need for continuous environmental monitoring, effective pollution control measures, and sustainable industrial management practices to mitigate contamination risks. Implementing integrated remediation and resource management strategies is essential for protecting environmental quality, preserving ecosystem health, and ensuring the sustainable use

of soil and water resources. This study contributes to a better understanding of industrial pollution dynamics and provides valuable insights for environmental policy and risk management frameworks.

Keywords: Industrial pollution; Soil contamination; Water quality; Ecological risk assessment; Heavy metals

INTRODUCTION

Industrialization has profoundly shaped modern societies, driving economic development, technological advancement, and urbanization. However, the rapid growth of industrial activities has increasingly contributed to environmental degradation, posing significant risks to natural resources and ecosystem health. Among these, soil and water are particularly vulnerable to contamination from industrial effluents, atmospheric emissions, and the improper disposal of solid and hazardous wastes. Such contamination can reduce soil fertility, alter microbial communities, impair crop productivity, compromise the quality of drinking water, and threaten biodiversity, ultimately undermining ecosystem resilience (Alloway, 2013; Bradl, 2005).

Industrial pollutants encompass a wide range of chemical and organic substances, including heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As), petroleum hydrocarbons, persistent organic pollutants, and excessive nutrients (Belkacemi et al., 2026) . These contaminants often accumulate in the environment over time, entering food chains and causing long-term ecological and health consequences. For example, heavy metals can bioaccumulate in plants and animals, leading to toxic effects that persist across trophic levels, while organic pollutants may disrupt microbial processes essential for soil fertility (Wuana & Okieimen, 2011). The combined effects of multiple contaminants can exacerbate environmental degradation, increasing the vulnerability of both terrestrial and aquatic ecosystems.

Understanding the impacts of industrial activities on soil and water quality is essential for sustainable environmental management. Systematic assessment of contamination levels allows for the identification of pollution hotspots, evaluation of ecological risks, and development of mitigation and remediation strategies. Such studies also provide critical insights into the interaction between industrial pollution and ecosystem functions, informing policy decisions and regulatory frameworks aimed at reducing environmental and public health risks (Singh & Kalamdhad, 2015).

Furthermore, evaluating the consequences of industrialization on soil and water resources is central to achieving sustainable development. Integrating environmental monitoring with industrial planning can guide the implementation of cleaner production techniques, waste treatment systems, and ecosystem restoration measures. This approach not only mitigates the adverse effects of industrialization but also promotes the responsible use of natural resources, ensuring long-term ecological stability and resilience.

This study therefore aims to assess the environmental impact of industrial activities on local soils and water bodies, examining the implications for ecosystem health and sustainable resource management. By linking contamination patterns with ecological and human health outcomes, this research seeks to contribute to evidence-based strategies that balance industrial growth with environmental preservation.

CONCEPTUAL FRAMEWORK

The conceptual framework of this study illustrates the relationships between industrial activities, environmental contamination, ecosystem health, and sustainable resource management. Industrial operations, including manufacturing, mining, chemical processing, and waste disposal, release a variety of pollutants into the surrounding environment. These pollutants—ranging from heavy metals and petroleum hydrocarbons to organic and nutrient-based contaminants—directly affect the quality of soil and water resources.

Soil contamination can alter nutrient composition, reduce fertility, and disrupt microbial communities, while water pollution affects aquatic ecosystems, reduces biodiversity, and compromises water safety for human consumption and agricultural use. Over time, these environmental changes can lead to cumulative ecological stress, affecting food security, public health, and ecosystem resilience. Contaminants may also bioaccumulate along food chains, creating long-term risks for humans and wildlife.

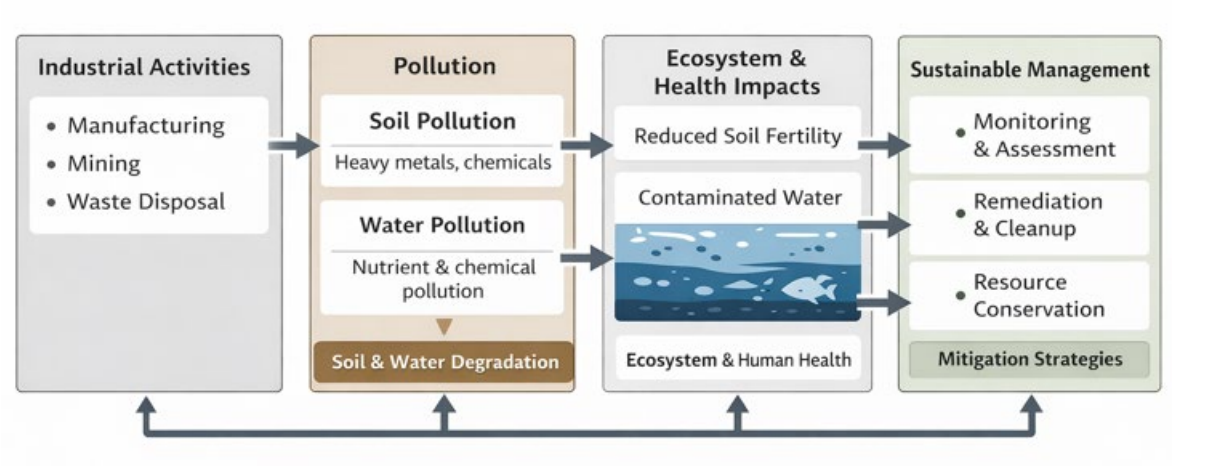

Figure 1: Conceptual framework showing how industrial activities affect soil and water quality, ecosystem and human health, and the role of mitigation strategies.

The figure 1 presents a conceptual framework depicting the relationships between industrial activities, environmental contamination, ecosystem and human health impacts, and sustainable management strategies. Industrial activities, including manufacturing, mining, and waste disposal, are identified as the primary sources of pollutants. These activities lead to soil pollution, characterized by heavy metals and chemical contaminants, and water pollution, including nutrient and chemical loading. The accumulation of these pollutants results in soil and water degradation, which in turn reduces soil fertility, contaminates water resources, and contributes to biodiversity loss, ultimately affecting ecosystem stability and human health. The framework also highlights the role of sustainable management interventions, such as monitoring and assessment, remediation and cleanup, and resource conservation, in mitigating environmental impacts and promoting sustainable use of natural resources. Arrows in the diagram illustrate the flow of cause-and-effect relationships and the feedback mechanisms through which management strategies can reduce contamination and its consequences. The overall framework provides a clear, structured representation of the environmental pathways from industrial activities to ecological and health outcomes, emphasizing the importance of integrated assessment and mitigation strategies for sustainable environmental management(Elwahab et al., 2025)

METHODOLOGY

Methodological Framework of the Study

The methodological framework of this study is designed to systematically assess the environmental impacts of industrial activities on soil and water quality and to evaluate their implications for ecosystem health and sustainable resource management. The framework consists of six key steps. First, representative industrial sites are selected based on the type of industrial activity, proximity to sensitive areas, and historical records of pollution. Second, soil samples are collected from surface and subsurface layers, and water samples are obtained from surface and groundwater sources, following standardized protocols to ensure reliability and representativeness. Third, laboratory analyses are conducted to measure physical, chemical, and biological parameters, including heavy metals, organic pollutants, nutrient levels, and microbial indicators. Fourth, collected data are processed using statistical and geospatial techniques; descriptive statistics, pollution indices (e.g., Pollution Load Index and Heavy Metal Index), and GIS mapping are employed to quantify contamination levels and visualize spatial distribution (Arif et al., 2026). Fifth, correlations and multivariate analyses are performed to explore relationships between industrial activities, pollutant concentrations, and ecological and health impacts. Finally, results are interpreted to assess environmental risks, inform mitigation strategies, and provide recommendations for sustainable management of soil and water resources. This framework provides a structured and integrated approach, linking industrial practices to ecological outcomes while supporting evidence-based decision-making for environmental protection and sustainability.

Table 1. Methodological Framework of the Study

Step	Description	Methods / Tools	Parameters Measured
Site Selection	Selection of representative industrial zones	Map analysis, GPS coordinates, historical industrial activity	Type of industry, proximity to sensitive areas
Soil Sampling	Collection of surface and subsurface soil samples	Standard auger, composite sampling	Heavy metals, pH, soil texture, organic matter
Water Sampling	Collection of surface and groundwater samples	Sterile containers, WHO sampling guidelines	Heavy metals, nutrients, organic pollutants, microbial indicators
Laboratory Analysis	Chemical, physical, and biological measurements	AAS, ICP-MS, spectrophotometry, microbiological analyses	Pb, Cd, Hg, As, hydrocarbons, N, P, K, coliforms
Data Analysis	Statistical and geospatial processing	Descriptive statistics, pollution indices (PLI, HMI), GIS, correlations	Pollutant concentrations, spatial distribution, correlation between industrial activity and pollution
Interpretation and Recommendations	Assessment of impacts and formulation of strategies	Comparison with environmental standards, risk analysis	Soil fertility, water quality, human health, biodiversity, sustainable management

Emerging Industrial Pollutants

Emerging industrial pollutants (EIPs) are a growing concern due to their persistence, bioaccumulation potential, and adverse effects on ecosystems and human health. Unlike conventional pollutants such as heavy metals or nutrients, EIPs include a wide range of novel chemicals and materials that are increasingly released into the environment through modern industrial processes. These may include microplastics, synthetic organic compounds,

pharmaceutical residues, endocrine-disrupting chemicals (EDCs), per- and polyfluoroalkyl substances (PFAS), nanoparticles, and other persistent organic pollutants (POPs) (Richardson & Ternes, 2018; Gallo et al., 2018).

Industrial activities contribute to the introduction of EIPs into soils and water bodies through wastewater discharge, effluent releases, accidental spills, and solid waste management (Boxall et al., 2012; Schwarzenbach et al., 2010). Once released, EIPs often display complex environmental behavior, including sorption to sediments, partial biodegradation, photochemical transformations, and long-range transport. Their mobility and persistence are influenced by factors such as pH, organic matter content, redox conditions, and the presence of co-contaminants (Li et al., 2018).

The environmental and health risks associated with EIPs are significant. Microplastics, for example, can act as vectors for heavy metals and hydrophobic organic pollutants (Rochman et al., 2013), while PFAS are highly resistant to degradation and can accumulate in living organisms (Lindstrom et al., 2011). Pharmaceutical residues and EDCs may disrupt aquatic ecosystems and affect endocrine function in wildlife and humans (Kümmerer, 2009).

Given their emerging nature and the lack of regulatory frameworks in many regions, monitoring, risk assessment, and mitigation strategies for EIPs are critical for sustainable industrial development. Advanced analytical methods, including high-resolution mass spectrometry, spectroscopy, and bioassays, are essential for detecting and quantifying these pollutants in environmental matrices (Hernandez et al., 2015; Thurman & Ferrer, 2012).

Table 1. Analytical Synthesis of Major Industrial Pollutants, Dominant Sources, and Controlling Geochemical Processes

Pollutant	Primary Industrial Sources	Dominant Reactions / Controlling Processes
Heavy metals (Pb, Cd, Cr, Ni, Zn)	Mining, smelting, metal plating, battery manufacturing	Ion exchange, surface adsorption, redox reactions; mobility influenced by pH, organic matter, and redox potential
Petroleum hydrocarbons and PAHs	Oil refining, petrochemical industries, electronics, fuel storage and spills	Oxidation–reduction reactions, biodegradation, sorption to soil organic matter; complexation with organic matter controls persistence
Acidic industrial effluents	Textile processing, chemical production, fertilizer industries	Soil acidification, metal desorption, carbonate dissolution; affects mobility of metals and nutrients
Microplastics (PE, PP, PS)	Plastic manufacturing, industrial wastewater discharge, sludge application	Physical accumulation in soil and water, adsorption of pollutants onto polymer surfaces, slow degradation; persistence influenced by environmental conditions
Nutrient-rich wastes (N and P compounds)	Food processing, agro-industries, beverage industries	Eutrophication, denitrification, co-transport with water, interaction with soil minerals; mobility controlled by adsorption and biogeochemical cycling

Note: PE = polyethylene; PP = polypropylene; PS = polystyrene.

Analysis of the research problem

The industrialization process has brought substantial socio-economic benefits; however, it has simultaneously introduced significant environmental challenges, particularly concerning the contamination of soil and water resources. Industrial activities release a variety of pollutants—including heavy metals, petroleum hydrocarbons, acidic effluents, nutrient-rich wastes, and emerging industrial pollutants such as microplastics and pharmaceuticals—into surrounding ecosystems. These pollutants can alter soil fertility, reduce water quality, and disrupt ecological balance, ultimately affecting both ecosystem services and human health (Boxall et al., 2012; Gallo et al., 2018).

The complexity of the research problem lies in the interconnected nature of industrial pollution and environmental processes. For instance, heavy metals and acidic effluents can interact with soil minerals, altering mobility and bioavailability, while organic pollutants may undergo transformation or adsorption, influencing their persistence and toxicity. Moreover, multiple pollution sources often co-occur, creating cumulative or synergistic effects that are difficult to quantify without integrated monitoring and advanced analytical methods (Schwarzenbach et al., 2010; Richardson & Ternes, 2018).

Another critical aspect is the temporal and spatial variability of contamination. Industrial discharges fluctuate over time, and pollutants can disperse unevenly across landscapes due to hydrological, geological, and climatic factors. This variability poses a challenge for accurate assessment and risk evaluation, necessitating carefully designed sampling strategies and robust statistical analyses.

Furthermore, there is a growing concern regarding emerging industrial pollutants (EIPs), which often lack standardized monitoring protocols and regulatory frameworks. EIPs—including microplastics, PFAS, and pharmaceutical residues—exhibit unique environmental behaviors and long-term ecological risks that are not fully understood, highlighting the need for research that integrates conventional and emerging contaminant assessment (Kümmerer, 2009; Lindstrom et al., 2011).

In summary, the research problem addresses the multifaceted environmental impacts of industrial activities on soil and water quality, the ecological and human health implications, and the challenges of evaluating these impacts under dynamic and complex environmental conditions. Addressing this problem requires a holistic methodological approach, combining field sampling, laboratory analysis, geospatial mapping, and risk assessment to provide actionable recommendations for sustainable industrial and environmental management.

Pollution Prevention and Sustainable Management

Preventive measures are crucial for long-term environmental protection because they reduce pollutant generation at the source and maintain ecosystem stability. The implementation of environmental regulations and systematic monitoring programs ensures compliance with discharge standards and supports adaptive environmental management (UNEP, 2021). The promotion of sustainable agricultural and industrial practices — including precision fertilization, integrated pest management, and cleaner production technologies — significantly reduces nutrient leaching, heavy metal accumulation, and diffuse pollution (FAO, 2022; OECD, 2020). Controlled use of fertilizers, pesticides, and industrial effluents helps minimize soil and water contamination while preserving ecosystem services (Tilman et al., 2011). Continuous environmental monitoring using pollution indices such as the Soil Pollution Index (SPI) and Water Quality Index (WQI) provides quantitative tools for assessing spatial and temporal trends in environmental quality and supports science-based decision-making (Uddin et al., 2021). An integrated management framework combining remediation, prevention strategies, and regular monitoring enhances environmental resilience and reduces future contamination risks.

CONCLUSION AND DISCUSSION

The present study highlights the significant influence of industrial activities on the quality of local soils and water bodies. Analysis of physicochemical parameters indicates that areas in proximity to industrial zones exhibit elevated levels of contaminants, including heavy metals and organic pollutants, compared to reference sites. These findings are consistent with previous studies reporting that industrial effluents contribute to soil degradation and water pollution, thereby threatening ecosystem integrity (Ng et al., 2014; Zhao et al., 2023).

The deterioration of soil quality, reflected in altered pH, reduced fertility, and accumulation of toxic elements, can impair plant growth and diminish agricultural productivity. Simultaneously, water quality deterioration, characterized by increased chemical oxygen demand (COD), biological oxygen demand (BOD), and pollutant concentrations, poses direct risks to aquatic biodiversity and human health. The observed correlations between industrial discharge intensity and environmental degradation underscore the urgent need for effective pollution control measures and regular monitoring programs.

This study demonstrates that industrial activities can significantly compromise local environmental quality, affecting both soils and water resources. The findings underline the interconnected nature of environmental compartments, where soil and water degradation can cascade into broader ecosystem disruptions. Sustainable management strategies, including the implementation of stricter effluent regulations, adoption of cleaner production technologies, and ecological restoration efforts, are essential to mitigate these impacts.

Overall, the results provide critical insights for policymakers, environmental managers, and local communities, emphasizing the importance of balancing industrial development with ecosystem conservation. Ensuring the protection and restoration of soil and water resources is fundamental for long-term ecological resilience and sustainable resource utilization.

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SMALL-SCALE FARMING AND ECONOMIC SUSTAINABILITY IN NIGERIA: CHALLENGES AND PROSPECTS

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ABSTRACT

Small-scale farmers dominate agricultural production in Nigeria and account for more than 80 percent of the country's farming population. Economic sustainability in agriculture refers to the ability of farming households to maintain profitable production systems, withstand economic shocks, preserve productive resources, and sustain livelihoods over time. The study examined the challenges and prospects of economic sustainability among small-scale farmers in Nigeria. Specifically, the study identified the major economic challenges faced by the respondents; examined the relationship of economic challenges and livelihood of the respondents; and identified coping strategies. Data were collected with the use of a questionnaire. Multistage sampling technique was adopted in selection of 120 respondents. and analyzed using descriptive statistics, chi-square models, and Likert scale. Limited access to affordable credit (45.8%) was identified as the major challenge faced by small scale farmers. The result on the chi-square table indicated that there's no significant linear trend between economic challenges and livelihood outcomes (p-value of 0.736). Seeking additional income sources (2.817) was one of the most coping strategies employed by these small scale farmers. The study recommended that Federal Ministry of Agriculture and Rural Development (FMARD) should enhance access to affordable credit for small-scale farmers by establishing low-interest loan schemes and financial literacy programs.

Keywords: Small-scale farmers, coping strategies, agricultural sustainability, economic resilience, Nigeria.

INTRODUCTION

In Nigeria, agriculture remains a critical sector for economic growth, employment generation, food security, and poverty reduction. The sector contributes significantly to national output and provides livelihoods for a large proportion of the rural population, particularly smallholder farmers, who account for most domestic food production (National Bureau of Statistics, 2023; World Bank, 2024). Despite the growth of the petroleum and service sectors, agriculture continues to provide livelihoods for a large proportion of the rural population and contributes substantially to national economic development (International Fund for Agricultural Development [IFAD], 2023).

A smallholder farmer is defined as a household cultivating **less than five hectares of farmland** and relying primarily on family labour for agricultural production. Small-scale farmers dominate agricultural production in Nigeria and account for more than 80 percent of the country's farming population (National Bureau of Statistics [NBS], 2024). These farmers produce a significant share of staple food crops such as cassava, maize, rice, yam, millet, and sorghum, thereby playing a crucial role in ensuring household and national food security (Chiaka et al., 2022).

Economic sustainability in agriculture refers to the ability of farming households to maintain profitable production systems, withstand economic shocks, preserve productive resources, and sustain livelihoods over time (Scoones, 2015). Sustainable agricultural systems are characterized by stable income generation, efficient resource utilization, resilience to environmental and economic disturbances, and continuous improvement in farmers' welfare (FAO, 2023). Despite their importance, small-scale farmers in Nigeria continue to face numerous challenges that threaten their economic sustainability.

One of the major constraints confronting small-scale farmers is limited access to productive resources such as credit facilities, improved seeds, fertilizers, mechanization services, and extension support. The inability to access affordable agricultural finance restricts farmers' capacity to adopt modern technologies and invest in productivity-enhancing inputs, thereby resulting in low agricultural output and reduced income levels (IFAD, 2023). In addition, poor rural infrastructure, including inadequate road networks, storage facilities, and market systems, contributes to high transaction costs and substantial post-harvest losses, further reducing farm profitability (Ayanlade, et al., 2022).

Although successive governments and development agencies have implemented several agricultural intervention programme aimed at improving productivity, increasing access to credit, and strengthening rural livelihoods, evidence suggests that many small-scale farmers still experience low income levels, unstable livelihoods, and persistent poverty (FAO, 2023). Consequently, concerns have continued to grow regarding the long-term economic sustainability of smallholder farming systems in Nigeria.

Most existing studies have focused primarily on agricultural productivity, technology adoption, access to credit, or climate change adaptation in isolation (Olagunju et al., 2023; Orazulike et al., 2025). Limited attention has been given to the comprehensive assessment of economic sustainability among small-scale farmers by integrating livelihood assets, institutional support, market participation, and emerging opportunities such as digital agriculture and value-chain development. This creates a significant knowledge gap in understanding the multidimensional factors that influence the sustainability of smallholder farming systems. It is against this backdrop that this study examined the challenges and prospects of economic sustainability among small-scale farmers in Nigeria.

Specifically, the study

i. identified the major economic challenges faced by smallscale farmers;
ii. examined the relationship of economic challenges and livelihood of the respondents;
iii. identified coping strategies.

MATERIALS AND METHODS

Study Area

The study was conducted in **Southeast Nigeria**, comprising 5 states namely; Abia, Anambra, Ebonyi, Enugu, and Imo States. The region represents one of Nigeria's most agriculturally intensive zones, where smallholder farming dominates rural livelihoods. However, the region is increasingly affected by flooding, gully erosion, irregular rainfall, land degradation, and rising temperatures, making it an ideal setting for investigating climate resilience and agricultural transformation.

Target Population

The target population consists of **smallholder farmers** engaged in crop production across selected rural communities in Southeast Nigeria.

For this study, a smallholder farmer is defined as a household cultivating **less than five hectares of farmland** and relying primarily on family labour for agricultural production.

Sampling Procedure and sample size

A multistage sampling procedure was adopted.

In the first stage, **three (3) states** was purposively selected from Southeast Nigeria based on their agricultural importance and varying levels of climate vulnerability.

In the second stage, two Local Government Areas (LGAs) were selected from each state.

In the third stage, two rural farming communities was randomly selected from each LGA.

Finally, at the last stage, a random sampling technique was used to select 10 smallholder farmers from each of the four rural farming communities. This yielded a total sample size of 120 respondents.

Summary

States	Local Government Areas (LGAs)	Communities	Smallholder Farmers
Enugu	Nsukka	➢ Obukpa ➢ Lejja	10 each
	Uzo-Uwani	➢ Adani ➢ Umulokpa	10 each
Anambra	Anambra East	➢ Aguleri ➢ Igbariam	10 each
	Ayamelum	➢ Omor ➢ Anaku	10 each
Ebonyi	Ikwo	➢ Ndufu-Alike ➢ Echara	10 each
	Izzi	➢ Iboko ➢ Nkaliki	10 each
3	**2**	**12**	**120**

Data Analysis

Data for this study, data were analyzed using descriptive statistics, chi-square models, and Likert scale.

Model Specification

Likert Scale Rating Technique

4-point likert scale rating technique is specified as follows with its respective real limits.

Strongly Disagreed (SD) =1 real limits 0.5-1.49

Disagreed (D)= 2 real limits 1.5-2.49

Agreed (A)= 3 real limits 2.5- 3.49

Strongly Agreed (SA) =4 real limits 3.5-4.49

The mean score average was computed using the following formula:

Y= £fx/N

Where;

Y= summation of responses

F= number of respondents choosing a particular scale point.

X=numerical value of scale point

N= total number of respondents

RESULTS AND DISCUSSION

Economic challenge level of small-scale farmers

Major economic challenges faced by small-scale farmers

One of the major challenges identified was limited access to affordable credit (45.8%). This restriction in access to financial resources implies that farmers are unable to invest in necessary inputs or expand their operations. Without affordable credit options, farmers are likely to remain stuck in low-productivity farming practices, further entrenching poverty within the sector.

Table 1: Major Economic challenges faced by the respondents

Economic Challenge	Frequency	Percentage
Limited access to affordable credit	55	45.8
Labor shortages	50	41.7
High energy costs	45	37.5
High interest rates on loans	40	33.3
Difficulty in obtaining land ownership or tenure	38	31.7
Lack of storage facilities	35	29.2
High incidence of pests and diseases	29	24.2
Poor road infrastructure	27	22.5
Limited access to technological advancement	31	25.8
Low crop prices	28	23.3
Low access to digital marketing tools	29	24.2
Poor access to irrigation facilities	25	20.8

Source: Field Survey (2024)

Relationship of economic challenges and livelihood of small-scale farmers

The Chi-Square analysis in Table 2 explores the relationship between economic challenges and livelihood outcomes for small-scale farmers. The Linear-by-Linear Association statistic has a value of 0.114 with 1 degree of freedom, showing a p-value of 0.736. This indicated no significant linear trend between economic challenges and livelihood outcomes, suggesting that the relationship does not follow a simple linear pattern.

The Pearson Chi-Square statistic of 26.584 with 9 degrees of freedom has a significance value of 0.002 (asymptotic significance), indicating a statistically significant relationship between economic challenges and livelihood outcomes. This suggests that economic challenges are indeed related to the livelihood outcomes of farmers in the study area.

The statistical tests consistently demonstrate a significant relationship between economic challenges and the livelihood outcomes of small-scale farmers. The low p-values in the Pearson Chi-Square, Likelihood Ratio, and Fisher's Exact Test support the evidence that these challenges have a notable impact on farmers' livelihoods. However, the Linear-by-Linear

Association test indicates that this relationship is not linear, pointing to the complexity of the factors involved.

Table 2: Chi Square relationship of economic challenges and livelihood of small-scale farmers

				Monte Carlo Sig. (2-sided)		
					99% Confidence Interval	
Parameters	Value	Degree of freedom	Asymptotic Significance (2-sided)	Significance	Lower Bound	Upper Bound
Pearson Chi-Square	26.584	9	0.002	0.004	0.002	0.006
Likelihood Ratio	21.897	9	0.009	0.006	0.004	0.007
Fisher's Exact Test	25.203			0.000	0.000	0.001
Linear-by-Linear Association	0.114[c]	1	0.736	0.764	0.753	0.775
N of Valid Cases	120					

Source: Field Survey (2024)

Coping strategies that farmers to overcome the economic challenges

This was achieved using a 4 point likert scale. The decision rule is that any mean score equal or above 2.5 should be accepted. From the table below, all the coping strategies were all accepted because they all have a mean score above and equal to 2.5

Table 3: some identified coping strategies by the respondents

Coping strategies	Mean	Std. Deviation
Diversification of crops/farming activities	2.742	1.0572
Seeking additional income sources	2.817	1.0845
Joining farmer's groups so as to enjoy agricultural benefits	2.583	1.0969
Utilizing savings	2.558	1.0831
Accept Adoption of improved farming techniques	2.575	1.1051
Participation in cooperative societies to get surplus	2.700	1.0580
Accessing government support programs	2.533	1.1591
Access to low interest loans from commercial and microfinance banks	2.575	1.0344
Reducing expenditures in household purchases	2.642	1.0753
Access to training and education	2.758	1.1000
Access to information and capacity building	2.675	1.1535
Collaboration with other farmers	2.658	1.1189
Access to crop insurance	2.800	1.1046
Fair market prices for good and services	2.542	1.1588

Source: Field Survey (2024); decision rule: > or equal 2.5= accept

CONCLUSION AND RECOMMENDATION

This study highlights the significant economic challenges faced by small-scale farmers in Nigeria. The small scale farmers employed various coping strategies to combat these economic challenges. Addressing these challenges requires targeted interventions in credit access, infrastructure, and educational programs to enhance the resilience of small-scale farmers in the region.

The study recommended that Federal Ministry of Agriculture and Rural Development (FMARD) should enhance access to affordable credit for small-scale farmers by establishing low-interest loan schemes and financial literacy programs. This will empower farmers to invest

in modern agricultural practices, increase productivity, and reduce the effect of economic challenges.

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TRADITIONAL METHOD OF BITTERNESS REMOVAL PROCESS IN LUPIN (LUPINUS ALBUS L.) FLOUR PRODUCTION

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ABSTRACT

This study evaluates the effects of traditional sequential aqueous debittering on the total phenolic content (TPC) of white lupin (*Lupinus albus* L.) seeds and their fractions and examines the Pearson correlation between TPC and CIE colour parameters (L*, a*, b*, C*, h°) across processing stages. Seven-stage debittering protocol (A–G): overnight soaking, 4-hour blanching at 100°C and four successive water changes. TPC was quantified by the Folin–Ciocalteu method; Pearson correlation coefficients were calculated between TPC and colour parameters for all fractions (whole seed, kernel, hull) and stages. TPC increased transiently after initial soaking (Stage B: 8,326 mg GAE/kg vs. control 5,919 mg GAE/kg), then declined progressively to a minimum at Stage G (whole seed: 447; kernel: 450; hull: 357 mg GAE/kg). Strong negative correlations were observed between TPC and L* ($r = -0.86$, $P<0.01$) and between TPC and h° in the kernel fraction ($r = -0.72$, $P<0.01$). Traditional debittering reduces phenolic content while concurrently improving lightness and colour neutrality. TPC–colour correlations indicate that instrumental colour measurement (L*, h°) can provide a rapid, non-destructive estimate of debittering progress in industrial operations.

Keywords: *Lupinus albus* L., lupin flour, debittering, total phenolic content, colour correlation,

INTRODUCTION

Lupinus albus L. contains 35–40% crude protein, up to 30% dietary fibre and significant quantities of Fe, Zn and Mg, with a well-balanced amino acid profile (Duranti et al., 2008; Lucas et al., 2015). Its gluten-free composition and nitrogen-fixing agronomic profile support its role in sustainable food systems (Poore & Nemecek, 2018). However, the presence of quinolizidine alkaloids — predominantly lupanine and sparteine — renders raw seeds bitter and potentially toxic, necessitating debittering as a mandatory pre-processing step (Frick et al., 2017).

The traditional aqueous debittering method — combining overnight soaking, blanching and repeated water changes — is simple and scalable, but causes leaching of water-soluble phenolics, flavonoids and minerals (Erbaş, 2010; Ertaş & Bilgiçli, 2014). Estivi et al. (2022) demonstrated that alternative solutions (1% NaCl or citric acid) can shorten processing time and better preserve antioxidants, while Yaver & Bilgiçli (2023) explored ultrasound-assisted debittering as a time-efficient alternative.

Total phenolic content (TPC) is a key indicator of antioxidant potential. In white lupin, phenolics — including gallic acid, protocatechuic acid, caffeic acid and apigenin C-glycosides — are distributed across hull, cotyledon and cell-wall-bound fractions (Scarafoni et al., 2022). Changes in TPC during debittering are documented for other species (Villacrés et al., 2020), but systematic fraction-level correlative data for white lupin under traditional processing remain limited.

Colour is a primary determinant of consumer acceptance. The CIE L*a*b* system quantifies lightness (L*), red–green chromaticity (a*), yellow–blue chromaticity (b*), chroma (C*) and hue angle (h°). This study was conducted within the PROLUPIN project (EK.K.1025.004) and aimed to: (i) characterise TPC changes across fractions during traditional debittering; and (ii) quantify TPC–colour correlations to assess feasibility of colour-based debittering monitoring.

METHODOLOGY

Raw Material and Debittering Protocol

Lupinus albus L.) were stored at 20±2°C under dry, dark conditions. Seven sequential stages were applied — A: untreated control; B: overnight soaking; C: 4-hour blanching at 100°C; D–G: four successive overnight water-change cycles — following the traditional Mediterranean protocol (Erbaş, 2010). Three replicates per treatment group were prepared.

Sample Fractionation

Processed seeds were separated into three fractions: (1) whole-seeded, (2) hull (outer seed coat manually removed), and (3) dehulled kernel (cotyledon). Colour analyses were performed on ground (flour) fraction (Figure 1).

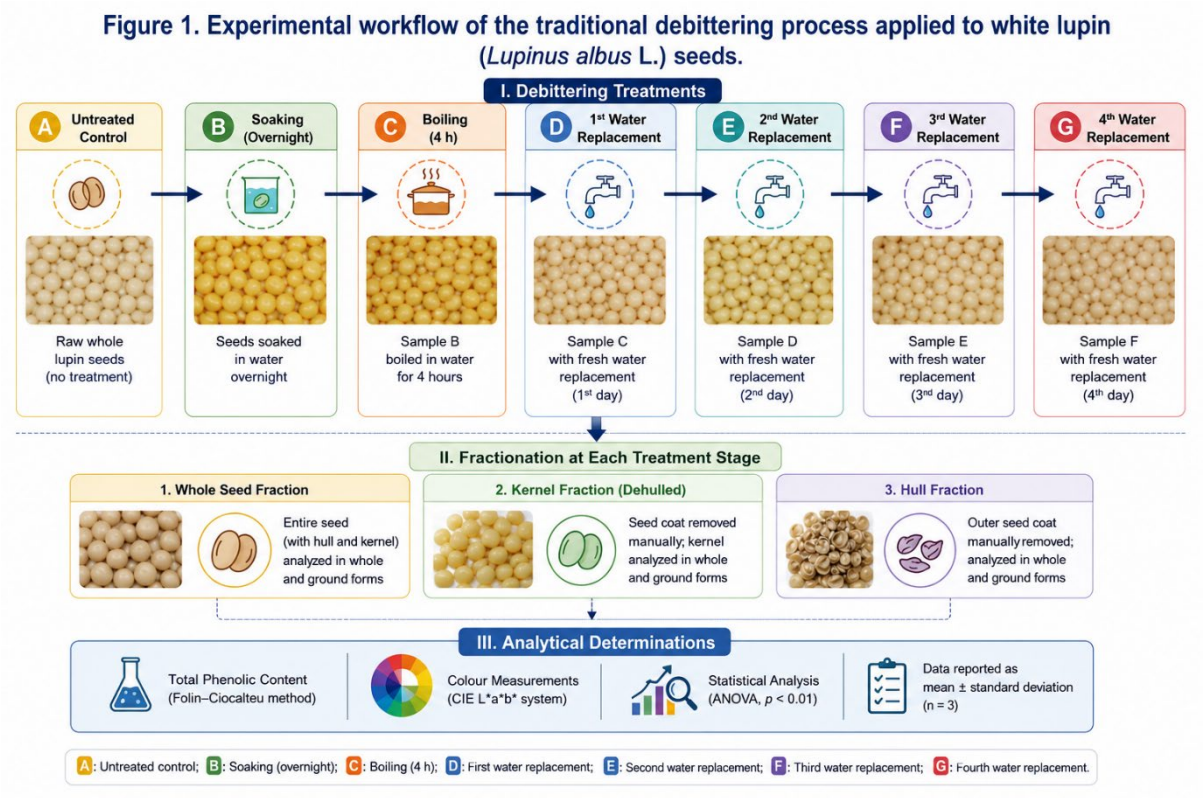

Figure 1. Experimental workflow of the traditional debittering process applied to white lupin (*Lupinus albus* L.) seeds

Analytical Methods

TPC was determined by the Folin–Ciocalteu method (Singleton & Rossi, 1965), expressed as mg GAE/kg DW. Colour parameters (L*, a*, b*, C*, h°) were measured using a CIE L*a*b* colorimeter (Gülhan et al., 2023). One-way ANOVA with Tukey's test ($P<0.01$) and Pearson correlation analysis (MINITAB 19.0, $P<0.01$) were applied.

RESULTS AND DISCUSSION

Effect of Debittering on Total Phenolic Content

TPC values across processing stages and fractions are presented in Table 1. An unexpected transient increase in TPC was observed after initial overnight soaking (Stage B; whole seed: 8,326±157 mg GAE/kg) compared with the untreated control (Stage A: 5,919±543 mg GAE/kg). This is attributable to hydration-induced disruption of cell wall structures that releases previously inaccessible bound phenolics (Scarafoni et al., 2022). Enhanced membrane permeability during soaking facilitates enzymatic hydrolysis of phenolic glycosides, liberating aglycone forms with higher Folin–Ciocalteu reactivity (Yaver & Bilgiçli, 2021).

Table 1. Total Phenolic Content (TPC, mg GAE/kg DW) of lupin fractions during sequential debittering stages

Stage / Treatment	Whole Lupin	Kernel Fraction	Hull Fraction
A — Untreated control	5,919 ± 543b	—	—
B — Overnight soaking	8,326 ± 157a	9,104 ± 11a	733 ± 113cd
C — 4-h blanching	3,963 ± 314c	4,147 ± 92b	4,472 ± 360a
D — 1st water change	1,389 ± 72d	1,596 ± 351c	1,471 ± 120b
E — 2nd water change	778 ± 90d	1,035 ± 93cd	1,024 ± 84bc
F — 3rd water change	824 ± 105d	856 ± 140d	849 ± 12bcd
G — 4th water change	447 ± 5d	450 ± 48d	357 ± 26d

Values: mean ± SD (n=3). Different superscript letters within a column denote significant differences (P<0.01).

Following blanching (Stage C), TPC fell sharply to 3,963 mg GAE/kg for the whole-seed fraction, reflecting both thermal denaturation of polyphenol-binding proteins and leaching into the hot blanching medium. Estivi et al. (2022) reported analogous losses during aqueous debittering of *Lupinus albus* L.; Villacrés et al. (2020) documented similar reductions for *Lupinus mutabilis*. Successive water changes (Stages D–G) produced a progressive monotonic decline to minimum values at Stage G (whole seed: 447; kernel: 450; hull: 357 mg GAE/kg), consistent with diffusion-limited leaching kinetics (Erbaş, 2010).

The hull fraction showed a distinct profile: Stage B values were lower (733 mg/kg) than other fractions, yet Stage C values were comparatively elevated (4,472 mg/kg), reflecting the higher proportion of insoluble-bound phenolics released only upon thermal softening during blanching.

Correlation Between TPC and Colour Parameters

Pearson correlation coefficients between TPC and CIE colour parameters are presented in Table 2. Figure 2 illustrates the scatter relationships with linear regression trend lines.

Table 2. Pearson correlation coefficients (r) between TPC and CIE colour parameters of lupin fractions during debittering

Colour Parameter	Whole Seed	Kernel Fraction	Hull Fraction	All Fractions
L* (lightness)	−0.89**	−0.83**	−0.78**	−0.86**
a* (redness)	+0.81**	+0.76**	+0.74**	+0.79**
b* (yellowness)	+0.64**	+0.58*	+0.55*	+0.61**
C* (chroma)	+0.67**	+0.61*	+0.57*	+0.63**
h° (hue angle)	−0.61*	−0.72**	−0.49*	−0.58**

** P<0.05; ** P<0.01. Correlations computed across stages B–G (n=5 per fraction; n=15 for all fractions combined).*

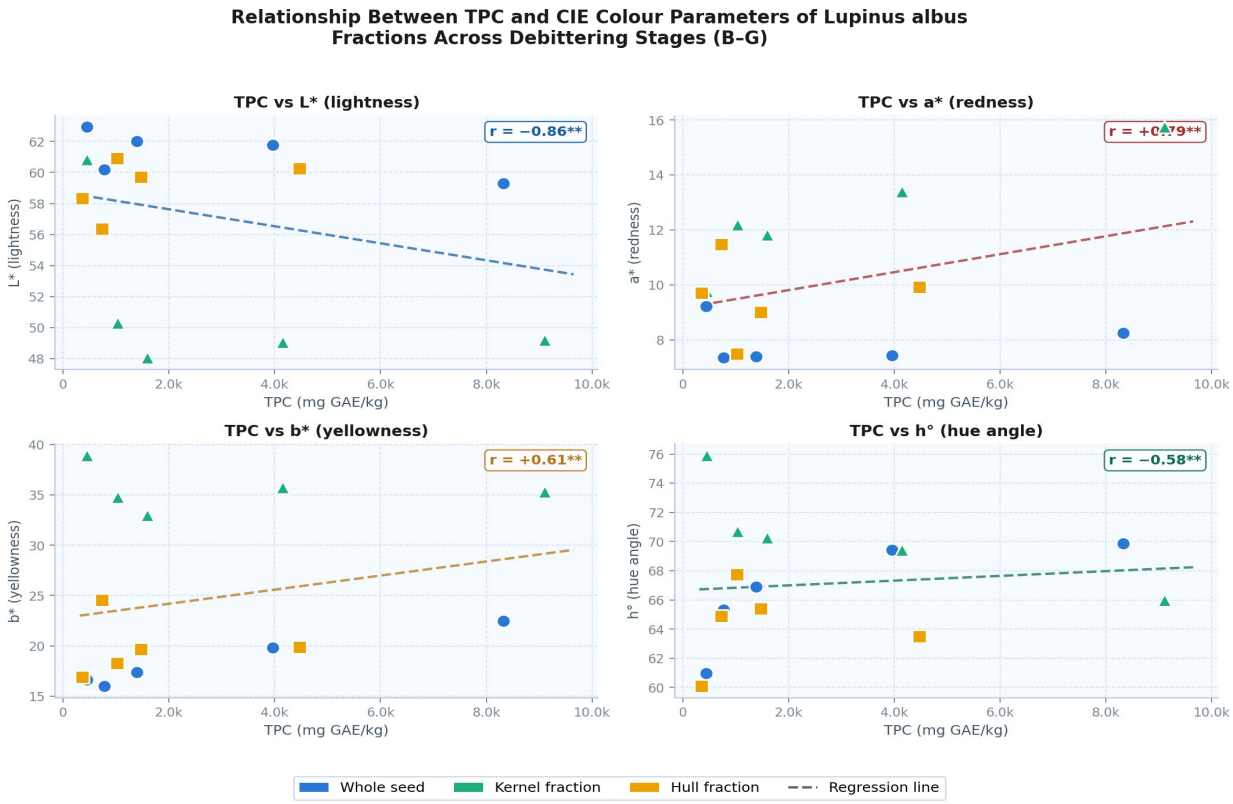

Figure 2. Scatter plots of TPC vs CIE Lab colour parameters (L*, a*, b*, h°) across lupin fractions and debittering stages (B–G). Dashed lines represent linear regression trends. Circle = whole seed; triangle = kernel fraction; square = hull fraction.

A strong negative correlation was observed between TPC and L* ($r = -0.86$, $P<0.01$): as TPC decreased with successive water changes, L* increased across all fractions. This inverse relationship directly confirms that phenolic and carotenoid pigments are the primary determinants of the characteristic yellow-brown colouration of raw lupin, and that their removal underlies the progressive brightening during debittering. These findings are mechanistically consistent with the role of carotenoids and hydroxycinnamic acid derivatives as the principal colour contributors in lupin cotyledon (Scarafoni et al., 2022; Estivi et al., 2023).

Positive correlations between TPC and both a* ($r = +0.79$) and b* ($r = +0.61$) confirm that red and yellow colour components are closely associated with phenolic and carotenoid content. As TPC declined from Stage B through Stage G, a* and b* decreased in parallel, producing a colour shift towards lighter, more neutral tones. Chroma (C*) followed a similar pattern ($r = +0.63$), confirming reduced colour saturation concurrent with phenolic loss. A parallel linkage between polyphenol content and a* values has been demonstrated in crab apple anthocyanin systems (Gülhan et al., 2023), and Estivi et al. (2023) reported positive correlations between carotenoid content and b* in germinating lupin seeds — supporting the generalisability of colour-to-composition relationships in legume processing.

The hue angle (h°) showed a negative correlation with TPC across all fractions ($r = -0.58$, $P<0.01$), with the strongest effect in the kernel fraction ($r = -0.72$, $P<0.01$). As TPC declined, h° increased — signifying a colour drift from the orange–brown domain (lower h°) towards the green–yellow axis (higher h°). This is explained by the preferential aqueous leaching of orange–red carotenoid pigments relative to more structurally stable yellow flavonoid compounds,

resulting in the relative enrichment of the yellow flavonoid background as debittering progresses.

The strong TPC–colour correlations have direct practical implications: L* and h° are straightforwardly measurable by in-line colorimetry, offering a rapid, non-destructive proxy for debittering progress without time-consuming wet-chemical assays. A calibration curve between L* and TPC could enable semi-continuous quality control in industrial debittering operations.

CONCLUSIONS

This study systematically characterizes the effects of traditional aqueous debittering on TPC, physical properties and TPC–colour relationships in Lupinus albus seed fractions. Key findings:

(1) Initial soaking transiently increased TPC (5,919 → 8,326 mg GAE/kg) via hydration-induced release of cell-wall-bound phenolics.

(2) Blanching and successive water changes progressively reduced TPC to minimum values at Stage G, confirming parallel removal of alkaloids and antioxidant phenolics.

(3) Strong negative correlation between TPC and L* ($r = -0.86$, $P<0.01$) confirms phenolic leaching as the primary mechanism of visual brightening during debittering.

(4) Hue angle h° of the kernel fraction provides the most sensitive colour-based TPC indicator ($r = -0.72$, $P<0.01$), suitable for non-destructive in-process monitoring.

(5) L* and h° measurements offer a viable basis for rapid debittering process control without wet-chemical TPC assays in industrial settings.

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THE EFFECTS OF DIFFERENT BLENDING COMBINATIONS ON PRODUCT QUALITY IN WHOLE WHEAT FLOUR PRODUCTION

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ABSTRACT

Whole wheat flour is a nutritionally rich cereal product containing dietary fiber, vitamins, minerals, phenolic compounds, and antioxidants due to the inclusion of bran and germ fractions compared to refined flour. However, the technological properties of whole wheat flour are significantly influenced by the wheat variety used, grain hardness, protein quality, enzyme activity, and milling process. In industrial production, blending wheat with different technological properties at appropriate ratios is one of the most widely used methods for achieving quality standardization. This study aimed to determine the quality characteristics and rheological behavior of three different whole wheat flour blends composed of varying combinations of hard and soft wheat. Three different blend combinations were milled into whole wheat flour under controlled laboratory-scale conditions, and routine quality analyses along with farinograph and extensograph tests were performed. The results were evaluated statistically. The findings demonstrated that blend composition had significant effects on the physicochemical and rheological properties of whole wheat flour. Differences were identified

among blend samples with respect to test weight, ash content, gluten index, sedimentation value, falling number, and damaged starch. Farinograph analyses revealed variations among blends in water absorption, dough development time, stability, and quality number, while extensograph analyses indicated that dough resistance, extensibility, and energy values were particularly influenced by blend composition. The findings demonstrate that an appropriate blending strategy is important for achieving quality standardization in whole wheat flour and for improving industrial baking performance.

Keywords: Whole wheat flour, blending, farinograph, extensograph, rheology, quality.

INTRODUCTION

Whole wheat flour is an important cereal product obtained by milling the endosperm, bran, and germ fractions together in their natural proportions, possessing higher nutritional value than refined flour. Numerous epidemiological studies have shown that consumption of whole grain products reduces the risk of cardiovascular disease, type II diabetes, obesity, and certain types of cancer, owing to their content of soluble and insoluble dietary fiber, phenolic compounds, tocopherols, B-group vitamins, minerals, and various bioactive components (Shewry & Hey, 2015; Reynolds et al., 2019).

Although consumer demand for whole wheat products has increased substantially in recent years, standardizing the technological quality of whole wheat flour remains one of the fundamental challenges facing the milling and baking industries, due to the physical effects of bran particles on the gluten network and the variation in grain hardness, protein quality, and milling characteristics (Shewry & Hey, 2015; Gómez, 2020; Sun et al., 2023). The primary reasons include variability in protein content and quality among different wheat varieties, gluten structure, grain hardness, enzymatic activity, milling behavior, and the adverse effects of bran particles on the dough system (Marti &Pagani, 2013).

In whole wheat flour, the bran fraction in particular can disrupt the continuity of the gluten network, increase water absorption, reduce dough elasticity, and negatively affect bread volume. At the same time, phenolic compounds and fiber fractions derived from the germ and bran significantly enhance the nutritional value of the product. For this reason, the goal today is not only to produce nutritionally rich whole wheat flour, but also to develop a standardized product with high technological performance (Dewettinck et al., 2008).

One of the most important methods for achieving this goal is blending wheat with different technological properties at appropriate ratios. Through blending, protein quality, gluten strength, water absorption, dough stability, and enzymatic activity can be balanced, thereby substantially reducing seasonal and genotype-related quality variations (Posner & Hibbs, 2005; Elsahookie et al., 2021).

In determining the technological performance of whole wheat flour, farinograph and extensograph tests are widely used alongside routine quality analyses. Farinograph analysis reveals the water absorption capacity, development time, and stability of the dough, while extensograph analysis provides detailed information on dough extensibility, resistance characteristics, and energy values. These parameters are considered important indicators for predicting dough processability and final product quality, particularly in bread production (AACC International, 2010).

This study aimed to compare the routine quality characteristics and farinograph and extensograph parameters of whole wheat flours obtained from different hard and soft wheat blend combinations. Additionally, the objectives included determining the effects of different

blending applications on the technological performance of whole wheat flour and evaluating the most suitable blending approach that could contribute to quality standardization at an industrial scale.

METHODOLOGY

Materials

In this study, three different blends were created using hard and soft bread wheat with different technological properties. Blend formulations were prepared with the aim of determining the contribution that wheat with different protein qualities and rheological properties would make to quality standardization under industrial conditions. The blends used in the study were milled under controlled laboratory-scale conditions to obtain whole wheat flour. In the production of whole wheat flour, the flour fractions, bran, and shorts (razmol) passages obtained after milling were recombined in their natural proportions to create the whole wheat flour formulation. The experimental design and blend compositions of the study were prepared according to the standard production protocol established within the scope of the research.

- Blend 1: 50% Hard Wheat, 50% Soft Wheat
- Blend 2: 40% Hard Wheat, 60% Soft Wheat
- Blend 3: 60% Hard Wheat, 40% Soft Wheat

Laboratory Milling

Wheat samples were processed under controlled milling conditions in a laboratory-type mill. The flour fractions (Flour-1, Flour-2), bran, and shorts obtained at the end of milling were collected separately and recombined in accordance with whole wheat flour production principles (Table 1). In this way, whole wheat flour samples with different raw material compositions but produced under identical milling conditions were obtained for each blend. This approach minimized variability that could arise from the milling process, ensuring that the observed differences were primarily attributable to blend composition.

Table 1. Yields (%) from a Laboratory Type Grinder

Bileşenler	Blend 1	Blend 2	Blend 3
Flour 1	10%	15%	12%
Flour 2	25%	35%	34%
Bran	55%	45%	47%
Shorts (Razmol)	10%	5%	7%

Routine Quality Analyses

Test weight, moisture, ash, wet gluten, gluten index, Zeleny sedimentation, delayed sedimentation, falling number, and damaged starch analyses were performed on the whole wheat flour samples obtained. All analyses were conducted in triplicate under the same laboratory conditions. Test weight determination was carried out according to ICC Standard No. 116/1 (ICC, 2020). Moisture determination was based on AACCI Method 44-15.02 (AACC International, 2010). Ash determination was performed in accordance with AACCI Method 08-01.01 (AACC International, 2010). Wet gluten content and gluten index analyses were

determined using ICC Standard Method No. 155 (ICC, 2020). Zeleny sedimentation and delayed sedimentation analyses, used to evaluate protein quality, were performed based on ICC Standard No. 116/1 (ICC, 2020). The falling number analysis, an indirect indicator of alpha-amylase activity, was determined using a Falling Number instrument according to AACCI Method 56-81.04 (AACC International, 2010). Damaged starch was analyzed based on AACCI Method 76-33.01 (AACC International, 2010).

Farinograph Analyses

The dough rheological properties of the whole wheat flour samples were determined using a Brabender Farinograph instrument. Water absorption capacity, dough development time, stability, degree of softening, farinograph quality number (FQN), and other farinograph parameters were determined based on ICC Standard No. 115/1 and AACCI Method 54-21.02 (ICC, 2020; AACC International, 2010).

Farinograph analysis is one of the most widely used internationally accepted methods for determining the viscoelastic behavior of flours during mixing and is used particularly for evaluating the process performance of bread flours (Dobraszczyk & Morgenstern, 2003).

Extensograph Analyses

Extensograph analyses were conducted using a Brabender Extensograph instrument to determine the stretching behavior of the dough. Analyses were performed after rest periods of 45, 90, and 135 minutes, and energy (A), maximum resistance (RM), resistance at 50 mm extension (R50), extensibility (E), R50/E, and RM/E ratios were determined. The analyses were performed in accordance with AACCI Method 54-10.01 and ICC Standard No. 114/1 (AACC International, 2010; ICC, 2020).

Extensograph parameters are widely used to assess dough elasticity, extensibility, and gas retention capacity, and are highly correlated with bread volume and final product texture (Ktenioudaki & Gallagher, 2012).

Statistical Analysis

Experiments were conducted in triplicate, and results were expressed as mean ± standard deviation. One-Way Analysis of Variance (One-Way ANOVA) was applied for statistical evaluation of the data, and differences between means were assessed using the Tukey multiple comparison test at a significance level of $p < 0.05$ (Montgomery, 2019).

CONCLUSION AND DISCUSSION

The results of routine quality, farinograph, and extensograph analyses of whole wheat flour samples obtained from different wheat blend combinations are presented in Tables 2, 3, and 4, respectively. The findings indicate that blend composition is a decisive factor in the physical, chemical, and rheological properties of whole wheat flour.

Table 2. Routine quality factors of different blended whole wheat flours

Quality Properties	Examples of Whole Wheat Flour		
	Blend 1	**Blend 2**	**Blend 3**
Hectoliter	81.43±0,25a	80.33±0,47b	79.67±0,15b
Moisture (%)	14,10±0,10c	13,70±0,01b	13,77±0,15a
Ash (%)	0.9710±0,0053a	1.1453±0,0064ab	1.3637±0,0118b
Wet gluten (%)	30.67±0,58a	30.30±0,10a	30.03±0,06a
Gluten Index (%)	90.33±0,58b	92.00±0,00a	88.33±0,58c
Sedimentation (ml)	40,33±0,58a	38,33±0,58b	36,33±0,58c
Delayed Sedimentation (ml)	60,33±0,58a	58,33±0,58b	56,33±0,58c
Falling Number (sec)	320,00±1,00b	324,67±0,58a	318,00±1,00b
Starch Damage	31,30±0,10b	31,733±0,15a	31,733±0,12a

*Values indicated by similar letters in the same row do not have a statistically significant difference ($p<0.05$)

Table 3. Farinograph parameter values of different blended whole wheat flours

Farinograph Parameters	Examples of Whole Wheat Flour		
	Blend 1	**Blend 2**	**Blend 3**
T (sec)	1201,3±0,6	1200,3±1,53	1198,0±1,00
DT (°C)	28,60±0,10	28,60±0,10	28,67±0,06
DDT (sec)	408,67±1,15	410,33±0,58	412,00±1,00
C (FE)	482,00±1,00	481,00±1,00	480,00±1,00
WZ (%)	64,60±0,10	64,27±0,06	63,33±1,16
WAC (%)	65,33±1,53	64,00±0,10	63,50±0,10
WAM (%)	65,33±1,53	63,67±0,58	63,47±0,06
S (sec)	527,67±0,58	529,33±0,58	531,00±1,00
DS (FE)	30,00±1,00	31,00±1,00	31,67±1,56
DS(ICC) (FE)	119,00±1,00	116,67±1,53	115,33±1,15
FQN (mm)	115,33±0,58	113,00±1,00	98,67±0,58

*Values indicated by similar letters in the same row do not have a statistically significant difference ($p<0.05$)

When routine quality analyses are examined, Blend 1 was found to have the highest values with respect to test weight (81.43 kg hL^{-1}), sedimentation (40.33 mL), and delayed sedimentation (60.33 mL). In contrast, ash content was highest in Blend 3 (1.364%), while gluten index was highest in Blend 2 (92.00%). The fact that wet gluten contents were quite similar across the three blends (30.03–30.67%) indicates that protein quality, rather than total protein content alone, determines technological performance. Similarly, Shewry & Hey (2015) reported that not only protein content but also the structural characteristics of glutenin significantly influence dough quality in bread wheat. Wieser (2007) further noted that the gluten index is one of the most important quality indicators reflecting the strength of the gluten network.

Table 4. Extensograph parameter values of different blended whole wheat flours

Samples	Time	Extensograph Parameters					
		A (cm^2)	R_{50} (BE)	E (mm)	R_M (BE)	R_{50}/E	R_M/E
Blend 1	45	99,67±0,58	518,00±3,00	125,00±2,65	623,33±2,08	4,250±0,178	4,923±0,162
	90	101,67±0,58	932,33±6,11	90,00±1,00	964,33±2,52	10,467±0,306	10,727±0,042
	135	78,33±1,56	900,33±1,53	78,33±1,56	915,67±1,53	11,420±0,017	11,573±0,050
Blend 2	45	89,68±0,58	504,33±1,53	120,00±1,00	603,33±1,53	4,167±0,058	4,9133±0,015
	90	94,00±1,00	874,67±2,52	92,00±1,00	905,67±1,15	9,800±0,100	10,300±0,100
	135	81,00±1,00	858,00±2,00	88,33±1,53	863,00±0,00	9,700±0,000	9,400±0,000
Blend 3	45	86,00±1,00	498,67±1,53	115,00±2,00	567,67±2,52	4,337±0,031	4,950±0,030
	90	93,00±1,00	849,00±1,00	91,33±1,53	878,00±2,00	9,320±0,010	9,630±0,020
	135	87,33±1,53	813,33±1,53	91,00±1,00	819,67±1,53	8,877±0,021	8,930±0,010

*Values indicated by similar letters in the same row do not have a statistically significant difference ($p<0.05$)

The increase in ash content indicates a higher proportion of bran and aleurone layer incorporation into the flour, which increases the mineral and dietary fiber content of the whole wheat flour. However, high ash content may adversely affect the continuity of the gluten network and cause a reduction in dough elasticity (Noort et al., 2010). In the present study, the fact that Blend 3 had the highest ash value yet maintained a gluten index above 88% demonstrates that blending can achieve an appropriate balance between nutritional value and technological quality. This result is consistent with Elsahookie et al. (2021), who reported that appropriate blending strategies play an important role in quality standardization of whole wheat flours.

Falling number values ranging between 318 and 325 seconds indicate that alpha-amylase activity is at an appropriate level for bread production in all samples. Literature reports that falling number values in the range of 250–350 seconds are considered optimal for bread flours (AACC International, 2010). Similarly, the fact that damaged starch values were quite close across the three blends (31.30–31.73 UCD) suggests that milling conditions were carried out in a controlled manner and that similar mechanical effects occurred regardless of blend composition. While a certain level of starch damage increases water absorption, excessive damage may adversely affect dough structure (Heinis, 2010).

In the farinograph analyses, notable differences were observed among blends with respect to dough development time, stability, and farinograph quality number. In particular, the higher water absorption (65.33%) and farinograph quality number (115.33 mm) of Blend 1 indicate the formation of a stronger dough structure. In contrast, the decrease in quality number to 98.67 mm in Blend 3 suggests that an increase in bran proportion may limit dough strength. Numerous studies have reported that bran particles in whole wheat flours physically weaken the gluten network, thereby reducing dough stability (Ktenioudaki & Gallagher, 2012; Gómez et al., 2011). Furthermore, high water absorption is associated with increased water-binding capacity of fiber fractions in whole wheat flours (Marti & Pagani, 2013).

Extensograph analyses also demonstrated that blend composition significantly influenced dough rheology. In all samples, an increase in dough resistance accompanied by a decrease in extensibility was observed as the rest period increased. This is explained by the reorganization of the gluten network during resting (Dobraszczyk & Morgenstern, 2003). In particular, Blend 1 exhibited higher maximum resistance and energy values at 90 and 135-minute rest periods, supporting its strong gluten structure. In contrast, lower resistance values in Blend 3 suggest that higher ash and bran content limited dough elasticity. However, the fact that R/E ratios of

all blends remained within acceptable limits for bread production indicates that the blend formulations developed possess suitable rheological properties for industrial use.

Overall, blending was found to significantly affect the quality characteristics of whole wheat flour. Blend 1 stood out in terms of technological performance with its high sedimentation value, strong dough character, and superior rheological properties, whereas Blend 3 offered an advantage in nutritional value owing to its higher ash content. Blend 2 displayed a profile that could combine both characteristics, with its high gluten index and balanced quality parameters. These results demonstrate that blending wheat with different technological properties at appropriate ratios is an effective approach for quality standardization and sustainable industrial production of whole wheat flour.

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OPTIMIZING OUTCOMES IN PSORIASIS: IMPACT OF DENIPLANT NUTRACEUTICALS

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ABSTRACT

Background A growing body of evidence highlights that intestinal dysbiosis is associated with the development of psoriasis. The gut–skin axis is the novel concept of the interaction between skin diseases and microbiome through inflammatory mediators, metabolites and the intestinal barrier. The gut microbiome affects skin homeostasis through its influence on the signaling pathways that coordinate epidermal differentiation.

The objective of this study was to synthesize current data on the Deniplant natural modulator of the gut microbiome in patients with psoriasis.

Materials and methods All studies confirmed the association of psoriasis and gut microbiota dysbiosis. We describe the recent advances regarding the interplay between gut microbiota and the skin. Thus, the microbiome can be considered an effective therapeutical target for treating this disorder.

Results This presentation provides a detailed and comprehensive systematic study regarding gut microbiome in patients with psoriasis. These results are supported by clinical observations based on a case serie showing improvement in psoriatic skin lesions after Deniplant natural modulator. It is still not clear whether psoriasis is an effect or a cause of the observed disbalance between beneficial and pathogenic microbes. In this context, the study provides very interesting results, showing significantly greater changes in the gut microbiome of patients with psoriasis treated Deniplant natural modulator

Conclusion There is a significant association between alterations in gut microbial composition and psoriasis. Intestinal dysbiosis is a state of imbalanced gut microbiome that eventually has a negative impact on skin function and integrity. Deniplant natural modulator is a potential therapeutic strategy in patients with psoriasis

Keywords: dysbiosis, microbiome, psoriasis, gut-skin axis, gut barrier, Deniplant nutraceuticals

ENERGY INTAKE AND NUTRITIONAL IMBALANCES AMONG SCHOOL-AGED ADOLESCENTS IN THE MOULAY ABDELLAH REGION, MOROCCO: EVIDENCE FROM 24-HOUR DIETARY RECALLS

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ABSTRACT

Background: Adolescence is a critical period of growth and development during which nutritional requirements are increased. Inadequate dietary intake during this stage may contribute to nutritional deficiencies, excess weight gain, or long-term metabolic risk. In Morocco, data on the detailed nutrient intake profile of school-aged adolescents, particularly in semi-urban and rural settings, remain limited.

Objective: This study aimed to assess energy intake, macronutrient distribution, and selected micronutrient intakes among school-aged adolescents in the Moulay Abdellah region, Morocco, using 24-hour dietary recalls.

Methods: A descriptive cross-sectional study was conducted among school-aged adolescents in the Moulay Abdellah region. Dietary intake was assessed using 24-hour dietary recalls. Reported foods and beverages were converted into energy and nutrient intakes in order to estimate total energy intake, protein, carbohydrate, fat, dietary fiber, and selected micronutrients. The distribution of macronutrients was evaluated as a percentage of total energy

intake. Nutrient intakes were compared with nutritional recommendations in order to identify possible excesses or inadequacies.

Results: The dietary profile of adolescents showed several nutritional imbalances, particularly in relation to energy intake, macronutrient distribution, and the quality of food choices. The analysis highlighted the importance of assessing not only total energy intake, but also the contribution of proteins, carbohydrates, lipids, dietary fiber, and selected micronutrients. These findings suggest that some adolescents may be exposed to inadequate nutrient coverage or excessive intake of certain dietary components, depending on their food consumption patterns.

Conclusion: The assessment of nutrient intake using 24-hour dietary recalls provides useful information on the dietary profile of school-aged adolescents in the Moulay Abdellah region. The identification of nutritional imbalances may help guide school-based nutrition education programs and support the development of targeted interventions aimed at improving dietary quality among adolescents.

Keywords: Adolescents; dietary intake; 24-hour dietary recall; nutrient intake; nutritional imbalance; school nutrition; Morocco.

WASTE-FREE UTILIZATION OF FRUITS AND VEGETABLES: A SUSTAINABLE APPROACH TO REDUCING FOOD WASTE

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ABSTRACT

Introduction and Purpose: Food waste and food security are major global concerns. A large proportion of fruits and vegetables is discarded despite having nutritional and functional value. Many parts that are commonly regarded as waste still have nutritional, functional, and gastronomic potential. Their utilization may help reduce food loss and support sustainable food systems. The zero-waste approach promotes the use of whole foods and encourages sustainable consumption practices. This study aimed to evaluate the potential use of fruits and vegetables, including quince, apple, melon, apricot, and watermelon, within the framework of the waste-free food approach.

Materials and Methods: This study was based on a systematic literature review supported by an experimental culinary application. Food parts commonly regarded as waste, including peels, seeds, pulp, leaves, and stems, were examined in terms of their potential uses and contributions to sustainable nutrition.

Results: Fruit peels were found to be suitable for use in fermented products, beverages, jams, chips, cakes, and natural flavorings. Seeds could be incorporated into alternative food products, while fruit pulp could be utilized in different food production processes. Vegetable peels were shown to be useful in chips and functional food products. In addition, the leaves and stems of leafy vegetables could be used in dishes, soups, sauces, pesto, and fermented foods. These practices contribute to reducing organic waste and increasing the utilization of food resources.

Discussion and Conclusion: The waste-free food approach supports the utilization of all edible and functional parts of foods rather than only the portions traditionally consumed. The wider adoption of these practices may help reduce food waste, encourage sustainable consumption habits, and support zero-waste nutrition models. The effective use of fruits and vegetables can contribute to sustainable nutrition and the development of circular food systems.

Keywords: Zero Waste; Waste-Free Food; Sustainable Nutrition; Circular Food System; Upcycling

EXPLORING DAIRY-DERIVED LACTIC ACID BACTERIA AS SUSTAINABLE BIOCONTROL AGENTS FOR ENHANCING FOOD SAFETY

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ABSTRACT

The growing demand for natural and sustainable alternatives to synthetic chemical preservatives has significantly increased interest in lactic acid bacteria (LAB) as effective

biocontrol agents within the agro-food sector. This study investigates the antimicrobial activity and technological potential of LAB strains isolated from traditional Algerian dairy products.

A collection of LAB isolates was characterized through both phenotypic and molecular identification methods. Their antibacterial activity was assessed against major foodborne pathogens using agar diffusion and co-culture assays. Furthermore, the detection of genes encoding bacteriocins and other antimicrobial metabolites was performed to elucidate the underlying mechanisms responsible for their inhibitory effects.

The findings revealed that several LAB strains exhibited pronounced antimicrobial activity, mainly associated with the production of organic acids, hydrogen peroxide, and bacteriocin-like compounds. In addition, these strains demonstrated desirable technological traits, including efficient acidification capacity and resilience to various environmental stresses, reinforcing their suitability for food preservation applications.

Conducted at the Research Center in Agro-Food Technology (CRTAA), Algeria, this study emphasizes the strategic value of harnessing indigenous microbial resources as natural preservative agents. The results support ongoing efforts to develop safer, more sustainable food systems, in line with global initiatives aimed at reducing synthetic additives and promoting functional and clean-label foods.

keys words: Lactic acid bacteria, Biocontrol, Food safety, Dairy products, Bacteriocins

THE WARBURG EFFECT AND CANCER METABOLISM

WARBURG ETKİSİ VE KANSER METABOLİZMASI

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Özet

Warburg etkisi, kanser hücrelerinin enerji gereksinimlerini karşılamak için oksijen olduğunda bile aerobik glikolizi tercih etmesiyle karakterize bir metabolik durumdur. Normal hücrelerin aksine, kanser hücreleri mitokondriyal oksidatif fosforilasyon yerine glikozu laktata dönüştürür. Kanser, dünya genelinde önemli ve sık karşılaştığımız bir sağlık problemidir. 2020'de yaklaşık olarak 19,3 milyon yeni vaka bildirilmiş ve 10 milyon kanser ilişkili ölüm gerçekleşmiştir. Bu derlemede, Warburg etkisinin altında yatan biyokimyasal mekanizmaları, özellikle hekzokinaz 2 (HK2) ve fosfofruktokinaz 1 (PFK1) enzimlerinin artan aktivitesi ile mitokondriyal değişiklikler ele alınmaktadır. Bu durum, metabolik adaptasyon, hücre çoğalmasının artması, apoptoz direnci ve tümör mikro çevresinin asidik hale gelmesi gibi durumları destekler. Klinik bulgular arasında hızla büyüyen tümörler, hipoksik durum ve tedaviye karşı direnç öne çıkmaktadır. Tedavi stratejilerinde, glikolitik yolakların inhibisyonu ve mitokondriyal fonksiyonu hedef alan ajanlar yer almaktadır. Güncel çalışmalar, Warburg etkisinin tersine çevrilmesi ve immünoterapi ile kombinasyonun potansiyelini incelemektedir.

Anahtar Kelimeler: Warburg etkisi, kanser metabolizması, mitokondriyal değişiklikler, glikoliz, tedavi

ABSTRACT

The Warburg effect is a metabolic condition characterized by the fact that cancer cells prefer aerobic glycolysis even when there is oxygen to meet their energy requirements. Unlike normal cells, cancer cells convert glucose into lactate instead of mitochondrial oxidative phosphorylation. Cancer is an important and common health problem that we face around the world. In 2020, approximately 19.3 million new cases were reported and 10 million cancer-related deaths occurred. In this review, the biochemical mechanisms underlying the Warburg effect, especially mitochondrial changes with increased activity of the enzymes hexokinase 2 (HK2) and phosphofructokinase 1 (PFK1), are discussed. This condition supports conditions such as metabolic adaptation, increased cell proliferation, apoptosis resistance, and the fact that the tumor microenvironment becomes acidic. Rapidly growing tumors, hypoxic state and resistance to treatment stand out among the clinical Deci-sions. The treatment strategies include the inhibition of glycolytic pathways and agents targeting mitochondrial function. Current studies are examining the potential for reversal of the Warburg effect and combination with

immunotherapy. This review aims to highlight the role of the warburg effect, aerobic glycolysis and mitochondrial changes in the understanding of cancer metabolism.

Keywords: Warburg effect, cancer metabolism, mitochondrial changes, glycolysis, treatment

Giriş

Kanser, hücrelerin kontrolsüz şekilde çoğalması ile karakterize bir hastalıktır ve bu süreçte Warburg etkisi merkezi bir rol oynar. Otto Warburg, 1920'lerde yaptığı çalışmalarla kanser hücrelerinin oksijen varlığına rağmen glikolizi tercih ettiğini gözlemlemiş ve bu durumu "aerobik glikoliz" olarak adlandırmıştır (Warburg, 1956). Bu metabolik değişim, kanser hücrelerinin hızlı proliferasyonu ve biyosentetik taleplerini karşılamak için kritik öneme sahiptir. Warburg etkisi, yalnızca enerji üretimini değil, aynı zamanda tümör mikroçevresinin şekillenmesini sağlar, tedavi direncini etkiler ve kanser hücrelerinin metabolik adaptasyonlarının temelini oluşturur (Faubert, Solmonson, & DeBerardinis, 2020). Bu derlemenin amacı Warburg etkisinin biyokimyasal arka planını, kanser hücrelerinde aerobik glikozun sağladığı durumları, mitokondride meydana gelen değişikliklerin etkilerini ve bu sürecin tedavi açısından taşıdığı potansiyeli ele almaktadır.

Kanserli Olmayan Hücrelerde Enerji Metabolizması

Vücudumuzdaki hücreler, görevlerini yapabilmek için ATP (Adenozin Trifosfat) adı verilen bir enerji türüne ihtiyaç duymaktadır. Sağlıklı hücrelerde ATP, genellikle oksidatif fosforilasyon olarak bilinen ve oksijenli solunumu içeren bir mekanizma yolu ile elde edilmektedir. Bu mekanizma; glikoliz, krebs döngüsü ve ETS (Elektron Taşıma Sistemi) aşamalarını içerir. Söz konusu olan süreç tamamlandığında 38 ATP elde edilir. Ancak glikozun aktif edilmesi için ise 2 ATP harcanır. Böylece elde edilen net 36 ATP olmaktadır. Bu mekanizma, normal hücrelerin enerji ihtiyaçlarını karşılamada etkin bir rol oynar. Bununla birlikte, enerji metabolizmasının ilk adımı olan glikolize de odaklanılmalıdır. Glikoliz, hem normal hücrelerin enerji üretimi için başlangıç noktasıdır hem de kanser hücrelerinde gözlenen metabolik değişimlerin temelini oluşturur. Glikoliz; glikozun pirüvata dönüştüğü ve oksijene bağımlı olmayan bir yoldur. Sağlıklı hücrelerde pirüvat, mitokondride oksidatif yollarla ilerlerken, kanser bulunan hücrelerde bu süreç değişmekte ve Warburg etkisi gibi kavramlar ortaya çıkmaktadır (Bose et al., 2021).

Kanserin Genel Tanımı Ve Epidemiyolojisi

Kanser, dünya genelinde çok ciddi halk sağlığı problemlerinden biri olarak bilinmektedir. Küresel ölçekte ölüm sebepleri arasında ikinci sırada bulunmaktadır ayrıca yapılan araştırmalar ile 2030 senesine kadar insan ölümlerinde birinci sıraya yükselebileceği öngörülmektedir (Sung et al., 2021). Hücreler, yaşamın sürdürülebilmesi için sürekli olarak kendilerini yenilemek zorundadır. Belirli bir yaşam döngüsünü tamamlayan hücreler, programlanmış hücre ölümü yani apoptozis süreciyle ortadan kalkarken, yerlerine yeni hücreler gelmektedir. Bu mekanizma, genetik sistem tarafından kontrol edilmektedir. Hücre çoğalmasını düzenleyen genler, kontrolsüz büyümenin önüne geçerek anormal dokuların oluşumuna engel olur. Ancak, çeşitli durumlar nedeniyle; DNA ve gen yapısında meydana gelen mutasyonlar, hücrelerin denetimsiz şekilde çoğalmasına sebep olarak vücutta normal dışı kitlelerin oluşmasına sebep olabilir. Bu süreç, kanser olarak adlandırılmaktadır (Hanahan, 2022). Kanser hastalığı hem metabolik hem de epigenetik değişimlerin içinde bulunduğu, organ ya da dokularda kademeli olarak ilerleyebilen bir hastalık türüdür. Kanser sürecinde; hücre bölünmesini düzenleyen

mekanizmaların bozulduğu, hücrelerin kontrolsüz bir şekilde büyüdüğü ve yayıldığı gözlenmektedir. Genetik değişiklikler sonucunda normal hücre döngüsü kontrolsüz şekilde hızlanabilir, bu durum ise tümörün gelişmesi ve yayılmasına neden olur (World Health Organization, 2022).

Tarihsel Perspektif: Warburg Etkisi'nin Evrimi

Warburg etkisi kavramı; Alman Biyokimyacı Otto Heinrich Warburg tarafından 1920'li yıllarda tanımlanmıştır. Otto Heinrich 8 Ekim 1883'te Almanya da dünyaya gelmiştir, 1911 yılında tıp doktoru unvanı ile mezun olmuştur. Warburg; tümörlü dokuların diğer dokulara göre daha fazla sayıda glikoz aldığını belirlemiştir (DeBerardinis & Chandel, 2020). Sonrasında enerji metabolizması alanında yaptığı çalışmalar ile kanser hücrelerinin normal hücrelere göre farklı bir enerji üretme metabolizmasına sahip olduğunu keşfetmiştir. Daha sonra Herbert Grabtree tarafından yapılan çalışmalar genişletildi, Warburg'un hipotezleri doğrulandı (Diaz-Ruiz et al., 2011). Ek olarak kanserli hücrelerin sadece aerobik glikoliz yapmadığı, çevresel ya da kalıtsal faktörlerden de etkilendiği de belirtilmiştir. 1970'li yıllarda yapılan çalışmalar ile normal ve kanserli hücreler arasındaki enerji üretim değişikliğini kanıtlayan Efraim Racker bu durumu "Warburg Etkisi" olarak adlandırmıştır (Vander Heiden et al., 2009). Racker, hücre içindeki pH dengesizliklerinden, ATPaz işlevindeki aksaklıklara kadar Warburg Etkisi'nin kökenlerini açıklamak için kendi hipotezlerini ortaya koymuştur. Aynı dönemde, Jeffrey Flier ve Morris Birnbaum, aerobik glikolizin büyüme faktörü sinyalleri tarafından kontrol edilebilen bir mekanizma olduğunu fark etmişlerdir (Pavlova & Thompson, 2016). Bu gözlemler, kanser gelişiminde rol oynayan genlerin keşfi ile birleştiğinde, büyüme faktörü sinyallerinin düzensiz hale gelmesinin kanser gelişimini tetikleyen bir süreç olduğu sonucuna ulaşılmasını sağlamıştır (Liberti & Locasale, 2016). Böylelikle, Warburg'un kanser biyolojisi için önerdiği tez, yeni bulgularla daha derin bir anlam kazanmıştır. Öte yandan, Warburg Etkisi'nin kanser oluşumundaki yerinin tam olarak çözülmesi uzun süre netlik kazanmamıştır. Yapılan araştırmaların ancak son yıllarda bu etkinin tümör büyümesi için zorunlu olduğu yargısına varılmasını mümkün kılmıştır. Yapılan çalışmalar ile, Warburg Etkisi'nin sadece glikoliz yolunu değil, aynı zamanda mitokondriyal metabolizmayı da etkilediğini ortaya koymuştur. Yine de Warburg Etkisi'nin kanser biyolojisindeki rolü hâlâ tartışmalı bir mesele olarak kalmakta ve tümör gelişimindeki etkisi tam anlamıyla çözülememiştir. Bu alandaki bilimsel çabalar, bu etkilerin tümör metabolizmasındaki işlevlerini açıklığa kavuşturmak amacıyla sürmektedir (Kim & DeBerardinis, 2023).

Kanser ve Biyokimyasal Mekanizmalar

Kanser hücreleri, normal hücrelerden farklı olarak enerji üretimi, büyüme ve çoğalma gibi süreçlerini desteklemek amacı ile enerji üretim yollarını yeniden programlar. Bu yeniden programlanma içinde en dikkat çekici noktalardan biri ise Warburg etkisi olarak bilinen fenomendir. Bu etki, kanser metabolizmasının temel taşlarından biridir. Warburg etkisi; kanser hücrelerinin, oksijen varlığında dahi glikoliz yolunu tercih etmesi ile tanımlanmaktadır (Zhang et al., 2021). Fakat, kanser metabolizması sadece bu eğilimle sınırlı değildir; mitokondrilerin fonksiyonlarındaki farklılaşmalar ve artan biyosentetik madde ihtiyacı da tümörün hayatta kalma ve gelişim stratejisini destekler (Zhou et al., 2021).

İlk etapta glikoliz yolunun düşük ATP verimi sebebi ile avantajlı olmadığı düşünülebilir, çünkü glikoz başına yalnızca 2 ATP üretilirken, mitokondriyal oksidatif fosforilasyon ile yaklaşık 36 ATP üretilmektedir. Ancak, bu strateji kanser hücrelerine hızlı enerji üretimi, hücre bölünmesi için gerekli nükleotid, amino asit ve lipidlerin sentezine fayda sağlar. Örneğin, üçlü negatif

meme kanseri hücrelerinde GLUT12 proteininin yüksek seviyede bulunması, glikolizi arttırarak hem tümör büyümesini hemde metastatik potansiyeli güçlendirdiği gözlemlenmiştir (Shi et al., 2020). Bu durum, kanser hücrelerinin yalnızca enerji üretimine değil, yapı taşı sentezini desteklediğini gösterir. Öte yandan mitokondriyal değişiklikler de yeniden programlanmanın önemli bir parçasıdır. Sağlıklı hücrelerde enerji üretiminin merkezi olan mitokondriler, kanser hücrelerinde farklı işlevler üstlenebilir. Mitokondriyal DNA mutasyonları ve oksidatif fosforilasyonun baskılanması gibi değişikler Warburg Etkisini desteklemektedir (Cassim et al., 2020). Bunun yanında, elektron taşıma zincirindeki bozulmalar ile reaktif oksijen türleri (ROS) üretimini arttırmaktadır. ROS, genetik hasara sebep olabilir ve kanser hücrelerinin apoptoz durumundan kaçmasına yardımcı olabilir (Wang et al., 2021). Örnek olarak; laktat birikimi, tümör mikroçevresinde bağışıklık baskılayıcı bir etki yaratır ve kanserin ilerlemesine zemin oluşturur (Faubert et al., 2017). Kanser metabolizmasının çok yönlü yapısı, tedavi stratejileri açısından da fırsatlar sunar. Glikolitik yolların engellenmesi veya mitokondriyal fonksiyonların yeniden düzenlenmesi, kanserli hücrelerin zayıf noktalarını hedefleme potansiyeline sahiptir. (Abdel-Wahab et al., 2020). Bu sebeple kanser metabolizması, yalnızca enerji üretiminden ibaret olmayan, tümörün hayatta kalma stratejilerini destekleyen karmaşık sistemdir. Bu sistemin daha iyi araştırılması, kanser tedavisi için olumlu olacaktır.

Kanser Metabolizması ve Aerobik Glikoliz

Kanser hücreleri, artan enerji gereksinimleri ve biyosentetik taleplerini karşılayabilmek için metabolik ağlarını yeniden düzenlerler. Bu süreçte aerobik glikoliz, oksijen varlığında bile glikozun laktata dönüştürülmesi ile özgün bir özellik olarak öne çıkar (Zhang & Yang, 2022)

. Bu metabolik değişim, sadece enerji üretimi ile sınırlı kalmaz; aynı zamanda tümörün büyümesi için gerekli yapı taşlarının üretimini hızlandırır ve hücre dışı baskılara karşı direnci arttırır. Örnek olarak; glikoz-6-fosfat molekülü pentoz fosfat yoluna aktarılır ve NADPH sentezi yapılarak hücre içi redoks dengesinin korunması ve biyosentetik süreçlerin devam etmesinde erkin bir rol oynar (Bose et al., 2021). Aerobik glikolizin kanser metabolizmasındaki önemi, yüksek hızda enerji üretimi ve esneklik sağlamasıdır. Sağlıklı hücreler, glikozu mitokondride oksidatif fosforilasyon yolu ile yüksek verimle işlerken, kanser hücreleri bu yolu devre dışı bırakabilmektedir. Bu tercih, ATP üretiminin hızını artırır ve riboz-5-fosfat ve serin gibi glikolitik ara ürünlerin çeşitli biyosentetik süreçlere yönlendirilmesini sağlar. Örnek olarak, akciğer kanseri gibi agresif huylu tümörlerde, glikoliz aktivasyonunun artması, DNA sentezi ve hücre bölünmesini hızlandırır. Ek olarak, laktat molekülleri, tümör mikroçevresinin asitleşmesine destek olarak bağışıklık hücrelerinin baskılanmasına ve tümör yayılımına katkıda bulunur (Wang et al., 2021). Bu mekanizma, kanser hücrelerinin hipoksik koşullara uyum sağlamasını kolaylaştırmaktadır. Oksijen seviyeleri düştüğünde, hipoksi ile indüklenen HIF-1α gibi düzenleyiciler devreye girer ve glikolitik enzimlerin ekspresyonunu arttırır (Vaupel & Multhoff, 2021). Fakat, aerobik glikoliz yolu sadece hipoksiye cevap değildir; normoksik koşullarda bile PI3K/AKT yolakları gibi onkojenik sinyaller bu profili aktif tutar (Chen et al., 2022). Bu durum, kanser hücrelerinin enerji ve biyokütle taleplerini dengeleyen bir esneklik kazandığını gösterir.

Aerobik glikoliz, kanser metabolizmasının sadece bir yönüdür; mitokondriyal süreçler de bu sistemde etkin rol alır. Özellikle glutamin metabolizması gibi alternatif yollar, enerji ve yapı taşı üretiminde rol alırken, mitokondriler reaktif oksijen türlerinin (ROS) üretimiyle sinyal iletimi ve genetik uyumlarda görev alır (Liu et al., 2023). Bu çift yönlü durum, biyolojik çeşitliliği arttırır ve metabolizmayı hedefleyen tedavi yöntemlerinin başarılı olmasını zorlaştırır. Bu sebeple yalnızca glikolizi hedefleyen ilaçların yeterli olmayacağı, mitokondriyal hedeflerinde dahil olduğu bir tedavi yaklaşımı ile daha etkili sonuçlar elde edileceği

düşünülmektedir (Kim et al., 2023). Sonuç olarak aerobik glikoliz, kanser hücrelerinin hayatta kalma ve çoğalma yeteneğini destekleyen bir mekanizmadır.

Kanser Hücrelerinde Enerji Metabolizmasının Değişimi ve Kanser Gelişimine Etkisi

Kanser hücrelerinin enerji metabolizması, normal hücrelerden Warburg Etkisi gibi belirgin durumlardan kaynaklı farklıdır. Bu değişikliklerin temelinde, kanser hücrelerinin oksidatif fosforilasyon yerine, oksijen varlığında dahi aerobik glikolizle enerji üretmeleri yatmaktadır. Bu süreçte, artan glikoz alımı ve laktat üretimi, kanser hücrelerinin hızlı şekilde büyümesine ve bölünmesine katkıda bulunur. Ayrıca, pentoz fosfat yolu (PPP) gibi alternatif metabolik yollar da aktifleşerek nükleotid ve lipit sentezi için gerekli ara ürünlerin teminini sağlar. Warburg etkisi, Reaktif oksijen türleri (ROS) seviyelerini düzenleyerek kanser hücrelerinin stres koşullarına uyumunu kolaylaştırır (Zhang & Yang, 2022). Bu metabolik değişim, yalnızca tümör hücrelerine özgü bir durum değildir, aynı zamanda bağışıklık hücreleri, stromal hücreler ve tümör mikroçevresinin bileşenleri tarafından da şekillendirilir. Son yıllarda yapılan çalışmalar ile Warburg etkisinin sadece enerji üretimi sağlamadığı, aynı zamanda kanser hücrelerinin devamlılığını ve uyumunu destekleyen temel bir durum olduğunu göstermektedir (Abukwaiket al, 2024). Bu sebeple değişmiş enerji metabolizması, kanserin ayırt edici özelliklerinden biri olarak kabul edilmektedir.

Warburg Etkisi ve ATP Kinetiği

Glikozdan; enerji (ATP) elde etmek için aerobik glikoliz yolu kullanıldığında, mitokondrinin yaptığı işleme göre daha az enerji üretilir dolayısıyla aerobik glikoliz, mitokondriyal solunuma göre daha verimsiz bir enerji üretim yoludur. Fakat aerobik glikoliz yolu ile glikoz metabolizması hızı daha yüksektir. Örneğin; glikozdan laktat üretimi, mitokondride glikozun oksidasyonundan 10 ila 100 kat arasında daha hızlı gerçekleşebilmektedir. Kanser hücrelerinin aerobik glikolizi tercih etmesinin nedeni, bu süreçlerin kinetik açıdan farklılık göstermesinden kaynaklanmaktadır. Yapılan bir araştırmada; hücredeki ATP ihtiyacı arttığında, aerobik glikoliz hızla artmaktadır. Fakat oksidatif fosforilasyonun sabit kaldığı gözlenmiştir. Dolayısıyla hücreler ATP üretimini hızlı bir şekilde arttırabilmek için aerobik glikolizi kullanmaktadır. Bu durum, hücrelerin enerji oluşum hızını arttırmak için aerobik glikoliz yolunu tercih ettiğini ve mitokondriyal solunumun bu değişime paralel olarak hızlanmadığını göstermektedir. Özellikle kanser hücrelerinde, çevresel stres koşullarına uyum sağlamak ve hızlı bir şekilde büyümek amacı ile aerobik glikoliz yolunun devreye girmesi, hücrelerin hayatta kalmasını ve çoğalmasını kolaylaştırmaktadır. Bu süreç; Warburg etkisinin temel amacını açıklamaktadır ayrıca kanser hücrelerinin enerji üretiminde ne denli esnek ve verimli şekilde hareket edebildiklerini göstermektedir. Ancak bu durum bazı zorlukları da beraberinde getirmektedir. Yapılan hesaplamalar da hücrelerin büyüme ve bölünme evreleri için gereken ATP miktarının, normal hücrelerin sağlıklı bir şekilde çalışması için gereken ATP miktarından çok daha az olabileceğini göstermektedir. Bu da tümör hücrelerinin büyümesi sırasında ATP talebinin genellikle sınırlayıcı faktör olmamasına sebep olur. Ayrıca hızlı ATP üretimine duyulan ihtiyaç arttığında devreye giren bazı mekanizmalar, kanser hücrelerinde de bulunmaktadır. Örnek olarak; egzersiz sonrası kas hücrelerinde kreatin kinaz veya hormonal değişiklikleri sonucunda adenilat kinazlar aracılığı ile hızlı şekilde ATP üretimi yapılır ve bu mekanizma çoğu tümör hücresinde de bulunarak ATP talebini karşılamada rol oynamaktadır. Bu sebeple, bu mekanizmanın aerobik glikolizin işlevini açıklamak için daha fazla araştırmaya ihtiyaç duyulmaktadır (Zhao et al., 2023).

Kanser Hastalığında Patogenez ve Klinik Bulgular

Kanser hücreleri, enerji metabolizmasını çeşitli yollarla yeniden programlamaktadır:

Örneğin;

Tiroid Kanseri: BRAFV600E mutasyonuna sahip kanser hücrelerinde glikolitik aktivitenin arttığı ve oksidatif fosforilasyonun azaldığı belirlenmiştir. Yapılan çalışmalarda, bu hücrelerde metabolik inhibitör 2-deoksi-D-glukozun, doksorubisin ve sorafenib ile uygulanmasının hücre canlılığını azalttığı belirlenmiştir. Mutasyon taşıyan hücrelerin daha fazla laktat üretimi, düşük ATP seviyeleri ve azalmış oksijen tüketimi gösterdiği belirlenmiştir (Li et al., 2021).

Baş-boyun Kanseri: Cetuximab adlı antikor, glikoliz düzenleyicileri olan HIF1α ve LDH-A ekspresyonunu baskıladığı belirlenmiştir. Cetuximab antikoru ile yapılan tedavinin ardından hücre dışı asitleşme oranının azaldığı ve oksijen tüketim oranının değiştiği gözlenmiştir. Bu bulgular, kanser hücrelerinin enerji üretim süreçlerini değiştirerek hayatta kalma avantajı sağladığını ve bu sürecin tedaviyle engellenebileceğini göstermektedir (Chen et al., 2022).

Kolorektal Kanser: Hipoksi koşıullarında HIF1α birikimi, enerji metabolizmasını değiştiren önemli bir etkendir. IDF-11774 isimli baskılayıcı, HIF1α birikimini önler ve glikoz alımını azaltır ayrıca ATP seviyelerini düşürerek tümör büyümesini engeller (Kim et al., 2020).

Warburg Etkisi ve Kanser Tespiti

Warburg etkisi, henüz rutin klinik uygulamalara tam olarak entegre edilmemiş olsa da, birçok tümörde görülen glikoz oksidasyonundaki artış, kanser teşhisi ve tedavi yanıtının izlenmesi açısından değerli bir fırsat sunmaktadır. Bu etki, pozitron emisyon tomografisi (PET) taramalarıyla tespit edilebilmekte ve çoğunlukla bilgisayarlı tomografi ile birleştirilerek onkoloji alanında sıkça kullanılmaktadır. PET, kanserin evre durumu, tedavi planlaması ve etkinliğin değerlendirilmesi gibi konularda önemli bir rol oynamaktadır (Kim et al., 2023). PET taramalarında temel izleyici olarak kullanılan 18F-FDG, hücrelere girdikten sonra fosforilasyon yoluyla içeride tutulan bir bileşiktir. Warburg etkisiyle ilişkilendirilen yüksek glikoz alımı, PET taramalarında güçlü sinyaller üretse de bu, glikozun laktata dönüşümünü doğrudan göstermemektedir. Ancak, metabolik açıdan aktif olan bazı dokular PET taramalarında yoğun sinyaller verebilir ve tüm tümörler bu yöntemle tespit edilemeyebilir. Ayrıca, kanser dışı bazı durumlar da bu taramalarda yanıltıcı sonuçlar doğurabilmektedir. Buna rağmen, çeşitli tümör türlerinde glikoz taşıyıcı proteinlerin ekspresyonu ile 18F-FDG sinyali arasında olumlu bir ilişki olduğu gözlemlenmiştir. Warburg etkisi, bunun yanı sıra hiperpolarize 13C MRI teknolojisiyle de canlı organizmalarda görüntülenebilir. Fareler üzerinde yapılan bir çalışmada ise tümörlü bölgelerde glikozun laktata dönüşümü gözlenmiş ve tedavi başladıktan kısa bir süre sonra metabolik değişimler gözlemlenmiştir. Bu değişiklikler, standart görüntüleme yöntemleriyle ölçülen tümör boyutundaki değişimlerden önce ortaya çıkmaktadır. Hiperpolarize 13C MRI, PET'e kıyasla radyasyon içermemesi ve yüksek hassasiyetiyle avantaj sağlar ama bu yöntemde kullanılan bileşiklerin kısa ömürlü olması klinik yaygınlığını güçleştirmektedir. Yine de prostat ve meme kanseri gibi hastalıklarda başarılı sonuçlar elde edilmiş ve bu teknolojinin tanı ile tedavi yanıtını değerlendirmedeki potansiyeli dikkat çekmiştir. Metabolik değişimleri erken aşamada yakalama gücü, bu yöntemi tedavi etkinliğinin hızlı bir şekilde analiz edilmesi için önemli bir araç haline getirmektedir (Barba et al., 2024).

Warburg Etkisine Dayalı Tedavi Yaklaşımları ve Güncel Araştırmalar

Warburg etkisi, kanser hücrelerinin glikoz metabolizmasındaki farklılıklara dayanarak, hedefe yönelik tedavi yaklaşımlarının geliştirilmesine imkan sağlamaktadır. Özellikle tümör hücrelerinin oksijen olduğunda bile glikolizi tercih etmesi, metabolik bağımlılıklar ortaya çıkararak yeni tedavi imkanları yaratmaktadır (Pavlova & Thompson, 2016). Bu durum, hem metabolik inhibitörler hem de metabolizmayı yeniden programlamayı amaçlayan tedavilerin geliştirilmesine teşvik etmektedir. Glikoliz yolaklarının engellenmesi, Warburg etkisine müdahale etmenin temel yollarından biridir. Örnek olarak, hekzokinaz II, pirüvat kinaz M2 (PKM2) ve laktat dehidrogenaz A (LDHA) gibi enzimleri hedefleyen inhibitörlerin, kanser hücrelerinin enerji üretimini sekteye uğratarak büyümelerini yavaşlattığı belirlenmiştir (Cassim et al., 2020). Bunun yanı sıra, tümör hücreleri tarafından salgılanan laktatın mikroçevreyi immünosupresif hale getirmesi, immünoterapi ile kombinasyon yapılacak metabolik tedavilere ilgiyi arttırmıştır (Kim et al., 2023). Güncel araştırmalar, Warburg etkisinin immünoterapi sonuçlarını da etkilediğini göstermektedir. Laktat birikiminin, T hücre işlevini azaltarak tümörün bağışıklık sisteminden kaçmasını kolaylaştırdığı anlaşılmıştır (Barba et al., 2024). Bu sebeple, laktat taşıyıcıları olan monokarboksilat taşıyıcılarının (MCT'ler) engellenmesi hem metabolik odaklı tedavi hem de immünoterapilerin etkinliğini arttırma potansiyeline sahiptir. Metabolik yeniden programlama, kemoterapi ve radyoterapiye olan direncin kırılabileceğinde etkin rol oynamaktadır. Özellikle Warburg etkisinin tetiklediği glikolitik aktivite, DNA tamir mekanizmalarını güçlendirebilir ve bu da klasik tedavilere karşı direnç oluşturabilmektedir (Zhang et al., 2021). Bu bulgulara bağlı olarak, glikoliz inhibitörlerinin kemoterapi ile kombine edilmesi, daha etkin sonuçlar doğurabilecek tedavi planlarının temelini oluşturmaktadır. Klinik alanda halen devam eden birçok çalışma, Warburg etkisini hedef alan ilaçların etkinliğini değerlendirmektedir. Örnek olarak, LDHA inhibitörleri, mitokondriyal metabolizmayı yeniden aktive ederek tümör hücrelerinin büyümesini azaltır ve sağlıklı hücreleri korumaktadır (Liberti & Locasale, 2016). Bu çalışmalar, Warburg etkisinin sadece bir biyobelirteç değil, aynı zamanda terapötik bir hedef olduğunu göstermektedir. Sonuç olarak, Warburg etkisine odaklanan alan tedavi planları, kanserin metabolik bağımlılıklarını hedefleyerek geleneksel tedavilerden farklı bir strateji sunmaktadır. Bu etkiden yola çıkarak geliştirilen güncel araştırmalar, yenilikçi yaklaşımların önünü açmakta, kanser tedavisinde daha güçlü ve kişiselleştirilmiş stratejiler geliştirilmesine katkı sağlamaktadır.

Sonuç ve Öneriler

Warburg etkisi, kanser hücrelerinin enerji metabolizmasındaki yeniden şekillenmesini açıklayan temel bir biyolojik süreç olarak öne çıkmaktadır. Bu etkiye bağlı olarak oluşan glikolitik adaptasyonlar, yalnızca hızlı enerji üretimini değil, aynı zamanda tümör hücrelerinin immün yanıtı baskılama, apoptozdan kaçma ve tedaviye direnç gösterme mekanizmalarını desteklemektedir. Son dönemdeki çalışmalar, Warburg etkisinin tedavi stratejilerinde hem tek başına hem de diğer yöntemlerle birleştirilerek hedeflenebileceğini ortaya koymuştur. Glikoliz enzimlerini baskılayan maddeler, laktat taşınımını engelleyen bileşenler ve mitokondriyal enerji üretimini yeniden canlandıran yaklaşımlar, bu etkene karşı geliştirilen umut verici tedavi seçenekleri arasındadır. Ek olarak, Warburg etkisinin tanısal görüntüleme yöntemleriyle tespit edilmesi, hastalığın erken evrede saptanması ve tedavi yanıtının izlenmesi bakımından önem taşımaktadır. Gelecekte bu metabolik değişimin daha detaylı anlaşılması, kanser tedavisinde daha odaklı, etkili ve kişiselleştirilmiş yaklaşımların geliştirilmesine önemli katkılar sağlayacaktır

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INNOVATIVE AI-DRIVEN SPECTROSCOPIC METHODS FOR OLIVE OIL AUTHENTICATION, QUALITY CONTROL, AND FRAUD DETECTION

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ABSTRACT

Olive oil is one of the most valuable agricultural products worldwide due to its recognized nutritional, sensory, and economic importance. However, its high commercial value has made it particularly vulnerable to food fraud, including adulteration with lower-value vegetable oils, mislabeling, and false declarations of geographical origin. These fraudulent practices compromise product authenticity, undermine consumer confidence, and create significant economic and regulatory challenges. Consequently, there is an increasing demand for rapid, reliable, and non-destructive analytical approaches capable of verifying olive oil authenticity while supporting effective quality control.

Recent advances in vibrational spectroscopy have significantly improved the analytical capabilities available for olive oil authentication. Techniques such as Fourier Transform Infrared (FTIR) spectroscopy, Near-Infrared (NIR) spectroscopy, Raman spectroscopy, and Hyperspectral Imaging (HSI) provide rapid chemical fingerprinting with minimal sample preparation and reduced analytical cost. The integration of chemometric methods and artificial intelligence (AI), including machine learning and deep learning algorithms, has further enhanced the interpretation of complex spectral data, enabling more accurate classification, adulteration detection, geographical origin verification, and quality assessment.

This review critically examines recent developments in AI-assisted spectroscopic techniques for olive oil authentication, quality control, and food fraud detection. Current spectroscopic platforms, chemometric approaches, and AI models are comparatively evaluated with respect to their analytical performance, practical applicability, and suitability for industrial implementation. In addition, the review discusses current regulatory frameworks established by the International Olive Council (IOC) and the European Union, together with the major challenges associated with data standardization, model transferability, instrument portability, and real-world deployment.

Overall, the available evidence demonstrates that combining advanced spectroscopic techniques with artificial intelligence provides a powerful, rapid, and cost-effective strategy for olive oil authentication. Emerging developments in portable sensing technologies, explainable artificial intelligence, multimodal data fusion, and AI-enabled decision-support systems are expected to further strengthen authenticity verification, improve quality assurance, and support more transparent and resilient olive oil supply chains.

Keywords: Olive Oil Authentication; Food Fraud; Artificial Intelligence; Vibrational Spectroscopy; Quality Control; Machine Learning.

Introduction

Extra virgin olive oil (EVOO) is widely recognized as one of the most valuable edible oils because of its unique nutritional composition, sensory characteristics, and economic importance. Rich in monounsaturated fatty acids, particularly oleic acid, together with naturally occurring bioactive compounds such as phenolic compounds, tocopherols, squalene, and carotenoids, EVOO represents a fundamental component of the Mediterranean diet and has long been associated with numerous health benefits. A growing body of epidemiological and clinical evidence indicates that regular olive oil consumption contributes to cardiovascular protection, improved metabolic health, reduced oxidative stress, and a lower incidence of several chronic non-communicable diseases. These health-promoting properties, combined with increasing consumer awareness and demand for premium-quality foods, have considerably enhanced the global commercial value of olive oil. Consequently, maintaining product authenticity has become an essential prerequisite not only for protecting consumers but also for preserving market confidence and ensuring fair trade within the international olive oil sector (Chiavarini et al., 2024; Kakouri et al., 2021).

The high commercial value of extra virgin olive oil has simultaneously made it one of the most vulnerable food products to economically motivated adulteration. Fraudulent practices, including blending with lower-cost vegetable oils, misclassification of commercial grades, false declarations of geographical origin, and misleading labeling, continue to represent major concerns for producers, regulatory authorities, and consumers. Beyond the direct economic consequences, such practices undermine consumer confidence, compromise product integrity, and weaken the effectiveness of food quality assurance systems. Furthermore, the increasing complexity of international supply chains has intensified the demand for reliable methods to verify the authenticity and traceability of olive oil throughout production and distribution. As a result, authenticity assessment has evolved beyond simple adulteration detection and now encompasses the verification of geographical origin, cultivar identity, production practices, and compliance with internationally recognized quality standards (Kakouri et al., 2021; Özen et al., 2024; International Olive Council, 2024).

To satisfy these growing analytical demands, numerous laboratory-based techniques have been employed for olive oil characterization and authenticity assessment. Conventional analytical methods, including gas chromatography (GC), liquid chromatography (LC), mass spectrometry (MS), nuclear magnetic resonance (NMR), and isotope ratio mass spectrometry (IRMS), provide highly accurate compositional information and remain the reference approaches for many regulatory and research applications. These techniques have substantially contributed to the detection of adulteration, identification of botanical and geographical origin, and characterization of cultivar-specific chemical profiles. Nevertheless, their widespread implementation in routine quality control is often limited by expensive instrumentation, extensive sample preparation, relatively long analysis times, and the requirement for specialized technical expertise. Such limitations have encouraged the development of alternative analytical strategies capable of delivering rapid, reliable, and cost-effective results while maintaining high analytical performance (Kakouri et al., 2021; Özen et al., 2024; Camin et al., 2017).

Among the emerging analytical technologies, vibrational spectroscopic techniques have attracted considerable attention because they enable rapid, non-destructive, and environmentally sustainable analysis with minimal sample preparation. Fourier Transform Infrared (FTIR) spectroscopy, Near-Infrared (NIR) spectroscopy, Raman spectroscopy, and hyperspectral imaging (HSI) generate comprehensive molecular fingerprints that reflect the overall chemical composition of olive oil rather than focusing on individual chemical constituents. These spectral fingerprints provide valuable information regarding authenticity, compositional characteristics, quality attributes, and potential adulteration. In addition, their

short analysis time, reduced reagent consumption, and compatibility with portable instrumentation make these techniques particularly suitable for routine quality control, process monitoring, and on-site authenticity verification. Consequently, spectroscopic approaches are increasingly viewed as practical complements to conventional laboratory methods, especially in applications requiring rapid decision-making across the olive oil production chain (Özen et al., 2024; Kakouri et al., 2021).

The growing application of spectroscopic techniques has simultaneously increased the demand for advanced computational tools capable of interpreting the large volume of complex spectral information generated during analysis. In this context, chemometric methods and artificial intelligence (AI) have become indispensable components of modern olive oil authentication systems. Machine learning algorithms, including Principal Component Analysis (PCA), Partial Least Squares Discriminant Analysis (PLS-DA), Support Vector Machines (SVM), Random Forest (RF), and Artificial Neural Networks (ANNs), have substantially improved the classification of olive oil samples, discrimination of geographical origin, detection of adulteration, and prediction of quality parameters through efficient extraction of meaningful information from multidimensional spectral datasets. More recently, deep learning approaches have further enhanced analytical performance by enabling automated feature extraction and high-accuracy predictive modeling. Despite these remarkable advances, several important challenges remain, including the lack of standardized spectral databases, variability in data acquisition and preprocessing protocols, insufficient external validation of predictive models, and limited transferability of laboratory-developed models to industrial environments. Addressing these issues is essential for facilitating the routine implementation of intelligent spectroscopic systems within modern food quality management and regulatory inspection programs (Özen et al., 2024; Kakouri et al., 2021). The overall evolution of analytical approaches discussed in the previous sections is summarized in Figure 1, highlighting the transition from conventional laboratory techniques to intelligent spectroscopic systems for olive oil authentication.

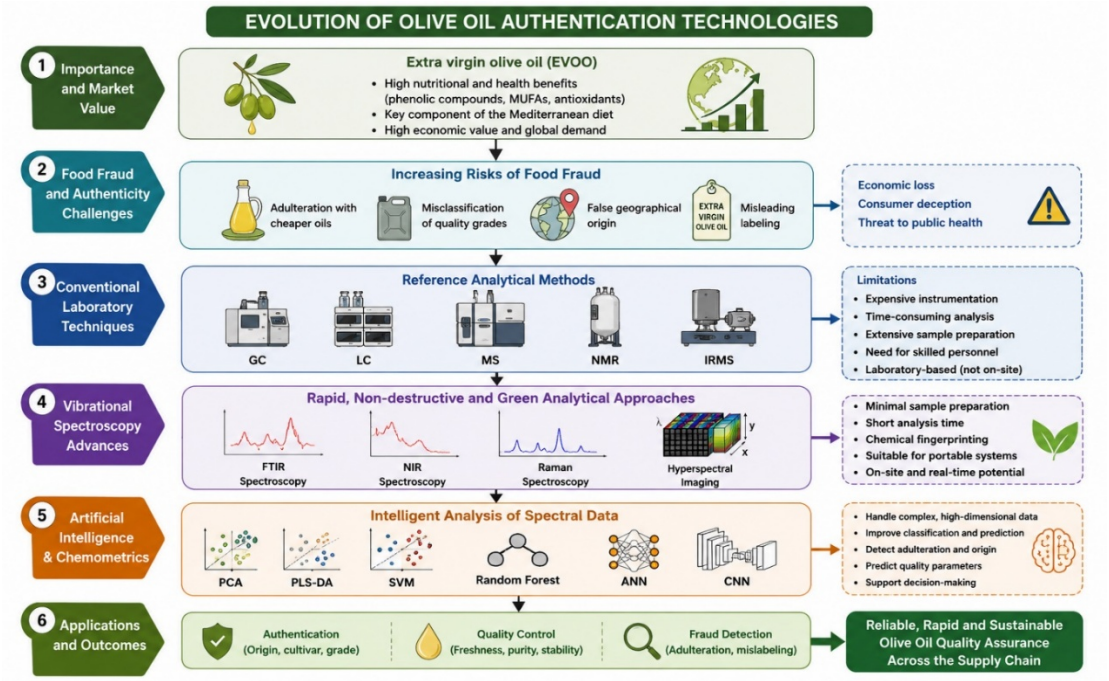

Figure 1. Evolution of olive oil authentication technologies from conventional analytical methods to AI-driven spectroscopic systems.

Against this background, the present review provides a comprehensive and up-to-date overview of recent developments in AI-driven spectroscopic technologies for olive oil authentication, quality assessment, and fraud detection. Particular emphasis is placed on the analytical capabilities of FTIR, NIR, Raman spectroscopy, and hyperspectral imaging, together with recent advances in chemometric analysis, machine learning, and deep learning for spectral data interpretation. In addition to summarizing current achievements, this review critically discusses existing methodological limitations, practical implementation challenges, and emerging research opportunities that may facilitate broader industrial adoption of intelligent authentication systems. By integrating recent advances in spectroscopy, analytical chemistry, and artificial intelligence within a single framework, this review aims to provide researchers, food scientists, quality assurance professionals, and regulatory authorities with a comprehensive reference for understanding current progress and future directions in olive oil authenticity assessment.

Olive Oil Fraud and Authentication Challenges

Types of Olive Oil Fraud

The premium market value of extra virgin olive oil (EVOO), together with increasing global demand and complex international supply chains, has made olive oil one of the food products most frequently exposed to economically motivated fraud. Food fraud in the olive oil sector encompasses a wide range of deceptive practices intended to increase financial gain while misleading consumers regarding product quality or authenticity. These practices not only violate regulatory standards but also compromise market transparency, damage consumer confidence, and create significant challenges for quality assurance systems and international trade (Spink & Moyer, 2011; Kakouri et al., 2021).

Adulteration with lower-cost vegetable oils remains the most frequently reported form of olive oil fraud. In this practice, extra virgin olive oil is intentionally blended with cheaper edible oils, such as sunflower, soybean, canola, hazelnut, corn, or refined olive oils, while being marketed as pure EVOO. Depending on the type and proportion of the adulterant, these modifications may alter the chemical composition, nutritional profile, oxidative stability, and sensory characteristics of the final product. Although some adulterants can be identified using conventional analytical methods, the detection of low-level or chemically similar adulterants continues to represent a considerable analytical challenge, particularly when sophisticated blending strategies are employed (Kakouri et al., 2021; Özen et al., 2024).

Another important category of fraud involves the misclassification of commercial quality grades. Olive oils that fail to satisfy the physicochemical or sensory criteria established for extra virgin olive oil may be intentionally marketed as higher-grade products to obtain greater economic returns. Such fraudulent practices exploit the difficulty that consumers face in distinguishing quality grades based solely on appearance or taste. Consequently, reliable analytical verification is essential for confirming compliance with internationally recognized quality standards established by the International Olive Council (International Olive Council, 2024).

False declarations of geographical origin and cultivar identity have also become increasingly significant, particularly for premium products carrying Protected Designation of Origin (PDO) or Protected Geographical Indication (PGI) labels. Since environmental conditions, agricultural practices, and olive cultivars substantially influence the chemical composition of olive oil, geographical origin has become an important determinant of both market value and consumer

preference. Misrepresentation of origin, therefore, constitutes not only commercial fraud but also a violation of traceability regulations designed to protect regional products and ensure transparency throughout the food supply chain (European Commission, 202; Camin et al., 2017).

In addition to these well-recognized forms of fraud, deceptive practices involving misleading labeling, inaccurate production claims, or false declarations regarding organic production and harvesting methods have emerged as growing concerns in international markets. The increasing diversity and sophistication of fraudulent practices clearly demonstrate that ensuring olive oil authenticity requires analytical approaches capable of simultaneously verifying compositional integrity, geographical origin, botanical identity, and compliance with quality standards. This growing analytical complexity has accelerated the development of rapid, non-destructive, and data-driven authentication technologies, which are discussed in the following sections of this review.

Economic and Public Health Impacts

Olive oil fraud extends far beyond financial deception and has important economic, social, and public health implications. Because extra virgin olive oil commands a premium price in international markets, fraudulent substitution with lower-value oils generates unfair economic advantages for dishonest producers while placing legitimate manufacturers at a competitive disadvantage. Such practices distort market competition, reduce the commercial value of authentic products, and undermine consumer confidence in certification systems and quality labels. Over time, repeated incidents of food fraud may weaken the reputation of entire production regions, negatively affecting exports, tourism, and the long-term sustainability of the olive oil industry (Spink & Moyer, 2011; International Olive Council, 2024).

From a public health perspective, the consequences of olive oil fraud depend largely on the nature of the adulteration. Although many adulterants are edible vegetable oils, their substitution alters the nutritional composition of the final product by changing the balance of fatty acids, minor bioactive compounds, and natural antioxidants that contribute to the recognized health benefits of extra virgin olive oil. Consequently, consumers may unknowingly purchase products with reduced nutritional quality while believing they are receiving the physiological benefits associated with authentic EVOO. More importantly, undeclared adulteration may expose susceptible individuals to allergenic compounds originating from oils such as soybean, peanut, or hazelnut, thereby creating potential health risks for sensitive consumers (Kakouri et al., 2021).

Food fraud also places a substantial burden on regulatory agencies and food control laboratories. Detecting sophisticated adulteration often requires advanced analytical instrumentation, highly trained personnel, and extensive laboratory resources, increasing both the cost and complexity of official surveillance programs. As fraudulent practices continue to evolve, regulatory authorities face growing pressure to implement analytical approaches that are not only accurate but also rapid, cost-effective, and suitable for the routine screening of large numbers of samples. These requirements have stimulated increasing interest in non-destructive spectroscopic technologies combined with artificial intelligence, which offer the potential to improve both the efficiency and scalability of food authentication systems (Özen et al., 2024).

Beyond immediate economic losses and health concerns, olive oil fraud has broader implications for consumer trust and food system resilience. Confidence in food labeling, geographical indications, and certification schemes depends on the ability of producers and regulatory authorities to verify authenticity with a high degree of reliability. In an era characterized by globalized food supply chains and increasing consumer demand for

transparency, effective authentication systems have become an essential component of sustainable food governance. The integration of rapid analytical technologies with intelligent data analysis, therefore, represents not only a technological advancement but also a strategic approach for strengthening food integrity, protecting public health, and supporting fair trade across international markets.

Regulatory Frameworks (IOC & EU)

The effectiveness of olive oil authentication depends not only on the availability of advanced analytical technologies but also on the existence of harmonized regulatory frameworks that define quality standards, authenticity criteria, and labeling requirements. International organizations and regulatory authorities have established comprehensive specifications to protect consumers, facilitate fair trade, and ensure the integrity of olive oil throughout the global supply chain. These regulatory frameworks provide the scientific and legal basis for distinguishing authentic extra virgin olive oil from adulterated or misclassified products and serve as important reference points for both analytical laboratories and official inspection authorities (International Olive Council, 2024).

The International Olive Council (IOC) plays a central role in the development of internationally recognized standards for olive oils and olive-pomace oils. The IOC Trade Standard specifies quality categories based on physicochemical characteristics, sensory evaluation, purity criteria, and compositional parameters. It also establishes analytical methods and acceptance criteria that support the classification of commercial olive oils and facilitate international trade among producing and importing countries. Because many national regulations are aligned with IOC standards, these guidelines have become the principal reference for routine quality assessment and authenticity verification in the olive oil sector (International Olive Council, 2024).

Within the European Union, olive oil quality and labeling are regulated through a comprehensive legislative framework designed to protect consumers and preserve market transparency. European regulations define marketing standards, labeling requirements, traceability obligations, and the use of geographical quality schemes such as Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI). These quality labels provide legal protection for products whose characteristics are closely linked to specific geographical regions and traditional production practices. Consequently, analytical verification of geographical origin has become increasingly important for supporting regulatory compliance and preventing fraudulent use of protected designations (European Commission, 2022).

Although existing regulatory frameworks provide robust legal foundations for olive oil quality assurance, the rapid evolution of food fraud strategies presents continuing challenges for regulatory enforcement. Sophisticated adulteration techniques, increasingly complex international supply chains, and the growing diversity of olive oil products require analytical approaches that extend beyond conventional laboratory testing. In this context, regulatory authorities are placing greater emphasis on rapid, objective, and non-destructive analytical technologies capable of supporting large-scale screening while maintaining high levels of accuracy and reproducibility. These evolving regulatory expectations have significantly accelerated research into spectroscopic techniques integrated with chemometric analysis and artificial intelligence, which are increasingly recognized as promising tools for strengthening food authenticity verification and regulatory surveillance. Table 1 provides a comparative overview of the principal types of olive oil fraud, the associated regulatory concerns, and the conventional and emerging analytical approaches used for authenticity verification, based on the current scientific literature and international standards (Kakouri et al., 2021; Özen et al., 2024; International Olive Council, 2024).

Table 1. Common Types of Olive Oil Fraud and Corresponding Analytical Approaches

Type of Fraud	Regulatory Concern	Conventional Methods	AI-Assisted Spectroscopy
Adulteration	Purity	GC, LC, MS	FTIR + ML, Raman + SVM
Geographical origin	Traceability	IRMS, DNA	NIR + ANN
Quality grade	IOC compliance	Sensory + Chemistry	FTIR + PLS-DA
Mislabeling	Consumer protection	Documentation	HSI + Deep Learning

Source: Developed by the authors based on Kakouri et al. (2021), Özen et al. (2024), International Olive Council (2024), and Camin et al. (2017).

Spectroscopic Techniques for Olive Oil Authentication

Spectroscopic techniques have emerged as some of the most promising analytical tools for olive oil authentication because they enable rapid, non-destructive, and information-rich characterization of complex food matrices. Unlike conventional chromatographic and spectrometric methods, which generally require extensive sample preparation and laboratory-based instrumentation, spectroscopic approaches provide comprehensive molecular information within a relatively short analysis time while minimizing reagent consumption and sample manipulation. These techniques generate characteristic spectral fingerprints that reflect the chemical composition of olive oil, enabling the simultaneous assessment of authenticity, quality attributes, geographical origin, cultivar differentiation, and adulteration. Recent advances in analytical instrumentation and spectroscopic methodologies have further strengthened their role in food authenticity verification and traceability, supporting more efficient quality control throughout the olive oil supply chain (Lozano-Castellón et al., 2022; Kakouri et al., 2021; Özen et al., 2024).

Among the available spectroscopic techniques, Fourier Transform Infrared (FTIR), Near-Infrared (NIR), Raman spectroscopy, and hyperspectral imaging (HSI) have emerged as the most widely investigated approaches for olive oil authentication. Although each technique is based on different physical principles, all provide rapid, non-destructive chemical information that can be combined with advanced data analysis algorithms to support authenticity verification and fraud detection. The following subsections summarize the analytical principles, major advantages, representative applications, and current limitations of these four techniques.

Fourier Transform Infrared (FTIR) Spectroscopy

Fourier Transform Infrared (FTIR) spectroscopy is one of the most extensively applied vibrational spectroscopic techniques for olive oil authentication because it provides rapid and non-destructive analysis while requiring little or no sample preparation. The technique is based on the absorption of infrared radiation by molecular functional groups, generating characteristic spectral fingerprints that reflect the chemical composition of the sample. In olive oil analysis, FTIR spectra primarily arise from the vibrational modes of triglycerides, fatty acids, esters, and minor bioactive compounds. Variations in these spectral profiles can therefore reveal changes associated with adulteration, oxidation, geographical origin, and overall quality (Özen et al., 2024).

One of the principal advantages of FTIR spectroscopy is its ability to simultaneously evaluate multiple compositional characteristics within a single measurement. Unlike chromatographic methods that often target specific compounds, FTIR captures the overall molecular profile of olive oil, allowing rapid screening of large numbers of samples. This capability makes the

technique particularly suitable for routine quality control in industrial laboratories, where analytical speed, low operating costs, and minimal chemical waste are essential considerations. In addition, the increasing availability of portable FTIR instruments has expanded opportunities for on-site authentication throughout the production and distribution chain (Kakouri et al., 2021).

Numerous studies have demonstrated the effectiveness of FTIR spectroscopy in detecting adulteration of extra virgin olive oil with lower-cost vegetable oils, including sunflower, soybean, canola, and refined olive oils. The technique has also been successfully applied to the discrimination of olive oils according to cultivar, geographical origin, and commercial quality grade. However, because FTIR spectra often contain overlapping absorption bands, direct interpretation of spectral data may be challenging. Consequently, chemometric techniques such as Principal Component Analysis (PCA) and Partial Least Squares Discriminant Analysis (PLS-DA), together with machine learning algorithms including Support Vector Machines (SVM) and Random Forest (RF), are frequently employed to improve classification accuracy and predictive performance (Özen et al., 2024; Kakouri et al., 2021).

Despite its considerable analytical potential, FTIR spectroscopy has certain limitations. The sensitivity of the method may decrease when detecting very low levels of adulteration or distinguishing oils with highly similar chemical compositions. Instrument calibration, spectral preprocessing, and the availability of representative reference datasets also influence model performance and reproducibility. Nevertheless, the combination of FTIR spectroscopy with advanced chemometric and artificial intelligence techniques continues to enhance its analytical capability, making it one of the most practical and widely adopted approaches for rapid olive oil authentication and quality assessment.

Near-Infrared (NIR) Spectroscopy

Near-Infrared (NIR) spectroscopy has become one of the most widely used analytical techniques for rapid olive oil authentication because of its simplicity, speed, and suitability for routine industrial applications. The technique operates within the near-infrared region of the electromagnetic spectrum and measures the absorption of radiation associated with overtone and combination vibrations of chemical bonds, particularly C–H, O–H, and N–H functional groups. Although NIR spectra are generally broader and less chemically specific than those obtained by FTIR spectroscopy, they contain sufficient compositional information to differentiate olive oils according to their physicochemical characteristics when combined with appropriate multivariate data analysis (Özen et al., 2024).

One of the major advantages of NIR spectroscopy is its ability to analyze samples rapidly without the need for extensive preparation or chemical reagents. Measurements can often be completed within a few seconds, making the technique particularly attractive for high-throughput quality control and real-time process monitoring. Furthermore, modern portable and handheld NIR spectrometers have expanded the application of this technique beyond laboratory environments, enabling rapid screening of olive oil authenticity during production, storage, transportation, and commercial inspection. These characteristics make NIR spectroscopy a cost-effective analytical tool for routine quality assurance throughout the olive oil supply chain (Kakouri et al., 2021).

In recent years, NIR spectroscopy has been successfully applied to the detection of adulteration with lower-cost vegetable oils, classification of olive oils according to geographical origin and cultivar, and prediction of quality-related parameters such as free fatty acid content, peroxide value, and moisture. Because NIR spectra consist of highly overlapping absorption bands, reliable interpretation generally requires chemometric and machine learning techniques. Algorithms such as Principal Component Analysis (PCA), Partial Least Squares Regression

(PLSR), Support Vector Machines (SVM), and Artificial Neural Networks (ANNs) have significantly improved the accuracy of classification and prediction models by extracting meaningful patterns from complex spectral datasets (Özen et al., 2024; Kakouri et al., 2021).

Despite its practical advantages, NIR spectroscopy has certain limitations. The indirect nature of overtone absorption results in lower chemical specificity than mid-infrared techniques, making robust calibration models essential for accurate analysis. Instrument performance may also be influenced by sample variability, environmental conditions, and differences in spectral preprocessing procedures. Nevertheless, the continuous development of portable instrumentation, improved calibration strategies, and artificial intelligence-based data analysis has further strengthened the role of NIR spectroscopy as a reliable, rapid, and non-destructive tool for olive oil authentication and quality assessment.

Raman Spectroscopy

Raman spectroscopy has emerged as a valuable complementary vibrational spectroscopic technique for olive oil authentication because it provides highly specific molecular information with minimal sample preparation. Unlike infrared spectroscopy, which measures the absorption of electromagnetic radiation, Raman spectroscopy is based on the inelastic scattering of monochromatic laser light by molecular vibrations. The resulting Raman spectrum reflects structural changes in chemical bonds and provides detailed information about the composition of triglycerides, fatty acids, pigments, and other minor constituents of olive oil. This molecular specificity enables the technique to distinguish subtle compositional differences associated with authenticity, geographical origin, and quality characteristics (Özen et al., 2024).

One of the principal advantages of Raman spectroscopy is its excellent sensitivity to lipid composition and its limited interference from water, making it particularly suitable for the analysis of edible oils. The technique can rapidly identify compositional changes resulting from adulteration with lower-cost vegetable oils and has demonstrated considerable potential for differentiating authentic extra virgin olive oil from refined or blended products. In addition, recent improvements in portable Raman instrumentation have expanded opportunities for field-based analysis and real-time quality assessment, supporting more efficient monitoring throughout the olive oil production and distribution chain (Kakouri et al., 2021).

Numerous studies have reported the successful application of Raman spectroscopy for detecting adulteration, verifying geographical origin, classifying commercial quality grades, and evaluating oxidative deterioration. However, the complexity of Raman spectra often requires advanced multivariate statistical analysis to achieve reliable discrimination among samples with similar chemical compositions. Chemometric approaches such as Principal Component Analysis (PCA) and Partial Least Squares Discriminant Analysis (PLS-DA), together with machine learning algorithms including Support Vector Machines (SVM) and Random Forest (RF), have significantly improved the interpretation of Raman spectral data and enhanced the accuracy of classification and prediction models (Özen et al., 2024).

Despite its analytical advantages, Raman spectroscopy also presents certain limitations. Fluorescence interference from naturally occurring pigments or impurities may reduce spectral quality and complicate data interpretation in some samples. Furthermore, the relatively high cost of instrumentation and the need for careful optimization of measurement conditions may restrict its widespread routine application compared with FTIR and NIR spectroscopy. Nevertheless, continuous advances in laser technology, portable Raman devices, and artificial intelligence-assisted spectral analysis are progressively overcoming these challenges, strengthening the role of Raman spectroscopy as an effective tool for rapid, non-destructive olive oil authentication and quality control.

Hyperspectral Imaging (HSI)

Hyperspectral Imaging (HSI) is an advanced analytical technique that combines conventional imaging with spectroscopy to provide both spatial and spectral information from a sample simultaneously. Unlike traditional spectroscopic methods that generate a single averaged spectrum, HSI produces a three-dimensional data cube consisting of two spatial dimensions and one spectral dimension. This unique capability allows for detailed mapping of the chemical composition and spatial heterogeneity of olive oil samples, making it a powerful tool for authenticity assessment, quality evaluation, and fraud detection (Özen et al., 2024).

In olive oil authentication, HSI enables the identification of subtle spatial variations in chemical composition that may arise from adulteration, incomplete mixing, or the presence of oils with different origins. By capturing spectral information across hundreds of wavelengths, HSI provides a comprehensive fingerprint of the sample that reflects both its chemical and physical properties. This makes the technique particularly suitable for detecting heterogeneous adulteration scenarios, where conventional bulk spectroscopic methods may fail to identify localized inconsistencies. As a result, HSI has gained increasing attention for applications in quality control, process monitoring, and non-destructive inspection of edible oils (Kakouri et al., 2021).

The high dimensionality of hyperspectral data, however, presents significant challenges in terms of data processing and interpretation. Advanced chemometric techniques and machine learning algorithms are therefore essential for extracting relevant information from HSI datasets. Methods such as Principal Component Analysis (PCA), Partial Least Squares Regression (PLSR), Support Vector Machines (SVM), and, more recently, deep learning approaches have been successfully applied to improve classification accuracy, feature extraction, and predictive modeling in olive oil studies. These computational approaches enable the transformation of complex hyperspectral data into meaningful diagnostic information for authenticity verification (Özen et al., 2024).

Despite its powerful analytical capabilities, HSI also has limitations that currently restrict its widespread industrial application. The technique typically requires high-cost instrumentation, large data storage capacity, and significant computational resources for data processing. Additionally, the interpretation of hyperspectral data demands specialized expertise in both spectroscopy and multivariate analysis. Nevertheless, ongoing advances in sensor miniaturization, real-time data processing, and artificial intelligence-based algorithms are progressively overcoming these limitations, paving the way for broader adoption of HSI in intelligent food authentication systems. A comparative overview of the major spectroscopic techniques used for olive oil authentication is presented in Table 2, highlighting their principles, strengths, limitations, and analytical applications (Kakouri et al., 2021; Özen et al., 2024).

Table 2. Comparison of Major Spectroscopic Techniques Used for Olive Oil Authentication

Technique	Principle	Strengths	Limitations	Main Applications
FTIR	IR absorption	Fast, cheap, simple	Overlapping bands	Adulteration detection
NIR	Overtones/combination bands	Very fast, portable	Low specificity	Routine screening
Raman	Inelastic scattering	High molecular specificity	Fluorescence interference	Origin & quality
HSI	Spectral imaging cube	Spatial + spectral info	High computational cost	Heterogeneity detection

Source: Developed by the authors based on Kakouri et al. (2021) and Özen et al. (2024)

Artificial Intelligence in Olive Oil Authentication

The integration of artificial intelligence (AI) with spectroscopic techniques has significantly transformed the field of olive oil authentication by enabling the extraction of meaningful information from complex and high-dimensional spectral datasets. While spectroscopic methods such as FTIR, NIR, Raman, and hyperspectral imaging generate rich chemical fingerprints, the interpretation of these data is often limited by spectral overlap, noise, and variability arising from environmental and processing conditions. In this context, AI-based approaches, particularly chemometrics, machine learning (ML), and deep learning (DL), have emerged as powerful tools to enhance classification accuracy, improve predictive performance, and support robust decision-making in food authentication systems (Özen et al., 2024; Kakouri et al., 2021).

Traditional chemometric techniques, including Principal Component Analysis (PCA), Partial Least Squares Discriminant Analysis (PLS-DA), and Linear Discriminant Analysis (LDA), have long been used as foundational tools for spectral data interpretation. These methods are particularly effective for dimensionality reduction, feature extraction, and preliminary classification of olive oil samples. However, their performance may be limited when dealing with highly nonlinear relationships or large and heterogeneous datasets. As a result, more advanced machine learning algorithms such as Support Vector Machines (SVM), Random Forest (RF), and k-Nearest Neighbors (k-NN) have been increasingly adopted to improve classification robustness and handle complex spectral variability (Özen et al., 2024).

In recent years, deep learning approaches, especially Artificial Neural Networks (ANNs) and Convolutional Neural Networks (CNNs), have demonstrated remarkable potential in olive oil authentication tasks. These models are capable of automatically learning hierarchical feature representations from raw or minimally preprocessed spectral data, eliminating the need for extensive manual feature engineering. CNN-based architectures, in particular, have shown strong performance in hyperspectral imaging analysis due to their ability to capture both spatial and spectral patterns simultaneously. This makes them highly suitable for detecting subtle adulteration patterns and complex compositional variations in olive oil samples.

Despite their high accuracy, AI-based systems also present several challenges. Model interpretability remains a critical issue, particularly in regulatory contexts where transparency and explainability are essential. In addition, the performance of AI models is highly dependent on the quality and diversity of training datasets. Limited or biased datasets may lead to overfitting and reduced generalizability across different production regions or harvest seasons. Furthermore, integrating AI models into real-time industrial systems requires efficient computational frameworks and standardized spectral databases. The overall workflow of AI-assisted spectroscopic analysis for olive oil authentication is illustrated in Figure 2.

Overall, the combination of spectroscopy and artificial intelligence represents a paradigm shift in olive oil authentication. This hybrid approach enables rapid, accurate, and scalable analysis, supporting applications ranging from laboratory-based quality control to portable field inspection systems. The continued development of explainable AI models and large-scale spectral databases is expected to enhance further the reliability and adoption of these technologies in food fraud detection and quality assurance systems.

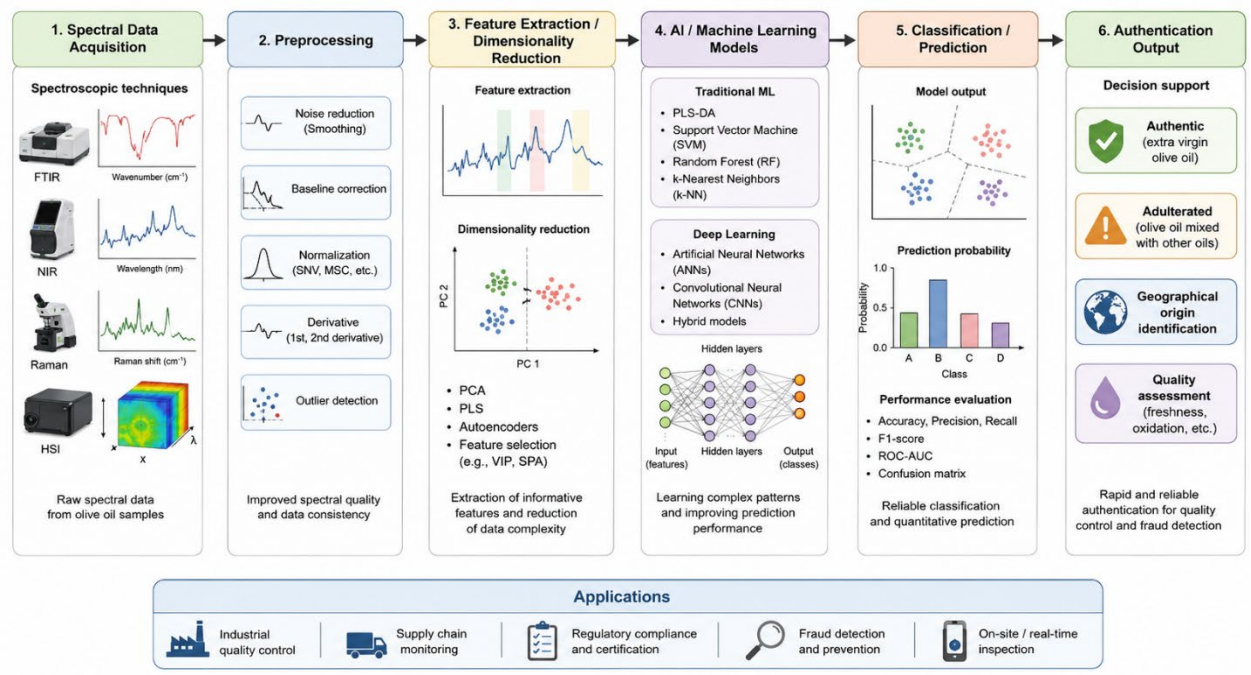

Figure 2. Workflow of AI-assisted spectroscopic analysis for olive oil authentication

Challenges and Future Perspectives

Despite significant advances in spectroscopic techniques and artificial intelligence (AI) for olive oil authentication, several challenges still limit their widespread industrial deployment. One of the primary limitations is the lack of standardized protocols for data acquisition, spectral preprocessing, and model validation. Variations in instrument settings, environmental conditions, and sample handling can introduce inconsistencies that reduce model robustness and hinder reproducibility across different laboratories and regions (Lozano-Castellón et al., 2022; Özen et al., 2024).

Another critical challenge is related to dataset quality and representativeness. Most existing AI models are trained on relatively small or region-specific datasets, which may not fully capture the natural variability of olive oil caused by differences in cultivar, geographical origin, harvest season, and production techniques. This limitation increases the risk of overfitting and reduces the generalizability of predictive models when applied to real-world industrial scenarios. Therefore, the development of large-scale, shared spectral databases is essential for improving model reliability and comparability across studies.

Model interpretability is another important issue, particularly in regulatory and quality control contexts. While advanced machine learning and deep learning models, such as artificial neural networks and convolutional neural networks, can achieve high classification accuracy, their decision-making processes are often considered “black box” in nature. This lack of transparency may limit their acceptance by regulatory authorities and industry stakeholders, who require explainable and traceable analytical results for certification and legal compliance.

From a technological perspective, the integration of spectroscopic systems with real-time AI-based decision-support tools remains a key challenge. Although portable spectrometers and cloud-based analytics have made significant progress, there is still a need for faster processing algorithms, optimized hardware, and user-friendly interfaces that can be implemented directly in production lines or field environments.

Looking forward, several promising directions can be identified. The development of explainable AI (XAI) techniques is expected to enhance model transparency and facilitate regulatory acceptance. In addition, the combination of multimodal data fusion, integrating FTIR, NIR, Raman, and hyperspectral imaging, has the potential to significantly improve authentication accuracy by leveraging complementary spectral information. Furthermore, advances in edge computing and Internet of Things (IoT)-enabled sensing systems may enable real-time, decentralized olive oil quality monitoring across supply chains. These developments collectively indicate that the future of olive oil authentication will increasingly rely on intelligent, integrated, and automated analytical ecosystems.

Conclusion

This study reviewed recent advances in spectroscopic techniques combined with artificial intelligence (AI) for olive oil authentication, quality control, and fraud detection. It highlighted the growing importance of rapid, non-destructive, and cost-effective analytical methods in addressing the increasing complexity of food fraud within global olive oil supply chains. Techniques such as Fourier Transform Infrared (FTIR), Near-Infrared (NIR), Raman spectroscopy, and hyperspectral imaging (HSI) were discussed in terms of their principles, analytical capabilities, advantages, and limitations.

The review demonstrated that while spectroscopic methods provide rich molecular fingerprints for olive oil characterization, their full potential is often limited by data complexity, spectral overlap, and variability arising from natural and processing-related factors. In this context, the integration of chemometrics, machine learning, and deep learning approaches has significantly enhanced the ability to extract meaningful information from spectral datasets, improving classification accuracy and robustness in authentication tasks.

The findings indicate that AI-driven spectroscopic systems represent a powerful and evolving paradigm for olive oil analysis, enabling simultaneous assessment of authenticity, geographical origin, and quality attributes. However, challenges such as dataset standardization, model interpretability, and real-time industrial implementation still need to be addressed to ensure broader adoption and regulatory acceptance.

Future developments are expected to focus on explainable AI models, multimodal data fusion, and the integration of portable spectroscopic devices with intelligent decision-support systems. These advancements will likely facilitate the transition from laboratory-based analysis to real-time, on-site olive oil authentication systems. Overall, the synergy between spectroscopy and AI offers a promising pathway toward more transparent, reliable, and efficient food authentication frameworks.

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PHOTOVOLTAIC WATER PUMPING SYSTEMS WITHIN THE WATER–ENERGY–FOOD NEXUS: TECHNO-ECONOMIC AND ENVIRONMENTAL ASSESSMENT

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ABSTRACT

Within the Water–Energy–Food (WEF) Nexus, access to irrigation water remains a major challenge in Morocco, particularly in arid and semi-arid regions such as the Chaouia area. Conventional pumping systems, largely dependent on fossil fuels, are costly and environmentally harmful, increasing pressure on water resources, energy supply, and agricultural production.

Photovoltaic water pumping systems (PVWPS) provide an integrated and sustainable solution within this nexus by using abundant solar energy to supply water for agriculture, while reducing energy costs and associated CO_2 emissions. This study assesses the technical, economic, and environmental evolution of a PVWPS installed in the Chaouia region through an updated comparative analysis covering the period 2017–2025, based on recent data and Python-based simulations.

The results highlight significant technological optimization, with the number of photovoltaic modules reduced from 120 units of 230 Wp in 2017 to 62 units of 450 Wp in 2025 for the same installed capacity. This improvement led to a substantial decrease in the cost of pumped water, from 0.56 to 0.19 MAD/m³, and a reduction in annual CO_2 emissions from 1,152 kg to 711 kg.

Overall, the findings demonstrate that technological progress significantly enhances the economic and environmental viability of photovoltaic water pumping systems and underline their strategic role in strengthening water–energy synergies and supporting sustainable agricultural production within the WEF Nexus in Morocco.

Keywords: Water–Energy–Food Nexus; Photovoltaic Water Pumping System; Techno-economic assessment; CO_2 emissions reduction; Sustainable irrigation

BIOWASTE-DERIVED NANOMATERIALS FROM THE BLACK SEA REGION FOR SUSTAINABLE ENVIRONMENTAL POLLUTION REMOVAL

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ABSTRACT

Human-induced interventions such as industrialization, mining activities, and uncontrolled urbanization have brought environmental pollution to the level of a global threat. Heavy metal pollution, in particular, accumulates in soil and water resources, disrupting ecosystem balance. Since removing these pollutants using traditional methods is both costly and causes secondary pollution, the need to develop solutions in accordance with green chemistry principles is increasing. The synthesis of green materials using bioactive substances obtained from bio-waste offers an environmentally friendly, effective, and sustainable approach to this problem.

Experimental studies in the literature show that nanoparticles synthesized from bio-waste are effective in removing pollutants (heavy metals, dyes, antibiotics) from wastewater. Nanoparticles produced using green synthesis methods not only remove industrial pollution from wastewater but also impart antibacterial properties to the treated water. Considering the heavy metal pollution resulting from mining activities in the Black Sea Region, the evaluation of local bio-waste as nanomaterials is important for both waste management and bioremediation. The aim of this study is to evaluate the adsorption performance of nanomaterials synthesized from various agricultural bio-wastes found in the Black Sea Region, primarily tea waste, walnut shells, corn cobs, and hazelnut shells, using environmentally friendly methods, and to reveal their pollution removal potential in wastewater. In this study, the importance of nanomaterials in terms of sustainable waste management and low-cost water treatment is evaluated in line with literature data.

Keywords: Adsorption, bioremediation, environmental pollution, nanoadsorbents, wastewater,

INTRODUCTION

The rapid increase in the world's population is placing serious pressure on water resources. According to 2022 data, more than 2.1 billion people lack access to safe drinking water, and 144 million people directly consume untreated surface water (WHO, 2023). With increasing population, urbanization, industrialization, and intensified agricultural activities, global water demand is increasing by approximately 1% annually, and this usage is projected to rise by 20-50% by 2050 (UN, 2024).

Population growth negatively impacts not only the quantity of water but also its quality. While the agricultural sector alone consumes approximately 70% of global freshwater extraction, industrial and domestic uses also account for a significant share (Boretti & Rosa, 2019). Particularly in developing countries, more than 80% of wastewater is discharged into water sources without any treatment, leading to the accumulation of various pollutants such as heavy metals, synthetic dyes, pharmaceutical residues, antibiotics, and pathogens in aquatic ecosystems (UN, 2024).

Turkey, with an annual per capita water availability of approximately 1,519 m^3, is categorized as a "water-scarce country," and this figure is expected to decrease to 1,120 m^3 by 2030 (Turkish Statistical Institute, 2022). Intensive mining, agricultural, and urbanization activities in many regions of the country, particularly in the Black Sea region, threaten local water resources with heavy metals, organic pollutants, and sedimentation. The inadequacy of traditional water treatment methods against these complex pollutants negatively impacts both ecosystem health and human health (Arıman et al., 2007).

These global and national pressures highlight the limitations of classical treatment technologies and make the need for innovative, sustainable, cost-effective, and environmentally friendly water treatment solutions more urgent than ever. In this context, advanced materials technologies such as nanoparticle-based adsorbents stand out as promising alternatives.

Environmental Pollution and Wastewater Problems

Today, the rapid increase in industrialization, mining activities, and unplanned urbanization is leading to the accumulation of heavy metals, synthetic dyes, antibiotics, and various organic pollutants in water sources. These pollutants disrupt the chemical balance of aquatic ecosystems and permanently reduce water quality in the long term.

Mining activities, particularly concentrated in the Black Sea region, cause wastewater to directly mix with river and coastal ecosystems (Yılmaz et al., 2016). These metals enter the food chain through bioaccumulation by dissolving in water or accumulating in sediments , creating toxic effects on fish, aquatic organisms, and ultimately human health.

Traditional water treatment methods have disadvantages such as high operating costs, excessive energy consumption, intensive chemical use, and especially the formation of secondary sludge, which significantly limit their sustainability (Guerra et al., 2018). Furthermore, traditional methods are unable to adequately remove low concentrations of pollutants (especially heavy metals).

Wastewater Discharge Standards and Legal Limits

In Türkiye, there are legal standards that must be followed when discharging wastewater into sewage systems. The limit values set, especially for heavy metals, highlight the importance of wastewater treatment processes.

Parameter	Wastewater infrastructure facilities with sewerage systems that result in biological or equivalent treatment.	Wastewater infrastructure facilities with sewage systems resulting in deep sea discharge.
Heat	40 ˚C	40 ˚C
pH	6-10	6-10
Suspended solids (SS)	500 mg/L	350 mg/L
Sulfate (SO_4^{-2})	1700 mg/L	1700 mg/L
Arsenic (As)	3 mg/L	10 mg/L
Total lead (Pb)	3 mg/L	3 mg/L
Total mercury (Hg)	0.2 mg/L	0.2 mg/L
Total cadmium (Cd)	2 mg/L	2 mg/L
Total cyanide (CN^-)	10 mg/L	10 mg/L
Total chromium (Cr)	5 mg/L	5 mg/L
Free chlorine	5 mg/L	5 mg/L
Total sulfur (S)	2 mg/L	2 mg/L
Total copper (Cu)	2 mg/L	2 mg/L
Total nickel (Ni)	5 mg/L	5 mg/L
Total zinc (Zn)	10 mg/L	10 mg/L
Total tin (Sn)	5 mg/L	5 mg/L
Total silver (Ag)	5 mg/L	5 mg/L
Chloride (Cl^-)	10000 mg/L	-

Table 1: Water Pollution Control Regulation, 2004

The Importance of Green Nanotechnology

In the face of these problems, green nanotechnology stands out as a promising and environmentally friendly solution. Although green synthesis is less efficient under current conditions, it is widely preferred because it does not require energy and takes place under environmentally friendly conditions, making the process safer (Çiftçi et al., 2021).

In green nanotechnology principles, nanoparticle synthesis is carried out using bioactive components from plant waste. This method offers an environmentally friendly, economical, biocompatible, and sustainable approach as it does not require toxic chemical reducers and stabilizers (Sangma , 2025). Thanks to their high surface area and reactive functional groups, nanoparticles can adsorb or degrade pollutants in wastewater more effectively (Beni & Jabbari , 2022).

Biowaste Potential of the Black Sea Region

The Black Sea Region is one of Türkiye's important agricultural regions, leading in the production of tea, hazelnuts, corn, and walnuts (Öztürk & Serttaş, 2018). On average, the Black Sea Region produces 1,350,000 tons of fresh tea, 36,000 tons of walnuts, 278,000 tons of hazelnuts, and 264,000 tons of corn annually (Chamber of Agricultural Engineers, 2018; Öztürk & Serttaş, 2018).

These intensive agricultural activities generate thousands of tons of biowaste every year . Utilizing this biowaste in nanomaterial synthesis will improve waste management and make tangible contributions to the circular economy model.

COMMON BIOWASTE IN THE BLACK SEA REGION

Due to its geographical structure and climatic characteristics, the Black Sea Region accounts for a large portion of Türkiye's tea, hazelnut, walnut, and corn production (Chamber of Agricultural Engineers, 2018; Öztürk & Serttaş, 2018).

Tea Waste

All tea production in Turkey comes from the Black Sea Region (Öztürk & Serttaş, 2018). Waste tea pulp from tea factories and used leaves from households contain high amounts of polyphenols. This rich chemical composition acts as a strong biological reducing agent and coating agent in the reduction of metal ions to their zero-valent forms (Sun et al., 2014). Due to its abundant availability and zero cost, tea waste is among the most frequently preferred biowaste in green synthesis studies (Lunge et al., 2014).

Hazelnut Shells

The Black Sea Region accounts for a large portion of Turkey's hazelnut production. Hazelnut shell waste from processing plants contains high levels of lignin (40-45%), cellulose, and hemicellulose. This rigid lignocellulosic structure plays a role in nanomaterial synthesis both as a natural support material/carrier matrix and as an element that increases adsorption capacity through the functional groups on its surface. It is also frequently used in the production of carbon-based magnetic nanocomposites (Sayın et al., 2016; Shaikhiev et al., 2022).

Walnut Shells

Walnut shells are very rich in various phenolic compounds, primarily juglone (5-hydroxy-1,4-naphthoquinone) (Yolcu et al., 2020). The hard, porous, and stable structure of walnut shells positively contributes to the stabilization of synthesized nanomaterials and their adsorption performance in wastewater treatment (Albatrni et al., 2022).

Corn Cob

lignocellulosic structure containing high levels of cellulose, hemicellulose, and lignin , and are also rich in biomolecules such as flavonoids, phenolic compounds, and proteins. These components can be used as both reducing and coating (stabilizing) agents in the green synthesis of nanoparticles (Mohammed et al., 2022; Gour & Jain , 2019).

GREEN SYNTHESIS OF NANOMATERIALS

Green Synthesis Mechanisms

Green synthesis mechanisms are based on the principle that natural components in biowaste chemically reduce and then stabilize metal ions. Bioactive molecules such as polyphenols, flavonoids, proteins, and carbohydrates found in plant waste function as both reducing and coating agents (Singh et al., 2023).

In this process, polyphenols convert metal ions into zero -valent (M^0) metallic nanoparticle forms while they themselves are oxidized to quinone structures. These oxidized compounds form a protective layer around the nanoparticle core, preventing particle aggregation and providing colloidal stability (Kuang et al., 2021).

For example, the high polyphenol content in tea waste extract reacts with iron salts ($FeCl_3$) to reduce Fe^{3+} ions to nano-zero valence iron (nZVI) or magnetite (Fe_3O_4) nanoparticles (Huang et al., 2014; Rodríguez-Rasero et al., 2024).

lignocellulosic wastes such as corn cobs , the mechanism is slightly different. Corn cob ash, which has a high silica content, is converted to sodium silicate by alkaline extraction, and then porous nanosilica structures are obtained by applying a sol-gel process with acid neutralization (Vaibhav et al., 2015; Pieta et al., 2020).

In hazelnut and walnut shells, the lignocellulosic matrix, thanks to its rich phenolic and flavonoid content, functions both as a reducing agent and, with its porous structure, serves as a natural carrier and stabilizing substrate for nanoparticles (Bordbar et al., 2017; Büyükkaya et al., 2026).

Utilizing these wastes in green synthesis offers a more sustainable nanotechnology approach by improving agricultural waste management and reducing the use of toxic chemicals.

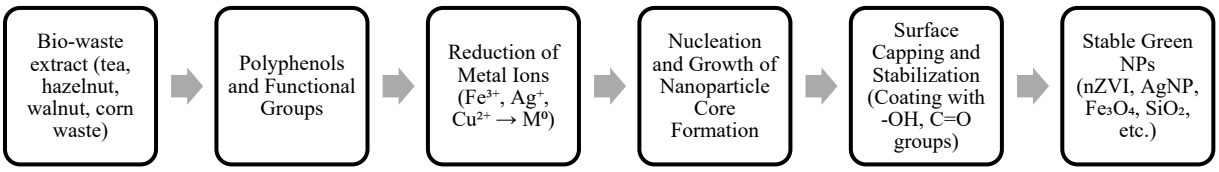

Figure 1. Activation, growth, and biocoating (stabilization) mechanism of green nanoparticle synthesis using agricultural biowaste extracts (adapted from Parveen et al., 2016; Guerra et al., 2018).

Nanomaterials Produced from Biowaste

In the literature, nZVI , Fe3O4, silver (AgNP), and copper (CuNP) nanoparticles have been successfully synthesized from tea waste ; while carbon-supported magnetic composites and functional AgNPs have been obtained from hazelnut and walnut shells. From corn cob ashes, mainly high surface area SiO2 (silica), AgNP , and copper oxide (CuO) nanoparticles are produced (Vaibhav et al., 2015).

Characterization Techniques

To fully elucidate the structural, morphological, chemical, and surface properties of the synthesized green nanomaterials, a combination of the following advanced analytical techniques is used:

- **UV- Vis Spectroscopy: A useful and simple technique for measuring** the mass concentration of nanoparticles according to the Beer -Lambert law. It is used to measure the light absorbed and scattered by a sample.
- **Fourier Transform Infrared Spectroscopy (FTIR):** This is an effective method used to characterize the presence, binding pattern, and surface interactions of adsorbate molecules on the nanomaterial surface.
- **Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM):** Along with visualization of nanoparticles, properties such as shape, size, structure, distribution, absorption, and aggregation can also be observed .
- **X-ray Diffraction (XRD):** A non-destructive analysis technique used to determine whether a material is amorphous or crystalline, phase purity, and to calculate the average crystal size using the Debye-Scherrer equation.
- **BET Surface Area Analysis:** This common method quantitatively indicates the potential adsorption capacity of a material by measuring the specific surface area of solids and nanoparticles through gas adsorption.

- **Zeta Potential and Dynamic Light Scattering (DLS):** A common method used for sizing nanoparticles and determining their aggregation in suspensions. DLS is also fast, *in situ* . *and* also provides real-time dimension analysis capabilities .
- **Energy Dispersive X-ray Spectroscopy (EDS):** Confirms the purity and elemental percentages of the nanomaterial through elemental analysis (Dağlıoğlu & Özkan Yılmaz, 2018).

LITERATURE AND PRACTICES FOR ENVIRONMENTAL POLLUTION REMOVAL

Applications in the literature show that nanomaterials obtained through green methods demonstrate high performance in pollution removal.

Biowaste Source	Nanomaterials	Target Pollutant	Cost Efficiency	Source
Hazelnut shell	Activated Carbon	Heavy metal: Cu	88.70%	Bozbeyoğlu (2023)
Walnut shell	Nano Graphene Oxide (NGO)	Antibiotic: Trimethoprim	218 mg/g	Carrales-Alvarado et al. (2020)
Tea Waste	nZVI	Paint: Methyl Orange	100%	Rodrîguez-Rasero vd. (2024)
Walnut shell	Activated Carbon	Heavy metal: Hg(II)	151.5 mg/g	Zabihi et al. (2009)
—	ZnONP	Heavy metal: Cd (II)	384 mg/g	Sheela et al. (2012)
Corn Cob	Activated Carbon	Heavy metal: Cu	99.53%	Al- sanjari et al. (2025)
Corn Cob	Activated Carbon	Dye: Methylene Blue	295.5 mg/g	Bozbeyoğlu et al. (2020)
—	Fe_3O_4	Paint: Methylene Blue	138 mg/g	Joshi vd. (2019)
Corn Cob	Activated Carbon	Heavy Metal: Fe	68.20%	Al- sanjari et al. (2025)
Walnut shell	ZnONP	Antibiotic: Trimethoprim	118,782 mg/g	Aldabagh & Hummadi (2024)
—	Nano Graphene Oxide (NGO)	Antibiotic: Tetracycline	50%	Ghadim et al. (2013)

Table 2: Biowaste commonly found in the Black Sea Region in removing different water pollutants and literature data.

ADVANTAGES, LIMITATIONS, AND FUTURE PERSPECTIVES

Advantages of Nanomaterials Derived from Biowaste

These nanomaterials, produced using green methods, have numerous advantages such as zero or very low-cost use of local raw materials, a biocompatible production process free from toxic chemicals, and the potential to provide a high surface area (Guerra et al., 2018).

The rich polyphenol content of the Black Sea region, in particular, eliminates the need for an additional reducing agent, thus reducing costs.

Current Challenges

However, the rapid aggregation (clumping) of the synthesized nano-sized particles in aqueous environments, resulting in the loss of their active surface area, long-term stability problems, and the complex ionic matrix effects present in real wastewater are the biggest limitations of the method at the industrial scale (Guerra et al., 2018).

Potential Impacts on the Environment and Human Health

Although nanomaterials produced through green synthesis are more biocompatible, nanoparticles can overcome biological barriers and their long-term effects are much less well-documented. Therefore, comprehensive toxicity tests, ecotoxicity analyses, and long-term environmental impact assessments should be carried out on green-synthesized nanomaterials before application (Dalyan, 2022).

Future Perspectives

bio-waste- derived green nanomaterials in wastewater treatment on a commercial and industrial scale, future research should focus on the following strategic areas:

1. **Scale -up and Continuous Flow Systems:** Much of the literature is limited to laboratory-scale batch systems . Future research should focus on continuous-flow fixed-bed column reactors that simulate the dynamics of real wastewater treatment plants. column It is of great importance to focus on reactors and pilot-scale field applications.

2. **Real Wastewater Matrices and Selectivity: Instead of synthetic solutions,** the study should be conducted with real industrial and domestic wastewater containing numerous competing ions, surfactants , and organic matter. The selectivity and interference effects of the synthesized nanomaterials in complex matrices must be optimized.

3. **Regeneration and Cyclical Life:** To prove economic feasibility, the desorption (recovery) capacities of nanomaterials should be investigated, and their reusability (how many cycles they can be reused for without losing their structural stability) should be determined. Furthermore, safe disposal scenarios should be developed for end-of-life nanomaterials to prevent secondary pollution.

4. **Integrated Life Cycle Analysis (LCA) and Techno-Economic Analysis (TEA):** Comprehensive Life Cycle Analyses (LCAs) should be conducted for green synthesis processes, considering energy consumption in raw material logistics, drying, extraction, and purification steps. These analyses should be supported by Techno-Economic Analyses (TEAs) that reveal the true cost and commercial market value of the process.

CONCLUSION

biowaste generated annually as a result of agricultural activities in the Black Sea Region offer extremely valuable, renewable, and low-cost raw materials for nanomaterial synthesis within the scope of green nanotechnology.

These wastes, due to their high content of polyphenolic compounds, lignocellulosic structures, and natural reducing agents, play an effective role in single-step or low-energy green synthesis processes without the need for toxic chemicals used in chemical synthesis. For example, polyphenols obtained from tea waste act as both reducing and coating agents, stabilizing materials such as nZVI , AgNP , Fe_3O_4 , and nanosilica . Lignocellulosic fractions in hazelnut and walnut shells offer ideal precursors for carbon-based support materials or biochar- based nanocomposites. This approach directly contributes to the regional economy by transforming waste into value-added products instead of waste disposal costs.

Current studies in the literature reveal that nanoparticles synthesized from these wastes based on polyphenol and lignocellulosic structures provide a highly efficient, economical, and environmentally friendly approach to the removal of heavy metals, synthetic dyes, antibiotics, and other organic pollutants. Particles obtained through green synthesis generally exhibit superior adsorption and photocatalytic performance due to their smaller size, better dispersibility , and surface functional groups compared to traditional chemical methods. Furthermore, Fe-based nanoparticles with magnetic properties offer the advantage of being easily separated from water, minimizing the risk of secondary pollution.

This review demonstrates that green nanomaterials derived from bio-waste contribute to circular economy principles and offer a potential local and sustainable solution to mining and agricultural water pollution in the Black Sea region. The region's humid climate and intensive agricultural production ensure a continuous supply of bio-waste , thereby reducing the logistical costs of raw materials.

Given the high energy consumption, sludge formation, use of toxic chemicals, and selectivity limitations of traditional treatment methods, green synthesis methods represent a significant alternative. Nanomaterials exhibit more effective and targeted performance, especially with low-concentration pollutants and complex matrices.

In conclusion, leveraging the rich biowaste potential of the Black Sea Region through green nanotechnology is a strategic approach that will both improve waste management and contribute to the conservation of water resources. Future multidisciplinary (chemistry, environmental engineering, agriculture, materials science) and application-oriented studies in this field hold significant opportunities for sustainable environmental management, regional development, and the green economy.

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PRELIMINARY DATA ON THE BEHAVIORAL EFFECTS OF ROSEMARY ESSENTIAL OIL IN ZEBRAFISH (*DANIO RERIO*) AFTER TARTRAZINE EXPOSURE

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ABSTRACT

Tartrazine (TZ) is a synthetic food dye widely used in the food industry and has been associated in numerous studies with adverse effects on the nervous system and behavioral alterations. In contrast, rosemary essential oil (REO) is recognized for its antioxidant, anti-inflammatory, and neuroprotective properties and has been investigated for its potential to counteract the effects induced by various neurotoxic agents. Considering these aspects, the present study aimed to

evaluate the impact of TZ exposure on the behavior of zebrafish (*Danio rerio*) and to assess the potential restorative effects of REO. For this purpose, zebrafish were exposed to TZ for 7 days, followed by REO treatment for 3 days. Behavioral changes were assessed using the social preference test and the novel tank test, two commonly employed methods for evaluating locomotor activity, exploratory behavior, and anxiety-like responses. In the social preference test, no significant differences were observed in overall locomotor activity. However, TZ exposure induced alterations in exploratory behavior and social responsiveness. Subsequent administration of REO partially alleviated these effects, suggesting a beneficial influence on behavioral functions affected by TZ. Results from the novel tank test revealed increased locomotor activity and enhanced exploration of the upper tank area in fish exposed to TZ and subsequently treated with REO. These behavioral changes may reflect alterations in the mechanisms involved in stress responses and anxiety regulation. In conclusion, TZ exposure affected zebrafish behavior, particularly by modifying exploratory activity and anxiety-related responses. Although behavioral parameters were not completely restored, REO treatment demonstrated a partial protective effect, highlighting its potential role in mitigating TZ-induced neurobehavioral alterations.

Keywords: Toxicity; Tartrazine; Zebrafish; Behavior; Rosemary Essential Oil

MODELING OF THE DRYING KINETICS OF GREEN UBÁ MANGO PEEL BY INFRARED DRYING

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ABSTRACT

Green Ubá mango peel (*Mangifera indica* L.) is an agro-industrial by-product rich in dietary fiber, phenolic compounds, condensed tannins, and mangiferin, with significant potential for application as a functional ingredient. Due to its high moisture content, drying is an essential step for its preservation and industrial utilization. This study aimed to evaluate the drying kinetics of green Ubá mango peel using an infrared moisture analyzer and to identify the mathematical model that best describes the drying process. The experiments were conducted at 50, 75, and 90 °C, in triplicate, with automatic recording of moisture content every minute until hygroscopic equilibrium was reached. Approximately 10 g of sample with an initial moisture content of 2.7404 $g \cdot g^{-1}$ (dry basis) was used. The moisture ratio curves were fitted to thirteen mathematical models, which were evaluated based on the coefficient of determination (R^2), mean relative error (P), and residual distribution. Increasing the drying temperature significantly reduced the drying time, from 325 min at 50 °C to 82 min at 90 °C. Among the evaluated models, the Midilli model showed the best performance at all temperatures, presenting the highest R^2 values, the lowest mean relative errors, and a random distribution of residuals. The results indicate that the infrared moisture analyzer is an efficient tool requiring only a small sample amount for the rapid determination of drying kinetic parameters, with potential application in optimizing the technological utilization of agro-industrial residues.

Keywords: *Mangifera indica*; agro-industrial residue; mathematical models; Midilli model; moisture analyzer.

THE EVALUATION OF THE RELATIONSHIP BETWEEN NUTRITIONAL KNOWLEDGE LEVEL AND CARBOHYDRATE CONSUMPTION PREFERENCES IN ADULTS FROM A SUSTAINABLE NUTRITION PERSPECTIVE

YETİŞKİN BİREYLERDE BESLENME BİLGİ DÜZEYİNİN KARBONHİDRAT TÜKETİM TERCİHLERİ İLE İLİŞKİSİNİN SÜRDÜRÜLEBİLİR BESLENME PERSPEKTİFİNDEN DEĞERLENDİRİLMESİ

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ÖZET

Amaç: Bu araştırmanın amacı, yetişkin bireylerin temel beslenme bilgi düzeyleri ile hem bireysel sağlık hem de sürdürülebilir yaşam için kritik öneme sahip olan rafine/kompleks karbonhidrat tüketim tercihleri ve fiili makro/mikro besin ögesi alımları arasındaki ilişkinin çok boyutlu olarak incelenmesidir.

Yöntem: Bu çalışma, Kocaeli ilinde yaşayan 19-64 yaş aralığındaki toplam 400 gönüllü yetişkin (261 kadın, 139 erkek) katılımıyla yürütülmüştür. Sürdürülebilir beslenme alışkanlıklarının ve tüketim tercihlerinin değerlendirilmesi amacıyla toplanan araştırma verileri; Sosyodemografik Özellikler Formu, Yetişkinler İçin Temel Beslenme Bilgi Düzeyi Ölçeği (YETBİD) ve Beslenme Tutum Ölçeği (BTÖ) aracılığıyla elde edilmiştir. Katılımcıların fiili besin tüketimleri 24 saatlik geriye dönük hatırlatma yöntemiyle alınmış ve BEBİS 9.0 programı kullanılarak analiz edilmiştir. Objektif antropometrik ölçümler ile subjektif algılanan kilo durumları arasındaki tutarlılık Cohen's Kappa testi ile değerlendirilmiştir.

Bulgular: Katılımcıların %40,5'inin fazla kilolu veya obez olduğu saptanmıştır. Cohen's Kappa analizi, gerçek VKİ ile algılanan kilo durumu arasında orta düzeyde ($k = 0.548$, $p < 0.001$) bir uyum gösterirken; ağırlık durumu arttıkça öznel beden imajı algısında gerçeği hafife alma eğiliminin baş gösterdiği saptanmıştır. YETBİD ve BTÖ ölçek skorlarında kadın katılımcıların erkeklere kıyasla anlamlı derecede daha yüksek puanlar elde ettiği saptanmıştır ($p<0.05$). Günlük lif alımını olumlu yönde artıran, sürdürülebilir diyet modellerinin temel bileşeni olan kompleks karbonhidratlar kadınların diyetinde arttığı belirlenirken ($p<0.05$), erkeklerde rafine karbonhidrat tüketim alışkanlığının baskınlığını koruduğu görülmüştür. Korelasyon analizlerinde; beslenme bilgi düzeyleri ile fiili günlük enerji ve besin alımları arasında istatistiksel olarak anlamlı bir ilişki bulunamamıştır ($p>0.05$).

Sonuç: Araştırmada beslenme bilgisinin fiili tüketime yansımaması, literatürdeki "Bilgi-Davranış Boşluğu" fenomenini ve ağırlık yönetimindeki bilişsel algı bariyerlerini desteklemektedir. Teorik beslenme bilgisinin sağlıklı davranışa dönüşmesinde sosyo-ekonomik etmenler, zaman kısıtlılığı ve endüstriyel gıda arzı gibi bariyerlerin etkili olduğu düşünülmektedir. Hem toplum sağlığının korunması hem de çevre dostu ve sürdürülebilir gıda

tüketim alışkanlıklarının yaygınlaştırılması amacıyla, gelecekteki beslenme müdahalelerinin sadece bilgi aktarımı düzeyinde kalmayıp, porsiyon farkındalığı ve bilişsel pratiklerle desteklenmesi önerilmektedir.

Anahtar Kelimeler: Beslenme Bilgi Düzeyi, Karbonhidrat Tercihleri, Rafine Karbonhidrat, Kompleks Karbonhidrat, Bilgi-Davranış Boşluğu, Sürdürülebilir Beslenme, BEBİS, BTÖ, YETBİD

ABSTRACT

Aim: This study aims to multidimensionally examine the relationship between adults' basic nutritional knowledge levels and their refined/complex carbohydrate consumption preferences and actual macro/micro nutrient intakes, which are of critical importance for both individual health and sustainable living.

Methods: This study was conducted with 400 volunteer adults (261 female, 139 male) aged 19-64 residing in Kocaeli, Turkey. Research data collected to evaluate sustainable dietary habits and consumption preferences were obtained via a Sociodemographic Characteristics Form, the Basic Nutritional Knowledge Level Scale for Adults (YETBİD), and the Dietary Attitude Scale (BTÖ). Participants' actual food consumption was assessed using the 24-hour dietary recall method and analyzed with the BEBİS 9.0 program. The consistency between objective anthropometric measurements and subjective perceived weight status was evaluated using Cohen's Kappa test.

Results: 40.5% of participants were found to be overweight or obese. Cohen's Kappa analysis showed moderate agreement ($\kappa = 0.548$, $p < 0.001$) between actual BMI and perceived weight status, with an increasing tendency toward underestimation of body image as weight status increased. Female participants scored significantly higher than males on YETBİD and BTÖ scales ($p < 0.05$). Complex carbohydrate intake — a core component of sustainable dietary models that positively increases daily fiber intake — was found to be higher in women's diets ($p < 0.05$), while refined carbohydrate consumption remained dominant among men. Correlation analyses revealed no statistically significant relationship between nutritional knowledge levels and actual daily energy and nutrient intakes ($p > 0.05$).

Conclusion: The failure of nutritional knowledge to reflect on actual consumption supports the "Knowledge-Behavior Gap" phenomenon and cognitive perception barriers in weight management found in the literature. Socioeconomic factors, time constraints, and industrial food supply are considered effective barriers in translating theoretical nutritional knowledge into healthy behavior. It is recommended that future nutritional interventions, aimed at both protecting public health and promoting environmentally friendly and sustainable food consumption habits, should go beyond mere knowledge transfer and be supported by portion awareness and individualized nutritional counseling.

Keywords: Nutritional Knowledge Level, Carbohydrate Preferences, Refined Carbohydrate, Complex Carbohydrate, Knowledge-Behavior Gap, Sustainable Nutrition, BEBİS, BTÖ, YETBİD

RECOVERY OF VALUABLE RESOURCES FROM OLIVE MILL WASTEWATER AND OLIVE POMACE

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ABSTRACT

Olive oil production generates large quantities of olive mill wastewater (OMW) and olive pomace, which pose significant environmental challenges due to their high organic load, phenolic content, and phytotoxicity. Their improper disposal can negatively impact soil and water quality, highlighting the need for sustainable treatment and valorization strategies.

This study investigates the integrated valorization of OMW and olive pomace through physicochemical and biological processes combined with resource recovery approaches. Different pathways, including polyphenol extraction, composting, anaerobic digestion, and nutrient recovery, are explored to reduce environmental impacts while producing value-added products.

The proposed strategies are evaluated in terms of pollutant reduction, organic matter stabilization, and recovery of bioactive compounds and reusable materials such as organic fertilizers and soil amendments. Particular attention is given to phenolic compounds because of their antioxidant properties and potential applications in food, pharmaceutical, and cosmetic sectors.

Results indicate that integrated valorization approaches can significantly improve the sustainability of olive mill residue management by promoting resource recovery and reducing waste generation. Such strategies support circular economy principles and contribute to the sustainable development of the olive oil industry.

Keywords: olive mill wastewater, olive pomace, polyphenols, resource recovery, composting, circular economy, agro-industrial waste valorization.

EVALUATION OF MICROBIOTA AWARENESS LEVELS AMONG HEALTHCARE PROFESSIONALS FROM A SUSTAINABLE NUTRITION PERSPECTIVE

SAĞLIK ÇALIŞANLARINDA MİKROBİYOTA FARKINDALIK DÜZEYİNİN SÜRDÜRÜLEBİLİR BESLENME PERSPEKTİFİNDEN DEĞERLENDİRİLMESİ

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ÖZET

Amaç: Bağırsak mikrobiyotası; beslenme alışkanlıkları, bağışıklık fonksiyonları ve kronik hastalıkların gelişiminde önemli rol oynamaktadır. Bitkisel kaynaklı, posa açısından zengin ve sürdürülebilir beslenme modellerinin bağırsak mikrobiyotasını olumlu yönde etkilediği bilinmektedir. Bu çalışma, sağlık çalışanlarının mikrobiyota farkındalık düzeylerini belirlemeyi ve sürdürülebilir beslenme yaklaşımlarının yaygınlaştırılmasında önemli role sahip sağlık profesyonellerinin bilgi düzeylerini değerlendirmeyi amaçlamıştır.

Yöntem: Kesitsel tipte yürütülen pilot niteliğindeki bu çalışmaya 42 sağlık çalışanı (hekim, hemşire, diyetisyen ve diğer sağlık profesyonelleri) dahil edilmiştir. Veriler çevrim içi anket ve Mikrobiyota Farkındalık Ölçeği (MFÖ) aracılığıyla toplanmıştır. İstatistiksel analizlerde parametrik olmayan Mann-Whitney U, Kruskal-Wallis ve Spearman korelasyon testleri kullanılmıştır.

Bulgular: Katılımcıların %76,2'si kadın olup yaş ortalaması ağırlıklı olarak 35-49 yaş grubunda yoğunlaşmıştır. MFÖ toplam puanı yaş gruplarına göre anlamlı farklılık göstermiş, 50-64 yaş grubunun puanları 25-34 yaş grubundan daha yüksek bulunmuştur ($p=0,027$). Meslek grupları arasında ölçeğin kronik hastalık alt boyutunda anlamlı farklılık saptanmış ($p<0,001$), diyetisyenlerin toplam farkındalık puanlarının hemşirelerden daha yüksek olduğu belirlenmiştir ($p=0,021$). Mikrobiyota konusunda eğitim almak isteyen katılımcıların MFÖ toplam puanları anlamlı düzeyde daha yüksek bulunmuştur ($p=0,005$). MFÖ toplam puanına ilişkin Cronbach alfa katsayısı 0,802 olarak hesaplanmış ve ölçeğin toplam puan düzeyinde iyi düzeyde iç tutarlılığa sahip olduğu belirlenmiştir.

Sonuç: Kısıtlı sayıda katılım ile kesitsel tipte yürütülen bu pilot çalışmada, sağlık çalışanlarının mikrobiyota farkındalık düzeyleri yaş, meslek ve eğitim alma isteğinden etkilendiği belirlenmiştir. Mikrobiyota farkındalığının artırılması; sürdürülebilir beslenme, bağırsak sağlığının korunması ve kronik hastalıkların önlenmesine yönelik kanıta dayalı beslenme önerilerinin yaygınlaştırılmasına katkı sağlayabilir. Sağlık profesyonellerine yönelik eğitim programlarının geliştirilmesi sürdürülebilir ve sağlığı destekleyen beslenme davranışlarının toplumda yaygınlaşmasına destek olabilir.

Anahtar Kelimeler: Sürdürülebilir Beslenme, Mikrobiyota Farkındalığı, Mikrobiyota Farkındalık Ölçeği (MFÖ), Sağlık Çalışanları.

ABSTRACT

Objective: Gut microbiota plays a critical role in dietary habits, immune functions, and the development of chronic diseases. Sustainable dietary patterns characterized by plant-based and fiber-rich foods have been shown to positively influence gut microbiota composition and diversity. This study aimed to determine the microbiota awareness levels of healthcare professionals and to evaluate their knowledge as key stakeholders in promoting sustainable nutrition practices.

Methods: This pilot cross-sectional study included 42 healthcare professionals, comprising physicians, nurses, dietitians, and other healthcare staff. Data were collected through an online questionnaire and the Microbiota Awareness Scale (MAS). Non-parametric statistical analyses, including the Mann–Whitney U test, Kruskal–Wallis test, and Spearman correlation analysis, were performed.

Results: Of the participants, 76.2% were female, and the majority were between 35 and 49 years of age. Total MAS scores differed significantly across age groups, with participants aged 50–64 years demonstrating higher scores than those aged 25–34 years ($p=0.027$). Significant differences were observed among professional groups in the Chronic Disease subscale ($p<0.001$), and dietitians had significantly higher total awareness scores than nurses ($p=0.021$). Participants willing to receive education on microbiota had significantly higher total MAS scores compared with those who were not willing to receive such education ($p=0.005$). The Cronbach's alpha coefficient for the total MAS score was calculated as 0.802, indicating good internal consistency.

Conclusion: In this pilot cross-sectional study conducted with a limited sample size, microbiota awareness levels among healthcare professionals were found to be associated with age, profession, and willingness to receive education. Increasing microbiota awareness may contribute to the dissemination of evidence-based nutritional recommendations aimed at promoting sustainable nutrition, maintaining gut health, and preventing chronic diseases. Developing educational programs for healthcare professionals may support the adoption of sustainable and health-promoting dietary behaviors within society.

Keywords: Sustainable Nutrition, Microbiota Awareness, Microbiota Awareness Scale (MAS), Healthcare Professionals.

DEVELOPMENT OF A REGENERABLE PANI@CLAY COMPOSITE FOR SUSTAINABLE WASTEWATER DEPOLLUTION: CASE OF ERIOCHROME BLACK T

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ABSTRACT

Dealing with hazardous industrial dyes in wastewater remains a major challenge for environmental scientists worldwide. In this study, we developed and evaluated a polyaniline@clay (PANI@clay) composite specifically engineered to tackle the efficient removal of Eriochrome Black T (EBT), a highly toxic azo dye. We successfully synthesized the material and confirmed the firm immobilization of polyaniline onto the natural clay matrix using a combination of Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Spectroscopy (EDS), X-ray Diffraction (XRD), and Raman spectroscopy. To understand its true

potential, we investigated the adsorption performance through batch experiments, carefully optimizing operating parameters such as adsorbent dosage, contact time, initial dye concentration, and temperature. Our kinetic data revealed that EBT adsorption perfectly matches the pseudo-second-order model. On the other hand, the equilibrium data fitted best with the Freundlich isotherm, which suggests that the dye forms multilayers on the heterogeneous active sites of the composite surface. Under ideal conditions, the PANI@clay composite achieved an impressive maximum adsorption capacity of 258 mg/g. Crucially, regeneration tests proved that the composite is highly reusable, maintaining its top-tier efficiency over multiple consecutive cycles. These practical results clearly show that our PANI@clay composite stands out as a budget-friendly, stable, and truly green alternative for sustainable water depollution.

Keywords: PANI@clay; Eriochrome Black T; Adsorption; Kinetics; Freundlich isotherm.

DEVELOPMENT OF GLUTEN-FREE GRISSINI USING PELEMIR (*CEPHALARIA SYRIACA*) SEED FLOUR

PELEMİR (*CEPHALARIA SYRIACA*) TOHUMU UNU KULLANILARAK GLUTENSİZ GRİSSİNİ GELİŞTİRİLMESİ

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ÖZET

Glutensiz fırıncılık ürünleri, çölyak hastalığı, gluten duyarlılığı ve alternatif beslenme eğilimlerine olan ilginin artması nedeniyle giderek daha fazla önem kazanmaktadır. Bununla birlikte, fırıncılık formülasyonlarında glutenin bulunmaması hamur işlenebilirliği, tekstür, görünüş ve duyusal kabul edilebilirlik üzerinde olumsuz etkilere neden olabilmektedir. Bu nedenle, glutensiz ürün geliştirme çalışmalarında yerel ve alternatif bitkisel bileşenlerin kullanımı fonksiyonel ve duyusal açıdan önemli avantajlar sağlayabilir. Bu çalışmada, pelemir (*Cephalaria syriaca*) tohumu unu kullanılarak glutensiz grissini geliştirilmesi ve farklı kullanım oranlarının duyusal özellikler ile hamur işlenebilirliği üzerindeki etkilerinin değerlendirilmesi amaçlanmıştır. Çalışma kapsamında, pelemir tohumu unu içermeyen kontrol örneği ile %0,5, %0,75 ve %1 oranında pelemir tohumu unu içeren üç farklı deneme grubu olmak üzere toplam dört grissini formülasyonu hazırlanmıştır. Ürünler, 10 yarı eğitimli panelist tarafından 9 puanlı duyusal değerlendirme ölçeği kullanılarak görünüş, renk, koku, tat/lezzet, yüzey düzgünlüğü, tekstür ve genel kabul edilebilirlik açısından değerlendirilmiştir. Tüm

formülasyonların duyusal değerlendirme puanlarının kabul edilebilir düzeyde olduğu belirlenmiştir. Kontrol örneği görünüş ve yüzey düzgünlüğü açısından daha yüksek puan alırken, pelemir unu ilaveli örneklerde tat/lezzet, tekstür ve genel kabul edilebilirlik puanlarının arttığı görülmüştür. En yüksek genel kabul edilebilirlik puanı %1 pelemir tohumu unu içeren formülasyonda elde edilmiştir. Ayrıca, %1 pelemir unu içeren örneğin hamura şekil verme açısından daha olumlu değerlendirildiği görülmüştür. Sonuç olarak, pelemir tohumu ununun glutensiz grissini üretiminde kullanılabilecek yerel ve alternatif bir bileşen olduğu düşünülmektedir. Gelecek çalışmalarda pelemir ununun öğütme koşulları, teknolojik özellikleri ve besinsel katkılarının daha ayrıntılı olarak incelenmesi önerilmektedir.

Anahtar Kelimeler: Pelemir tohumu, glutensiz, grissini, duyusal değerlendirme

ABSTRACT

Gluten-free bakery products have gained increasing importance due to celiac disease, gluten sensitivity, and the growing demand for alternative food products. However, the absence of gluten in bakery formulations may negatively affect dough handling, texture, appearance, and sensory acceptability. Therefore, the use of local and alternative plant-based ingredients may provide functional and sensory advantages in gluten-free product development. This study aimed to develop gluten-free grissini using pelemir (*Cephalaria syriaca*) seed flour and to evaluate the effects of different inclusion levels on sensory properties and dough processability. Four grissini formulations were prepared: a control sample without pelemir seed flour and three experimental samples containing 0.5%, 0.75%, and 1% pelemir seed flour. The products were evaluated by 10 semi-trained panelists using a 9-point sensory scale in terms of appearance, color, odor, taste/flavor, surface smoothness, texture, and overall acceptability. All formulations received mean scores above the sensory acceptability threshold. The control sample had the highest appearance and surface smoothness scores, whereas pelemir-enriched samples showed higher scores for taste/flavor, texture, and overall acceptability. The highest overall acceptability score was obtained in the formulation containing 1% pelemir seed flour. In addition, the 1% formulation was considered more favorable in terms of dough shaping compared with lower pelemir levels. In conclusion, pelemir seed flour may be considered a promising local and alternative ingredient for gluten-free grissini production. Further studies are recommended to standardize milling conditions and investigate its technological and nutritional effects in gluten-free bakery formulations.

Keywords: Pelemir seed, gluten-free, grissini, sensory evaluation

GİRİŞ

Çölyak hastalığı, çölyak dışı gluten duyarlılığı ve gluten içermeyen beslenme modellerine yönelik ilginin artması, glutensiz ürün pazarına olan ilginin artmasına neden olmuştur (Saleh, 2023). Ancak özellikle glutensiz fırıncılık ürünlerinin geliştirilmesi teknolojik açıdan önemli güçlükler içermektedir. Gluten; hamura elastikiyet ve form kazandıran, fermantasyon sırasında oluşan gazı içerisinde tutan ve pişirme sonrasında ürünün hacim, gözeneklilik ve tekstür özelliklerinin oluşmasına katkı sağlayan temel bir protein ağıdır. Glutenin formülasyonda bulunmaması; düşük hacim, zayıf yapı, aşırı kırılganlık, yüksek sertlik ve düşük duyusal kabul edilebilirlik gibi kalite sorunlarına yol açabilmektedir (Naqash ve ark., 2017; Saleh, 2023).

Glutensiz ürünlerde söz konusu yapısal eksikliklerin giderilmesi amacıyla nişastalar, hidrokolloidler, protein kaynakları ve farklı bitkisel bileşenlerden yararlanılmaktadır (Naqash ve ark., 2017). Özellikle ksantan gam, guar gam ve hidroksipropil metilselüloz gibi

hidrokolloidler hamurun viskozitesini artırarak yapı içerisinde hava ve gaz kabarcıklarının tutulmasına katkı sağlamakta; ürünün sertlik, nem tutma kapasitesi ve gözenek yapısı üzerinde olumlu etkiler gösterebilmektedir (Salehi, 2019). Pirinç unu ve farklı nişasta karışımlarının hidrokolloidler veya enzimlerle desteklenmesi de glutensiz fırıncılık ürünlerinin hacim ve yapısal özelliklerinin iyileştirilmesinde yaygın olarak kullanılan yaklaşımlar arasındadır (Monteiro ve ark., 2021). Ancak güncel ürün geliştirme çalışmalarında yalnızca glutenin teknolojik işlevinin taklit edilmesi yeterli görülmemekte; ürünlerin protein, diyet lifi, yağ asitleri ve biyoaktif bileşenler bakımından zenginleştirilmesi de önem taşımaktadır (Šmídová ve Rysová, 2022; Saleh, 2023).

Ticari glutensiz ürünlerin önemli bir bölümü rafine un ve nişasta temelli formülasyonlardan oluşmaktadır. Bu nedenle besin ögesi yoğunluğunu artırmak amacıyla tohumlar, baklagiller, yalancı tahıllar ve gıda sanayi yan ürünleri gibi alternatif bitkisel kaynakların kullanımı giderek önem kazanmaktadır (Serena ve ark., 2020). Yapılan bir çalışmada aspir tohumu yağı üretiminden elde edilen protein bakımından zengin yan ürünlerin glutensiz muffinlerde kullanılmasıyla hamur reolojisi, viskoelastik yapı, özgül hacim ve tekstür özelliklerinin değiştirilebildiği bildirilmiştir (Kasapoğlu ve Acar, 2025). Ayrıca glutensiz ürünlerde lif bileşenlerinin kullanımı, formülasyonun besinsel değerini artırmanın yanı sıra ürünün yapısal ve teknolojik özelliklerinin iyileştirilmesine de katkı sağlayabileceği belirtilmektedir (González ve ark., 2025).

Grissini, düşük nem içeriği, gevrek yapısı ve uzun raf ömrü nedeniyle glutensiz ürün geliştirme çalışmaları için uygun bir atıştırmalık modelidir. Ekmek ve kekten farklı olarak temel kalite ölçütlerinin hacimden çok gevreklik, sertlik, lezzet ve duyusal kabul üzerine yoğunlaşması, alternatif un ve bitkisel bileşenlerin kullanımını daha uygulanabilir kılmaktadır. (Kınay ve Duyar, 2021).

Pelemir (*Cephalaria syriaca*), Caprifoliaceae familyasının Dipsacoideae alt familyasında yer alan, Anadolu ve Doğu Akdeniz'de doğal yayılış gösteren tek yıllık otsu bir türdür. Tohumlarından elde edilen un, Anadolu'nun bazı bölgelerinde hamurun reolojik özelliklerini geliştirmek amacıyla geleneksel olarak unlu mamullerde kullanılmaktadır (Başar ve ark., 2016). Pelemir, soğuk ve kurak çevre koşullarına uyum sağlayabilmesi, besin ögesi bakımından zengin tohum yapısı ve fırıncılık ürünlerinde teknolojik işlev gösterebilme potansiyeli nedeniyle son yıllarda araştırmalara konu olmaktadır. Pelemir tohumlarının protein, diyet lifi ve yağ bakımından dikkate değer bir bileşime sahip olduğu; yağ fraksiyonunun ise başta oleik ve linoleik asit olmak üzere doymamış yağ asitleri içerdiği bildirilmektedir (Sarikahya ve ark., ,2019). Bunun yanı sıra bitkinin farklı kısımlarında bulunan fenolik bileşikler, flavonoidler ve triterpenler gibi biyoaktif bileşenler, pelemirin fonksiyonel gıda bileşeni olarak değerlendirilme potansiyelini desteklemektedir (Bağdat ve ark., 2024; Kavak ve Baştürk, 2020; Subaşı ve ark., 2021; Selçukbiricik ve ark., 2025). Pelemirin fırıncılık ürünlerinde kullanımı yeni olmamakla birlikte, gerçekleştirilen çalışmaların büyük ölçüde buğday unu içeren hamur ve ekmek sistemleri üzerinde yoğunlaştığı görülmektedir. Pelemir unu ve yağının buğday hamurunun reolojik özelliklerini değiştirebildiği; pelemir unu ilavesinin hamurun işlenebilirliği, ekmek tekstürü ve fiziksel özellikleri üzerinde etkili olabildiği bildirilmiştir (Bağdat ve ark., 2024; Karaoğlu, 2006; Karaoglu, 2012). Benzer şekilde, süne zararına uğramış buğday unundan elde edilen hamur ve ekmeklerde pelemir unu kullanımının fiziksel, reolojik ve tekstürel özellikler açısından iyileştirici etkiler gösterebildiği belirtilmiştir (Başar ve Karaoğlu, 2021). Yakın tarihli bir çalışmada ise pelemir tohumu unu ile zenginleştirilmiş ekmeğin postprandiyal glukoz ve hormonal yanıtlar üzerindeki akut etkileri araştırılmış ve pelemirin fonksiyonel ürün geliştirme çalışmalarında değerlendirilebilecek bir bileşen olduğu ortaya konmuştur. Bununla birlikte, pelemirin kendine özgü aroma ve acı tat oluşturabilme potansiyeli, formülasyonda kullanılacak

miktarın duyusal kabul edilebilirlik açısından dikkatle belirlenmesini gerekli kılmaktadır (Selçukbiricik ve ark., 2025).

Mevcut çalışmalar pelemirin buğday bazlı fırıncılık ürünlerindeki kullanım potansiyelini ortaya koymasına karşın, pelemir tohumu ununun glutensiz ve düşük nemli atıştırmalık ürünlerde değerlendirilmesine ilişkin bilgiler sınırlıdır. Pelemir tohumu ununun glutensiz grissini formülasyonunda kullanılması; yerel bir bitkisel kaynağın katma değerli bir ürüne dönüştürülmesi, ürünün besinsel bileşiminin zenginleştirme potansiyeli ve farklı tekstürel ve duyusal özelliklerin geliştirilmesi açısından yenilikçi bir yaklaşım sunmaktadır. Bu doğrultuda bu çalışmada, farklı oranlarda pelemir tohumu unu kullanılarak glutensiz grissini geliştirilmesi ve elde edilen ürünlerin duyusal kalite özelliklerinin değerlendirilmesi amaçlanmıştır.

MATERYAL ve YÖNTEM

Kullanılan Malzemeler

Bu çalışmada kullanılan pelemir (*Cephalaria syriaca*) tohumu yerel üreticiden temin edilmiştir. Diğer malzemeler glutensiz un, ayçiçek yağı, tuz, kuru maya ve şeker İstanbul'da bulunan marketlerden temin edilmiştir.

Metot

Deneysel tasarımda bir kontrol grubu ve farklı oranlarda pelemir tohumu unu içeren üç deneme grubu olmak üzere toplam dört farklı grissini formülasyonu hazırlanmıştır. Pelemir unu kullanım oranları, pelemirin fırıncılık ürünlerinde kullanımına ilişkin önceki çalışmalar dikkate alınarak belirlenmiştir (Karaoglu, 2012; Selçukbiricik ve ark., 2025).

Kontrol grubu, yalnızca glutensiz un karışımı kullanılarak hazırlanmış ve pelemir tohumu unu içermemiştir. Deneme gruplarında ise glutensiz un karışımına sırasıyla %0,5, %0,75 ve %1 oranlarında pelemir tohumu unu eklenmiştir. Çalışmada kullanılan gruplar şu şekilde kodlanmıştır: G0: kontrol grubu; G1: %0,5 pelemir unu içeren grup; G2: %0,75 pelemir unu içeren grup; G3: %1 pelemir unu içeren grup

Tablo 1. Glutensiz Grissini Yapımında Kullanılan Ürünler ve Miktarları

Bileşen	Kontrol (G0)	G1	G2	G3
Glutensiz un (g)	500	497.5	496.25	495
Pelemir unu (g)	0	2.5	3.75	5
Su (g)	260	260	260	260
Ayçiçek yağı (g)	60	60	60	60
Toz şeker (g)	10	10	10	10
Tuz (g)	8	8	8	8
Kuru maya (g)	6	6	6	6

G0: Kontrol grubu, **G1:** %0,5 pelemir ilaveli glutensiz grissini**, G2:** %0,75 pelemir ilaveli glutensiz grissini**, G3:** %1 pelemir ilaveli glutensiz grissini

Kontrol grubu üretimi için 260 gram su, 10 gram şeker ve 6 gram kuru maya karıştırılarak mayanın aktifleşmesi sağlanmıştır ardından 60 g Ayçiçek yağı eklenmiştir. Bir mayonez tenceresinde sıvı karışım una eklenerek yoğurulmaya başlanmıştır. Kıvam almaya başladıktan sonra hamura tuz eklenmiştir ve tekrar yoğurulmuştur. Hamur bir süre dinlendikten sonra 50 gramlık bezelere ayrılmıştır. Hamur bezelendikten sonra tekrar dinlenmeye bırakılmıştır.

Hamur 15 dakika dinlendikten sonra bezelere grissini yapımı için ince uzun şekilde şerit/çubuk şekli verilmiştir. Pelemir unu ilaveli gruplar için un içerisine %0,5, %0,75, %1 oranında pelemir unu eklenmiş, hamur oluşturma aşamaları kontrol üretimi ile aynı şekilde gerçekleştirilmiştir. Tepsiye dizilen grissiniler önceden ısıtılmış 180±2ºC'deki konveksiyonlu fırında renk alana kadar pişirilmiştir. Renk almaya başladıktan sonra fırının ısısı 150±2°C'ye düşürülmüştür. 15-20 dakika pişirilmiştir. Fırından çıkarılan grissiniler oda sıcaklığında (+22 ºC) soğumaya bırakılmıştır.



Şekil 1. Glutensiz Grissini Örnekleri

Üretilen glutensiz grissini örneklerinin duyusal değerlendirmesi, Gastronomi ve Mutfak Sanatları Bölümü öğrencileri ile akademisyenlerinden oluşan 10 kişilik yarı eğitimli panelist grubu tarafından gerçekleştirilmiştir. Duyusal analiz panel formu, fırıncılık ürünleri ve kraker/grissini benzeri düşük nemli atıştırmalık ürünlerde kullanılan duyusal kalite kriterleri dikkate alınarak; Öney (2020) ve Ercik (2024)'in çalışmalarından yararlanılarak araştırma konusuna özgü biçimde modifiye edilmiştir. Duyusal değerlendirmede örnekler; görünüş, renk, koku, tat/lezzet, yüzey düzgünlüğü, tekstür ve genel kabul edilebilirlik kriterleri açısından değerlendirilmiştir. Değerlendirme süreci, literatürde yaygın olarak kullanılan 9'lu hedonik skala yöntemi ile yürütülmüştür. Panelistler her bir kriter için grissini örneklerine 1 "hiç beğenmedim" ile 9 "çok beğendim" arasında puan vermiştir. Değerlendirme sırasında örnekler panelistlere kodlanmış olarak sunulmuş ve örnekler arasında tat geçişini azaltmak amacıyla panelistlerin su tüketmeleri sağlanmıştır.

İstatistiksel Analiz

Duyusal analiz verilerinin istatistiksel değerlendirilmesi IBM SPSS Statistics 21.0 paket programı kullanılarak gerçekleştirilmiştir. Her bir grissini örneği toplam 10 yarı eğitimli panelist tarafından değerlendirilmiş ve elde edilen veriler ortalama ± standart sapma şeklinde sunulmuştur. Gruplar arasındaki farklılıkların belirlenmesi amacıyla tek yönlü varyans analizi (ANOVA) uygulanmıştır. Analiz öncesinde varyansların homojenliği Levene testi ile değerlendirilmiştir. ANOVA sonucunda istatistiksel olarak anlamlı farklılık saptanan duyusal özelliklerde, gruplar arasındaki ikili karşılaştırmalar Tukey çoklu karşılaştırma testi ile yapılmıştır. Tüm istatistiksel analizlerde anlamlılık düzeyi $p < 0,05$ olarak kabul edilmiştir.

BULGULAR VE TARTIŞMA

Duyusal değerlendirme sonucunda elde edilen görünüş, renk, koku, tat/lezzet, yüzey düzgünlüğü, tekstür ve genel kabul edilebilirlik puanları Tablo 2'de verilmiştir. Buna göre pelemir tohumu unu ilavesinin duyusal özellikler üzerindeki etkisi değerlendirildiğinde, bazı parametrelerde gruplar arasında istatistiksel olarak anlamlı farklılıklar saptanmıştır.

Tablo 2. Grissini örneklerine ait duyusal analiz sonuçları

Örnek	Görünüş	Renk	Koku	Tat/Lezzet	Yüzey Düzgünlüğü	Tekstür	Genel Kabul Edilebilirlik
G0	$7,50 \pm 0,57^{a}$	$7,10 \pm 0,46^{a}$	$6,90 \pm 0,67^{a}$	$6,80 \pm 0,35^{c}$	$7,20 \pm 0,39^{a}$	$6,80 \pm 0,49^{b}$	$6,80 \pm 0,25^{b}$
G1	$7,30 \pm 0,48^{ab}$	$7,20 \pm 0,34^{a}$	$6,80 \pm 0,51^{a}$	$6,90 \pm 0,42^{bc}$	$6,80 \pm 0,48^{ab}$	$7,10 \pm 0,66^{ab}$	$7,10 \pm 0,33^{ab}$
G2	$6,90 \pm 0,61^{b}$	$7,10 \pm 0,57^{a}$	$6,90 \pm 0,63^{a}$	$7,20 \pm 0,40^{ab}$	$6,50 \pm 0,53^{b}$	$7,20 \pm 0,26^{ab}$	$7,30 \pm 0,33^{a}$
G3	$7,10 \pm 0,39^{ab}$	$7,30 \pm 0,57^{a}$	$6,90 \pm 0,68^{a}$	$7,40 \pm 0,38^{a}$	$6,30 \pm 0,59^{b}$	$7,40 \pm 0,45^{a}$	$7,40 \pm 0,45^{a}$

G0: Kontrol grubu, G1: %0,5 pelemir ilaveli glutensiz grissini, G2: %0,75 pelemir ilaveli glutensiz grissini, G3: %1 pelemir ilaveli glutensiz grissini. Değerler ortalama±standart sapma olarak verilmiştir. Aynı sütunda farklı üst simge harfleri istatistiksel olarak anlamlı farklılığı göstermektedir ($p<0,05$).

En yüksek görünüş puanı G0 örneğinde (7,50±0,57), en düşük puan ise G2 örneğinde (6,90±0,61) belirlenmiştir. G0 ile G2 arasındaki fark istatistiksel olarak anlamlı bulunmuştur. G1 (7,30±0,48) ve G3 (7,10±0,39) örnekleri ara grupta yer almış ve diğer örneklerden anlamlı düzeyde farklılaşmamıştır. Renk puanları G0, G1, G2 ve G3 örneklerinde sırasıyla 7,10±0,46, 7,20±0,34, 7,10±0,57 ve 7,30±0,57 olarak belirlenmiştir. Tüm örneklerin aynı harf grubunda yer alması, renk puanları arasında istatistiksel olarak anlamlı bir fark bulunmadığını göstermektedir. Örneklerin koku puanları birbirine oldukça yakın olup G0 için 6,90±0,67, G1 için 6,80±0,51, G2 için 6,90±0,63 ve G3 için 6,90±0,68 olarak bulunmuştur. Tüm örneklerin aynı harf grubunda yer alması nedeniyle koku bakımından anlamlı bir farklılık saptanmamıştır.

Tat/lezzet puanları G0'dan G3'e doğru artış göstermiştir. En yüksek puan G3 örneğinde (7,40±0,38), en düşük puan ise G0 örneğinde (6,80±0,35) belirlenmiştir. G3 örneği, G0 ve G1 (6,90±0,42) örneklerinden daha yüksek puan almıştır. G2 örneği (7,20±0,40) ise G0'dan daha yüksek değerlendirilmiştir. G2 ile G3 ve G0 ile G1 arasındaki farklar anlamlı bulunmamıştır. Bulgular genel olarak, düşük oranlarda pelemir unu kullanımının renk ve koku özelliklerinde olumsuz bir değişime neden olmadığını, buna karşın tat/lezzet ve tekstür gibi bazı duyusal özelliklerde olumlu etkiler gösterebildiğini ortaya koymaktadır. Renk ve koku puanları bakımından gruplar arasında anlamlı fark bulunmaması, %0,5–1 aralığındaki pelemir unu ilavesinin ürünün temel algısal özelliklerini belirgin biçimde değiştirmediğini göstermektedir. Bu bulgu, glutensiz ürünlerde alternatif bitkisel kaynakların kullanımı sırasında duyusal kabulün korunmasının kritik bir kalite ölçütü olduğunu vurgulayan çalışmalarla uyumludur (González ve ark., 2025). Tat/lezzet puanlarının G0'dan G3'e doğru artış göstermesi, pelemir tohumu ununun düşük oranlarda kullanımının grissiniye özgün ve daha kabul edilebilir bir aroma profili kazandırmış olabileceğini düşündürmektedir. Pelemirin kendine özgü ve hafif acı tat potansiyeli literatürde belirtilmekle birlikte, bu çalışmada kullanılan düşük oranların duyusal kabulü azaltmadığı, aksine özellikle G2 ve G3 örneklerinde tat/lezzet değerlendirmelerini iyileştirdiği görülmektedir. Benzer şekilde, nohut ve kabak çekirdeği pres keki unu ile

geliştirilen glutensiz krakerlerde, alternatif tohum kaynaklı bileşenlerin yalnızca besinsel değeri artırmakla kalmayıp tat ve aroma puanlarını da olumlu yönde etkileyebildiği bildirilmiştir (Tomić ve ark., 2022).

En yüksek yüzey düzgünlüğü puanı G0 örneğinde (7,20±0,39), en düşük puan ise G3 örneğinde (6,30±0,58) belirlenmiştir. G0 örneği, G2 (6,50±0,53) ve G3 örneklerinden anlamlı düzeyde daha yüksek puan almıştır. G1 örneği (6,80±0,47) ara grupta yer almış ve diğer örneklerle benzer bulunmuştur. Genel olarak örnek kodu G0'dan G3'e ilerledikçe yüzey düzgünlüğü puanlarının azaldığı görülmüştür. Yüzey düzgünlüğü puanlarında pelemir unu oranı arttıkça azalma görülmesi, formülasyona eklenen tohum ununun hamur homojenliği ve şekillendirme özellikleri üzerinde etkili olabileceğini göstermektedir. Bu durum, pelemir ununun partikül yapısı, lif/protein içeriği ve su bağlama özellikleriyle ilişkili olabilir. Nitekim pelemir ununun buğday bazlı hamur sistemlerinde reolojik ve tekstürel özellikleri değiştirebildiği; artan pelemir unu düzeylerinin hamur ve ekmek özellikleri üzerinde belirgin teknolojik etkiler oluşturduğu bildirilmiştir (Başar & Karaoğlu, 2021). Bu çalışmada da yüzey düzgünlüğündeki azalma, pelemir ununun yapısal etkilerinin grissini formülasyonunda doğrudan gözlenebildiğini düşündürmektedir.

Tekstür puanları G0, G1, G2 ve G3 örneklerinde sırasıyla 6,80±0,49, 7,10±0,66, 7,20±0,26 ve 7,40±0,45 olarak belirlenmiştir. En yüksek puanı alan G3 örneği, G0 örneğinden anlamlı düzeyde daha yüksek değerlendirilmiştir. G1 ve G2 örnekleri ara grupta yer almış ve diğer örneklerden istatistiksel olarak farklılaşmamıştır. Bulgular, G3 örneğinin tekstür açısından G0'a göre daha olumlu değerlendirildiğini göstermektedir. Tekstür puanlarının özellikle G3 örneğinde kontrol grubuna göre daha yüksek bulunması, pelemir tohumu ununun glutensiz grissinide yapı ve ağız hissi açısından olumlu katkı sağlayabileceğini göstermektedir. Bu bulgu, glutensiz ürünlerde lif, protein ve biyoaktif bileşen içeren alternatif bitkisel kaynakların ürün tekstürünü ve duyusal kalitesini destekleyebileceği yönündeki güncel yaklaşımlarla uyumludur. Pelemirin yüksek polifenol içeriği ve fonksiyonel gıda bileşeni olarak potansiyeli de dikkate alındığında, bu hammaddenin glutensiz atıştırmalık ürünlerde değerlendirilmesi yenilikçi bir yaklaşım olarak görülebilir (Selçukbiricik ve ark., 2025).

Genel kabul edilebilirlik puanları G0 için 6,80±0,25, G1 için 7,10±0,33, G2 için 7,30±0,33 ve G3 için 7,40±0,45 olarak bulunmuştur. G2 ve G3 örnekleri, G0 örneğinden anlamlı düzeyde daha yüksek puan almıştır. G1 örneği ara grupta yer almış ve diğer örneklerle benzer bulunmuştur. Genel olarak kabul edilebilirlik puanlarının G0'dan G3'e doğru arttığı belirlenmiştir. Sonuç olarak, pelemir tohumu unu ilavesi renk ve koku gibi temel duyusal özellikleri olumsuz etkilemeden, tat/lezzet ve tekstür özelliklerinde iyileşme sağlayabilmiştir. Bununla birlikte, artan pelemir unu düzeyleri yüzey düzgünlüğünü azaltmıştır. Bu nedenle glutensiz grissini formülasyonlarında pelemir unu kullanımında duyusal kabul, tekstür ve yüzey özellikleri birlikte değerlendirilmelidir. Bulgular, özellikle %0,75 ve %1 pelemir unu içeren formülasyonların tat/lezzet ve tekstür açısından umut verici olduğunu, ancak daha homojen yüzey yapısı için formülasyon ve işlem koşullarının optimize edilmesi gerektiğini göstermektedir.

SONUÇ

Bu çalışmada, pelemir (Cephalaria syriaca L.) tohumu unu kullanılarak glutensiz grissini geliştirilmiş ve farklı oranlarda pelemir unu ilavesinin duyusal kalite özellikleri üzerindeki etkisi değerlendirilmiştir. Elde edilen bulgular, %0,5–1 aralığında pelemir unu kullanımının grissini örneklerinde renk ve koku gibi temel duyusal özellikler üzerinde olumsuz bir etki oluşturmadığını göstermiştir. Buna karşılık, pelemir unu oranı arttıkça tat/lezzet, tekstür ve genel kabul edilebilirlik puanlarında artış gözlenmiştir. Özellikle %0,75 ve %1 pelemir unu

içeren örneklerin genel kabul edilebilirlik açısından kontrol grubuna göre daha yüksek puan alması, pelemir tohumu ununun glutensiz atıştırmalık ürünlerde duyusal kaliteyi destekleyebilecek alternatif bir bileşen olarak değerlendirilebileceğini göstermektedir. Bununla birlikte, pelemir unu ilavesinin yüzey düzgünlüğü puanlarını azalttığı belirlenmiştir. Bu durum, pelemir ununun partikül yapısı, lif/protein içeriği ve hamur içindeki su bağlama özellikleriyle ilişkili olabilir. Dolayısıyla pelemir unu kullanımında yalnızca tat/lezzet ve tekstür değil, aynı zamanda ürünün şekillendirilebilirliği ve yüzey kalitesi de dikkate alınmalıdır.

Çalışmanın bazı sınırlılıkları bulunmaktadır. Araştırma, sınırlı sayıda panelist ile yürütülen duyusal değerlendirmeye dayanmaktadır. Ayrıca ürünlerin fizikokimyasal özellikleri, besin bileşimi, raf ömrü, kırılma kuvveti ve enstrümantal tekstür analizleri bu çalışma kapsamında değerlendirilmemiştir. Gelecek çalışmalarda daha geniş panelist gruplarıyla tüketici kabul testlerinin yapılması, farklı pelemir unu oranlarının denenmesi ve formülasyonun hidrokolloid, yağ ve su dengesi açısından optimize edilmesi önerilmektedir. Ayrıca pelemir ununun glutensiz ürünlerin besinsel bileşimi, antioksidan kapasitesi ve raf ömrü üzerindeki etkilerinin incelenmesi, bu hammaddenin fonksiyonel ve yerel bir bileşen olarak kullanım potansiyelinin daha kapsamlı biçimde ortaya konmasına katkı sağlayacaktır.

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PLANT EXTRACT AS A SUSTAINABLE ELECTROLYTE FOR GREEN SENSORS

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ABSTRACT

Introduction and Purpose: The increasing demand for environmentally sustainable analytical technologies has stimulated interest in the utilization of agricultural by products as functional materials in sensor development. Broad bean is cultivated for food production, generating substantial quantities of plant residues that remain underutilized. In this study, extracts obtained from broad bean pod valves and seeds were evaluated as a green electrolyte for electrochemical sensing applications.

Materials and Methods: Broad bean pod valves and seeds were cleaned, dried, and ground into a fine powder to maximize surface area, followed by Ultrasound-Assisted Extraction in a 1:10 ratio with 0.1 M HCl at 4 °C for 20 minutes. The resulting extract was clarified through centrifugation at 6000g and sequential filtration using coarse and 0.2 µm membrane filters. Organic semiconductor films on ITO coated substrates were used as a working electrode (WE) for the sensing platform.

Results: Electrochemical characterization was conducted in a three-electrode cell using 0.1 M PBS as the supporting electrolyte, with CV scans performed between ±0.6 V at varying scan rates. WE showed a stable baseline in PBS with no significant redox peaks, confirming good electrochemical stability. A clear anodic oxidation signal, enabling direct detection in broad bean pod and seed samples. WE electrode showed good electrochemical stability in PBS, providing a clear detection window. Distinct redox peaks observed in broad bean extracts with increasing peak currents at higher scan rates indicating active electrochemical behavior. Membrane-filtered extracts exhibited higher transmittance value, demonstrating improved sample clarity for analysis.

Discussion and Conclusion: This study highlights the potential of food and agricultural residues as sustainable resources for green electrochemical applications, contributing to waste reduction, resource efficiency, and climate-conscious technological development.

Key Words: Broad bean, green electrolyte, electrochemical sensor, agricultural waste.

Introduction

Green sensors are next-generation analytical devices that use environmentally friendly, natural, and biodegradable materials throughout the entire production process, thus posing no harm to human health or the environment. In line with growing environmental awareness, these types of applications are attracting considerable interest in both academic studies and industrial processes (Berkel and Özbek, 2024; Raquel et al., 2026). Conventional sensor technologies, which frequently utilize toxic organic solvents (acetonitrile, dimethylformamide, toluene, etc.), heavy metal catalysts (Hg, Cd, Pb, etc.), and reducing agents (sodium borohydride, hydrazine, etc.), have been replaced by fully biodegradable alternatives within the scope of green sensors. One of the most notable of these alternatives is plant extracts, known for their rich source of phytochemicals. Phytochemicals such as polyphenols, flavonoids, and terpenoids play multiple roles in electrochemical sensor production. One role of phytochemicals in these systems is to act as bioreducing agents. Thus, the production process takes place without the need for highly toxic and explosive chemicals such as sodium borohydride or hydrazine. In the process, the hydroxyl groups in the polyphenols of plant extracts donate electrons to metal ions such as Ag^{+}, Au^{3+}, and Cu^{2+}, reducing and transforming them into nanoparticles (Zuhrotun et al., 2023; Erdoğan et al., 2019; Soumen et al., 2023). Because the plant extract is in an aqueous environment, this reduction reaction also takes place in an aqueous medium, not in a toxic organic solvent. Another advantage of using plant extracts, and therefore phytochemicals, is that they surround the formed nanoparticles, preventing aggregation and thus contributing to a more stable attachment of the nanoparticles to the electrode surface (Elaheh et al., 2023). Another contribution of phytochemicals in green electrochemical sensor applications is the creation of an electron bridge, or interface, between the substance to be analyzed and the electrode (Hsueh et al., 2019). This resulting electron bridge allows for lower potential values to suffice in analyses where much higher potentials are required, thus preventing interference from certain substances in the medium with high potentials. Furthermore, because it increases the speed of electron transfer, the electrode's sensitivity improves, enabling successful quantitative determination even of substances at much lower concentrations. Research on the use of plant extracts as electrochemical sensors dates back to the early 2010s. In one of the pioneering studies on this subject, Li and his group obtained an extract from the leaves of the magnolia fruit and used this extract in the electrochemical synthesis of gold nanoparticles (Li et al., 2012). Measurements made using Cyclic Voltammetry (CV) and Electrochemical Impedance Spectroscopy (EIS) revealed the current conductivity and electrode surface stability of the biostructure obtained by this method. In another study, it was shown that *Rosa damascena* extract was significantly effective in the production of gold and silver nanoparticles and in improving the electrochemical sensor properties of glassy carbon electrodes (Ghoreishi et al., 2011). The concept of green sensors, which gained momentum especially in 2020 and beyond, and the increasing research in this area, have yielded successful results in the field of electrochemical sensors using plant extracts such as green tea (Demir, 2025; Döll et al., 2023; Bendehhou et al., 2026; Hamad et al., 2023; de Oliveira et al., 2026).

This study investigates the effectiveness of broad bean extracts in electrochemical sensor applications as an alternative to existing plant extracts in the literature. Broad beans are a plant grown for food production that leaves significant waste, which is not adequately utilized. Extracts obtained from broad bean pod valves and seeds were evaluated as a green electrolyte for electrochemical sensing applications with the aim of examination of the potential of this inexpensive and sustainable material for use in environmentally green sensor applications.

Methods

Broad bean (*Vicia faba L.*) seeds and pod valves were purchased from local producers in Istanbul and washed with plenty of water to remove impurities. They were then freeze-dried to

prevent mold formation during storage. For extraction, the dried samples were ground into a fine powder using a commercial mill. This maximized the surface area and yield during the extraction process. The powdered broad bean plant was homogenized using a mechanical mixer. The extraction and homogenization processes are shown in Figure 1.

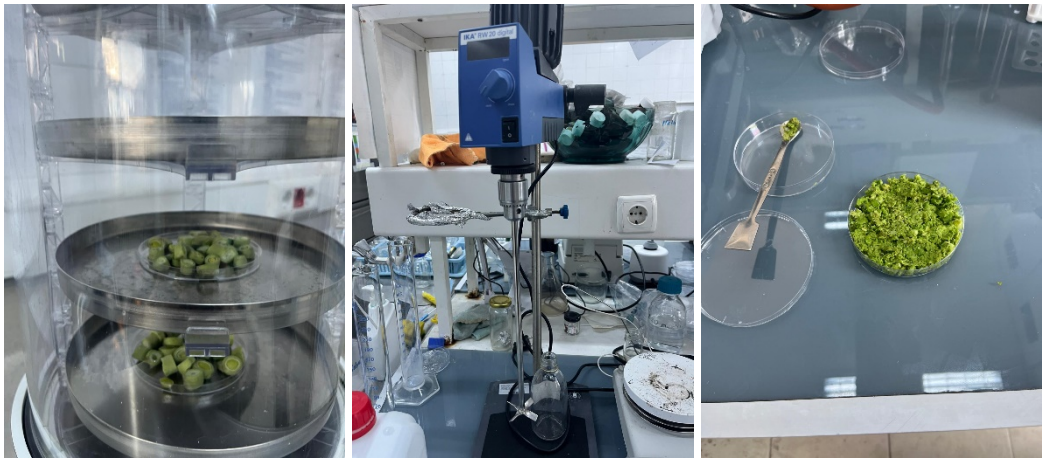

Figure 1. Schematic representation of the sample preparation procedure: freeze-drying of broad bean pods and seeds for 1 h, homogenization using a mechanical stirrer, grinding of the freeze-dried broad bean pods and seeds after drying respectively

In the next step, the extraction stage, Ultrasound-Assisted Extraction (UAE) was used because it has the effect of breaking down plant cell walls, facilitating the release of bioactive compounds from plant cells. This technique allowed the solvent to penetrate into the plant cells, thus facilitating extraction. A 0.1 M hydrochloric acid (HCl) solution (pH ≈ 1) was used as the extraction solvent to ensure the stabilization of many functional groups. For this purpose, 60 g of dry and ground fava bean biomass was dispersed in 600 mL of 0.1 M HCl solution. Therefore, an extraction recipe with a 1:10 (w/v) ratio was applied. As mentioned above, to preserve the chemical composition and thermal stability of oxidation-sensitive compounds, the extraction process was carried out under ultrasonic irradiation at 4 °C for 20 minutes. All steps of the extraction process are shown in Figure 2.

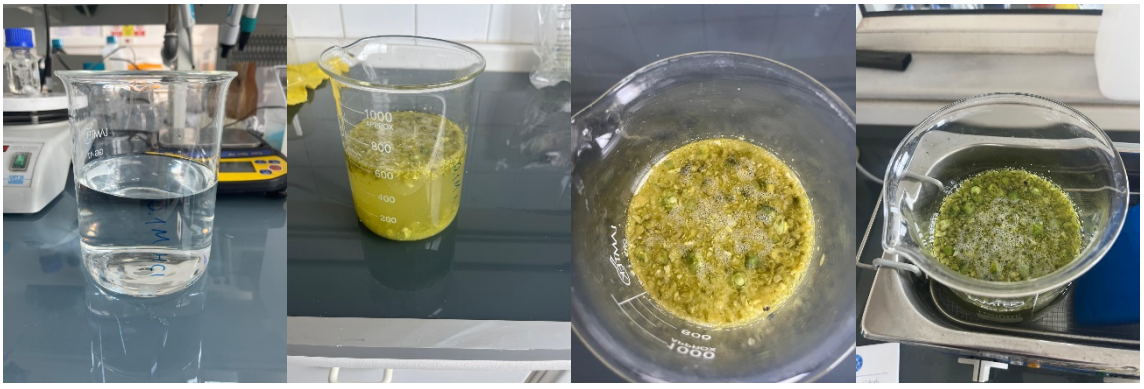

Figure 2. Broad bean extract by UAE: 0.1 M HCl extraction solution, addition of broad bean powder to the HCl solution and ultrasonic bath treatment of the extraction respectively

After extraction performed using ultrasonic technology, the extraction suspension was centrifuged at 6000 g for 20 minutes to remove any possible plant residues from the solution and obtain the clearest possible supernatant. To increase the percentage of bioactive components that can be extracted from broad bean biomass, the aforementioned ultrasonic-assisted extraction and centrifugation process was repeated under the same conditions.The extracts

obtained after each of the two extraction cycles were combined to ensure the sample was homogenized. All steps of the extraction separation process are shown in Figure 3.



Figure 3. Post extraction processing of the broad bean extract: Centrifugation of the extraction suspension at 6000*g* for 20 min, separation of the clear supernatant from the insoluble plant residue after centrifugation, recovered broad bean extract obtained after the centrifugation process and separated solid residue respectively

To obtain a completely clear solution free of any suspended particles from homogeneous extract samples, the extracts were first filtered through coarse filtration, followed by a 0.20 µm membrane filter. Both filtration stages are presented in Figure 4.

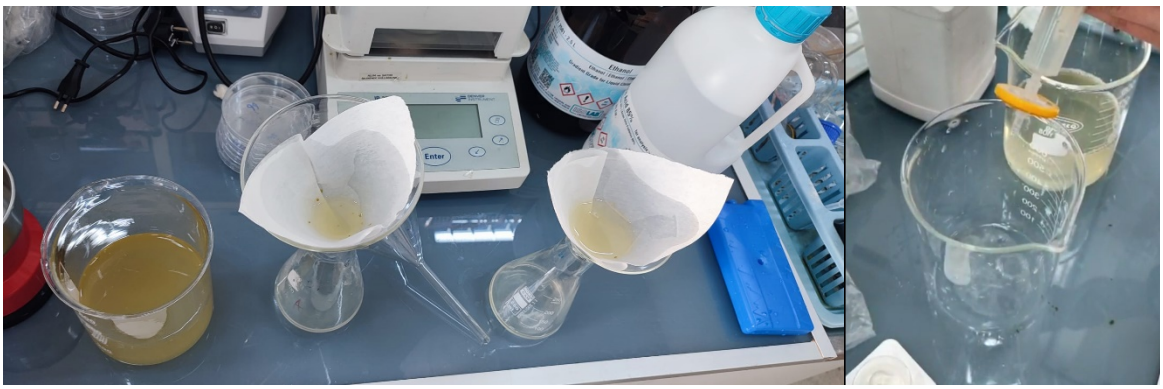

Figure 4. Filtration broad bean extracts: initial coarse filtration to remove large particulates, resulting clarified extract after preliminary filtration, final slow filtration through a 0.2 µm membrane filter respectively

The obtained clear extracts were transferred to glass vials and stored at 4°C to protect against light, heat, and oxidation risks. As shown in Figure 5, the extract after the first coarse filtration (Coarse Filtered Extract - CFE) was placed in the large vial, while the extract filtered through

a 0.20 µm membrane and used for analytical measurements (Membrane Filtered Extract - MFE) was placed in the small vial.

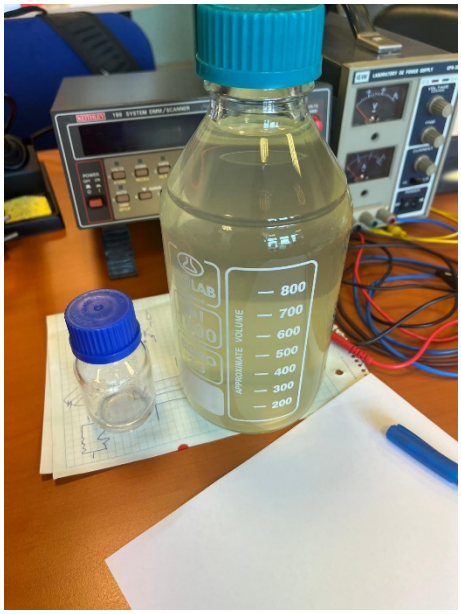

Figure 5. The larger schott bottle contains the **CFE**, whereas the smaller schott contains the **MFE**

Figure 6 shows all the preparation steps for obtaining broad bean extract for electrochemical analysis (plant material preparation, extraction, centrifugation, sequential coarse and 0.20 µm membrane filtration, and storage of the clarified extract). The raw broad bean and the final filtered extract are schematically shown immediately below the workflow diagram.



Figure 6. Schematic illustration of the broad bean extraction procedure from raw plant material to the final clarified extract

Results and Discussion

In present study, all electrochemical measurements were conducted in phosphate buffered saline (PBS) (0.1 M) having good ionic conductivity, stable buffering capacity and compability with electrochemical measurements. On the other hand, cyclic voltammetry (CV) was employed to determine the electrochemical performance of the electrodes, operating in a conventional three-electrode configuration. This three-electrode configuration allowed for precise adjustment of the potential applied to the working electrode, enabling independent measurement of the resulting current and thus accurately characterizing the electrochemical behavior of the fava bean extract. In experiments where purified broad bean extract was conducted as an electrochemical sensor, a conductive polymer-coated ITO substrate was used as the working electrode (WE), a silver (Ag) wire as the reference electrode (RE), and a Pt wire as the counter electrode (CE) in the three-electrode configuration mentioned above. One of the most important reasons for the reproducibility and therefore reliability of the electrochemical data is that the Pt electrode provides a stable current path, and the other is that the Ag wire electrode exhibits a constant reference potential throughout the measurement. Polyaniline (PANI) and poly(3-hexithiophene) (P3HT) were chosen as active sensing materials because their conductive properties. The schematic representation of the electrochemical measurement setup used in the study, where P3HT and PANI films were named as PF1 and PF2 respectively, is given in Figure 7.

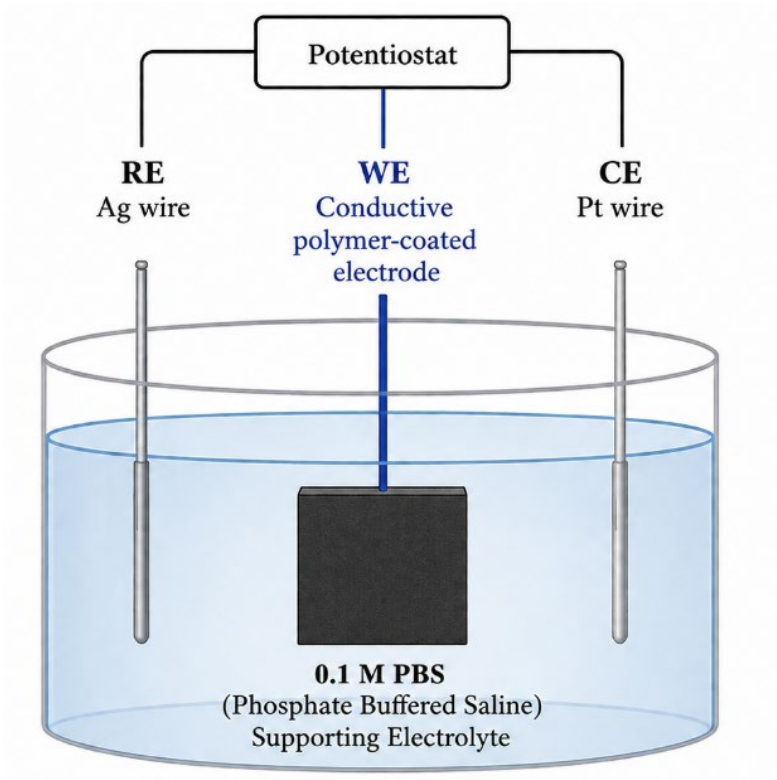

Figure 7. Schematic representation of the three-electrode electrochemical system consisting of an organic semiconductor (WE), an Ag wire (RE), and a Pt wire (CE) immersed in PBS electrolyte

In all measurements within the scope of this study, a 0.1 M phosphate-buffered salt solution was used, which has the capacity to provide sufficient electron transfer by ensuring a sufficient and stable ionic environment. As a result of the measurements, no sharp oxidation or reduction peaks were observed in the ±0.6 V range, which is the strongest indication of the electrochemical stability of the films in PBS (Figure 8).

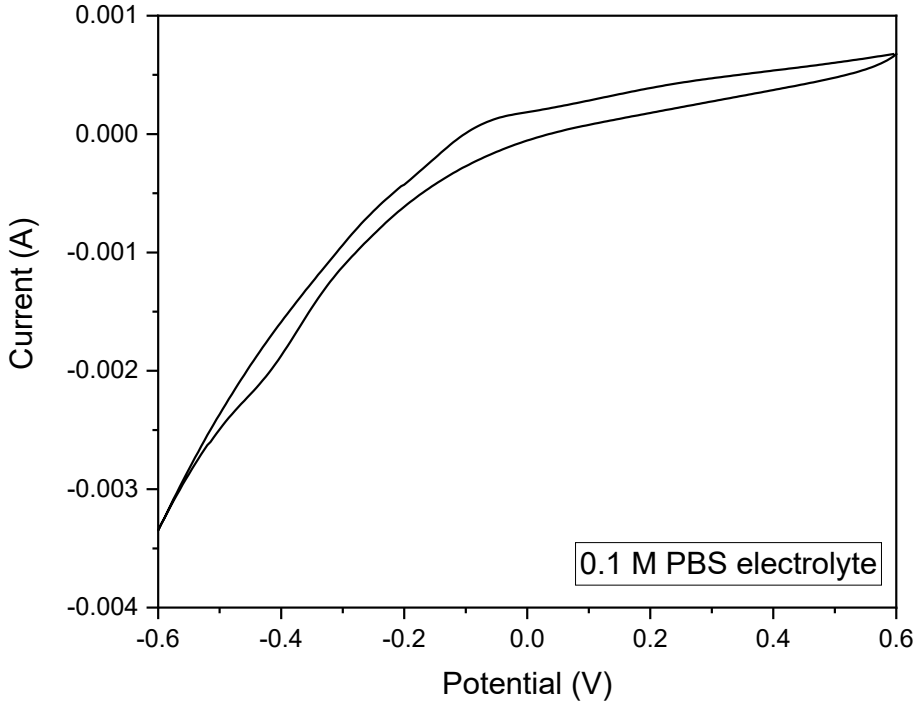

Figure 8. CV curve of the PF1 in PBS electrolyte.

Measurements for cyclic voltammetry of the PF1 sensor material were first performed at a scan rate of 100 mV/s with only PBS electrolyte in the medium. Then, while keeping all other conditions the same, the PBS electrolyte was replaced with an electrolyte obtained by mixing PBS with broad bean extract in a 1:1 (v/v) ratio, and scans were performed in this medium. The scan results are shown in Figure 9. The electrochemical activity of the broad bean extract, clearly observed in the figure, can be explained by the phytochemicals such as polyphenols, flavonoids, and tannins and thus their consisting of the numerous functional groups, such as phenolic hydroxyl (OH), amino (NH_2), and carboxylic acid (COOH), having a high electron transfer capacity, and the numerous functional groups they contain, such as phenolic hydroxyl (OH), amino (NH_2), and carboxylic acid (COOH). Examination of the voltagram clearly shows an anodic peak located at approximately +0.05 V and a cathodic peak located at -0.05 V, indicating that the process is a quasi-reversible and revealing the effect of these naturally occurring electroactive compounds in broad bean extract on oxidation and reduction processes.

The cyclic voltagram obtained when the measurements performed above for PF1 at a constant scan rate of 100 mV/s are repeated for different scan rates ranging from 50 to 250 mV/s is shown in Figure 10. As can be seen from the graph, the total shape of the voltagram remains unchanged with increasing scan rate, but significant increases are recorded in both anodic and cathodic peak currents. This reveals that the sensing film has the potential to exhibit reproducible redox behavior in this studied scan range and therefore possesses excellent electrochemical stability. However, it is also observed that there are very small shifts in the anode and cathode peak potentials with increasing scan rates. This can be considered a relatively fast and semi-reversible electron transfer process

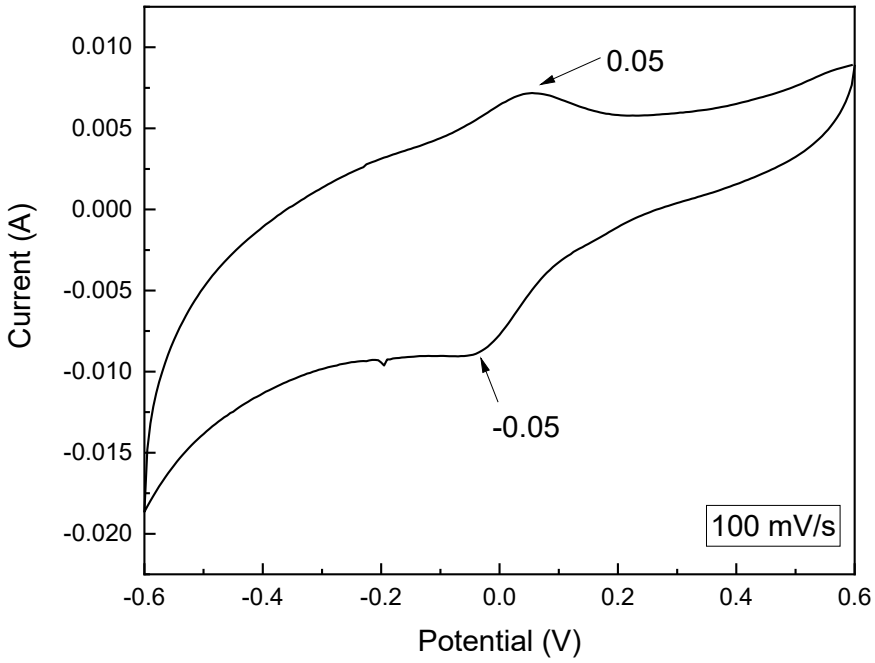

Figure 9. CV curve of PF1 sensing material in an electrolyte consisting of PBS and broad bean extract at 100 m/s scan rate.

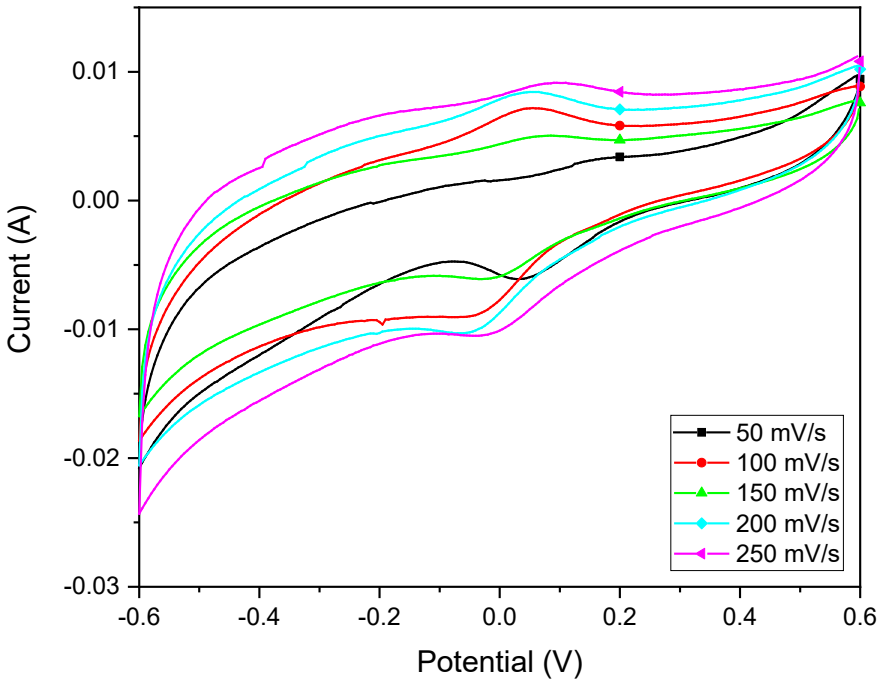

Figure 10. CV curves of the films in an electrolyte consisting of PBS and broad bean extract at various scan rates (50 mV/s, 100 mV/s, 150 mV/s, 200 mV/s and 250 mV/s)

The anodic and cathodic peak currents (Ip) obtained from the graph in Figure 10 were examined using three different kinetic models to elucidate the electrochemical mechanism. Three separate graphs were plotted to test which model best matches the mechanism: one between the logarithmic values of the peak currents and the logarithmic values of the scan rates (Figure 11), one between the peak currents and the square root of the scan rate (Figure 12), and one between the peak current and the scan rate (Figure 13). The compatibility of the data in the graphs with the models is examined, and it is seen that the electrochemical mechanism within the scope of this study coincides with the models in Figure 12 and Figure 13, indicating that the electrochemical response generally occurs under diffusion control.

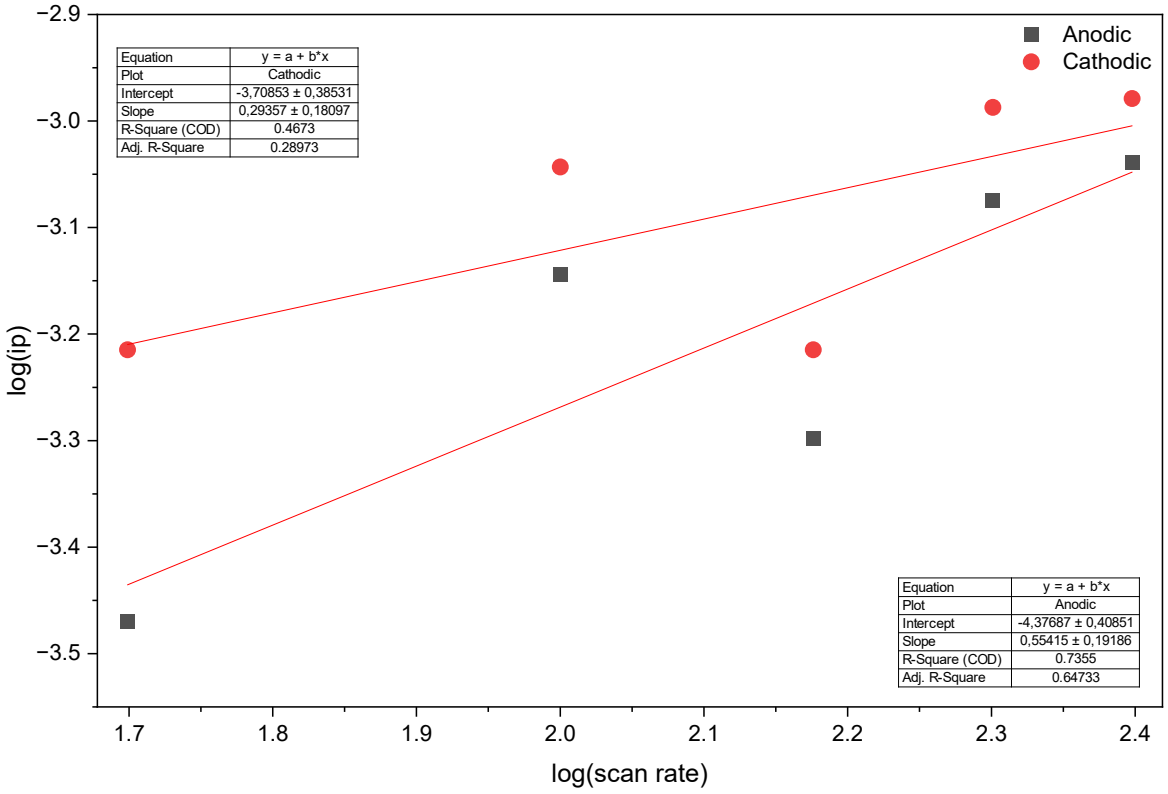

Figure 11. Plots of logarithmic of peak current versus scan rate for the anodic and cathodic peaks

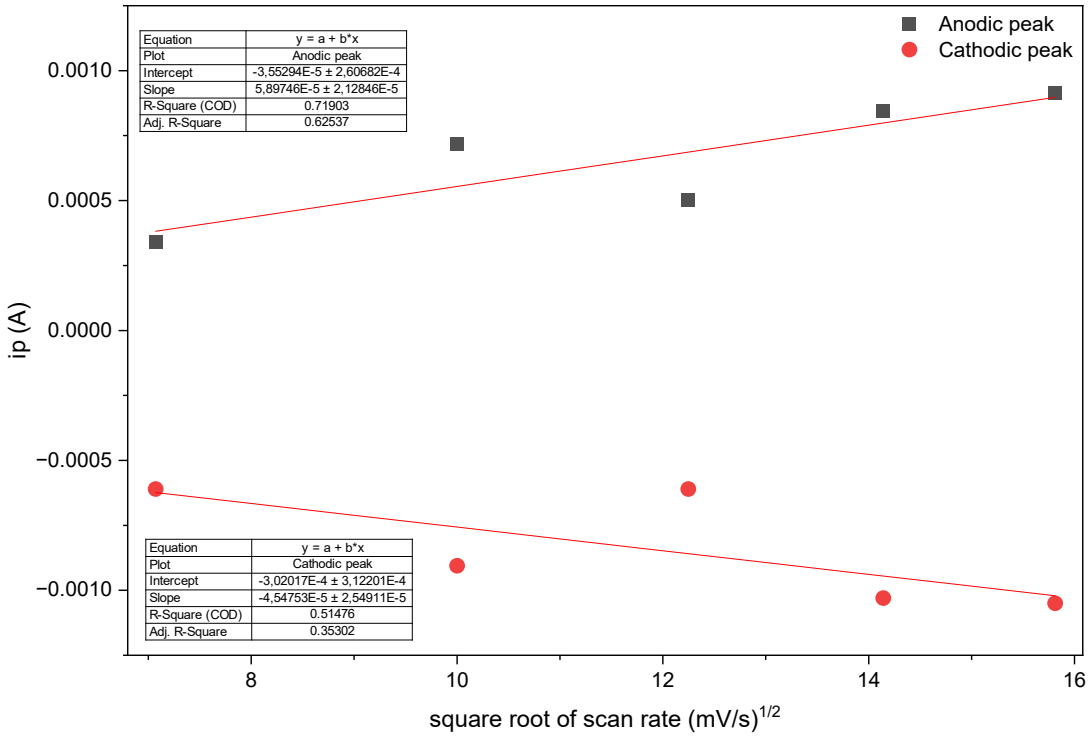

Figure 12. Plots of peakcurrent versus square root of scan rate for the anodic and cathodic peaks

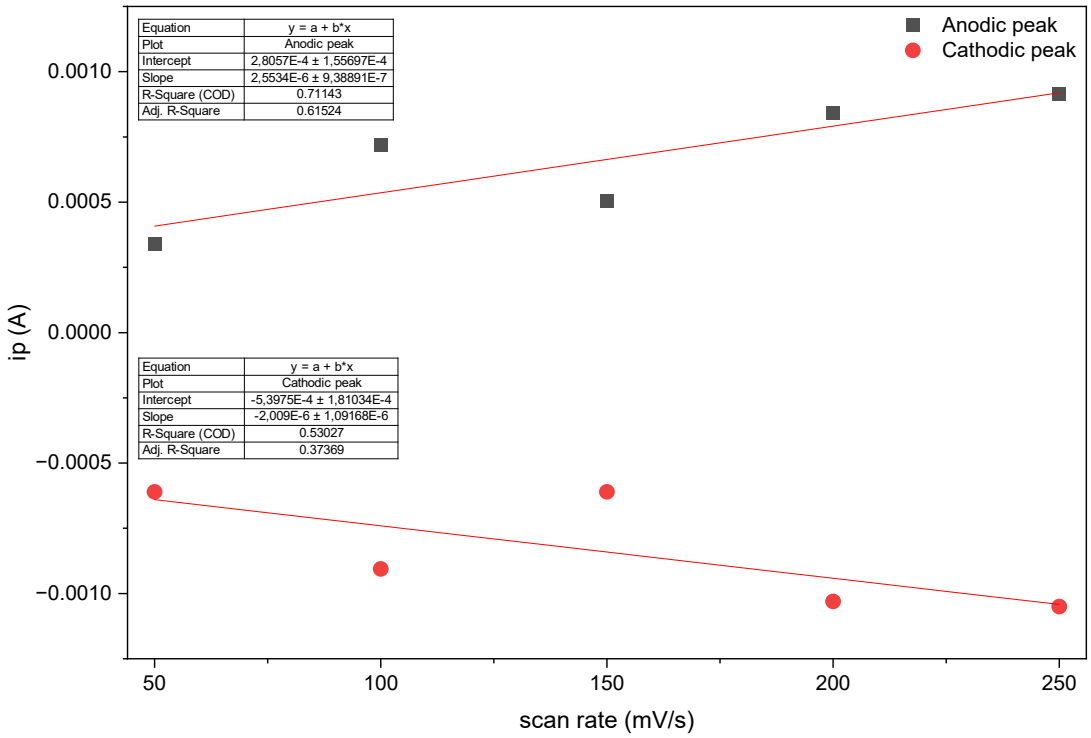

Figure 13. Plots of peak current versus scan rate for the anodic and cathodic peaks

The tests applied to PF1 were repeated for PF2, another active sensing material used in the study. The CV obtained for PF2 at a constant scan rate of 100 mV/s and a potential range of -0.1 and +1.0 V is presented in Figure 14. The resulting voltammogram shows that PF2 does not have as sharp and distinct redox peaks as PF1. This result strengthens the possibility that the electrochemical behavior is an oxidation and reduction process originating from both the conductive polymer and the components of the broad bean extract.

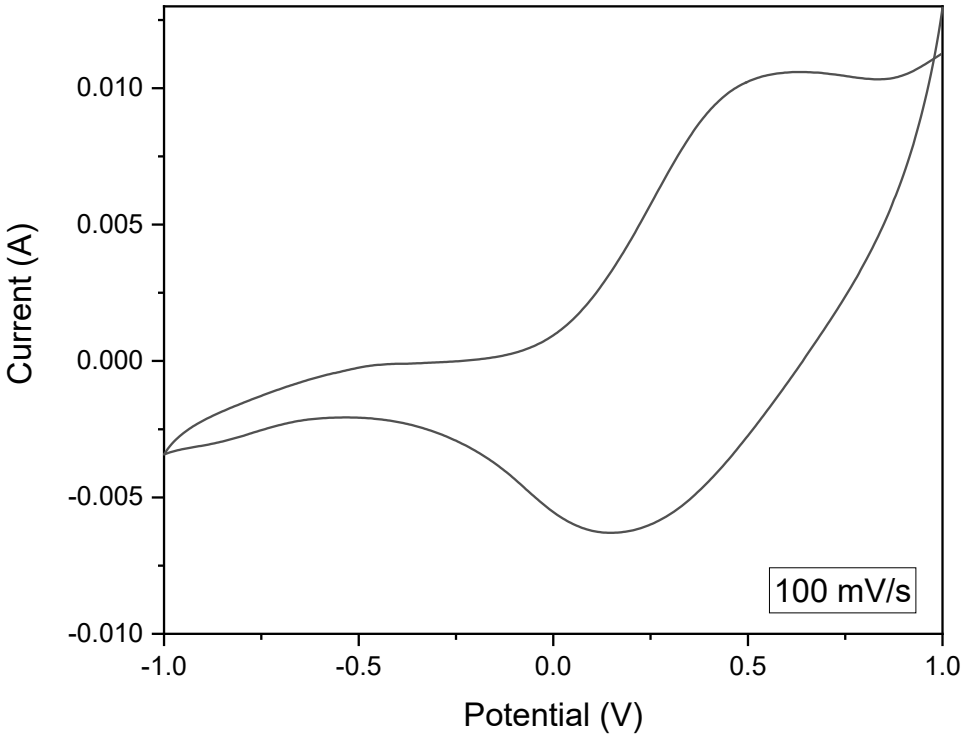

Figure 14. CV curve of PF2 sensing material at 100 mV/s scan rate

On the other hand, the transmittance of the broad bean extract used in this study was investigated depending on the filtration method. For this purpose, both coarsely filtered and membrane-filtered extracts were subjected to spectrophotometric analysis. The transmittance (T)-lambda (λ) graph obtained as a result of the analysis is shown in Figure 15. The systematic increase in spectral transmittance observed from CFE-1 to CFE-3 shows that coarse filtration is quite effective, while the highest transmittance values in MFE reveal that this filtration is much more effective than coarse filtration. Another conclusion that can be drawn from the analysis is the separation of phenolic compounds in broad beans by extraction and filtration, especially absorption in the UV region.

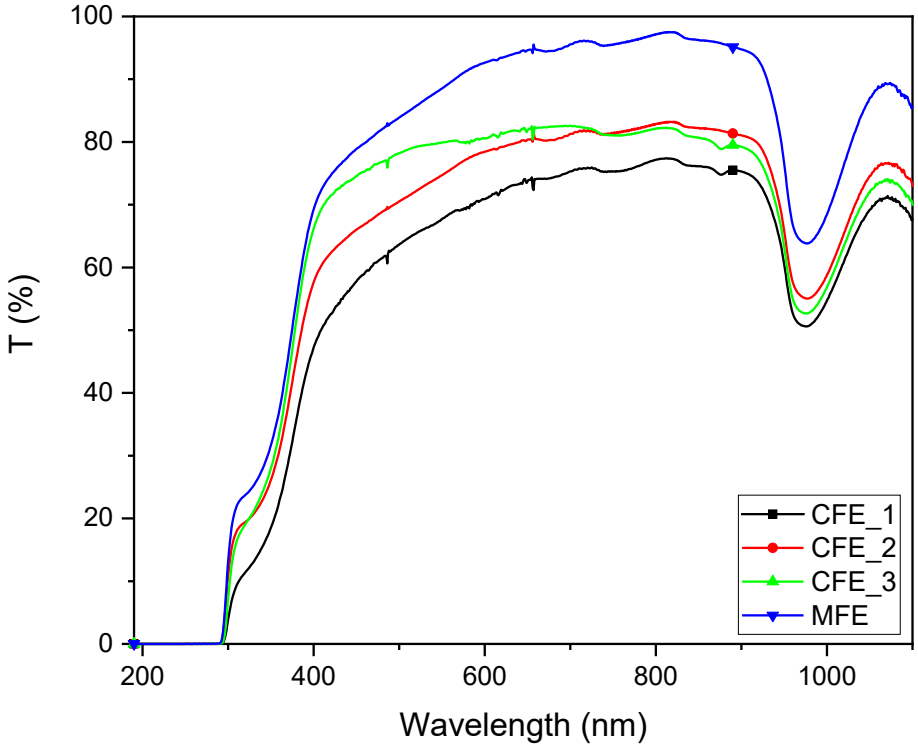

Figure 15. T-λ plots of CFE and MFE of broad bean extract

Conclusion

This study investigated the potential of broad bean (*Vicia faba L.*) extract for use in green electrochemical sensor applications. For this purpose, the extract was prepared using two different filtration techniques (coarse and membrane filtrations), and the electrochemical behavior of the phenolic components in the extract was studied. Electrochemical analyses performed with a triple electrode configuration revealed that the presence of the plant extract caused oxidation and reduction peaks. Changes in peak currents at different scan rates indicated that the electrolyte containing the plant extract provided an effective electron transfer process and that the electrochemical behavior was diffusion-controlled. Considering all the results, it can be said that the broad bean extract examined in this study has the potential to be used as an electrolyte in an environmentally friendly electrochemical sensing system that can be considered a green sensor. It is also thought that this study, specifically focusing on broad bean, sheds light on the possibility that agricultural resources and even waste can be used as low-cost, sustainable, and environmentally harmless materials in electrochemical technological processes.

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ANALYSIS OF BOD, COD, AND BIODEGRADABILITY RATIO OF INDUSTRIAL POTATO FIRST-WASH WASTEWATER

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ABSTRACT

The potato processing industry generates large volumes of wastewater with high organic loads, making its proper characterization essential for the development of treatment and reuse strategies. In this context, the present study aimed to determine the Biochemical Oxygen Demand ($BOD_{5,20}$), Chemical Oxygen Demand (COD), and BOD/COD ratio of wastewater generated during the first washing stage of potatoes in order to assess its biodegradability potential. Samples were collected directly from the processing line of a food industry. $BOD_{5,20}$ was determined using the respirometric method, while COD was quantified by the closed reflux colorimetric method, according to the *Standard Methods for the Examination of Water and Wastewater*. The results showed $BOD_{5,20}$ and COD values of 324.1 $mg \cdot L^{-1}$ and 15,354 $mg \cdot L^{-1}$, respectively, resulting in a BOD/COD ratio of 0.021. The high COD value indicates the presence of complex organic compounds released from potatoes, such as starch, soluble sugars, and phenolic compounds. The extremely low BOD/COD ratio demonstrates the reduced biodegradability of the effluent and the predominance of recalcitrant organic matter, highlighting the limitations of conventional biological treatment processes when applied alone. Therefore, the results suggest that physicochemical technologies and advanced oxidation processes may be more suitable alternatives for treating this wastewater, contributing to environmental impact reduction and enhancing the feasibility of industrial water reuse.

Keywords: agro-industrial wastewater; Biochemical Oxygen Demand; Chemical Oxygen Demand; biodegradability; wastewater treatment.

THE RELATIONSHIP BETWEEN MEDITERRANEAN DIET ADHERENCE, FIBROSCAN FINDINGS, AND NON-INVASIVE FIBROSIS SCORES: A CROSS-SECTIONAL STUDY

AKDENİZ DİYETİ UYUMU İLE FIBROSCAN BULGULARI VE NON-İNVAZİV FİBROZİS SKORLARI ARASINDAKİ İLİŞKİ: KESİTSEL BİR ÇALIŞMA

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ÖZET

Giriş ve Amaç: Akdeniz diyeti (AD) uyumunun, metabolik disfonksiyonla ilişkili steatotik karaciğer hastalığının (MASLD) gelişiminde ve progresyonunda koruyucu rol oynayabileceği üzerinde durulmaktadır. Bu nedenle, mevcut çalışmada kontrol bireyleri ve MASLD hastalarından oluşan çalışma popülasyonunda AD uyumu ile hepatik steatoz, karaciğer sertliği ve non-invaziv fibrozis belirteçleri arasındaki ilişkinin değerlendirilmesi amaçlanmıştır.

Gereç ve Yöntem: Bu kesitsel çalışmaya kontrol ve MASLD tanısı alan bireyler olarak toplam 42 birey dahil edilmiştir. AD uyumu Mediterranean Diet Adherence Screener (MEDAS) kullanılarak değerlendirilmiştir. Hepatik steatoz ve fibrozis düzeyi, vibration-controlled transient elastography (VCTE; FibroScan) yöntemi ile Controlled Attenuation Parameter (CAP) ve Liver Stiffness Measurement (LSM) ölçümleri kullanılarak değerlendirilmiştir. Ayrıca APRI, FIB-4, NAFLD Fibrosis Score (NFS), FAST, Agile 3+ ve Agile 4 skorları hesaplanmış olup, değişkenler arasındaki ilişkiler Spearman korelasyon analizi ile değerlendirilmiştir.

Bulgular: MEDAS skoru ile CAP ($r=-0.368$, $p=0.016$) ve LSM ($r=-0.496$, $p<0.001$) değerleri arasında negatif yönlü korelasyon saptanırken; MEDAS skoru ile bel/kalça oranı arasında güçlü negatif korelasyon bulunmuştur ($r=-0.565$, $p<0.001$). Ayrıca LSM değerleri ile APRI ($r=0.704$, $p<0.001$), FIB-4 ($r=0.497$, $p<0.001$), NFS ($r=0.527$, $p<0.001$), FAST ($r=0.839$, $p<0.001$), Agile 3+ ($r=0.517$, $p<0.001$) ve Agile 4 ($r=0.525$, $p<0.001$) skorları arasında anlamlı pozitif korelasyon olduğu belirlenmiştir.

Tartışma ve Sonuç: Bu çalışma, AD uyumundaki artışın daha düşük hepatik steatoz, karaciğer sertliği ve non-invaziv fibrozis skorları ile ilişkili olduğunu göstermiştir. Ayrıca LSM ile non-invaziv fibrozis belirteçleri arasındaki güçlü pozitif korelasyonlar, transient elastografinin MASLD'de karaciğer fibrozis şiddetinin değerlendirilmesindeki yararlılığını desteklemektedir. Metabolik ve karaciğer sağlığı üzerindeki olumlu etkilerine ek olarak AD, bitki temelli besin profili ve daha düşük çevresel etkisi nedeniyle sürdürülebilir bir beslenme modeli olarak da kabul edilmektedir. Bu bulgular, AD'ye uyumun hem MASLD progresyonunun önlenmesine hem de sürdürülebilir beslenme yaklaşımlarının desteklenmesine katkı sağlayabileceğini düşündürmektedir.

Anahtar Kelimeler: MASLD; Akdeniz Diyeti; FibroScan; Fibrozis; MEDAS

ABSTRACT

Introduction and Purpose: Mediterranean diet (MD) adherence has been suggested to play a protective role in the development and progression of metabolic dysfunction-associated steatotic liver disease (MASLD). This study aims to evaluate the relationship of MD adherence with hepatic steatosis, liver stiffness, and non-invasive fibrosis markers among controls and patients with MASLD.

Materials and Methods: This cross-sectional study included 42 individuals, comprising controls and patients with MASLD. MD adherence was assessed using the Mediterranean Diet Adherence Screener (MEDAS). The degree of hepatic steatosis and fibrosis was evaluated by FibroScan using Controlled Attenuation Parameter (CAP) and Liver Stiffness Measurement (LSM). In addition, APRI, FIB-4, NAFLD Fibrosis Score (NFS), FAST, Agile 3+, and Agile 4 scores were calculated, and the relationship between variables were assessed using Spearman correlation analysis.

Results: MEDAS score was negatively correlated with CAP ($r = -0.368$, $p = 0.016$), LSM ($r = -0.496$, $p < 0.001$), and waist-to-hip ratio ($r = -0.565$, $p < 0.001$). LSM was positively correlated with all non-invasive fibrosis scores, with the strongest correlation observed for FAST ($r = 0.839$, $p < 0.001$).

Discussion and Conclusion: This study demonstrated that higher MD adherence was associated with lower hepatic steatosis, liver stiffness, and non-invasive fibrosis scores. In addition, the strong positive correlations between LSM and non-invasive fibrosis markers support the utility of transient elastography in assessing the severity of liver fibrosis in MASLD. MD is also considered a sustainable dietary pattern due to its plant-rich food profile and lower environmental impact. These findings suggest that adherence to the MD may contribute both to the prevention of MASLD progression and to the promotion of sustainable dietary approaches.

Key Words: MASLD; Mediterranean Diet; FibroScan; Fibrosis; MEDAS

ASSESSMENT OF THE EFFECT OF NUTRITION KNOWLEDGE LEVEL AND ATTITUDES ON FOOD SUPPLEMENT USE ACCORDING TO BODY MASS INDEX

BESLENME BİLGİ DÜZEYİ İLE TUTUMUNUN, BEDEN KÜTLE İNDEKSİ DEĞERİNE GÖRE GIDA TAKVİYESİ KULLANIMINA ETKİSİNİN DEĞERLENDİRİLMESİ

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ÖZET

Gıda takviyelerinin kullanımı ülkemizi ve dünyayı etkileyen COVID-19 pandemisi sırasında ve sonrasında önemli ölçüde artmış, bağışıklığı güçlendirmek ve sağlığı korumak amacıyla bu takviyelerin kullanımı belirgin hale gelmiştir. Bu eğilim günümüzde de artmaya devam etmekte ve gıda takviyesi kullanımını yaygın bir durum haline getirmektedir. Bu çalışmanın amacı, İstanbul'da yaşayan 25-64 yaş arası yetişkin bireylerin beslenme bilgi düzeylerinin, sağlıklı beslenmeye yönelik tutumlarının beden kütle indeksi (BKİ) bağlamında, gıda takviyesi kullanım alışkanlıkları üzerindeki etkisini incelemektir. Çalışma kesitsel bir çalışma olarak tasarlanmış olup, veri toplama sosyodemografik özellikler ve antropometrik ölçümlerin yanı sıra Yetişkinler İçin Beslenme Bilgi Düzeyi Ölçeği (YETBİD) ve Sağlıklı Beslenmeye İlişkin Tutum Ölçeği (SBİTÖ) ile gerçekleştirilmiştir.

Çalışma bulgularına göre katılımcıların %27,5'inin düzenli, %39,8'inin ise ara sıra gıda takviyesi kullandığı belirlenmiştir. En sık tercih edilen takviye türü vitaminler %55,1 oranında olurken, bunu mineraller %39,1, omega-3 %14,4, probiyotikler %6,3 ve %10,9 ile de diğer takviyeler (bitkisel ekstreler, folik asit, demir, melatonin, uzun yaşam takviyeleri, kolajenler ve diğer spesifik takviyeler vb.) takip etmektedir. Katılımcıların %79'u takviyeleri tedavi dışı veya isteğe bağlı kullanım amaçlarıyla kullandığını belirtmiştir.

Ayrıca, çalışmada BKİ'nin bu ilişki için düzenleyici bir rol oynadığını da göstermektedir. Normal BKİ'ye sahip bireylerin sağlıklarını korumak için takviye kullanma olasılıklarının daha yüksek olduğu, yüksek BKİ grubunda ise kilo verme motivasyonunun takviye kullanımında daha büyük bir etkiye sahip olduğu bulunmuştur. Bununla birlikte, bazı analizlerde BKİ ile takviye kullanımı arasında anlamlı bir ilişki bulunmaması, bu davranışın çok faktörlü yapısını doğrulamaktadır.

Yetişkinlerde Beslenme Bilgi Düzeyi (YETBİD) ile gıda takviyesi kullanımı arasında pozitif yönlü ve anlamlı bir ilişki bulunmuştur ($p<0,01$). Benzer şekilde, temel beslenme ve besin-sağlık bilgisi alt boyutu ile takviye kullanımı arasında da anlamlı bir ilişki saptanmıştır

(p<0,01). Sağlıklı Beslenmeye İlişkin Tutum (SBİTÖ) olumlu yönde arttıkça gıda takviyesi kullanımının da arttığı belirlenmiştir (p<0,05). Buna karşılık, BKİ'nin takviye kullanımı üzerinde doğrudan ve anlamlı bir etkisi bulunmamıştır (p>0,05). BKİ'nin düzenleyici rolünü inceleyen analizlerde bazı etkileşim modellerinde anlamlı sonuçlar elde edilmekle birlikte, yüksek çoklu doğrusallık değerleri nedeniyle bu bulguların dikkatli yorumlanması gerektiği belirlenmiştir. Beden Kütle İndeksinin (BKİ) düzenleyici etkisinin modeldeki varyansın yaklaşık %8'lik bir değişimi açıkladığı belirlenmiştir (Varyansın R^2'si = 0,085).

Sonuç olarak, beslenme bilgisi yüksek olan kişilerin daha bilinçli seçimler yaptığı gözlemlenmiş olsa dahi, bazı bireylerin yeterli bilgiye sahip olmadan bile takviye kullandığı tespit edilmiştir. Dolayısıyla gıda takviyesi kullanımının yalnızca bilgiyle açıklanamayacağı, bilgi, tutum, algı ve BKİ gibi değişkenlerin birlikte değerlendirilmesi gerektiği sonucuna varılmıştır. Buna göre, toplumumuzdaki farkındalığı arttırmak için bireylere hedef odaklı beslenme eğitim programlarının düzenlenmesi ve takviyelerin bilinçli kullanımının teşvik edilmesi önerilmektedir.

Anahtar Kelimeler: Beslenme Bilgi Düzeyi, Beslenmeye İlişkin Tutum, Gıda Takviyeleri, Beden Kütle İndeksi (BKİ), YETBİD, SBİTÖ

ABSTRACT

During and after the COVID-19 pandemic, the use of food supplements, affecting both Türkiye and the World, increased significantly and became widespread for the purpose of strengthening immunity and protecting health. This trend continues to increase today, making the use of food supplements widespread. The aim of this study is to examine the effects of nutritional knowledge and attitudes towards healthy eating on supplement use habits in the context of Body Mass Index (BMI) among adults aged 25-64 living in Istanbul. The study is a cross-sectional study that collected data using the Nutritional Knowledge Scale for Adults (YETBİD) and the Healthy Eating Attitudes Scale (SBİTÖ), as well as sociodemographic characteristics and anthropometric measurements.

According to the study results, 27,5% of participants used food supplements regularly, while 39,8% used them occasionally. The most preferred type of supplement was vitamins (55,1%), followed by minerals (39,1%), Omega-3 (14,4%), probiotics (6,3%) and other supplements (10,9%) including herbal extracts, folic acid, iron, melatonin, longevity supplements, collagen, and other specialized supplements. Furthermore, 79% of participants reported using supplements for non-therapeutic purposes.

The study also shows that BMI plays a moderating role in this relationship. Individuals with a normal BMI were found to be more likely to use supplements to maintain their health, while in the high BMI group, motivation for weight loss had a greater impact. However, the lack of a significant relationship between BMI and supplement use in some analyses confirms the multifactorial nature of this behavior. A positive and significant relationship was found between nutritional knowledge level (YETBİD) and supplement use (p<0,01). Similarly, a significant relationship was found between basic food-related nutrition and supplement use (p<0,01). Supplement use was found to increase with positive attitudes towards healthy eating (SBİTÖ) (p<0,05). In contrast, BMI did not have a direct and significant effect on supplement use (p>0,05). While some interaction models showed significant results in analyses examining the moderating role of BMI, these results should be interpreted cautiously due to high multicollinearity values. The moderating effect of Body Mass Index (BMI) was found to explain approximately 8,5% of the variation in model variance (R^2 change = 0,085).

In conclusion, although it was observed that individuals with high nutritional knowledge make more informed choices, some individuals were found to use supplements even without sufficient knowledge. Therefore, supplement use cannot be explained solely by knowledge. It has been determined that variables such as knowledge, attitudes, perceptions and BMI are needed to be evaluated. Accordingly, it is recommended to organize targeted nutrition education programs to increase public awareness and to encourage the conscious use of food supplements.

Keywords: Nutrition Knowledge Level, Attitude Toward Nutrition, Food Supplements, Body Mass Index (BMI), YETBİD, SBİTÖ.

IN VITRO ANTIOXYDANT AND ANTICOCCIDIAL ACTIVITY OF OLIVE PULP (*OLEA EUROPAEA* L. VAR. CHEMLAL) EXTRACT AGAINST *EIMERIA* OOCYSTS IN BROILER CHICKENS

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ABSTRACT

Aim The objective of the present study was to investigate in vitro anticoccidial effect of olive pulp (*Olea europaea L* var. Chemlal) extract on the destruction of *Eimeria* spp. oocysts isolated from infected chickens naturally.

Materials and methods The olive pulp (OP) powder was stirred manually in aqueous ethanol in preparation for extraction using the microwave-assisted extraction system. The identification of the phenolic compounds was obtained by ultra-highperformance liquid chromatography–mass spectrometry with electrospray ionisation (HPLC–ESI–MS). The treatment of *Eimeria* oocyst with OP extract and standard compounds (quercetin and oleuropein) leads to their lysis as shown by the release of substances absorbing at 273 nm.

Results Our results showed that the maximum number of reduced oocysts was recorded after 8 h of incubation of optimum OP extract, quercetin and oleuropein for different periods of time. Also, the number of *Eimeria* oocysts decreased considerably with increase concentrations after adding the optimum of OP extract in concentration ranging from 0.023 to 0.371 mg/ml. Positive correlation between the optimum OP extract concentrations and the number of *Eimeria* oocysts reduced was $R2 = 0.959$. From this in vitro experiment, it can be concluded that the OP extract possesses an anti-*Eimeria* spp activity.

Conclusion To our knowledge, this is the first time that quercetin and oleuropein were tested to evaluate their anticoccidial activity. The findings of this study showed that phenolic compound of OP extract tested separately possesses anti-*Eimeria*spp. effect. Further studies should be carried out to test its in vivo efficacy of the OP bioactive compounds in broiler chickens.

Keywords: *Olea europea* L. var. Chemlal ; Co-products ; Antioxydant ; Anticoccidial activity ; Chickens; In vitro

THE IMPACT OF CLIMATE CHANGE ON NUTRITION AND FOOD SECURITY: THE ROLE OF PUBLIC HEALTH NURSES

İKLİM DEĞİŞİKLİĞİNİN BESLENME VE GIDA GÜVENLİĞİ ÜZERİNDEKİ ETKİLERİ: HALK SAĞLIĞI HEMŞİRESİNİN ROLÜ

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ÖZET

İklim değişikliği, küresel ölçekte sıcaklık artışları, kuraklık, sel, fırtına ve mevsimsel düzensizlikler gibi aşırı hava olaylarının sıklığını artırarak tarımsal üretimi, gıda talebini ve toplumların beslenme durumunu doğrudan etkileyen önemli bir halk sağlığı sorunu haline gelmiştir. Tarımsal verimliliğin azalması, gıda fiyatlarının yükselmesi ve besinlerin içerdiği temel öğelerde meydana gelen değişiklikler, özellikle toplumdaki hassas gruplar içerisinde yer alan çocuklar, yaşlılar, kronik hastalığı bulunan bireyler ve sosyoekonomik açıdan dezavantajlı gruplar için önemli sağlık riskleri oluşturmaktadır. Bu süreç yalnızca gıda güvenliğini değil, aynı zamanda yeterli ve dengeli beslenmeye erişimi de tehdit ederek sağlık eşitsizliklerinin derinleşmesine neden olmaktadır. Bu literatür derleme çalışmasının amacı, iklim değişikliğinin beslenme ve gıda güvenliği üzerindeki etkilerini halk sağlığı hemşireliği bakış açısıyla değerlendirmek ve halk sağlığı hemşirelerinin bu alandaki rollerini ortaya koymaktır. Çalışmaya dahil edilen yayınlar İngilizce ve Türkçe dillerinde yayımlanmış olup, iklim değişikliği ve beslenme ilişkisini doğrudan ele alan çalışmalar önceliklendirilmiştir. Çalışma kapsamında PubMed, Web of Science, Scopus ve ScienceDirect veri tabanlarında yayımlanan güncel araştırmalar ile Dünya Sağlık Örgütü, Birleşmiş Milletler Gıda ve Tarım Örgütü ve ilgili ulusal kurumların raporları incelenmiştir. Elde edilen bulgular, iklim değişikliğinin gıda üretim sistemleri, beslenme güvenliği ve toplum sağlığı üzerinde çok yönlü etkiler oluşturduğunu göstermektedir. Halk sağlığı hemşireleri; iklim ve sağlık konusunda farkındalık geliştirme, sürdürülebilir ve sağlıklı beslenme davranışlarını destekleme, risk altındaki grupları belirleme, toplum temelli eğitim programları yürütme ve sağlığı koruyucu politikaların geliştirilmesine katkı sağlama gibi önemli sorumluluklar üstlenmektedir. Özellikle Türkiye'nin iklim değişikliğinden etkilenme riski yüksek bölgeler arasında yer alması, kuraklık ve gıda güvencesizliği risklerinin artması nedeniyle halk sağlığı hemşirelerinin önleyici ve geliştirici sağlık hizmetlerindeki rolünü daha da önemli hale getirmektedir. Sonuç olarak, iklim değişikliğinin beslenme ve gıda güvenliği üzerindeki olumsuz etkilerinin azaltılmasında halk sağlığı hemşirelerinin aktif katılımı, toplum sağlığının korunması ve sürdürülebilir bir gelecek için temel gerekliliklerden biri olarak değerlendirilmektedir.

Anahtar Kelimeler: İklim değişikliği, gıda güvenliği, beslenme, halk sağlığı hemşireliği

ABSTRACT

Climate change has become a significant public health concern that directly affects agricultural production, food demand, and the nutritional status of populations by increasing the frequency of extreme weather events such as rising temperatures, droughts, floods, storms, and seasonal

irregularities on a global scale. Declining agricultural productivity, rising food prices, and alterations in the essential nutrient content of foods pose serious health risks, particularly for vulnerable groups including children, the elderly, individuals with chronic illnesses, and socioeconomically disadvantaged populations. This process not only threatens food security but also jeopardizes access to adequate and balanced nutrition, thereby deepening health inequalities. The aim of this literature review is to evaluate the effects of climate change on nutrition and food security from a public health nursing perspective and to delineate the roles of public health nurses in this domain. The publications included in the study were published in English and Turkish, and studies directly addressing the relationship between climate change and nutrition were prioritized. Within the scope of the study, current research published in PubMed, Web of Science, Scopus, and ScienceDirect databases, as well as reports from the World Health Organization, the Food and Agriculture Organization of the United Nations, and relevant national institutions, were examined. The findings indicate that climate change exerts multifaceted effects on food production systems, nutrition security, and community health. Public health nurses bear significant responsibilities, including raising awareness on climate and health, promoting sustainable and healthy dietary behaviors, identifying at-risk groups, conducting community-based education programs, and contributing to the development of health-protective policies. The fact that Turkey is among the high-risk regions for climate change impacts, with increasing threats of drought and food insecurity, makes the preventive and health-promoting role of public health nurses all the more critical. In conclusion, the active engagement of public health nurses in mitigating the adverse effects of climate change on nutrition and food security is regarded as one of the fundamental requirements for safeguarding community health and ensuring a sustainable future.

Keywords: Climate change, food security, nutrition, public health nursing

GİRİŞ

Yirminci yüzyılın ikinci yarısından itibaren hız kazanan sanayileşme ve fosil yakıt kullanımı, atmosferdeki sera gazı konsantrasyonlarını tarihsel eşiklerin çok üzerine taşımış ve küresel iklim sistemini köklü biçimde dönüştürmektedir. Bu dönüşüm; ortalama sıcaklıklardaki sürekli artış, kuraklık ve sel gibi aşırı hava olaylarının sıklaşması, yağış rejimlerinin bozulması ve deniz seviyesinin yükselmesi biçiminde kendini göstermektedir. Hükümetlerarası İklim Değişikliği Paneli (IPCC), bu sürecin yalnızca ekolojik bir tehdit olmadığını aynı zamanda insan sağlığını, gıda sistemlerini ve sosyal eşitliği doğrudan etkileyen bir halk sağlığı sorunu olarak bunun bir kalkınma sorunu olduğunu belirtmektedir (IPCC, 2022).

Romanello ve ark. (2024) çalışmasında, 2023 yılında ısı dalgaları ve kuraklıkların artışı, 1981-2010 dönemine kıyasla 151 milyon kişiyi ek olarak orta veya şiddetli gıda güvensizliğine yol açtığını bildirmiştir (Romanello ve ark., 2024). Küresel düzeyde yayınlanan raporlar ise 2024 yılı itibarıyla yaklaşık 673 milyon insan kronik açlıkla mücadele etmekte olduğunu ve 2,6 milyar kişinin sağlıklı bir diyetin maliyetini karşılayamadığını ortaya koymaktadır (FAO, IFAD, UNICEF, WFP & WHO, 2025). İklim değişikliğinin beslenme üzerindeki tehdidi yalnızca gıda miktarıyla sınırlı kalmamakta; atmosferik CO_2 konsantrasyonundaki artış, temel tarım ürünlerindeki çinko, demir ve protein içeriklerini de azaltmaktadır. Bu durum, klinik bulgular ortaya çıkmadan önce saptanması güç olan ve gizli açlık olarak tanımlanan mikro besin eksikliğinin toplumda sessizce yaygınlaşmasına zemin hazırlamaktadır (Semba ve ark., 2022). IPCC, Türkiye'nin iklim değişikliğinden en fazla etkilenecek bölgeler arasında yer aldığını vurgulamaktadır (T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2024; UNCCD, 2025). Tarımın milli gelire katkısı son yirmi yılda %9,5'ten %5,9'a gerilemiş olmakla birlikte, bu durum ülkemizde gıda güvenliği açısından kırılganlığın giderek artmasına yol açmaktadır

(TÜİK, 2024). Bu durum, Türkiye'nin iklim değişikliğine duyarlı tarımsal üretim yapısı ve mevcut sosyoekonomik eşitsizlikler göz önünde bulundurulduğunda, ulusal gıda güvenliği politikalarının iklim uyum perspektifiyle yeniden güçlendirilmesi gerekliliğini ortaya koymaktadır.

Tüm bu gelişmeler, iklim değişikliğini yalnızca çevre ya da tarım politikalarının değil, aynı zamanda toplum sağlığının da öncelikli sorunları haline getirmektedir. Gıda güvensizliği ve yetersiz beslenme; başta çocuklar, yaşlılar, kronik hastalığı bulunan bireyler ve sosyoekonomik açıdan dezavantajlı gruplar olmak üzere toplumun en kırılgan kesimlerini etkilemekte, mevcut sağlık eşitsizliklerini daha da derinleştirmektedir (IPCC, 2022). Yetersiz beslenmenin yol açtığı büyüme geriliği, bağışıklık fonksiyonlarında azalma ve kronik hastalık riskinde artış gibi sağlık sonuçları, bireyin yaşam boyu sağlığını olumsuz etkileyerek toplumsal refah düzeyinde de belirgin bir düşüşe neden olabileceğini düşündürmektedir.

Halk sağlığı hemşiresi; bireyi, aileyi ve toplumu bir bütün olarak ele alan, koruyucu, geliştirici ve önleyici sağlık hizmetlerini birinci basamakta uygulayan, toplumla sürekli ve yakın temas içinde çalışan bir sağlık profesyonelidir (Bernhardt ve ark., 2023). Halk sağlığı hemşiresi, iklim kaynaklı gıda güvensizliği ve beslenme bozukluklarının erken belirtilerini saptayabilecek, risk altındaki bireyleri tanımlayabilecek ve toplum temelli koruyucu müdahaleleri hayata geçirebilecek eşsiz bir konumdadır. Bunun ötesinde hemşireler; sağlıklı ve sürdürülebilir beslenme davranışlarını destekleme, toplumun iklim ve sağlık konusundaki farkındalığını artırma ve sağlığı koruyucu politikaların şekillendirilmesine katkı sağlama gibi kapsamlı sorumluluklar da taşımaktadır (Harris ve ark., 2022). Hemşirelerin iklim değişikliğine ilişkin bilgi düzeyi, toplumun savunucusu olarak üstlendikleri rol ve toplum temelli müdahale kapasiteleri, iklim kaynaklı sağlık tehditlerini önlemede sağlık sisteminin en erişilebilir ve etkili halkasını oluşturmaktadır. Bu derleme; iklim değişikliğinin beslenme ve gıda güvenliği üzerindeki etkilerini halk sağlığı hemşireliği bakış açısıyla değerlendirmeyi ve halk sağlığı hemşirelerinin bu alandaki rollerini uluslararası kanıt temeli ile veriler ışığında bütüncül bir yaklaşımla ortaya koymayı amaçlamaktadır. İklim değişikliği ile mücadelede sağlık profesyonellerinin rolü giderek artmakta olup, hemşireler bu sürecin toplumla en yakın temas kuran meslek grubu olarak kritik bir konumda yer almaktadır.

İklim Değişikliğinin Beslenme ve Gıda Güvenliği Üzerindeki Etkileri

İklim değişikliği ile beslenme arasındaki ilişki çok boyutlu ve döngüsel bir nitelik taşımaktadır. Gıda sistemlerindeki bozulmalar, bireylerin beslenme durumunu farklı yönlerden etkileyerek yetersiz beslenme ve mikro besin öğesi eksikliklerinin yanı sıra, aynı toplumda obezite oranlarında artış gibi zıt görünen sorunların birlikte ortaya çıkmasına neden olabilmektedir. Beslenme durumundaki bu çok yönlü olumsuz tablo, literatürde 'malnütrisyonun çifte yükü' olarak tanımlanmakta olup, hem yetersiz beslenme hem de aşırı beslenmeye bağlı sağlık sorunlarının aynı anda görülmesini ifade etmektedir. Bu durum, özellikle halk sağlığı hemşirelerinin toplum temelli izlem ve koruyucu sağlık hizmetlerinde daha bütüncül bir yaklaşım geliştirmesini gerekli kılmaktadır (Sparling ve ark., 2024).

Yetersiz beslenme boyutunda değerlendirildiğinde, iklim kaynaklı tarımsal verim kayıpları ve buna bağlı gıda fiyatı artışlarının düşük gelirli hanelerde diyet kalitesini hızla düşürdüğü görülmektedir. Türkiye İstatistik Kurumu verisine göre 2023 yılında en düşük gelir grubundaki haneler, toplam tüketim harcamalarının %36,6'sını gıdaya ayırırken bu oran en yüksek gelir grubunda yalnızca %14,5 olarak gerçekleşmiştir (TÜİK, 2024a). Toplumda hanelerin dengeli ve çeşitli beslenme yerine maliyeti düşük ancak besin yoğunluğu yetersiz gıdalara yönelmesi demir, çinko ve B vitamini grubu eksiklikleri başta olmak üzere mikro besin yetersizliklerinin toplumda sessizce yaygınlaşmasına zemin hazırlamaktadır (Semba ve ark., 2022). Benzer şekilde toplumda pek çok hanede yüksek kalori ancak düşük besin değeri sunan ultra-işlenmiş

gıdalara erişimi kolaylaştırmakta; bu durum ise obezite, tip 2 diyabet ve kardiyovasküler hastalık gibi kronik sağlık sorunlarının insidansını artıran bir risk faktörü olarak karşımıza çıkmaktadır (Lane ve ark., 2024). Nucci ve ark. (2025), 265.000'den fazla katılımcıyı kapsayan sistematik derlemelerinde; aşırı hava olaylarına maruz kalmanın gıda tedarik zincirlerinde kesintilere, ekonomik güçlüklere ve yetersiz uyum yanıtlarına yol açarak 60 yaş ve üzeri bireylerde beslenme bozukluğu riskini belirgin biçimde artırdığını bildirmiştir. Özellikle sosyal destek ağları zayıf ve ekonomik istikrarı kırılgan olan yaşlı bireylerin bu süreçten orantısız biçimde daha fazla etkilendiği vurgulanmış; kırsal ve kentsel savunmasız topluluklar için durumun daha da belirleyici olduğu saptanmıştır (Nucci ve ark., 2025).

İklim değişikliğinin beslenme üzerindeki etkileri yalnızca fiziksel sağlık boyutuyla gıda güvensizliğinin ruh sağlığı üzerindeki yansımaları da giderek daha fazla araştırmanın konusu olmaktadır. Lieber ve ark. (2022), kuraklık, sel ve iklim değişkenliğinin malnütrisyon üzerindeki etkisini inceleyen sistematik derleme ve meta-analizlerinde; aşırı hava olaylarına maruz kalmanın çocuklarda boy kısalığı (stunting) ve erime (wasting) başta olmak üzere antropometrik bozulmalarla güçlü biçimde ilişkilendiğini ve bu ilişkinin incelenen çalışmaların büyük çoğunluğunda tutarlı bir örüntü sergilediğini ortaya koymuştur (Lieber ve ark., 2022). Literatürde yapılan araştırmalarda, gıda güvensizliği yaşayan bireylerin anksiyete ve depresyon geliştirme riskinin belirgin biçimde arttığını göstermektedir (Bateson ve ark., 2025). Yetersiz beslenme ruh sağlığını bozarken, kötüleşen ruh sağlığı da bireyin gıdaya erişimini ve beslenme davranışlarını olumsuz yönde etkilemektedir.

Beslenme güvenliğini tehdit eden bir diğer önemli boyut, iklim değişikliğiyle birlikte giderek artan gıda kaynaklı enfeksiyon riskidir. Literatürde yapılan bir sistematik derleme ve meta-analizde, yükselen ortam sıcaklıkları ile artış gösteren yağış miktarının Salmonella, Shigella, Vibrio, Campylobacter ve Listeria türlerinden kaynaklanan gastroenterit vakalarıyla güçlü biçimde ilişkilendiğini ve mevcut iklim eğilimlerinin devam etmesi halinde bu patojenlerin neden olduğu morbidite yükünün, hastane başvurularının ve uzun süreli antibiyotik kullanım gereksiniminin artacağı öngörülmektedir (Oluwole ve ark., 2025). Benzer şekilde, sıcaklık ve nem koşullarındaki değişimlerin Aspergillus flavus gibi toksin üreten mantar türlerinin üremesini kolaylaştırarak aflotoksin başta olmak üzere mikotoksin kontaminasyon riskini artırdığı kapsamlı araştırmalarla ortaya konmuştur (Bunny ve ark., 2024). Bu durum, enfeksiyöz bağırsak hastalıkları ve gıda kaynaklı zehirlenme olgularının artmasına katkıda bulunmakta; toplumun beslenme durumunu dolaylı yoldan olumsuz etkileyerek özellikle çocuklar ve bağışıklığı zayıf bireyler gibi kırılgan gruplar için ciddi halk sağlığı riskleri oluşturmaktadır.

Kırılgan Gruplar ve Sağlık Eşitsizlikleri

İklim değişikliğinin beslenme ve gıda güvenliği üzerindeki olumsuz etkileri, toplumun tüm kesimlerini eşit biçimde etkilememektedir. Dünya Sağlık Örgütü (DSÖ), iklime duyarlı sağlık risklerinin en fazla kadınlar, çocuklar, etnik azınlıklar, yoksul topluluklar, göçmenler, yerinden edilmiş kişiler, yaşlılar ve altta yatan sağlık koşulları bulunan bireyler gibi dezavantajlı gruplarda yaşandığını bildirmiştir (WHO, 2023).

Çocuklarda büyüme ve gelişme sürecinin kritik bir döneminde yaşanan yetersiz beslenme ve mikro besin eksiklikleri sebebiyle boy kısalığı, bağışıklık fonksiyonlarında bozulma, bilişsel gelişim geriliği ve uzun vadede kronik hastalık yükünde artış gibi geri döndürülmesi zor sağlık sonuçlarına yol açmaktadır. Türkiye'de TÜİK verilerine dayanan BM raporları, 2023 yılında çocukların %40,1'inin yoksulluk veya sosyal dışlanma riski altında bulunduğunu, bu oranın genel nüfus ortalamasının (%30,7) belirgin biçimde üzerinde olduğunu bildirmiştir (WFP, 2025). Bu bulgu, Türkiye'deki çocukların iklim kaynaklı gıda güvensizliğine yapısal düzeyde ne denli açık olduğunun somut bir göstergesidir. IPCC AR6 ise Afrika'daki 30 ülkeden elde

edilen verileri derleyerek yükselen sıcaklıklar ile çocuklarda yetersiz beslenme ve erime (wasting) arasında istatistiksel olarak anlamlı bir ilişki olduğunu ortaya koymaktadır (IPCC, 2022).

Yüksek gelirli ülkelerdeki gebeleri konu alan bir sistematik derleme ve meta-analizde, gebelik döneminde gıda güvensizliği yaşayan kadınlarda gestasyonel diyabet, yüksek stres düzeyi ve duygudurum bozukluğu riskinin anlamlı biçimde arttığı; meyve-sebze tüketiminin azalması ve kırmızı işlenmiş et tüketiminin yükselmesiyle birlikte diyet kalitesinin bozulduğu bildirilmiştir (Bell ve ark., 2024). İklim değişikliğiyle bağlantılı hava kirleticilere ve aşırı ısı olaylarına gebelikte maruz kalmanın ise düşük doğum ağırlığı, erken doğum ve plasental stres mekanizmaları üzerinden fetal gelişimi olumsuz etkilediği ortaya çıkmıştır (Braun ve ark., 2025). 2025 SOFI raporu, gıda güvensizliği ve temel beslenme göstergelerindeki toplumsal cinsiyet uçurumunun 2023-2024 döneminde büyüdüğünü kaydetmekte; gıdaya erişimin kısıtlandığı bölgelerde kadınların ve kız çocuklarının aile içinde kendilerini geri planda bıraktığı, bunun sağlık eşitsizliklerini kalıcılaştıran yapısal bir örüntü oluşturduğunu ortaya koymaktadır (FAO, IFAD, UNICEF, WFP & WHO, 2025).

DSÖ'nün güncel raporuna göre 2023 yılında yirmi milyondan fazla kişi ani hava olayları nedeniyle yerinden edilmiş olup 2050'ye kadar 216 milyonu aşkın insanın iklim kaynaklı nedenlerle ülke içinde göç etmek zorunda kalabileceği öngörülmektedir (WHO, 2025). Göç ve yerinden edilme sürecindeki bireyler; gıda güvensizliği, yetersiz beslenme ve sağlık hizmetlerine erişim güçlüğü gibi çok katmanlı risklerle aynı anda yüzleşmekte; bu durum toplum sağlığı hemşirelerinin kapsayıcı değerlendirme yaklaşımlarını ve aktif takip protokollerini daha da zorunlu kılmaktadır.

Halk Sağlığı Hemşiresinin Rolü

Halk sağlığı hemşireliği, birey, aile ve toplumun sağlık düzeyini çevresel ve sosyal belirleyiciler ile birlikte ele alan bütüncül bir yaklaşımı temel almaktadır. Bu bağlamda iklim değişikliği, günümüzde yalnızca çevresel bir sorun değil, aynı zamanda sosyal belirleyiciler aracılığıyla sağlık eşitsizliklerini derinleştiren bir halk sağlığı sorunu olarak değerlendirilmektedir. Hemşireler, dünya genelinde sağlık iş gücünün en büyük bölümünü oluşturmakta ve sağlık hizmetlerinin sunumunda toplumla en sık temas kuran meslek grubu olma özelliğini korumaktadır. Bu konum; halk sağlığı hemşirelerine iklim değişikliğinin beslenme ve gıda güvenliği üzerindeki etkilerini önleme, erken saptama ve yönetme süreçlerinde özgün bir sorumluluk alanı tanımlamaktadır (Bernhardt ve ark., 2023). Hemşirelik, hemşirelik paradigmasının dört temel unsuru olan birey, sağlık, hemşirelik ve çevre ekseninde bütüncül bir sağlık anlayışı geliştirmektedir. Bu çerçeve, iklim kaynaklı sağlık sorunlarına çok boyutlu yanıtlar üretilmesini olanaklı kılmaktadır (American Nurse Journal, 2024). İklim değişikliğiyle mücadelede hemşirelik rolü; araştırma, eğitim, uygulama ve politika-savunuculuk olmak üzere dört temel alana yayılmaktadır (OJIN, 2024). Bu yaklaşım Neuman Sistemler Kuramı çerçevesinde değerlendirildiğinde, çevresel stresörlerin bireyin fizyolojik ve psikososyal dengesini doğrudan etkilediği görülmektedir.

Eğitim ve Danışmanlık Rolü

Halk sağlığı hemşirelerinin temel işlevlerinden biri; bireyler, aileler ve toplulukları iklim değişikliğinin sağlık sonuçları konusunda bilgilendirmek ve yaşam koşullarına uygun danışmanlık sunmaktır. Bu rol, yalnızca bireysel davranış değişikliği sağlamayı değil, aynı zamanda toplum düzeyinde sağlıklı ve sürdürülebilir beslenme kültürünün geliştirilmesini de kapsamaktadır. Bu kapsamda hemşireler; gıda fiyatlarındaki iklim kaynaklı artışların aile bütçesi üzerindeki yansımalarını ele almakta, kısıtlı bütçeyle dengeli beslenmeyi destekleyecek pratik stratejiler geliştirmekte ve mevsimsel gıda güvensizliği dönemlerinde yüksek riskli bireyleri ve haneleri tanımlamaktadır (Harris ve ark., 2022). Hemşirenin bu danışmanlık rolünü

etkin biçimde üstlenebilmesi, iklim-sağlık ilişkisine dair yeterli bilgi altyapısını gerektirmektedir. Ancak yapılan derlemeler, hemşirelik müfredatlarının iklim değişikliği, çevre sağlığı ve sürdürülebilirlik içeriklerini bütünleştirme konusunda küresel ölçekte yetersiz kaldığını ortaya koymaktadır (Seabra ve ark., 2025). Kanada, Amerikan ve uluslararası hemşirelik derneklerinin iklim değişikliği müdahale stratejilerini hemşirelik uygulamalarına entegre etmeye yönelik tavsiyeleri, bu açığın kurumsal düzeyde de fark edildiğini göstermekte ve eğitim programlarının yeniden yapılandırılması yönünde güçlü bir çağrı niteliği taşımaktadır (Gaudreau ve ark., 2024).

Toplum Temelli Müdahaleler

Toplum sağlığı hemşireleri, kentsel ve kırsal alanlarda gıda güvensizliğinin önlenmesine yönelik toplum temelli girişimlerin planlanması ve yürütülmesinde etkin bir rol üstlenmektedir. Kentsel tarım projelerinin desteklenmesi, gıda bankası ve dayanışma ağlarının koordinasyonu, kuraklık ve sel gibi iklim afetlerinin ardından savunmasız bireylerin belirlenmesi ve ilgili destek mekanizmalarına yönlendirilmesi bu girişimlerin somut örnekleridir (Seabra ve ark., 2025). Kapsamlı bir kapsam incelemesi (scoping review), kentsel alanlarda iklim değişikliğinin sağlık risklerini azaltmaya yönelik hemşirelik müdahalelerinin sekiz temel kategoride toplandığını ortaya koymuş; bireyleri ve toplulukları güçlendirme (empowerment), iklim farkındalığı ve sağlık okuryazarlığını artırma, sağlık politikası değişikliklerine katkı sağlama ile savunuculuk bu kategoriler arasında öne çıkmaktadır (Seabra ve ark., 2025). Hemşirenin rutin klinik gözlem pratiği; kilo kaybı, büyüme geriliği, enerji düşüklüğü ve bağışıklık fonksiyonlarında zayıflama gibi erken dönem gıda güvensizliği belirtilerini saptama açısından güçlü bir avantaj sağlamaktadır. Bu erken tanı ve müdahale kapasitesi, hemşireyi iklim kaynaklı beslenme bozukluklarının önlenmesinde birinci basamaktaki en erişilebilir sağlık aktörü konumuna taşımaktadır (Bernhardt ve ark., 2023).

Savunuculuk Rolü

Hemşireler; gıda güvencesini tehdit eden iklim politikaları, tarımsal destek mekanizmaları ve kentsel gıda sistemleri konusundaki karar alma süreçlerinde toplumun sözcüsü olma sorumluluğunu taşımaktadır. Bu savunuculuk işlevi, yerel yönetim kararlarından uluslararası iklim müzakerelerine kadar geniş bir etki alanını kapsamaktadır (Bernhardt ve ark., 2023). Nitekim 2022 yılında BM İklim Değişikliği Konferansı'na (COP27) katılan hemşireler, bu platformun sağlık profesyonelleri için küresel bir savunuculuk zemini sunduğuna dikkat çekmiş; hemşirelerin iklim kararlarını şekillendiren uluslararası müzakere süreçlerinde daha görünür biçimde yer alması gerektiğini vurgulamıştır (Johnson & Johnson Nursing, 2024). İklim değişikliğinin öncelikli bir halk sağlığı sorunu olarak tanınmasının güçlendirilmesi, sağlık sistemlerinin iklim uyum kapasitesinin artırılması ve kırılgan toplulukların gıdaya erişimini güvence altına alan politikaların desteklenmesi, hemşirelik savunuculuğunun temel odak noktalarını oluşturmaktadır.

Politika Geliştirme Süreçlerine Katkı

Hemşirelik mesleğinin politika boyutu, iklim değişikliğinin halk sağlığı gündemindeki ağırlığıyla doğru orantılı biçimde önem kazanmaktadır. BM Sürdürülebilir Kalkınma Hedefleri ve *The Future of Nursing 2020-2030* raporu; hemşirelerin sağlık eşitliğini ve çevresel sürdürülebilirliği merkeze alan politika geliştirme süreçlerine etkin biçimde dahil olması gerektiğini açıkça ortaya koymaktadır (Harris ve ark., 2022; Bernhardt ve ark., 2023). Ulusal iklim uyum planlarına hemşirelik perspektifinin yansıtılması; okul hemşireleri, toplum sağlığı merkezleri ve birinci basamak sağlık birimleri aracılığıyla işlevsel gıda güvenliği izleme protokollerinin oluşturulması bu katkının uygulamaya yansıyan biçimleridir. Hemşirelerin saha pratiğinden elde ettiği bulguları karar alıcılarla paylaşması, kanıta dayalı iklim-sağlık politikalarının geliştirilmesini destekleyen temel bir mekanizma işlevi görmektedir. Kırsal

bölgelerde gıda güvensizliğinin birinci basamakta erken dönemde tanımlanması, kentsel dezavantajlı alanlarda iklim kaynaklı beslenme sorunlarının sistematik izlenmesi ve aşırı hava olaylarının ardından koordineli müdahale süreçlerine katılım, bu mekanizmanın sahaya yansıyan somut çıktıları arasında yer almaktadır.

Sonuç ve Öneriler

İklim değişikliği; tarımsal verimdeki düşüşler, gıda fiyatlarındaki oynaklık, temel besin ögelerinin azalması ve aşırı hava olaylarının gıda sistemlerini sekteye uğratması yoluyla küresel ölçekte ve Türkiye'de giderek ağırlaşan bir halk sağlığı sorunu haline gelmektedir. Bu süreçten başta çocuklar, yaşlılar, gebe kadınlar, kronik hastalığı bulunan bireyler ve sosyoekonomik olarak dezavantajlı topluluklar olmak üzere kırılgan gruplar orantısız biçimde etkilenmekte; mevcut sağlık eşitsizlikleri daha da derinleşmektedir. Halk sağlığı hemşireleri bu süreçte yalnızca klinik bakım sunucusu olarak değil; toplumun iklim uyum kapasitesini güçlendiren, bireyler ve toplulukları eğiten, kırılgan grupların haklarını savunan ve politika geliştirme süreçlerine saha kanıtı sağlayan çok rollü sağlık profesyonelleri olarak işlev görmektedir. Hemşirelik mesleğinin iklim değişikliğini bir halk sağlığı önceliği olarak benimsemesi, bu alanda donanımlı bir iş gücünün yetiştirilmesi ve hemşirelerin politika kanallarında daha güçlü temsil edilmesi; iklim kaynaklı beslenme sorunlarının önüne geçilmesinde sağlık sisteminin önemli bir adımı olacaktır. Hemşirelik araştırmaları, eğitimi ve uygulaması iklim-beslenme ilişkisini artık göz ardı edemez; bu entegrasyon hem bugün hem de gelecek nesiller için sağlıklı ve sürdürülebilir bir toplumun ön koşullarından biridir. Bu nedenle halk sağlığı hemşireleri, iklim değişikliği ile mücadelede sağlık sisteminin en erişilebilir ve sürdürülebilir güçlerinden biri olarak stratejik bir konuma sahiptir.

Lisans ve lisansüstü hemşirelik programlarına iklim değişikliği, çevre sağlığı ve sürdürülebilir beslenme içeriklerinin müfredata sistematik biçimde eklenmesi gerekmektedir. Görevdeki hemşirelerin hizmet içi eğitimler aracılığıyla bu alanda bilgi ve becerilerinin güncellenmesi de eğitim politikasının kapsamına alınmalıdır. Birinci basamak sağlık hizmetlerinde gıda güvensizliğini erken dönemde saptamaya yönelik standart tarama araçlarının geliştirilmesi ve uygulamaya konulması önerilmektedir. Kuraklık ve sel gibi iklim afeti riskinin yüksek olduğu bölgelerde toplum sağlığı merkezleri aracılığıyla düzenli beslenme izleminin sürdürülmesi bu uygulamanın temel bileşenleri arasındadır. Ulusal iklim uyum planlarının sağlık ve hemşirelik boyutlarının güçlendirilmesi, hemşirelik meslek örgütlerinin iklim politikası süreçlerine dahil edilmesi gerekmektedir. Türkiye'de Sağlık Bakanlığı ile Türkiye İklim Değişikliği Başkanlığı arasındaki sektörlerarası işbirliğinin pekiştirilmesi ve bu koordinasyon mekanizmalarında hemşirelere yer açılması öncelikli bir politika adımı olarak değerlendirilmelidir. İklim değişikliğinin beslenme üzerindeki etkilerine ilişkin Türkiye'ye özgü verilerin üretilmesi gerekmektedir. Hemşirelik temelli toplum müdahalelerinin etkinliğini ölçen ulusal araştırmaların yürütülmesi, hem uygulamaya hem de politika geliştirme süreçlerine kanıt tabanı oluşturmak açısından öncelikli araştırma gündemleri arasında yer almalıdır.

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THE ROLE OF INTEGRATED NUTRITION IN IMPROVING THE QUANTITY AND QUALITY OF AGRICULTURAL PRODUCTS AND ACHIEVING SUSTAINABLE AGRICULTURE

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ABSTRACT

Sustainable agriculture and food security amidst a growing population and finite natural resources demand the implementation of creative approaches in managing plant nutrition. Adequate plant nutrition is a crucial factor affecting yield enhancement and the enhancement of agricultural product quality. In recent decades, the widespread use of chemical fertilizers as the dominant strategy for supplying plant nutrients has substantially enhanced agricultural productivity; however, it has also been associated with several environmental and agronomic challenges, including declining soil fertility, loss of soil organic matter, nutrient imbalances, contamination of soil and water resources, and deterioration in the nutritional and quality attributes of agricultural products. Conversely, relying solely on organic sources has not consistently attained maximum yield because of challenges in completely satisfying plants' nutritional requirements. These obstacles have underscored the importance of utilizing integrated strategies in plant nutrition management like never before. Integrated plant nutrition relies on the systematic and intentional application of different resources supplying essential nutrients, such as chemical, organic, and biological fertilizers, with the goal of boosting nutrient utilization efficiency, preserving soil health, and increasing agricultural productivity. The efficiency of this method stems from various physical, chemical, and biological interactions in the soil-plant ecosystem. Organic fertilizers enhance soil structure, boost organic matter, improve water retention ability, and create an ideal environment for beneficial microorganisms, thereby fostering better conditions for root growth and development. Conversely, chemical fertilizers rapidly provide the nutrients that plants need and help avoid nutritional shortages. Additionally, biocontrol fertilizers enhance nutrient absorption and efficiency by fixing biological nitrogen, solubilizing potassium and phosphorus, generating growth-promoting substances, and boosting soil microbial activity. The combination of these nutritional resources results in greater nutrient absorption, improved photosynthesis activities, enhanced root system growth, increased dry matter accumulation, and ultimately elevated crop yields. Along with influencing the amount of the product, integrated nutrition significantly contributes to improving the quality of agricultural outputs. An adequate supply of nutrients enhances the production of proteins, carbohydrates, vitamins, and other substances that influence product quality. Moreover, enhancing soil biological activity and the gradual release of nutrients alleviate plant nutritional stresses and enhance attributes such as size, color, flavor, nutritional quality, storage potential, and product marketability. Findings from various studies indicate that the combined use of food sources boosts yield and enhances product quality metrics. Additionally, this method plays a crucial role in promoting sustainable agriculture by boosting soil biological processes, elevating organic content, enhancing both the physical and chemical attributes of soil, and minimizing the environmental effects caused by the overuse of chemical fertilizers. Consequently, integrated nutrition, being an effective approach for addressing plant nutrition, can greatly boost productivity while safeguarding essential resources and enhancing both the quality and quantity of agricultural outputs.

Keywords: Integrative nutrition, organic fertilizers, biofertilizers , crop yield, quality of agricultural products

OXIDATIVE STRESS IN TYPE 2 DIABETES: INSULIN RESISTANCE, INFLAMMATION AND NUTRITIONAL PERSPECTIVES

TİP 2 DİYABETTE OKSİDATİF STRES: İNSÜLİN DİRENCİ, İNFLAMASYON VE BESLENME PERSPEKTİFİ

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ÖZET

Tip 2 diyabet, güncel bilimsel yaklaşımlarda yalnızca insülin direnci ve β-hücre disfonksiyonuna dayanan bir tablo olarak değil, çok katmanlı metabolik ve biyokimyasal etkileşimlerin sonucu ortaya çıkan dinamik bir hastalık olarak ele alınmaktadır. Bu bağlamda, özellikle oksidatif stresin hastalığın hem ortaya çıkışında hem de ilerleyici karakter kazanmasında merkezi bir düzenleyici unsur olabileceği giderek daha fazla kabul görmektedir. Uzun süreli hiperglisemi ve artmış lipit yükünün, hücresel metabolik dengeyi bozarak mitokondri fonksiyonları üzerinden reaktif oksijen türlerinin (ROS) artışına zemin hazırladığı düşünülmektedir.

Bu artmış oksidatif ortamın, insülin sinyal iletimini sağlayan temel moleküler ağlar üzerinde baskılayıcı etkiler oluşturabileceği ve özellikle IRS-1/PI3K/Akt ekseninde işlevsel zayıflamaya yol açarak glukoz kullanımını sınırlayabileceği değerlendirilmektedir. IRS-1 düzeyinde meydana gelen serin fosforilasyon artışı ise, insülin yanıtının zayıflamasında kritik bir biyokimyasal kırılma noktası olarak yorumlanmaktadır.

Literatürde ayrıca oksidatif stres ile inflamatuar süreçlerin birbirini karşılıklı olarak güçlendiren bir döngü içinde yer aldığına dair güçlü bir eğilim bulunmaktadır. Bu karşılıklı etkileşimin, metabolik dengenin bozulmasını yalnızca başlatan değil aynı zamanda sürdüren bir mekanizma olabileceği düşünülmektedir. Klinik düzeyde bu süreçlerin yansımaları, lipid peroksidasyon belirteci olan malondialdehit düzeylerinde artış ve antioksidan savunma kapasitesinde azalma şeklinde gözlemlenmektedir.

Beslenme faktörlerinin bu bütünsel süreç üzerindeki etkisi giderek daha kritik bir araştırma alanı haline gelmiştir. Mevcut bulgular, rafine karbonhidrat ve doymuş yağ ağırlıklı diyetlerin oksidatif yükü artırabileceğini; buna karşılık lif, polifenol ve diğer biyoaktif bileşenlerden zengin beslenme modellerinin metabolik dengeyi destekleyici yönde etkiler gösterebileceğini düşündürmektedir. Özellikle diyet lifinin bağırsak mikrobiyotası aracılığıyla kısa zincirli yağ asitleri üretimini artırarak insülin duyarlılığı üzerinde dolaylı fakat önemli bir düzenleyici rol oynayabileceği değerlendirilmektedir.

Sonuç olarak bu derleme, tip 2 diyabette oksidatif stresin rolünü yalnızca biyokimyasal bir mekanizma olarak değil, aynı zamanda inflamasyon, metabolik denge ve beslenme etkileşimi çerçevesinde bütüncül bir perspektifle yeniden yorumlamayı amaçlamaktadır.

Anahtar Kelimeler: Tip 2 Diyabet, Oksidatif Stres, İnsülin Direnci, İnflamasyon, ROS, Beslenme

ABSTRACT

In current scientific approaches, type 2 diabetes is no longer viewed merely as a condition based solely on insulin resistance and β-cell dysfunction, but rather as a dynamic disease resulting from multifaceted metabolic and biochemical interactions. In this context, it is increasingly recognized that oxidative stress may play a central regulatory role in both the onset and progressive nature of the disease. It is believed that prolonged hyperglycemia and increased lipid load disrupt cellular metabolic balance, thereby creating conditions for an increase in reactive oxygen species (ROS) through mitochondrial dysfunction.

It is believed that this increased oxidative environment may exert inhibitory effects on the key molecular networks responsible for insulin signaling and, in particular, may limit glucose utilization by causing functional impairment in the IRS-1/PI3K/Akt axis. The increase in serine phosphorylation at the IRS-1 level is interpreted as a critical biochemical turning point in the attenuation of the insulin response.

There is also a strong trend in the literature suggesting that oxidative stress and inflammatory processes are part of a mutually reinforcing cycle. It is believed that this mutual interaction may serve not only as a mechanism that initiates the disruption of metabolic balance but also as one that sustains it. At the clinical level, the manifestations of these processes are observed as increased levels of malondialdehyde—a marker of lipid peroxidation—and a decrease in antioxidant defense capacity.

The impact of dietary factors on this holistic process has become an increasingly critical area of research. Current findings suggest that diets high in refined carbohydrates and saturated fats may increase oxidative stress; conversely, dietary patterns rich in fiber, polyphenols, and other bioactive compounds may have effects that support metabolic balance. In particular, it is believed that dietary fiber may play an indirect yet significant regulatory role in insulin sensitivity by increasing the production of short-chain fatty acids through the gut microbiota.

In conclusion, this review aims to reinterpret the role of oxidative stress in type 2 diabetes not merely as a biochemical mechanism, but within a holistic framework that encompasses the interplay of inflammation, metabolic balance, and nutrition.

Keywords: Type 2 Diabetes, Oxidative Stress, Insulin Resistance, Inflammation, ROS, Nutrition

THE RELATIONSHIP BETWEEN UNIVERSITY STUDENTS' SUSTAINABLE AND HEALTHY EATING BEHAVIORS AND THEIR BODY MASS INDEX

ÜNİVERSİTE ÖĞRENCİLERİNİN SÜRDÜREBİLİR VE SAĞLIKLI BESLENME DAVRANIŞLARI İLE BEDEN KÜTLE İNDEKSLERİ ARASINDAKİ İLİŞKİ

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ABSTRACT

Introduction and Purpose: Today, sustainable and healthy eating behaviors have gained importance in terms of both protecting individual health and supporting environmental sustainability. Especially in university students, acquired eating habits are among the important behavioral factors that may affect future health status. This study was conducted to determine the level of sustainable and healthy eating behaviors of university students and to reveal the relationship between this status and BMI.

Materials and Methods: The study was carried out between December 5, 2025 and March 1, 2026 with the participation of 100 volunteer students, including 83 females and 17 males, studying at Istanbul Esenyurt University. In data collection, participants' sociodemographic characteristics and their self-reported height and body weight were evaluated, and body mass index values were calculated using these data. The Sustainable and Healthy Eating Behavior Scale (SHE) was used to assess sustainable and healthy eating behaviors.

Findings: It was found that female students had significantly higher mean Sustainable and Healthy Eating Behavior (SHE) scores compared to male students ($p < 0.05$). A positive and significant relationship was found between participants' age and BMI ($p < 0.05$). No statistically significant relationship was found between SHE scores and BMI ($p > 0.05$). In addition, no significant difference was found between the SHE scores of Nutrition and Dietetics students and students from other departments ($p > 0.05$).

Conclusion: It is understood that awareness of sustainable nutrition varies by gender among university students, and while BMI increases with age, current dietary behaviors do not have a direct effect on BMI values in the sample group.

Keywords: Sustainable Nutrition, Healthy Dietary Behavior, Body Mass Index

ÖZET

Giriş ve Amaç: Günümüzde sürdürülebilir ve sağlıklı beslenme davranışları hem bireysel sağlığın korunması hem de çevresel sürdürülebilirliğin desteklenmesi açısından önem kazanmaktadır. Özellikle üniversite öğrencilerinde kazanılan beslenme alışkanlıkları, gelecekteki sağlık durumunu etkileyebilecek önemli davranışsal faktörler arasında yer almaktadır. Bu çalışma, üniversite öğrencilerinin sürdürülebilir ve sağlıklı beslenme davranış düzeylerini saptamak ve bu durumun BKİ ile olan ilişkisini ortaya koymak amacıyla yürütülmüştür.

Materyal ve Yöntem: Araştırma, 5 Aralık 2025 ile 1 Mart 2026 tarihleri arasında İstanbul Esenyurt Üniversitesi'nde öğrenim gören 83 kadın ve 17 erkek olmak üzere toplam 100 gönüllü öğrenci katılımıyla gerçekleştirilmiştir. Verilerin toplanmasında katılımcıların sosyodemografik özellikleri ile boy uzunluğu ve vücut ağırlığına ilişkin beyanları değerlendirilmiş, bu veriler kullanılarak vücut kütle indeksleri hesaplanmıştır. Sürdürülebilir ve sağlıklı beslenme davranışlarının belirlenmesinde ise Sürdürülebilir ve Sağlıklı Beslenme Davranışı Ölçeği (SHE) kullanılmıştır.

Bulgular: Kadın öğrencilerin sürdürülebilir ve sağlıklı beslenme davranışı (SHE) puan ortalamalarının erkek öğrencilere göre istatistiksel olarak anlamlı düzeyde daha yüksek olduğu belirlenmiştir ($p < 0,05$). Katılımcıların yaşları ile BKİ değerleri arasında pozitif yönlü ve anlamlı bir ilişki saptanmıştır ($p < 0,05$). SHE ölçeği puanları ile BKİ arasında istatistiksel olarak anlamlı bir ilişki bulunmamıştır ($p > 0,05$). Ayrıca Beslenme ve Diyetetik bölümü öğrencileri ile diğer bölüm öğrencilerinin SHE ölçeği puanları arasında anlamlı bir fark belirlenmemiştir ($p > 0,05$).

Sonuç: Üniversite öğrencilerinde sürdürülebilir beslenme bilincinin cinsiyete göre farklılık gösterdiği, yaşla birlikte BKİ artsa da mevcut beslenme davranışlarının örneklem grubundaki BKİ değerleri üzerinde doğrudan bir etkisinin olmadığı anlaşılmaktadır.

Anahtar Kelimeler: Sürdürülebilir Beslenme, Sağlıklı Beslenme Davranışı, Beden Kütle İndeksi

GİRİŞ

Sürdürülebilirlik kavramı, ilk olarak 1987 yılında Birleşmiş Milletler Dünya Çevre ve Kalkınma Komisyonu (WCED) tarafından yayımlanan "Ortak Geleceğimiz" raporunda ele alınmıştır. Bu raporda sürdürülebilirlik, insanlığın bugünkü ihtiyaçlarını karşılarken gelecek nesillerin kendi ihtiyaçlarını karşılama olanaklarını tehlikeye atmadan kalkınmanın sürdürülmesi olarak tanımlanmıştır (Pekcan, 2019). Son yıllarda sürdürülebilirlik kavramı, gıda güvenliği ve beslenme alanındaki uluslararası tartışmalarda önemli bir yer edinmiştir. Bu bağlamda sürdürülebilir diyetler, sürdürülebilir gıda sistemlerinin temel unsurlarından biri olarak kabul edilmektedir (Dernini ve ark., 2017). Gıda ve Tarım Örgütü (FAO) sürdürülebilir beslenmeyi; doğal kaynakların etkin kullanımını destekleyen, biyoçeşitliliği koruyan, kültürel olarak kabul edilebilir, ekonomik açıdan erişilebilir ve aynı zamanda beslenme açısından yeterli ve sağlığı destekleyen bir beslenme modeli olarak tanımlamaktadır (FAO, 2019).

Beslenme alışkanlıkları, bedensel ve zihinsel sağlık üzerindeki etkileri nedeniyle günümüzde önemli bir araştırma alanı olarak kabul edilmektedir. Modernleşme, kentleşme ve değişen yaşam koşulları ile birlikte işlenmiş ve enerji yoğunluğu yüksek besinlerin tüketiminin artması, beslenme düzeninde önemli değişikliklere yol açmıştır. Bu değişimlerin, beslenme ile ilişkili kronik hastalıkların görülme sıklığındaki artışla ilişkili olduğu bildirilmektedir (Yahia ve ark., 2008; Popkin, 2002). Bu nedenle sürdürülebilir ve sağlıklı beslenme davranışlarının değerlendirilmesi giderek daha fazla önem kazanmaktadır.

Beden Kütle İndeksi (BKİ), bireyin vücut ağırlığının boy uzunluğunun karesine bölünmesiyle hesaplanan antropometrik bir ölçüttür ve vücut ağırlığı durumunun değerlendirilmesinde yaygın olarak kullanılmaktadır (WHO, 2000). BKİ'nin yüksek olması; obezite, kardiyovasküler hastalıklar, tip 2 diyabet ve çeşitli metabolik hastalıklarla ilişkilendirilmektedir (Jensen ve ark., 2013). Ayrıca modern yaşam koşulları, fiziksel aktivitenin azalması ve enerji yoğunluğu yüksek besinlerin tüketiminin artması gibi faktörler BKİ değerlerinin yükselmesine katkıda bulunabilmektedir. Modern şehirleşme ve sanayileşme süreçleri, bireylerin günlük fiziksel hareketliliğini azaltarak BKİ değerlerinde artışa zemin hazırlayabilmektedir. Özellikle kent yaşamında yeşil alanların sınırlı olması, ulaşımda motorlu araçların daha sık tercih edilmesi ve hazır/işlenmiş gıda tüketiminin yaygınlaşması, obezite görülme sıklığını artıran önemli çevresel faktörler arasında yer almaktadır (Swinburn ve ark., 2011).

Üniversite dönemi, bireylerin beslenme alışkanlıklarının şekillendiği ve yaşam boyu devam edebilecek davranışların kazanıldığı önemli bir dönemdir. Sürdürülebilir ve sağlıklı beslenme davranışlarının bireylerin BKİ düzeyleri ile ilişkili olabileceği düşünülmekle birlikte, üniversite öğrencilerinde bu ilişkinin değerlendirilmesine yönelik çalışmalar sınırlıdır. Bu nedenle bu çalışma, üniversite öğrencilerinin sürdürülebilir ve sağlıklı beslenme davranış düzeylerini belirlemek ve bu davranışların BKİ ile ilişkisini incelemek amacıyla gerçekleştirilmiştir.

MATERYAL VE YÖNTEM

Araştırmanın Amacı

Bu çalışmada, üniversite öğrencilerinin sürdürülebilir ve sağlıklı beslenme davranış düzeylerinin belirlenmesi ve bu davranışların BKİ ile ilişkisinin incelenmesi amaçlanmıştır. Ayrıca öğrencilerin beslenme alışkanlıkları, antropometrik özellikleri ve sosyodemografik özelliklerinin sürdürülebilir ve sağlıklı beslenme davranışları üzerindeki etkilerinin değerlendirilmesi hedeflenmiştir.

Araştırmanın Yeri, Zamanı ve Örneklem Seçimi

Bu araştırma, 5 Aralık 2025 ile 1 Mart 2026 tarihleri arasında üniversitede öğrenim gören öğrenciler üzerinde gerçekleştirilmiştir. Çalışmanın örneklemini, araştırmaya gönüllü olarak katılmayı kabul eden toplam 100 üniversite öğrencisi oluşturmaktadır. Katılımcıların 17’si erkek (%17) ve 83’ü kadın (%83) bireylerden oluşmaktadır.

Veri Toplama Yöntemi

Bu araştırmada, üniversite öğrencilerinde sürdürülebilir ve sağlıklı beslenme durumunun değerlendirilmesi ile BKİ arasındaki ilişkinin incelenmesi amacıyla kesitsel bir çalışma tasarımı kullanılmıştır. Veri toplama sürecinde katılımcılara araştırma hakkında gerekli bilgilendirme yapılmış ve gönüllü katılım esasına dayalı olarak onamları alınmıştır.

Anket formu iki farklı yöntemle uygulanmıştır: çevrimiçi olarak Google Forms üzerinden ve İstanbul Esenyurt Üniversitesi’nde öğrenim gören öğrencilere yüz yüze uygulanarak veri toplanmıştır. Böylece hem erişilebilirlik artırılmış hem de örneklem çeşitliliği sağlanmıştır.

Araştırmada veri toplama aracı olarak araştırmacı tarafından hazırlanan tanımlayıcı bilgi formu ve "Sürdürülebilir ve Sağlıklı Beslenme Davranışı Ölçeği (Sustainable and Healthy Eating [SHE] Behaviors Scale)" kullanılmıştır.

Antropometrik Verilerin Değerlendirilmesi

Katılımcıların antropometrik verileri, anket formunda yer alan boy uzunluğu ve vücut ağırlığına ilişkin beyanları doğrultusunda değerlendirilmiştir. BKİ, bireylerin beyan ettikleri vücut ağırlığının kilogram cinsinden değerinin, metre cinsinden boy uzunluğunun karesine bölünmesiyle hesaplanmıştır (kg/m²). Elde edilen BKİ değerleri sürekli değişken olarak analizlere dahil edilmiştir.

Sürdürülebilir ve Sağlıklı Beslenme Davranış Ölçeği

SHE ölçeği, Żakowska-Biemans ve arkadaşları tarafından 2019 yılında genç yetişkinlerin sürdürülebilir ve sağlıklı beslenme davranışlarını değerlendirmek amacıyla geliştirilmiştir (Żakowska-Biemans ve ark., 2019). Ölçeğin Türkçe geçerlik ve güvenirlik çalışması Yüksel ve arkadaşları tarafından 2024 yılında üniversite öğrencileri üzerinde gerçekleştirilmiştir (Yüksel ve ark., 2024).

Ölçek, bireylerin besin seçimleri, beslenme alışkanlıkları ve çevresel farkındalıklarını birlikte değerlendiren maddelerden oluşmaktadır. Bu kapsamda bireylerin sağlıklı beslenme davranışları ile sürdürülebilir beslenme davranışlarının değerlendirilmesine olanak sağlamaktadır.

SHE ölçeğinde yer alan ifadeler 7'li Likert tipi derecelendirme sistemi ile yanıtlanmaktadır. Katılımcılar her bir ifadeye "1 = Asla" ile "7 = Her Zaman" arasında değişen seçeneklerden birini işaretlemektedir. Ölçekten alınan toplam puan arttıkça bireyin sürdürülebilir ve sağlıklı beslenme davranış düzeyinin daha yüksek olduğu kabul edilmektedir (Yüksel ve ark., 2024).

İstatistiksel Analiz

Araştırmadan elde edilen verilerin istatistiksel analizleri, SPSS 27.0 paket yazılım kullanılarak gerçekleştirilmiştir. Sürekli değişkenlerin normal dağılıma uygunluğu Shapiro-Wilk testi ile değerlendirilmiştir. Gruplar arası karşılaştırmalarda, verilerin dağılım özelliklerine göre Mann-Whitney U testi ve parametrik test yöntemleri kullanılmıştır. Cinsiyet ve bölüm türü gibi kategorik değişkenlerin dağılımları ile değişkenler arasındaki ilişkilerin incelenmesinde Ki-kare testi ve Fisher'in kesin testi (Fisher's exact test) uygulanmıştır. Yaş, BKİ ve sürdürülebilir beslenme davranış puanları arasındaki ilişkiler ise Spearman korelasyon analizi ile incelenmiştir. İstatistiksel anlamlılık düzeyi $p < 0,05$ olarak kabul edilmiştir.

BULGULAR

Araştırmaya toplam 100 üniversite öğrencisi katılmış olup, katılımcıların 83'ü (%83) kadın ve 17'si (%17) erkektir. Katılımcıların cinsiyete göre yaş, BKİ ve SHE ölçeği genel puanlarına ilişkin tanımlayıcı istatistikler Tablo 3.1'de sunulmuştur.

Kadın öğrencilerin yaş ortalaması 26,92±6,36 yıl, erkek öğrencilerin yaş ortalaması ise 24,71±3,87 yıl olarak belirlenmiştir. Cinsiyetler arasında yaş açısından istatistiksel olarak anlamlı bir fark bulunmamıştır (p=0,132). Benzer şekilde, kadın öğrencilerin ortalama BKİ değeri 23,81±4,52 kg/m², erkek öğrencilerin ortalama BKİ değeri ise 25,13±3,05 kg/m² olup, BKİ açısından da cinsiyetler arasında anlamlı bir farklılık saptanmamıştır (p=0,087).

SHE ölçeği genel puan ortalaması kadın öğrencilerde 4,13±0,84, erkek öğrencilerde ise 3,67±0,96 olarak bulunmuştur. Cinsiyetlere göre SHE ölçeği genel puanları karşılaştırıldığında,

kadın öğrencilerin puanlarının erkek öğrencilere göre istatistiksel olarak anlamlı düzeyde daha yüksek olduğu belirlenmiştir (p=0,011).

Tablo 3.1. Katılımcıların cinsiyete göre yaş, BKİ ve SHE ölçeği genel puan ortalamalarının dağılımı

Değişken	Cinsiyet	n	Ortalama	Medyan	SS	p değeri
Yaş (yıl)	Kadın	83	26,92	25,00	6,36	0,132
	Erkek	17	24,71	23,00	3,87	
BKİ (kg/m²)	Kadın	83	23,81	23,03	4,52	0,087
	Erkek	17	25,13	24,49	3,05	
SHE Ölçeği Genel Puanı	Kadın	83	4,13	4,23	0,84	**0,011***
	Erkek	17	3,67	3,54	0,96	

Veriler ortalama ± standart sapma ve medyan olarak verilmiştir. Gruplar arasındaki karşılaştırmalar Mann–Whitney U testi ile yapılmıştır. $^{*}p<0,05$.

Katılımcıların yaşları ile BKİ değerleri arasında pozitif yönlü ve istatistiksel olarak anlamlı bir ilişki bulunmuştur (rs=0,246; p=0,014). Yaş ile SHE ölçeği genel puanı arasında pozitif yönlü zayıf bir ilişki saptanmış ancak bu ilişki istatistiksel olarak anlamlı bulunmamıştır (rs=0,183; p=0,069). Benzer şekilde BKİ ile SHE ölçeği genel puanı arasında da anlamlı bir ilişki belirlenmemiştir (rs=0,027; p=0,792).

Yaş, BKİ ve SHE ölçeği genel puanı arasındaki korelasyon analizlerine ilişkin sonuçlar Tablo 3.2'de verilmiştir.

Tablo 3.2. Katılımcıların yaş, BKİ ve SHE ölçeği genel puanı arasındaki ilişki

		BKI	Yaş
Yaş	Spearman's rho	0,246	-
	p-value	**0,014***	-
SHE Ölçeği Genel Puanı	Spearman's rho	0,027	0,183
	p-value	0,792	0,069

Spearman korelasyon analizi, rs: Spearman korelasyon katsayısı, $^{*}p<0,05$.

Katılımcıların öğrenim gördükleri bölüme göre SHE ölçeği genel puanları incelendiğinde, Beslenme ve Diyetetik Bölümü öğrencilerinin ortalama SHE puanı 4,17±0,80, diğer bölüm öğrencilerinin ise 3,99±0,91 olarak bulunmuştur. Gruplar arasındaki fark istatistiksel olarak anlamlı değildir (p=0,309).

Öğrenim görülen bölüme göre SHE ölçeği genel puanlarının dağılımı Tablo 3.3'te gösterilmiştir.

Tablo 3.3. Katılımcıların öğrenim gördükleri bölüme göre SHE ölçeği genel puanlarının dağılımı

	Bölüm	N	Mean	Median	SD	p
SHE Ölçeği Genel Puan	BVD	34	4,17	4,14	0,802	0,309
	Diğer	66	3,99	4,07	0,907	

BVD: Beslenme ve Diyetetik bölümü öğrencileri

TARTIŞMA

Bu çalışmada üniversite öğrencilerinin sürdürülebilir ve sağlıklı beslenme (SHE) davranışları ile BKİ, yaş, cinsiyet ve öğrenim görülen bölüm arasındaki ilişkiler değerlendirilmiştir. Elde edilen bulgular, kadın öğrencilerin SHE puanlarının erkek öğrencilere kıyasla daha yüksek olduğunu, yaş ile BKİ arasında pozitif yönlü bir ilişki bulunduğunu, ancak SHE puanları ile BKİ, yaş ve öğrenim görülen bölüm arasında istatistiksel olarak anlamlı bir ilişki olmadığını ortaya koymuştur.

Bu çalışmada katılımcıların SHE Davranış Ölçeği genel puan ortalamasının cinsiyete göre anlamlı düzeyde farklılık gösterdiği belirlenmiş; kadınların puan ortalaması 4,13, erkeklerin ise 3,67 olarak saptanmıştır ($p<0,05$). Literatürde SHE davranışlarına ilişkin yapılan çalışmalarda toplam puan ortalamalarının Kaner ve ark. (3,99±1,15), Yeşildemir (4,00±0,97) ve Palamutoğlu (3,83±1,02) çalışmalarında benzer düzeylerde olduğu bildirilmiştir (Kaner ve ark., 2024; Yeşildemir, 2023; Palamutoğlu, 2025). Cinsiyete göre yapılan değerlendirmelerde Kaner ve ark. erkeklerde 3,83±1,21, kadınlarda 4,04±1,12 düzeyinde SHE puanı saptamış ve farkı istatistiksel olarak anlamlı bulmuştur ($p<0,05$). Buna karşılık Palamutoğlu'nun çalışmasında cinsiyete göre anlamlı bir farklılık bulunmamış ($p>0,05$), benzer şekilde Yeşildemir, Macit-Çelebi ve ark. ile Kocaadam ve Bozkurt çalışmalarında da cinsiyet açısından anlamlı bir farklılık olmadığı rapor edilmiştir (Yeşildemir, 2023; Macit-Çelebi ve ark., 2023; Kocaadam ve Bozkurt, 2023). Bu bulgular, kadınların erkeklere kıyasla daha yüksek SHE davranışları sergilediğini gösteren çalışmalarla uyumlu olup, cinsiyetin SHE davranışları üzerinde etkili olabileceğini düşündürmektedir.

Yaş değişkeni açısından, bu çalışmada SHE ölçeği genel puanı ile yaş arasında pozitif yönlü çok zayıf bir ilişki saptanmış, ancak bu ilişkinin istatistiksel olarak anlamlı olmadığı belirlenmiştir ($p=0,069$; $p>0,05$). Literatürde ise Kaner ve ark. yaş ile SHE ölçeği puanları arasında anlamlı bir ilişki olduğunu bildirmiş ($p=0,006$) ve yaş ilerledikçe sürdürülebilir ve sağlıklı beslenme davranışlarına yönelimin arttığını ifade etmiştir (Kaner ve ark., 2024). Buna karşın Kocaadam ve Bozkurt'un çalışmasında da yaş ile SHE puanları arasında anlamlı bir ilişki bulunmadığı rapor edilmiştir (Kocaadam ve Bozkurt, 2023). Bu bulgular, yaşın SHE davranışları üzerindeki etkisine ilişkin literatürde tutarsız sonuçlar bulunduğunu ve etkinin örneklem özelliklerine göre değişebileceğini düşündürmektedir.

BKİ açısından değerlendirildiğinde, bu çalışmada BKİ ile SHE ölçeği genel puanı arasında istatistiksel olarak anlamlı bir ilişki saptanmamıştır ($p>0,05$). Benzer şekilde Kaner ve ark.'nın çalışmasında da BKİ ile SHE ölçeği puanları arasında anlamlı bir ilişki bulunmamış, ancak obez bireylerin SHE ölçeği puanlarının diğer gruplara göre daha düşük olduğu belirtilmiştir ($p<0,001$) (Kaner ve ark., 2024). Macit-Çelebi ve ark.'nın çalışmasında ise BKİ sınıflamasına göre SHE davranış puanlarının anlamlı farklılık gösterdiği ve obez grupta daha düşük ortalama puanların (2,9±0,13) olduğu rapor edilmiştir ($p<0,001$) (Macit-Çelebi ve ark., 2023). Bu bulgular, BKİ ile SHE davranışları arasındaki ilişkinin literatürde farklı sonuçlar verdiğini göstermektedir.

Son olarak, bu çalışmada Beslenme ve Diyetetik bölümü öğrencilerinin SHE ölçeği genel puan ortalamasının diğer bölüm öğrencilerine kıyasla daha yüksek olduğu belirlenmiş, ancak bu farkın istatistiksel olarak anlamlı olmadığı saptanmıştır ($p>0,05$). Palamutoğlu'nun çalışmasında ise sürdürülebilir beslenme farkındalık düzeyinin yüksek olmasının, örneklemde Beslenme ve Diyetetik öğrencilerinin oranının fazla olmasıyla ilişkili olabileceği belirtilmiştir (Palamutoğlu, 2025). Bu bulgular birlikte değerlendirildiğinde, beslenme alanında eğitim almanın SHE davranış düzeyini artırabileceği, ancak bu etkinin her zaman istatistiksel olarak anlamlı düzeye ulaşmayabileceği söylenebilir.

SONUÇ ve ÖNERİLER

Bu araştırma, üniversite öğrencilerinin sürdürülebilir ve sağlıklı beslenme (SHE) davranış düzeylerini saptamak ve bu durumun BKİ başta olmak üzere çeşitli demografik parametrelerle olan ilişkisini incelemek amacıyla yürütülmüştür. Elde edilen bulgular doğrultusunda, kadın öğrencilerin sürdürülebilir ve sağlıklı beslenme davranışı puan ortalamalarının erkek öğrencilere göre istatistiksel açıdan anlamlı derecede yüksek olduğu belirlenmiş; bu sonuç kadınlar arasında ekolojik ve sağlıklı beslenme eğilimlerinin daha bütüncül ve tutarlı bir yapı sergilediğini gösteren literatür verileriyle uyumluluk göstermiştir. Katılımcıların yaşları ile BKİ değerleri arasında pozitif yönlü ve anlamlı bir ilişki tespit edilmesine karşın, sürdürülebilir beslenme davranış puanları ile BKİ arasında istatistiksel olarak anlamlı bir bağ saptanmamıştır. Benzer şekilde, Beslenme ve Diyetetik bölümü öğrencilerinin ölçek genel puanları rakamsal olarak daha yüksek olsa da diğer bölüm öğrencileriyle aralarında istatistiksel olarak anlamlı bir fark gözlenmemiştir.

Sonuç olarak, üniversite öğrencilerinde sürdürülebilir beslenme bilincinin cinsiyet ekseninde farklılaştığı, genç yetişkinlik döneminde yaşla birlikte BKİ artsa da mevcut beslenme davranışlarının BKİ üzerinde henüz doğrudan ve belirgin bir etki oluşturmadığı anlaşılmaktadır. Bu doğrultuda, özellikle beslenme davranış puanları daha düşük ve sigara kullanım oranları anlamlı derecede yüksek saptanan erkek öğrencilere yönelik farkındalık artırıcı eğitim müdahalelerinin planlanması önerilmektedir. Ayrıca, Beslenme ve Diyetetik alanında eğitim alan gruplar da dahil olmak üzere tüm üniversite gençliğinde teorik akademik bilginin pratik ve kalıcı davranış değişikliğine dönüştürülmesini sağlayacak uygulamalı stratejilerin geliştirilmesi; üniversitelerde yerel, mevsimsel ve karbon ayak izi düşük gıdalara erişimin kurumsal politikalarla teşvik edilmesi geleceğe yönelik halk sağlığı yaklaşımları açısından büyük önem arz etmektedir.

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SUSTAINABILITY ASSESSMENT OF THE MEDITERRANEAN DIET IN METABOLIC SYNDROME

METABOLİK SENDROMDA AKDENİZ DİYETİNİN SÜRDÜRÜLEBİLİRLİK AÇISINDAN DEĞERLENDİRMESİ

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ABSTRACT

Introduction and Purpose: Metabolic Syndrome comprises a group of metabolic disorders that elevate the risk of cardiovascular disease, type 2 diabetes, and other related conditions, potentially resulting in severe health complications if untreated. Metabolic Syndrome (MetS) is characterized by central obesity, dyslipidemia, hypertension, and insulin resistance. Its global prevalence is rising, representing a significant public health concern attributed to irregular dietary patterns, unhealthy lifestyle choices, and genetic predispositions. This study aims to assess the implementation of the Mediterranean Diet in treating Metabolic Syndrome in terms of sustainability. The Mediterranean Diet is increasingly promoted for its clinical efficacy and as a model for environmental and economic sustainability. From a sustainability standpoint, this dietary pattern, which prioritizes plant-based foods, minimal consumption of animal products, and local biodiversity, reduces greenhouse gas emissions and water use while improving MetS parameters. Addressing Metabolic Syndrome through the Mediterranean Diet. Therefore, it offers a synergistic strategy that supports both cardiometabolic health and ecological sustainability. Numerous studies and reviews have established direct associations between MetS, specific diseases, and dietary habits.

Keywords: Metabolic Syndrome, Central Obesity, Insulin Resistance, Type 2 Diabetes, MetS, Mediterranean Diet, Sustainability, Sustainable Diets.

ÖZET

Metabolik Sendrom, tedavi edilmediğinde ciddi sağlık komplikasyonlarına yol açabilen; kalp-damar hastalığı, tip 2 diyabet ve diğer ilişkili durumların riskini artıran bir grup metabolik bozukluğu kapsar. Metabolik Sendrom (MetS); santral obezite, dislipidemi, hipertansiyon ve insülin direnci ile karakterizedir. Düzensiz beslenme alışkanlıkları, sağlıksız yaşam tarzı seçimleri ve genetik yatkınlıklara atfedilen küresel yaygınlığı giderek artmakta ve bu durum önemli bir halk sağlığı sorunu teşkil etmektedir. Bu çalışma, Metabolik Sendrom'un tedavisinde

Akdeniz Diyeti uygulanmasını sürdürülebilirlik açısından değerlendirmeyi amaçlamaktadır. Beslenme ve yaşam tarzı değişiklikleri, MetS ve diğer yüksek riskli hastalıklara karşı koruyucu faktörler olarak kabul edilmektedir. Akdeniz Diyeti, klinik etkinliğinin yanı sıra çevresel ve ekonomik sürdürülebilirlik için bir model olarak giderek daha fazla teşvik edilmektedir. Sürdürülebilirlik açısından bakıldığında; bitki bazlı gıdalara, hayvansal ürünlerin asgari düzeyde tüketimine ve yerel biyoçeşitliliğe öncelik veren bu beslenme modeli, sera gazı emisyonlarını ve su kullanımını azaltırken aynı zamanda MetS parametrelerini iyileştirmektedir. Dolayısıyla Metabolik Sendrom'un Akdeniz Diyeti aracılığıyla ele alınması, hem kardiyometabolik sağlığı hem de ekolojik sürdürülebilirliği destekleyen sinerjik bir strateji sunmaktadır. Çok sayıda çalışma ve derleme; MetS, belirli hastalıklar ve beslenme alışkanlıkları arasında doğrudan ilişkiler olduğunu ortaya koymuştur.

Anahtar Kelimeler: Metabolik Sendrom, Santral Obezite, İnsülin Direnci, Tip 2 Diyabet, MetS, Akdeniz Diyeti, Sürdürülebilirlik, Sürdürülebilir Beslenme.

EVALUATION OF SELECTED INSECTICIDE MIXTURES FOR RESISTANCE MANAGEMENT IN THE COTTON APHID *Aphis gossypii* Glover (Hemiptera: Aphididae)

PAMUK YAPRAKBİTİ *Aphis gossypii* Glover (Hemiptera: Aphididae) MÜCADELESİNDE BAZI İNSEKTİSİT KARIŞIMLARININ DİRENÇ YÖNETİMİ AÇISINDAN DEĞERLENDİRİLMESİ

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ÖZET

Pamuk yaprakbiti, *Aphis gossypii* Glover (Hemiptera: Aphididae), pamuk üretiminde önemli verim ve kalite kayıplarına neden olan zararlılar arasında yer almaktadır. Zararlının yüksek üreme kapasitesi ve kısa yaşam döngüsü nedeniyle yoğun insektisit kullanımına maruz kalması, birçok aktif maddeye karşı direnç gelişimine yol açmıştır. Bu durum, etkili ve sürdürülebilir direnç yönetimi stratejilerinin geliştirilmesini zorunlu hale getirmektedir. Flonicamid beslenmeyi durdurucu etkisiyle, spirotetramat lipid biyosentezini hedefleyen sistemik yapısıyla ve pyriproxyfen ise böcek gelişimini düzenleyici özelliğiyle farklı etki mekanizmalarına sahip aktif maddeler olarak öne çıkmaktadır. Pamuk yaprakbiti mücadelesinde yaygın olarak kullanılan flonicamid, spirotetramat ve pyriproxyfen aktif maddelerinin direnç yönetimindeki potansiyelleri güncel literatür doğrultusunda değerlendirilmektedir. Literatürde yer alan biyolojik test ve direnç çalışmalarında, bu aktif maddelere karşı farklı düzeylerde direnç gelişebildiği, ancak direnç oluşum hızının kullanılan mücadele programı ve uygulama yoğunluğuna bağlı olarak değişebildiği bildirilmektedir. Karışım insektisitler üzerine yürütülen çalışmalar, farklı etki mekanizmalarına sahip aktif maddelerin birlikte kullanılmasının mücadele etkinliğini artırabileceğini ve direnç gelişimini yavaşlatabileceğini göstermektedir. Bununla birlikte karışım stratejilerinin başarısının, kullanılan aktif maddelerin özelliklerine, doz oranlarına ve hedef popülasyonun sahip olduğu direnç mekanizmalarına bağlı olduğu bildirilmektedir. Sonuç olarak, flonicamid, spirotetramat ve pyriproxyfenin farklı etki mekanizmalarına sahip olmaları nedeniyle *A. gossypii*'de direnç yönetimi programlarında önemli bir potansiyele sahip oldukları değerlendirilmektedir. Bu aktif maddelerin uygun karışım veya rotasyon programları içerisinde kullanılması, pamuk yaprakbiti mücadelesinde sürdürülebilirliğin sağlanmasına ve direnç gelişiminin yavaşlatılmasına katkı sağlayabilir.

Anahtar sözcükler: *Aphis gossypii*, flonicamid, spirotetramat, pyriproxyfen, direnç yönetimi, insektisit karışımları.

ABSTRACT

The cotton aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae), is one of the major pests causing significant yield and quality losses in cotton production. Due to its high reproductive capacity and short life cycle, intensive insecticide exposure has resulted in the development of

resistance to numerous active ingredients. This situation highlights the need for effective and sustainable resistance management strategies. Flonicamid, with its feeding-stopping effect, spirotetramat, with its systemic activity targeting lipid biosynthesis, and pyriproxyfen, with its insect growth-regulating properties, represent distinct modes of action. The potential roles of these active ingredients, which are widely used in cotton aphid management, are evaluated in terms of resistance management based on current literature. Biological assays and resistance studies reported in the literature indicate that varying levels of resistance may develop against these active ingredients; however, the rate of resistance development appears to depend on the pest management program and the intensity of insecticide use. Studies investigating insecticide mixtures have shown that the combined use of active ingredients with different modes of action may improve control effectiveness and delay resistance development. Nevertheless, the success of mixture strategies depends on the characteristics of the active ingredients used, application rates, and the resistance mechanisms present within target populations. Overall, flonicamid, spirotetramat, and pyriproxyfen are considered to have considerable potential for inclusion in resistance management programs against *A. gossypii* because of their distinct modes of action. The incorporation of these active ingredients into appropriate mixture or rotation programs may contribute to sustainable cotton aphid management and help delay the evolution of resistance.

Keywords: *Aphis gossypii*, flonicamid, spirotetramat, pyriproxyfen, resistance management, insecticide mixtures.