https://dergipark.org.tr/tr/pub/food
OPEN ACCESS JOURNAL

ISSN 2667-5803

FHTI

JOURNAL OF FOOD HEALTH AND TECHNOLOGY INNOVATIONS

DECEMBER VOL 7, NO 15 (2024)

Editor
Prof. Dr. Özlem TOKUŞOĞLU

Journal of Food Health and Technology Innovations
December Vol 7, No 15 (2024)

https://dergipark.org.tr/tr/pub/food
OPEN ACCESS JOURNAL

ISSN 2667-5803

FHTI Journal of Food Health and Technology Innovations
December Vol 7, No 15 (2024)

DergiPark AKADEMİK

Editorial Note

EDITORIAL NOTE

Dear authors, reviewers and readers of Food, Health and Technology Innovations (FHTI).

It gives me great pleasure to welcome you to the seventh year and volume 7th (number 15) edition of Food Health and Technology Innovations for which I have acted as Editor in Chief..

Food Health and Technology ınnovations (FHTI) is an international open access, peer-reviewed scientific research journal by DergiPark Ulakbim that provides rapid publication of articles in all disciplines of food science including food chemistry, food microbiology, food quality, food shelf life; food technology including conventional and innovative food processing; food engineering; nutrition including consumer nutrition and clinical nutrition; and their connected basic sciences including biochemistry, molecular biology, analytical chemistry, organic chemistry and connected applied sciences such as bioengineering, biomedical engineering, industrial engineering, mechanical engineering, material science, nanotechnology, nano sciences; health sciences including cancer science, cancer biology, hematology, oncology, surgery with clinical nutritive applications.

I would like to point out that the policy of top priority of FHTI is especially to put forward and to reveal the innovations and inspiring outputs for food, health and innovative technology applications. FHTI offers an exceptionally fast publication schedule including prompt peer-review by the experts in the field and immediate publication upon acceptance. Not only my deputy editorial concept but also the all editorial board aims the fast reviewing and evaluation of the submitted articles for the forthcoming issues. Our journal distinction is to make difference in this inspection point. In the context, Journal of Food, Health and Technology Innovations will continue to publish high quality researches on basic sciences and applied sciences..

Original research articles form the bulk of the content, with systematic reviews an important sub-section. We will encourage all authors to work to these standards. Such emphasis on methodological rigour is vital to ensure that conclusions reached from publications contained in the journal are valid and reliable. Peer review processing remains a vital component of our assessment of submitted articles to FHTI.

I would like to say that there is strong consensus which accepted articles are often improved by peer review after referees' comments and criticisms are dealt with; this explicit appraisal process also helps to engender trust of the reader. It is predicated that the criticisms of evaluating process containing publication delaying, unreliability of decision making as overly conservative approach. Besides, weaknesses can be managed by an effective and active editorial office, and I believe they are outweighed by the benefits. Lastly I should thank all our submitting authors, who have toiled in the production of their work, and have chosen Food Health and Technology as the journal they would like to publish in.

Have a great ublishing with FHTI…

Professor, Ozlem Tokusoglu, PhD

Editor in Chief
Food Health and Technology Innovations

Ozlem Tokusoglu, Professor Dr.
Editor in Chief, FHTI Journal, Ulakbim Tübitak Dergipark, Ankara

TÜBİTAK ULAKBİM

https://dergipark.org.tr/tr/pub/food
OPEN ACCESS JOURNAL

ISSN 2667-5803

FHTI Journal of Food Health and Technology Innovations
December Vol 7, No 15 (2024)

DergiPark AKADEMİK

Review Article

THE BIOLOGICAL ACTIVITIES OF OLEUROPEIN AND HYDROXYTYROSOL

Ibrahim CANBEY[1], Aycan YIGIT CINAR[2], Ozan GURBUZ[3]

Abstract Oleuropein and hydroxytyrosol, two bioactive phenolic compounds predominantly found in olive leaves and olive oil, have garnered significant attention due to their extensive range of biological activities. These compounds exhibit potent antioxidant, anti-inflammatory, and antimicrobial properties, which contribute to their therapeutic potential in preventing and managing various chronic diseases, including cardiovascular disorders, metabolic syndromes, and neurodegenerative conditions. Furthermore, recent studies highlight their role in modulating cellular signaling pathways, promoting apoptosis in cancer cells, and enhancing immune responses. This review aims to provide a comprehensive analysis of the current scientific literature on the biological activities of oleuropein and hydroxytyrosol, with an emphasis on providing scientific data for future scientific studies, applications in clinical and nutraceutical settings.

Keywords: Oleuropein; hydroxytyrosol; biological activities; bioactive phenolic compounds.

TÜBİTAK ULAKBİM

1Bursa Uludag University, Faculty of Agriculture, Department of Food Engineering, 16059, Nilufer, Bursa, Turkiye.
2Bursa Technical University, Faculty of Engineering and Natural Science, Department of Food Engineering, https://orcid.org/0000-0003-2038-725X 16310, Bursa, Turkiye
3Bursa Uludag University, Faculty of Agriculture, Department of Food Engineering, 16059, Nilufer, Bursa, Turkiye.

Introduction

The Mediterranean diet is highly regarded for its role in reducing the risk of numerous chronic illnesses, such as cardiovascular disorders, neurodegenerative diseases, and various types of cancer (1,2,80). A defining characteristic of the this diet type is its abundant use of olive oil and derivatives, renowned for their high biophenol content (3,81). Oleuropein (OLE) and hydroxytyrosol (HT) are two primary polyphenolic compounds found in the olive tree (*Olea europaea*) and its products, particularly in olive oil (80). Derived from tyrosine or phenylalanine, these phytochemicals impart a bitter and sharp flavor to olive oil due to their intricate interplay with the taste receptors (25,82,83). Nevertheless, various genetic and environmental variables influence the levels, profiles, and bioaccessibility of these polyphenols (108). These compounds are widely recognized for their potent biological activities, which contribute to the health benefits associated with olive oil consumption (80).

OLE is a prevalent biophenolic compound found in a range of olive-derived products, including olive leaves, fruits, and oil (4,5). Its content varies significantly depending on the olive cultivar, geographic region, and the method of olive oil production. This compound is also present in olives in their unripe, bitter form, contributing to the bitterness of the fruit (80,81). OLE, the predominant phenolic constituent in olive oil, is distributed across various parts of the olive. Belonging to the secoiridoid class, it undergoes hydrolysis to yield HT and 2-(3,4-dihydroxyphenyl)-ethanol. The abundance of this bioactive compound is greater in the initial phases of fruit maturation, where it is converted into glycosylated derivatives by esterase enzymes (51,85). This secoiridoid has garnered significant interest from researchers owing to its diverse health-promoting effects, such as antioxidative, neural-protective, inflammation-modulating, oncoprotective, heart-protective, etc. (6,7,8).

The other important bioactive phytochemical HT is a smaller phenolic compound, which is the primary metabolite of oleuropein after hydrolysis (81). OLE is broken down through hydrolysis during the ripening of olives and is subsequently transformed into HT upon digestion, facilitated by lipase enzymes (5,9). It is abundant in both olive oil and the olive fruit, and its content increases as the fruit ripens (19). Structurally, hydroxytyrosol is a simple phenolic compound, consisting of a hydroxylated tyrosol structure (80). Hydroxytyrosol is also found in other parts of the olive tree, including the leaves and stems (15). HT, also exhibits biological activities like OLE, such as antioxidative, brain-protective, antimicrobial, heart health-enhancing, cancer-fighting, etc. (5,10-12).

This review examines the biological properties and functions of oleuropein and hydroxytyrosol, which are present in varying concentrations in olives, olive products, and their by-products, focusing on their molecular mechanisms of action, therapeutic potential, and implications for human health, and providing scientific insights that may be essential for future research.

The crucial bioactive compounds: oleuropein and hydroxytyrosol

OLE, the main phenolic compound present in olives belonging to the Oleaceae family, may account for up to 14% of their total mass, equivalent to 140 mg per gram of dry matter (85,98,99). Nonetheless, certain studies report that olive leaves may contain oleuropein at concentrations reaching as high as 19% (w/w) (106). Identified in 1908 by Bourquelot and Vintilesco, it is composed of three distinct subunits: a secoiridoid (elenolic acid), a polyphenol (HT), and a glucose molecule. The synthesis of OLE in olives takes place within the secondary metabolism of terpenes. In this metabolic route, the mevalonic acid pathway is pivotal, with a branching point leading to the production of OLE (95,99). This secoiridoid is an ester derivative of 2-(3,4-

dihydroxyphenyl) ethanol (hydroxytyrosol) and exhibits an oleosidic framework, a common characteristic shared by many secoiridoid glucosides found within the Oleaceae family (7,13,14,81), and this bioactive compound chemically consists of a glucose molecule attached to a secoiridoid aglycone, which contains a phenolic structure. OLE is the primary compound found in olives, contributing to the characteristic bitter flavor of untreated and raw olives (7), and both fruits and leaves of olive are abundant in the OLE (Figure 1), with minimal levels of its metabolite, HT (15). As olives ripen, the level of OLE diminishes, whereas the concentration of HT rises as a result of OLE hydrolysis (5). For example; the levels of HT and OLE in olive oil can differ, with values typically found between 1.4–5.6 mg/kg for HT and 2.3–9.0 mg/kg for OLE (15,16). OLE is renowned for its diverse pharmacological and biological activities, including antioxidative, anti-inflammatory, antiviral, anticancer, antimicrobial, protecting heart health, and hypolipidemic effects. These properties have made oleuropein a central subject of extensive *in vivo* and *in vitro* researches (100,101,102).

The other important biaoctive compound HT, or 3,4-dihydroxyphenylethanol, is a phenolic alcohol with a molecular weight of 154.16 g/mol and a chemical formula of $C_8H_{10}O_3$, which is primarily obtained from olives as a byproduct in the olive oil manufacturing process (17,80). In olive oil and olives, HT is found in both its unbound form and as a conjugate with various other substances, including OLE (18). The formation of HT occurs via the hydrolytic breakdown of oleuropein, which is naturally occurring in olives, and this process happens inherently during the maturation of olives and can also be induced artificially throughout the processing and also storage of table olives (Figure 2) (19). As can be seen in Figure 2, the degradation metabolites of oleuropein arehydroxytyrosol, elenolic acid, and glucose (99,109). Following hydrolysis, HT becomes accessible in a form that allows for extraction and further application (20,21). HT is a low-molecular-weight compound, resulting in a higher bioactivity-to-mass ratio compared to that of OLE. HT demonstrates potent antioxidative properties and is closely linked to positive outcomes in the management of several human diseases (111), exhibiting anti-tumor properties (112,113), heart-protecting (114,115), and neural protection properties (116,117). The surge in global interest in OLE and HT can be attributed to its wide-ranging health functions and biological effects (12,16,22-24).

The biological activities of oleuropein and hydroxytyrosol

Polyphenols are organic, polar compounds that are commonly present in olive oil, playing a significant role in the health benefits associated with the Mediterranean diet (25-27). Nutritional research involving human participants, as well as animal and *in vitro* studies, has shown that OLE and HT derived from olive, olive oil, olive leaves, etc. display distinct biological activities and health-enhancing functions (12,16,28). OLE and its metabolite, HT, have demonstrated anti-cellular proliferation, apoptosis-inhibiting, inflammation-suppressing, and obesity-preventing effects (107). The biological acitvities of OLE and HT are summarized in Figure 3.

OLE and HT have garnered significant interest due to their availability, safety profile, potent antioxidative properties, effective scavenging of oxygen-derived free radicals, and debated inflammation-reducing effects (80,81). The antioxidant activities of these phenolic substituents have been demonstrated to surpass those of vitamin E or butylated hydroxytoluene in terms of potency (25). At elevated concentrations, these bioactive compounds exhibit pro-oxidant activity in cancer cells, a phenomenon that is associated with their anti-growth effects (97). This pro-oxidant activity could also be associated with the cytotoxicity of

OLE and HT at these high concentrations (84).

Over the past two decades, OLE and HT, either individually or in combination, have been the subject of extensive research regarding infective diseases and the prevention/management of chronic non-communicable diseases, such as cancer, yielding promising findings from *in vitro* and *in vivo*. OLE and its metabolite, HT, have demonstrated significant cancer-inhibiting effects across a variety of tumors, including those of the bladder, brain, breast, cervical, colorectal, gastric, hematologic, liver, lung, prostate, skin, and thyroid regions. Additionally, these bioactive phytochemicals are capable of crossing the blood-brain barrier and exhibit no toxic effects, making them potential candidates for the treatment of various types of neoplastic lesions. Given the promising results of OLE and HT as potential therapies for various tumors, it is crucial to investigate the potential of these compounds in the context of neuroblastoma. Investigation into these compounds is ongoing, with numerous researches highlighting the necessity for further in-depth analysis of their mechanisms of action, especially in relation to cancer therapy. The promising results observed in *in vitro*/*in vivo* investigations provide a solid foundation for continued research, particularly in pediatric oncology, where there is an ongoing demand for safer and less toxic treatment options (51,80,81,86,87,88,89,90,91,92).

Moreover, these significant bioactive compounds exhibits strong antioxidative properties, eliminating free radicals, inhibiting oxidative degradation of lipids, preventing oxidative stress, and protecting cellular integrity which plays a key role in aging and various diseases, including heart and blood vessel-related and neurological degeneration disorders (7,8,12,16,81,96). Besides, the worldwide awareness for naturally antioxidative substances like OLE and HT is growing as consumers become more aware of their health benefits and as there is a shift toward natural substitutes for synthetic additives (12,29,30). Particularly, HT is a extensively researched constituent of the olive tree and a recognized food additive with diverse biological properties. Consequently, the extraction of HT-rich compounds from natural sources has become a focal point of scientific research, driven by the growing market demand for products enriched with naturally occurring antioxidants (110).

Moreover, OLE has been recognized for its ability to lower blood pressure and its wide-ranging pharmacological activity, including heart-guarding, inflammation-suppressing, cancer-preventing, and neural protection properties (93). Indeed, the neural protection properties of OLE have been demonstrated through its ability to trigger apoptosis and autophagy, as well as to suppress the activation of microglia and astrocytes, thereby preventing the excessive release of inflammation-inducing cytokines and, in turn, mitigating central nervous system inflammation. This explains the association between OLE intake and a reduced likelihood of developing Alzheimer's disease, persistent sadness, and other neurological conditions (94). Furthermore, OLE demonstrated a notable inflammation-preventing effect in rats by decreasing levels of TNF, IL-1, COX-2, and NO (103), as well as reducing the mRNA expression of immune-stimulating cytokines in the brains of diabetic rats (104). A study revealed that OLE's gastrointestinal instability was observed under simulated conditions using human digestive enzymes. Additionally, the research demonstrated a potent cell-proliferation blocking and inflammatory-preventing activities of both pure OLE and olive leaf extract. However, to preserve the biological activity of OLE as a dietary supplement, olive leaf extract, or infusion, microencapsulation techniques should be employed due to its gastrointestinal instability (99). In another study, it was found that administering OLE to diabetic rats led to a reduction in serum leptin and an raise in rates of adiponectin, while also significantly inhibiting the elevated expression of COX-2 and TNF-α mRNA in the livers of the STZ-treated group. Consequently,

OLE has demonstrated encouraging outcomes in alleviating high cholesterol, free radical damage, irritation, and biomarkers of hepatic dysfunction in rats with diabetes (105).

Conclusion

In conclusion, OLE and HT emerge as promising natural compounds with a broad spectrum of biological activities that underscore their potential as therapeutic agents. Their antioxidative, anticancer, anti-inflammatory, antimicrobial, and neuroprotective properties, combined with their roles in modulating critical molecular pathways, suggest significant applications in the prevention and management of chronic diseases such as cardiovascular disorders, cancer, and neurodegenerative conditions. Given their potential, these compounds represent valuable targets for further research and may contribute significantly to the development of functional foods and therapeutic agents. However, despite their demonstrated efficacy in preclinical studies, further research is needed to establish their pharmacokinetics, bioavailability, and long-term safety in clinical settings. Future investigations should focus on optimizing their delivery systems and exploring synergistic effects with other bioactive compounds to fully harness their therapeutic potential.

References

1. Augimeri, G. & BonoAglio, D. (2021). The Mediterranean diet as a source of natural compounds: does it represent a protective choice against cancer?" *Pharmaceuticals*, *14*(9), 920.

2. Guasch-Ferré, M. & Willett, W. (2021). The Mediterranean diet and health: a comprehensive overview. *Journal of Internal Medicine*, 290(3), 549–566.

3. Farràs, M.; Almanza-Aguilera, E.; Hernáez, Á.; Agustí, N.; Julve, J.; Fitó, M. & Castañer, O. (2021). Beneficial effects of olive oil and Mediterranean diet on cancer physio- pathology and incidence. *Seminars in Cancer Biology*, *73*, 178–195.

4. Goldsmith, C. D.; Bond, D. R.; Jankowski, H.; Weidenhofer, J.; Stathopoulos, C. E.; Roach, P. D. & Scarlett, C. J. (2018). The olive biophenols oleuropein and hydroxytyrosol selectively reduce proliferation, in3uence the cell cycle, and induce apoptosis in pancreatic cancer cells. *International Journal of Molecular Sciences*, *19*(7), 1937.

5. García-Molina, G.; Peters, E.; Palmeri, R.; Awoke, Y.; Márquez-Álvarez, C. & Blanco, R. M. (2024). Enzymatic synthesis of Hydroxytyrosol from Oleuropein for valorization of an agricultural waste. *Bioengineered*, *15*(1), 1-17.

6. Nediani, C.; Ruzzolini, J.; Romani, A. & Calorini, L. (2019). Oleuropein, a bioactive compound from olea europaea L., as a potential preventive and therapeutic agent in noncommunicable diseases. *Antioxidants*, *8*(12), 578.

7. Asghariazar, V.; Mansoori, B.; Kadkhodayi, M.; Safarzadeh, E., Mohammadi, A., Baradaran, B. & Sakhinia, E. (2022).MicroRNA-143 act as a tumor suppressor microRNA in human lung cancer cells by inhibiting cell proliferation, invasion, and migration. *Molecular Biology Reports*, *49*(8), 7637–7647.

8. Christodoulou, A.; Nikolaou, P.-E.; Symeonidi, L.; Katogiannis, K.; Pechlivani, L.; Nikou, T.; Varela, A.; Chania, C.; Zerikiotis, S.; Efentakis, P.; Vlachodimitropoulos, D.; Katsoulas, N.; Agapaki, A.;

Dimitriou, C.; Tsoumani, M.; Kostomitsopoulos, N.; Davos, C. H., Skaltsounis, A. L., Tselepis, A., Halabalaki, M., Tseti, I., Iliodromitis, E. K., Ikonomidis, I., & Andreadou, I. (2024). Cardioprotective potential of oleuropein, hydroxytyrosol, oleocanthal and their combination: Unravelling complementary effects on acute myocardial infarction and metabolic syndrome. *Redox Biology*, *76*(2024), 1-19.

9. Rishmawi, S.; Haddad, F.; Dokmak, G. & Karaman, R. (2022). A comprehensive review on the anti-cancer e4ects of oleuropein. *1e Life*, *12*(8), 1140.

10. Fernández-Bolaños, J. G.; López, O.; Fernández-Bolaños, J. & Rodríguez-Gutiérrez, G. (2008). Hydroxytyrosol and derivatives: isolation, synthesis, and biological properties. *Curr Org Chem.*, *12*(6), 442–463.

11. Richard, N.; Arnold, S.; Hoeller, U.; Kilpert, C.; Wertz, K. & Schwager, J. (2011). Hydroxytyrosol is the major anti-inflammatory compound in aqueous olive extracts and impairs cytokine and chemokine production in macrophages. *Planta Medica*, *77*(17), 1890–1891.

12. Batarfi,W. A.; Yunus, M. H. M.; Hamid, A. A.; Lee, Y. T. & Maarof, M. (2024). Hydroxytyrosol: A Promising Therapeutic Agent for Mitigating Inflammation and Apoptosis. *Pharmaceutics*, *16*, 1504.

13. Khalil, A. A.; Rahman, M. M.; Rauf, A.; Islam, M. R.; Manna, S. J.; Khan, A. A.; Ullah, S.; Akhtar, M. N.; Aljohani, A. S. M.; Abdulmonem, W. A. & Simal-Gandara, J. (2023). Oleuropein: chemistry, extraction techniques and nutraceutical perspectives-An update. *Critical Reviews in Food Science and Nutrition*, 22, 1–22.

14. Iantomasi, M.; Terzo, M. & Tsiani, E. (2024). Anti-Diabetic Effects of Oleuropein. *Metabolites*, *14*, 1-21.

15. Tuck, K. L. & Hayball, P. J. (2002). Major phenolic compounds in olive oil: metabolism and health effects. *J Nutr Biochem.*, *13*(11), 636–644.

16. Frumuzachi, O.; Gavrilas, L. I.; Vodnar, D.C.; Rohn, S. & Mocan, A. (2024). Systemic Health Effects of Oleuropein and Hydroxytyrosol Supplementation: A Systematic Review of Randomized Controlled Trials. *Antioxidants*, *13*, 1-26.

17. Vijakumaran, U.; Yazid, M. D.; Hj Idrus, R. B.; Abdul Rahman, M. R. & Sulaiman, N. (2021). Molecular action of hydroxytyrosol in attenuation of intimal hyperplasia: A scoping review. *Front. Pharmacol.*, *12*, 663266.

18. Hu, T.; He, X.-W.; Jiang, J.-G. & Xu, X.-L. (2014). Hydroxytyrosol and its potential therapeutic effects. *J. Agric. Food Chem.*, *62*, 1449–1455.

19. Charoenprasert, S. & Mitchell, A. (2012). Factors Influencing Phenolic Compounds in Table Olives (*Olea europaea*). *J. Agric. Food Chem.*, *60*, 7081–7095.

20. Luzi, F.; Pannucci, E.; Clemente, M.; Grande, E.; Urciuoli, S.; Romani, A.; Torre, L.; Puglia, D.; Bernini, R. & Santi, L. (2021). Hydroxytyrosol and oleuropein-enriched extracts obtained from olive oil wastes and by-products as active antioxidant ingredients for poly (vinyl alcohol)-based films. *Molecules*, *26*, 2104.

21. Monteiro, M.; Silva, A. F.; Resende, D.; Braga, S. S.; Coimbra, M. A.; Silva, A. M. Cardoso, S. M. (2021). Strategies to broaden the applications of olive biophenols oleuropein and hydroxytyrosol in food products. *Antioxidants*, *10*, 444.

22. Aydar, A.; Oner, T. O. & Ucok, E. (2017). Effects of hydroxytyrosol

on human health. *EC Nutr.*, *11*, 147–157.

23. Wani, T. A.; Masoodi, F.; Gani, A.; Baba, W. N.; Rahmanian, N.; Akhter, R.; Wani, I. A. & Ahmad, M. (2018). Olive oil and its principal bioactive compound: Hydroxytyrosol–A review of the recent literature. *Trends Food Sci. Technol.*, *77*, 77–90.

24. Batarfi, W. A.; Mohd Yunus, M. H. & Hamid, A. A. (2023) The Effect of Hydroxytyrosol in Type II Epithelial-Mesenchymal Transition in Human Skin Wound Healing. *Molecules*, *28*, 2652

25. Visioli, F. & Poli A. (2002). Antioxidant and other biological activities of phenols from olives and olive oil. *Med Res Rev.*, *22*(1), 65–75.

26. Tripoli, E.; Giammanco, M.; Tabacchi, G.; Majo, D. D.; Giammanco, S. & Guardia, M. L. (2005). The phenolic compounds of olive oil: structure, biological activity and beneficial effects on human health. *Nutr Res Rev.*, *18*(1), 98–112

27. Huang, C. L. & Sumpio, B. E. (2008). Olive oil, the mediterranean diet, and cardiovascular health. *J Am Coll Surg.*, *207*(3), 407–416.

28. Tarabanis, C.; Long, C.; Scolaro, B. & Heffron, S. P. (2023). Reviewing the cardiovascular and other health effects of olive oil: Limitations and future directions of current supplement formulations. *Nutr. Metab. Cardiovasc. Dis.*, *33*, 2326–2333.

29. Li, A.-N.; Li, S.; Zhang, Y.-J.; Xu, X.-R.; Chen, Y.-M. & Li, H.-B. (2014) Resources and biological activities of natural polyphenols. *Nutrients*, *6*, 6020–6047.

30. Rasouli, H.; Mazinani, M. H. & Haghbeen, K. (2021). Chapter 41 - Benefits and challenges of olive biophenols: A perspective. In Olives and Olive Oil in Health and Disease Prevention (Second Edition), 489–503.

31. Qabaha, K.; Al-Rimawi, F.; Qasem, A. & Naser, S. A. (2018). Oleuropein Is Responsible for the Major Anti-Inflammatory Effects of Olive Leaf Extract. *J Med Food*, *21*(3), 302-305.

32. Silvestrini, A.; Giordani, C.; Bonacci, S.; Giuliani, A.; Ramini, D.; Matacchione, G.; Sabbatinelli, J.; Di Valerio, S.; Pacetti, D.; Procopio, A.D.; et al. (2023). Anti-Inflammatory Effects of Olive Leaf Extract and Its Bioactive Compounds Oleacin and Oleuropein-Aglycone on Senescent Endothelial and Small Airway Epithelial Cells. *Antioxidants*, *12*, 1-17.

33. Şahin, S.; Şahin, E.; Esenülkü, G.; Renda, G.; Gürgen, S. G.; Alver, A.; Abidin, İ., & Cansu, A. (2024). Oleuropein Has Modulatory Effects on Systemic Lipopolysaccharide-Induced Neuroinflammation in Male Rats. *The Journal of Nutrition*, *154*(4), 1282-1297.

34. Sonmez, M., & Gunes Yapucu, U. (2018). Topikal uygulamada zetinyağının etkinliği. *Ege Üniversitesi Hemşirelik Fakültesi Dergisi*, *34*(3), 159-168.

35. Al-Rimawi, F.; Sbeih, M.; Amayreh, M.; Rahhal, B. & Mudalal, S. (2024). Evaluation of the antibacterial and antifungal properties of oleuropein, olea Europea leaf extract, and *Thymus vulgaris* oil. *BMC Complementary Medicine and Therapies*, *24*, 297.

36. Karabey, B.; Saygılı, E. & Karabey, F. (2024). *Olea europaea* L.'den elde edilen triterpenoid ve polifenol bileşiklerinin antimikrobiyal ve yaşlanma karşıtı etkilerinin değerlendirilmesi: Ekstraksiyon, Tanılama ve *in vitro* Testler. *Ege Journal of Medicine*, *63*(3), 369-377.

37. Magyari-Pavel, I. Z.; Moacă, E.-A.; Avram, S.; Diaconeasa, Z.; Haidu,

D.; Stefănut, M. N.; Rostas, A. M.; Muntean, D.; Bora, L.; Badescu, B.; et al. (2024) Antioxidant Extracts from Greek and Spanish Olive Leaves: Antimicrobial, Anticancer and Antiangiogenic Effects. *Antioxidants*, *13*, 1-30.

38. Kimura, Y. & Sumiyoshi, M. (2009). Olive leaf extract and its main component oleuropein prevent chronic ultraviolet B radiation-induced skin damage and carcinogenesis in hairless mice. *1e Journal of Nutrition*, *139*(11), 2079–2086.

39. Kikuchi, M.; Mano, N.; Uehara, Y.; Machida, K. & Kikuchi, M. (2011). Cytotoxic and EGFR tyrosine kinase inhibitory activities of aglycone derivatives obtained by enzymatic hydrolysis of oleoside-type secoiridoid glucosides, oleuropein and ligustroside. *Journal of Natural Medicines*, 65(1), 237–240.

40. Asghariazar, V.; Makaremi, S.; Zare, E.; Danesh, H., Matin, S., Fouladi, N. & Safarzadeh, E. (2024). Oleuropein induces apoptosis in gastric cancer cell lines by regulating mir-34a, mir-21, and related genes: an experimental and bioinformatic study. *International Journal of Biological Macromolecules*, *265*(1).

41. Bulotta, S.; Corradino, R.; Celano, M.; Maiuolo, J.; D'Agostino, M.; Oliverio, M.; Procopio, A.; Filetti, S. & Russo, D. (2013). Antioxidant and antigrowth action of peracetylated oleuropein in thyroid cancer cells. *Journal of Molecular Endocrinology*, *51*(1), 181–189.

42. Casaburi, I.; Puoci, F.; Chimento, A.; Sirianni, R.; Ruggiero, C.; Avena, P. & Pezzi, V. (2013). Potential of olive oil phenols as chemopreventive and therapeutic agents against cancer: a review of in vitro studies. *Molecular Nutrition & Food Research*, *57*(1), 71–83.

43. Barbaro, B.; Toietta, G.; Maggio, R.; Arciello, M.; Tarocchi, M.; Galli, A. & Balsano, C. (2014). Effects of the olivederived polyphenol oleuropein on human health. *International Journal of Molecular Sciences*, *15*(10), 18508–18524.

44. Antognelli, C.; Frosini, R.; Santolla, M. F.; Peirce, M. J. & Talesa, V. N. (2019). Oleuropein-induced apoptosis is mediated by mitochondrial glyoxalase 2 in nsclc A549 cells: a mechanistic inside and a possible novel nonenzymatic role for an ancient enzyme. *Oxidative Medicine and Cellular Longevity*, *2019*, 1-10.

45. Bayat, S.; Mansoori Derakhshan, S.; Mansoori Derakhshan, N.; Shekari Khaniani, M. & Alivand, M. R. (2019). Downregulation of HDAC2 and HDAC3 via oleuropein as a potent prevention and therapeutic agent in MCF-7 breast cancer cells," *Journal of Cellular Biochemistry*, *120*(6), 9172–9180.

46. Andreadou, I.; Iliodromitis, E. K.; Mikros, E.; Constantinou, M.; Agalias, A.; Magiatis, P.; Skaltsounis, A. L.; Kamber, E.; Tsantili-Kakoulidou, A. & Kremastinos, D. T. (2006) The olive constituent oleuropein exhibits anti-ischemic, antioxidative, and hypolipidemic effects in anesthetized Rabbits12. *J. Nutr.*, *136*, 2213–2219.

47. Joshi-Barr, S.; de Gracia Lux, C.; Mahmoud, E. & Almutairi, A. (2014). Exploiting oxidative microenvironments in the body as triggers for drug delivery systems. *Antioxidants and Redox Signaling*, 21(5), 730–754.

48. Allaw, M.; Manca, M. L.; Gòmez-Fernández, J. C.; Pedraz, J. L.; Terencio, M. C.; Sales, O. D.; Nacher, A. & Manconi, M. (2021).

Oleuropein multicompartment nanovesicles enriched with collagen as a natural strategy for the treatment of skin wounds connected with oxidative stres. *Nanomedicine*, *16*(26), 2363–2376

49. Karimi, A.; Niazkar, H. R. & SeAdmooye Azar, P. (2021). Protective effect of hydro-alcoholic extract of*achillea millefolium*on renal injury and biochemical factors in streptozotocin-induced diabetic rats. *Nutrition and Food Science*, *51*(7), 1068–1083.

50. Geyikoğlu, F.; Colak, S.; Türkez, H.; Bakır, M.; Koç, K.; Hosseinigouzdagani, M. K.; Çerığ, S. & Sönmez, M. (2017). Oleuropein ameliorates cisplatin-induced hematological damages via restraining oxidative stress and DNA injury. *Indian Journal of Hematology and Blood Transfusion*, *33*(3), 348–354.

51. Imran, M.; Nadeem, M.; Gilani, S. A.; Khan, S.; Sajid, M. W. & Amir, R. M. (2018). Antitumor perspectives of oleuropein and its metabolite hydroxytyrosol: recent updates. *Journal of Food Science*, *83*(7), 1781–1791.

52. Ahamad, J.; Toufeeq, I.; Khan, M. A.; Ameen, M. Sh. M; Anwer, E. T; Uthirapathy, S.; Mir, S. R. & Ahmad, J. (2019). Oleuropein: a natural antioxidant molecule in the treatment of metabolic syndrome. *Phytotherapy Research*, 33(12), 3112–3128.

53. Al-Shaal, S.; Karabet, F. & Daghestani, M. (2019). Determination of the antioxidant properties of the Syrian olive leaves extracts and isolation oleuropein by HPLC techniques," *Analytical and Bioanalytical Chemistry Research*, *6*(1), 97–110.

54. Romero, M.; Toral, M.; Gómez-Guzmán, M.; Jiménez, R.; Galindo, P.; Sánchez, M.; Olivares, M.; Gálvez, J. & Duarte, J. (2016). Antihypertensive effects of oleuropein-enriched olive leaf extract in spontaneously hypertensive rats. *Food Funct.*, *7*, 584–593.

55. Al-Azzawie, H. F. & Alhamdani, M. - S. S. (2006). Hypoglycemic and antioxidant effect of oleuropein in alloxan-diabetic rabbits. *Life Sci.*, *78*, 1371–1377.

56. Zheng, S.; Huang, K. & Tong, T. (2021). Efficacy and mechanisms of oleuropein in mitigating diabetes and diabetes complications. *J. Agric. Food Chem.*, *69*,6145–6155.

57. Oi-Kano, Y.; Iwasaki, Y.; Nakamura, T.; Watanabe, T.; Goto, T.; Kawada, T.; Watanabe, K. & Iwai, K. (2017). Oleuropein aglycone enhances UCP1 expression in Brown adipose tissue in high-fat-diet-induced obese rats by activating β-adrenergic signaling. *J. Nutr. Biochem.*, *40*(2017), 209–218.

58. Tsoumani, M.; Georgoulis, A.; Nikolaou, P.-E.; Kostopoulos, I. V.; Dermintzoglou, T.; Papatheodorou, I.; Zoga, A.; Efentakis, P.; Konstantinou, M.; Gikas, E.; Kostomitsopoulos, N.; Papapetropoulos, A.; Lazou, A.; Skaltsounis, A.-L.; Hausenloy, D. J.; Tsitsilonis, O.; Tseti, I.; Di Lisa, F.; Iliodromitis, E. K. & Andreadou, I. (2021). Acute administration of the olive constituent, oleuropein, combined with ischemic postconditioning increases myocardial protection by modulating oxidative defense. *Free Radic. Biol. Med.*, *166*, 18–32.

59. Granados-Principal, S.; Quiles, J. L.; Ramirez-Tortosa, C. L.; Sanchez-Rovira, P. & Ramirez-Tortosa, M. C. (2010). Hydroxytyrosol: From laboratory investigations to future clinical trials. *Nutr. Rev.*, *68*, 191–206.

60. Karković Marković, A.; Torić, J.; Barbarić, M. & Jakobušić Brala, C. (2019). Hydroxytyrosol, tyrosol and

derivatives and their potential effects on human health. *Molecules*, *24*, 2001.

61. Kamil, K.; Yazid, M. D.; Idrus, R. B. H. & Kumar, J. (2020). Hydroxytyrosol promotes proliferation of human schwann cells: An in vitro study. *Int. J. Environ. Res. Public Health*, *17*, 4404.

62. Pérez-Barrón, G.; Montes, S.; Aguirre-Vidal, Y.; Santiago, M.; Gallardo, E.; Espartero, J. L.; Ríos, C. & Monroy-Noyola, A. (2021). Antioxidant effect of hydroxytyrosol, hydroxytyrosol acetate and nitrohydroxytyrosol in a rat MPP+ model of Parkinson's disease. *Neurochem.Res.*, *46*, 2923–2935.

63. Camargo, A.; Ruano, J.; Fernandez, J. M.; Parnell, L. D.; Jimenez, A.; Santos-Gonzalez, M.; Marin, C.; Perez-Martinez, P.; Uceda, M. & Lopez-Miranda, J. (2010). Gene expression changes in mononuclear cells in patients with metabolic syndrome after acute intake of phenol-rich virgin olive oil. *BMC Genom.*, *11*, 253.

64.Terracina, S.; Petrella, C.; Francati, S.; Lucarelli, M.; Barbato, C.; Minni, A.; Ralli, M.; Greco, A.; Tarani, L. & Fiore, M. (2022). Antioxidant intervention to improve cognition in the aging brain: The example of hydroxytyrosol and resveratrol. *Int. J. Mol. Sci.*, *23*, 15674.

65. Warleta, F.; Quesada, C. S.; Campos, M.; Allouche, Y.; Beltrán, G. & Gaforio, J. J. (2011). Hydroxytyrosol protects against oxidative DNA damage in human breast cells. *Nutrients*, *3*, 839–857.

66. Robles-Almazan, M.; Pulido-Moran, M.; Moreno-Fernandez, J.; Ramirez-Tortosa, C.; Rodriguez-Garcia, C.; Quiles, J. L. & Ramirez-Tortosa, M. (2018). Hydroxytyrosol: Bioavailability, toxicity, and clinical applications. *Food Res. Int.*, *105*, 654–667.

67. Burattini, S.; Salucci, S.; Baldassarri, V.; Accorsi, A.; Piatti, E.; Madrona, A.; Espartero, J. L.; Candiracci, M.; Zappia, G. & Falcieri, E. (2013) Anti-apoptotic activity of hydroxytyrosol and hydroxytyrosyl laurate. *Food Chem. Toxicol.*, *55*, 248–256.

68. Yu, H.; Zhang, Z.; Wei, F.; Hou, G.; You, Y.; Wang, X.; Cao, S.; Yang, X.; Liu, W.; Zhang, S.; et al. (2022). Hydroxytyrosol Ameliorates Intervertebral Disc Degeneration and Neuropathic Pain by Reducing Oxidative Stress and Inflammation. *Oxidative Med. Cell. Longev.*, *2022*, 2240894.

69. Razali, R. A.; Yazid, M. D.; Saim, A.; Idrus, R. B. H. & Lokanathan, Y. (2023). Approaches in Hydroxytyrosol Supplementation on Epithelial—Mesenchymal Transition in TGFβ1-Induced Human Respiratory Epithelial Cells. *Int. J. Mol. Sci.*, *24*, 3974.

70. Vijakumaran, U.; Shanmugam, J.; Heng, J. W.; Azman, S. S.; Yazid, M. D.; Haizum Abdullah, N. A. & Sulaiman, N. (2023). Effects of hydroxytyrosol in endothelial functioning: A comprehensive review. *Molecules*, *28*, 1861.

71. Calabriso, N.; Gnoni, A.; Stanca, E.; Cavallo, A.; Damiano, F.; Siculella, L. & Carluccio, M. A. (2018). Hydroxytyrosol ameliorates endothelial function under inflammatory conditions by preventing mitochondrial dysfunction. *Oxidative Med. Cell. Longev.*, *2018*, 9086947.

72. Chen, Q.; Sun, T.; Wang, J.; Jia, J.; Yi, Y. H.; Chen, Y. X.; Miao, Y. & Hu, Z. Q. (2019). Hydroxytyrosol prevents dermal papilla cells inflammation under oxidative stress by inducing autophagy. *J. Biochem. Mol. Toxicol.*, *33*, e22377.

73. Alblihed, M. A. (2021). Hydroxytyrosol ameliorates

oxidative challenge and inflammatory response associated with lipopolysaccharidemediated sepsis in mice. *Hum. Exp. Toxicol.*, *40*, 342–354.

74. Chen, C.; Ai, Q. & Wei, Y. (2021) Hydroxytyrosol protects against cisplatin-induced nephrotoxicity via attenuating CKLF1 mediated inflammation, and inhibiting oxidative stress and apoptosis. *Int. Immunopharmacol.*, *96*, 107805.

75. Elmaksoud, H. A.; Motawea, M. H.; Desoky, A. A.; Elharrif, M. G. & Ibrahimi, A. (2021) Hydroxytyrosol alleviate intestinal inflammation, oxidative stress and apoptosis resulted in ulcerative colitis. *Biomed. Pharmacother.*, *142*, 112073.

76. Cao, K.; Xu, J.; Zou, X.; Li, Y.; Chen, C.; Zheng, A.; Li, H.; Li, H.; Szeto, I. M.-Y.; Shi, Y.; Long, J.; Liu, J. & Feng, Z. (2014). Hydroxytyrosol prevents diet-induced metabolic syndrome and attenuates mitochondrial abnormalities in obese mice. *Free Radic. Biol. Med.*, *67*, 396–407.

77. Efentakis, P.; Iliodromitis, E. K.; Mikros, E.; Papachristodoulou, A.; Dagres, N.; Skaltsounis, A.-L. & Andreadou, I. (2015). Effects of the olive tree leaf constituents on myocardial oxidative damage and atherosclerosis. *Planta Med.*, *81*, 648–654.

78. Poudyal, H.; Lemonakis, N.; Efentakis, P.; Gikas, E.; Halabalaki, M.; Andreadou, I.; Skaltsounis, L. & Brown, L. (2017). Hydroxytyrosol ameliorates metabolic, cardiovascular and liver changes in a rat model of diet-induced metabolic syndrome: pharmacological and metabolism-based investigation. *Pharmacol. Res.*, *117*, 32–45.

79. Illesca, P.; Valenzuela, R.; Espinosa, A.; Echeverría, F.; Soto-Alarcon, S.; Ortiz, M. & Videla, L. A. (2019). Hydroxytyrosol supplementation ameliorates the metabolic disturbances in white adipose tissue from mice fed a high-fat diet through recovery of transcription factors Nrf2, SREBP-1c, PPAR-γ and NF-κB. *Biomed. Pharmacother.*, *109*(2019), 2472–2481.

80. Gervasi, F. & Pojero, F. (2024). Use of Oleuropein and Hydroxytyrosol for Cancer Prevention and Treatment: Considerations about How Bioavailability and Metabolism Impact Their Adoption in Clinical Routine. *Biomedicines*, *12*, 1-36.

81. Goncalves, M.; Aiello, A.; Rodríguez-Pérez, M.; Accardi, G.; Burgos-Ramos, E. & Silva, P. (2024). Olive Oil Components as Novel Antioxidants in Neuroblastoma Treatment: Exploring the Therapeutic Potential of Oleuropein and Hydroxytyrosol. *Nutrients*, *16*, 1-20.

82. Silva, P.; Rodríguez-Pérez, M. & Burgos-Ramos, E. (2023). Zebrafish Model Insights into Mediterranean Diet Liquids: Olive Oil and Wine. *Antioxidants*, *12*, 1843

83. Wahrburg, U.; Kratz, M. & Cullen, P. (2002). Mediterranean diet, olive oil and health. *Eur. J. Lipid Sci. Technol.*, *104*, 698–705.

84. Kouka, P.; Priftis, A.; Stagos, D.; Angelis, A.; Stathopoulos, P.; Xinos, N.; Skaltsounis, A.L.; Mamoulakis, C.; Tsatsakis, A.M.; Spandidos, D.A.; et al. (2017). Assessment of the antioxidant activity of an olive oil total polyphenolic fraction and hydroxytyrosol from a Greek Olea europea variety in endothelial cells and myoblasts. *Int. J. Mol. Med.*, *40*, 703–712.

85. Carrera-González, M. P.; Ramírez-Expósito, M. J.; Mayas, M. D. & Martínez-Martos, J. M. (2013). Protective role of oleuropein and its metabolite hydroxytyrosol on

cancer. *Trends Food Sci.*, *31*, 92–99.

86. Castejón, M. L.; Montoya, T.; Alarcón-de-la-Lastra, C. & Sánchez-Hidalgo, M. (2020). Potential Protective Role Exerted by Secoiridoids from Olea europaea L. in Cancer, Cardiovascular, Neurodegenerative, Aging-Related, and Immunoinflammatory Diseases. *Antioxidants*, *9*, 149.

87. Gorzynik-Debicka, M.; Przychodzen, P.; Cappello, F.; Kuban-Jankowska, A.; Marino Gammazza, A.; Knap, N.; Wozniak, M. & Gorska-Ponikowska, M. (2018). Potential Health Benefits of Olive Oil and Plant Polyphenols. *Int. J. Mol. Sci.*, *19*, 686.

88. Nediani, C.; Ruzzolini, J.; Romani, A. & Calorini, L. (2019). Oleuropein, a Bioactive Compound from Olea europaea L., as a Potential Preventive and Therapeutic Agent in Non-Communicable Diseases. *Antioxidants*, *8*, 578.

89. Karković Marković, A.; Torić, J.; Barbarić, M. & Jakobušić Brala, C. (2019). Hydroxytyrosol, Tyrosol and Derivatives and Their Potential Effects on Human Health. *Molecules*, *24*, 2001.

90. Lockyer, S.; Corona, G.; Yaqoob, P.; Spencer, J. P. E. & Rowland, I. (2015). Secoiridoids delivered as olive leaf extract induce acute improvements in human vascular function and reduction of an inflammatory cytokine: A randomised, double-blind, placebo-controlled, cross-over trial. *Br. J. Nutr.*, *114*, 75–83.

91. Pojero, F.; Aiello, A.; Gervasi, F.; Caruso, C.; Ligotti, M. E.; Calabr., A.; Procopio, A.; Candore, G.; Accardi, G. & Allegra, M. (2022). Effects of Oleuropein and Hydroxytyrosol on Inflammatory Mediators: Consequences on Inflammaging. *Int. J. Mol. Sci.*, *24*, 380.

92. Pojero, F.; Gervasi, F.; Fiore, S. D.; Aiello, A.; Bonacci, S.; Caldarella, R.; Attanzio, A.; Candore, G.; Caruso, C.; Ligotti, M. E.; et al. (2023). Anti-Inflammatory Effects of Nutritionally Relevant Concentrations of Oleuropein and Hydroxytyrosol on Peripheral Blood Mononuclear Cells: An Age-Related Analysis. *Int. J. Mol. Sci.*, *24*, 11029.

93. Sun, W.; Frost, B. & Liu, J. (2017). Oleuropein, unexpected benefits! *Oncotarget*, *8*, 17409.

94. Butt, M. S.; Tariq, U.; Iahtisham-Ul-Haq; Naz, A. & Rizwan, M. (2021). Neuroprotective effects of oleuropein: Recent developments and contemporary research. *J. Food Biochem.*, *45*, e13967.

95. Gamli, O. (2016). The health effects of oleuropein, one of the major phenolic compounds of olives, *Olea europaea* L. *Ital. J. Food Sci.*, *28*, 2016–2178.

96. Bucciantini, M.; Leri, M.; Nardiello, P.; Casamenti, F. & Stefani, M. (2021). Olive Polyphenols: Antioxidant and Anti-Inflammatory Properties. *Antioxidants*, *10*, 1044.

97. Bulotta, S.; Celano, M.; Lepore, S.M.; Montalcini, T.; Pujia, A. & Russo, D. (2014). Beneficial effects of the olive oil phenolic components oleuropein and hydroxytyrosol: Focus on protection against cardiovascular and metabolic diseases. *J. Transl. Med.*, *12*, 219.

98. Ercelik, M.; Tekin, C.; Tezcan, G.; Ak Aksoy, S.; Bekar, A.; Kocaeli, H.; Taskapilioglu, M.O.; Eser, P. & Tunca, B. (2023) Olea europaea Leaf Phenolics Oleuropein, Hydroxytyrosol, Tyrosol, and Rutin Induce Apoptosis and Additionally Affect Temozolomide against Glioblastoma: In Particular, Oleuropein Inhibits Spheroid Growth by Attenuating Stem-like Cell Phenotype. *Life*, *13*, 1-28.

99. Soldo, B.; Bilušić, T.; Giacometti, J.; Ljubenkov, I.; Čikeš Čulić, V.;

Bratanić, A.; Bošković, P.; Šola, I.; Ilić, K. (2024). A Comparative Study of Oleuropein Extraction from Wild Olive Leaves (Olea europea subsp. oleaster, Hoffmanns. & Link), Its Gastrointestinal Stability, and Biological Potential. Appl. Sci., *14*, 1-14.

100. Nediani, C.; Ruzzolini, J.; Romani, A. & Calorini, L. (2019). Oleuropein, a Bioactive Compound from Olea europaea L., as a Potential Preventive and Therapeutic Agent in Non-Communicable Diseases. *Antioxidants*, *8*, 578.

101. Fayez, N.; Khalil, W.; Abdel-Sattar, E. & Abdel-Fattah, A. M. (2023). In Vitro and In vivo Assessment of the Anti-Inflammatory Activity of Olive Leaf Extract in Rats. *Inflammopharmacology*, *3*, 1529–1538.

102. Emma, M. R.; Augello, G.; Di Stefano, V.; Azzolina, A.; Giannitrapani, L.; Montalto, G.; Cervello, M. & Cusimano, A. (2021). Potential Uses of Olive Oil Secoiridoids for the Prevention and Treatment of Cancer: A Narrative Review of Preclinical Studies. *Int. J. Mol. Sci.*, *22*, 1234.

103. Fayez, N.; Khalil, W.; Abdel-Sattar, E. & Abdel-Fattah, A. M. (2023). In Vitro and In vivo Assessment of the Anti-Inflammatory Activity of Olive Leaf Extract in Rats. *Inflammopharmacology*, *3*, 1529–1538.

104. Berkoz, M.; Kahraman, T.; Shamsulddin, Z. N. & Kro´sniak, M. (2021). Antioxidant and Anti-inflammatory Effect of Olive Leaf Extract Treatment in Diabetic Rat Brain. *J. Basic Clin. Physiol. Pharmacol.*, *34*, 187–196.

105. Mohamed, N. A.; Hussein, M. M.; Ahmed, O. M.; Al-Jameel, S. S.; Al-Muzafar, H. M.; Amin, K.A. & Abdou, H.M. (2024). Oleuropein ameliorates hyperlipidemia, oxidative stress, inflammatory and liver dysfunction biomarkers, in streptozotocin-induced diabetic rats. *Journal of Applied Pharmaceutical Science*, *14*(09), 227-234.

106. Rashed, S. A.; Saad, T. I. & El-Darier, S. M. (2022). Potential aptitude of four olive cultivars as anticancer and antioxidant agents: oleuropein content. *Rend Fis Acc Lincei.*, *33*, 195–203.

107. Martínez-Navarro, M. E.; Cebrián-Tarancón, C.; Oliva, J.; Salinas, M. R. & Alonso, G. L. (2021). Oleuropein degradation kinetics in olive leaf and its aqueous extracts. *Antioxidants*, *10*, 1963.

108. Markhali, F. S.; Teixeira, J. A. & Rocha, C. M. R. (2020). Olive tree leaves-A source of valuable active compounds. *Processes*, *8*, 1177.

109. Ramírez, E.; Brenes, M.; García, P.; Medina, E. & Romero, C. (2016). Oleuropein hydrolysis in natural green olives: Importance of the endogenous enzymes. *Food Chem.*, *206*, 204–209.

110. Kourti, M.; Skaperda, Z.; Tekos, F.; Stathopoulos, P.; Koutra, C.; Skaltsounis, A. L. & Kouretas, D. (2024). The Bioactivity of a Hydroxytyrosol-Enriched Extract Originated after Direct Hydrolysis of Olive Leaves from Greek Cultivars. *Molecules*, *29*, 1-19.

111. Bertelli, M.; Kiani, A.K.; Paolacci, S.; Manara, E.; Kurti, D.; Dhuli, K.; Bushati, V.; Miertus, J.; Pangallo, D.; Baglivo, M.; et al. (2020). Hydroxytyrosol: A natural compound with promising pharmacological activities. *J. Biotechnol.*, *309*, 29–33.

112. Hormozi, M.; Marzijerani, A. S. & Baharvand, P. (2020). Effects of hydroxytyrosol on expression of apoptotic genes and activity of antioxidant enzymes in ls180 cells. *Cancer Manag. Res.*, *12*, 7913–7919.

113. Jesús Ramírez-Expósito, M.; Manuel, J. & Id, M. M. (2018). Anti-Inflammatory and Antitumor Effects of Hydroxytyrosol but Not Oleuropein on Experimental Glioma In Vivo. A Putative Role for the Renin-Angiotensin System. *Biomedicines*, *6*, 11.

114. Vijakumaran, U.; Shanmugam, J.; Heng, J. W.; Azman, S. S.; Yazid, M. D.; Haizum Abdullah, N. A. & Sulaiman, N. (2023). Effects of Hydroxytyrosol in Endothelial Functioning: A Comprehensive Review. *Molecules*, *28*, 1861.

115. Wu, L.; Xu, Y.; Yang, Z. & Feng, Q. (2018). Hydroxytyrosol and olive leaf extract exert cardioprotective effects by inhibiting GRP78 and CHOP expression. *J. Biomed. Res.*, *32*, 371–379

116. Nardi, M.; Brocchini, S.; Somavarapu, S. & Procopio, A. (2023). Hydroxytyrosol oleate: A promising neuroprotective nanocarrier delivery system of oleuropein and derivatives. *Int. J. Pharm.*, *631*, 122498.

117. Joséantonio Gonzaíez-Correa, J.; Dolores Rodríguez-Pérezpérez, M.; Márquezmárquez-Estrada, L.; Antonio Lopezlopez-Villodres, J.; Reyes, J.J.; Rodriguez-Gutierrez, G.; Fernández-Bolanos, J. & De La Cruz, J. P. (2018). Neuroprotective Effect of Hydroxytyrosol in Experimental Diabetic Retinopathy: Relationship with Cardiovascular Biomarkers. *J. Agric. Food Chem.*, *66*, 637–644.

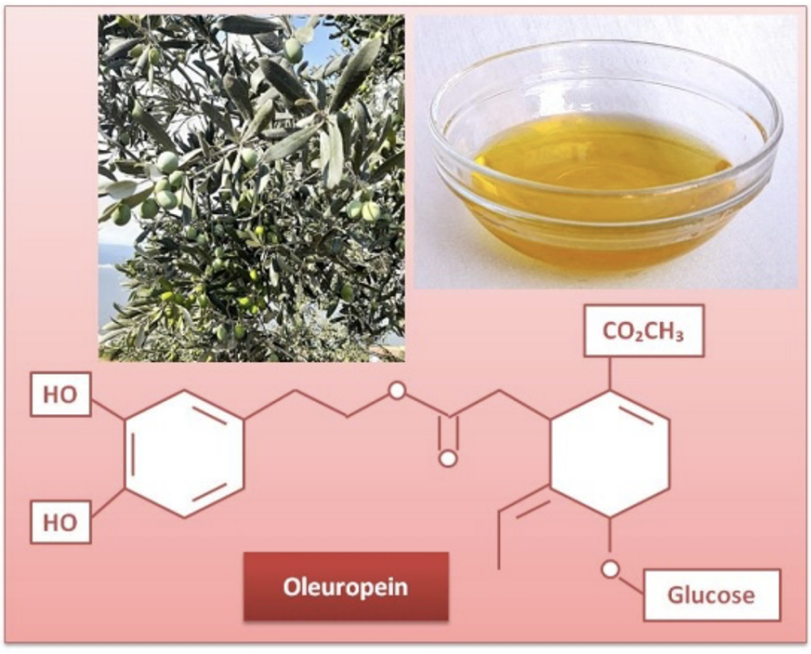

Figure 1. The chemical structure of OLE (7,16)

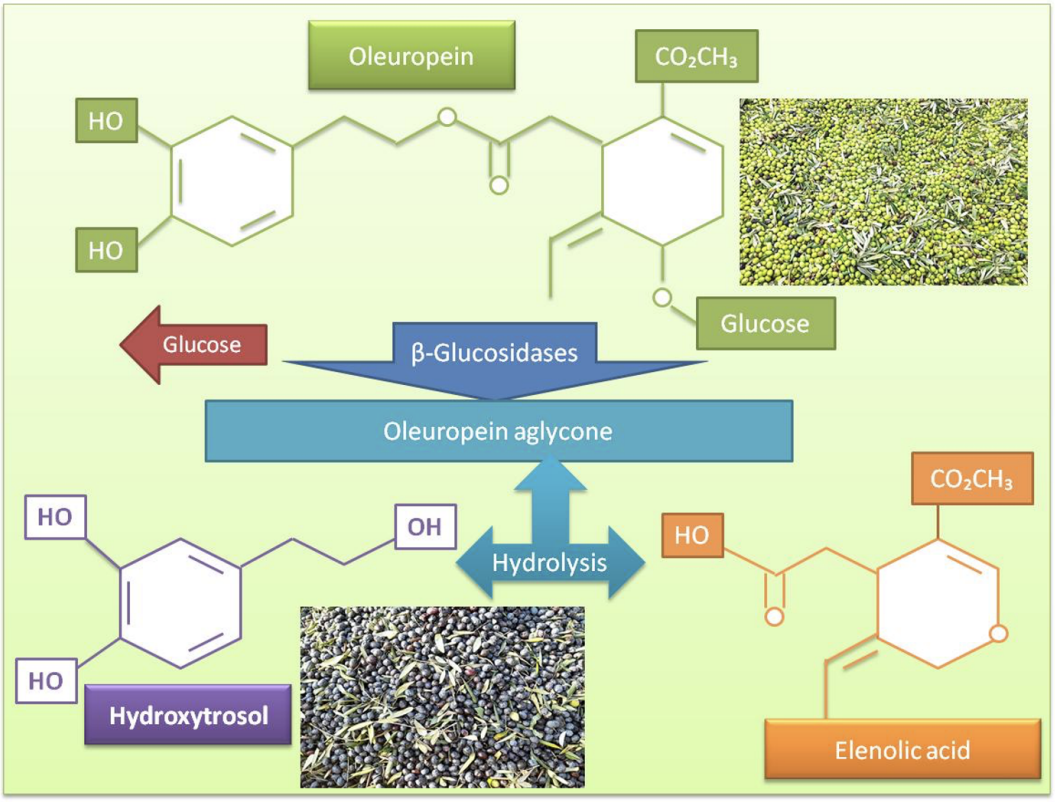

Figure 2. The enzymatic breakdown of OLE results in the formation of hydroxytyrosol (16,19,99)

Oleuropein (secoiridoid)	Hydroxytyrosol (phenylethanoid)
• **Anti-inflammatory** (14,31-33) • **Antimicrobial** (31,34-37) • **Anticancer** (7,9,14,37-40,80) • **Antitumor, pro-apoptotic and anti-proliferative activities against several cancer cell lines in humans** (41-45) • **Antioxidant** (14,33,43,46-49) • **Suppressing reactive oxygen species** (50-53) • **Antihypertensive** (54), **antidiabetic** (14) • **Hypoglycemic** (55,56), **hypolipidemic** (46), **antiobesity** (57) • **Cardioprotective** (14,37,58) • **Wound-healing activity on skin, etc.** (37,48)	• **Antioxidant** (11,24,59-64) • **Reactive oxygen species scavenger** (11, 24,62) • **Cardioprotective** (11,24,61,62,63,65,66, 68-70) • **Anti-inflammatory** (59,63,67,71-75) • **Anti-apoptotic** (67,71-75,80) • **Neuroprotective** (61,65,66,68-70) • **Anticancer, antimicrobial, protecting skin and eye** (61,65,66,69,80) • **Anti-fibrogenesis, preventing osteoporosis, positive impacts on obesity, hypercholesterolemia, insulin resistance** (76-79)

Figure 3. The biological activities of OLE and HT (7,8,12,16,81)

https://dergipark.org.tr/tr/pub/food
OPEN ACCESS JOURNAL

ISSN 2667-5803

FHTI Journal of Food Health and Technology Innovations
December Vol 7, No 15 (2024)

DergiPark AKADEMİK

Review Article

ARTIFICIAL INTELLIGENCE IN THE FOOD INDUSTRY

Seval Sevgi KIRDAR [1, 2]

Abstract Nutrition is vital for human survival. It is essential to reduce food waste, streamline the supply chain, and improve food logistics, delivery, and safety. Artificial intelligence and machine learning significantly contribute to achieving these objectives. Artificial Intelligence (AI) refers to the development of intelligent systems capable of doing activities that typically require human intelligence. In the food industry, it is seen that solution tools such as ANN (Neural Network), Fuzzy Logic and Genetic Algorithm are widely used in solving problems and performing their analyses. Artificial intelligence has been employed in food science and technology for classification, process modeling and optimization, quality control of food, prediction of dough rheological properties, classification of wine based on anthocyanin content, forecasting the maximum or minimum temperature attained in a sample post-pressurization, determining the time required for thermal re-equilibration in high-pressure food processing systems, and classifying fruits and vegetables according to their morphological characteristics. This article discusses artificial intelligence applications in the food industry and manufacturing.

Keywords: Artificial İntelligence, Food ındustry, Food Engineering

TÜBİTAK ULAKBİM

1Mehmet Akif Ersoy University Burdur Food, Agriculture and Livestock Vocational Higher Education School Food Processing Department ,Burdur, TURKEY
2Mehmet Akif Ersoy University Healt Sciences Institute, Burdur, TURKEY
*Corresponding Author: Seval Sevgi KIRDAR
The University of Mehmet Akif Ersoy, Burdur Food, Agriculture and Livestock Vocational Higher Education School Food Department of Food Processing, Milk and Dairy Products Programme, 15030 İstiklal Campus, Burdur/Turkey
Phone: +90 2482132274 Email: skirdar@mehmetakif.edu.tr

Introduction

Artificial intelligence (AI) comprises technologies replicating human intellect, enabling computers to emulate human cognition and behavior for autonomous learning, reasoning, planning, and decision-making. The essence of artificial intelligence encompasses machine learning (ML), deep learning, natural language processing, computer vision, and additional technologies applicable across diverse sectors and industries (4). The term 'big data' denotes a vast and varied assemblage of data, usually produced by numerous sensors or mobile devices, extracted from the internet and other origins, encompassing organized and unstructured data, including text, photos, and videos. These data collections are typically defined by high velocity, high volume, and high dimensionality, necessitating storage, processing, and analysis through specialized technologies, commonly known as 'big data technologies.' In the food industry, big data analytics can forecast market demand, enhance the supply chain, elevate food safety and quality, and provide enterprises with additional opportunities and competitive benefits (4,17,31,52,56).

Artificial intelligence significantly contributes to food science and industry by enhancing the efficiency of cleaning-in-place (CIP) systems, managing supply chains (33), developing new products aligned with consumer preferences, categorizing fresh produce, ensuring food quality (42,47,50,58,69), controlling processes (45,70), processing images (29,69), evaluating sensory attributes such as odor and flavor (2), and, crucially, conserving time and resources (9). It has also recently grown to include predictions about keeping an eye on food safety and illnesses that come from eating (9,36,42,47,65,70). Machine learning positively influences sales of fast-moving consumer goods, particularly perishable food products, enhancing supply chain efficiency, profitability, and consumer accessibility (60).

Application in food industry

The role of artificial intelligence in these challenges is to assist both in overcoming these difficulties and in creating, diversifying and improving products (Figure 1) (43).

Applications of artificial intelligence in the food industry are expressed in the following areas (43):

- ✓ Sales forecasting. Artificial intelligence can track customer preferences and purchases to predict sales.
- ✓ Predicting consumer preferences and purchasing methods by tracking customer emotions on social media processes and analyzes data to sort their posts and label them as positive, negative or neutral.
- ✓ Improvement of food products. Many food brands are improving their product offerings by using artificial intelligence and deep learning technologies to create flavor combinations that will be popular with consumers.
- ✓ Inventory forecasting. Artificial intelligence can provide accurate guidance for better market analysis.
- ✓ This will facilitate pricing, inventory forecasts and more accurate planning.
- ✓ Supply chain improvement. Food safety regulations are becoming more and more stringent, requiring full transparency in supply chain management for food industry businesses. The need for AI-driven supply chain tracking can optimize the supply chain to increase enterprise profitability.
- ✓ Sorting for quality assurance. Sorting is one of the most labor-intensive operations in the production process. It can be facilitated with the help of artificial intelligence. This will contribute to increased productivity, reduced scrap and higher quality.
- ✓ Food security. The food industry is faced with the challenge of meeting the increased demand for food, due to the growing world population, climate change, decreasing areas of agricultural land, etc.
- ✓ Food safety. With artificial intelligence, practices that are not in line with the corporate policy for healthy and safe production can be identified.

Table 1 shows the areas where AI and ML can be implemented in the food industry to enhance food quality while keeping up with the food industry's problems. These are not the only applications of AI; they can also improve food processing, storage, and transportation. Intelligent technology, such as robots and drones, can also help reduce packaging costs. It will also help with food delivery work fulfillment in hazardous areas and the provision of high-quality items (24,31,32).

Data collection and analysis divide the food industry into four categories, as shown in Figure 2.

The first category is smart farming. AI has various significant uses in food, such as soil monitoring, robocropping, and predictive analysis(32).

Smart transportation constitutes the second category. The transportation sector is evolving due to artificial intelligence. It has been utilized across various industries, including automobiles, trains, ships, and aircraft, as well as in optimizing traffic flow. It possesses the potential to transform the food industry and all modes of transportation, enhancing their safety, environmental sustainability, intelligence, and efficiency. Artificial intelligence-assisted autonomous mobility may mitigate human error, a significant factor in road accidents. Nonetheless, there are tangible risks linked to these scenarios, including unintended consequences and potential exploitation, such as cyberattacks and biased transit decisions.In addition to ethical concerns, there are further implications for employment about the accountability of artificial intelligence for decisions made in the absence of human oversight (31,32).

The third category includes smart processing. Artificial intelligence (AI) is attracting the attention of businesses across all sectors and industries, including food processing and handling (FP and H). AI exerts both direct and indirect impacts on the FP and H sectors. It indirectly aids farmers in weather forecasting, allowing them to generate superior raw materials for food processing companies, hence minimizing costs related to product sorting. Artificial intelligence assists transportation companies in minimizing shipping prices, hence lowering transportation costs for food manufacturing enterprises. In all circumstances, it aids FP and H firms in reducing revenue (32).

The final category of financial inclusion is intelligent distribution and consumption. The name signifies the intended application of agricultural products in FI. Machine learning (ML) can effectively address challenges such as optimizing delivery routes, managing raw material supply, predicting demand for particular food items, and enhancing logistics planning. Machine learning can help with distribution problems by determining where the delivery person should be based on current or expected traffic conditions and then telling them the best way to get there in real-time. Numerous applications in the food service industry today aid in forecasting the quantity and type of food orders, along with the associated inventory. (32).

Statistical analyses of visitor traffic and the required food products over time can utilize the data. The data are put together by combining information from past customer interactions, like their meal preferences, habits, and complaints, with details about what goods were available then (32).

AI in food enzymes development

Artificial intelligence has demonstrated significant efficacy in examining the links between enzyme structure and function. AI is anticipated to facilitate the simulation of the most complex reactions executed by process-aid enzymes in food processing. This presents a significant benefit over traditional approaches employed to enhance these enzymes, which account for a restricted number of parameters and fail to consider the actual food processing environment (5).

Wang et al. (66) have recently examined the advantages of AI-assisted design and engineering of enzymes for food processing applications. The substantially reduced computing time is A primary benefit

of AI in food enzyme engineering. Significantly less time and resources are utilized than conventional physical approaches while potentially providing extensive knowledge that aids in innovative product development.

AI in precision fermentation

AI-driven methodologies have garnered significant interest recently in the domain of industrial microbiology. AI techniques provide a significantly accelerated comprehension of the optimal modifications to implement in the microbial genome to enhance the yield of a desired chemical. AI tools facilitate the editing and customization of microbes for the synthesis of specific chemicals required in the food business, while also assisting in the storage and manipulation of extensive data sets generated from the integration of experimental and in silico studies. Currently, numerous food organizations are concentrating on this emerging technology to address the expanding variety of food demands (5).

AI in food safety and food toxicity

Food safety is crucial to human survival and health. AI is used in food supply chain management, quality control, sorting, and hygiene. Food fraud was predicted by a Bayesian network model (MedISyss-FF) developed by the European Union's Rapid Alert System for Food and Feed (7). In contrast, the U.S. FDA (Food and Drug Administration) has used AI to develop a model for predicting aflatoxin to help identify low- and high-risk seafood sourcing (18). Similarly, a study conducted in Taiwan by Chang et al. (8) describes the development of an automated alarm system for food safety. Microbial toxins and toxic chemicals are significant factors contributing to food safety risks. The methodologies currently used to detect such risks are costly and time-consuming. Integrating AI and machine learning software into the conventional methods used for assessing food toxicity has led to significant improvements in the rapidity and cost-effectiveness of food analyses to detect toxic compounds of both chemical and biological origins. Managing large datasets enabled by AI tools allows one to detect and classify poisonous compounds rapidly and efficiently. In this context, the chemical migration from package to food can also represent the risk of food toxicity (5).

Wang et al. (66) have developed an AI-based system that addresses these issues by utilizing a mix of data related to chemical properties, material type, food category, and temperature. The rapidity of AI-driven methodologies facilitates the examination of deleterious compounds throughout all critical phases of food production. The varied shapes and sizes of food items often hinder the advancement of AI-based food sorting and packaging. Once implemented, AI can enhance decision-making and automation, resulting in rapid, efficient, and hygienic operations, among other benefits. TOMRA and TensorFlow are two leading AI technologies that employ a combination of high-resolution cameras, laser technology, X-ray systems, and infrared spectroscopy. Product sorting efficiency has reportedly risen by around 90% due to these strategies (34).

AI in food pathogen microbiology

Artificial intelligence and machine learning are discovering crucial uses in food pathogen microbiology. Microbial infections in food can lead to food poisoning or deterioration. In traditional laboratories, food samples are examined for pathogens by isolating contaminants on agar plates, thereafter undergoing biochemical analysis. These procedures are inefficient and frequently hindered by the difficulty to isolate bacteria using the growth media accessible in ordinary laboratories. AI applications can significantly decrease detection time and enhance sensitivity (5).

Lupolova et al. (38) demonstrated that AI-based techniques can ascertain host specificity and zoonotic potential of species such as Salmonella enterica and Escherichia coli, which is of significant relevance to public health.

Wang et al. (64) utilized an AI-based technology platform to identify bacterial growth in under 3 hours and accurately

classify over 80% of bacterial kinds within about 8 hours, resulting in a time savings of over 12 hours compared to traditional approaches. Artificial intelligence is facilitating the deployment of technologies and tools for food safety, enabling the swift and precise identification of adulterations and microbial contaminants. This includes hyperspectral imaging (HSI), which integrates traditional imaging with spectroscopy (23), and innovative electronic devices like electronic noses (ENs), which are automated detectors of odors or microbial growth that amalgamate chemical sensor arrays with a pattern recognition system (20).

AI in precision nutrition

Precision nutrition synthesizes genetic, metagen omic, metabolomic, physiopathological, behavioral, and sociocultural factors to comprehend metabolism and human well-being, facilitating the implementation of health interventions (37). This signifies a developing subject within the field of food biotechnology. Gut bacteria and dietary components exhibit a mutually reliant relationship. Gut microorganisms convert food components into metabolites that affect and modulate the host's immunological and metabolic responses, while dietary components determine the type and functional characteristics of the gut microbes. These exchanges are often intricate and highly individualized. AI serves as a potent instrument for analyzing extensive datasets and conducting thorough studies to formulate dietary guidelines aimed at mitigating disease onset and progression (14). Artificial intelligence is increasingly employed to analyze gut microbiota and utilize the findings to develop diagnostic and therapeutic interventions for critical diseases. AI algorithms are adept in establishing correlations among nutrition, health, and dietary behaviors (13).

Artificial intelligence techniques in food engineering

In the food industry, it is seen that solution tools such as ANN (Neural Network), Fuzzy Logic and Genetic Algorithm are widely used in solving problems and performing their analyses.

Artificial neural networks (ann)

One of the most studied subjects within the scope of artificial intelligence science is artificial neural networks. ANNs are systems that learn the relationships between events from examples and then make decisions using the information they have learned about examples they have never seen (44).

In order to increase quality and control capacities in the food industry, modeling of multivariate data obtained from computer imaging analysis, electronic nose and electronic tongue analysis is successfully applied in analysis applications using artificial neural networks, fuzzy logic and genetic algorithm processes (15,55,67). In studies on dairy farming (19,25,30), in a study on the shelf life of yoghurts (55), in modelling the heat treatment applied to canned foods (22), in a study to determine the temperatures and the time required to reach thermal equilibrium in foods processed in high-pressure food processes (62), in modelling the drying of tomatoes (41), in a study to determine the correlation between the farinographic properties of dough and the protein content of flour, wet gluten, sedimentation value and falling number (46), in the sun drying of foods (63), in the Biomass Generation with Artificial Neural Network in Industrial Baker's Yeast Fermentation It has been used in the classification of whole corn kernels by separating them from broken ones (35), in the determination of rheological properties of dough (48), in the classification of wines by determining anthocyanin contents (27), in the evaluation of heat processes in foods, in the estimation of heat conductivity according to apparent porosity, temperature and moisture content in foods, in the infrared spectrometry (NIRS) in yogurt fermentation (11), in the modeling of process according to galactose, lactate and lactose contents with artificial neural networks with the data obtained from the measurements with electronic nose (electronicnose-en) and bioreactor probes (68), in the estimation of the freezing time of food products (40), in the characterization and classification of some teas (12), in the

determination of physical properties of oat varieties (59), and in the classification of durum wheat varieties (61) they have achieved success using artificial neural networks.

Fuzzy logic

Fuzzy Logic is a mathematical discipline. In daily life, people solve problems by making decisions using linguistic qualifiers that are not fully defined and numerical (such as cold, slightly cold, lukewarm, hot, very hot, etc.). The reason why people can control some systems better than machines is based on the fact that people have the ability to make decisions using some information that cannot be expressed with certainty (uncertain). In Fuzzy Logic, approximate thinking is used instead of thinking based on definite values (54,56).

Fuzzy Logic provides the opportunity to be used in areas such as clustering, classification, product grading, product design in foods. In the food industry, it is used in biochemical processes that are highly nonlinear and difficult to control, and in the control of bacterial growth with biochemical reactors (26).

Fuzzy logic modeling is used in applications in cooking pressing processes in cheese making (26), estimation of frying time in foods (49), classification of apples according to their hardness levels (53), classification of tomatoes according to their quality criteria (28), classification of pizza (57), assessment of food safety (1), pH control in food production (10), use as a preservative in essential oils and fruit juices (6), modeling of kefir production (3), optimization opportunities in the dairy industry (16) have used.

Genetic algorithm

Genetic Algorithms (GA) are search algorithms based on natural selection and natural genetic mechanisms (21). GA was first studied by John Holland in 1975, and in the last thirty years, successful applications have been made in many areas from scheduling to network optimization to find solutions to difficult optimization problems. GA, which is quite successful in capturing global optima without getting stuck in local optima, does not require special mathematical analysis for optimization problems. The user can easily code the problem without having in-depth mathematical and algorithm knowledge. Due to this feature, GA is used in areas such as process modeling in foods, product design, control of storage systems, and estimation of product yield (21). Application of genetic algorithm and adaptive network based fuzzy inference systems for parameter optimization and estimation in drying of foods was used to determine sensory properties of fast foods.

Conclusion

In conclusion, artificial intelligence and machine learning can be utilized along the entire farm-to-fork continuum. This include forecasting climate change, agricultural yields, meteorological patterns, precipitation conditions, soil quality assessment, optimal seed selection and planting techniques, as well as the management of dairy farms for animals and poultry. Additionally, it encompasses the administration and repurposing of several waste categories. The algorithms demonstrate efficacy in the manufacturing phases of food products, functional foods, and nutraceuticals, encompassing formulation, sensory evaluation, industrial processing, analytical testing, nutrient content evaluation, packaging, storage, and food supply chain management, while ensuring food quality and safety. Furthermore, it encompasses food distribution, customer delivery, pleasure with consumption, and the evaluation of how food or alternative medicine intake influences human health, both physically and psychologically. It involves monitoring food consumption quantities, caloric values, efficacy, dietary control, and facilitation through prospective artificial intelligence techniques. The capabilities of artificial intelligence-based approaches and technologies facilitate the prediction and regulation of food-related crystallization

processes, ultimately improving both processes and products. The implementation of artificial intelligence, machine learning, and associated technologies establishes a promising intelligent cycle, encompassing agriculture and nutrition, which are integral to the fundamental human necessity of food.

References

1. Abiyeva, R.H., Uyarb, K., Ilhanc, Ü., Imanovd, E. (2016). Assessment of food security risk level using type 2 fuzzy system. 12th International Conference on Application of Fuzzy Systems and Soft Computing, ICAFS 2016, 29-30 August, Vienna, Austria. Procedia *Computer Science* 102: 547 – 554.
2. Addanki, M., Patra, P., Kandra, P. (2022). Recent advances and applications of artificial intelligence and related technologies in the food industry. *Applied Food Research*, 2(2), Article 100126.
3. Akgül, N.A., Akgül, F.Y., Tuna, D. (2014). Bulanık Mantık ile Kefir Üretiminin Modellenmesi. *Türk Tarım Gıda Bilim ve Teknoloji Dergisi*, 2(6): 251-255.
4. Akoka, J., Comynfi Wattiau, I., Laoufi, N. (2017). Research on Big Data—A systematic mapping study. *Comput. Stand. Interfaces*, 54, 105–115.
5. Amore, A., Philip, S. (2023) Artificial intelligence in food biotechnology: trends and perspectives. *Front. Ind. Microbiology,* 1,1255505.
6. Basak, S. (2018). The use of fuzzylogic to determine the concentration of betel leaf essential oil and itspotency as a juice preservative. *FoodChemistry* 240,1113–1120.
7. Bouzembrak, Y., Marvin, H. J. P. (2016). Prediction of food fraud type using data from Rapid Alert System for Food and Feed (RASFF) and Bayesian network modelling. *Food Control*, 61, 180–187.
8. Chang, W. T., Yeh, Y. P., Wu, H. Y., Lin, Y. F., Dinh, T. S., Lian, I. B. (2020). An automated alarm system for food safety by using electronic invoices. *PloS One* 24, 15(1), e0228035.
9. Chidinma-Mary-Agbai. (2020). Application of artificial intelligence (AI) in food industry. *GSC Biological and Pharmaceutical Sciences*, 13(1), 171–178.
10. Chung, C., Chen, H.,Tıng, C. (2010). Grey prediction fuzzy control for pH processes in the food industry. *Journal of Food Engineering,* 96, 575–582.
11. Cimander, C., Carlssn,M., Mandenıus, C.F. (2002). Sensor fusion for online monitoring of yoghurt fermentation. *Journal of Biotechnology,* 99(3), 237 – 48.
12. Cimpoiu, C., Cristea, V.M., Hosu, A., Sandru M., Seserman L. (2011). Antioxidant activity prediction and classification of some teas using artificial neural networks. *Food Chemistry* 127: 1323–1328.
13. Cote, M., Lamarche, B. (2021). Artificial intelligence in nutrition research: Perspectives on current and future applications. *Appl. Physiol. Nutr. Metabol*. 1(15), 1–8.
14. Danneskiold-Samsøe, N. B., de Freitas Queiroz Barros, H. D., Santos, R., Bicas, J. L., Cazarin, C. B. B., Madsen, L. (2019). Interplay between food and gut microbiota in health and disease. *Food Res. Int*. 115, 23–31.
15. Demir, N., Balaban, M.O., Brecht, J.K., Sıms, C.A., Gülay, M.S. (2002). Objective Quality Assessment of Modified Atmosphere Stored Zucchini Slices Using Electronic Nose, Machine Vision, and Instron, 15th-19th June, pp181.
16. Demiral, M.F. (2013). Bulanık Doğrusal Programlama İle Süt Endüstrisinde Bir Uygulama. *Süleyman Demirel Üniversitesi İktisadi Ve İdari Bilimler Fakültesi Dergisi*, 18(2), 373-397.
17. Ding, H., Tian, J., Yu, W., Wilson, D.I., Young, B.R., Cui, X., Xin, X., Wang, Z., Li, W. (2023). The Application of Artificial Intelligence and Big Data in the Food Industry. *Foods*, 12, 4511.
18. FDA. (2022). Import screening pilot unleashes the power of data and leverages artificial intelligence. US Food and Drug Administration. Available at: https://www.fda.gov/news-events/fda-voices/import-screening-pilot-unleashes-power-data-

andleverages-artificial- intelligence (Accessed 22 October, 2024).
19. Gevrekçi, Y.E., Yeğenoğlu, D., Akbağ,Y., Sesli, M. (2011). Yapay sinir ağlarının tarımsal alanda kullanımı. *E.Ü. Ziraat Fak. Dergi*, 48(1), 71-76.
20. Gobbi, E., Falasconi, M., Zambotti, G., Sberveglieri, V., Pulvirenti, A., and Sberveglieri, G. (2015). Rapid diagnosis of Enterobacteriaceae in vegetable soups by a metal oxide sensor based electronic nose. *Sensors Actuators B: Chemistry,* 207 (B), 1104– 1113.
21. Goldberg, D.E. (1989). Genetic Algorithms in Search, Optimization, and Machine Learning. Addison-Wesley, Reading, Mass.
22. Gonçalves, E.C., Minim, L.A., Coimbra, J.S.R., Minim,V.P.R. (2005). Modeling sterilization process of canned foods using artificial neural networks. *Chemical Engineering and Processing*, 44,1269-1276.
23. Gowen, A., O'Donnell, C. P., Cullen, P. J., Downey, G., Frias, J. M. (2007). Hyperspectral imaging – an emerging process analytical tool for food quality and safety control. *Trends Food Sci. Tech.*, 18 (12), 590–598.
24. Gr´ac, S., Beno, P., Duchon, F., Dekan, M., T¨olgyessy, M. (2020). "Automated detection of multifirotor UAVs using a machinelearning approach," *Applied System Innovation*, 3, 29.
25. Grzesıak, W., LacroiX, R., WojcıK, J., Blaszczyk, P. (2003). A comparison of neural network and multipleregressionpredictions for 305-day lactation yield using partiallactation records. *Can. J. Anim. Sci*., 83 (2): 307-310.
26. Guıllaume, S., Charnomordic, B. (2000). Knowledge discovery for control purposes in food industry data bases. *Fuzzy Sets and Systems,* 122,487–497.
27. Hussıan, M.A., Shafıur,M., Rahman, Ng, C.W. (2002). Prediction of poresformation (porosity) in foods during drying: generic models by the use of hybrid neural network. *Journal of Food Engineering*, 51, 239-248.
28. Jahns, G., Nielsen,H.M., Paul, W. (2001). Measuring İmage Analysis Attributes and Modelling Fuzzy Consumer Aspects For Tomato Quality Grading. *Computers and Electronics in Agriculture*, 31,17–29.
29. Kakani, V., Nguyen, V. H., Kumar, B. P., Kim, H., Pasupuleti, V. R. (2020). A critical review on computer vision and artificial intelligence in food industry. *Journal of Agriculture and Food Research*, 2, e100033.
30. Kavas, G. (2012). Gıdalarda yapay sinir ağları ve bulanık mantık.http://www.dunyagida. com.tr/kose-yazisi/gidalarda-yapay-sinir-aglari-ve-bulanikmantik/1043.
31. Khan, R. (2021). Artificial Intelligence and Machine Learning in Food Industries: A Study. *J Food Chem Nanotechnol,* 7(3), 60-67.
32. Kler, R. (2023). Machine Learning and Artificial Intelligence in the Food Industry: A Sustainable Approach (Retraction of Vol 2022, art no 8521236,).
33. Kler, R., Elkady, G., Rane, K., Singh, A., Hossain, M. S., Malhotra, D. 2022. Machine learning and artificial intelligence in the food industry: A sustainable approach. *Journal of Food Quality*. *2022*(1), 8521236.
34. Kumar, I., Rawat, J., Mohd, N., Husain, S. (2021). Opportunities of artificial intelligence and machine learning in the food industry. *Journal of Food Quality*, *2021*(1), 4535567.
35. Liao, K., Paulsen, M.R., Reid, J.F., Ni B.C, Bonıfacio-Maghirang, E.P. (1993). Corn kernel breakage classification by machine vision using a neural network classifier. *Transactions of the ASAE,* 36(6), 1949–1953.
36. Linko, S. (1998). Expert systems - what can they do for the food industry? *Trends in Food Science and Technology*, 9(1), 3–12.
37. Livingstone, K. M., Ramos-Lopez, O., Pé russe, L., Kato, H., Ordovas, J. M., do Martınez, J. A. (2022). Precision nutrition: A review of current approaches and future´ endeavors. *Trends Food Science and Technology,*128 (10184).
38. Lupolova, N., Dallman, T. J., Holden, N. J., Gally, D. L. (2017). Patchy promiscuity: machine learning applied to predict the host specificity of Salmonella enterica and Escherichia coli. *Microbial genomics*, *3*(10), e000135.
39. Luzuriaga D., Balaban M., Yeralan S. 1997. Analysis of Visual Quality Attributes of White Shrimp by Machine Vision, *Journal of Food Science*, 62(1), 113-118.

40. Mıttal, G.S., Zhang, J. (2000). Prediction of freezing time for food products using a neural network. *Food Research International*, 33, 557-562.
41. Movagharnejad, K., Nıkzad, M. (2007). Modeling of tomato drying using artificial neural network. *Computers and Electronics in Agriculture*, 59,78-85.
42. Nayak, J., Vakula, K., Dinesh, P., Naik, B., Pelusi, D. (2020). Intelligent food processing: Journey from artificial neural network to deep learning. *Computer Science Review*, 38, Article 100297.
43. Nikolola-Alexieva, V., Valeva, K., Pashev, S. (2024). Artificial intelligence in the food industry. In *BIO Web of Conferences* (Vol. 102, p. 04002). EDP Sciences.
44. Oztemel, E., 2006. Artificial neural networks. Papatya Publishing, Istanbul.
45. P´erez-Correa, J. R., Zaror, C. A. (1993). Recent advances in process control and their potential applications to food processing. *Food Control*, 4(4), 202–209.
46. Razmi-Rad, E., Ghanbarzadeh, B., Mousavi, S.M, Emam-Djomeh, Z., Khazaei, J. (2007). Prediction of rheological properties of Iranian bread dough from chemical composition of wheat flour by using artificial neural networks. *Journal of Food Engineering*, 81, 728-734.
47. Ropodi, A. I., Panagou, E. Z., Nychas, G. J. E. (2016). Data mining derived from food analyses using non-invasive/non-destructive analytical techniques; determination of food authenticity, quality & safety in tandem with computer science disciplines. *Trends in Food Science and Technology*, 50, 11–25.
48. Ruan, R., Almaer, S., Zhang, J. (1995). Prediction of Dough Rheological Properties Using Neural Networks. *Cereal Chem*., 72(3), 308-311.
49. Rywotycki, R. (2003). Food frying process control system. *Journal of Food Engineering,* 59, 339–342.
50. Saha, D., Manickavasagan, A. (2021). Machine learning techniques for analysis of hyperspectral images to determine quality of food products: A review. *Current Research in Food Science*, 4, 28–44.
51. Samani, B.H., HouriJafari, H., Zareiforoush, H. (2017). Artificial neural networks, genetic algorithm and response surface methods: the energy consumption of food and beverage industries in Iran. *Journal of AI and Data Mining,* 5(1), 79-88.
52. Schroeder, R. (2016).Big data business models: Challenges and opportunities. *Cogent Soc. Sci.*, 2, 1166924.
53. Shahin, M.A., Tollner, E.W., Mcclendon, R.W. (2001). Artificial intelligence classifiers for sorting apples based on water core. *Journal of Agricultural Engineering Research*, 79(3),: 265–274.
54. Sofu, A., Ekinci Kitiş, F.Y. (2005). Predicting survival rate of Yersinia Enterocolitica in Turkish feta cheese during maturation and storage by using fuzzy logic modelling. 1st International Food and Nutrition Congress- Food Safety, İstanbul.
55. Sofu, A. (2006). *Yoğurtların depolama esnasında mikrobiyal ve kimyasal değişimlerinin bilgisayarlı görüntüleme sistemiyle belirlenmesi ve elde edilen verilerin yapay sinir ağlarıyla değerlendirilmesi.* Süleyman Demirel Üniversitesi, Fen Bilimleri Enstitüsü, Gıda Mühendisliği Anabilim Dalı, yüksek lisans tezi, Isparta, 98s.
56. Sofu, B.A., Demir, N., Ekinci, F.Y. (2007). Gıda Bilimi Ve Teknolojisi Alanında Yapay Zeka Uygulamaları. *GIDA* 32 (2), 93-99.
57. Sun, D.W., Brosnan, T. (2003). Pizza quality evaluation using computervision—Part 1 Pizza base and sauce spread. *Journal of Food Engineering*, 57, 81–89.
58. Tan, J., Xu, J. (2020). Applications of electronic nose (e-nose) and electronic tongue (etongue) in food quality-related properties determination: A review. *Artificial Intelligence in Agriculture*, 4, 104–115.
59. Taner, A., Tekgüler,A., Sauk, H., Demirel, B. (2012). Yulaf Çeşitlerinin Yapay Sinir Ağları Kullanılarak Sınıflandırılması. 27. Tarımsal Mekanizasyon Ulusal Kongresi, 5-7 Eylül 2012, Samsun, 519-529s.
60. Tarallo, E., Akabane, G. K., Shimabukuro, C. I., Mello, J., Amancio, D. (2019). Machine learning in predicting demand for fast-moving consumer goods: An exploratory research. *IFAC-PapersOnLine*, 52(13), 737–742.
61. Tollner, E.W., Shahin, M.A., Maw, B.W., Gitaitis, R.D., Summer, D.R. (1999). Classification of onions based on internal defects using imaging processing and neural network techniques, In 1999 ASAE

Annual International Meeting, Paper No, 993165, St, Joseph, Michigan, USA: ASAE.
62. Torrecilla, J.S, Otero L, Sanz, P.D. (2005). Artificial neural networks: a promising tool to design and optimize high-pressure food processes. *Journal of Food Engineering*, 69,299-306.
63. Trıpathy, P.P., Kumar,S. (2009). Neural network approach for food Temperature prediction during solar drying. *International Journal of ThermalSciences*, 48,1452-1459.
64. Wang, H., Ceylan, K. H., Qiu, Y., Bai, B., Zhang, Y., Jin, Y. (2020). Early detection and classification of live bacteria using time-lapse coherent imaging and deep learning. *Light Sci. Appl*. 9, 118.
65. Wang, X., Bouzembrak, Y., Lansink, A.G.J.M.O., van der Fels-Klerx, H.J. (2022). Application of machine learning to the monitoring and prediction of food safety: A review. *Comprehensive Reviews in Food Science and Food Safety*, 21(1), 416–434.
66. Wang, S. S., Lin, P., Wang, C. C., Lin, Y. C., and Tung, C. W. (2023). Machine learning for predicting chemical migration from food packaging materials to foods. *Food and Chemical Toxicology*, *178*, 113942.
67. Yin Y-G, Ding, Y. (2009). A close to real-time prediction method of total coliform bacteria in foods based on image identification technology and artificial neural network. *Food Research International,* 42,191-199.
68. Yongnıan, N., Chao, L.(1999). Artificial neural networks and multivariate calibration for spectrophotometric differential kinetic determinations of food antioxidants. *Analytica Chimica Acta,* 396,: 221–230.
69. Zhu, L., Spachos, P., Pensini, E., Plataniotis, K. N. (2021). Deep learning and machine vision for food processing: A survey. *Current Research in Food Science*, 4, 233–249.
70. Zhu, N., Wang, K., Zhang, S., Zhao, B., Yang, J., Wang, S.W. (2021). Application of artificial neural networks to predict multiple quality of dry-cured ham based on protein degradation. *Food Chemistry*, 344, 128586.

Table.1. Application of AI and ML in FI.

Area	AI and ML techniques
Food security management	(i) ANN (ii) Data mining (iii) Data analysis (iv) Intelligent optimisation techniques
Food quality management	(i) Genetic algorithm (ii) Predictive models (iii) Tree decisionfimaking
Food production	(i) ANN (ii) Decision tree (iii) Gaussian mixture models (iv) Data mining
Food logistics	(i) ABS techniques (ii) Robot programming (iii) Simulated annealing (iv) Automated planning
Food supply chain	(i) Bayesian network (ii) Stochastic simulation (iii) ANN (iv) Fuzzy logic
Food processing industry	(i) Decision fimaking data analytics (ii) Predictive models (iii) Forecasting models of AI and ML

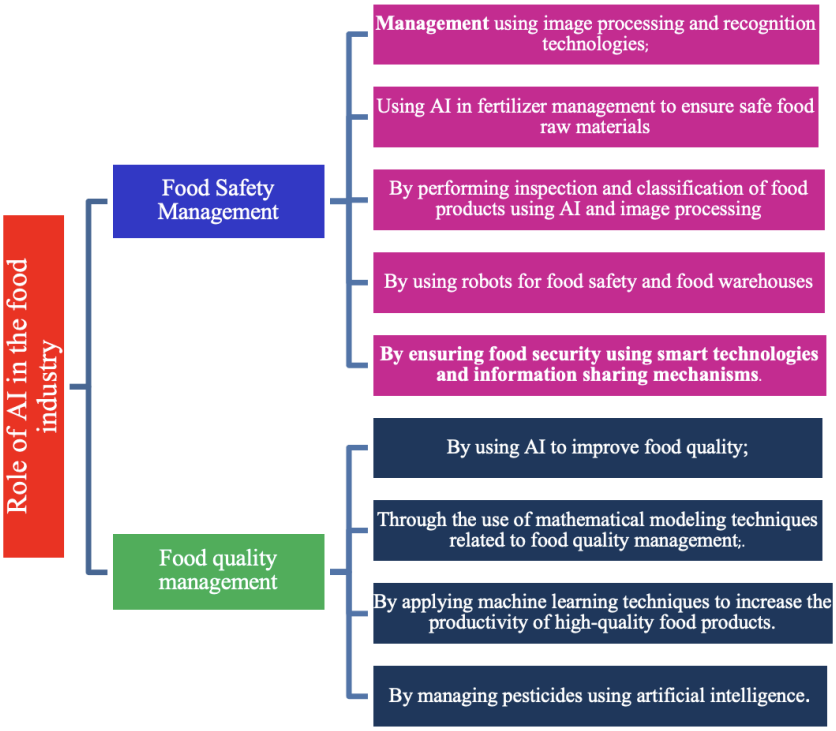

Fig. 1. Role of AI in the food industry

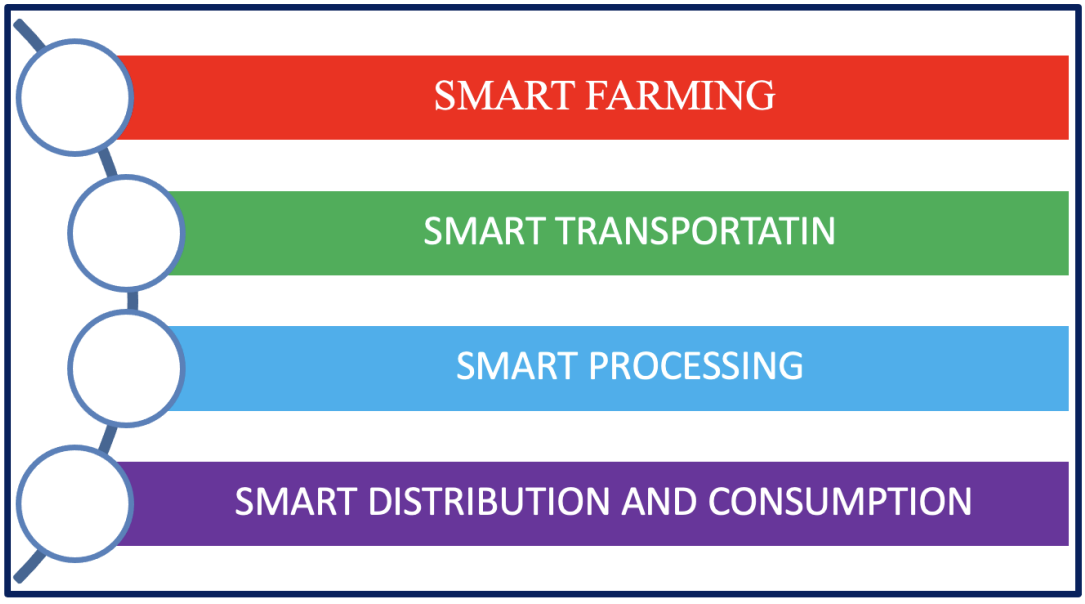

Figure. 2.Categorization food industry

https://dergipark.org.tr/tr/pub/food
OPEN ACCESS JOURNAL

ISSN 2667-5803

FHTI Journal of Food Health and Technology Innovations
December Vol 7, No 15 (2024)

DergiPark AKADEMİK

ResearchArticle

COLOR MEASUREMENT CAPABILITY OF SMARTPHONES: ANALYSIS OF CHOCOLATE COLOR

Betül ARSLAN[1] , Deniz BAŞ[2]

Abstract Color measurement of foods can be made with many techniques, both sensory and instrumental. With the developing technology, fast and low-cost innovative techniques are getting more attention. In this study, color analysis made through smart phone application compared with the colorimetric method. In this context, the color differences of chocolates with various cocoa solids ratios were calculated. Taking advantage of the accessibility and user friendliness of smartphones, images were taken from the sample surface in a regular illuminated home/office environment. Photos taken from the phone gallery were measured with the Color Grab (Loomatix) application. Correlations of L*a*b* color values obtained in CIE Lab space system were calculated. These values were also used to calculate the Total Color Difference (ΔE) and Whiteness Index (WI). As a result, it has been observed that the color of chocolate, which is considered as a food sample in the study, can be measured with a smart phone application, which is a faster and less costly method. It is predicted that smart phone application can be used as a very practical tool in the measurement of food quality due to its updateability, ability to storage and shareability of measurement information on smartphones.

Keywords: Food quality, Smartphone, Chocolate, Color analysis, Consumer

TÜBİTAK ULAKBİM

1 Department of Food Engineering, Graduate School of Natural and Applied Sciences, Çankırı Karatekin University, Çankırı, 18100, Turkiye
2 Department of Food Engineering, Faculty of Engineering, Çankırı Karatekin University, Çankırı, 18100, Turkiye
http://orcid.org/0000-0003-1494-681X
*Corresponding Author: denizbas@gmail.com

Introduction

Color is a perceptual phenomenon that depends on the observer and the conditions under which the color is observed. This phenomenon depends on the properties of light, which can be measured in terms of intensity and wavelength. The concept of color emerges when light reaches the retina of the human eye at different wavelengths. The perception of color by the eye varies due to the light striking objects and partially reflecting them. This situation is defined as hue or color. The color of matter becomes visible only when light from a bright object or source illuminates or hits the surface (1).

The color of food is a key indicator of its quality, influencing how we assess freshness, ripeness, and safety. Bright, vibrant colors often signal freshness, on the other hand dull or faded colors or changes in color may create negative perception. Briefly, color is one of the most important sensory aspects of food products. As well as indicating its likely freshness and flavour, it can also influence consumer choice and enjoyment of a product. Thus, measurement of the color of food products play a crucial in role for food quality and safety.

Color determination can be done by visual inspection or by using color measuring devices (colorimeters). Despite the differences in lighting, human control is quite successful, but in this case, color determination is subjective since it varies from observer to observer. Color standards are used as reference materials to make a more objective color analysis. Their use in this way is slow and requires special training of observers. For this reason, the use of colorimeters has become widespread (2). Thus, more accurate, effective and repeatable analyzes have become possible (3). These tools are essential for applications requiring consistent and precise color analysis. However, for casual users, small businesses, or non-critical tasks, a cost-effective and accessible alternative must be offered.

Smartphones, with their sophisticated cameras and processing power, are emerging as a viable option for basic color measurement. With the help of specialized apps and accessories, smartphones can approximate color analysis for non-critical tasks.

Currently, smartphones function as portable microcomputers, capable of performing complex tasks while remaining lightweight, mobile, and suitable for real-time monitoring. According to statistics, there are currently over 7.2 billion smartphones worldwide and it is estimated to exceed 8 billion in 2029. This high penetration rate, coupled with a vast user base, makes smartphones increasingly accessible tools.

Equipped with advanced technical features—such as high-speed processors, digital cameras, batteries, high-resolution displays, and intuitive user interfaces—smartphones are well-suited for various types of measurements. Wireless data transfer technologies, including Wi-Fi, Bluetooth, and cellular services, enable real-time viewing of results and seamless data sharing. Recent studies have demonstrated that smartphones, when integrated with appropriate accessories, can serve as portable laboratory tools for applications like food analysis (4-12).

Moreover, verification and quality assessment of food products can be made from photographs obtained via smartphones (13). In our group, smartphones had been previously used for colorimetric paper-based sensors (14), and their capability of being low-cost spectrophotometer alternative were investigated (15). Smartphones worked great for measuring color of solutions or paper zones.

The aim of this study is to determine whether food color analysis via a smartphone application is an alternative to conventional methods.

Within the scope of the study, the measurability of color, which is a quality and/or safety criterion for food products, was examined with a smartphone. In this context, the color of chocolate samples containing different cocoa solids was measured with a smartphone. The results obtained with smartphone were compared with the results of the colorimeter, and their performance was evaluated.

Material and methods

Material

Chocolate samples produced under 10 different brand names were purchased from a local market in Ankara and stored at room temperature. In total, 36 chocolate samples,

weighing between 60-80 grams, were studied and the samples were coded and grouped according to the brand. The complete list of chocolate products and their cocoa mass content were given in Table 1. The cocoa mass content values in Table 1 refer to the amount of cocoa mass declared on the label by the manufacturer.

Color measurement

Portable Colorimeter: Color analysis of chocolate samples was performed with a colorimeter (Model CR400, Konica Minolta, Japan). For each sample, color measured from 5 different points and every measurement was performed twice. Color values of the samples were recorded in CIE Lab color system.

Smartphone: Color measurement via smartphone was made using the Color Grab (Loomatix © 2021 Version 3.9.2) application, which can run on the Android operating system and is accessible from the application store. A Samsung SM-A51 5F model smartphone was used to capture images. The sample images were taken under stabilized camera features according to the variables in Table 2.

Image acquisition and capture

The photographing procedure was carried out between 12:00 and 15:00 in a closed environment with variable daylight to meet the conditions of being simple, versatile and low cost. The samples were placed on a certain brand-model A4 paper to ensure that the background color was standard and sustainable. To prevent color differences that different light angles could create in the samples, measurements were carried out by positioning the samples differently on the A4 paper. The results were obtained by taking the average of these measurements. Photographs were taken from a distance of 30-50 cm, in 4 different positions, and images were obtained in 4 different positions for each sample (Figure 1). For color analysis, L*, a* and b* values were obtained via Color Grab application in the CIE Lab system by browsing from the phone's photo gallery and taking measurements from 5 different points of the chocolate sample image.

Color value calculations

Total color difference (ΔE): The total color difference is the linear distance in color space between the two set of co-ordinates and defined by the Equation 1. Total color difference value of the samples was calculated by the taking the A4 paper as our reference point. In equation 1, L_0*, a_0* and b_0* values refer to the average L*, a* and b* values of A4 paper under each sample.

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \quad (1)$$

$$\Delta L = L^*_1 - L_0^*$$

$$\Delta a = a^*_1 - a_0^*$$

$$\Delta b = b^*_1 - b_0^*$$

Whiteness index (WI): WI is the condition in which the color of an object appears different depending on the light source. Although substances appear to be the same color when viewed under the same light source, they may appear to be different colors from each other under different light sources. In addition to the CIE L*a*b* system provided by the colorimeter; it can be used to define the character of color quality (chocolate surface color). It is an important quality measurement parameter for measuring the color of chocolate, which changes depending on the change in temperature conditions or inappropriate storage conditions after the cooling phase of the chocolate. It is calculated using Equation 2 (16-17).

$$WI = 100 - \sqrt{((100-L)^2 + a^2 + b^2)} \quad (2)$$

Results and Discussion

Comparison of measured color values

The L*, a*, b* data measured with the colorimeter are given in Table 3. Among the same group of chocolate samples, the lowest L* values were observed in the chocolate samples coded U6, N5, E4, T2, V2, M2, B5, O3, P2 and G1; the highest L* values were observed in the white chocolate samples coded U1, N1, M1, B1 and O1. L* is the brightness-lightness component and its values vary between 0-100.

"0" gives information about darkness and "100" about lightness. Within the scope of the obtained data, it was observed that the L* values of the chocolate samples specified as "bitter chocolate" and with a cocoa dry matter ratio higher than 35% were at lower values (close to 0). It was observed that the L* values of the chocolate samples specified as "white chocolate" in the label information, and which did not contain a cocoa mass were at higher values (close to 100). The average color ranges of all measured samples were measured between 23.35 and 83.72 for L* values.

In the CIE Lab system, the a* value is the component that shows the color change from green (-a) to red (+a) and varies between (-120) and (+120). According to the obtained data, no similarity was observed among the a* values of the samples. It was observed that the average color values of the a* values of all measured samples were between -5.09 and 10.30.

In the CIE Lab system, the b* value is the component that shows the color change from blue (-b) to yellow (+b) and varies between (-120) and (+120). When the b* values were compared according to the obtained data, it was seen that all of them consisted of positive values, showed a similarity to the L* values and were inversely proportional to the cocoa mass content as expected. The average color values of the b* values of all measured samples were measured between 1.91 and 27.82.

These results show that L* values have a wider distribution, and the chocolate sample colors are generally in reddish-yellow color tones. In the white chocolate sample samples (U1, N1, M1, B1 and O1), the a* values are negative and the b* values are positive, and the b* values are measured higher than the other sample values. These results confirm that the white chocolate samples have greenish-yellow color tones (the change of the a* color parameter from negative to positive indicates that the color changes from green to red).

L*, a*, b* data measured with a smartphone application are given in Table 4. In a similar manner, the lowest L* values were observed in U7, N4, E3, T2, V2, M2, B5, O3, P2 and G1 coded chocolate samples; the highest L* values were observed in U1, N1, M1, B1 and O1 coded white chocolate samples. It was observed that the average color ranges of all measured samples were between 25.2 and 88 for L* values.

When the a* values of the samples were examined, it was observed that there was no closeness or similarity between the samples in terms of cocoa dry matter, and it was seen that the average a* values of the samples were measured between -3.3 and 18.1. When b* values were examined, it was seen that they were inversely proportional to cocoa dry matter, as in L* values. The b* values of the samples were measured between -5 and 32.2.

Total color difference

In order to calculate the total color difference for each chocolate sample, the L*, a*, b* values of the A4 white paper measured with the colorimeter and smartphone application were calculated as L_0*, a_0*, b_0* in Equation 1, and the values given in Table 5 were obtained. In an effort to make a better visual evaluation, the data in Table 5 has been converted into a graph (Figure 1). As can be seen from the figure, there is a close similarity between the Total Color Difference value of the samples.

Whiteness index (WI) values

Calculated Whiteness index (WI) values of the samples were listed in Table 4 and they were visualized in Figure 2 for better comparison. As with the Total Color Difference values, there is a close similarity between the values of colorimeter and smartphone.

Last of all, collected data were analyzed and smartphone data were compared with the colorimeter data. In this context, colorimeter data was accepted or recognised as standart. The coefficient of determination (R^2) and absolute average deviation (AAD) were determined, and these values were used to compare smartphone with colorimeter. The AAD is calculated by Equation 3, where $y_{i,col}$ and $y_{i,phone}$ denote the colorimetric and smartphone data, respectively, and p is the number of sample.

$$AAD = \left\{ \left[\sum_{i=1}^{p} \left(\left| y_{i,col} - y_{i,phone} \right| / y_{i,col} \right) \right] / p \right\} \times 100 \quad (3)$$

R^2 and AAD values for Total Color Difference were found to be as 0.99 and 18.98%, respectively. For the Whiteness Index, the R^2 were determined as 0.99 and the AAD value was calculated as 13.67%. Although the R^2 values found were acceptable, it was observed that the calculated AAD values were above 10%, which shows that the method has room for improvement.

Conclusion

In this study, samples of chocolate, a widely consumed food product, were analyzed to measure the usability of smartphone applications in daily life. The effectiveness of this new method was questioned by comparing the measurement data obtained from the colorimeter and smartphone applications of various chocolate samples containing different amounts of cocoa solids.

Smartphones, which are easy-to-use, portable and fast devices, are increasingly preferred in the field because they do not require expensive equipment or high levels of expertise. For this purpose, it is quite practical to use a smartphone with a processor and detector function. Smartphones are available everywhere and the calculated numerical values can be easily shared over long distances thanks to internet access. Smartphones, which do not require any cost and are owned by almost everyone today, have the potential to perform routine tests performed by trained personnel using laboratory instrumentation quickly and on-site.

Many advanced smartphone-based devices have been identified, showing applications in the food safety sector, as well as in medicine, the environment and industry. The real question is perhaps when these smartphones will start to be widely seen on farms, restaurants and markets. Because this will mean a greater awareness of what we eat.

This study has shown that smartphones can be used as an effective tool for color analysis in foods and can store information about color differences in foods. Considering the prevalence of smartphones, it is an exciting result that consumers can quickly access information about the appearance of foods regardless of time or place. Future research can be devoted to the accessibility of applications that will provide access to color information about foods using smartphones and the development of these applications.

Acknowledgement

Authors declare no conflicts of interest.

References

1. Sahin S, Sumnu SG. Physical properties of foods. Springer Science & Business Media; 2006 May 24.
2. Leon K, Mery D, Pedreschi F, Leon J. Color measurement in L∗ a∗ b∗ units from RGB digital images. Food research international. 2006 Dec 1;39(10):1084-91.
3. Keskin M, Setlek P, Demir S. Use of color measurement systems in food science and agriculture. InInternational advanced researches & engineering congress 2017 Nov 16 (pp. 16-18).
4. Rateni G, Dario P, Cavallo F. Smartphone-based food diagnostic technologies: A review. Sensors. 2017 Jun 20;17(6):1453.
5. Ma T, Wang H, Wei M, Lan T, Wang J, Bao S, Ge Q, Fang Y, Sun X. Application of smart-phone use in rapid food detection, food traceability systems, and personalized diet guidance, making our diet more health. Food Research International. 2022 Feb 1;152:110918.
6. Gopal J, Muthu M. Handheld portable analytics for food fraud detection, the evolution of next-generation smartphone-based food sensors: The journey, the milestones, the challenges debarring the destination. TrAC Trends in Analytical Chemistry. 2023 Dec 27:117504.
7. Nelis JL, Tsagkaris AS, Dillon MJ, Hajslova J, Elliott CT. Smartphone-

based optical assays in the food safety field. TrAC Trends in Analytical Chemistry. 2020 Aug 1;129:115934.
8. Yang T, Luo Z, Bewal T, Li L, Xu Y, Jafari SM, Lin X. When smartphone enters food safety: A review in on-site analysis for foodborne pathogens using smartphone-assisted biosensors. Food Chemistry. 2022 Nov 15;394:133534.
9. Upadhyay S, Kumar A, Srivastava M, Srivastava A, Dwivedi A, Singh RK, Srivastava SK. Recent advancements of smartphone-based sensing technology for diagnosis, food safety analysis, and environmental monitoring. Talanta. 2024 Apr 10:126080.
10. Kalinowska K, Wojnowski W, Tobiszewski M. Smartphones as tools for equitable food quality assessment. Trends in Food Science & Technology. 2021 May 1;111:271-9.
11. Franca AS, Oliveira LS. Applications of smartphones in food analysis. InSmartphone-Based Detection Devices 2021 Jan 1 (pp. 249-268). Elsevier.
12. Lu Y, Shi Z, Liu Q. Smartphone-based biosensors for portable food evaluation. Current Opinion in Food Science. 2019 Aug 1;28:74-81.
13. Song W, Jiang N, Wang H, Vincent J. Use of smartphone videos and pattern recognition for food authentication. Sensors and Actuators B: Chemical. 2020 Feb 1;304:127247.
14. Baş D. Sensitive and reliable paper-based glucose sensing mechanisms with smartphone readout using the L* a* b* color space. Analytical Methods. 2017;9(47):6698-704.
15. Baş D, Özgen S. Gıda Analizlerinde Akıllı Telefon ile Renk Ölçümü: Spektrofotometrik Ölçüme Kolay ve Düşük-Maliyetli Bir Alternatif. Ankara/Turkey. 2022 May 7:112.
16. Baş D, Özgen S, Gıda Analizlerinde Akıllı Telefon ile Renk Ölçümü: Spektrofotometrik Ölçüme Kolay ve Düşük Maliyetli Bir Alternatif, The 2nd International Congress of Engineering and Natural Sciences Studies (ICENSS-2022), Ankara/Turkiye, 2022, p 112-121, ISBN: 978-605-71156-5-2.
17. Dinçel E. Kakao Yağı Enkapsülasyonunun Çikolatada Yağ Kusmasına Etkisinin İncelenmesi (Doctoral dissertation, İSTANBUL AYDIN ÜNİVERSİTESİ FEN BİLİMLERİ ENSTİTÜSÜ).

Table 1. Cocoa mass content of chocolate products and their groups

GROUP	Sample Code	Cocoa Dry Matter Ratio
U	U1	White chocolate
	U2	29%
	U3	30%
	U4	52%
	U5	53%
	U6	60%
	U7	80%
N	N1	White chocolate
	N2	29%
	N3	55%
	N4	60%
	N5	82%
E	E1	32%
	E2	45%
	E3	54%
	E4	70%
M	M1	White chocolate
	M2	33%
B	B1	White chocolate
	B2	30%
	B3	31%
	B4	36%
	B5	60%
	B6	85%
O	O1	White chocolate
	O2	34%
	O3	61%
V	V1	30%
	V2	57%
T	T1	30%
	T2	60%
P	P1	37%
	P2	57%
G	G1	52%
	G2	72%
	G3	90%

Table 2. Smartphone camera settings

Image size	3000 x 4000
Zoom	-
Flash mode	off
White balance	Fluorescent
Operation mode	Manual
Aperture	f /2,0
Shutter Speed	1/50 s
Recording Type	JPEG
Focal Length	4.60 mm
Resolution	72 dpi

Table 3 Average L*, a* and b* values of the samples obtained via Portable Colorimeter

SAMPLES	Portable Colorimeter		
	L*	a*	b*
U1	83,00(± 0,0)	-3,8(± 0,0)	27,11(± 0,2)
U2	36,04(± 0,0)	9,72(± 0,0)	11,19(± 0,0)
U3	35,26(± 0,4)	10,01(± 0,0)	11,38(± 0,0)
U4	27,85(± 0,1)	5,19(± 0,1)	4,19(± 0,0)
U5	41,22(± 1,5)	4,12(± 0,2)	7,14(± 0,2)
U6	25,28(± 0,0)	3,76(± 0,0)	2,89(± 0,0)
U7	26,60(± 0,0)	3,33(± 0,0)	2,75(± 0,0)
N1	77,50(± 0,7)	-1,00(± 0,0)	27,80(± 0,4)
N2	33,89(± 0,2)	8,90(± 0,0)	9,49(± 0,1)
N3	27,00(± 0,0)	4,98(± 0,0)	3,93(± 0,1)
N4	26,57(± 0,1)	4,15(± 0,1)	3,21(± 0,0)
N5	24,97(± 0,2)	2,90(± 0,2)	1,91(± 0,1)
E1	35,06(± 0,1)	8,77(± 0,0)	9,88(± 0,0)
E2	28,40(± 0,0)	5,94(± 0,1)	4,92(± 0,1)
E3	26,46(± 0,1)	4,09(± 0,1)	3,03(± 0,0)
E4	25,78(± 0,1)	3,94(± 0,0)	3,00(± 0,0)
M1	83,72(± 0,4)	-5,09(± 0,1)	27,82(± 0,0)
M2	39,01(± 0,0)	10,30(± 0,0)	13,00(± 0,0)
B1	80,50(± 0,7)	-2,00(± 0,0)	24,00(± 0,0)
B2	36,43(± 0,0)	9,36(± 0,0)	12,10(± 0,0)
B3	36,60(± 0,0)	9,56(± 0,0)	12,76(± 0,0)
B4	32,02(± 0,0)	8,88(± 0,0)	9,69(± 0,0)
B5	23,35(± 0,0)	3,11(± 0,0)	2,90(± 0,0)
B6	25,95(± 0,1)	4,51(± 0,0)	3,53(± 0,0)
O1	81,49(± 0,0)	-2,54(± 0,0)	23,84(± 0,0)
O2	36,39(± 0,1)	8,52(± 0,6)	11,46(± 0,0)
O3	27,12(± 0,0)	3,33(± 0,1)	3,13(± 0,0)
V1	35,35(± 0,9)	9,55(± 0,0)	11,45(± 0,0)
V2	25,79(± 0,0)	4,39(± 0,0)	3,86(± 0,0)
T1	37,10(± 0,1)	9,49(± 0,1)	11,89(± 0,0)
T2	26,25(± 0,1)	2,12(± 0,0)	1,95(± 0,0)
P1	34,41(± 0,0)	9,27(± 0,0)	10,66(± 0,0)
P2	28,00(± 0,3)	5,74(± 0,2)	5,03(± 0,1)
G1	28,47(± 0,5)	6,79(± 0,1)	5,46(± 0,0)
G2	29,13(± 0,2)	4,83(± 0,0)	3,85(± 0,0)
G3	35,45(± 2,1)	4,42(± 0,0)	5,69(± 0,6)

Table 4 Average L*, a* and b* values of the samples obtained via smartphone and mobile app

Samples	Smartphone		
	L*	a*	b*
U1	84,0(± 5,1)	-3,3(± 2,0)	31,8(± 4,9)
U2	43,7(± 6,4)	16,3(± 3,2)	20,8(± 3,9)
U3	46,2(± 8,0)	16,3(± 3,1)	20,5(± 3,4)
U4	36,1(± 3,9)	9,2(± 3,1)	8,5(± 4,6)
U5	34,9(± 4,1)	8,4(± 2,8)	8,1(± 3,5)
U6	32,0(± 6,8)	2,4(± 1,6)	5,5(± 4,0)
U7	28,9(± 6,1)	2,0(± 1,9)	6,9(± 3,0)
N1	83,2(± 8,1)	4,4(± 1,3)	22,8(± 2,4)
N2	42,3(± 7,7)	14,2(± 3,5)	10,2(± 3,1)
N3	32,3(± 3,4)	9,0(± 2,6)	4,2(± 1,3)
N4	27,3(± 4,5)	7,8(± 2,9)	2,2(± 2,0)
N5	28,5(± 4,5)	4,7(± 1,6)	0,0(± 2,5)
E1	43,7(± 5,9)	18,1(± 2,8)	11,4(± 2,6)
E2	31,5(± 2,0)	13,1(± 2,0)	3,5(± 1,9)
E3	29,7(± 2,0)	8,2(± 2,0)	-0,1(± 2,1)
E4	30,3(± 2,0)	7,1(± 2,0)	-0,8(± 2,1)
M1	85,9(± 3,3)	1,9(± 1,0)	25,1(± 2,7)
M2	42,6(± 2,9)	14,1(± 1,7)	15,9(± 1,9)
B1	85,8(± 3,0)	-2,4(± 0,7)	32,2(± 1,9)
B2	39,5(± 2,8)	15,0(± 1,3)	27,0(± 1,8)
B3	38,9(± 2,6)	12,0(± 2,3)	26,0(± 2,3)
B4	33,7(± 3,0)	12,1(± 2,1)	20,3(± 2,1)
B5	25,2(± 2,4)	2,7(± 1,2)	7,2(± 1,7)
B6	25,3(± 3,3)	3,4(± 1,6)	10,2(± 1,7)
O1	88,0(± 2,3)	1,1(± 1,2)	31,0(± 2,6)
O2	42,8(± 1,7)	17,3(± 0,6)	22,1(± 1,6)
O3	27,8(± 2,7)	4,5(± 2,0)	6,7(± 0,9)
V1	42,4(± 3,6)	13,6(± 1,9)	11,4(± 1,3)
V2	33,4(± 3,5)	5,4(± 1,0)	2,2(± 1,3)
T1	42,8(± 2,7)	13,6(± 2,2)	7,3(± 3,9)
T2	33,2(± 3,0)	1,3(± 1,4)	-5,0(± 1,8)
P1	40,7(± 1,5)	15,6(± 0,7)	15,0(± 1,2)
P2	36,1(± 1,0)	8,0(± 1,2)	4,5(± 0,8)
G1	33,3(± 1,3)	7,9(± 2,2)	5,0(± 2,0)
G2	36,8(± 2,3)	2,3(± 1,4)	2,0(± 1,1)
G3	42,6(± 2,8)	2,4(± 1,3)	3,6(± 0,9)

Table 5. Total Color Difference and whiteness index (WI) values of the samples

Samples	Colorimeter	Smartphone	Colorimeter	Smartphone
	TOTAL COLOR DIFFERENCE (ΔE)		WHITENESS INDEX (WI)	
U1	87,4(± 0,0)	90,0(± 5,1)	67,8(± 0,1)	64,0(± 4,9)
U2	39,0(± 0,0)	51,3(± 6,9)	34,3(± 0,0)	37,5(± 5,0)
U3	38,4(± 0,3)	53,4(± 7,7)	33,5(± 0,4)	39,9(± 6,8)
U4	28,6(± 0,1)	38,6(± 3,7)	27,5(± 0,1)	34,7(± 4,1)
U5	42,0(± 1,5)	37,1(± 4,3)	40,6(± 1,5)	33,8(± 4,0)
U6	25,7(± 0,0)	32,9(± 6,3)	25,1(± 0,0)	31,6(± 6,9)
U7	26,9(± 0,0)	30,0(± 6,0)	26,5(± 0,0)	28,4(± 5,9)
N1	82,3(± 0,5)	86,5(± 8,2)	64,3(± 0,7)	70,5(± 4,6)
N2	36,3(± 0,2)	46,0(± 7,7)	32,6(± 0,1)	39,5(± 7,1)
N3	27,7(± 0,0)	33,9(± 3,1)	26,7(± 0,0)	31,5(± 3,5)
N4	27,1(± 0,1)	28,7(± 4,1)	26,4(± 0,2)	26,8(± 4,6)
N5	25,2(± 0,2)	29,0(± 4,3)	24,9(± 0,2)	28,3(± 4,6)
E1	37,5(± 0,1)	48,7(± 6,5)	33,7(± 0,1)	39,5(± 4,7)
E2	29,4(± 0,0)	34,5(± 5,6)	28,0(± 0,0)	30,0(± 6,1)
E3	26,9(± 0,1)	30,9(± 4,2)	26,3(± 0,1)	29,1(± 4,4)
E4	26,3(± 0,1)	31,3(± 3,6)	25,6(± 0,1)	29,8(± 3,8)
M1	88,4(± 0,4)	89,5(± 2,8)	67,4(± 0,2)	71,1(± 3,5)
M2	42,4(± 0,0)	47,7(± 2,8)	36,8(± 0,0)	38,8(± 2,9)
B1	84,0(± 0,7)	91,7(± 2,4)	69,0(± 0,4)	64,6(± 2,7)
B2	39,5(± 0,0)	50,2(± 2,1)	34,6(± 0,0)	32,0(± 2,8)
B3	39,9(± 0,0)	48,4(± 2,6)	34,6(± 0,0)	32,4(± 2,6)
B4	34,6(± 0,0)	41,2(± 2,9)	30,8(± 0,0)	29,5(± 2,9)
B5	23,7(± 0,0)	26,5(± 2,1)	23,2(± 0,0)	24,8(± 2,4)
B6	26,6(± 0,1)	27,6(± 2,5)	25,7(± 0,1)	24,5(± 3,4)
O1	84,9(± 0,0)	91,8(± 1,6)	70,0(± 0,0)	64,6(± 3,1)
O2	39,1(± 0,2)	50,8(± 1,5)	34,8(± 0,0)	36,4(± 1,7)
O3	27,5(± 0,0)	30,2(± 2,4)	27,0(± 0,0)	28,7(± 2,8)
V1	38,8(± 0,8)	46,0(± 2,8)	34,1(± 0,8)	39,7(± 3,9)
V2	26,4(± 0,1)	34,0(± 3,4)	25,6(± 0,1)	33,2(± 3,5)
T1	40,1(± 0,0)	45,6(± 3,1)	35,3(± 0,1)	40,5(± 2,5)
T2	26,4(± 0,1)	33,7(± 3,0)	26,2(± 0,1)	33,0(± 3,0)
P1	37,2(± 0,0)	45,4(± 1,5)	32,9(± 0,0)	36,8(± 1,4)
P2	29,0(± 0,2)	37,8(± 1,1)	27,6(± 0,3)	36,1(± 1,0)
G1	29,8(± 0,5)	35,3(± 1,5)	27,9(± 0,5)	31,6(± 1,4)
G2	29,8(± 0,2)	38,5(± 2,3)	28,9(± 0,2)	37,9(± 2,3)
G3	36,2(± 2,2)	45,1(± 2,8)	35,0(± 2,1)	44,6(± 2,8)

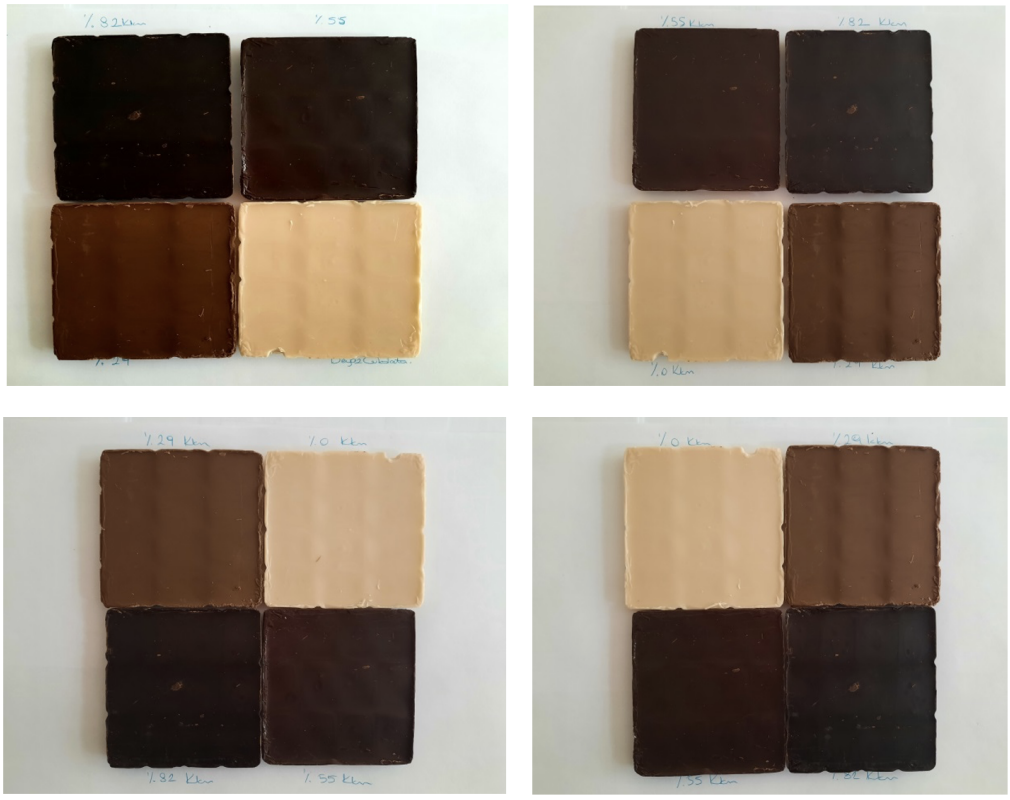

Figure 1. Images of chocolate samples in different locations captured with a smartphone camera

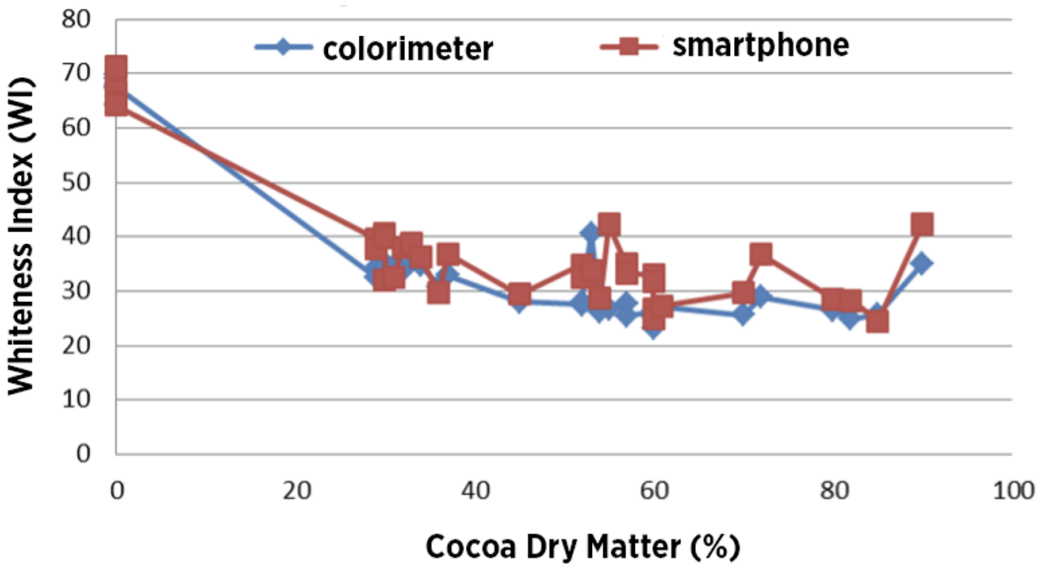

Figure 2. Whiteness index of the samples (blue: portable colorimeter, red: smartphone)

https://dergipark.org.tr/tr/pub/food
OPEN ACCESS JOURNAL

ISSN 2667-5803

FHTI Journal of Food Health and Technology Innovations
December Vol 7, No 15 (2024)

DergiPark AKADEMİK

Review Article

SALEP and ITS IMPORTANCE in TURKISH CUISINE

Semih Arabacı[1], İlkay Gök[2*]

Abstract

Salep is a one of the important cultural heritage of Turkey, recognized for its botanical diversity and traditional use in winter beverages and some desserts like icecream. Traditional salep beverages, widely consumed during cold seasons, hold a special place in Turkish social and cultural rituals. The cultivation of salep plants, particularly in Anatolia and the Aegean, transforms this heritage into regional economic value. Artisanal production methods, including meticulous drying and grinding, preserve its intrinsic qualities. Beyond being a biological product, salep symbolizes cultural identity, becoming an essential part of Turkish cuisine through its use in beverages, desserts, and ice cream. This study summurizes iformation and emphasizes the importance of preserving and promoting salep as a cultural symbol. Its unique sensory characteristics, cultural value and health supporting properties can drive regional economic development and ensure its transmission to future generations. Recognizing salep as both a product and cultural heritage is crucial for safeguarding this valuable plant.

Keywords: Salep, Natural Salep, Traditional food, Spices

TÜBİTAK ULAKBİM

1 semiharabaci54@gmail.com, 0009-0009-5507-0077, Istanbul Okan University
2 *Corresponding Author, ilkygok@gmail.com, 0000-0002-4871-8981, Istanbul Okan University

Introduction

Salep, a powdered product derived from the tubers of orchid plants, is traditionally consumed as a beverage and used in dessert preparation in countries such as Turkey, Iran, Greece, Syria, and neighboring regions. Turkey stands out as one of the richest areas in Europe and the Middle East for mid-latitude salep orchids. According to the Turkish Plant Data Service (TUBIVES), salep is classified under the Orchidaceae family, encompassing 24 genus and 187 taxa. This rich biodiversity underscores Turkey's significant potential for salep production. Salep species, predominantly characterized by an annual vegetation cycle, begin sprouting in late August to early September and mature between April and June, after which they enter a dormant state during the hot summer months. Research on enhancing salep production efficiency is guided by these biological characteristics [1]. Salep is sourced from the tubers of plants within the Orchidaceae (orchid) family. Prominent species include Orchis mascula (early-purple orchid), Orchis militaris (military orchid), Orchis anatolica (Anatolian orchid), and Dactylorhiza (spotted orchid).

Regional cultivation of salep orchids in Turkey

Salep, valued for its traditional and economic significance, is primarily used in ice cream and hot beverages. Turkey's rich biodiversity positions it as a global leader in salep orchid varieties. The cultivation of salep orchids is region-specific, influenced by geographic and climatic conditions [2]. The Marmara Region's humid climate and fertile soils support salep orchid species such as Orchis italica, Orchis purpurea, and Ophrys apifera. Natural growth occurs in forested areas, moist meadows, and coastal zones. Key production areas include Sakarya, Kocaeli, Balıkesir, and Bursa, with Sakarya emerging as a hub for commercial salep cultivation due to favorable environmental conditions [3]. In the Aegean Region, species such as Serapias vomeracea, Orchis anatolica, and Orchis italica are naturally distributed in rural and mountainous areas, olive groves, and forest edges. Prominent production areas include Izmir, Aydın, Denizli, and Muğla. Controlled cultivation is emphasized to counteract the threats posed by overharvesting. Salep orchids, including Dactylorhiza romana, Orchis papilionacea, and Ophrys speculum, thrive in the Mediterranean Region's high-altitude forests, maquis, and mountainous areas. Production is concentrated in Antalya, Isparta, Mersin, and Adana. These regions' biodiverse and climatically suitable conditions facilitate cultivation. The arid conditions of Central Anatolia favor species like Orchis mascula and Dactylorhiza umbrosa. Major production occurs in Konya, Eskişehir, Kayseri, and Sivas. The Ministry of Agriculture and Forestry has implemented policies promoting controlled cultivation to mitigate overharvesting risks [4]. The Black Sea Region's humid climate and rich vegetation foster species like Dactylorhiza maculata and Ophrys fusca. Key production areas include Trabzon, Rize, Samsun, and Ordu. Despite favorable conditions, sustainable practices are crucial to prevent species decline [5]. Eastern Anatolia's high-altitude landscape supports species such as Orchis militaris and Dactylorhiza osmanica. Production hubs include Erzurum, Van, Ağrı, and Bingöl. Controlled cultivation efforts aim to address the impact of overharvesting [6]. The Southeastern Anatolia Region features salep orchid species like Orchis anatolica and Ophrys lutea. Production is concentrated in Diyarbakır, Mardin, and Şanlıurfa. The region's agricultural landscapes support sustainable cultivation initiatives.

Regional salep production in Turkey

Salep production in Turkey relies on Orchidaceae tubers for powdered products used in beverages and ice cream. Although statistical data are limited due to wild harvesting, estimates suggest annual production ranges from 30-40 tons, with significant contributions from provinces like Muğla and Samsun. In 2022, Samsun accounted for nearly 48% of total production, emphasizing the dominance of the Black Sea and Aegean (Table 1).

Historical perspective of salep

Salep (Orchis species) has played a significant role across various civilizations, serving botanical, medicinal, gastronomical, and commercial purposes throughout history. This paper summarizes the historical development and uses of the salep plant from antiquity to the present day. The initial utilization of salep dates back to antiquity. Hippocrates' works highlight the aphrodisiac and digestive benefits of salep [7]. Greek physician Dioscorides emphasized the energy-

enhancing properties of salep in his renowned book De Materia Medica. Similarly, Pliny (Naturalis Historia) and Theophrastus (Historia Plantarum) elaborated on the classification and medicinal uses of the salep orchid. During the Middle Ages, salep emerged as a significant nutritional and medicinal product in both the Islamic world and Europe. Prominent scholars such as Avicenna and Ibn Baytar recommended salep for gastrointestinal issues and general weakness. The practice of consuming salep mixed with milk laid the foundation for the modern salep beverage. Furthermore, salep became a key commodity in Mediterranean and Middle Eastern trade routes. In the Ottoman Empire, salep gained popularity as a beverage commonly served in coffeehouses. It also became a crucial ingredient in the production of Maraş ice cream, acting as a thickening agent. In Europe, salep—known as "saloop"—gained prominence, especially in England, where it was regarded as an exotic product and sold at premium prices [8]. In the 19th century, the export of salep from the Ottoman Empire to Europe persisted. However, growing demand led to overharvesting, which diminished the natural habitats of salep orchids. By the 20th century, the food industry developed alternatives such as guar gum to replace natural salep as a thickener. Despite this, countries like Turkey and Iran maintained their status as leading producers of salep [2]. In the 21st century, salep continues to hold a place in both traditional and modern gastronomy. Turkey has initiated efforts to conserve natural resources and cultivate salep orchids in greenhouses. While natural salep powder remains a luxury product, innovative uses such as salep-based vegan ice creams and prebiotic products have gained traction in the market. Nevertheless, uncontrolled harvesting continues to pose a threat to several orchid species. Salep remains a vital component of Turkish gastronomy and a growing trend in global culinary practices. Throughout history, salep has bridged cultures, influencing fields from gastronomy to medicine. However, the development of sustainable production methods and the preservation of natural habitats are crucial for ensuring its future.

Production stages of salep

Salep plants typically bloom during spring and summer. During this period, the tubers located underground are carefully harvested. Ensuring minimal damage to the natural population of the plant is essential during this process. The harvested tubers are thoroughly washed to remove soil and other foreign materials. Subsequently, they are boiled in milk or water to enhance their durability and inhibit enzymatic activity. This process also helps eliminate undesirable odors.

Boiled tubers are traditionally strung on threads or spread out to dry in shaded areas. This drying process, conducted without direct exposure to sunlight, hardens the tubers and ensures long-term preservation. Once the tubers are completely dried and hardened, they are ground, typically using stone mills. The grinding process involves multiple stages, including crushing, refining, and pulverizing, to achieve the desired fineness and homogeneity of the salep powder. The ground salep powder is rested for several days in a moisture-free and sun-protected environment. This resting phase helps stabilize the moisture content of the powder. Afterward, the powder is packaged under appropriate conditions, making it ready for consumption (Figure 2).

Traditional use of salep powder

Salep powder is commonly consumed as a hot beverage prepared by mixing it with milk or water, particularly during winter months [9]. It is often garnished with cinnamon, which adds a pleasant aroma and flavor. This traditional drink is favored for its warming properties and its potential to support the immune system during cold weather. Salep is a key ingredient in Turkish ice cream, contributing to its elastic and dense texture due to its glucomannan content. It extends the melting time of the ice cream and enhances its flavor [10]. Salep is used as a thickening and flavoring agent in various desserts and pastries. Its addition to dishes like pudding, rice pudding, cakes, cookies, and baklava helps achieve the desired consistency and aroma. The mucilage and other components in salep aid in regulating digestion, soothing the stomach, and preventing constipation. It is also used as a remedy for soothing the throat, alleviating cough, and relieving symptoms of colds. Due to its moisturizing and skin-renewing properties, salep is included in some cosmetic products [11]. However, reliable and detailed sources on this usage are limited. Additionally, salep plays a significant role in cultural festivals and events, particularly in the Middle East and the Balkans,

where consuming salep as a hot beverage during cold winter months is a traditional practice and a social activity.

Components and health effects of salep

Glucomannan, a polysaccharide composed of mannose and glucose molecules, is the primary active component of salep. When in contact with water, it forms a gel-like structure, giving salep its thickening properties [12]. Starch constitutes a major portion of the carbohydrate content in salep, serving as an essential energy source. Mucilage is the plant-based fiber content of salep promotes digestion and supports intestinal health [13]. Salep contains minerals such as calcium, potassium, phosphorus, and magnesium, which contribute to bone health and metabolism. Present in small amounts, proteins contribute to the nutritional value of salep and support muscle building and cell regeneration. Natural fiber content contributes to a feeling of satiety and aids in digestion. Salep contains natural sugars providing a mildy sweet aroma.

Chemical transformations of salep

When heated, the mucilage in salep interacts with water to form a gel, enhancing the viscosity of products. However, extreme temperatures may degrade the mucilage structure. Starch-like components in salep gelatinize under high temperatures, influencing product texture and stability. Salep is sensitive to pH changes. Acidic or basic environments can alter the chemical structure of mucilage, affecting product consistency and stability. The drying process in salep production can lead to oxidation of certain components, affecting the color and chemical composition of the product. Phenolic compounds in salep may undergo enzymatic oxidation upon exposure to oxygen, leading to color changes. Additionally, natural amylase enzymes in salep can degrade starch, but these enzymes are deactivated at high temperatures. Salep tends to absorb moisture during storage, altering the characteristics of mucilage. Prolonged storage may decrease the chemical stability of certain components in salep.

Chemical changes during salep beverage preparation

Salep, derived from the tubers of orchid plants, is primarily used as a thickening agent in beverages. When heated with milk, various chemical interactions occur between the components of salep and milk. Glucomannan in salep absorbs water or milk, swelling to form a viscous solution. This property forms the basis of salep's thickening effect. During heating, hydrogen bonds between glucomannan molecules create a gel structure. This gel increases the beverage’s density and gives it its characteristic texture [14]. The mucilage in salep dissolves in water, absorbing more liquid when heated, which enhances its solubility. This property contributes to a smoother and more homogeneous consistency in the milk-based beverage. The main proteins in milk, casein, and whey proteins, denature during heating, altering their structures. This denaturation facilitates interactions between proteins and components in salep, such as glucomannan.

Denatured milk proteins interact with glucomannan in salep, forming complex structures that influence the stability and texture of the beverage. During heating, lactose (milk sugar) reacts with amino acids from salep or milk, initiating the Maillard reaction. This reaction contributes to the beverage’s darker color and characteristic aroma. At high temperatures, some water-soluble vitamins (e.g., Vitamin C and certain B vitamins) may be lost. However, controlled heat treatments like pasteurization minimize these losses. Heat treatment can alter the bioavailability of certain minerals in milk, though significant losses in mineral content are uncommon. The reaction between lactose in milk and amino acids in salep or milk during heating leads to the Maillard reaction. This contributes to a darker color and characteristic flavors [15]. The components of milk and salep form a better emulsion under heat and mixing. This results in a smoother texture and prevents the separation of liquid and solid components. When spices like cinnamon or ginger are added to the salep mixture, their water-soluble polyphenols and volatile oils are dispersed into the beverage. These compounds enhance the antioxidant capacity of the drink.

Differences between natural and artificial salep

Understanding natural salep and distinguishing it from artificial products can be achieved through various methods and scientifically backed indicators. When mixed with hot milk, natural salep produces a thick,

elastic consistency with a subtle aroma, offering a more natural flavor compared to artificial products. Artificial salep is often contains starch, flour, or additives and lacks the authentic aroma or exhibits an artificial smell. Natural salep is finely milled, cream-colored, and homogeneous, free from clumps or foreign particles. Artificial products may include starch or sugar additives, creating noticeable textural differences. Natural salep is quickly dissolves in water or milk, forming a dense, elastic consistency due to its natural glucomannan content [16]. Artificial salep tends to clump, dissolve unevenly, and often results in a texture that is either too liquid or excessively thick. Natural salep is expensive due to the limited availability of orchid tubers. Extremely cheap salep products typically contain additives. Natural salep products are labeled as "additive-free" or "natural" and list "salep". Artificial products often include starch, flavorings, and sweeteners. In Turkey, high-quality natural salep is sourced from regions like Kahramanmaraş, Bucak (Burdur), Isparta, and Muğla. Distinguishing natural salep requires attention to factors like flavor, texture, price, and ingredient information. Imitation products can cause economic and cultural losses, making it important to purchase from reliable producers. Chemical analyses are the most definitive way to identify natural salep. Natural salep contains 40-60% glucomannan. The unique protein and carbohydrate structures of natural salep can be identified through microscopic examination of its particles, revealing distinct orchid tuber structures.

Ingredients in commercial salep products

Thickening agents substances mimic the thickening effect of glucomannan found in natural salep. Starch is commonly used as a replacement for the mucilage in natural salep. Guar Gum is derived from guar beans, creating a dense texture when mixed with liquids. Xanthan Gum is a polysaccharide produced through fermentation, stabilizing the texture. Carrageenan is Extracted from red seaweed, providing a gel-like texture. Sweeteners are used to increase the sweetness of ready salep beverage. Granulated sugar is the most common sweetener, though excessive amounts can result in overly sweet products. Fructose or glucose syrup is economical alternatives considered less healthy. Flavorings are used to strengthen the aroma and taste of ready salep beverage. Vanillin is synthetic vanilla flavor mimicking natural salep aroma. Stabilizers are added to maintain homogeneity and prevent separation. Preservative agents used to extend shelf life. Potassium Sorbate is inhibits microbial growth. Sodium benzoate is prevents spoilage, though high amounts may be harmful. Colorants are used to make ready salep look better. Titanium Dioxide (E171) provides a bright white appearance. Some commercial salep products contain milk powder or substitutes. Nonfat milk powder used in milk-based products but not equivalent to fresh milk.

References

1. Erbaş, S. (2024). Salep Tarımı ve Endüstrisi. Batı Akdeniz Kalkınma Ajansı.
2. Şen, M.A., (2017). Osmanlı Mutfağından Günümüze Gastronomik Değerimiz "Salep", Aralık, 2017, 260.
3. Koyuncu, O., Yaylaci, O., Oeztuerk, D., Potoglu Erkara, I., Savaroglu, F., Osoydan, K., Ardic, M., (2011). Distribution, elements of destruction and evaluation of risk categories of Orchids in Osmaneli(Bilecik/Turkey) and its environs, Biological Diversity and Conservation 4(1) 122-133.
4. Karık, Ü., Kösoğlu, İ., Akaalp, H., (2020). Salep Yetiştiriciliği, Ege Tarımsal Araştırma Enstitüsü Tıbbi Bitkiler Şubesi, İzmir.
5. Gümüş, C., (2009). Batı Karadeniz bölgesinde salep elde edilmesinde kullanılan bazı orkide türlerinin (Orchidaceae) çoğaltım yöntemleri üzerinde araştırmalar. Doktora Tezi, Ankara Üniversitesi, Fen Bilimleri Enstitüsü, Ankara.
6. Erzurumlu, G., Doran, İ., (2011). Türkiye'de salep orkideleri ve salep kültürü, Harran Tarım ve Gıda Bilimleri Dergisi 15(1) 29-34.
7. Akdeniz, D., Sirtli, A., (2020). Erken Dönem Mitolojisinde Afrodizyak Yiyeceklere Ait İnanışlar (Beliefs on Aphrodisiac Food in Early Ages Mythology), Journal of Tourism & Gastronomy Studies 8(4) 2745-2768.
8. Çalışkan, Ö., Kurt, D., (2019). Tarihi kayıtlar ile geçmişten günümüze salep orkideleri, Türkiye Tarımsal Araştırmalar Dergisi 6(3) 349-355.

9. üren, T., Kızıleli, M., (2021). Geleneksel Türk İçecekleri, Ankara Hacı Bayram Veli Üniversitesi Turizm Fakültesi Dergisi 24(1) 46-71.
10. Or F., (2009). Kahramanmaraş'ta Üretilen Maraş Usulü Dondurmaların Mikrobiyolojik Kalitelerinin Değerlendirilmesi Üzerine Bir Araştırma.Yüksek Lisans Tezi, Çukurova Üniversitesi, Fen Bilimleri Enstitüsü, Adana.
11. Arslan, N., Baydar, H., Kızıl, S., Karık, Ü., Şekeroğlu, N., Gümüşçü, A., (2015). Tibbi aromatik bitkiler üretiminde değişimler ve yeni arayişlar, Türkiye Ziraat Mühendisliği VIII. Teknik Kongresi 12, 16.
12. Seyman, Y., (2023). Farklı Salep Türlerinde Doku Kültürü, Sera ve Tarla Koşullarında Üretim Çalışmaları.
13. Hürkul, M.M., Çift, R., Köroğlu, A., (2020). Investigation of salep and salep containing products in view of food and pharmacy, Biodivers Conserv 13(2) 144-52.
14. Şahin, M., Farklı hidrokolloidlerin gıdalardaki su dağılımına ve reolojik özelliklerine etkileri, Kahramanmaraş Sütçü İmam Üniversitesi Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, 2019.
15. Batu, A., Aydoymuş, R.E., Batu, H.S., (2014). Gıdalarda hidroksimetilfurfural (HMF) oluşumu ve insan sağlığı üzerine etkisi, Electronic Journal of Food Technologies 9(1) 40-55.
16. Turgay, Ö., Çinar, İ., (2017). Salep: The Common Name of The Plant, Powder, Hot Beverage, Food Ingredient Bitki, Toz, Sıcak İçecek ve Gıda Katkısı Olarak Salep, Journal of Enginering Sciences 20(3) 68-71.

Table 1. Salep Production of Amount (2022)

Region	Country	Production Amount (tons)	Total Production (%)
Black Sea Region	Samsun	56	47.9
	Sinop	7	6.0
Aegean Region	Muğla	42	35.9
Marmara Region	Bursa	5	4,3
	İstanbul	1	0,9
	Sakarya	1	0.9
Mediterranean Region	Hatay	2	1,7
	Adana	1	0.9
Central Anatolia Region	Amasya	1	0.9
	Kahramanmaraş	1	0.9
Total		**117**	**100**

Figure 1. The large tubers of the salep orchid [1]

Figure 2. Salep Powder Production Steps

https://dergipark.org.tr/tr/pub/food
OPEN ACCESS JOURNAL

ISSN 2667-5803

FHTI Journal of Food Health and Technology Innovations
December Vol 7, No 15 (2024)

DergiPark AKADEMİK

ResearchArticle

EXTRACTION AND CHARACTERIZATION OF LOQUAT SEED STARCH: A POTENTIAL ALTERNATIVE STARCH SOURCE

Şerife ÇAYLAK[1], Banu Koç[2*]

Abstract

The seeds of loquat (Eriobotrya japonica Lindl.), which are often discarded as agricultural waste, contain significant amounts of starch with unique properties. The aim of this study was to extract starch from loquat seeds and investigate its chemical and functional properties as well as its potential to replace wheat starch in traditional desserts such as jelly. The starch from loquat seeds was extracted by alkaline extraction and freeze-drying. The extracted starch had a moisture content of 4.47%, a water holding capacity of 303.2 g/g, an oil holding capacity of 19.21 g/g, a swelling power of 40.8 g/g at 95°C and a water solubility index of 85.7% at 95°C. The color parameters L*, a* and b* were 95.86, 2.02 and 4.79, respectively. Microscopic analysis revealed granules with various shapes, including flat, spherical, hemispherical, ellipsoidal and irregular polygonal and angular morphology. These characteristics make loquat seed starch suitable for various food and industrial applications, especially for the development of functional foods and sustainable gastronomy.

Keywords: Loquat seeds, starch, physicochemical property, sustainability, alternative starch source

TÜBİTAK ULAKBİM

Gastronomy and Culinary Arts Department, Faculty of Tourism, Gaziantep University, 27310 Gaziantep, Turkey
*Correspondence to: Banu Koç Phone: +90.342.3601200/3480 Fax: +90.342.3601013 E-mail address: banukoc@gantep.edu.tr
Şerife Çaylak: 0009-0008-9472-6334
Banu Koç: 0000-0002-1239-3353

Introduction

Sustainability, a concept that affects many industries, is particularly important for the food sector due to its economic, environmental and social aspects. Sustainability in food means adopting an ecological approach throughout the production and consumption chain that conserves natural resources and is guided by the principles of sustainable development [6]. Sustainable food production relies on several key elements, including good agricultural practices, increased consumer and producer awareness and effective waste management strategies [1]. Fruit and vegetable parts such as peels, stems and seeds, which contain important nutrients and bioactive elements, are often discarded as waste. The recycling of plant waste is considered economically beneficial as its economic value is higher compared to other types of waste [23]. Research has shown that both the powdered and oil extracts from the seeds can be used effectively as dietary supplements and bioactive compounds [21].

Carbohydrates in the human diet are primarily starch, which plays a crucial role both for nutrition and for technological applications in the food industry. Outside the food industry, starch is used in various areas, including pharmaceutical production, fertilizer production, paper production and the formulation of adhesives [3]. Current conventional sources of starch are not sufficient to meet the increasing demand due to population growth. Therefore, alternative sources of starch need to be explored to supplement the existing ones. Recently, researchers have turned their attention to unexplored crops, underutilized plant varieties, agricultural residues and wastes, various plant components and by-products of fruit and vegetable processing with high starch content. Non-traditional starches derived from the utilization of waste and by-products help reduce pollution while supporting the local economy. Some examples of these alternative starch sources are avocado seeds, sweet potatoes, Chinese chestnuts, sago and ramie roots. The industrial usability of these sources is determined by factors such as availability, physicochemical properties and molecular structures [13]. While the search for alternative starch sources continues, the further development and application of non-conventional starch offer a promising solution to meet the challenges posed by the increasing global demand for starch [13]. Starch obtained from loquat seeds is an alternative source of starch.

The evergreen loquat (*Eriobotrya japonica* Lindl.) from the Rosaceae family of the order Rosales is a fruit species that generally grows in subtropical climates between 20-35° north and south latitude [19]. The home of the loquat fruit, also known as Maltese plum, is Japan, China and northern India. In our country, the Mediterranean region is the most widely cultivated region [9]. The country with the highest production of loquat fruit with a total production of 982 thousand tonnes is China with 919 thousand tonnes, which corresponds to 93.6 % of production. This is followed by Spain (28,836 tonnes) and Turkey (16,402 tonnes) as the countries where most cultivation takes place [19]. Loquat seeds are usually discarded as agricultural waste as they account for 20-30% of the weight of the fresh fruit and have no practical use [7]. These seeds contain significant amounts of starch, amygdalin, amino acids and fatty acids. Despite their nutritional content, the seeds are not suitable for human consumption due to their bitter taste [2]. Loquat seed starch has emerged as a promising non-conventional starch source with unique properties and potential applications in various industries. The starch extraction yield from loquat seeds ranges from 30.04% to 45.2%, with high amylose content (>50%) [13, 20].

The aim of this study was to extract starch loquat seed and to investigate the chemical and functional properties of the extracted starch. In addition, the possibility of replacing wheat starch in classic desserts such as jelly with the extracted loquat seed starch was investigated.

Materials and Methods

Materials

The seeds of the loquat were harvested from trees that had grown in the neighborhood garden of Özlüce in Tarsus, a district of Mersin. After the seeds were extracted from the fruit, they were stored at -24°C. All solvents and chemicals were obtained from Sigma Aldrich (St. Louis, MO, USA).

Production of Starch

For starch extraction, loquat seeds were mixed with alkaline water (0.1 % NaOH) in a ratio of 1:2 and soaked at +4°C for 24 hours. The mixture was then ground in a high-speed

grinder for 5 minutes before being filtered through steel sieves with a pore size of 80 and 70 micrometres. The sieve residue was rinsed 2-3 times with distilled water and the resulting filtrate was centrifuged at 3000 rpm for 15 minutes. This centrifugation procedure was repeated four times, washing with distilled water between each cycle. After the last centrifugation, the supernatant was collected and frozen at -24°C for 48 hours. The frozen samples were then dried in a freeze dryer (Labconco, NewYork) at -54 °C and 0.250 mbar [18].

Production of Jelly

The jelly was made using traditional methods. Jelly is produced separately from wheat starch and loquat seed starch. The jelly consisted of 200 mL of water and 20 g starch. To make jelly, starch and water were mixed in a bowl and the mixture was heated in a saucepan over medium heat, stirring constantly. Stirring was maintained until the consistency of the mixture increased in viscosity. Once the mixture had reached a jelly-like consistency, it was allowed to cool and then stored in the refrigerator (Figure 1).

Analysis

Moisture contents of loquat seed starch determined by infrared moisture analyzer at 105˚C. The pH measurement was performed with a pH meter. A colorimeter (3NH colorimeter, China) was used for color measurements of (CIE L^*, a^* and b^* values). The granular structure of the starch sample obtained from the loquat seed was examined by microscopy. A minute amount of the dry starch sample was placed on a microscope slide. A drop of distilled water was applied to the dry starch, covered with a coverslip and placed in the microscope apparatus. The granular structure of the prepared samples was observed at 10x, 40x and 100x magnification. To determine the water holding capacity, 0.5 g of the starch sample was mixed with 4 ml of distilled water, and the mixture was shaken for 30 seconds every 10 minutes for a total of 70 minutes. The mixture was then centrifuged for 15 minutes at 25°C and 6000 rpm. After centrifugation, the liquid phase was removed, and the tubes were placed at an angle of 45° to the horizontal plane to facilitate drainage of the remaining liquid phase for 10 minutes. The mass of the solid fraction separated from the liquid phase was determined and the water holding capacity was calculated. The results were expressed in grams of water per gram of sample (g water/g sample) [12]. To determine the oil holding capacity, 0.5 g of the starch sample was mixed with 3 ml of sunflower oil. The mixture was homogenized with a glass rod for 30 seconds at 5-minute intervals for a total of 30 minutes. The homogenized samples were centrifuged at 25°C and 6000 rpm for 25 minutes. After centrifugation, the liquid phase was removed, and the tubes were inverted to allow the remaining liquid phase to drain for 5 minutes. The solid portion was weighed and the weight gain measured. The results were expressed in grams of oil per gram of sample (g oil/g sample). The swelling power (SP, g/g) and water solubility index (WSI, %) were determined according to a method modified by Li et al. [16]. In brief, the sample (0.15 g, db) was weighed into a centrifuge tube with a coated screw cap and 10 mL of deionized water was added. The tubes were then heated to 55◦C, 65◦C, 75◦C, 85◦C, and 95◦C, respectively, with frequent shaking for 1 h before cooling and centrifugation in an ice water bath (6000 rpm, 30 min). The supernatant was poured into an aluminum dish. The remaining solid fraction was weighed (Ws). The supernatant was dried at 100◦C until constant weight (W1). The WSI and SP were calculated as follows:

$$\text{WSI (\%)} = \frac{W_1}{W_0} x\ 100 \qquad (1)$$

$$\text{SP (g/g)} = \frac{W_S}{W_0 \times (1 - WSI)} \qquad (2)$$

Results and Discussion

The results of the physicochemical and fuctional parameters of loquat seed starch (moisture content, dry matter content, water holding capacity, oil holding capacity, swelling capacity, solubility index, L*, a*, b*, pH value) are shown in Table 1. The moisture content of the starch from the loquat seed was determined to be 4.47 %. Barbi et al. [5] determined the moisture content values of loquat seed starch in the range of 7.92 to 8.29 % in their study. The moisture content of loquat seed starch was lower than that of corn, wheat and quinoa starch and similar to that of canistel starch [15, 17, 23]. The reason for the lower moisture content of the starch obtained in this study is due to the freeze-drying process.

The water holding capacity is defined as the amount of water retained by the starch under certain conditions (temperature, time and mechanical force). The water holding capacity of loquat seed starch was determined to be 303.2 g/g. Inatçı [12] reported the water holding capacity of alkali-treated horse chestnut starch as 234.60 g/g in his study. Inatci [12] determined the water- holding capacity of conventionally treated acorn starch to be 212.88 g/g. The water-holding capacity of starches depends largely on the properties of the amylopectin structure. A long-chain ratio of the amylopectin molecules increases the water-holding capacity of the starch. In addition, the crystal structure of the molecules influences the water holding capacity of the starch and the triggering of the gelatinization process. A high-water holding capacity has a positive effect on properties such as thickening and gelling. It was determined that the data on the water holding capacity of loquat core starch is consistent with the information in the literature.

The oil holding capacity of loquat seed starch was determined to be 19.21 g/g. In comparison, Inatçı [12] found that alkali-treated horse chestnut starch and classically treated acorn starch have an oil holding capacity of 175.26 g/g and 169.38 g/g, respectively. The study by Inatçı [12] concluded that the oil holding capacity of loquat seed starch is significantly lower. The combination of oil and starch affects the physical properties of starch, as oils and fats can form complexes with amylose, which hinder the swelling of starch granules and make gelatinization more difficult [10]. Although starch with a high amylose content has a low oil holding capacity, no definitive correlation between amylose content and oil holding capacity has been established. Charles et.al. (2016) found that oil holding capacity is an indicator of emulsifiability, a critical property for products such as mayonnaise. In addition, high oil absorption properties are essential in various foods such as meat substitutes and extenders, doughnuts, baked goods and soups [4].

The properties of swelling power and solubility index are decisive factors for the industrial use of starch. The gelatinization of starch is caused by the interaction of water and temperature. In addition, factors such as the ratio of amylose and amylopectin, the formation of amylose-lipid complexes, the granule structure, the size, the morphological characteristics and the starch modifications have a significant influence on the swelling capacity of starch. The swelling power of loquat seed starch was determined to be 40.8 g/g at 95 ℃. In their study, Kong et al. [13] determined the swelling power of five loquat cultivar seed starches in the range of 25-62 g/g. Koyuncu Aydın [14] reported that the swelling power of domestic quinoa starch is 14.4 g/g. From this, it was concluded that loquat seed starch has a higher swelling power than domestic quinoa starch. Güzel (2009) determined the swelling power properties of starch from kidney beans, beans and chickpeas from legumes to be 8.19, 7.08 and 7.71 g/g, respectively. Chung et al. [8] determined the swelling capacity of starches from three different pea varieties at 90 °C to be 21.7, 19.1 and 18.8 g/g, respectively. Gani et al. [11] extracted starches from four different kidney bean varieties and determined the swelling power values of these starches to be 11.6, 11.3, 10.6 and 11.0 g/g, respectively. The differences in the solubility and swelling power of starch from different sources can be attributed to differences in the morphological structure of the starch granules. In addition, experimental parameters such as starch concentration, centrifuge conditions, mixing and separation methods and granule structure can influence the results. This variability can pose a challenge when comparing the results of different studies [16]. The average value of the water solubility index of loquat seed starch was determined to be 85.7 % at 95 ℃. Yaşar [24] reported that the water solubility property of navel starch increases with increasing temperature. According to the results of the analysis, the water solubility was 4.92±0.35 % and 16.86±0.15 % at 60 and 90 °C, respectively. The low solubility of starch at low temperatures is attributed to the semi-crystalline structure of the starch granules and the hydrogen bonds between the hydroxyl groups in the starch molecules. As the temperature increases, the solubility increases due to the disintegration of the starch granules and the increased interaction of the hydrophilic groups with water [24]. Koyuncu Aydın [14] determined that the water solubility index of quinoa seed starch at 95 ℃ was 89%.

Color is an important factor in determining starch quality. Analysis of the color of the starch sample yielded the parameters L*, a* and b* of 95.86, 2.02 and 4.79, respectively. These results indicate that the starch had high

lightness (high L*), minimal redness (low a*) and minimal yellowness (low b*). Yaşar [24] reported L*, a* and b* values for sea flea starch of 90.87, 2.19 and 4.71, respectively. Rafiq et al. [18] reported an L* value of 96.2, with a* (red/green) and b* (yellow/blue) values of 2.43 and 2.77, respectively. Comparison with previous studies shows comparable results. These color parameters also influence the color values of the gelatinized starch. The color of the loquat seed starch darkens during the gelatinization process (Figure 1-b).

The pH value of the starch of loquat seeds was measured at 11.210. Inatci [12] determined the pH of classically treated acorn starch to be 5.63. The pH values of starch extracted from horse chestnuts using alkaline and ultrasound-assisted methods were 9.94 and 10.44, respectively. Although the pH is lower than in this study, it remains alkaline. Careful evaluation of the effects of this pH in application is essential for starch processing and food quality.

Microscopic images of the starch of loquat seeds are shown in Figure 2. The starch granules have smooth surfaces and various shapes, including flat, spherical, hemispherical, ellipsoidal and irregular polygonal and angular morphology, with no visible damage due to isolation conditions. In this study, truncated granules characterized by a flat surface on one side (referred to as truncated ends) were also observed, which is consistent with the results reported for the seed starches of five loquat cultivars [13]. Similarly, Yaşar [24] found in his study that the morphological structures of starch granules of sea voles were irregular, dome-shaped and polygonal as well as agglomerated and discrete.

Conclusion

Loquat seed starch is a promising alternative source of starch with unique properties. In this study, starch was extracted from loquat seeds and its chemical and functional properties were investigated. The extracted starch had a moisture content of 4.47%, a water holding capacity of 303.2 g/g, an oil holding capacity of 19.21 g/g, a swelling power of 40.8 g/g at 95°C and a water solubility index of 85.7% at 95°C. Microscopic analysis revealed granules with various shapes, including spherical, ellipsoidal and irregular morphology. These characteristics make loquat seeds starch suitable for various food and industrial applications, especially for the development of functional foods and the promotion of sustainable gastronomy. In addition, the traditional desserts produced by using loquat seeds, which are considered a waste product, and the use of their starch form, are considered to also support sustainable gastronomy, especially in environmental and social terms. Further research is needed to optimize processing techniques and explore new applications of this promising starch source in the food industry and beyond.

References

1. Adanacıoğlu, H., Saner, G., & Ağır, H.B. (2018). Sürdürülebilir Gıda Değer Zinciri Yaklaşımı. *Kahramanmaraş Sütçü İmam Üniversitesi Tarım Ve Doğa Dergisi*, 21, 221-226. https://doi.org/10.18016/ksutarimdoga.vi.472847
2. Al-Bachir, M., & Koudsi, Y. (2021). Composition and quality characteristics of loquat (Eriobotrya japonica L.) kernel. *Journal of Agroalimentary Processes and Technologies*, *27*(1), 66-73.
3. Albano, K. M., Franco, C. M., & Telis, V. R. (2014). Rheological behavior of Peruvian carrot starch gels as affected by temperature and concentration. *Food Hydrocolloids*, *40*, 30-43.
4. Azima, F., Nazir, N., & Efendi, H. C. (2020, February). Characteristics of physico-chemical and functional properties of starch extracts from tubers. In *Journal of Physics: Conference Series* (Vol. 1469, No. 1, p. 012002). IOP Publishing.
5. Barbi, R. C. T., Teixeira, G. L., Hornung, P. S., Ávila, S., & Hoffmann-Ribani, R. (2018). Eriobotrya japonica seed as a new source of starch: Assessment of phenolic compounds, antioxidant activity, thermal, rheological and morphological properties. *Food Hydrocolloids*, *77*, 646-658.
6. Bilgin, S. (2018). Yiyecek İçecek İşletmelerinde Yerel Mutfak Ögelerinin Kullanımı ve Sürdürülebilirlik Açısından İncelenmesi: İzmir Örneği. Yüksek Lisans Tezi. Bolu Abant İzzet Baysal Üniversitesi Sosyal Bilimler Enstitüsü, Bolu.
7. Cao, T. L., & Song, K. B. (2019). Effects of gum karaya addition on the characteristics of loquat seed starch films

containing oregano essential oil. *Food Hydrocolloids*, *97*, 105198.
8. Chung, H. J., Liu, Q., Donner, E., Hoover, R., Warkentin, T. D. and Vandenberg, B. (2008). Composition, molecular structure, properties, and in vitro digestibility of starches from newly released Canadian pulse cultivars. *Cereal Chemistry, 85(4),* 471-479p.
9. Erkölencik, M.F. (2016). *Farklı Malta Eriği Çeşitlerinin Biyoaktik ve Aromatik Özelliklerinin Belirlenmesi.* Yüksek Lisans Tezi. Namık Kemal Üniversitesi Fen Bilimleri Enstitüsü, Tekirdağ.
10. Fennema O R 1985 Food Chemistry (New York: Marcel Decker Inc.)
11. Gani, A., Bashir, M., Wani, S. M. and Masoodi, F. A. (2012). Modification of bean starch by γirradiation: Effect on functional and morphological properties, *LWT-Food Science and Technology, 49(1)*, 162-169p.
12. İnatçı, Z. (2023). *At Kestanesi ve Meşe Palamudundan Farklı Yöntemler ile Nişasta Üretimi ve Üretilen Nişastaların Özelliklerinin Tespiti.* Yüksek Lisans Tezi. Tokat Gaziosmanpaşa Üniversitesi Lisansüstü Eğitim Enstitüsü, Tokat.
13. Kong, X., Yang, W., Zuo, Y., Dawood, M., & He, Z. (2023). Characteristics of physicochemical properties, structure and in vitro digestibility of seed starches from five loquat cultivars. *International Journal of Biological Macromolecules*, *253*(Pt 2), 126675. https://doi.org/10.1016/j.ijbiomac.2023.126675
14. Koyuncu Aydın, M. (2018). *Yerli Kinoa Tohumundan Nişasta Eldesi, Karakterizasyonu ve Fonksiyonel Özelliklerin İncelenerek Ürüne Uygulanması.* Yüksek Lisans Tezi. İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, İstanbul.
15. Li, B., Zhang, Y., Zhang, Y., Zhang, Y., Xu, F., Zhu, K., & Huang, C. (2021). A novel underutilized starch resource—Lucuma nervosa A. DC seed and fruit. *Food Hydrocolloids*, *120*, 106934.
16. Li, G., Wang, S., & Zhu, F. (2016). Physicochemical properties of quinoa starch. *Carbohydrate polymers*, *137*, 328-338.
17. Mir, S. A., Bosco, S. J. D., Bashir, M., Shah, M. A., & Mir, M. M. (2017). Physicochemical and structural properties of starches isolated from corn cultivars grown in Indian temperate climate. *International Journal of Food Properties*, *20*(4), 821-832.
18. Rafıq, S. I., Jan, K., Singh, S. ve Saxena, D. C., 2015. Physicochemical, pasting, rheological, thermal and morphological properties of horse chestnut starch. Journal of food science and technology, 52, 5651-5660.
19. Sezer, U., & Polat, A.A. (2022). Farklı anaçların Hafif Çukurgöbek yenidünya çeşidinde verim ve meyve kalitesi üzerine etkileri. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi,* 8(3), 376-390, https://doi.org/ 10.24180/ijaws.1107932.
20. Sharma, M., Sharma, M., Sridhar, K., Patil, S., Chawla, P., Ali, N., Attia, S. M., Bains, A., & Inbaraj, B. S. (2024). Exploring the Structural, Thermal, and Protective Potential of Loquat Seed Starch and Flax Seed Oil Nanoemulsion Coating on Strawberry. *Starch - Stärke*. https://doi.org/10.1002/star.202300166
21. Tuna, H.E. (2015). *Gıda Atığı Olan Vişne, Nar, Kabak ve Kayısı Çekirdeklerinin Kek Üretiminde Değerlendirilmesi.* Yüksek Lisans Tezi. İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, İstanbul.
22. Ünal, D.C. (2023). *Sürdürülebilir Gastronomi Kapsamında Gıda Atıklarından Şerbet Üretimi.* Yüksek Lisans Tezi. İstanbul Gelişim Üniversitesi Lisansüstü Eğitim Enstitüsü, İstanbul.
23. Xie, X. S., Cui, S. W., Li, W., & Tsao, R. (2008). Isolation and characterization of wheat bran starch. *Food Research International*, *41*(9), 882-887.
24. Yaşar, B. (2017). *Gölevez Nişastasının Yapısal, Fizikokimyasal ve Jelleşme Özelliklerinin Belirlenmesi.* Yüksek Lisans Tezi. Yıldız Teknik Üniversitesi Fen Bilimleri Enstitüsü, İstanbul.

Table 1. *Properties of Loquat Seed Starch*

Properties	Mean ± Standard Deviation
Moisture Content (%)	4.470 ± 0.248
Water Holding Capacity (g/g)	303.2 ± 7.002
Oil Holding Capacity (g/g)	19.21 ± 0.235
Swelling power (g/g)	40.8 ± 1.888
Water Solubility Index (%)	85.7 ± 0.771
*L**	95.86 ± 0.530
*a**	2.02 ± 0.216
*b**	4.79 ± 0.578
pH	11.210 ± 0.026

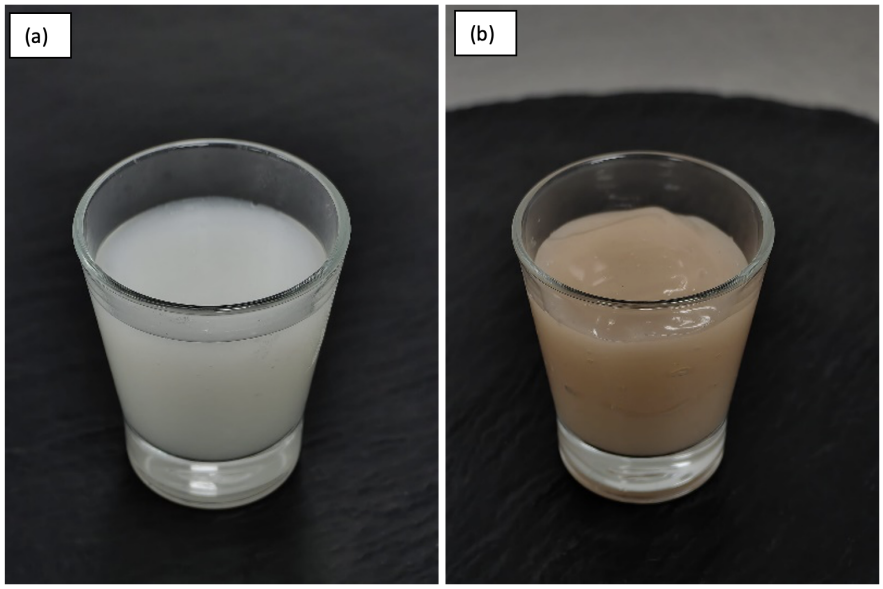

Figure 1. Jelley images, (a): wheat starch jelly, (b): loquat seed starch jelly

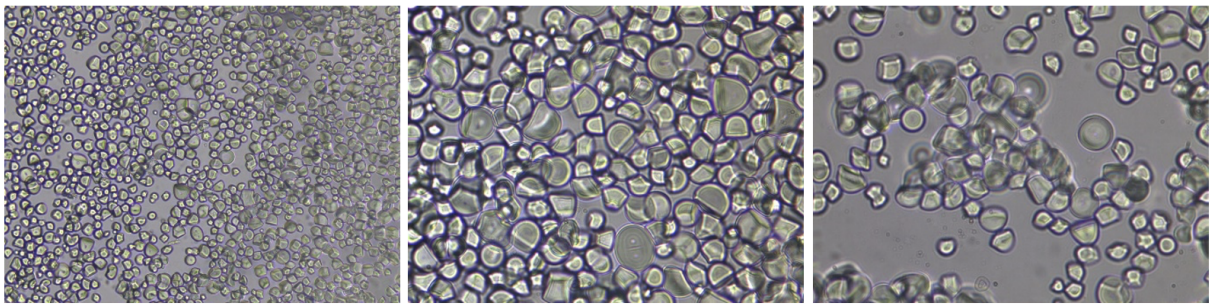

Figure 2. Microscope image of loquat seed starch.

https://dergipark.org.tr/tr/pub/food
OPEN ACCESS JOURNAL

ISSN 2667-5803

FHTI Journal of Food Health and Technology Innovations
December Vol 7, No 15 (2024)

DergiPark AKADEMİK

Review Article

SALEP and ITS IMPORTANCE in TURKISH CUISINE

Semih Arabacı[1], İlkay Gök[2*]

Abstract

Salep is a one of the important cultural heritage of Turkey, recognized for its botanical diversity and traditional use in winter beverages and some desserts like icecream. Traditional salep beverages, widely consumed during cold seasons, hold a special place in Turkish social and cultural rituals. The cultivation of salep plants, particularly in Anatolia and the Aegean, transforms this heritage into regional economic value. Artisanal production methods, including meticulous drying and grinding, preserve its intrinsic qualities. Beyond being a biological product, salep symbolizes cultural identity, becoming an essential part of Turkish cuisine through its use in beverages, desserts, and ice cream. This study summurizes iformation and emphasizes the importance of preserving and promoting salep as a cultural symbol. Its unique sensory characteristics, cultural value and health supporting properties can drive regional economic development and ensure its transmission to future generations. Recognizing salep as both a product and cultural heritage is crucial for safeguarding this valuable plant.

Keywords: Salep, Natural Salep, Traditional food, Spices

TÜBİTAK ULAKBİM

1 semiharabaci54@gmail.com, 0009-0009-5507-0077, Istanbul Okan University
2 *Corresponding Author, ilkygok@gmail.com, 0000-0002-4871-8981, Istanbul Okan University

Introduction

Salep, a powdered product derived from the tubers of orchid plants, is traditionally consumed as a beverage and used in dessert preparation in countries such as Turkey, Iran, Greece, Syria, and neighboring regions. Turkey stands out as one of the richest areas in Europe and the Middle East for mid-latitude salep orchids. According to the Turkish Plant Data Service (TUBIVES), salep is classified under the Orchidaceae family, encompassing 24 genus and 187 taxa. This rich biodiversity underscores Turkey's significant potential for salep production. Salep species, predominantly characterized by an annual vegetation cycle, begin sprouting in late August to early September and mature between April and June, after which they enter a dormant state during the hot summer months. Research on enhancing salep production efficiency is guided by these biological characteristics [1]. Salep is sourced from the tubers of plants within the Orchidaceae (orchid) family. Prominent species include Orchis mascula (early-purple orchid), Orchis militaris (military orchid), Orchis anatolica (Anatolian orchid), and Dactylorhiza (spotted orchid).

Regional cultivation of salep orchids in Turkey

Salep, valued for its traditional and economic significance, is primarily used in ice cream and hot beverages. Turkey's rich biodiversity positions it as a global leader in salep orchid varieties. The cultivation of salep orchids is region-specific, influenced by geographic and climatic conditions [2]. The Marmara Region's humid climate and fertile soils support salep orchid species such as Orchis italica, Orchis purpurea, and Ophrys apifera. Natural growth occurs in forested areas, moist meadows, and coastal zones. Key production areas include Sakarya, Kocaeli, Balıkesir, and Bursa, with Sakarya emerging as a hub for commercial salep cultivation due to favorable environmental conditions [3]. In the Aegean Region, species such as Serapias vomeracea, Orchis anatolica, and Orchis italica are naturally distributed in rural and mountainous areas, olive groves, and forest edges. Prominent production areas include Izmir, Aydın, Denizli, and Muğla. Controlled cultivation is emphasized to counteract the threats posed by overharvesting. Salep orchids, including Dactylorhiza romana, Orchis papilionacea, and Ophrys speculum, thrive in the Mediterranean Region's high-altitude forests, maquis, and mountainous areas. Production is concentrated in Antalya, Isparta, Mersin, and Adana. These regions' biodiverse and climatically suitable conditions facilitate cultivation. The arid conditions of Central Anatolia favor species like Orchis mascula and Dactylorhiza umbrosa. Major production occurs in Konya, Eskişehir, Kayseri, and Sivas. The Ministry of Agriculture and Forestry has implemented policies promoting controlled cultivation to mitigate overharvesting risks [4]. The Black Sea Region's humid climate and rich vegetation foster species like Dactylorhiza maculata and Ophrys fusca. Key production areas include Trabzon, Rize, Samsun, and Ordu. Despite favorable conditions, sustainable practices are crucial to prevent species decline [5]. Eastern Anatolia's high-altitude landscape supports species such as Orchis militaris and Dactylorhiza osmanica. Production hubs include Erzurum, Van, Ağrı, and Bingöl. Controlled cultivation efforts aim to address the impact of overharvesting [6]. The Southeastern Anatolia Region features salep orchid species like Orchis anatolica and Ophrys lutea. Production is concentrated in Diyarbakır, Mardin, and Şanlıurfa. The region's agricultural landscapes support sustainable cultivation initiatives.

Regional salep production in Turkey

Salep production in Turkey relies on Orchidaceae tubers for powdered products used in beverages and ice cream. Although statistical data are limited due to wild harvesting, estimates suggest annual production ranges from 30-40 tons, with significant contributions from provinces like Muğla and Samsun. In 2022, Samsun accounted for nearly 48% of total production, emphasizing the dominance of the Black Sea and Aegean (Table 1).

Historical perspective of salep

Salep (Orchis species) has played a significant role across various civilizations, serving botanical, medicinal, gastronomical, and commercial purposes throughout history. This paper summarizes the historical development and uses of the salep plant from antiquity to the present day. The initial utilization of salep dates back to antiquity. Hippocrates' works highlight the aphrodisiac and digestive benefits of salep [7]. Greek physician Dioscorides emphasized the energy-

enhancing properties of salep in his renowned book De Materia Medica. Similarly, Pliny (Naturalis Historia) and Theophrastus (Historia Plantarum) elaborated on the classification and medicinal uses of the salep orchid. During the Middle Ages, salep emerged as a significant nutritional and medicinal product in both the Islamic world and Europe. Prominent scholars such as Avicenna and Ibn Baytar recommended salep for gastrointestinal issues and general weakness. The practice of consuming salep mixed with milk laid the foundation for the modern salep beverage. Furthermore, salep became a key commodity in Mediterranean and Middle Eastern trade routes. In the Ottoman Empire, salep gained popularity as a beverage commonly served in coffeehouses. It also became a crucial ingredient in the production of Maraş ice cream, acting as a thickening agent. In Europe, salep—known as "saloop"—gained prominence, especially in England, where it was regarded as an exotic product and sold at premium prices [8]. In the 19th century, the export of salep from the Ottoman Empire to Europe persisted. However, growing demand led to overharvesting, which diminished the natural habitats of salep orchids. By the 20th century, the food industry developed alternatives such as guar gum to replace natural salep as a thickener. Despite this, countries like Turkey and Iran maintained their status as leading producers of salep [2]. In the 21st century, salep continues to hold a place in both traditional and modern gastronomy. Turkey has initiated efforts to conserve natural resources and cultivate salep orchids in greenhouses. While natural salep powder remains a luxury product, innovative uses such as salep-based vegan ice creams and prebiotic products have gained traction in the market. Nevertheless, uncontrolled harvesting continues to pose a threat to several orchid species. Salep remains a vital component of Turkish gastronomy and a growing trend in global culinary practices. Throughout history, salep has bridged cultures, influencing fields from gastronomy to medicine. However, the development of sustainable production methods and the preservation of natural habitats are crucial for ensuring its future.

Production stages of salep

Salep plants typically bloom during spring and summer. During this period, the tubers located underground are carefully harvested. Ensuring minimal damage to the natural population of the plant is essential during this process. The harvested tubers are thoroughly washed to remove soil and other foreign materials. Subsequently, they are boiled in milk or water to enhance their durability and inhibit enzymatic activity. This process also helps eliminate undesirable odors.

Boiled tubers are traditionally strung on threads or spread out to dry in shaded areas. This drying process, conducted without direct exposure to sunlight, hardens the tubers and ensures long-term preservation. Once the tubers are completely dried and hardened, they are ground, typically using stone mills. The grinding process involves multiple stages, including crushing, refining, and pulverizing, to achieve the desired fineness and homogeneity of the salep powder. The ground salep powder is rested for several days in a moisture-free and sun-protected environment. This resting phase helps stabilize the moisture content of the powder. Afterward, the powder is packaged under appropriate conditions, making it ready for consumption (Figure 2).

Traditional use of salep powder

Salep powder is commonly consumed as a hot beverage prepared by mixing it with milk or water, particularly during winter months [9]. It is often garnished with cinnamon, which adds a pleasant aroma and flavor. This traditional drink is favored for its warming properties and its potential to support the immune system during cold weather. Salep is a key ingredient in Turkish ice cream, contributing to its elastic and dense texture due to its glucomannan content. It extends the melting time of the ice cream and enhances its flavor [10]. Salep is used as a thickening and flavoring agent in various desserts and pastries. Its addition to dishes like pudding, rice pudding, cakes, cookies, and baklava helps achieve the desired consistency and aroma. The mucilage and other components in salep aid in regulating digestion, soothing the stomach, and preventing constipation. It is also used as a remedy for soothing the throat, alleviating cough, and relieving symptoms of colds. Due to its moisturizing and skin-renewing properties, salep is included in some cosmetic products [11]. However, reliable and detailed sources on this usage are limited. Additionally, salep plays a significant role in cultural festivals and events, particularly in the Middle East and the Balkans,

where consuming salep as a hot beverage during cold winter months is a traditional practice and a social activity.

Components and health effects of salep

Glucomannan, a polysaccharide composed of mannose and glucose molecules, is the primary active component of salep. When in contact with water, it forms a gel-like structure, giving salep its thickening properties [12]. Starch constitutes a major portion of the carbohydrate content in salep, serving as an essential energy source. Mucilage is the plant-based fiber content of salep promotes digestion and supports intestinal health [13]. Salep contains minerals such as calcium, potassium, phosphorus, and magnesium, which contribute to bone health and metabolism. Present in small amounts, proteins contribute to the nutritional value of salep and support muscle building and cell regeneration. Natural fiber content contributes to a feeling of satiety and aids in digestion. Salep contains natural sugars providing a mildy sweet aroma.

Chemical transformations of salep

When heated, the mucilage in salep interacts with water to form a gel, enhancing the viscosity of products. However, extreme temperatures may degrade the mucilage structure. Starch-like components in salep gelatinize under high temperatures, influencing product texture and stability. Salep is sensitive to pH changes. Acidic or basic environments can alter the chemical structure of mucilage, affecting product consistency and stability. The drying process in salep production can lead to oxidation of certain components, affecting the color and chemical composition of the product. Phenolic compounds in salep may undergo enzymatic oxidation upon exposure to oxygen, leading to color changes. Additionally, natural amylase enzymes in salep can degrade starch, but these enzymes are deactivated at high temperatures. Salep tends to absorb moisture during storage, altering the characteristics of mucilage. Prolonged storage may decrease the chemical stability of certain components in salep.

Chemical changes during salep beverage preparation

Salep, derived from the tubers of orchid plants, is primarily used as a thickening agent in beverages. When heated with milk, various chemical interactions occur between the components of salep and milk. Glucomannan in salep absorbs water or milk, swelling to form a viscous solution. This property forms the basis of salep's thickening effect. During heating, hydrogen bonds between glucomannan molecules create a gel structure. This gel increases the beverage’s density and gives it its characteristic texture [14]. The mucilage in salep dissolves in water, absorbing more liquid when heated, which enhances its solubility. This property contributes to a smoother and more homogeneous consistency in the milk-based beverage. The main proteins in milk, casein, and whey proteins, denature during heating, altering their structures. This denaturation facilitates interactions between proteins and components in salep, such as glucomannan.

Denatured milk proteins interact with glucomannan in salep, forming complex structures that influence the stability and texture of the beverage. During heating, lactose (milk sugar) reacts with amino acids from salep or milk, initiating the Maillard reaction. This reaction contributes to the beverage’s darker color and characteristic aroma. At high temperatures, some water-soluble vitamins (e.g., Vitamin C and certain B vitamins) may be lost. However, controlled heat treatments like pasteurization minimize these losses. Heat treatment can alter the bioavailability of certain minerals in milk, though significant losses in mineral content are uncommon. The reaction between lactose in milk and amino acids in salep or milk during heating leads to the Maillard reaction. This contributes to a darker color and characteristic flavors [15]. The components of milk and salep form a better emulsion under heat and mixing. This results in a smoother texture and prevents the separation of liquid and solid components. When spices like cinnamon or ginger are added to the salep mixture, their water-soluble polyphenols and volatile oils are dispersed into the beverage. These compounds enhance the antioxidant capacity of the drink.

Differences between natural and artificial salep

Understanding natural salep and distinguishing it from artificial products can be achieved through various methods and scientifically backed indicators. When mixed with hot milk, natural salep produces a thick,

elastic consistency with a subtle aroma, offering a more natural flavor compared to artificial products. Artificial salep is often contains starch, flour, or additives and lacks the authentic aroma or exhibits an artificial smell. Natural salep is finely milled, cream-colored, and homogeneous, free from clumps or foreign particles. Artificial products may include starch or sugar additives, creating noticeable textural differences. Natural salep is quickly dissolves in water or milk, forming a dense, elastic consistency due to its natural glucomannan content [16]. Artificial salep tends to clump, dissolve unevenly, and often results in a texture that is either too liquid or excessively thick. Natural salep is expensive due to the limited availability of orchid tubers. Extremely cheap salep products typically contain additives. Natural salep products are labeled as "additive-free" or "natural" and list "salep". Artificial products often include starch, flavorings, and sweeteners. In Turkey, high-quality natural salep is sourced from regions like Kahramanmaraş, Bucak (Burdur), Isparta, and Muğla. Distinguishing natural salep requires attention to factors like flavor, texture, price, and ingredient information. Imitation products can cause economic and cultural losses, making it important to purchase from reliable producers. Chemical analyses are the most definitive way to identify natural salep. Natural salep contains 40-60% glucomannan. The unique protein and carbohydrate structures of natural salep can be identified through microscopic examination of its particles, revealing distinct orchid tuber structures.

Ingredients in commercial salep products

Thickening agents substances mimic the thickening effect of glucomannan found in natural salep. Starch is commonly used as a replacement for the mucilage in natural salep. Guar Gum is derived from guar beans, creating a dense texture when mixed with liquids. Xanthan Gum is a polysaccharide produced through fermentation, stabilizing the texture. Carrageenan is Extracted from red seaweed, providing a gel-like texture. Sweeteners are used to increase the sweetness of ready salep beverage. Granulated sugar is the most common sweetener, though excessive amounts can result in overly sweet products. Fructose or glucose syrup is economical alternatives considered less healthy. Flavorings are used to strengthen the aroma and taste of ready salep beverage. Vanillin is synthetic vanilla flavor mimicking natural salep aroma. Stabilizers are added to maintain homogeneity and prevent separation. Preservative agents used to extend shelf life. Potassium Sorbate is inhibits microbial growth. Sodium benzoate is prevents spoilage, though high amounts may be harmful. Colorants are used to make ready salep look better. Titanium Dioxide (E171) provides a bright white appearance. Some commercial salep products contain milk powder or substitutes. Nonfat milk powder used in milk-based products but not equivalent to fresh milk.

References

1. Erbaş, S. (2024). Salep Tarımı ve Endüstrisi. Batı Akdeniz Kalkınma Ajansı.
2. Şen, M.A., (2017). Osmanlı Mutfağından Günümüze Gastronomik Değerimiz "Salep", Aralık, 2017, 260.
3. Koyuncu, O., Yaylaci, O., Oeztuerk, D., Potoglu Erkara, I., Savaroglu, F., Osoydan, K., Ardic, M., (2011). Distribution, elements of destruction and evaluation of risk categories of Orchids in Osmaneli(Bilecik/Turkey) and its environs, Biological Diversity and Conservation 4(1) 122-133.
4. Karık, Ü., Kösoğlu, İ., Akaalp, H., (2020). Salep Yetiştiriciliği, Ege Tarımsal Araştırma Enstitüsü Tıbbi Bitkiler Şubesi, İzmir.
5. Gümüş, C., (2009). Batı Karadeniz bölgesinde salep elde edilmesinde kullanılan bazı orkide türlerinin (Orchidaceae) çoğaltım yöntemleri üzerinde araştırmalar. Doktora Tezi, Ankara Üniversitesi, Fen Bilimleri Enstitüsü, Ankara.
6. Erzurumlu, G., Doran, İ., (2011). Türkiye'de salep orkideleri ve salep kültürü, Harran Tarım ve Gıda Bilimleri Dergisi 15(1) 29-34.
7. Akdeniz, D., Sirtli, A., (2020). Erken Dönem Mitolojisinde Afrodizyak Yiyeceklere Ait İnanışlar (Beliefs on Aphrodisiac Food in Early Ages Mythology), Journal of Tourism & Gastronomy Studies 8(4) 2745-2768.
8. Çalışkan, Ö., Kurt, D., (2019). Tarihi kayıtlar ile geçmişten günümüze salep orkideleri, Türkiye Tarımsal Araştırmalar Dergisi 6(3) 349-355.

9. üren, T., Kızıleli, M., (2021). Geleneksel Türk İçecekleri, Ankara Hacı Bayram Veli Üniversitesi Turizm Fakültesi Dergisi 24(1) 46-71.
10. Or F., (2009). Kahramanmaraş'ta Üretilen Maraş Usulü Dondurmaların Mikrobiyolojik Kalitelerinin Değerlendirilmesi Üzerine Bir Araştırma.Yüksek Lisans Tezi, Çukurova Üniversitesi, Fen Bilimleri Enstitüsü, Adana.
11. Arslan, N., Baydar, H., Kızıl, S., Karık, Ü., Şekeroğlu, N., Gümüşçü, A., (2015). Tibbi aromatik bitkiler üretiminde değişimler ve yeni arayişlar, Türkiye Ziraat Mühendisliği VIII. Teknik Kongresi 12, 16.
12. Seyman, Y., (2023). Farklı Salep Türlerinde Doku Kültürü, Sera ve Tarla Koşullarında Üretim Çalışmaları.
13. Hürkul, M.M., Çift, R., Köroğlu, A., (2020). Investigation of salep and salep containing products in view of food and pharmacy, Biodivers Conserv 13(2) 144-52.
14. Şahin, M., Farklı hidrokolloidlerin gıdalardaki su dağılımına ve reolojik özelliklerine etkileri, Kahramanmaraş Sütçü İmam Üniversitesi Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, 2019.
15. Batu, A., Aydoymuş, R.E., Batu, H.S., (2014). Gıdalarda hidroksimetilfurfural (HMF) oluşumu ve insan sağlığı üzerine etkisi, Electronic Journal of Food Technologies 9(1) 40-55.
16. Turgay, Ö., Çinar, İ., (2017). Salep: The Common Name of The Plant, Powder, Hot Beverage, Food Ingredient Bitki, Toz, Sıcak İçecek ve Gıda Katkısı Olarak Salep, Journal of Enginering Sciences 20(3) 68-71.

Table 1. Salep Production of Amount (2022)

Region	Country	Production Amount (tons)	Total Production (%)
Black Sea Region	Samsun	56	47.9
	Sinop	7	6.0
Aegean Region	Muğla	42	35.9
Marmara Region	Bursa	5	4,3
	İstanbul	1	0,9
	Sakarya	1	0.9
Mediterranean Region	Hatay	2	1,7
	Adana	1	0.9
Central Anatolia Region	Amasya	1	0.9
	Kahramanmaraş	1	0.9
Total		**117**	**100**

Figure 1. The large tubers of the salep orchid [1]

Figure 2. Salep Powder Production Steps

https://dergipark.org.tr/tr/pub/food
OPEN ACCESS JOURNAL

ISSN 2667-5803

FHTI Journal of Food Health and Technology Innovations
December Vol 7, No 15 (2024)

DergiPark AKADEMİK

Research Note

ONION PEEL POWDER: SOURCE OF BIOACTIVE ANTIOXIDANT PHENOLIC QUERCETIN DERIVATIVES

Ozlem TOKUSOGLU[1,2]

Abstract

Functional food progression and by-product/ waste management is rapidly increasing as a result of consumer consciousness regarding healthy and nutritious foods/ drugs and value-added products. Onion peel or skin is a by-product obtained from onion processing[1,2] that includes various phytochemicals, contributing to its antioxidant potential. Researches have confirmed that onion peel is a more concentrated source of phytochemicals than edible flesh, with quercetin as the major phenolic constituents in onion peel. Besides, quercetin 3,4'-diglycoside, quercetin, protocatechuic acid, kaempferol, 2-(3,4-dihydroxybenzoyl)–2,4,6-trihydroxy-3(2H)-benzofuranone, isorhamnetin, quercetin-7,4'-diglycoside, isorhamnetin-3,4'diglycoside, quercetin-3-glycoside, quercetin-4'-glucoside, isorhamnetin-4'-glycoside, protocatecoyl quercetin, quercetin dimer 4'-glycoside, quercetin dimer hexoside, quercetin dimer, and quercetin trimer have been identified in onion skin. The presence of all those bioactives confers on onion peel its various therapeutic influences in preventing cancer (CA), diabetes, obesity, cardiovascular disorders, neurodegenerative problems, possible microbial detriment and erectile dysfunction. In this context, onion peel in the form of powders or extracts can be employed in diversified industries as a therapeutic and pharmaceutical agent.

Keywords: Key Words: Onion, Onion Peel, Quercetin, Quercetin Glycosides, By-Product, Waste

TÜBİTAK ULAKBİM

Ozlem Tokusoglu 1,2
1Celal Bayar University, Engineering Faculty, Department of Food Engineering, Manisa, Turkey
2Dokuz Eylül University Technology Development Zone, DEPARK Technopark, SPİL INNOVA Ltd.Şti, İzmir, Turkey
E-mail: proftokusogluozlem@gmail.com
ORCHID ID : https://orcid.org/0000-0002-8960-5641

Introduction

Dried onion (Allium cepa L., Alliaceae) and dried onion peel powder; They are the dried and ground forms of the products obtained as a result of production using fresh onions. Spring onions contain approximately 91% water before they are dried. By drying, the water content in the dried fresh product is reduced to very low values. 20-30 grams of 1 kg of medium-sized onion is onion peel (1).

The annual level of onion by-products produced in the European Union Countries is estimated to be approximately 450,000 tonnes. Onion peels, the major by-products obtained by industrial peeling of onions, have brownish skin; It consists of two watery layers: upper and lower. It has strong odor and flavor characteristics; It is not suitable to use onion waste peels as feed because onion peels, in addition to being a source of flavor components and fiber compounds, are very rich in quercetin glycosides. Onion peel also contains vitamin C (ascorbic acid), Vitamin E and B group vitamins. Besides being a source of carotenes, onion peel is rich in potassium (K), manganese (Mn) and phosphorus (P) minerals (1).

Onion Peel Phytochemicals and Bioactives

The antioxidant major flavonoids present in onion peels, especially quercetin 3,4',O-diglucoside and quercetin 4,O-monoglucoside, constitute 85% of the total flavonoids. Quercetin taken from onion consumption is rapidly absorbed and slowly eliminated; Therefore, it shows significant antioxidant activity. In addition, onion core and onion skins (in terms of their upper and lower parts) are important sources of prebiotic fructans and fructooligosaccharides (FOS); Food supplements, alcohol and snacks can be produced from onion powder (1,2) (Table 1; Figure 1.)

General Health Effects of Onion Peel

It has been revealed that onion peels are an important source of antioxidants due to the powerful flavonoids and flavonols they contain, and it is stated that they help prevent the risk of cardiovascular diseases by accelerating blood flow (1).

Onion peels have antibiotic, antiseptic and antioxidant effects, have anti-inflammatory properties, support muscle development and a very important feature is that the sulfur (S) in onions triggers collagen production.

It is reported that consuming raw onions and onion peels can help produce high-density fatty protein and balance cholesterol. In a related study, it was found that cholesterol was balanced in 30% of individuals who consumed onion peels for a certain period of time (1,2).

Scientific research has determined that onion has antibacterial properties. The high level of sulfur (S) in onion juice increases blood circulation. Onion and onion peel improve blood flow and therefore can help improve hair follicles; Its healing effects have been determined on dermatitis, dandruff, seborrhea and scalp irritations. Due to its sulfur content, it has been shown that onion peel strengthens hair follicles and accelerates hair growth (1).

It is reported that onion juice has a therapeutic effect against chocolate cyst (endometriosis) and myoma formations in women and can help in the treatment of polycystic ovary syndrome.

Quercetin is effective in inhibiting allergic reactions and chronic inflammation, and it has been reported that quercetin is effective in helping prevent the oxidation of fatty acids in the body.

Studies have shown that the minerals contained in onion peel balance blood pressure and have therapeutic properties for blood pressure patients (1,2).

Protective Health Effects of Onion Peel Against Types of Cancer and Type-2 Diabetes

It has been found that onion peel is effective in helping prevent colon cancer and Type-2 diabetes. It is emphasized that the risk of developing colon and ovarian cancer is lower with the consumption of onion peels, which have high quercetin content.

Consumption and Usage Methods

Onion peels can be turned into powder (powder) form and consumed in salads and meals. It is also suggested that onion peels can be used in ready-made soup mixtures, chicken, meat and meatball mixtures, ravioli and flour.

The separated onion peels can be consumed by washing and cleaning in cold water and then boiling them in boiled water for 5 minutes (1,2).

The easiest method to extract the nutritional ingredients in onion peels is to add the peels to soup or sauce and cook over low heat. After the food or sauce is cooked, the shells are removed, and with the effect of heat treatment, the food components and bioactives in the shell can be transferred to the food / sauce.

Onion peels boiled for 5 minutes through a tea ball strainer can be consumed as tea; The product, boiled for 15-20 minutes and filtered, has a positive effect on leg cramp problems. After boiling 30-35 g of onion peel in 1 glass of water and straining, the washed hair is dyed naturally and brightly (1,2).

References

1. Tokuşoğlu Ö. 2018. Vegetable By-Product-Based Food Powders and Utilizations- Onion Peel Powder (Chapter 3) p 65-67, In BOOK. ``Food By-Product Based Functional Food Powders``CRC Press, Taylor & Francis, Boca Raton, Florida, USA. ISBN 9781482224375, Cat # K22366. 275pages.
2. Tokuşoğlu Ö. 2018. Onion Peel Powder, Source of Phenolic Quercetin Diglucosides: Antioxidant and Antibacterial Aspects and Consumption Properties. Food for Life Portal, Food, Cancer and Nutrition Corner, January 2018, Çankaya, Ankara.

Table 1. Contents of Total Phenolics (mg GAE g^{-1} DM), Flavonoids (mg QE g^{-1} DM) and Flavonols (mg g^{-1} DM), and Antioxidant Capacity (μmol Fe $^{+2}$ g^{-1} DM) in Whole Onion and Its Industrial Onion Wastes

	Whole Onion	Inner Scales	Outer Scales	Top–Bottom	Brown Skin
Total phenolics	17.3 ± 1.3^{a}	9.4 ± 0.6^{b}	19.7 ± 1.6^{a}	30.5 ± 2.0^{c}	52.7 ± 0.9^{d}
Total flavonoids	10.3 ± 0.3^{a}	7.0 ± 0.1^{b}	19.5 ± 0.7^{c}	25.9 ± 0.7^{d}	43.1 ± 1.8^{e}
Total flavonols	8.84 ± 1.41^{c}	6.19 ± 0.23^{b}	19.27 ± 1.42^{e}	15.29 ± 1.39^{d}	7.89 ± 0.37^{a}
Quercetin 4′-glucoside	4.02 ± 0.53^{a}	2.00 ± 0.07^{b}	7.37 ± 0.53^{d}	6.35 ± 0.60^{c}	5.16 ± 0.34^{c}
Quercetin 3,4′-diglucoside	3.10 ± 0.68^{a}	3.70 ± 0.11^{a}	9.49 ± 0.68^{d}	5.90 ± 0.50^{c}	0.30 ± 0.03^{b}
Quercetin	0.91 ± 0.04^{c}	0.02 ± 0.00^{b}	0.59 ± 0.04^{a}	1.21 ± 0.09^{d}	1.61 ± 0.02^{e}
Quercetin 3-glucoside	0.16 ± 0.03^{a}	0.10 ± 0.01^{b}	0.42 ± 0.03^{d}	0.40 ± 0.03^{d}	0.31 ± 0.01^{c}
Isorhamnetin 3,4′-diglucoside	0.12 ± 0.02^{b}	0.12 ± 0.01^{b}	0.37 ± 0.02^{c}	0.57 ± 0.04^{d}	0.19 ± 0.01^{a}
Isorhamnetin 4′-glucoside	0.53 ± 0.07^{c}	0.25 ± 0.01^{b}	1.03 ± 0.07^{e}	0.86 ± 0.07^{d}	0.32 ± 0.02^{a}
Ratio Di:Mon^{f}	1:1.3	1.8:1	1.3:1	1:1.1	1:17
Antioxidant activity (FRAP)	83.5 ± 1.8^{a}	28.7 ± 1.7^{b}	105.1 ± 0.6^{c}	156.1 ± 1.6^{d}	227.8 ± 3.2^{e}

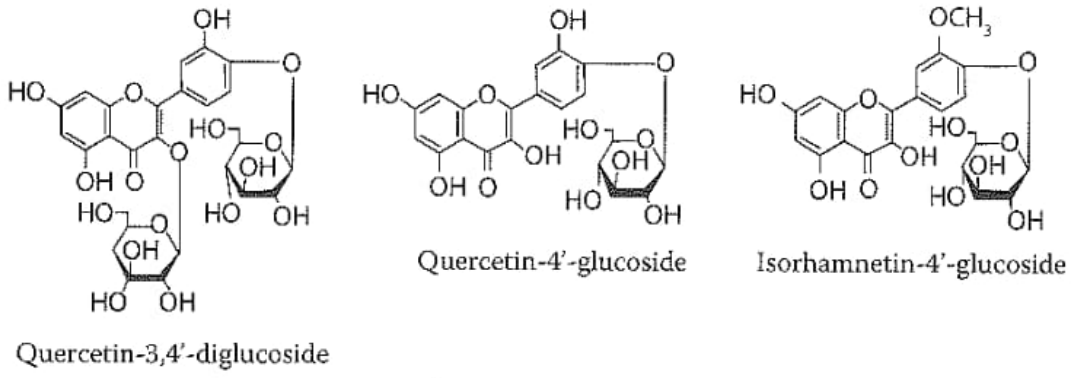

Figure 1. Quercetin Glycosides in Onion Peel Powders

https://dergipark.org.tr/tr/pub/food
OPEN ACCESS JOURNAL

ISSN 2667-5803

FHTI Journal of Food Health and Technology Innovations
December Vol 7, No 15 (2024)

DergiPark AKADEMİK

Research Article

EDITORIAL NOTE

Special Issues Guidelines of FHTI - 2025

FHTI Special Issue

Special Issues (SIs) are collections of papers centered around a subject of special interest and are organized and led by subject experts who take on the role of Special Issue Editor of FHTI. A Special Issue is not an classical issue of the journal and it is an additional issue.

All submissions follow the same peer review process as regular papers and are published in the regular issues of the journal when they are accepted, but are additionally labelled as belonging to a Special Issue and are discoverable within the collection.

Special Issue Sub-editors will have the opportunity to improve the scope of the Special Issue while receiving submissions and create a welcoming environment for researchers to share their possible findings.

When it comes to benefits of publishing in a FHTI Special Issue;

- Greater discoverability: Articles published in Special Issues benefit from greater discoverability and more frequent citations than articles spontaneously submitted to the respective journal, due to their connectivity within the article collection.
- Ease of navigation: Clustering papers within specific topics helps scholars to easily navigate through the content of broad scope journals.
- External promotion: Articles in Special Issues are often promoted through the journal's social media channels for the relevant subject areas to increase visibility and readership.
- Rigorous peer-review: Articles in Special Issues follow the same rigorous and independent peer review process as regular papers and are published in the regular issues of the journal. They are generally handled by a Special Issues Editor who is an influential researcher in the discipline.
- Expand your research network: Special Issues are a great place to find new collaborators among the authors of other manuscripts published within the collection of articles.

Our 2025 FTHI Special Issue Concept;

The editor of FHTI is pleased to announce that a Special Issue on "Widespread Tropical Fruits: Chemistry and Bioactives"(In Turkish: (Yaygın Tropikal Meyveler: Kimyası ve Biyoaktifleri) will be published in the June 2025.

We now invite food scientists, food engineers, pharmacologists, chemical engineers, chemists, biologs, veterinary scientists who are working in this area to submit reports of original, unpublished empirical studies, for inclusion in the Special Issue.

Publications submitted to a FHTI will appear as regular submissions via website. The papers will be kept as regular papers and published in after editorial review processing. Deadline April 30, 2025.

Editor in Chief
Professor, Ozlem Tokusoglu, PhD

Ozlem Tokusoglu, Professor Dr.
Editor in Chief, FHTI Journal, Ulakbim Tübitak Dergipark, Ankara

TÜBİTAK ULAKBİM

TÜBİTAK
ULAKBİM

FHTI

JOURNAL OF FOOD HEALTH AND TECHNOLOGY INNOVATIONS

ISSN 2667-5803

DECEMBER VOL 7, NO 15 (2024)