Natural and Biotechnological Antioxidants in Health Protection

Mahira Firudin kizi Amirova
Department of Biochemistry, Azerbaijan Medical University, Baku, Azerbaijan

* Corresponding Author: **Mahira Firudin kizi Amirova**

Article Info

P-ISSN: 3051-3405
E-ISSN: 3051-3413
Impact Factor (RSIF): 8.41
Volume: 02
Issue: 01
Received: 26-11-2025
Accepted: 28-12-2025
Published: 30-01-2026
Page No: 33-37

Abstract
Natural and biotechnological antioxidants are increasingly interpreted through redox homeostasis rather than through simple free-radical scavenging. This narrative review examines ergothioneine, ovothiols, mycosporine-like amino acids, food-derived antioxidant peptides, and postbiotic antioxidant systems as examples of mechanism-dependent antioxidant strategies. Antioxidants biological value depends on transport, tissue localization, photoprotection, fermentation-derived production, digestive stability, gut-host interaction, and sustainable manufacturing. Ergothioneine illustrates the importance of dedicated uptake and tissue retention; ovothiols and mycosporine-like amino acids show how marine and stress-adapted organisms generate specialized redox and photoprotective metabolites; antioxidant peptides and postbiotics demonstrate the growing role of food biotechnology and microbiome-related products. The review also discusses why DPPH, ABTS, FRAP, and ORAC values should be treated as preliminary screening results rather than proof of *in vivo* efficacy. Overall, natural antioxidant development is strongest when chemical activity, mechanism-specific biomarkers, and reproducible manufacturing are considered together.

DOI: https://doi.org/10.54660/IJABRN.2026.2.1.33-37

Keywords: food biotechnology, health protection, gut redox biology, natural antioxidants

1. Introduction

Interest in natural antioxidants has shifted from broad claims about free-radical scavenging toward more specific questions about bioavailability, transport, compartmental localization and disease context. This change is important for food science and biomedical translation because many natural compounds show strong chemical antioxidant activity but limited *in vivo* impact. In contemporary redox biology, oxidation is not viewed only as damage; reactive oxygen species also participate in signaling, adaptation and immune regulation [1, 2]. Therefore, a modern review must ask not only whether a compound reacts with oxidants, but whether it reaches the relevant biological site and remains active there [3]. Natural and biotechnology-derived antioxidants include molecules from fungi, bacteria, algae, marine invertebrates, edible proteins and fermented microbial systems. Ergothioneine, ovothiols, mycosporine-like amino acids, antioxidant peptides and postbiotics are particularly useful examples because each represents a different route to redox protection: transporter-enabled accumulation, specialized sulfur chemistry, UV energy management, sequence-dependent peptide activity and gut-host signaling [4, 5, 8]. Against this background, ergothioneine provides a useful first example because it links dietary origin with active transport and tissue retention. Ergothioneine is a sulfur-containing histidine derivative found mainly in fungi, some bacteria and mushroom-rich foods. Its renewed importance arises from a combination of chemical stability, low nonspecific reactivity and dedicated transporter biology through OCTN1/SLC22A4 [9, 10]. Unlike many dietary antioxidants that circulate passively and are rapidly metabolized, ergothioneine can accumulate in tissues that express its transporter [11]. This feature changes the evaluation framework. Ergothioneine should not be judged only by a colorimetric antioxidant score. Its biological relevance depends on dietary intake or fermentation production, intestinal absorption, transporter expression, tissue retention and interaction with oxidative or inflammatory stress. This makes it a bridge between nutrition, redox medicine and industrial biotechnology [9, 12].

Transporter biology gives ergothioneine a special position in the field because an actively accumulated compound may show biological relevance even when its simple radical-scavenging score is not the highest among natural products. Recent literature emphasizes the industrial feasibility of ergothioneine production through fermentation and synthetic biology approaches [10, 12]. This is significant because scalable production can move a molecule from biochemical curiosity to functional ingredient. Food, nutraceutical, dermocosmetic and possible clinical-adjunct uses depend on consistent purity, safety, cost and validated endpoints. Potential application areas include healthy aging, neuroprotection, chronic inflammation, red blood cell biology and skin protection [9, 11, 12]. However, evidence should be interpreted carefully. Mechanistic and observational arguments are strong, but human intervention studies remain less mature than promotional language sometimes suggests. Industrial development should therefore be accompanied by careful endpoint selection. Studies on cognition, inflammation, red blood cells or skin should use outcome measures that reflect the proposed mechanism instead of relying only on plasma total antioxidant capacity [3, 13]. The aim of this review was to analyze some novel compounds as natural and biotechnological antioxidants, and to clarify how their biological relevance depends on bioavailability, transport, tissue or cellular localization, photoprotective behavior, digestive stability, gut-host interaction, manufacturing reproducibility and mechanism-matched biomarkers. The author's indexed publications on tea, coffee and plant-based immune support also underline that diet-related exposures may have biochemical relevance [14-16].

2. Methods

The study was conducted by selecting peer-reviewed literature relevant to natural and biotechnology-derived antioxidants, including ergothioneine, ovothiols, mycosporine-like amino acids, antioxidant peptides and postbiotics. Foundational and recent studies were included when they addressed redox biology, antioxidant mechanisms, bioavailability, stability, manufacturing, assay limitations or translational applications.

3. Dietary compounds as emerging antioxidants

The discussion of transport-enabled dietary compounds naturally leads to marine sulfur antioxidants, where specialized thiol chemistry offers a different route to redox protection. Ovothiols are sulfur-containing histidine derivatives originally associated with marine organisms. They attract attention because their acid-base and thiol chemistry can make them highly reactive under physiological conditions [17]. Their occurrence in organisms exposed to variable oxygen tension, salinity, metal chemistry and reproductive oxidative stress supports the idea that extreme environments are valuable antioxidant discovery platforms. Recent work on ovothiol biosynthesis and distribution broadens the biological relevance of this family [17]. Yet translation remains early. Ovothiols are better described as frontier marine redox molecules than as established therapeutics. Their value for research is high because they expand chemical diversity and provide models for designing sulfur antioxidants with controlled reactivity. The marine setting is scientifically valuable because it exposes organisms to photochemical, osmotic and reproductive oxidative pressures. Molecules shaped by these pressures may provide templates for future antioxidant design even before they become commercial products [17]. Marine redox chemistry also includes photoprotective molecules, especially mycosporine-like amino acids, whose antioxidant value is closely connected with UV-energy management. Mycosporine-like amino acids are small water-soluble compounds produced by algae, cyanobacteria and other marine organisms. They are best known for UV absorption, but their relevance extends to antioxidant and anti-inflammatory functions as well [18, 19]. This dual identity is important because a photoprotective molecule can reduce oxidative stress both by preventing radical formation and by scavenging reactive species after formation. Mycosporine-like amino acids are especially attractive for skin and cosmetic applications because they combine natural origin, photophysical shielding and redox protection [16-18]. Patent activity and formulation research suggest growing industrial interest [19]. However, systemic biomedical applications remain less developed than topical and dermocosmetic uses. Their most realistic near-term role may be as multifunctional ingredients in photoprotection and skin-health formulations [17, 19, 20]. Their combined photoprotective and antioxidant roles also make them useful for sustainable product development. Beyond single marine metabolites, food proteins can generate antioxidant activity through bioactive peptide release during hydrolysis, fermentation or digestion. Antioxidant peptides are generated from food proteins by enzymatic hydrolysis, fermentation, digestion or computational discovery. Their activity depends on sequence, amino acid composition, hydrophobicity, aromatic residues, sulfur-containing residues and metal-chelating capacity. Some peptides act directly by scavenging radicals or chelating metals; others influence Nrf2/Keap1 signaling, inflammatory mediators or gut microbiota [21, 22]. The main challenge is translation from *in vitro* activity to physiological relevance. Peptides may be degraded during digestion, modified by intestinal enzymes or poorly absorbed. Yet this does not make them irrelevant. Many food-derived peptides may act locally in the gut, influence microbial ecology or support barrier function before systemic absorption becomes necessary. Peptide research benefits from modern mass spectrometry, bioinformatics and controlled hydrolysis, which can connect sequence profiles with reproducible functional claims [26].

The same food-biotechnology perspective extends to postbiotics, where antioxidant effects arise from microbial components and metabolites rather than from one purified molecule. Postbiotics are non-viable microbial cells, cell components or metabolites that provide health benefits. Their antioxidant action is system-level rather than single-molecule. It may involve exopolysaccharides, peptides, organic acids, cell wall fragments, microbial metabolites, immune modulation, barrier support and host antioxidant pathway activation [8, 24]. The gut is a particularly suitable environment for postbiotic antioxidant effects because it contains dietary oxidants, microbial metabolites, immune cells and epithelial barriers. A postbiotic product does not need high plasma exposure if it improves mucosal redox balance, tight-junction integrity or inflammatory signaling locally. This makes postbiotics promising for gut and metabolic conditions, but standardization remains a major hurdle [8, 24, 25]. Postbiotics also illustrate the difficulty of standardization. The same microbial species can generate different metabolite profiles depending on substrate,

fermentation time and processing. For this reason, postbiotic antioxidant claims should be supported by strain information, processing details, chemical fingerprints and biological endpoints rather than only by a single radical-scavenging value [24, 26, 27]. These natural and microbial antioxidants are particularly relevant for skin and aging, because exposed tissues face continuous photochemical and inflammatory stress. Skin is exposed to UV radiation, pollution, thermal stress and inflammatory triggers, making it a practical target for multifunctional antioxidants. Mycosporine-like amino acids, seaweed-derived compounds, ergothioneine and selected postbiotic or peptide ingredients are relevant because they can combine photoprotection, barrier support, anti-inflammatory effects and oxidative stress mitigation [12, 16-18]. Cosmeceutical translation can proceed faster than drug development because claims are often centered on protection, appearance and skin wellness rather than disease treatment. This can accelerate formulation and safety studies, but it also increases the risk of overstated marketing. Scientific evaluation should include photostability, skin penetration, irritation testing, oxidative damage markers and realistic user conditions. Improving photoprotection or reducing markers of photoaging is different from proving efficacy in inflammatory skin disease, even when oxidative stress is involved in both [18, 20]. Their potential value in skin protection also connects with broader questions of metabolic inflammation and healthy aging, where oxidative imbalance is usually part of a wider biological network. Metabolic disease and aging are associated with low-grade inflammation, mitochondrial stress, altered gut microbiota and oxidative imbalance [30]. Natural antioxidants may be most useful as adjunctive modulators rather than stand-alone treatments. Ergothioneine may support tissues under chronic oxidative burden; peptides may affect gut and vascular pathways; postbiotics may influence inflammation and barrier function; and mycosporine-like amino acids may reduce photoaging-related stress [12, 21, 22, 24]. The key is mechanistic matching: a compound intended for neuroprotection should demonstrate tissue access and relevant biomarkers; a gut-directed postbiotic should be evaluated with mucosal and microbial endpoints; and a topical photoprotectant should be tested under UVA and UVB exposure [12, 23, 27]. This mechanism-aware approach prevents natural antioxidant research from becoming a list of disconnected positive assays. In these long-term conditions, antioxidant products may be most defensible when framed as supportive interventions that complement diet quality, physical activity and medical care, but they should not be presented as replacements for metabolic correction. Before these compounds can be compared or promoted, their activity must be interpreted through assays that match their mechanisms and intended applications. Natural antioxidants are frequently promoted using DPPH (2, 2-diphenyl-1-picrylhydrazyl), ABTS (2, 2-prime-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)), FRAP (ferric reducing antioxidant power), or ORAC (oxygen radical absorbance capacity) values. These assays are useful screening tools, but they cannot establish biological efficacy [3, 13]. For ergothioneine, transporter expression and tissue accumulation are central. For mycosporine-like amino acids, photophysical behavior matters. For peptides, digestion stability and sequence-activity relationships are crucial. For postbiotics, composition and host response are more important than a single radical-scavenging number [12, 16, 21, 24]. A stronger evaluation package would combine chemical assays, lipid oxidation models, cellular stress models, bioavailability data and mechanism-specific biomarkers. For skin products this may include UV-induced oxidative markers; for gut products it may include barrier integrity and inflammatory mediators; and for aging studies it may include mitochondrial and systemic inflammatory markers. This layered approach supports more credible claims. For mixed products such as extracts or postbiotics, batch-to-batch reproducibility is as important as initial activity. Without chemical fingerprints or standardized biological markers, positive antioxidant results are difficult to compare across studies [3, 13, 27]. Finally, realistic translation depends not only on biological activity but also on sustainable manufacturing, reproducibility and regulatory positioning. Other indexed studies by the author support a general connection between immune status, inflammation and biochemical monitoring [31, 34].

Sustainability is increasingly relevant in antioxidant selection. Fermentation-derived ergothioneine, valorization of food by-products for peptide production and marine-biomass sourcing of mycosporine-like amino acids connect antioxidant science with green chemistry and circular bioeconomy principles [10, 12, 19, 26]. A moderately potent compound that is safe, scalable and sustainable may have greater real-world impact than a highly potent but impractical molecule. Manufacturing also affects reproducibility. Postbiotics require defined strains, fermentation conditions, inactivation methods and composition control. Peptide products require reproducible hydrolysis and sequence profiling. Marine extracts require source authentication and contaminant monitoring. Natural antioxidants may enter the market as foods, nutraceuticals, cosmetics, medical foods or drug candidates, and each route requires different evidence. Future research should prioritize transparent sourcing, mechanism-matched assays and realistic claims. The translational outlook is strongest when a product satisfies four criteria: mechanistic plausibility, reproducible manufacturing, safety under intended use and an application where oxidative or photochemical stress is clearly relevant [3, 13, 27]. Author-indexed diagnostic and disease-focused publications also illustrate why antioxidant claims should be linked with practical clinical endpoints [35, 38].

4. Conclusion

A moderately potent compound that is safe, scalable and sustainable may have greater real-world impact than a highly potent but impractical molecule. Manufacturing also affects reproducibility: postbiotics require defined strains, fermentation conditions, inactivation methods and composition control, peptide products require reproducible hydrolysis and sequence profiling, marine extracts require source authentication and contaminant monitoring. Natural antioxidants may enter the market as foods, nutraceuticals, cosmetics, medical foods or drug candidates, and each route requires different evidence. Future research should prioritize transparent sourcing, and mechanism-matched assays.

References

1. Sies H, Berndt C, Jones DP. Oxidative stress. Annu Rev Biochem. 2017;86:715-48. doi:10.1146/annurev-biochem-061516-045037.
2. Sies H, Jones DP. Reactive oxygen species (ROS) as pleiotropic physiological signalling agents. Nat Rev Mol

Cell Biol. 2020;21(7):363-83. doi:10.1038/s41580-020-0230-3.
3. Gülçin İ. Antioxidants and antioxidant methods: an updated overview. Arch Toxicol. 2020;94(3):651-715. doi:10.1007/s00204-020-02689-3.
4. Zhang H, Liu Z, Wang Z, Lei Z, Jia Y, Chen W, *et al*. A review of novel antioxidant ergothioneine: biosynthesis pathways, production, function and food applications. Foods. 2025;14(9):1588. doi:10.3390/foods14091588.
5. Zuccarotto A, Sollitto M, Leclere L, Panzella L, Gerdol M, Leone S, *et al*. Molecular evolution of ovothiol biosynthesis in animal life reveals diversity of the natural antioxidant ovothiols in Cnidaria. Free Radic Biol Med. [2]025;227:117-28. doi:10.1016/j.freeradbiomed.2024.11.037.
6. Hammerle FJ, Schopf R, Karg CA, Krumme U, Gostner JM, Karsten U, *et al*. Photoprotective mycosporine-like amino acids in different organs of Baltic flatfish species revealed by targeted and untargeted metabolomics analyses. Front Mar Sci. 2025;12:1688685. doi:10.3389/fmars.2025.1688685.
7. Zhu Y, Lao F, Pan X, Wu J. Food protein-derived antioxidant peptides: molecular mechanism, stability and bioavailability. Biomolecules. [2]022;12(11):1622. doi:10.3390/biom12111622.
8. Amobonye A, Pillay B, Hlope F, Asong ST, Pillai S. Postbiotics: an insightful review of the latest category in functional biotics. World J Microbiol Biotechnol. [2]025;41(8):293. doi:10.1007/s11274-025-04483-8.
9. Syahputra RA, Ahmed A, Asriadi, *et al*. Ergothioneine as a functional nutraceutical: mechanisms, bioavailability, and therapeutic implications. J Nutr Biochem. [2]025;145:110006. doi:10.1016/j.jnutbio.2025.110006.
10. Liang L, Shan-Shan X, Yan-Jun J. Ergothioneine biosynthesis: the present state and future prospect. Synth Syst Biotechnol. 2024;10(1):314-25. doi:10.1016/j.synbio.2024.10.008.
11. Thomas TA, Francis RO, Zimring JC, Kao JP, Nemkov T, Spitalnik SL. The role of ergothioneine in red blood cell biology: a review and perspective. Antioxidants (Basel). [2]024;13(6):717. doi:10.3390/antiox13060717.
12. Lei Z, Wang Z, Zhang H, Jia Y, Zhang D, Shi R, *et al*. Ergothioneine as a promising natural antioxidant: bioactivities, therapeutic potential, and industrial applications. Food Funct. 2025;16:7473-90. doi:10.1039/D5FO02337H.
13. Gülçin İ. Antioxidants: a comprehensive review. Arch Toxicol. 2025;99(5):1893-1997. doi:10.1007/s00204-025-03997-2.
14. Amirova MF, Dadashova AR, Huseynova EE, Kerimova IA, Hasanova ShI, Guliyeva FE, *et al*. Black tea and coffee impact on steroid hormones status in young men. Ukr Biochem J. 2022;94(4):83-92. doi:10.15407/ubj94.04.083.
15. Amirova MF, Azizova GI, Efendiev AM, *et al*. The effect of strong tea and coffee on cortisol and ergogenes in the blood of young men. Azerbaijan Med J. 2022;(4):159-63.
16. Maharramova S, Veliyeva M, Amirova M, Azizova U, Majidova U, Abiyev H, *et al*. Surrounding plants as reliable immune boosters. Health (Irvine Calif). 2022;14:1105-13. doi:10.4236/health.2022.1411078.
17. Urrea-Victoria V, Hernandez AR, Castellanos L, Alves IA, Novoa DMA. The role of mycosporine-like amino acids in skin care formulations: a patent review (2014-2024). Photochem Photobiol Sci. [2]025;24(5):847-61. doi:10.1007/s43630-025-00717-8.
18. Lawrence KP, Long PF, Young AR. Mycosporine-like amino acids for skin photoprotection. Curr Med Chem. 2018;25(40):5512-27. doi:10.2174/0929867324666170529124237.
19. Chrapusta E, Kaminski A, Duchnik K, Bober B, Adamski M, Bialczyk J. Mycosporine-like amino acids: potential health and beauty ingredients. Mar Drugs. [2]017;15(10):326. doi:10.3390/md15100326.
20. Pangestuti R, Shin K-H, Kim S-K. Anti-photoaging and potential skin health benefits of seaweeds. Mar Drugs. 2021;19(3):172. doi:10.3390/md19030172.
21. Rosic NN. Mycosporine-like amino acids: making the foundation for organic personalised sunscreens. Mar Drugs. 2019;17(11):638. doi:10.3390/md17110638.
22. de la Coba F, Aguilera J, Korbee N, de Galvez MV, Herrera-Ceballos E, Alvarez-Gomez F, *et al*. UVA and UVB photoprotective capabilities of topical formulations containing mycosporine-like amino acids (MAAs) through different biological effective protection factors. Mar Drugs. [2]019;17(1):55. doi:10.3390/md17010055.
23. Lee CC, Fan H, Tsopmo A, Regenstein JM. Plant-based antioxidant peptides: impact on oxidative stress and gut microbiota. Crit Rev Food Sci Nutr. [2]025;65(32):8006-29. doi:10.1080/10408398.2025.2490270.
24. Zhou S, Hu X, Lin L. Editorial: Food-derived bioactive peptides: preparation, identification, and structure-activity relationship. Front Nutr. [2]024;11:1412875. doi:10.3389/fnut.2024.1412875.
25. Hamdi A, Lloyd C, Eri R, Van TTH. Postbiotics: a promising approach to combat age-related diseases. Life (Basel). [2]025;15(8):1190. doi:10.3390/life15081190.
26. Rahimi A, Qaisar SA, Janeh T, *et al*. Clinical trial of the effects of postbiotic supplementation on inflammation, oxidative stress, and clinical outcomes in patients with CVA. Sci Rep. [2]024;14:24021. doi:10.1038/s41598-024-76153-y.
27. Asefa Z, Belay A, Welelaw E, Haile M. Postbiotics and their biotherapeutic potential for chronic disease and their future perspective: a review. Front Microbiomes. [2]025;4:1489339. doi:10.3389/frmbi.2025.1489339.
28. Meena KK, Joshi M, Gupta L, Meena S. Comprehensive insights into postbiotics: bridging the gap to real-world application. Food Nutr. 2025;1(2):100024. doi:10.1016/j.fnutr.2025.100024.
29. Rezaie N, Aghamohammad S, Haj Agha Gholizadeh Khiavi E, *et al*. The comparative anti-oxidant and anti-inflammatory efficacy of postbiotics and probiotics through Nrf-2 and NF-kB pathways in DSS-induced colitis model. Sci Rep. [2]024;14:11560. doi:10.1038/s41598-024-62441-0.
30. Jomova K, Raptova R, Alomar SY, Alwasel SH, Nepovimova E, Kuca K, *et al*. Reactive oxygen species, toxicity, oxidative stress, and antioxidants: chronic diseases and aging. Arch Toxicol. [2]023;97(10):2499-2574. doi:10.1007/s00204-023-03562-9.
31. Abdullayeva AM, Mamedova VM, Nasirova VB, Amirova MF. Improving immunity indicators in eyewash with Aktipol in keratoconus. Adv Biol Earth Sci. [2]023;8(2):187-95.

32. Amirova M, Taghiyeva A. Specific biochemical indicators and inflammatory markers in rheumatoid arthritis (RA). Adv Biol Earth Sci. 2024;9(1):175-83. doi:10.62476/abes9175.
33. Amirova M, Huseynova E, Azim S, Nagiyeva S, Lovely M, Dashdamirova G, *et al.* Antibiotic therapy and offstage about Covid-19 vaccination. Health (Irvine Calif). 2022;14:675-83. doi:10.4236/health.2022.146049.
34. Amirova M, Bagirova S, Azizova U, Guliyeva S. The main directions of antimicrobial peptides use and synthesis overview. Health (Irvine Calif). 2022;14:853-65. doi:10.4236/health.2022.148060.
35. Musayeva AK, Amirova MF. Genetic, neuropeptidergic, and cardiometabolic interplay in female central precocious puberty. Cardiovasc Endocrinol Metab. 2025;14(3):e00343. doi:10.1097/XCE.0000000000000343.
36. Dadashova A, Amirova M, Azizova G, Mammadova F. Impact of methylenetetrahydrofolate reductase gene polymorphism on cancer and thalassemia incidence. Zaporozhye Med J. 2025;27(4):320-4. doi:10.14739/2310-1210.2025.4.324860.
37. Amirova MF, Huseynova EE, Baghirova SA, Guliyeva SR, Mammadova FI. Comparative analysis of conventional and novel laboratory assays for the communicable disease hepatitis C. SDGs Rev. 2025;5:e06438.
38. Akhundova JN, Amirova MF. Lymph nodes morphological changes and breast cancer subtypes in prediction of metastases. World Med Biol. 2024;90(4):15-9.

How to Cite This Article
Amirova MFK. Natural and biotechnological antioxidants in health protection. International Journal of Advanced Biochemistry Research Noosphere. 2026;2(1):33–37. doi:10.54660/IJABRN.2026.2.1.33-37.