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The potential of probiotics derived from functional foods for skin health

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Abstract: Probiotics, widely recognised for their benefits in gut health, have gained increasing attention for their comprehensive role in skin health maintenance and improvement. This review explores the multifaceted impact of food-derived probiotics on various aspects of skin health, including anti-aging, inflammation regulation, barrier function enhancement, and hydration. Probiotics exert protective effects against oxidative stress and inflammatory responses through modulation of the gut-skin axis, enhancement of the skin microbiome balance, and immunomodulatory properties. Additionally, functional foods enriched with probiotics have demonstrated efficacy in promoting skin hydration, elasticity, collagen production, and overall resilience. By synthesising recent research findings, this review highlights the potential of probiotic-enriched foods as a natural approach to supporting comprehensive skin health and addressing age-related skin changes. The implications for functional food development and dietary interventions are also discussed, providing insights into future research directions in probiotic-based holistic skin care strategies.

Keywords: microbiome; skin barrier function; oxidative stress; anti-aging; collagen synthesis

Probiotics, defined as specific strains of beneficial microorganisms, have long been recognised for their positive impact on human health and have been incorporated into various food products for decades. These non-pathogenic microorganisms, including certain bacteria and yeasts, modulate the host immune response, inhibit pathogenic microorganisms, and compete for adhesion sites, contributing to their antimicrobial properties. By colonising the gut, probiotics confer a range of health benefits when consumed through functional foods or supplements (Bodke and Jogdand 2022). Consequently, the probiotics market has expanded rapidly, with increasing efforts to incorporate these microorganisms into various food products and dietary supplements (De Simone 2019). Table 1 shows various probiotics used as food ingredients in the world.

While probiotics have traditionally been used to support gastrointestinal health, their application has expanded to include skin, oral, and vaginal health as well (Kumar et al. 2023). As the body's largest organ, the skin serves as a critical barrier against external pathogens. When harmful bacteria colonise the skin, it can lead to tissue damage and chronic inflammatory conditions such as dermatitis, psoriasis, and acne. Conventional treatments for these conditions often rely on antibiotics, which can have adverse effects, including the development of antibiotic resistance. In this context, probiotics and postbiotics have gained attention as promising alternatives to antibiotics for managing chronic skin conditions. Research has demonstrated that probiotics and postbiotics can positively influence skin health by fostering beneficial microorganisms, inhibiting pathogens, stimulating immune responses, enhancing skin barrier function, and regulating inflammation (Rawal and Ali 2023).

The International Scientific Association for Probiotics and Prebiotics (ISAPP) defines prebiotics as sub-

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Table 1. Probiotics used in various products around the world (Bodke and Jogdand 2022).

Probiotic strain (full designation)	Product type	Country
Bifidobacterium bifidum BB-12	infant formula	Türkiye
Bifidobacterium breve M-16V	drink	Japan
Bifidobacterium animalis subsp. *lactis* Bl-04	infant formula	Israel
Lactobacillus acidophilus NCFM	yogurt	UK
Lacticaseibacillus casei Shirota	drink	Japan, Argentina, Australia, Belgium, Brazil, China, Germany, Indonesia, UK, USA, Taiwan
Lacticaseibacillus casei DN-114001	yogurt	France, USA
Lactococcus lactis L1A	yogurt	Sweden
Lactiplantibacillus plantarum 299v	fruit drink, ice cream, recovery drink, oat mixture	Sweden
Lacticaseibacillus rhamnosus GG (ATCC 53103)	yogurt, dietary supplements	Finland, USA
Streptococcus thermophilus ST-M5	yogurt	Global

strates that, when utilised by microorganisms, confer beneficial effects on the host (Gibson et al. 2017). These compounds, such as fructooligosaccharides (FOS), galactooligosaccharides (GOS), and inulin, promote the activity of gut microbiota and have been shown to support skin health as well (Azad et al. 2018; Wang et al. 2020). For example, extracts derived from *Lactobacillus plantarum* and *Lactobacillus paracasei* strains have been found to reduce acne lesions, alleviate skin erythema, enhance skin barrier function, and decrease microbial presence on the skin (Muizzuddin et al. 2012). GOS have been utilised not only for their beneficial effects in photoaging but also in the management of atopic dermatitis and eczema (Lolou and Panayiotidis 2019; Mahmud et al. 2022). Furthermore, recent research demonstrated that the combination of GOS and *Bifidobacterium* significantly reduced transepidermal water loss (TEWL) and helped prevent erythema, suggesting their potential role in enhancing skin barrier function.

This review aims to investigate the growing role of food-derived probiotics in mitigating skin aging and enhancing photoprotection. By synthesising current research, the review will explore the mechanisms through which probiotics and postbiotics influence skin aging processes, protect against ultraviolet (UV)-induced damage, and promote overall skin health. Furthermore, this paper will examine how the incorporation of probiotics into functional food products and dietary supplements can serve as an effective strategy to prevent premature skin aging and improve skin resilience against environmental stressors.

LITERATURE SEARCH STRATEGY

This review was initiated out of interest in understanding how food-derived probiotics influence skin aging and their potential photoprotective mechanisms. The literature review was conducted from January 8–27, 2025, with the goal of summarising the current state of research on this topic. The review aims to elucidate how probiotics derived from food sources can modulate biological processes related to skin aging, including their roles in antioxidation, anti-inflammation, and photoprotection. In doing so, the review also explores how probiotics can strengthen the skin barrier, enhance hydration, and protect against ultraviolet (UV)-induced damage. Below, the search strategy, article selection methods, and data synthesis procedures are described in detail.

Search strategy. Following the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines, a comprehensive literature search was conducted using three primary databases: PubMed, Medline, and Scopus. The search employed a combination of keywords and Medical Subject Headings (MeSH) terms relevant to the core topics of the review. Search terms included: 'food-derived probiotics', 'skin aging', 'photoprotection', 'probiotic mechanisms', 'gut-skin axis', 'oxidative stress', 'inflammation', 'UV protection', and 'skin barrier function'. The search targeted studies published between 2019 and 2024, focusing on research involving human subjects, *in vitro* studies, animal models, and relevant clinical or epidemiological evidence. To ensure comprehensive coverage, manual searches

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of reference lists from key articles were also performed. The literature search strategy and review process are illustrated in the PRISMA 2020 flow diagram (Figure 1).

Eligibility criteria. Studies were eligible for inclusion if they examined the effects of food-derived probiotics on skin aging processes or photoprotective mechanisms. Eligible studies addressed at least one of the following criteria: (*i*) investigation of antioxidative or anti-inflammatory effects of probiotics related to skin aging; (*ii*) evaluation of probiotics' roles in strengthening the skin barrier or improving hydration; (*iii*) analysis of probiotic-mediated photoprotection, including reduction of UV-induced damage; or *iv*) examination of the gut-skin axis and its connection to skin health and aging. Clinical trials, *in vitro* studies, *in vivo* animal studies, and epidemiological research were considered, provided they were published in peer-reviewed journals or reputable sources. Studies were excluded if they focused on non-food-derived probiotics, lacked relevant data, or did not directly relate to skin aging or photoprotection. Reviews, conference abstracts without full-text availability, and unpublished dissertations were also excluded.

Screening and data extraction. The initial search results were screened by title and abstract to exclude irrelevant studies. Full-text articles of potentially eligible studies were then assessed for inclusion. During the data extraction process, we systematically collected detailed information from each included study. Specifically, we examined the type of study design (e.g. randomised controlled trial, *in vitro* study), the specific probiotic strains investigated, the probiotic dosage and administration method (e.g. oral supplement or topical application), the primary measured outcomes related to skin aging and photoprotection (e.g. wrinkle depth, transepidermal water loss, erythema), and the biological mechanisms proposed through the effects of probiotics on the skin. Extracted data focused on identifying how food-derived probiotics modulate oxidative stress, inflammation, and skin barrier function, as well as their effects on mitigating UV-induced skin damage. In cases where studies included both human and animal data, findings were categorised accordingly to ensure clarity and relevance. Duplicate records in the research selection or data extraction process were removed. This systematic approach ensured a thorough examination of recent research on the influence of food-derived probiotics on skin aging and photoprotection.

RESULTS

Photoprotective and anti-aging effects of food-derived probiotics. Aging is characterised by the gradual

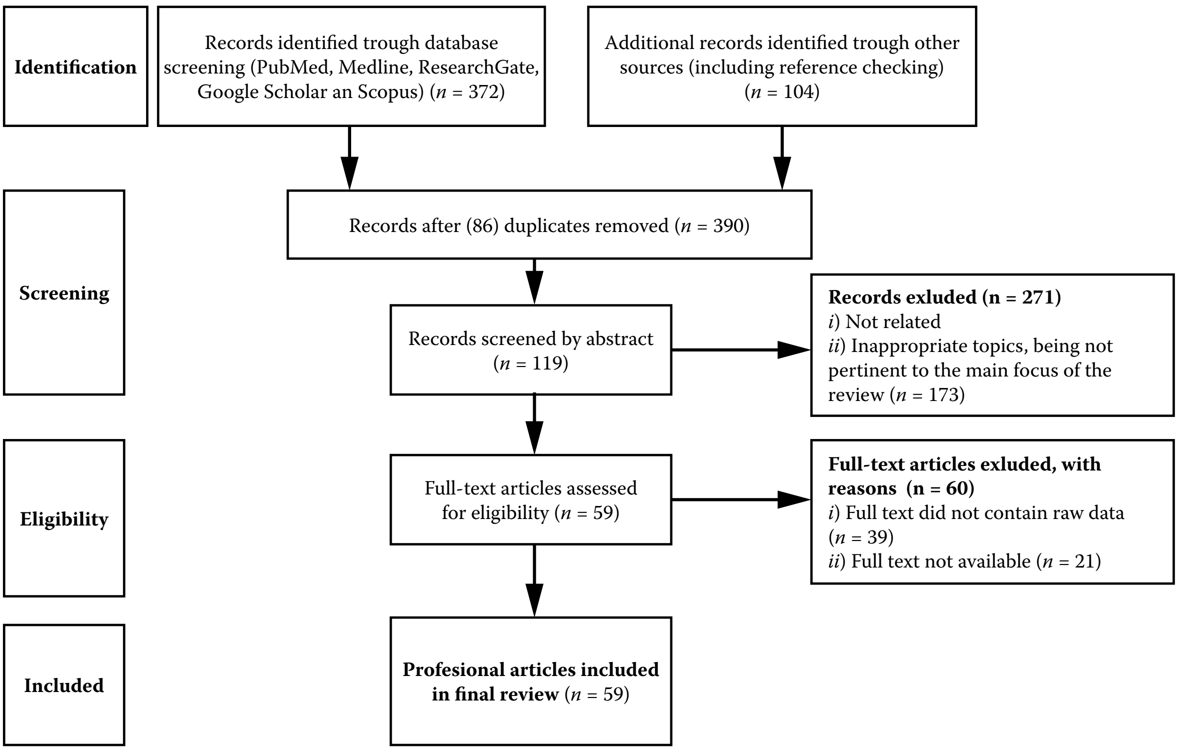

Figure 1. PRISMA flow chart for literature review search results (Authors' own creation)

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decline of biological functions, resulting in irreversible physiological dysfunction and an increased susceptibility to age-related diseases (Jones et al. 2014). External factors such as ultraviolet radiation, dietary composition, and environmental conditions are significant contributors to the aging process (Stoessl 1999; Di Ciaula and Portincasa 2020). A hallmark of cutaneous aging is the formation of wrinkles, primarily driven by the degradation of collagen fibres. Reactive oxygen species (ROS) and free radicals play a critical role in this process by impairing collagen biosynthesis and inhibiting the proliferation of keratinocytes and fibroblasts, ultimately weakening the structural connection between the epidermal and dermal layers. Consequently, the suppression of collagen production and the promotion of cellular apoptosis are fundamental mechanisms underlying skin aging (Li et al. 1996). Addressing these molecular pathways is essential for developing effective strategies to prevent and mitigate age-related conditions (Tang et al. 2016; Longo and Anderson 2022). Among various interventions, dietary modulation has emerged as a key factor in enhancing health span and delaying the onset of aging-related physiological decline. In particular, bioactive compounds derived from food sources – such as polyphenols, flavonoids, carotenoids, and bioactive peptides – demonstrate potent antioxidant properties. These compounds effectively scavenge ROS and reactive nitrogen species (RNS), thereby reducing oxidative stress and its detrimental effects on skin integrity and overall aging (Li et al. 2023).

Ultraviolet radiation (UVR) is a predominant extrinsic factor that adversely affects skin health through multiple mechanisms. Chronic exposure to UVR accelerates skin aging, commonly referred to as photoaging, by directly impairing the structural integrity of cellular components, including DNA, RNA, and proteins. Such damage disrupts the homeostatic balance essential for maintaining skin function and resilience. Moreover, UVR stimulates the intracellular generation of ROS, which exacerbates molecular damage by inducing oxidative stress and further compromising the genetic material within skin cells (Teng et al. 2022).

The maintenance of a stable and healthy skin microenvironment is profoundly influenced by the skin microbiome, which predominantly consists of bacterial genera such as *Cutibacterium*, *Corynebacterium*, *Staphylococcus*, and *Streptococcus* (Byrd et al. 2018). Similar to the gut microbiome, the skin microbiome plays a pivotal role in defending against external pathogens, modulating immune responses, and regulating metabolic processes (Li et al. 2020). Probiotics, defined as live microorganisms that confer health benefits to the host by modulating the composition of local microbiota, have been increasingly recognised for their potential to enhance skin health (Reid et al. 2003). A growing body of evidence highlights the close association between skin microbiome balance and the maintenance of skin integrity and resilience. The concept of the gut-skin axis emphasises the interconnection between the gastrointestinal microbiome and skin health, mainly through immunomodulatory pathways. Both the consumption of probiotics and topical administration have emerged as promising interventions for the prevention of photoaging of the skin. In particular, probiotic consumption can exert a photoprotective effect on the skin by modulating the composition of the gut microbiota, thereby affecting immunomodulation and the production of inflammatory cytokines. In addition, it has been shown that taking probiotics can increase blood levels of short-chain fatty acids (SCFAs) such as acetate, which can trigger beneficial immune and anti-inflammatory responses that contribute to skin homeostasis (Teng et al. 2022). Figure 2 summarises the role of probiotics in skin photoaging.

In addition, probiotics have a positive effect on skin health, such as reducing oxidative stress levels, inhibiting inflammatory cascades, and maintaining immune homeostasis.

Lim et al. (2020) demonstrated that *Lactobacillus acidophilus* KCCM12625 exhibits remarkable antioxidant properties and effectively alleviates the increase in reactive oxygen species (ROS) levels in HaCaT keratinocytes after UVB exposure. This intervention was shown to alleviate photoaging of the skin caused by oxidative stress. Similarly, Ishii et al. (2014) reported that the consumption of *Bifidobacterium breve* Yakult significantly inhibited ROS production in an animal model and reduced UV-induced damage to the skin barrier, highlighting its potential to counteract oxidative stress and maintain skin integrity.

In addition to its antioxidant effects, *Lactobacillus acidophilus* IDCC3302, one of the probiotics, has been shown to alleviate UVB-induced skin inflammation by modulating the MAPK (mitogen-activated protein kinase) signalling pathway and thereby suppressing the production of pro-inflammatory cytokines (Im et al. 2019). Similarly, Keshari et al. (2019) reported that butyric acid produced by a new probiotic strain of Staphylococcus epidermidis can alleviate the inflammatory cascade by downregulating interleukin-6 (IL-6) expression through activation of the short-chain fatty acid receptor. Certain probiotic strains, such as *Lactobacillus paracasei*, have been shown to enhance immune

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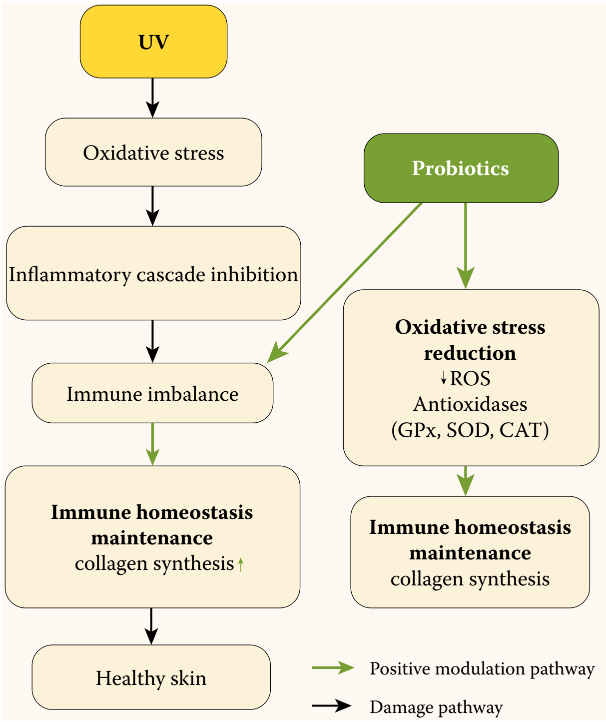

Figure 2. The role o f probiotics in skin photoaging adapted from Teng et al. (2022). It summarises the mechanisms of action of probiotics in photoaging, such as reducing oxidative stress levels, inhibiting the inflammatory cascade, and maintaining immune homeostasis

GPx – glutathione peroxidase; SOD – superoxide dismutase; CAT – catalase; ROS – reactive oxygen species

responses, facilitating the elimination of pathogenic microorganisms (Kober and Bowe 2015). Moreover, these probiotics play a crucial role in modulating immune activity by suppressing excessive immune reactions, thereby promoting immune homeostasis and mitigating chronic inflammatory conditions.

Probiotics that relieve inflammation related to skin aging. The skin, along with other tissues, serves as a critical interface between the host and the external environment, continuously exposed to various external stressors. To preserve homeostasis under inflammatory conditions, diverse immune cell populations either reside within or are recruited to the skin (Kabashima et al. 2019). Both immune and non-immune cells in the epidermis and dermis collectively form an organised structure known as the skin-associated lymphoid tissue (SALT), which plays a pivotal role in cutaneous adaptive immunity. Initially conceptualised in the early 1980s, this framework emphasises the skin's capacity to capture, process, and present antigens, positioning it not only as a physical barrier but also as an integral component of the lymphatic and immune systems (Hsu et al. 2014). Natural products (NPs) have long been explored for their wide-ranging applications in health and disease management, largely attributed to their multifunctionality, favourable safety profiles, and cost-effectiveness. Numerous bioactive compounds derived from NPs – such as fatty acids, polyphenols, polysaccharides, and probiotics – have shown significant potential in modulating immune responses (Wang et al. 2021).

Numerous studies have demonstrated the therapeutic potential of NPs in managing various skin disorders. The growing demand for novel compounds with antibiotic and anti-inflammatory properties has intensified research efforts to identify alternative strategies to combat antibiotic resistance (Yousefi et al. 2021; Mahdi et al. 2022). Bioactive peptides exhibit a wide range of pharmacological properties, including antimicrobial, antioxidant, and immunomodulatory effects. Probiotics, in particular, have been recognised for their ability to inhibit infections, modulate inflammatory responses, and potentially enhance the wound healing process. Notably, both topical and systemic applications of probiotics have demonstrated beneficial outcomes in managing inflammatory skin disorders, such as atopic dermatitis and various skin infections (Knackstedt et al. 2020).

In recent decades, there has been a significant increase in research highlighting the crucial role of microbiota in both health and disease. While investigations into the cutaneous microbiota are relatively newer, the evidence gathered so far underscores its essential contribution to maintaining skin homeostasis, with some considering it a 'second barrier' against environmental insults. The beneficial effects of probiotics have been demonstrated in certain dermatological conditions, such as atopic dermatitis and acne. However, their impact on other skin disorders, including psoriasis and rosacea, remains less thoroughly studied (Fernandes et al. 2023). The effects of probiotics can be both local and systemic. In animal models, oral administration of probiotics has been shown to enhance insulin sensitivity and regulate the release of inflammatory cytokines in the skin via interactions with gut-associated lymphoid tissue (Hsieh et al. 2013). Recent studies have also demonstrated that not only do various skin conditions influence the composition of the gut microbiome in humans, but the presence of certain skin diseases is often associated with pre-existing alterations in the gut microbiome (Kober and Bowe 2015). Furthermore, research has highlighted a fundamental connection between the skin and gut

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microbiomes, referred to as the gut-skin axis. This relationship appears to be mediated by the host's immune system, with both organs communicating through diet, microbial metabolites, neuroendocrine pathways, and the central nervous system (De Pessemier et al. 2021).

Over the past decade, the availability of commercially available probiotics has increased significantly, mainly due to their growing popularity. These probiotics are attracting attention not only as a treatment for various skin diseases, but also as a potential agent for slowing down skin aging and preventing photoaging. For example, probiotics that target the immune system have shown significant benefits in acne patients, suggesting that they affect the whole body, including the skin (Kim et al. 2018; Porubsky et al. 2018). A pivotal development in this field was the discovery of the role of topical probiotics in promoting the production of ceramides in the skin. Di Marzio et al. (1999) demonstrated that the addition of *Streptococcus thermophilus* to human keratinocyte cultures increases ceramide synthesis, which appears to be due to the presence of the sphingomyelinase enzyme in the bacteria. Sphingomyelinase is known to hydrolyse sphingomyelin into ceramide, and similar enzymes have been identified in other bacteria such as *Bacillus*, *Listeria*, *Staphylococcus*, and *Mycobacterium*. Sphingomyelinase and phospholipase are associated with bacterial virulence, but they have potential therapeutic effects in the treatment of acne, especially in cases where ceramide levels are reduced (Flores-Díaz et al. 2016). Figure 3 illustrates the various mechanisms by which topical and oral applications modulate the immune response of the skin, as research into the role of probiotics in the skin is increasing.

The synergistic effect of probiotic functional food for skin health. The skin, as the body's largest and most externally exposed organ, serves a crucial role in safeguarding against environmental aggressors. Dietary patterns and lifestyle choices substantially influence the process of skin aging. Although numerous synthetic skincare products are commercially available, prolonged use may lead to adverse effects such as irritation, erythema, desquamation, blistering, and hyperpigmentation. Consequently, natural remedies and adherence to a balanced diet are considered preferable therapeutic strategies. Nonetheless, mere food consumption is insufficient; instead, a carefully planned, nutrient-rich diet is essential to support the regeneration and maintenance of the integumentary system. The concept of 'functional food' refers to food products that offer additional health advantages beyond basic nutrition. These foods hold potential as natural interventions for various health concerns. In particular, functional foods enriched with probiotics, collagen, lipids, proteins, vitamins, and minerals have demonstrated efficacy in decelerating or preventing wrinkle formation and age-related skin changes (Muraleedharan et al. 2023).

Oral supplementation with probiotics has demonstrated potential in mitigating skin aging and enhancing skin health through various biological mechanisms. In murine models, administration of *Bifidobacterium breve* B-3 has been shown to ameliorate UV-induced photoaging by reducing transepidermal water loss and epidermal thickening, preserving basement membrane integrity, and lowering cutaneous IL-1β levels (Satoh et al. 2015). Similarly, treatment with a tyndallised preparation (sterilised through intermittent heating) of *Lactobacillus acidophilus* in aged rats resulted in diminished wrinkle formation, improved skin hydration, and decreased epidermal moisture loss, alongside the suppression of MMP-1 and MMP-9 expression (Im et al. 2016). For instance, oral intake of heat-killed *Lactococcus lactis* strain H61 improved skin condition in Japanese women, likely through modulation of gut microbiota, antioxidant activity, and immune regulation (Kimoto-Nira et al. 2012)

Moreover, *Lactococcus lactis* NCC 2461 has been reported to enhance skin barrier function and reduce sensitivity in human clinical trials by inhibiting neurotransmitter release involved in sensory responses (Gueniche et al. 2014). Although the precise pathways underlying these probiotic-mediated dermatological benefits remain to be fully elucidated, emerging evidence supports their promising role in photoprotection and skin homeostasis.

Emerging evidence indicates that gut-resident commensal microorganisms play a pivotal role in regulating systemic immune responses, thereby contributing to the maintenance of skin homeostasis. Recent intervention studies have explored the therapeutic potential of probiotics in the prevention and management of various dermatological conditions, including atopic dermatitis, allergic rhinitis, and impaired wound healing (Bakir et al. 2025). Probiotics play a crucial role in supporting the regulation and maintenance of immune functions in the human body, as well as in mitigating allergic responses. While they hold promise as a therapeutic approach for allergies, it is essential to carefully select the appropriate probiotic strain(s), standardise the dosage, and possess a comprehensive understanding of their beneficial effects, particularly in comparison to any potential toxic effects (Patel and Shah 2014).

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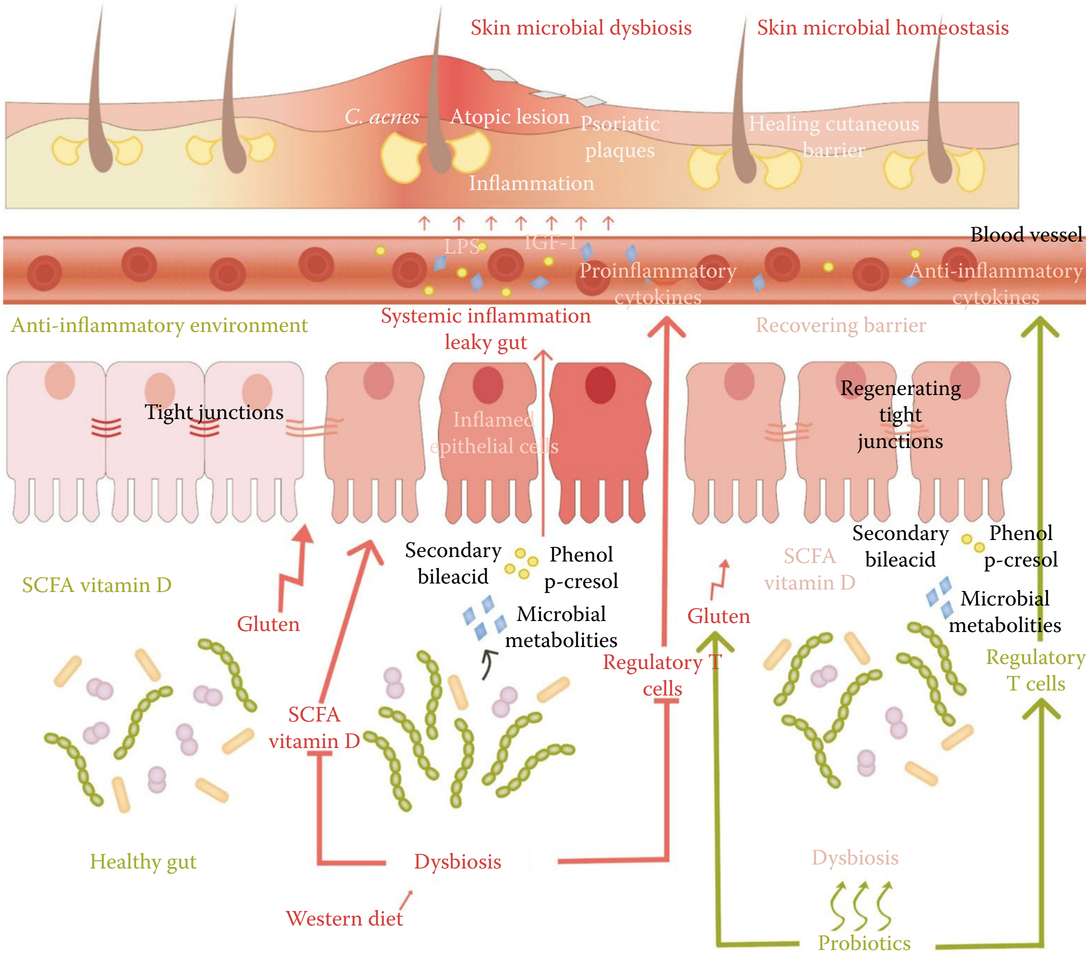

Figure 3. Probiotic intervention to help alleviate the inflammatory state adapted from Szanto et al. (2019). It highlights the potential sites of action of probiotic intervention that can alleviate the inflammatory state of the skin

SCFA – short-chain fatty acids, i.e. fatty acids with fewer than six carbon atoms (e.g. acetate, propionate, butyrate); LPS – lipopolysaccharide, an outer membrane component of Gram-negative bacteria, can cause a strong immune response and inflammation when it enters the bloodstream; IGF-1 – Insulin-like growth factor 1, a hormone similar in structure to insulin, involved in cell growth and development, high levels can influence skin conditions like acne; p-cresol – para-cresol, a microbial metabolite derived from amino acid breakdown, in excess, it may have toxic effects and contribute to inflammation

Vegetables and fruits are rich sources of bioactive compounds that play a significant role in mitigating diseases such as cancer, aging, and oxidative stress. The incorporation of lactic acid bacteria into these foods has been shown to enhance their nutritional profile and functional properties. Fermentation remains the predominant technique employed to develop probiotic-enriched vegetable and fruit products. In a study by Chan et al. (2022) fermented pomegranate products utilising *Saccharomyces cerevisiae* and *Lactiplantibacillus plantarum* demonstrated notable improvements in skin parameters, including brightness, collagen density, elasticity, and hydration following an eight-week intervention. Similarly, research conducted by Chan et al. (2021) revealed that consumption of apple juice fermented with *S. cerevisiae* and *Streptococcus thermophilus* stimulated collagen production and attenuated signs of skin aging in individuals aged 35 to 55 years. Additionally, oral administration of soymilk fermented with *Lactobacillus casei* Shirota over a 12-week period was associated with enhancements in various skin characteristics, such as texture, dryness, elasticity, hydration, pigmentation, and the structural integrity of the stratum corneum (Nagino et al. 2018). Functional foods containing probiotics for skin health are well organised in Table 2.

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DISCUSSION

While this review highlights the potential benefits of probiotics in preventing skin aging and providing photoprotection, the field of probiotic intake for skin care remains in its early stages. Extensive research is still required to elucidate their effectiveness and underlying biological mechanisms across diverse dermatological conditions (Lee et al. 2019). Additionally, there is a pressing need to refine regulatory frameworks and establish comprehensive guidelines governing the use of probiotics as functional foods. As scientific exploration in this area progresses, future studies are expected to offer greater insight into the therapeutic applications of probiotic-based functional foods for skin health and disease management (França 2021).

Impact of food components on probiotic viability. The interaction between probiotics and food components plays a critical role in determining the stability, viability, and functionality of probiotics during production, storage, and consumption. Various additives commonly used in food manufacturing, including salts, sugars, sweeteners, and flavouring agents, have been shown to significantly affect probiotic survival rates (Burgain et al. 2014). For instance, Rodríguez et al. (2009) reported that certain polyphenolic compounds found in plant-based foods, although beneficial to human health, can inhibit the growth and metabolic activity of lactic acid bacteria.

Moreover, the composition of the food matrix itself can influence the protective environment surrounding probiotics. In fruit-based matrices, probiotics often encounter acidic conditions, which can impair their viability unless encapsulation techniques are employed (Horáčková et al. 2018). Aziz et al. (2023) demonstrated that the addition of 8% sucrose to pineapple juice significantly improved the survival of *Lactiplantibacillus plantarum* over 42 days of refrigerated storage, suggesting that specific carbohydrate supplementation can serve as a stabilising strategy.

However, even with such strategies, maintaining probiotic viability remains challenging, particularly under non-refrigerated conditions. Yoha et al. (2022) emphasised that probiotics exposed to high humidity and low pH environments are prone to metabolic inactivation and oxidative damage, thereby reducing their functional efficacy. These findings underscore the need for innovative encapsulation and stabilisation technologies that can extend the shelf life of probiotics in functional foods without compromising sensory qualities.

Encapsulation using milk protein matrices has emerged as a promising technique to enhance probiotic stability, especially in acidic beverages such as citrus-based juices (Horáčková et al. 2018). Nevertheless, as Burgain et al. (2014) pointed out, the interaction between the encapsulating materials and the host food matrix must be carefully optimised to prevent adverse changes in probiotic metabolism and food quality attributes.

Overall, although significant progress has been made in improving probiotic survival within functional foods, future research is needed to develop standardised, cost-effective methods that ensure both probiotic efficacy and consumer acceptability under practical storage conditions (Yoha et al. 2022).

Challenges in studying food-derived probiotics for skin health. Despite growing interest, research on the impact of food-derived probiotics on skin health remains in its early stages and faces significant challenges (Lee et al. 2019). One primary difficulty lies in the lack of standardised protocols regarding probiotic strain selection, optimal dosage, and administration duration necessary to achieve consistent dermatological benefits (França 2021).

Table 2. Probiotics functional food for healthy skin (Authors' own creation)

Functional food (probiotic source)	Reported skin health benefit
Fermented pomegranate (with *Saccharomyces cerevisiae* and *Lactiplantibacillus plantarum*)	improved skin brightness, collagen density, elasticity, and hydration
Fermented apple juice (with *Saccharomyces cerevisiae* and *Streptococcus thermophilus*)	increased collagen production and reduced signs of skin aging
Ffermented soymilk (with *Lactobacillus casei* Shirota)	enhanced skin texture, reduced dryness, improved elasticity, hydration, pigmentation, and stratum corneum integrity
Functional foods containing lactic acid bacteria	anti-wrinkle effects, moisturising properties, antioxidant activity, and modulation of gut-skin axis
Bifidobacterium breve B-3 supplementation	reduced UV-induced transepidermal water loss, epidermal thickening, and cutaneous inflammation

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The biological mechanisms by which orally ingested probiotics influence skin physiology are not yet fully understood, particularly concerning how gut microbiota alterations translate into improvements in skin barrier function and inflammation regulation (De Pessemier et al. 2021). Furthermore, individual variability – including age, sex, skin type, gut microbiome composition, and dietary habits – can significantly impact the efficacy of probiotic interventions for skin health (Bakir et al. 2025).

Another major limitation is the challenge of ensuring probiotic viability through the gastrointestinal tract and achieving sufficient colonisation or activity to exert systemic effects, including on the skin (Burgain et al. 2014). Although encapsulation techniques and functional food formulations have shown promise in enhancing probiotic survival, these methods require further refinement to optimise bioavailability without compromising sensory properties or consumer acceptance (Horáčková et al. 2018).

Additionally, while some clinical studies have demonstrated the photoprotective and anti-aging effects of probiotics, much of the existing evidence is derived from small-scale trials or animal models, thus limiting the generalisability to broader human populations (Ishii et al. 2014; Satoh et al. 2015). Large, well-designed randomised controlled trials are urgently needed to validate the therapeutic potential of food-derived probiotics for skin health and to determine their long-term safety and efficacy profiles (França 2021).

Ultimately, addressing these challenges will be crucial for advancing the field and for the successful development of probiotic-based functional foods targeted at improving skin health and resilience.

CONCLUSION

The growing body of evidence supports the role of food-derived probiotics in promoting skin health, particularly in mitigating skin aging and enhancing photoprotection. Through their antioxidant, anti-inflammatory, and immunomodulatory properties, probiotics influence critical biological pathways that contribute to skin integrity and resilience. Functional foods enriched with probiotics offer a promising avenue for developing dietary strategies aimed at preventing premature skin aging and protecting against environmental stressors. However, further clinical research is necessary to establish standardised probiotic strains, optimal dosages, and long-term effects on skin health. Future studies should also explore the integration of probiotics into innovative food formulations to maximise their bioavailability and efficacy. As interest in functional foods continues to rise, probiotic-based dietary interventions may serve as a valuable tool in advancing skin health and overall well-being.

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