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Review

The Therapeutic Potential of Probiotics in Restoring Skin Microbiome Balance and Managing Dermatological Disorders

Anis Ahmad Chaudhary[1,*]

[1]Department of Biology, College of Science, Imam Mohammad Ibn Saud Islamic University (IMSIU), 11564 Riyadh, Saudi Arabia
*Correspondence: aachaudhary@imamu.edu.sa (Anis Ahmad Chaudhary)
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Abstract

The skin microbiome is a diverse ecosystem essential that is for maintaining barrier integrity and regulating immune responses. Disruptions to this ecosystem (dysbiosis) are associated with a range of dermatological disorders (including acne, atopic dermatitis, and psoriasis). Probiotic skincare uses live, beneficial microorganisms or their derivatives to restore microbial balance, reduce inflammation, and strengthen the skin's barrier. Mechanistically, probiotics produce antimicrobial substances (e.g., lactic acid, bacteriocins, and H_2O_2) that inhibit pathogens, lower skin pH, stimulate antimicrobial peptide production, and modulate immunity. Studies have shown effectiveness in key conditions. For example, probiotic strains (e.g., *Streptococcus salivarius*) can inhibit *Cutibacterium acnes* in acne treatment. Additionally, topical preparations derived from *Vitreoscilla filiformis* have been shown to reduce *S. aureus* colonization and improve clinical outcomes in atopic dermatitis. In psoriasis, oral probiotics have been shown to reduce disease severity and inflammation markers. Moreover, probiotic promote wound healing through anti-pathogenic and antibiofilm activities and protect against ultraviolet (UV)-induced damage by boosting antioxidant defenses. Emerging trends include the use of postbiotics (inactive probiotic components) and research into the gut–skin axis. Ongoing research is focused on identifying new probiotic strains, optimizing formulations, and developing targeted delivery methods to improve the use of probiotics in skincare applications. Meanwhile, growing consumer interest and market investment are accelerating translation into cosmetic and therapeutic products. Collectively, current evidence underscores the significant potential of probiotic-based strategies as adjunctive or novel approaches for the management of dermatological disorders.

Keywords: probiotics; skin microbiome; skin disorders; cosmetics; *Lactobacillus*; *Cutibacterium acnes*

1. Introduction

The skin microbiome is a highly dynamic and intricate community of microorganisms—including bacteria, fungi, and viruses-that reside on the skin's surface and are crucial for maintaining skin health. Similar to the gut microbiome, it includes a wide variety of microbial species that support protective and regulatory functions. From birth, this microbial ecosystem is influenced by multiple factors, such as genetics, environmental exposure, hygiene habits, and aging. Maintaining the diversity and balance of the skin microbiota is vital for optimal skin function. A healthy microbiome helps protect against harmful microbes by competing with them for nutrients and space, which lowers the risk of infection. It also enhances the skin's barrier, regulates immune responses, and plays an important role in controlling inflammation.

Furthermore, the skin microbiome interacts with immune cells to regulate immune responses, preventing unnecessary inflammation and allergic reactions. When the balance of the skin microbiome is disturbed, a condition called dysbiosis occurs. Dysbiosis allows opportunistic pathogens to flourish and has been linked to various skin issues, including acne, eczema, and autoimmune diseases like psoriasis [1]. Probiotics interact with the existing skin microbiota and modulate the immune system. This interaction helps in maintaining the skin's homeostasis and protecting it from external aggressors. Studies have shown that topical probiotics can be effective in treating various inflammatory skin diseases such as acne, rosacea, and psoriasis, due to their ability to reduce inflammation and enhance wound healing [2,3].

Probiotics, which are live microorganisms conferring health benefits to the host, have gained significant attention for their role in enhancing skin health. The skin is the body's largest organ, serving as a critical barrier against environmental threats, and maintaining its health is paramount. Recent research highlights several mechanisms through which probiotics can support skin health.

Moreover, probiotics have been found to influence the skin indirectly through the gut-skin axis. The concept of a gut-skin axis brings into focus how the balance of intestinal microbiota can be reflected in skin health. Probiotics help restore and maintain this balance, which, in turn, can reduce oxidative stress and inflammatory responses on the skin, potentially improving conditions like eczema and atopic dermatitis [4,5].

Interest in probiotics is increasing within the realm of micro-ecological skincare, particularly for their roles in skin whitening, moisturizing, and anti-aging treatments. Skincare products that incorporate probiotics have been shown to reduce skin wrinkles, boost skin hydration, and even mitigate body odor [6]. Given the potential of probiotics to enhance skin health, the current review delves into their mechanisms of action and determines effective dosages to ensure safety. It also investigates and validates the effectiveness of specific probiotic strains in skincare, setting the stage for new therapeutic approaches.

2. Methods

A comprehensive literature search was performed across major electronic databases, including PubMed, Web of Science, Scopus, and Embase. The search strategy employed a combination of keywords and Medical Subject Headings terms, utilizing Boolean operators ("AND", "OR") to maximize sensitivity and specificity. Key search terms included: "probiotics", "prebiotics", "postbiotics", "skin microbiome", "cutaneous microbiome", "dermatological disorders", "skin diseases", "atopic dermatitis", "eczema", "acne", "psoriasis", "wound healing", "skin health", "skin barrier."

Specific term combinations included: ("probiotics" OR "prebiotics" OR "postbiotics") AND ("skin microbiome" OR "cutaneous microbiome") AND ("dermatological disorders" OR "skin diseases" OR "atopic dermatitis" OR "acne" OR "psoriasis" OR "wound healing"). Reference lists of included articles and relevant reviews were also manually screened for additional pertinent studies.

3. Role of Probiotics in Restoring Skin Microbiome Balance

3.1 Empire of Microbials on Skin

The skin, as the body's largest organ, performs numerous functions, including protection against pathogens, regulation of body temperature, sensory perception, and storage of lipids and water [7]. Skin acts as a mediator between internal organs and the external environment. The microflora present on the skin is categorized into two types: resident and transient (Fig. 1). Resident microbes, such as *Cutibacterium acnes* (formerly known as *Propionibacterium acnes*) [8] and *Staphylococcus epidermidis*, adhere to the skin surface, are metabolically active, and play a central role in maintaining skin homeostasis. Transient species (deposited but not adhering and not reproducing on skin surfaces) consist of pathogens such as *Streptococcus pyogenes* and *Staphylococcus aureus*, which cause infections [9].

3.2 Microbial Mechanisms Supporting Probiotic Skincare Efficacy

In contemporary research, a growing scholarly focus has emerged on the use of probiotics in dermatology, attributed to their potential health benefits. These beneficial microorganisms, which provide health advantages to their host, have several mechanisms of action. They can produce substances such as hydrogen peroxide, organic acids (including lactic acid), and bacteriocins, which can directly suppress or eliminate harmful bacteria [10,11].

Additionally, the acids generated by probiotics, particularly lactic acid, help lower the skin's pH. This more acidic environment is less favourable for many pathogenic bacteria, which prefer a neutral pH for optimal growth [10]. Skin cells can produce more antimicrobial peptides when certain probiotics are taken. The skin's innate immune defense includes antimicrobial peptides, which help shield the skin from various illnesses [12]. Some probiotics interfere with quorum sensing, a communication system used by bacteria to coordinate their behavior, including the production of virulence factors. By disrupting this communication, probiotics can diminish the pathogen's capacity to cause damage [13].

Bacteria create protective shields called biofilms to guard themselves against environmental factors and antimicrobial agents. Some probiotics can prevent biofilm formation, thus increasing the susceptibility of infections to elimination by breaking down their protective layers.

Besides lactobacilli and bifidobacterial, other unconventional probiotics linked to a healthy skin microbiome have been shown to have beneficial effects on skin healing. *S. thermophilus* produces sphingomyelinase, which stimulates the production of phosphorylcholine and ceramides by keratinocytes in a time-dependent manner [14]. The topical use of *S. thermophilus* has been shown to increase ceramide concentrations in the stratum corneum of normal, healthy skin. Ceramides play a crucial role in forming extracellular lipid bilayers, which strengthen the skin's lipid barrier [15]. Decreased ceramide levels have been linked to epidermal barrier dysfunction, including reduced defence against microbes and antigens [16].

Therefore, probiotic therapies that stimulate ceramide synthesis may support the restoration of the skin barrier during wound healing. *S. epidermidis*, a well-characterized commensal and probiotic species of the skin, secretes an extracellular serine protease that impedes the colonization of *S. aureus* through multiple actions. This enzyme breaks down the biofilm structure, degrades host surface proteins necessary for *S. aureus* adhesion and infection—such as Protein A, fibronectin, fibrinogen, and vitronectin—and effectively prevents the establishment of *S. aureus* biofilms [17]. Skin's outermost layer acts as the primary defense against external threats. The microbiome influences the development of the stratum corneum, a protective barrier composed of multiple thin layers of epidermal keratinocytes that undergo a tightly regulated process of terminal differentiation. Epidermal keratinocytes are held closely together by tight junctions and adherent junctions, creating an almost impenetrable barrier against harmful microorganisms [18].

In the epidermis, keratinocytes form a robust defense against harmful microorganisms through tight junctions and adherent connections, which maintain their close physical contact. During wound healing, proteins such as zona occludent, found in tight junctions, aid in keratinocyte proliferation and differentiation, thus restoring the microbial bar-

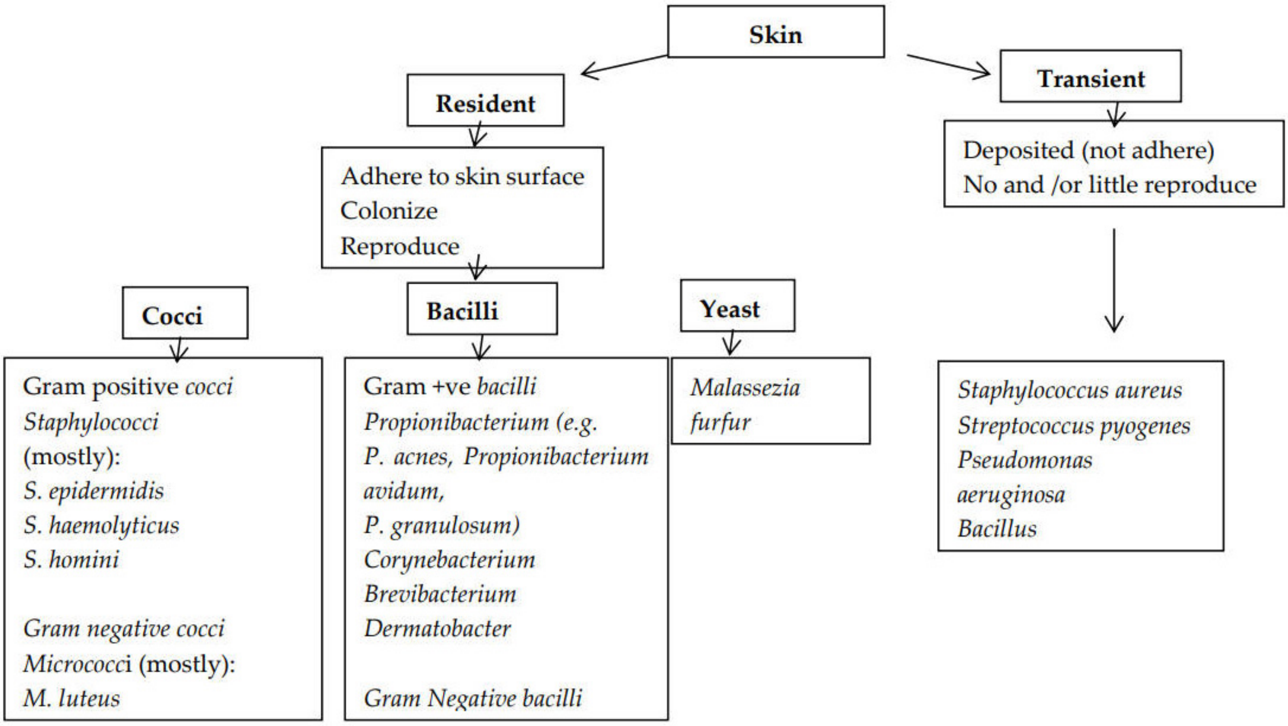

Fig. 1. Composition of resident and transient microorganisms of normal skin microbiota.

rier [19]. The skin's chemical defense is established by various lipids and acids produced by both the microbiota and epidermis. While most skin areas share similar microbial compositions, variations exist among sebaceous, moist, and dry regions [1]. The cornified envelope's cytoskeleton consists of keratin-based intermediate filaments, which contribute to epidermal barrier stability. Keratin mutations lead to the formation of incomplete intermediate filaments and compromised barrier function [20]. Filaggrin, a protein crucial for late epidermal development, plays a vital role in aggregating keratin filaments. Multiple studies have demonstrated that loss of filaggrin function negatively affects skin barrier function and hinders epidermal development. Loricrin, an essential component of the cornified envelope, is critical for epidermal barrier function [20]. Immunohistochemical images revealed that LR-treated tissues exhibited increased levels of cytokeratin 5 and 1 in the upper epidermal layer, along with elevated loricrin and filaggrin levels, indicating that LR may enhance epidermal differentiation. This was further supported by qPCR analysis of loricrin and filaggrin [21]. The improvement in epidermal differentiation induced by LR lysate may have enhanced barrier function by strengthening the stratum corneum, as evidenced by H&E-stained tissues [22]. The composition of skin microbes differs among individuals and across various body regions. Both internal and external factors influence the skin's microbiome. Internal factors include genetic makeup, immune response, diet, and hormones, while external factors encompass personal hygiene practices, use of personal care products, medication exposure, and UV exposure. These factors collectively impact skin health and determine the types of bacteria that colonize the skin [23].

The presence of water, lipids, and proteins on the skin promotes microbial colonization. The colonization of resident bacteria is crucial for maintaining healthy skin, as it prevents the growth and colonization of pathogens through competition for nutrients, adherence to mucosal membranes, and production of antimicrobial substances such as bacteriocins [24,25,26]. Disruption of resident bacteria by topical antibiotics can reduce or eliminate antimicrobial substances, allowing potentially pathogenic bacteria, such as *S. aureus*, to colonize (Table 1, Ref. [27,28,29,30,31,32]; Table 2, Ref. [10,30,33,34,35,36,37,38,39,40]). A shift from a healthy to a pathogenic environment can lead to various skin conditions, including acne vulgaris, atopic dermatitis, psoriasis, and seborrheic dermatitis [41].

3.3 Use of Probiotics in Different Skin Disorders

Probiotics have emerged as promising therapeutic agents in the management of various dermatological disorders through both topical application and oral administration. Probiotics can directly act on the skin to prevent and treat skin conditions and represent a new frontier in skin health. They are promising candidates for treating issues such as acne, psoriasis, and atopic dermatitis, as well as promoting wound healing due to their antibacterial and immunomodulatory effects. Scientific data indicates that certain probiotic strains can influence the lipid barrier, skin immune system, cutaneous microbiota, and help preserve skin health [42].

Table 1. Probiotics bacteria used and their benefits on skin.

Bacteria strain	Benefits
Streptococcus thermophilus	Increased the production of ceramides and use in atopic dermatitis [27]
Lactobacillus paracasei, *Enterococcus faecalis*, *Streptococcus salivarius*	Inhibited the *C. acnes*, which increases oil production [28]
Bacillus coagulans	It protects the skin from free radicals and UV rays [29]
Bifidobacterium longum	Decrease in skin sensitivity and increase in skin resistance against physical and chemical aggression [30]
Heat-treated probiotic strain *Lactobacillus johnsonii* NCC	Affects the colonization of *S. aureus* and is used in atopic dermatitis [31]
Roseomonas mucosa	A substantial decrease in disease severity, the need for topical steroids, and *S. aureus* load [32]

UV, ultraviolet.

Table 2. Probiotic strains and their mechanism of action.

Probiotic strain	Mechanism of action	Ref
Staphylococcus epidermidis	*Staphylococcus epidermidis* inhibits the growth of *C. acnes* through the production of short-chain fatty acids as a by-product of fermentation.	[10]
Lactobacillus rhamnosus	*Lactobacillus rhamnosus* inhibits *Staphylococcus aureus* by competing for binding sites on skin cells, reducing its colonization and adhesion. It also modulates the immune response, decreases inflammation, and aids in skin barrier repair, thereby improving symptoms of atopic dermatitis.	[33]
Lactobacillus reuteri DSM 17938	*Lactobacillus reuteri* DSM 17938 helps manage atopic dermatitis by inhibiting pathogens, such as *Staphylococcus aureus*, through the production of antimicrobial substances and competitive exclusion. It also reduces inflammation via immune modulation and enhances skin barrier function by improving hydration and reducing water loss.	[34]
Lactobacillus species	*Lactobacillus* species reduce malodour by modulating the axillary microbiome, thereby increasing the diversity of beneficial bacteria and decreasing the presence of odour-causing bacteria, such as *Corynebacterium* and *Staphylococcus*. This competition leads to a reduction in malodor-producing bacteria and body odor.	[35]
Bacillus coagulans	*Bacillus coagulans* MTCC 5856 protects the skin by exhibiting antioxidant activity, preventing UV-induced cell death, and inhibiting enzymes such as collagenase and elastase. It also upregulates genes related to extracellular matrix integrity, promoting skin health.	[36]
Streptococcus salivarius	*Streptococcus salivarius* inhibited *C. acnes* growth by producing a bacteriocin-like inhibitory substance.	[37]
Lactobacillus acidophilus	Production of Lactic Acid: Lowers skin pH, creating an acidic environment unfavorable for *C. acnes* growth. Competition for Nutrients: Competes with *C. acnes* for resources like sebum. Enhancement of Skin Barrier: Certain strains may stimulate ceramide production, thereby strengthening the skin barrier and potentially inhibiting *C. acnes* colonization.	[37]
B. amyloliquefaciens	*B. amyloliquefaciens* produces bacillomycin D, macrolactin, and bacitracin, which have shown antagonistic effects against *Malassezia spp*. (a yeast associated with dandruff and other skin conditions).	[38]
Staphylococcus lugdunensis	Lugdunin, an antimicrobial substance produced by *S. lugdunensis*, amplifies innate immune responses in the skin in synergy with host- and microbiota-derived factors. It demonstrates Lugdunin's ability to inhibit the growth of *S. aureus*, including methicillin-resistant strains, acting as an antibiotic.	[39]
Bifidobacterium longum	*B. longum* lysate shows promise in alleviating skin sensitivity and reducing inflammation.	[30]
Micrococcus luteus	Highlights that *M. luteus* produces a pigment that absorbs UV wavelengths (350–475 nm), which is linked to skin cancer. This natural sunscreen's potential makes it intriguing for cosmetics.	[40]

4. The Role of Probiotics in Treating Dermatological Disorders

4.1 Acne

Cutibacterium (*C. acnes*) is a bacterial colonization of hair follicles in the face, neck, chest, and back that causes increased sebum production, inflammation, immunologic processes, and altered keratinization [43]. Acne is a chronic skin disease that affects the pilosebaceous unit. Anaerobic gram-positive bacteria, including *P. acnes*, are known to colonize and persist in human skin, particularly in pilosebaceous follicles. This bacterium is well-known for playing a significant role in the development of inflammatory acne vulgaris [44]. Probiotic strains, such as *Streptococcus salivarius* and *Enterococcus faecalis*, have demonstrated the ability to directly suppress the growth of *C. acnes in vitro* by producing antibacterial agents. One such compound is a bacteriocin-like inhibitory substance (BLIS), which has shown potential antimicrobial activity against *P. acnes*. In addition to its antibacterial effects, BLIS exhibits immunomodulatory actions in keratinocytes and epithelial cells, suggesting a physiological basis for its potential role as an adjunctive therapy in acne management [45]. Despite its promise, the use of probiotics in acne treatment remains relatively underexplored. However, clinical evaluation of a lyophilized preparation containing enterocins derived from *Enterococcus faecalis* SL-5 has shown encouraging results. In a study involving patients with acne, this preparation resulted in a 60% reduction in inflammatory lesions after eight weeks compared to the control group [37].

4.2 Atopic Dermatitis

Atopic dermatitis (AD) is a highly variable, multifactorial, chronic inflammatory disease characterized by scaly, erythematous, and itchy lesions that are often found on the body's flexural surfaces [46]. It is thought that a genetic flaw in filaggrin that disrupts the epidermis is the cause of AD [47]. Live bacteria known as probiotics can be taken orally and may be beneficial in the prevention or treatment of certain diseases. It has recently been shown that oral bacteriotherapy can help prevent AD [48]. In earlier research, giving the probiotic *L. rhamnosus* GG to babies who had both cow's milk allergy and AD considerably lessened the severity of their eczema. *L. rhamnosus* GG has been demonstrated to prevent antigen-induced IgE formation in mouse lymphocytes *in vitro* [49]. In atopic dermatitis, colonization of pathogenic bacteria like *Staphylococcus aureus* increased, and there was a decrease in microbial diversity [38]. When coagulase-negative *Staphylococci* were applied to the skin of an atopic dermatitis patient, the application resulted in a decrease in *S. aureus* pathogenic bacteria [39].

4.3 Psoriasis

Psoriasis is an immune-mediated ailment with a significant hereditary predisposition that presents numerous obstacles for affected persons, including chronic sickness, and is connected with various comorbidities such as cardiovascular disease, metabolic syndrome, inflammatory bowel disease, and psychosocial issues [50]. The innate and adaptive immune systems interact intricately in the underlying pathomechanisms. T cells can interact with keratinocytes, macrophages, and dendritic cells through the release of cytokines. The primary clinical signs, which can affect the entire body, are erythema and scaly skin. Patients experience a lengthier illness course and are more likely to relapse [51].

Probiotics are currently being studied in preclinical and clinical research for treating psoriasis. They have shown how probiotics can decrease the Psoriasis Area and Severity Index in patients, reduce psoriasis inflammation, regulate immune cells, and change the microbiota composition [52]. Supplementing with a probiotic blend containing five Bacillus strains—*B. indicus* HU36, *B. subtilis* HU58, *B. coagulans* SC208, *B. licheniformis* SL307, and *B. clausii* SC109—led to increased diversity in the gut microbiota. This was linked to higher beneficial bacterial populations, increased production of short-chain fatty acids, and a noticeable drop in inflammatory biomarkers.

4.4 Wound Healing

Probiotics are widely recognized for their beneficial effects on human health and have shown potential in the treatment of various diseases. Their decisive antipathogenic, antibiofilm, and immunomodulatory actions also contribute to accelerated wound healing. Both *in vitro* and *in vivo* studies have explored these therapeutic mechanisms, and probiotic formulations—administered orally or topically—have demonstrated promising outcomes in dermatological applications [53].

Host cells such as epithelial cells, adipocytes, and mast cells play a crucial role in producing antimicrobial peptides (AMPs), which are central to maintaining skin integrity. These peptides help to minimize inflammation, hinder microbial adhesion, and prevent biofilm development, forming the basis of the antimicrobial defense mechanism [54].

Probiotics can also interfere with quorum sensing (QS) pathways through the secretion of lactic acid, which lowers the local pH, as well as other bioactive substances such as hydrogen peroxide, reuterin, and bacteriocins. These metabolites can either disrupt or attenuate the virulence of common pathogens involved in chronic wound infections [55]. Among probiotic species, lactic acid bacteria (LAB)—including L. plantarum, *L. acidophilus*, *L. fermentum*, *L. paracasei*, *L. rhamnosus*, *L. bulgaricus*, *L. reuteri*, *L. delbrückii*, *L. salivarius*, and *Bifidobacterium lactis*—are the most extensively studied for their wound healing capabilities, making them attractive candidates for novel therapeutic interventions [56].

4.5 Skin Photo Aging

Photoaging refers to the premature aging of the skin caused by chronic exposure to ultraviolet (UV) radiation from sunlight [57]. Probiotics, defined as live microorganisms that beneficially alter the host's microbial composition, have shown promise in counteracting the effects of photoaging [58]. For instance, a fermented extract of *Agastache rugosa* (ARE-F), processed with *Lactobacillus*, has been shown to mitigate UVB-induced oxidative stress in HaCaT keratinocytes by boosting total glutathione levels and superoxide dismutase activity, while reducing reactive oxygen species (ROS) and matrix metalloproteinases (MMP-2 and MMP-9) [59].

Topical application of *L. acidophilus* IDCC 3302 has also demonstrated protective effects against UVB-induced skin damage. It enhanced antioxidant enzyme activity, improved skin hydration, and downregulated MMP expression by modulating the MAPK signaling pathway [60]. Similarly, *L. acidophilus* KCCM12625 exhibited potent antioxidant properties, significantly reducing ROS levels in UVB-irradiated HaCaT cells and thereby alleviating oxidative damage and photoaging [61]. Furthermore, oral supplementation with *Bifidobacterium breve* Yakult has been shown in animal studies to inhibit ROS generation and protect the skin barrier from UV-induced oxidative stress [62].

5. Clinical Study of Probiotic-Loaded Cosmetics

The exploration of probiotics in cosmetic formulations has gained attention in recent years, with various studies investigating their potential benefits for skin health. These clinical studies aim to assess the efficacy of different probiotic strains in improving skin appearance, hydration, elasticity, and overall dermatological health [63]. By employing diverse methodologies and considering participant demographics, researchers can gain valuable insights into the role of probiotics in enhancing cosmetic products.

The following Table 3 (Ref. [29,34,64,65,66]) summarizes key clinical studies that evaluated the effects of probiotics in cosmetics. Each entry includes information on the specific probiotic strain used, study type, participant details, duration, and significant findings.

6. Currently Marketed Cosmetic Product Containing Probiotics

Probiotics in cosmetic products have gained popularity due to their ability to support the skin's microbiome, providing a range of benefits for various skin concerns. Probiotics, recognized for their role in maintaining gut health, are now being incorporated into skincare formulations to promote a healthy balance of bacteria on the skin, which can enhance overall skin health and appearance [4].

One key role of probiotics in cosmetics is their ability to soothe inflammation and decrease redness, making them perfect for sensitive skin. For example, products like Clinique Redness Solutions Soothing Cleanser and ESSE Sensitive Serum, which contain *Lactobacillus* and *Bifidobacterium*, are designed to calm irritation while gently cleansing or hydrating the skin [67].

Probiotic strains like *Lactococcus* ferment lysate and *Bifidobacterium longum* are also included in moisturizers such as TULA Skincare Hydrating Day & Night Cream and Aurelia Probiotic Skincare Miracle Cleanser. These products help strengthen the skin's natural barrier, boost hydration, and support a healthy microbiome. The aim is to prevent issues like dryness, irritation, or skin imbalance that could lead to acne or eczema [68].

For those with acne-prone skin, probiotics can help balance the bacteria that cause breakouts. Products like Yun Probiotherapy ACN Cream, containing *Staphylococcus epidermidis*, and Naturopathica Probiotic Acne Control Daily Serum, formulated with *Lactobacillus* and *Bifidobacterium*, work to reduce inflammation and treat acne by supporting a healthier skin microbiome [69].

Additionally, probiotic-infused products like Algenist Alive Prebiotic Balancing Moisturizer and Biossance Squalane + Probiotic Gel Moisturizer aim to restore balance to the skin's microbiome while providing deep hydration. These products are especially beneficial for those experiencing skin sensitivity or dryness, as they help improve skin tone, soothe irritation, and promote smoother, healthier-looking skin [70].

6.1 Postbiotics: Definition and Composition

In 2021, the International Scientific Association for Probiotics and Prebiotics (ISAPP) introduced a formal definition for postbiotics. According to this, postbiotics are preparations consisting of inactivated microbial cells and/or their structural components that offer beneficial effects on the host's health [71]. These preparations encompass a broad spectrum of elements, including non-living microbial cells, fragments of cell walls, functional proteins, bioactive peptides, short-chain fatty acids (SCFAs), polyamines, vitamins, bacteriocins, and a variety of metabolites with therapeutic potential. In contrast to probiotics—which are live bacteria or yeast strains that, when consumed in sufficient quantities, benefit the host—and prebiotics—which are typically indigestible dietary fibers that encourage the proliferation or activity of helpful gut microbes—postbiotics are devoid of live organisms but still exert positive biological effects [71].

6.2 Therapeutic Roles of Postbiotics in Dermatological Conditions

6.2.1 Atopic Dermatitis (AD)

Inactivated microbial-based therapies are emerging as effective alternatives to live probiotics for treating inflammatory skin disorders such as atopic dermatitis. Studies investigating oral administration of *Lactobacillus*-derived

Table 3. Clinical study of probiotic-loaded cosmetics.

Probiotic	Study type & duration	Participants	Key findings	Ref
Lactiplantibacillus plantarum HY7714	Double-blind, randomized study for 12 weeks	110 women (age 41–59)	Improved facial gloss and decreased wrinkle depth. 13.2% elasticity increase at week 4, 21.7 % at week 12. Significant increase in skin moisture and decreased trans-epidermal water loss ($p < 0.01$).	[64]
Nitrosomonas eutropha (D23)	Prospective study for 1 week	29 volunteers	Significant improvement in facial wrinkles and skin radiance. A high concentration of *N. eutropha* enhanced results more effectively.	[65]
Lactiplantibacillus pentosus KCA1	Topical application	25 young adults	Participants reported absence of axillary malodor. 96% decrease in *C. striatum* and 73% in *C. jeikeium*. 38.5% increase in *Lactobacillus* diversity.	[34,66]
Lactiplantibacillus plantarum LB244R (Commercial Ointment)	Controlled study	46 post-menopausal women (mean age 58.7)	Significant improvement in dermal density, hydration, and crow's feet wrinkles compared to the placebo. Increased collagen fiber density and skin firmness.	[29]

postbiotics in both children and adults have reported symptom relief. Specifically, *L. rhamnosus* has demonstrated substantial efficacy in pediatric AD cases [71]. Additionally, extracts from *Smilax china L.*, rich in compounds like flavonoids, polyphenols, steroidal saponins, and polysaccharides, have shown promise due to their anti-inflammatory actions. Chemokines such as TARC and MDC, known mediators in inflammatory and immune processes, are closely associated with AD symptom severity [72]. Postbiotic components from *Lactobacillus* and *Bifidobacterium* species may help regulate the Neuro–Immune–Cutaneous–Endocrine (NICE) system, offering a multifactorial approach to managing AD [73].

6.2.2 Acne Vulgaris

Postbiotic ingredients integrated into collagen-based systems (such as TAC/Collagen) have been found effective in suppressing the growth of *C. acnes* and reducing the expression of inflammatory cytokines like TSLP and IL-33 *in vitro*. These formulations also promoted healing in keratinocyte (HaCaT) cultures and visibly reduced facial pigmentation and porphyrin levels [74]. Another compound, LactoSporin (a cell-free extract from *B. coagulans*), exhibited strong antimicrobial activity, remained stable under acidic pH and high temperatures (70–90 °C), and inhibited the enzyme 5-alpha reductase, which plays a role in acne pathogenesis [75].

A topical lotion formulated with a ferment lysate of *L. plantarum* VHProbi E15 demonstrated both safety and tolerability in individuals with mild to moderate acne. Noticeable improvements in skin lesions, hydration, and pH balance were observed after four weeks of treatment [76]. Fermenza postbiotic gel has also emerged as a dual-purpose product targeting both *Malassezia* folliculitis and acne, with additional applications in scalp and hair care [77].

6.2.3 Dandruff and Alopecia

Topical formulations derived from *Bifidobacterium lactis* are effective in alleviating dandruff by restoring the skin microbiota balance and enhancing the skin's defensive barrier. These actions contribute to scalp homeostasis and immune regulation [78]. In another study, a formulation known as TR-PRP plus-Celsi—comprising plantaricin A peptides, postbiotics from *L. kunkeei*, and *Tropaeolum majus* extract—showed therapeutic benefits in patients with alopecia areata [79].

6.2.4 Acne, Seborrheic Conditions, and Skin Strengthening

A skin cream featuring a lysate of *L. plantarum* VH-Probi V22, isolated initially from infant gut flora, was shown to improve acne symptoms in mild-to-moderate cases. Similarly, LactoSporin®—containing both the cell-free supernatant from *B. coagulans* and heat-killed *B. longum* cells—demonstrated effectiveness in treating acne and seborrheic conditions [35].

Lysates from *Vitreoscilla filiformis* interact with toll-like receptors on skin cells, reducing inflammation and enhancing skin immunity. They also help fortify the skin barrier by upregulating tight junction proteins [80].

Postbiotics from *L. plantarum* K8 were shown to increase the gene expression of hydrating factors, such as HAS2 and AQP3, making them suitable for inclusion in moisturizing cosmetic products. Additionally, the ferment lysate from *L. plantarum* significantly reduced acne severity and improved skin parameters, such as transepidermal water loss and sebum levels, after four weeks of topical use [67].

The lysate of *S. thermophilus*, which includes the enzyme sphingomyelinase, was found to elevate ceramide concentrations in the stratum corneum. This contributed to improved skin lipid barrier function and reduced water loss through the skin [81].

Table 4. Clinical study of postbiotic-loaded cosmetics.

Probiotic	Study Type	Participants	Intervention	Duration	Key findings	Ref
S. thermophilus S244	Randomized controlled trial	17 healthy subjects	Sonicated *S. thermophilus* S244 cream vs. placebo cream	7 days	Increased ceramide levels, improved skin hydration, and enhanced lipid barrier. Function has no effect on trans-epidermal water loss.	[85]
B. longum lysate	Randomized double-blind study	66 female volunteers	10% *B. longum* reuter lysate cream	2 months	Reduced skin sensitivity, improved skin barrier recovery, decreased roughness, and dryness.	[89]
L. brevis DSM17250	Randomized controlled trial	30 volunteers (mean age 39)	Ointment with *L. brevis* vs. placebo	1 month	Significant improvement in xerosis parameters, along with increased commensal skin bacteria.	[86]
L. plantarum-GMNL6	Randomized controlled trial	15 healthy volunteers	Cream with heat-killed *L. plantarum*-G MNL6 vs. placebo	2 months	Improved skin hydration, decreased wrinkles and skin erythema, and increased beneficial bacteria.	[84]
E. keratini (EPI-7)	Randomized split-face study	55 Korean women	EPI-7 ferment filtrate vs. control	3 weeks	Enhanced skin barrier performance, skin elasticity, and skin microbiome diversity.	[83]
L. plantarum HDB	Randomized controlled trial	21 healthy females	Essence with *L. plantarum* HDB vs. placebo	2 weeks	Enhanced skin hydration, reduced transepidermal water loss, and decreased redness.	[87]
Fermented lysates VH-Probi® Mix R	Randomized controlled trial	52 adults with sensitive skin	Lotion with VH-Probi® Mix R vs. placebo	1 month	Significant reductions in skin redness, transepidermal water loss (TEWL), and enhanced moisturization; 75% of respondents said their skin condition had improved.	[88]

6.2.5 Wound Repair and Skin Recovery

Cold cream formulations infused with postbiotics from *L. fermentum*, *Lactobacillus reuteri*, and *Bacillus subtilis natto* have demonstrated wound-healing potential. Among these, *L. reuteri* notably enhanced epithelial regeneration while avoiding any signs of inflammation, underscoring its role in skin repair strategies [82].

7. Clinical Study of Postbiotic-Loaded Cosmetics

Recent advancements in cosmetic science have highlighted the role of postbiotics—beneficial metabolic byproducts of probiotics—in enhancing skin health. These postbiotic compounds are increasingly being incorporated into cosmetic formulations, with various studies investigating their effects on skin hydration, barrier function, and overall dermatological health [67]. This emerging area of research aims to provide insights into how postbiotics can improve skin conditions and enhance cosmetic products.

The following Table 4 (Ref. [83,84,85,86,87,88,89]) summarizes key clinical studies that evaluated the effects of different postbiotics in cosmetics. Each entry includes the specific postbiotic strain used, study design, participant details, intervention type, duration, and significant findings.

8. Patents in Probiotic Use in Cosmetic

Probiotics have garnered significant attention in industrial sectors of the cosmetics and pharmaceutical because of their beneficial effects on the skin and mucosal health [86]. When used in sufficient quantities, probiotics can strengthen the skin's barrier function, aid in the restoration of the natural microbiome, and offer defense against infections. Probiotic-containing products are increasingly being created to treat a variety of skin and mucosal disorders, including dandruff, psoriasis, eczema, and acne, as well as to enhance general skin health and lessen inflammation [4].

The integration of probiotic bacteria into pharmaceutical and cosmetic products has become a growing area of research, leading to advances that combine microbiology and skincare science. These products aim to utilize the antimicrobial, anti-inflammatory, and immune-modulating properties of probiotics, providing new options for both cosmetic improvements and treating dermatological conditions [90].

The following Table 5 summarizes key patents that represent recent advancements in probiotic formulations for cosmetic and pharmaceutical uses. These patents describe innovative approaches to combining probiotic strains with other active ingredients to develop effective treatments for various skin and mucosal disorders.

Table 5. Patents on probiotic use in cosmetic.

Patents	Application number	Inventor	Description	Mechanism/method of use	Uses
Cosmetic Composition having Probiotic	2016338321	De Miranda Chaves Vasquez Pinto, Luciana	Microbiota, betaines, prebiotic agents, and cosmetically acceptable carrier.	Applying the probiotic cosmetic formulation to the skin.	Skin treatment.
Probiotic Formulation and Uses	PCT/IN2019/050234	Kaur, Indu Pal	Probiotic bacterial spores (10^6 to 10^{14} CFU/mL), hydrophobic agent, aqueous phase.	Germination of probiotic spores upon contact with the epidermal surface, providing slow, sustained release.	Maintain vaginal health, anti-acne, anti-inflammatory, and immunomodulatory effects.
Probiotic, Color, Cosmetic Composition and Methods	2011224690	Dao, Khanh Ngoc	Probiotic microorganism extract, non-clay lamellar phyllosilicate mineral particulate, anti-inflammatory ingredients.	Treat skin inflammation by applying the composition.	Improve skin condition, reduce inflammation.
Use of probiotic *Lactobacillus Paracasei* for treating greasy scalp disorders.	09166247	Castiel, Isabelle	*Lactobacillus paracasei*, probiotic fractions/metabolites, and antidandruff agents.	Topical application of each active agent in separate formulations.	Prevents dandruff and scalp disorders.
Cosmetic Use of Microorganisms for Treating Scalp Disorders	PCT/IB2009/053208	Castiel, Isabelle	Probiotic microorganisms and anti-dandruff agents for treating dandruff and scalp disorders.	Apply both agents separately to the scalp in different compositions.	Prevent and treat dandruff, and improve scalp health.
Probiotic Skin Barrier Formulation	2/2017/000146	Ludan, Arturo C.	*Bacillus coagulans*, *Saccharomyces boulardii*, zinc, mineral oil, ceteary1.	Probiotics provide antimicrobial protection, and zinc aids in tissue repair	Relief from acne, atopic dermatitis, eczema, and psoriasis.
Formulation and Device Including Probiotic Bacteria Strains	PCT/EP2023/078874	Biazzo, Manuele	(i) Primary powder phase: Freeze-dried probiotic bacteria strain, gelling agent. (ii) Complementary aqueous phase: Sterile, physically separated from the powder phase.	The two phases are combined to create an active probiotic formulation for cosmetic or pharmaceutical use.	Treatment of skin and mucosa disorders in cosmetic and pharmaceutical applications.

9. Future Scope

Probiotics hold significant promise for improving human health in the future, including through topical applications. Increased opportunities now exist for applying bacterial strains in skincare due to the discovery that many can support the natural processes of maintaining healthy tissue, especially in the skin. The ability to modify the skin microbiota to treat various skin conditions has opened new therapeutic possibilities. Although probiotic formulations are becoming more popular for their potential to enhance skin health by maintaining a balanced microbiota, their effectiveness via topical application varies depending on the strains used and the individual's microbiota composition. Probiotics in skincare products face challenges such as the slow-acting nature of natural compounds, high costs, and limited shelf life. Techniques like prebiotic stimulation, skin bacteriotherapy, and microbiome transplantation are used to manipulate the skin microbiome to treat different conditions. Studies show that altering bacterial strains in the skin microbiome to improve medical outcomes can significantly boost skin health and attractiveness. Worldwide, the market for probiotic skincare products is rapidly growing, driven by positive scientific findings and the belief that probiotics are inherently healthier than other bioactive compounds, such as synthetics.

10. Conclusion

This thorough review highlights the considerable and encouraging therapeutic potential of probiotics in the field of dermatology. By skillfully altering the skin's microbial ecosystem, probiotic treatments present a flexible strategy for addressing a broad range of skin issues, from speeding up the healing of chronic wounds through strong anti-pathogen and antibiofilm effects to alleviating inflammation. Although the effectiveness of these treatments is clear, their success largely hinges on the careful selection of strains and individual host characteristics. Addressing current obstacles, especially in creating stable topical formulations due to the sensitivity of many probiotics to environmental conditions and their short shelf life, is essential. Probiotic- and postbiotic-based cosmetics must meet strict microbiological standards for safety. According to EU Regulation (EC) No. 1223/2009 and ISO 17516:2014, high-risk products (e.g., for children, eyes, mucous membranes) must have $\leq 10^2$ CFU/g, while low-risk products allow $\leq 10^3$ CFU/g. Live probiotics pose challenges for safety and stability, whereas postbiotics offer a safer, more stable alternative. Compliance with these standards is crucial for clinically safe and marketable microbiome-based cosmetics. Future progress will require improved delivery techniques, such as cell encapsulation or the use of resilient spore-formers, along with thorough clinical trials, to fully leverage the healing potential of a healthy microbiome in dermatological treatment.

Author Contributions

The single author AAC was responsible for the conception of the ideas presented, the writing, and the entire preparation of this manuscript.

Ethics Approval and Consent to Participate

Not applicable.

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Conflicts of Interest

The author declares no conflicts of interest.

References

[1] Dréno B, Araviiskaia E, Berardesca E, Gontijo G, Sanchez Viera M, Xiang L, et al. Microbiome in healthy skin, update for dermatologists. Journal of the European Academy of Dermatology and Venereology. 2016; 30: 2038–2047. https://doi.org/10.1111/jdv.13965

[2] Alves AC, Martins SMDSB, Belo JVT, Lemos MVC, Lima CEDMC, Silva CDD, et al. Global Trends and Scientific Impact of Topical Probiotics in Dermatological Treatment and Skincare. Microorganisms. 2024; 12: 2010. https://doi.org/10.3390/microorganisms12102010

[3] Habeebuddin M, Karnati RK, Shiroorkar PN, Nagaraja S, Asdaq SMB, Khalid Anwer M, et al. Topical Probiotics: More Than a Skin Deep. Pharmaceutics. 2022; 14: 557. https://doi.org/10.3390/pharmaceutics14030557

[4] Gao T, Wang X, Li Y, Ren F. The role of probiotics in skin health and related gut–skin axis: a review. Nutrients. 2023; 15: 3123. https://doi.org/10.3390/nu15143123

[5] Fuchs-Tarlovsky V, Marquez-Barba MF, Sriram K. Probiotics in dermatologic practice. Nutrition (Burbank, Los Angeles County, Calif.). 2016; 32: 289–295. https://doi.org/10.1016/j.nut.2015.09.001

[6] Yu J, Ma X, Wang X, Cui X, Ding K, Wang S, et al. Application and mechanism of probiotics in skin care: a review. Journal of cosmetic dermatology. 2022; 21: 886–894. https://doi.org/10.1111/jocd.14734

[7] Mahmud MR, Akter S, Tamanna SK, Mazumder L, Esti IZ, Banerjee S, et al. Impact of gut microbiome on skin health: gut-skin axis observed through the lenses of therapeutics and skin diseases. Gut Microbes. 2022; 14: 2096995. https://doi.org/10.1080/19490976.2022.2096995

[8] Corvec S, Dagnelie MA, Khammari A, Dréno B. Taxonomy and phylogeny of Cutibacterium (formerly Propionibacterium) acnes in inflammatory skin diseases. Annales De Dermatologie et De Venereologie. 2019; 146: 26–30. https://doi.org/10.1016/j.annder.2018.11.002

[9] Zeng L, Yu G, Wu Y, Hao W, Chen H. The effectiveness and safety of probiotic supplements for psoriasis: a systematic review and meta-analysis of randomized controlled trials and preclinical trials. Journal of Immunology Research. 2021; 2021: 7552546. https://doi.org/10.1155/2021/7552546

[10] Wang Y, Kuo S, Shu M, Yu J, Huang S, Dai A, et al. Staphylococcus epidermidis in the human skin microbiome mediates fermentation to inhibit the growth of Propionibacterium acnes: implications of probiotics in acne vulgaris. Applied Microbiology and Biotechnology. 2013; 98: 411–424. https://doi.org/10.1007/s00253-013-5394-8

[11] Prabhurajeshwar C, Chandrakanth K. Evaluation of antimicrobial properties and their substances against pathogenic bacteria in-vitro by probiotic Lactobacilli strains isolated from commercial yoghurt. Clinical Nutrition Experimental. 2019; 23: 97–115. https://doi.org/10.1016/j.yclnex.2018.10.001

[12] Maldonado Galdeano C, Cazorla S, Lemme Dumit J, Vélez E, Perdigón G. Beneficial Effects of Probiotic Consumption on the Immune System. Annals of Nutrition and Metabolism. 2019; 74: 115–124. https://doi.org/10.1159/000496426

[13] Chu W, Lu F, Zhu W, Kang C. Isolation and characterization of new potential probiotic bacteria based on quorum-sensing system. Journal of Applied Microbiology. 2011; 110: 202–208. https://doi.org/10.1111/j.1365-2672.2010.04872.x

[14] Di Marzio L, Cinque B, De Simone C, Cifone MG. Effect of the Lactic Acid BacteriumStreptococcus thermophilus on Ceramide Levels in Human KeratinocytesIn Vitro and Stratum Corneum In Vivo. Journal of Investigative Dermatology. 1999; 113: 98–106. https://doi.org/10.1046/j.1523-1747.1999.00633.x

[15] Jensen JM, Förl M, Winoto-Morbach S, Seite S, Schunck M, Proksch E, et al. Acid and neutral sphingomyelinase, ceramide synthase, and acid ceramidase activities in cutaneous aging. Experimental Dermatology. 2005; 14: 609–618. https://doi.org/10.1111/j.0906-6705.2005.00342.x

[16] Mizutani Y, Mitsutake S, Tsuji K, Kihara A, Igarashi Y. Ceramide biosynthesis in keratinocyte and its role in skin function. Biochimie. 2009; 91: 784–790. https://doi.org/10.1016/j.biochi.2009.04.001

[17] Qi P, Gong F, Leng M, Wei Z. Beneficial perspective on Staphylococcus epidermidis: a crucial species for skin homeostasis and

pathogen defense. Frontiers in Immunology. 2025; 16: 1674392. https://doi.org/10.3389/fimmu.2025.1674392

[18] Lee H, Kim M. Skin barrier function and the microbiome. International journal of molecular sciences. 2022; 23: 13071. https://doi.org/10.3390/ijms232113071

[19] Volksdorf T, Heilmann J, Eming SA, Schawjinski K, Zorn-Kruppa M, Ueck C, et al. Tight junction proteins claudin-1 and occludin are important for cutaneous wound healing. The American journal of pathology. 2017; 187: 1301–1312. https://doi.org/10.1016/j.ajpath.2017.02.006

[20] Méchin MC, Simon M. Deimination in epidermal barrier and hair formation. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences. 2023; 378: 20220245. https://doi.org/10.1098/rstb.2022.0245

[21] Catunda R, Rekhi U, Clark D, Levin L, Febbraio M. Loricrin downregulation and epithelial-related disorders: a systematic review. JDDG: Journal Der Deutschen Dermatologischen Gesellschaft. 2019; 17: 1227–1238. https://doi.org/10.1111/ddg.14001

[22] Jung YO, Jeong H, Cho Y, Lee EO, Jang HW, Kim J, et al. Lysates of a Probiotic, Lactobacillus rhamnosus, Can Improve Skin Barrier Function in a Reconstructed Human Epidermis Model. International Journal of Molecular Sciences. 2019; 20: 4289. https://doi.org/10.3390/ijms20174289

[23] Tagliari E, Campos LF, Casagrande TAC, Fuchs T, de Noronha L, Campos ACL. Effects of oral probiotics administration on the expression of transforming growth factor β and the proinflammatory cytokines interleukin 6, interleukin 17, and tumor necrosis factor α in skin wounds in rats. JPEN. Journal of Parenteral and Enteral Nutrition. 2021; 46: 721–729. https://doi.org/10.1002/jpen.2216

[24] Nakatsuji T, Chen TH, Butcher AM, Trzoss LL, Nam SJ, Shirakawa KT, et al. A commensal strain of Staphylococcus epidermidis protects against skin neoplasia. Science Advances. 2018; 4: eaao4502. https://doi.org/10.1126/sciadv.aao4502

[25] Jiang W, Ni B, Liu Z, Liu X, Xie W, Wu IXY, et al. The Role of Probiotics in the Prevention and Treatment of Atopic Dermatitis in Children: An Updated Systematic Review and Meta-Analysis of Randomized Controlled Trials. Pediatric Drugs. 2020; 22: 535–549. https://doi.org/10.1007/s40272-020-00410-6

[26] Amar Y, Grube J, Köberle M, Schaubeck M, Biedermann T, Volz T. Bifidobacterium breve DSM 32583 and Limosilactobacillus fermentum CECT5716 postbiotics attenuate S. aureus and IL-33-induced Th2 responses. Microbiological Research. 2024; 289: 127913. https://doi.org/10.1016/j.micres.2024.127913

[27] Meroni G, Panelli S, Zuccotti G, Bandi C, Drago L, Pistone D. Probiotics as Therapeutic Tools against Pathogenic Biofilms: Have We Found the Perfect Weapon? Microbiology Research. 2021; 12: 916–937. https://doi.org/10.3390/microbiolres12040068

[28] Bowe WP, Logan AC. Acne vulgaris, probiotics and the gut-brain-skin axis - back to the future? Gut Pathogens. 2011; 3: 1. https://doi.org/10.1186/1757-4749-3-1

[29] Falholt Elvebakken H, Bruntse AB, Vedel C, Kjaerulff S. Topical Lactiplantibacillus plantarum LB244R® ointment alleviates skin aging: An exploratory trial. Journal of Cosmetic Dermatology. 2023; 22: 1911–1918. https://doi.org/10.1111/jocd.15657

[30] Guéniche A, Bastien P, Ovigne JM, Kermici M, Courchay G, Chevalier V, et al. Bifidobacterium longum lysate, a new ingredient for reactive skin. Experimental Dermatology. 2010; 19: e1–e8. https://doi.org/10.1111/j.1600-0625.2009.00932.x

[31] Blanchet-Réthoré S, Bourdès V, Mercenier A, Haddar CH, Verhoeven PO, Andres P. Effect of a lotion containing the heat-treated probiotic strain Lactobacillus johnsonii NCC 533 on Staphylococcus aureus colonization in atopic dermatitis. Clinical, Cosmetic and Investigational Dermatology. 2017; 10: 249–257. https://doi.org/10.2147/CCID.S135529

[32] Myles IA, Castillo CR, Barbian KD, Kanakabandi K, Virtaneva K, Fitzmeyer E, et al. Therapeutic responses to Roseomonas mucosa in atopic dermatitis may involve lipid-mediated TNF-related epithelial repair. Science Translational Medicine. 2020; 12: eaaz8631. https://doi.org/10.1126/scitranslmed.aaz8631

[33] Mohammedsaeed W, McBain AJ, Cruickshank SM, O'Neill CA. Lactobacillus rhamnosus GG inhibits the toxic effects of Staphylococcus aureus on epidermal keratinocytes. Applied and Environmental Microbiology. 2014; 80: 5773–5781. https://doi.org/10.1128/AEM.00861-14

[34] Butler É, Lundqvist C, Axelsson J. Lactobacillus reuteri DSM 17938 as a Novel Topical Cosmetic Ingredient: A Proof of Concept Clinical Study in Adults with Atopic Dermatitis. Microorganisms. 2020; 8: 1026. https://doi.org/10.3390/microorganisms8071026

[35] Onwuliri V, Agbakoba NR, Anukam KC. Topical cream containing live lactobacilli decreases malodor-producing bacteria and downregulates genes encoding PLP-dependent enzymes on the axillary skin microbiome of healthy adult Nigerians. Journal of Cosmetic Dermatology. 2021; 20: 2989–2998. https://doi.org/10.1111/jocd.13949

[36] Majeed M, Majeed S, Nagabhushanam K, Lawrence L, Arumugam S, Mundkur L. Skin Protective Activity of LactoSporin-the Extracellular Metabolite from Bacillus Coagulans MTCC 5856. Cosmetics. 2020; 7: 76. https://doi.org/10.3390/cosmetics7040076

[37] Dapkevicius I, Romualdo V, Marques AC, Lopes CM, Amaral MH. Acne Vulgaris Topical Therapies: Application of Probiotics as a New Prevention Strategy. Cosmetics. 2023; 10: 77. https://doi.org/10.3390/cosmetics10030077

[38] Qi H. Application of probiotics and metazoans in cosmetics. Theoretical and Natural Science. 2023; 4: 134–144. https://doi.org/10.54254/2753-8818/4/20220533

[39] Bitschar K, Sauer B, Focken J, Dehmer H, Moos S, Konnerth M, et al. Lugdunin amplifies innate immune responses in the skin in synergy with host- and microbiota-derived factors. Nature Communications. 2019; 10: 2730. https://doi.org/10.1038/s41467-019-10646-7

[40] Heo YM, Lee DG, Mun S, Kim M, Baek C, Lee H, et al. Skin benefits of postbiotics derived from Micrococcus luteus derived from human skin: an untapped potential for dermatological health. Genes & Genomics. 2023; 46: 13–25. https://doi.org/10.1007/s13258-023-01471-w

[41] SanMiguel AJ, Meisel JS, Horwinski J, Zheng Q, Grice EA. Topical Antimicrobial Treatments Can Elicit Shifts to Resident Skin Bacterial Communities and Reduce Colonization by Staphylococcus aureus Competitors. Antimicrobial Agents and Chemotherapy. 2017; 61: e00774–17. https://doi.org/10.1128/AAC.00774-17

[42] Khameneh B, Kianmehr S, Jahani M, Moazzen N, Ahanchian H. The Potential of Probiotics for Treating Skin Disorders: A Concise Review. Current Pharmaceutical Biotechnology. 2022; 23: 1851–1863. https://doi.org/10.2174/1389201023666220411090301

[43] Beylot C, Auffret N, Poli F, Claudel J, Leccia M, Del Giudice P, et al. Propionibacterium acnes: an update on its role in the pathogenesis of acne. Journal of the European Academy of Dermatology and Venereology. 2013; 28: 271–278. https://doi.org/10.1111/jdv.12224

[44] Zouboulis CC, Eady A, Philpott M, Goldsmith LA, Orfanos CE, Cunliffe WC et al. What is the pathogenesis of acne? Experimental dermatology. 2005; 14: 143. https://doi.org/10.1111/j.0906-6705.2005.0285a.x

[45] Kober M, Bowe WP. The effect of probiotics on immune regu-

lation, acne, and photoaging. International journal of women's dermatology. 2015; 1: 85–89. https://doi.org/10.1016/j.ijwd.2015.02.001
[46] Sugarman JL. The epidermal barrier in atopic dermatitis. Seminars in Cutaneous Medicine and Surgery. 2008; 27: 108–114. https://doi.org/10.1016/j.sder.2008.04.005
[47] Berke R, Singh A, Guralnick M. Atopic dermatitis: an overview. American family physician. 2012; 86: 35–42.
[48] Nakatsuji T, Gallo RL, Shafiq F, Tong Y, Chun K, Butcher AM, et al. Use of Autologous Bacteriotherapy to Treat Staphylococcus aureus in Patients With Atopic Dermatitis. JAMA Dermatology. 2021; 157: 978–982. https://doi.org/10.1001/jamadermatol.2021.1311
[49] Rosenfeldt V, Benfeldt E, Nielsen SD, Michaelsen KF, Jeppesen DL, Valerius NH, et al. Effect of probiotic Lactobacillus strains in children with atopic dermatitis. The Journal of Allergy and Clinical Immunology. 2003; 111: 389–395. https://doi.org/10.1067/mai.2003.389
[50] Man AM, Orăsan MS, Hoteiuc OA, Olănescu-Vaida-Voevod MC, Mocan T. Inflammation and Psoriasis: A Comprehensive Review. International Journal of Molecular Sciences. 2023; 24: 16095. https://doi.org/10.3390/ijms242216095
[51] Kamiya K, Kishimoto M, Sugai J, Komine M, Ohtsuki M. Risk Factors for the Development of Psoriasis. International Journal of Molecular Sciences. 2019; 20: 4347. https://doi.org/10.3390/ijms20184347
[52] Navarro-López V, Martínez-Andrés A, Ramírez-Boscá A, Ruzafa-Costas B, Núñez-Delegido E, Carrión-Gutiérrez MA, et al. Efficacy and Safety of Oral Administration of a Mixture of Probiotic Strains in Patients with Psoriasis: A Randomized Controlled Clinical Trial. Acta Dermato-venereologica. 2019; 99: 1078–1084. https://doi.org/10.2340/00015555-3305
[53] Karimi F, Montazeri-Najafabady N, Mohammadi F, Azadi A, Koohpeyma F, Gholami A. A potential therapeutic strategy of an innovative probiotic formulation toward topical treatment of diabetic ulcer: an in vivo study. Nutrition & Diabetes. 2024; 14: 66. https://doi.org/10.1038/s41387-024-00320-3
[54] Knackstedt R, Knackstedt T, Gatherwright J. The role of topical probiotics on wound healing: A review of animal and human studies. International Wound Journal. 2020; 17: 1687–1694. https://doi.org/10.1111/iwj.13451
[55] Lukic J, Chen V, Strahinic I, Begovic J, Lev-Tov H, Davis SC, et al. Probiotics or pro-healers: the role of beneficial bacteria in tissue repair. Wound Repair and Regeneration : Official Publication of the Wound Healing Society [and] the European Tissue Repair Society. 2017; 25: 912–922. https://doi.org/10.1111/wrr.12607
[56] Gudadappanavar AM, Hombal PR, Timashetti SS, Javali SB. Influence of Lactobacillus acidophilus and Lactobacillus plantarum on wound healing in male Wistar rats - an experimental study. International Journal of Applied & Basic Medical Research. 2017; 7: 233–238. https://doi.org/10.4103/ijabmr.IJABMR_329_16
[57] Scharffetter-Kochanek K, Brenneisen P, Wenk J, Herrmann G, Ma W, Kuhr L, et al. Photoaging of the skin from phenotype to mechanisms. Experimental Gerontology. 2000; 35: 307–316. https://doi.org/10.1016/s0531-5565(00)00098-x
[58] Reid G, Jass J, Sebulsky MT, McCormick JK. Potential uses of probiotics in clinical practice. Clinical Microbiology Reviews. 2003; 16: 658–672. https://doi.org/10.1128/CMR.16.4.658-672.2003
[59] Shin D, Lee Y, Huang YH, Lim HW, Jang K, Kim DD, et al. Probiotic fermentation augments the skin anti-photoaging properties of Agastache rugosa through up-regulating antioxidant components in UV-B-irradiated HaCaT keratinocytes. BMC Complementary and Alternative Medicine. 2018; 18. https://doi.org/10.1186/s12906-018-2194-9
[60] Im A, Lee B, Kang D, Chae S. Protective effects of tyndallized Lactobacillus acidophilus IDCC 3302 against UVB-induced photodamage to epidermal keratinocytes cells. International Journal of Molecular Medicine. 2019. https://doi.org/10.3892/ijmm.2019.4161
[61] Lim HY, Jeong D, Park SH, Shin KK, Hong YH, Kim E, et al. Antiwrinkle and Antimelanogenesis Effects of Tyndallized Lactobacillus acidophilus KCCM12625P. International Journal of Molecular Sciences. 2020; 21: 1620. https://doi.org/10.3390/ijms21051620
[62] Ishii Y, Sugimoto S, Izawa N, Sone T, Chiba K, Miyazaki K. Oral administration of Bifidobacterium breve attenuates UV-induced barrier perturbation and oxidative stress in hairless mice skin. Archives of Dermatological Research. 2014; 306: 467–473. https://doi.org/10.1007/s00403-014-1441-2
[63] Choi HY, Lee YJ, Kim CM, Lee YM. Revolutionizing cosmetic ingredients: harnessing antioxidants, probiotics and peptides in skin care products. Cosmetics. 2024; 11: 157.
[64] Lee DE, Huh CS, Ra J, Choi ID, Jeong JW, Kim SH, et al. Clinical Evidence of Effects of Lactobacillus plantarum HY7714 on Skin Aging: A Randomized, Double Blind, Placebo-Controlled Study. Journal of Microbiology and Biotechnology. 2015; 25: 2160–2168. https://doi.org/10.4014/jmb.1509.09021
[65] Notay M, Saric-Bosanac S, Vaughn AR, Dhaliwal S, Trivedi M, Reiter PN, et al. The use of topical Nitrosomonas eutropha for cosmetic improvement of facial wrinkles. Journal of Cosmetic Dermatology. 2020; 19: 689–693. https://doi.org/10.1111/jocd.13060
[66] Theodorou IM, Kapoukranidou D, Theodorou M, Tsetis JK, Menni AE, Tzikos G, et al. Cosmeceuticals: A Review of Clinical Studies Claiming to Contain Specific, Well-Characterized Strains of Probiotics or Postbiotics. Nutrients. 2024; 16: 2526. https://doi.org/10.3390/nu16152526
[67] De Almeida CV, Antiga E, Lulli M. Oral and Topical Probiotics and Postbiotics in Skincare and Dermatological Therapy: A Concise Review. Microorganisms. 2023; 11: 1420. https://doi.org/10.3390/microorganisms11061420
[68] Hiramoto K, Kubo S, Tsuji K, Sugiyama D, Iizuka Y, Hamano H. The Effect of Bacillus coagulans Induced Interactions among Intestinal Bacteria, Metabolites, and Inflammatory Molecules in Improving Natural Skin Aging. Dermatopathology (Basel, Switzerland). 2023; 10: 287–302. https://doi.org/10.3390/dermatopathology10040037
[69] Sutema IAMP, Latarissa IR, Widowati IGAR, Sartika CR, Ciptasari NWE, Lestari K. Efficacy of Probiotic Supplements and Topical Applications in the Treatment of Acne: A Scoping Review of Current Results. Journal of Experimental Pharmacology. 2025; 17: 1–14. https://doi.org/10.2147/JEP.S498769
[70] Prajapati SK, Lekkala L, Yadav D, Jain S, Yadav H. Microbiome and Postbiotics in Skin Health. Biomedicines. 2025; 13: 791. https://doi.org/10.3390/biomedicines13040791
[71] Xie A, Chen A, Chen Y, Luo Z, Jiang S, Chen D, et al. Lactobacillus for the treatment and prevention of atopic dermatitis. Frontiers in cellular and infection microbiology. 2023; 13: 1137275. https://doi.org/10.3389/fcimb.2023.1137275
[72] Kim YK, Cho M, Kang DJ. Anti-Inflammatory Response of New Postbiotics in TNF-α/IFN-γ-Induced Atopic Dermatitis-like HaCaT Keratinocytes. Current Issues in Molecular Biology. 2024; 46: 6100–6111. https://doi.org/10.3390/cimb46060364
[73] Plaza-Diaz J, Ruiz-Ojeda FJ, Gil-Campos M, Gil A. Mechanisms of Action of Probiotics. Advances in Nutrition (Bethesda, Md.). 2019; 10: S49–S66. https://doi.org/10.1093/advances/nmy063
[74] Ho H, Chen C, Yi T, Huang Y, Kuo Y, Lin J, et al. Novel application of a Co-Fermented postbiotics of TYCA06/AP-32/CP-

9/collagen in the improvement of acne vulgaris—A randomized clinical study of efficacy evaluation. Journal of Cosmetic Dermatology. 2022; 21: 6249–6260. https://doi.org/10.1111/jocd.15228

[75] Majeed M, Majeed S, Nagabhushanam K, Mundkur L, Rajalakshmi HR, Shah K, et al. Novel topical application of a postbiotic, LactoSporin®, in mild to moderate acne: A randomized, comparative clinical study to evaluate its efficacy, tolerability and safety. Cosmetics. 2020; 7: 70. https://doi.org/10.3390/cosmetics7030070

[76] Cui H, Feng C, Guo C, Duan Z. Development of Novel Topical Anti-Acne Cream Containing Postbiotics for Mild-to-Moderate Acne: An Observational Study to Evaluate Its Efficacy. Indian Journal of Dermatology. 2022; 67: 667–673. https://doi.org/10.4103/ijd.ijd_655_22

[77] Ghosh S, Bhattacharya M. FermenZa: a patented bioactive fermented product developed through process optimization. Journal of Pharmaceutical and BioTech Industry. 2025; 2: 6. https://doi.org/10.3390/jpbi2020006

[78] de Jesus GFA, Rossetto MP, Voytena A, Feder B, Borges H, da Costa Borges G, et al. Clinical evaluation of paraprobiotic-associated Bifidobacterium lactis CCT 7858 anti-dandruff shampoo efficacy: A randomized placebo-controlled clinical trial. International Journal of Cosmetic Science. 2023; 45: 572–580. https://doi.org/10.1111/ics.12850

[79] Rinaldi F, Trink A, Pinto D. Efficacy of Postbiotics in a PRP-Like Cosmetic Product for the Treatment of Alopecia Area Celsi: A Randomized Double-Blinded Parallel-Group Study. Dermatology and Therapy. 2020; 10: 483–493. https://doi.org/10.1007/s13555-020-00369-9

[80] Gueniche A, Liboutet M, Cheilian S, Fagot D, Juchaux F, Breton L. Vitreoscilla filiformis Extract for Topical Skin Care: A Review. Frontiers in Cellular and Infection Microbiology. 2021; 11: 747663. https://doi.org/10.3389/fcimb.2021.747663

[81] Dimarzio L, Cinque B, Cupelli F, De Simone C, Cifone M, Giuliani M. Increase of Skin-Ceramide Levels in Aged Subjects following a Short-Term Topical Application of Bacterial Sphingomyelinase from Streptococcus Thermophilus. International Journal of Immunopathology and Pharmacology. 2008; 21: 137–143. https://doi.org/10.1177/039463200802100115

[82] Golkar N, Ashoori Y, Heidari R, Omidifar N, Abootalebi SN, Mohkam M, et al. A Novel Effective Formulation of Bioactive Compounds for Wound Healing: Preparation, In Vivo Characterization, and Comparison of Various Postbiotics Cold Creams in a Rat Model. Evidence-based Complementary and Alternative Medicine : ECAM. 2021; 2021: 8577116. https://doi.org/10.1155/2021/8577116

[83] Kim J, Lee YI, Mun S, Jeong J, Lee DG, Kim M, et al. Efficacy and Safety of Epidermidibacterium Keratini EPI-7 Derived Postbiotics in Skin Aging: A Prospective Clinical Study. International journal of molecular sciences. 2023; 24: 4634. https://doi.org/10.3390/ijms24054634

[84] Tsai WH, Chou CH, Chiang YJ, Lin CG, Lee CH. Regulatory effects of Lactobacillus plantarum-GMNL6 on human skin health by improving skin microbiome. International journal of medical sciences. 2021; 18: 1114–1120. https://doi.org/10.7150/ijms.51545

[85] Di Marzio L, Cinque B, De Simone C, Cifone MG. Effect of the lactic acid bacterium Streptococcus thermophilus on ceramide levels in human keratinocytes in vitro and stratum corneum in vivo. The Journal of Investigative Dermatology. 1999; 113: 98–106. https://doi.org/10.1046/j.1523-1747.1999.00633.x

[86] Shirkhan F, Safaei F, Mirdamadi S, Zandi M. The Role of Probiotics in Skin Care: Advances, Challenges, and Future Needs. Probiotics and Antimicrobial Proteins. 2024; 16: 2132–2149. https://doi.org/10.1007/s12602-024-10319-y

[87] Kim KM, Song JW, Lee CW, Kim DS, Sohn J, Lee S. Skin Barrier-Enhancing Effects of Dermabiotics HDB with Regulation of Skin Microbiota. Journal of microbiology and biotechnology. 2024; 34: 65–73. https://doi.org/10.4014/jmb.2306.06042

[88] Cui H, Guo C, Wang Q, Feng C, Duan Z. A pilot study on the efficacy of topical lotion containing anti-acne postbiotic in subjects with mild -to -moderate acne. Frontiers in medicine. 2022; 9: 1064460. https://doi.org/10.3389/fmed.2022.1064460

[89] Guéniche A, Bastien P, Ovigne JM, Kermici M, Courchay G, Chevalier V, et al. Bifidobacterium longum lysate, a new ingredient for reactive skin. Experimental Dermatology. 2010; 19: e1–e8. https://doi.org/10.1111/j.1600-0625.2009.00932.x

[90] Puebla-Barragan S, Reid G. Probiotics in Cosmetic and Personal Care Products: Trends and Challenges. Molecules (Basel, Switzerland). 2021; 26: 1249. https://doi.org/10.3390/molecules26051249