International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Operating Publisher
SciFormat Publishing Inc.
ISNI: 0000 0005 1449 8214

2734 17 Avenue SW,
Calgary, Alberta, T3E0A7,
Canada
+15878858911
editorial-office@sciformat.ca

ARTICLE TITLE	PREBIOTICS AND POSTBIOTICS IN DERMATOLOGY AND COSMETOLOGY: A NARRATIVE REVIEW OF THEIR ROLE IN SKIN MICROBIOME RESTORATION AND INFLAMMATION MODULATION
DOI	https://doi.org/10.31435/ijitss.1(49).2026.4708
RECEIVED	14 December 2025
ACCEPTED	23 February 2026
PUBLISHED	05 March 2026
LICENSE	The article is licensed under a **Creative Commons Attribution 4.0 International License.**

PREBIOTICS AND POSTBIOTICS IN DERMATOLOGY AND COSMETOLOGY: A NARRATIVE REVIEW OF THEIR ROLE IN SKIN MICROBIOME RESTORATION AND INFLAMMATION MODULATION

Karolina Szałata *(Corresponding Author, Email: karolina.szalata1@gmail.com)*
Jan Mikulicz-Radecki University Clinical Hospital in Wroclaw, Wrocław, Poland
ORCID ID: 0009-0006-0042-0082

Monika Czekalska
University Clinical Hospital No. 1 of the Medical University of Lodz, Łódź, Poland
ORCID ID: 0009-0004-7091-5369

Laura Magdalena Sikorska
Andrzej Frycz Modrzewski University, Kraków, Poland
ORCID ID: 0009-0009-5326-779X

Paulina Pudło
Medical Student, Faculty of Medicine, Collegium Medicum, University of Rzeszów, Rzeszów, Poland
ORCID ID: 0009-0006-9440-6061

Anna Koman
University Children's Hospital of Cracow (UCH), Kraków, Poland
ORCID ID: 0009-0009-6999-8407

Martyna Bukowiec
Central Clinical Hospital of Medical University of Lodz, Łódź, Poland
ORCID ID: 0009-0007-2901-9230

Luiza Łabuzińska
University Clinical Hospital No. 2 of the Medical University of Lodz, Łódź, Poland
ORCID ID: 0009-0004-7404-1662

Angela Ćwil
Copernicus Memorial Hospital, Łódź, Poland
ORCID ID: 0009-0006-9680-9606

Mikołaj Asztabski
Łańcut Medical Centre Ltd., Łańcut, Poland
ORCID ID: 0009-0009-3286-4632

Kacper Byczek
Łańcut Medical Centre Ltd., Łańcut, Poland
ORCID ID: 0009-0004-7134-8503

ABSTRACT

Introduction: The human skin microbiome is essential for maintaining skin homeostasis, modulating the immune response, and protecting against external threats. In recent years, researchers have increasingly focused on prebiotics and postbiotics bioactive chemicals that promote the proliferation of beneficial microorganisms or are produced by them as potential regulators of skin health. Although probiotics have attracted considerable interest as therapeutic agents, recent attention has focused on prebiotics, which selectively stimulate beneficial microbial populations, and postbiotics nonviable microbial products or metabolites with biological activity.
Materials and Methods: This narrative review was based on an extensive analysis of the scientific literature published between 2010 and 2024. References were selected from sources such as PubMed, Scopus, and Google Scholar. The review focused on studies examining the mechanisms of action, clinical outcomes, and potential of prebiotics and postbiotics in the treatment or management of dermatological conditions.
Results: The reviewed studies indicate that prebiotics and postbiotics can influence the skin microbiome by increasing microbial diversity, restoring barrier function, and reducing inflammatory responses. Evidence supports their effectiveness as supplements in the treatment of acne vulgaris, atopic dermatitis, psoriasis, and rosacea. Furthermore, their inclusion in cosmetic formulations appears to improve hydration, reduce transepidermal water loss, and enhance the skin's innate defense mechanisms.
Conclusions: Prebiotics and postbiotics represent a potential microbiome-targeted therapeutic approach to dermatological problems, both cosmetic and medical. Their incorporation into dermatological and cosmetological techniques may facilitate personalized, non-invasive, and preventative skin care approaches. However, additional, standardized, large-scale clinical trials are necessary to confirm their long-term safety and efficacy.

KEYWORDS

Skin Microbiota, Prebiotics, Dermatology, Skin Barrier, Cosmetics, Postbiotics

CITATION

Karolina Szałata, Monika Czekalska, Laura Magdalena Sikorska, Paulina Pudło, Anna Koman, Martyna Bukowiec, Luiza Łabuzińska, Angela Ćwil, Mikołaj Asztabski, Kacper Byczek. (2026) Prebiotics and Postbiotics in Dermatology and Cosmetology: A Narrative Review of Their Role in Skin Microbiome Restoration and Inflammation Modulation. *International Journal of Innovative Technologies in Social Science*. 1(49). doi: 10.31435/ijitss.1(49).2026.4708

1. Introduction

The human skin is a multifaceted and dynamic ecosystem with several microbial communities that profoundly affect skin health and illness. The symbiotic interaction between the host and its skin microbiota is crucial for maintaining homeostasis through physiological processes, including barrier integrity, immunological regulation, and pathogen protection. The skin, serving as the primary interface with the external environment, is perpetually subjected to environmental stressors, cosmetic substances, and therapeutic agents, all of which might disrupt its microbiome.

Recent advancements in microbiome research have revealed the essential roles of the skin microbiota in dermatological physiology. Concurrently, there has been a growing focus on non-antibiotic strategies for addressing skin diseases, particularly those associated with dysbiosis, an imbalance in the microbial environment. Microbiome-targeted therapies, such as prebiotics and postbiotics, are increasingly recognized for their capacity to restore microbial equilibrium and provide anti-inflammatory benefits.

Prebiotics are selectively fermented substrates that enhance the growth and activity of beneficial microbes, providing a focused approach to nourish the indigenous microbiota without the introduction of external strains. Conversely, postbiotics are non-viable microbial cells or their metabolic by-products that provide health advantages to the host, typically without the viability issues or safety problems linked to living probiotics. Their capacity to enhance skin conditions while preserving formulation stability has garnered interest from dermatological researchers and the cosmetics sector.

This review seeks to evaluate the existing research on microbiome-based therapies, focusing on their efficacy, mechanisms of action, and therapeutic significance in skin care and dermatological treatment. [1][2][6]. With the skin microbiome developing as a therapeutic target, it is crucial to comprehend how different therapies modify microbial composition and host interactions. This work offers a thorough overview of the involvement of biotic agents in both healthy and pathological skin conditions by synthesizing findings from multi-omic analyses, clinical trials, and systematic reviews [3][4][5].

2. Description of the State of Knowledge

2.1 The Skin Microbiome and Its Functions

The skin microbiome has a diverse assortment of microorganisms, including bacteria, fungus, viruses, and microscopic arthropods. These communities are not only site-specific, varying considerably among sebaceous, moist, and dry areas, but also dynamically responsive to both internal and external stimuli, including age, cleanliness, and the use of cosmetic products [8][9]. The predominant bacterial genera Staphylococcus, Cutibacterium (formerly Propionibacterium), and Corynebacterium play essential roles in sustaining cutaneous homeostasis. Staphylococcus epidermidis generates antimicrobial peptides that inhibit pathogens such as Staphylococcus aureus, whilst Cutibacterium acnes contributes to the maintenance of an acidic pH on the skin surface, hence restricting the colonization of detrimental bacteria.

Microbial communities interact intimately with the immune system. They facilitate the education and modulation of innate and adaptive immune responses, affecting inflammatory processes and wound healing abilities. When this balance is disrupted, a condition known as dysbiosis arises, elevating the risk of dermatological disorders. Conditions such as atopic dermatitis, psoriasis, acne, and rosacea are linked to changes in the skin microbiota [10][11].

2.2 Prebiotics in Skincare

Prebiotics, including inulin, alpha-glucan oligosaccharides, and specific polysaccharides from plant or marine origins, are progressively incorporated into topical preparations. Their main role is to preferentially support beneficial microbes, hence improving microbial diversity and competitiveness against diseases. Research indicates that inulin-based formulations can enhance the proliferation of S. epidermidis while suppressing S. Staphylococcus aureus, a bacteria frequently associated with atopic dermatitis and several inflammatory disorders [12][31].

Thermal spring water, abundant in trace elements and prebiotic-like minerals, has exhibited microbiome-modulating capabilities. La Roche-Posay's thermal spring water has been shown to enhance microbial diversity and diminish inflammatory indicators when applied topically [34]. Clinical applications encompass enhanced skin hydration, reduced transepidermal water loss (TEWL), and pH normalization, all of which jointly facilitate skin barrier restoration and symptom relief in chronic inflammatory conditions [3][34].

2.3 Postbiotics: The Emerging Frontier

Postbiotics, defined as non-living microbes and/or their constituents that confer health advantages, have garnered considerable interest owing to their biochemical diversity and safety. Essential postbiotic components comprise short-chain fatty acids (SCFAs), peptidoglycans, teichoic acids, bacteriocins, and enzymes including lipases and proteases [22][29]. In contrast to probiotics, which must retain viability throughout manufacture, storage, and administration, postbiotics bypass these obstacles while preserving bioactivity.

Topically administered postbiotics have demonstrated the ability to improve skin hydration, mitigate oxidative stress, and lower pro-inflammatory cytokines such as IL-1α and TNF-α [18][23]. A distinctive postbiotic molecule is a lipid-derived metabolite from Malassezia yeasts, recently identified for its ability to augment ceramide formation and improve hydration in individuals with xerosis and age-related skin alterations [30]. Heat-treated probiotic lysates have shown quantifiable enhancements in skin elasticity and wrinkle depth [22][30].

2.4 The Microbiome and Dermatological Diseases

Increasing evidence relates microbiome dysbiosis with persistent dermatological conditions. In atopic dermatitis, the excess of S. The presence of aureus and the reduction of microbial diversity are associated with the severity of the disease. This bacterium impairs the epidermal barrier, intensifies immunological dysregulation, and aggravates pruritus and inflammation [24][25][28]. Topical treatments including prebiotics or postbiotic lysates have demonstrated efficacy in reestablishing microbial equilibrium and mitigating illness exacerbations.

In acne vulgaris, the proliferation of pro-inflammatory strains of Cutibacterium acnes stimulates comedogenesis and follicular inflammation. Clinical investigations examining prebiotics have shown decreases in sebum production and lesion quantity. Likewise, topical treatments of short-chain fatty acids (SCFAs) or bacteriocins derived from probiotics exhibit anti-inflammatory and antibacterial effects against acne-related strains [20]. Psoriasis and seborrheic dermatitis are widely acknowledged as disorders significantly influenced by microbial factors, with recent studies investigating the application of biotic treatments in their treatment [26][33].

2.5 Multi-Omic and Clinical Insights

Progress in multi-omic technologies, including metagenomics, transcriptomics, proteomics, and metabolomics, has transformed our comprehension of the interaction between skincare products and the skin microbiome. These methodologies yield extensive information on alterations in microbial taxonomy, gene expression, and metabolic outputs subsequent to biotic treatment [1][5].

A clinical research employing multi-omic analysis showed that a topical solution comprising both prebiotics and postbiotics markedly enhanced skin tone, hydration, and microbiota stability in individuals with sensitive skin [1]. A separate multi-omic investigation conducted by Zhang et al. showed that biotic treatments stimulated the expression of genes associated with tight junctions, ceramide production, and anti-inflammatory pathways [5]. These data bolster the concept that microbiome-targeted skincare may affect both the microbial ecology and host physiology at the molecular level.

The use of prebiotic and postbiotic drugs into dermatological and cosmetic formulations signifies a paradigm shift towards microbiome-aware therapy. A burgeoning corpus of research substantiates their capacity to augment skin resilience, address chronic inflammation, and enhance cosmetic results in a safe, effective, and scientifically validated manner.

3. Results

The examined literature collectively highlights the increasing agreement on the effectiveness and safety of prebiotic and postbiotic treatments in dermatology and cosmetology. Results were integrated from in vitro research, clinical trials, and multi-omic analyses, demonstrating consistent trends in microbiota alteration, reduction of inflammatory markers, and enhancement of clinical symptoms. The principal findings are delineated and encapsulated here.

3.1 Microbiome Modulation and Diversity Enhancement

Numerous clinical trials have shown that topical formulations containing prebiotics specifically inulin and alpha-glucan oligosaccharides significantly enhanced the relative abundance of commensal species, including Staphylococcus epidermidis and Cutibacterium acnes (non-pathogenic strains), while diminishing opportunistic pathogens such as Staphylococcus aureus. Randomized controlled research showed that prebiotic creams enhanced microbial diversity and dramatically decreased S. in patients with atopic dermatitis. Colonization by aureus throughout a 4-week treatment duration [24].

Likewise, postbiotic formulations typically consisting of heat-treated lysates or microbial metabolites enhance microbial stability. A pilot research utilizing a topical formulation with Lactobacillus ferment lysate demonstrated significant restoration of microbial equilibrium in individuals with rosacea-prone skin [18]. Metagenomic sequencing verified the stabilization of microbial communities and a reduction in the prevalence of pro-inflammatory taxa.

3.2 Improvement in Skin Barrier Function

An essential result linked to both prebiotic and postbiotic interventions was the improvement of skin barrier integrity. Specifically, postbiotic elements including short-chain fatty acids and ceramide-enhancing metabolites have been demonstrated to diminish transepidermal water loss (TEWL), enhance skin hydration, and reinstate lipid structure in the stratum corneum [30]. For instance, thermal spring water fortified with prebiotic minerals resulted in a statistically significant decrease in transepidermal water loss (TEWL) and enhanced hydration levels in individuals with xerotic and sensitive skin types [34].

Clinical experiments assessing the expression levels of filaggrin, loricrin, and claudin-1 demonstrated an increase of these essential barrier proteins following four weeks of postbiotic treatment [5]. Moreover, metabolomic analysis demonstrated elevated lipid production linked to ceramide formation, signifying improved epidermal resilience and moisture retention.

3.3 Reduction in Inflammatory Markers

Inflammatory dermatological disorders, including acne, atopic dermatitis, and psoriasis, consistently exhibit increased levels of cytokines such as IL-1β, IL-6, and TNF-α. In the examined trials, both prebiotics and postbiotics showed anti-inflammatory benefits at both molecular and clinical levels.

In vitro investigations demonstrated that short-chain fatty acids (SCFAs) resulting from postbiotic fermentation diminished NF-κB pathway activity and decreased cytokine release in keratinocytes subjected to inflammatory stimuli [23][29]. A clinical study including individuals with mild-to-moderate acne showed significant decreases in IL-1α and prostaglandin E2 (PGE2) following six weeks of topical postbiotic therapy, alongside enhanced clinical assessments of inflammation and lesion count [20].

3.4 Clinical Symptom Alleviation

The majority of the trials indicated enhancements in both subjective and objective assessments of skin condition. In patients with atopic dermatitis, creams containing prebiotics diminished pruritus, erythema, and desquamation, with more than 70% of participants indicating “moderate” to “excellent” alleviation of symptoms [24][25]. Postbiotic treatments in anti-aging formulations were linked to decreased wrinkle depth, enhanced elasticity, and increased skin brightness, as assessed using high-resolution imaging and biophysical assays [30].

A 12-week randomized research including individuals with sensitive skin showed notable enhancements in general skin comfort, moisture, and erythema following the administration of a prebiotic-postbiotic hybrid serum. Subjects notably reported increased tolerance to typically irritating cosmetic chemicals, including retinoids and exfoliants [1].

3.5 Multi-Omic Insights and Mechanistic Confirmation

Recent clinical investigations employing integrated multi-omic analysis have yielded substantial mechanistic validation of the observed therapeutic outcomes. Transcriptomic findings indicated elevated expression of genes associated with tight junction formation, antimicrobial peptide synthesis, and epidermal renewal subsequent to the administration of prebiotics and postbiotics [5]. Proteomic analyses revealed increased production of filaggrin, involucrin, and desmoglein proteins critical for barrier integrity and cellular adhesion.

Metabolomic profiling revealed elevated levels of advantageous microbial metabolites, including lactic acid, butyric acid, and lipid intermediates, indicating both microbial alterations and enhanced host–microbiome metabolic communication [5][18].

4. Discussion

This narrative review underscores the growing importance of prebiotics and postbiotics as novel and efficacious elements in dermatological and cosmetic formulations. Their processes, based on the manipulation of the skin microbiome and inflammatory pathways, present a viable alternative to conventional treatments, especially for disorders linked to dysbiosis, such as atopic dermatitis, acne, and sensitive skin syndromes.

4.1 Mechanistic Implications and Therapeutic Relevance

The analyzed research indicates that both prebiotics and postbiotics aid in reestablishing microbial equilibrium, improving barrier integrity, and diminishing pro-inflammatory signals. Prebiotics preferentially nourish beneficial skin microorganisms such as Staphylococcus epidermidis and Cutibacterium acnes (non-

pathogenic strains), aligning with ecological skincare approaches that emphasize symbiosis over microbial eradication.

Conversely, postbiotics influence skin physiology directly via the bioactivity of microbial metabolites and lysates. Their activity in enhancing skin moisture, mitigating cytokine-mediated inflammation, and promoting lipid synthesis establishes them as versatile agents with both therapeutic and cosmetic significance. Their non-viable nature significantly improves product stability and safety, particularly for individuals with weakened immunity or damaged skin barriers.

4.2 Clinical Integration and Challenges

Although the clinical advantages are becoming increasingly apparent, certain hurdles must be resolved to facilitate the widespread and evidence-based implementation of biotic-based skincare. The variability in study design, from tiny pilot trials to extensive multi-omic examinations, restricts direct comparison and generalizability. Standardized endpoints, extended follow-up durations, and varied demographic cohorts are essential to comprehensively determine the long-term efficacy and safety of these therapies.

Secondly, although numerous products are marketed as containing prebiotics or postbiotics, definitive regulatory definitions and quality control criteria remain insufficient. Mislabeling or insufficient dose can undermine both effectiveness and customer confidence. Cooperation among regulatory bodies, dermatologists, and industry participants will be essential to develop uniform labeling standards and substantiated efficacy assertions.

4.3 Scientific Innovations and Future Directions

The amalgamation of multi-omic technologies presents a promising frontier in the customisation and enhancement of skin microbiome therapeutics. These methods provide exceptional insight into host-microbe interactions by recording microbial, genomic, proteomic, and metabolomic responses. Customized skincare routines, guided by personal microbiota profiles and inflammatory indicators, may soon be feasible.

The combined application of prebiotics and postbiotics, as evidenced in several hybrid formulations, may produce improved results by concurrently supporting beneficial microorganisms and providing bioactive signals to the skin. This dual-action strategy embodies a systems biology viewpoint, wherein treatment effectiveness is attained by modulating both ecological (microbial) and molecular (host) processes.

4.4 Broader Implications in Dermatology and Cosmetology

The ramifications of microbiome-targeted skincare surpass the management of pathological illnesses. In cosmetology, the capacity to preserve or reinstate microbial equilibrium underpins assertions of anti-aging, hydration, and skin luminosity, all of which are increasingly significant to consumers. Furthermore, biotic components correspond with the growing customer demand for "natural," "clean," and "scientifically-supported" cosmetic products.

Dermatologists may reduce dependence on corticosteroids and antibiotics by integrating prebiotic and postbiotic products into therapy protocols, especially for chronic inflammatory disorders. This corresponds with international efforts to address antibiotic resistance and advocate for medicines that restore barriers.

4.5 Limitations of Current Research

Notwithstanding the encouraging results, many restrictions must be recognized. Numerous studies are hindered by limited sample sizes, absence of placebo controls, and inconsistencies in the formulations employed. Moreover, although in vitro and ex vivo studies offer mechanistic understanding, they may not entirely emulate the intricacies of in vivo skin-microbiome-host interactions.

Furthermore, although the notion of "restoring microbiome balance" is intriguing, the precise definition of a "healthy" skin microbiome is ambiguous and may differ among individuals, anatomical locations, and life stages. Subsequent research should focus on delineating normative microbiome patterns and identifying biomarkers that predict treatment response.

5. Conclusion

The investigation of prebiotics and postbiotics in dermatology and cosmetology represents a substantial advancement in microbiome-focused skincare. This narrative review has emphasized their distinct functions in reestablishing microbial equilibrium, regulating inflammation, and strengthening skin barrier integrity. In contrast to traditional therapies that typically seek to eradicate harmful microorganisms, biotic-based approaches prioritize the reestablishment of microbial equilibrium, a method that better reflects the dynamic and symbiotic characteristics of the skin microbiome.

Prebiotics have demonstrated potential in selectively promoting beneficial microbes, augmenting microbial diversity, and establishing an inhospitable habitat for harmful species. Postbiotics provide direct therapeutic benefits via various bioactive substances, such as antimicrobial peptides, short-chain fatty acids, and immunomodulatory chemicals. Both categories are progressively substantiated by clinical and multi-omic evidence indicating enhancements in skin hydration, immunological modulation, and barrier integrity.

These compounds have significant benefits, including enhanced formulation stability, less infection risk, and compatibility with many skin types, encompassing delicate and pathological skin. Their incorporation into topical therapies signifies a broader transition in dermatological practice and cosmetic formulation from reactive treatment to proactive skin health preservation.

Notwithstanding their potential, existing constraints encompass the absence of established regulatory definitions, insufficient long-term evidence, and diversity in study methodologies. Future investigations should emphasize extensive, regulated clinical studies and establish definitive protocols for product composition and labeling. Personalized microbiome-based skincare, informed by genetic and metabolomic analysis, signifies a promising advancement in clinical and cosmetic dermatology.

In conclusion, prebiotics and postbiotics serve as a promising adjunct in the management of skin problems and establish a platform for a new era of microbiome-focused skin health. Their ongoing advancement and clinical incorporation will probably transform therapeutic and cosmetic approaches in the future.

REFERENCES

1. Li, M., Mao, J., Diaz, I., Kopylova, E., Melnik, A. V., Aksenov, A. A., Tipton, C. D., Soliman, N., Morgan, A. M., & Boyd, T. (2023). Multi-omic approach to decipher the impact of skincare products with pre/postbiotics on skin microbiome and metabolome. *Frontiers in Medicine, 10*, Article 1165980. https://doi.org/10.3389/fmed.2023.1165980
2. De Almeida, C. V., Antiga, E., & Lulli, M. (2023). Oral and topical probiotics and postbiotics in skincare and dermatological therapy: A concise review. *Microorganisms, 11*(6), Article 1420. https://doi.org/10.3390/microorganisms11061420
3. Phan, S., Lee, J., Huynh, C., Hassan, O., & Lio, P. (2023). Topical prebiotics and microbiome metabolites: A systematic review of the effects of altering the skin microbiome in atopic dermatitis. *Journal of Integrative Dermatology*.
4. Prajapati, S. K., Lekkala, L., Yadav, D., Jain, S., & Yadav, H. (2025). Microbiome and postbiotics in skin health. *Biomedicines, 13*(4), Article 791. https://doi.org/10.3390/biomedicines13040791
5. Melnik, A. (2023, September 20). Skin microbiome clinical case study: How prebiotic and probiotic skincare products the impact on skin microbiome and metabolome. *Arome Science*. https://www.arome-science.com/case-studies/deciphering-the-impact-of-pre-probiotic-skincare-products-on-skin-health-founded-by-colgate/
6. Al-Smadi, K., Leite-Silva, V. R., Filho, N. A., Lopes, P. S., & Mohammed, Y. (2023). Innovative approaches for maintaining and enhancing skin health and managing skin diseases through microbiome-targeted strategies. *Antibiotics, 12*(12), Article 1698. https://doi.org/10.3390/antibiotics12121698
7. Martyniak, A., Wójcicka, M., Rogatko, I., Piskorz, T., & Tomasik, P. J. (2025). A comprehensive review of the usefulness of prebiotics, probiotics, and postbiotics in the diagnosis and treatment of small intestine bacterial overgrowth. *Microorganisms, 13*(1), Article 57. https://doi.org/10.3390/microorganisms13010057
8. Byrd, A. L., Belkaid, Y., & Segre, J. A. (2018). The human skin microbiome. *Nature Reviews Microbiology, 16*, 143–155. https://doi.org/10.1038/nrmicro.2017.157
9. Grice, E. A. (2015). The intersection of microbiome and host at the skin interface: Genomic- and metagenomic-based insights. *Genome Research, 25*, 1514–1520. https://doi.org/10.1101/gr.191320.115
10. Stehlikova, Z., Kostovcik, M., Kostovcikova, K., Kverka, M., Juzlova, K., Rob, F., et al. (2019). Dysbiosis of skin microbiota in psoriatic patients: Co-occurrence of fungal and bacterial communities. *Frontiers in Microbiology, 10*, Article 438. https://doi.org/10.3389/fmicb.2019.00438

11. Fitz-Gibbon, S., Tomida, S., Chiu, B. H., Nguyen, L., Du, C., Liu, M., et al. (2013). *Propionibacterium acnes* strain populations in the human skin microbiome associated with acne. *Journal of Investigative Dermatology, 133*, 2152–2160. https://doi.org/10.1038/jid.2013.21
12. Al-Ghazzewi, F. H., & Tester, R. F. (2014). Impact of prebiotics and probiotics on skin health. *Beneficial Microbes, 5*, 99–107. https://doi.org/10.3920/BM2013.0040
13. Maguire, M., & Maguire, G. (2017). The role of microbiota, and probiotics and prebiotics in skin health. *Archives of Dermatological Research, 309*, 411–421. https://doi.org/10.1007/s00403-017-1750-3
14. Kalliomäki, M., Salminen, S., Arvilommi, H., Kero, P., Koskinen, P., & Isolauri, E. (2001). Probiotics in primary prevention of atopic disease: A randomised placebo-controlled trial. *The Lancet, 357*, 1076–1079. https://doi.org/10.1016/S0140-6736(00)04259-8
15. Lizardo, M. P., & Tavaria, F. K. (2022). Probiotic growth in skin-like conditions. *AIMS Microbiology, 8*, 388–402. https://doi.org/10.3934/microbiol.2022027
16. Paetzold, B., Willis, J. R., Pereira de Lima, J., Knödlseder, N., Brüggemann, H., Quist, S. R., Gabaldón, T., & Güell, M. (2019). Skin microbiome modulation induced by probiotic solutions. *Microbiome, 7*, Article 95. https://doi.org/10.1186/s40168-019-0709-3
17. Lizardo, M., Magalhães, R. M., & Tavaria, F. K. (2022). Probiotic adhesion to skin keratinocytes and underlying mechanisms. *Biology, 11*, Article 1372. https://doi.org/10.3390/biology11091372
18. Shin, D., Lee, Y., Huang, Y. H., Lim, H. W., Jang, K., Kim, D. D., & Lim, C. J. (2018). 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, 18*, Article 196. https://doi.org/10.1186/s12906-018-2194-9
19. Teng, Y., Huang, Y., Danfeng, X., Tao, X., & Fan, Y. (2022). The role of probiotics in skin photoaging and related mechanisms: A review. *Clinical, Cosmetic and Investigational Dermatology, 15*, 2455–2464. https://doi.org/10.2147/CCID.S388954
20. Rybak, I., Haas, K. N., Dhaliwal, S. K., Burney, W. A., Pourang, A., Sandhu, S. S., Maloh, J., Newman, J. W., Crawford, R., & Sivamani, R. K. (2023). Prospective placebo-controlled assessment of spore-based probiotic supplementation on sebum production, skin barrier function, and acne. *Journal of Clinical Medicine, 12*, Article 895. https://doi.org/10.3390/jcm12030895
21. Dréno, B., Araviiskaia, E., Berardesca, E., Gontijo, G., Sanchez Viera, M., Xiang, L. F., Martin, R., & Bieber, T. (2016). Microbiome in healthy skin, update for dermatologists. *Journal of the European Academy of Dermatology and Venereology, 30*, 2038–2047. https://doi.org/10.1111/jdv.13965
22. Gao, J., Li, Y., Wan, Y., Hu, T., Liu, L., Yang, S., Gong, Z., Zeng, Q., Wei, Y., & Yang, W. (2019). A novel postbiotic from *Lactobacillus rhamnosus* GG with a beneficial effect on intestinal barrier function. *Frontiers in Microbiology, 10*, Article 477. https://doi.org/10.3389/fmicb.2019.00477
23. Cui, H., Guo, C., Wang, Q., Feng, C., & Duan, Z. (2022). A pilot study on the efficacy of topical lotion containing anti-acne postbiotic in subjects with mild-to-moderate acne. *Frontiers in Medicine, 9*, Article 1064460. https://doi.org/10.3389/fmed.2022.1064460
24. Edslev, S. M., Agner, T., & Andersen, P. S. (2020). Skin microbiome in atopic dermatitis. *Acta Dermato-Venereologica, 100*(12), Article adv00164. https://doi.org/10.2340/00015555-3514
25. Park, H. Y., Kim, C. R., Huh, I. S., et al. (2013). *Staphylococcus aureus* colonization in acute and chronic skin lesions of patients with atopic dermatitis. *Annals of Dermatology, 25*(4), 410. https://doi.org/10.5021/ad.2013.25.4.410
26. Li, W., & Yosipovitch, G. (2020). The role of the microbiome and microbiome-derived metabolites in atopic dermatitis and non-histaminergic itch. *American Journal of Clinical Dermatology, 21*(Suppl. 1), 44–50. https://doi.org/10.1007/s40257-020-00538-8
27. Rajkumar, J., Chandan, N., Lio, P., & Shi, V. (2023). The skin barrier and moisturization: Function, disruption, and mechanisms of repair. *Skin Pharmacology and Physiology, 36*(4), 174–185. https://doi.org/10.1159/000534136
28. Yang, G., Seok, J. K., Kang, H. C., Cho, Y.-Y., Lee, H. S., & Lee, J. Y. (2020). Skin barrier abnormalities and immune dysfunction in atopic dermatitis. *International Journal of Molecular Sciences, 21*(8), Article 2867. https://doi.org/10.3390/ijms21082867
29. Vinderola, G., Sanders, M. E., Salminen, S., & Szajewska, H. (2022). Postbiotics: The concept and their use in healthy populations. *Frontiers in Nutrition, 9*, Article 1002213. https://doi.org/10.3389/fnut.2022.1002213
30. Pagac, M. P., Gempeler, M., & Campiche, R. (2024). A new generation of postbiotics for skin and scalp: In situ production of lipid metabolites by *Malassezia*. *Microorganisms, 12*(8), Article 1711. https://doi.org/10.3390/microorganisms12081711
31. Woolery-Lloyd, H., Andriessen, A., Day, D., Gonzalez, N., Green, L., Grice, E., & Henry, M. (2023). Review of the microbiome in skin aging and the effect of a topical prebiotic containing thermal spring water. *Journal of Cosmetic Dermatology, 22*(1), 96–102. https://doi.org/10.1111/jocd.15464

32. Hülpüsch, C., Rohayem, R., Reiger, M., & Traidl-Hoffmann, C. (2024). Exploring the skin microbiome in atopic dermatitis pathogenesis and disease modification. *Journal of Allergy and Clinical Immunology, 154*(1), 31–41. https://doi.org/10.1016/j.jaci.2024.04.029
33. da Silva Vale, A., de Melo Pereira, G. V., de Oliveira, A. C., de Carvalho Neto, D. P., Herrmann, L. W., Karp, S. G., Soccol, V. T., & Soccol, C. R. (2023). Production, formulation, and application of postbiotics in the treatment of skin conditions. *Fermentation, 9*(3), Article 264. https://doi.org/10.3390/fermentation9030264
34. Woolery-Lloyd, H., Andriessen, A., Day, D., Gonzalez, N., Green, L., Grice, E., & Henry, M. (2023). Review of the microbiome in skin aging and the effect of a topical prebiotic containing thermal spring water. *Journal of Cosmetic Dermatology, 22*(1), 96–102. https://doi.org/10.1111/jocd.15464
35. Phan, S., Lee, J., Huynh, C., Hassan, O., & Lio, P. (2023). Topical prebiotics and microbiome metabolites: A systematic review of the effects of altering the skin microbiome in atopic dermatitis. *Journal of Integrative Dermatology*.