Proceedings of the 4th International Conference on Biological Engineering and Medical Science
DOI: 10.54254/2753-8818/59/20241412

Microorganisms and microbial metabolites: The next frontier in skincare products

Yiang Lyu

Materials Science and Engineering, Southern University of Science and Technology, Shenzhen, 518055, China

12233271@mail.sustech.edu.cn

Abstract. Microorganisms and microbial metabolites are important resources for skincare product ingredients. The development of synthetic biology has brought more opportunities for the application of microorganisms and their metabolites in skincare products. With increasing consumer interest in natural and probiotic skincare, market acceptance of microbial metabolites is also gradually improving. However, this trend faces challenges such as regulatory issues, technical difficulties, and cost constraints. This paper explores the application prospects of microorganisms and their metabolites in skincare products, focusing on a review of several major microorganisms and their metabolites, including *Bifidobacterium*, *Lactobacillus*, and *Saccharomyces cerevisiae*, and their mechanisms of action in skincare. Additionally, it analyzes the potential application value of other microorganisms in skincare, such as *Cutibacterium acnes* and *Streptococcus thermophilus*, which have also been found to have positive effects on skin health. Finally, the review identifies the current opportunities and challenges faced by microorganisms and their metabolites in the skincare field, providing direction for future research.

Keywords: Microorganisms, Skincare, Metabolites, Microbiome.

1. Introduction

The skin is the largest organ of the human body and serves as the first line of defense against external aggressions. In its constant interaction with the external environment, the skin becomes colonized by a variety of microorganisms, including bacteria, fungi, and viruses [1]. With the advancement of microbiological research, an increasing number of studies have demonstrated the inseparable relationship between the balance of skin microbiota and skin health. Dysbiosis of the skin microbiome or colonization by pathogenic microorganisms is related to certain skin diseases. Conversely, the oral or topical application of specific probiotics and their metabolites have been shown can treat or prevent certain skin conditions, such as acne, atopic dermatitis, and psoriasis [2].

In most countries and regions, regulatory authorities impose stringent regulations and requirements on the direct use of live bacterial components in skincare products. As a result, most skincare companies prefer to use crude or purified metabolites of certain probiotics as ingredients in their products. Because of the rapid development of synthetic biology, a growing number of new microbial metabolite-based skincare ingredients and products have emerged, marking the advent of the era of microbiome skincare [3].

DOI: 10.54254/2753-8818/59/20241412

This paper reviews the roles and mechanisms of common probiotic metabolites in skincare products and explores the opportunities and challenges of future applications of probiotic metabolites in this field.

2. Microorganisms

Microorganism associated with skincare products include *Bifidobacterium*, *Lactobacillus*, *Saccharomyces*, etc. (Table 1)

2.1. Bifidobacterium

The genus *Bifidobacterium* belongs to the phylum Actinobacteria. These bacteria are Gram-positive, pleomorphic, rod-shaped microorganisms. As members of the gut microbiota of mammals and other animals, certain strains of *Bifidobacterium* can exert health-promoting effects and are widely utilized in the food and health industries [4]. Notably, *Bifidobacterium* is commonly added to and fermented in yogurt products, which may help improve lactose malabsorption, treat infectious diarrhea, reduce the duration and incidence of respiratory infections, and enhance immune and anti-inflammatory responses [5].

As one of the most studied probiotics, *Bifidobacterium* has been a focal point for many researchers, including in the field of skin health. One study found that a combination of *Bifidobacterium* and galacto-oligosaccharides effectively prevented skin photoaging, indicating its potential application in sun protection [6]. Atopic dermatitis (AD) is a widespread inflammatory skin disease with high prevalence in Europe and North America. Recent in vitro experiments have shown that the supernatant of *Bifidobacterium* cultures possesses strong antioxidant properties for human skin cells, enhances skin barrier function, and is safe for topical use [7]. Some studies have also indicated that *Bifidobacterium* can promote skin wound healing [8].

With the growing understanding and recognition of microbial resources, *Bifidobacterium* products have also been gradually applied in skincare products in recent years. A research team in China isolated a strain of *Bifidobacterium* longum ZJ1 from centenarians, whose lysate was found to effectively reduce melanin production in cells and melanin content in zebrafish embryos. Moreover, in vitro experiments demonstrated its indirect inhibition of intracellular tyrosinase activity and antioxidant activity, suggesting the broad application potential of *Bifidobacterium* extracts in the whitening field [9]. The skin barrier is intricately linked to the human skin microbiome. Research teams have found that *Bifidobacterium* extracts can alleviate adverse reactions caused by skin irritation and enhance the skin barrier [10]. This also implies the potential broad application of *Bifidobacterium* extracts in soothing and moisturizing skincare products.

Bifidobacterium-related products have already been applied in many areas, particularly in the treatment and prevention of intestinal diseases. The above evidence indicates that *Bifidobacterium* extracts have extensive prospects in whitening, sun protection, and antioxidant applications. It is expected that we will see more *Bifidobacterium* related products promoted and applied in the field of skin health in the future.

2.2. Lactobacillus

Lactobacillus is beneficial to human health and has a wide range of applications in the food, cosmetics, and pharmaceutical industries due to its Generally Recognized As Safe (GRAS) status and various therapeutic and functional properties. Some *Lactobacillus* strains are considered probiotics and promote host health [11].

Lactobacillus is extensively used in skincare products, including those for sun protection, moisturizing, and acne treatment. Sun protection typically refers to protecting the skin from UV radiation damage. Certain *Lactobacillus* strains have been found to have photoprotective properties. In a mouse study, *Lactobacillus* acidophilus IDCC 3302 was found to inhibit UVB-induced wrinkle formation by downregulating related genes [12]. Some *Lactobacillus* strains can mitigate immune-related inflammatory responses. For instance, a study found that *Lactobacillus* salivarius LA307 and

DOI: 10.54254/2753-8818/59/20241412

Lactobacillus rhamnosus LA305 reduced skin inflammation in hairless mice, which is particularly beneficial for patients with atopic dermatitis (AD) [13].

The imbalance of the skin microbiome is closely associated with the occurrence of skin diseases. *Lactobacillus* plantarum GMNL6 can regulate the skin microbiome, improving skin condition. This was observed in volunteers, where significant improvements in skin condition and physicochemical indicators were noted, indicating multiple mechanisms and broad potential for skincare product development [14]. Acne is one of the most common skin diseases. In a randomized double-blind study, *Lactobacillus* plantarum CJLP55 showed significant clinical improvement in symptoms of acne vulgaris compared to the control group [15].

Lactobacillus ferment also serves as an important skincare ingredient. In a recent study, female volunteers with Chinese sensitive scalp syndrome experienced significant symptom relief after using a yeast and *Lactobacillus* ferment complex for 28 days [16]. Another study found that the supernatant of *Lactobacillus* helveticus NS8-fermented milk had protective effects against UV-induced skin oxidative damage and hyperpigmentation [17]. In a recent randomized trial, volunteers using a lotion containing probiotic ferment lysate as the main functional ingredient for 30 days showed significant increases in skin hydration and enhanced skin barrier function [18]. As one of the most studied probiotics, the evidence suggests that *Lactobacillus* and its ferments have broader application prospects in the skincare industry.

2.3. Saccharomyces

Saccharomyces cerevisiae is a fungus widely used for fermentation. It can grow under both aerobic and anaerobic conditions and ferments sugars to produce alcohol and carbon dioxide [19]. Due to its diverse applications and health benefits, *Saccharomyces cerevisiae* has become a crucial resource in the food, beverage, pharmaceutical, and skincare industries.

Saccharomyces cerevisiae has extensive applications in the field of skincare. Recently, a research team in South Korea found that the fermentation residues of *Saccharomyces cerevisiae* significantly inhibited melanin production in B16F10 cells, exhibited free radical scavenging activity, and reduced tyrosinase activity. This discovery suggests its potential as a novel skin whitening agent [20]. There is a close association between Staphylococcus aureus and atopic dermatitis (AD), with S. aureus considered one of the causative factors of AD. One study found that *Saccharomyces cerevisiae* significantly inhibited the formation and expression of S. aureus alpha-toxin and enterotoxin A genes, indicating its potential use in controlling S. aureus-related skin infections [21]. Another recent finding showed that *Saccharomyces cerevisiae* extract obtained through ultrasound treatment had a significant inhibitory effect on melanoma [22].

The application value of components obtained from the fermentation of different *Saccharomyces cerevisiae* strains also varies. A Chinese research team studied the differential impact of four different *Saccharomyces cerevisiae* strains fermented with the plant Panax notoginseng on the antioxidant capacity of skin fibroblasts. Compared to unfermented Panax notoginseng extract, the fermented components exhibited stronger antioxidant capabilities [23].

Approximately 13.5% of the global population suffers from chronic pruritus. In a recent study, a novel yeast extract was found to rapidly alleviate itching, outperforming ingredients like oatmeal extract currently used in skincare products [24]. Due to the low cost and high safety of *Saccharomyces cerevisiae*, with some strains being edible and considered probiotics, its products are more easily accepted by consumers for inclusion in skincare products. Compared to other microbial products, *Saccharomyces cerevisiae* has lower potential risks and is easier to cultivate on a large scale, making it particularly advantageous. Skincare companies should pay more attention to its potential application scenarios in the future.

2.4. Others

Cutibacterium acnes is an important component of the human skin microbiome and is closely associated with the development of acne. Certain subspecies play a crucial role in the skin barrier function. In a

DOI: 10.54254/2753-8818/59/20241412

recent volunteer study, researchers applied a care regimen containing culture and fermentation products of *Cutibacterium acnes* strain XYCM42 topically as part of a post-surgical care protocol. Combined with other techniques, the results demonstrated high safety and enhanced therapeutic effects [25]. This indicates that specific strains of *Cutibacterium acnes* might become effective means in future care and treatment scenarios.

Streptococcus thermophilus is a lactic acid bacterium widely used in the food industry, belonging to the genus *Streptococcus*. In dairy products, *Streptococcus thermophilus* is one of the main fermenting agents for products like yogurt and cheese, capable of converting lactose into lactic acid, thereby imparting unique flavors and textures. A recent study discovered that *Streptococcus thermophilus* TCI633, a newly isolated probiotic from human breast milk, can produce hyaluronic acid (HA) when colonizing the gastrointestinal (GI) tracts of rodents and humans. This can alleviate synovial tissue inflammation and potentially slow the progression of osteoarthritis. An 8-week study on volunteers found that TCI633 promoted skin cell proliferation, increased collagen content, protected against DNA damage, and inhibited hyaluronidase activity [26]. This suggests the potential of *Streptococcus thermophilus* TCI633 in delaying skin aging and improving skin conditions.

Sunscreens and sunblock lotions are crucial skincare products that prevent photoaging and photocarcinogenesis by adding chemicals to absorb or block ultraviolet (UV) radiation. Recent researchers discovered antioxidant and UV-absorbing capabilities in a group of actinomycetes derived from Cliona varians, which lacked cytotoxicity [27]. This indicates that UV protectants found in marine *Streptomyces* have significant application potential, possibly replacing existing environmentally harmful chemicals to block or absorb UV radiation in skincare products.

Table 1. Microorganisms in skincare

Microorganisms	Applications	References
Bifidobacterium	Enhance skin barrier function, facilitates the healing of skin wounds and helps maintain skin hydration.	[4-10]
Lactobacillus	Offers hydrating and anti-drying benefits, may inhibit the growth of pathogenic bacteria, and possesses certain antioxidant effects.	[11-18]
Saccharomyces	Inhibits melanin production, possesses antioxidant capabilities, and alleviates chronic itching.	[19-24]
Cutibacterium	Enhances skin barrier function, possesses potential for post-surgical repair and future care.	[25]
Streptococcus	Promotes skin cell proliferation, accelerates skin metabolism, and increases collagen content.	[26]
Streptomyces	Has antioxidant and UV-absorbing capabilities, is non-cytotoxic, and may replace environmentally harmful chemicals in skincare products.	[27]

3. Current opportunities and challenges

With the advent of the era of microbiome skincare, more and more consumers are paying attention to the ingredients, efficacy, and mechanisms of skincare products. The inseparable relationship between microorganisms and human skin offers broad prospects for future applications. As more microbial resources are discovered and utilized, there will be more choices and opportunities.

3.1. Regulatory and safety issues

Regulations regarding the use of microorganism-related products in skincare vary across different countries and regions. Ensuring the safety and stability of these products is crucial. Rigorous testing and adherence to regulatory standards are necessary to gain consumer trust and approval from regulatory bodies [28]. To date, many countries and regions have strict standards for the addition of active substances, and meeting these stringent standards is a challenge that needs to be addressed [29].

DOI: 10.54254/2753-8818/59/20241412

3.2. Consumer acceptance

As consumer interest in natural probiotic skincare products increases, market acceptance of microbial metabolites is also gradually improving. Marketing strategies should emphasize the scientific basis and efficacy of these products, helping consumers understand the benefits and safety of these ingredients.

3.3. Technical challenges

Producing and extracting high-quality microbial metabolites poses technical difficulties. Optimizing strain selection, fermentation conditions, and purification processes is necessary to ensure product consistency and efficacy. Advances in biotechnology and synthetic biology can help improve production efficiency and yield, thereby overcoming these technical challenges [30]. Additionally, utilizing advanced detection technologies and equipment can more precisely control the production process, ensuring product quality stability.

3.4. Cost and scalability

Developing cost-effective and scalable production methods is crucial for commercialization. Collaboration between industry and academia can drive innovation in this field, providing more economical solutions and enabling large-scale production.

3.5. Personalized skincare

The application of microbial metabolites in skincare can be personalized based on individual skin microbiome differences. By analyzing personal skin microbiome data, customized skincare solutions can be developed, improving the specificity and efficacy of products. Achieving personalized skincare requires the combination of big data and artificial intelligence technologies. By analyzing large amounts of skin microbiome data, the common and unique characteristics of different skin types and problems can be identified [31]. Targeted microbial metabolite skincare products can then be developed, providing more precise care.

3.6. Environmental protection and sustainability

Microbial metabolites, as natural and renewable skincare ingredients, are environmentally friendly and contribute to sustainable development. Increased environmental awareness prompts consumers to prefer green skincare products, providing more opportunities for the application of microbial metabolites in skincare products [32].

4. Conclusion

The application of microbial metabolites in skincare represents a significant advancement, offering various benefits such as anti-aging, anti-inflammatory, and skin barrier enhancement effects. Throughout this review, we have explored the roles and mechanisms of several key microorganisms and their metabolites in skincare, including *Bifidobacterium*, *Lactobacillus*, and *Saccharomyces cerevisiae*. Additionally, other microorganisms such as *Cutibacterium acnes* and *Streptococcus thermophilus* have also been highlighted for their potential applications in skincare. Despite the challenges, continuous research and technological advancements are expected to overcome obstacles such as regulatory issues, technical difficulties, and cost constraints. The future of skincare lies in the combination of microbiome science with innovative product development, heralding a new era of skin health and beauty. Exploring and utilizing the potential of microbial metabolites in skincare products is poised to revolutionize the industry. Ongoing collaboration between researchers and the skincare industry will be key to unlocking the full potential of microbial metabolites, paving the way for more scientifically-backed products. Personalized skincare, enabled by advancements in big data and artificial intelligence, will offer tailored solutions based on individual skin microbiome differences. This, combined with the natural and renewable nature of microbial metabolites, promotes environmental sustainability and aligns with the increasing consumer preference for green skincare products. In conclusion, the future of skincare should

increasingly rely on the scientific exploration of microbial metabolites, ensuring a safer, more effective, and sustainable approach to skin health.

References

[1] Byrd AL, Belkaid Y and Segre JA 2018 Nat Rev Microbiol 16 143-155
[2] França K 2021 Dermatol Ther (Heidelb) 11 71-77
[3] Han JH and Kim HS 2024 J Microbiol 62 181-199
[4] Hidalgo-Cantabrana C, Delgado S, Ruiz L, Ruas-Madiedo P, Sánchez B and Margolles A 2017 Microbiol Spectr 5
[5] Kok CR and Hutkins R 2018 Nutr Rev 76 4-15
[6] Kim D, Lee KR, Kim NR, Park SJ, Lee M and Kim OK 2021 J Med Food 24 606-616
[7] Ma X, et al. 2022 Exp Dermatol 31 1089-1094
[8] Panagiotou D, et al. 2023 Nutrients 15
[9] Wu J, Zhang F, Yu H, Qi S, Wu Y and Xiao W 2023 Int J Mol Sci 24
[10] Wang R, Yan S, Ma X, Zhao J, Han Y, Pan Y and Zhao H 2023 J Cosmet Dermatol 22 3427-3435
[11] Huang HC, Lee IJ, Huang C and Chang TM 2020 Curr Pharm Biotechnol 21 566-577
[12] Im AR, Lee B, Kang DJ and Chae S 2018 J Med Food 21 1016-1023
[13] Holowacz S, Blondeau C, Guinobert I, Guilbot A, Hidalgo S and Bisson JF 2018 Benef Microbes 9 299-309
[14] Tsai WH, Chou CH, Chiang YJ, Lin CG and Lee CH 2021 Int J Med Sci 18 1114-1120
[15] Kim MJ, Kim KP, Choi E, Yim JH, Choi C, Yun HS, Ahn HY, Oh JY and Cho Y 2021 Nutrients 13
[16] Wang Y, Li J, Wu J, Gu S, Hu H, Cai R, Wang M and Zou Y 2023 Clin Cosmet Investig Dermatol 16 2623-2635
[17] Rong J, Shan C, Liu S, Zheng H, Liu C, Liu M, Jin F and Wang L 2017 J Appl Microbiol 123 511-523
[18] Cui H, Feng C, Zhang T, Martínez-Ríos V, Martorell P, Tortajada M, Cheng S, Cheng S and Duan Z 2023 Sci Rep 13 16879
[19] Eldarov MA, Kishkovskaia SA, Tanaschuk TN and Mardanov AV 2016 Biochemistry (Mosc) 81 1650-1668
[20] Jo DU, Chin YW, Kim Y, Kim KT, Kim TW and Lim TG 2022 Food Sci Biotechnol 31 587-596
[21] Saidi N, Owlia P, Marashi SMA and Saderi H 2019 Iran J Microbiol 11 246-254
[22] Eom SJ, Lim TG, Jhun H, Lee NH, Kang MC and Song KM 2021 Ultrason Sonochem 76 105620
[23] Wang Z, Fang J, Zu S, Sun Q, Song Z, Geng J, Wang D, Li M and Wang C 2024 Clin Cosmet Investig Dermatol 17 621-635
[24] Dhurat R, et al. 2021 J Cosmet Dermatol 20 207-209
[25] Alqam ML, Jones BC and Hitchcock TM 2023 J Clin Aesthet Dermatol 16 18-30
[26] Liu C, Tseng YP, Chan LP and Liang CH 2022 J Cosmet Dermatol 21 2635-2647
[27] Sánchez-Suárez J, Villamil L, Coy-Barrera E and Díaz L 2021 Mar Drugs 19
[28] Urban K, Giesey R and Delost G 2022 J Drugs Dermatol 21 1012-1013
[29] Nakra T 2024 Int Ophthalmol Clin 64 13-22
[30] Jiang B, Jia Y and He C 2018 J Cosmet Dermatol 17 968-976
[31] Markiewicz E and Idowu OC 2018 Clin Cosmet Investig Dermatol 11 161-171
[32] Aslam A, Bahadar A, Liaquat R, Saleem M, Waqas A and Zwawi M 2021 Sci Total Environ 772 144905