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Influence of Cosmetic Formulations on Skin Microbiome Homeostasis

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Introduction

The human skin, the body's largest organ, is a dynamic ecosystem colonized by a complex and diverse community of microorganisms collectively referred to as the skin microbiome. This includes bacteria, fungi, viruses, and mites that coexist in a symbiotic relationship with the host. The skin microbiome plays a vital role in maintaining barrier function, modulating immune responses, and protecting against pathogenic invasion. In recent years, the skin microbiome has garnered significant scientific and commercial interest. Advances in high-throughput sequencing have revealed that skin microbial communities vary by body site, age, gender, environment, and health status. Importantly, alterations in microbial balance-termed dysbiosis-have been linked to a variety of dermatological disorders such as acne, atopic dermatitis, psoriasis, rosacea, and even skin aging. Parallel to this growing understanding is the booming cosmetics industry, which formulates products intended to cleanse, hydrate, protect, or beautify the skin. These formulations contain a variety of emulsifiers, preservatives, surfactants, alcohols, fragrances, and active ingredients, each of which can interact with the skin's microbial communities. While these ingredients aim to improve skin appearance and function, they may also disrupt microbiome homeostasis, leading to unintended consequences on skin health [1-3].

The native skin pH is mildly acidic, which favors commensal bacteria and inhibits pathogen growth. Soaps and alkaline cleansers can shift pH toward neutrality or alkalinity, impairing microbial defense and facilitating dysbiosis. Surfactants and emulsifiers remove sebum and lipids, which are essential for microbial nourishment and habitat. This can reduce Cutibacterium acnes populations and favor the growth of less beneficial species. Ingredients such as parabens, phenoxyethanol, triclosan, benzalkonium chloride, and formaldehyde releasers can kill both pathogenic and beneficial microbes, leading to a reduced microbial diversity and resilience. Heavy emollients, silicones, and certain waxes may occlude pores and alter oxygenation, changing microbial growth conditions and leading to overgrowth of anaerobes or yeasts. Probiotic cosmetics may introduce live bacteria, while contamination during manufacturing or improper storage can introduce unintended pathogens.

Description

Soaps and facial cleansers often contain anionic surfactants (e.g., sodium lauryl sulfate) that are effective at removing dirt and oil but also disrupt microbial membranes. Regular use can reduce microbial diversity, increase skin dryness, and promote irritation. Toners, especially alcohol-based formulations, exhibit strong antimicrobial activity, which can be too harsh for sensitive or acne-prone skin. While they temporarily reduce sebum and kill bacteria, they may disrupt long-term microbiome equilibrium. Moisturizers can either support or disrupt the microbiome depending on formulation. Microbiome-friendly moisturizers: Contain ceramides, lipids, or prebiotics to nourish skin and its microbes. These products influence the axillary microbiome. Studies show that regular use of antiperspirants changes microbial community structure, reducing Staphylococcus hominis (a commensal) and increasing Corynebacterium (associated with odor production).

Foundations, primers, and powders create a physical barrier on the skin. Long-term wear or poor removal can lead to pore congestion and microbial imbalance. Shared makeup tools can introduce foreign microbial strains, including Staphylococcus aureus. Many sunscreens contain UV filters, emulsifiers, and preservatives that may affect skin flora. Newer formulations aim to maintain microbiome neutrality while ensuring UV protection. While Cutibacterium acnes is a natural commensal, dysbiosis-marked by the dominance of inflammatory subtypes (e.g., phylotype IA1)-has been linked to acne. Overuse of cleansers, exfoliants, and antimicrobials may exacerbate imbalance. Dysbiosis in eczema is characterized by an increase in Staphylococcus aureus and a decrease in microbial diversity. Harsh products may exacerbate the condition, whereas microbiome-supportive emollients help restore balance. Certain cosmetic ingredients can trigger rosacea flares by altering Demodex mite populations or causing inflammation. Formulations free of alcohol, fragrance, and preservatives are generally better tolerated. In psoriatic skin, microbial imbalance includes altered ratios of Streptococcus, Staphylococcus, and Malassezia. Cosmetics that alter skin barrier function may worsen symptoms [4,5].

Non-digestible ingredients that nourish beneficial microbes, such as inulin, Fructooligosaccharides (FOS), and alpha-glucan oligosaccharide. They enhance commensal growth without introducing live organisms. Live microorganisms, often from I or I species, applied topically to modulate the skin environment. Though challenges in viability and stability exist, they show promise in acne and eczema care. Metabolites of probiotic bacteria (e.g., lactic acid, short-chain fatty acids) that benefit skin health by reinforcing the barrier and reducing inflammation. Avoiding harsh surfactants, preservatives, alcohols, and synthetic fragrances helps maintain skin pH and microbial diversity. Airless and antimicrobial packaging prevents contamination and reduces the need for strong preservatives.

Conclusion

Cosmetic formulations, once considered superficial agents of beautification, are now recognized as potent modulators of the skin ecosystem. The skin microbiome, a delicate and complex network of microorganisms, plays a critical role in maintaining skin health, resilience, and disease prevention. The evidence is increasingly clear: cosmetic ingredients and practices can significantly alter the microbiome's structure and function-sometimes restoring balance, but often causing disruption. As scientific understanding deepens, it becomes imperative for cosmetic chemists, dermatologists, regulators, and consumers to shift toward microbiome-conscious formulations. The future of skincare lies in harmony-not just between product and skin, but between

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human and microbe. By embracing a microbiome-centric paradigm, we can move toward a new era of cosmetics that are not only effective but also ecologically and biologically respectful.

Acknowledgment

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Conflict of Interest

None.

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