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Exploring the Interplay Between the Skin Microbiome & Cosmetic Products: A Comprehensive Review

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Abstract

The Skin, as the body's largest organ, has a complex and dynamic microbial ecosystem known as the Skin Microbiome. These unravel the intricate relationship between Cosmetic Products and the Skin Microbiome. This article will examine how common skincare ingredients, formulations, and application methods may influence the composition and behavior of microbial communities on the skin. This also addresses the potential consequences of disrupting the skin microbiome equilibrium. The discussion encompasses topics such as prebiotics, probiotics and postbiotics in skincare formulations. This review synthesis current research to provide a comprehensive understanding of the intricate interplay between cosmetic products and the skin microbiome. By shedding light on the delicate balance that exists in the skin's surface, it aims to guide future developments in cosmetic science, fostering formulations that not only enhance aesthetics but also prioritize the holistic health of the skin microbiome.

Keywords: Microbiome, skin, cosmetics, probiotics, environment

Introduction

Skin: The human skin, being the largest organ, serves as an amazing interface between our internal physiology and the external world. It acts as a barrier to protect us from dangerous microorganisms, ultraviolet light, and physical injury while controlling body temperature and preserving fluid balance. [1]

Skin is made up of three main layers: the epidermis, dermis, and hypodermis. Its structure and function are extremely complicated. The outermost layer, the epidermis, is mainly in charge of providing waterproofing and defense against microbiological invaders. Beneath it is the dermis, which contains vital components like sweat glands and hair follicles as well as blood vessels and nerve endings. The hypodermis, the lowest layer, acts as a reserve energy source and an insulator (showed in fig. no. 1). [1]

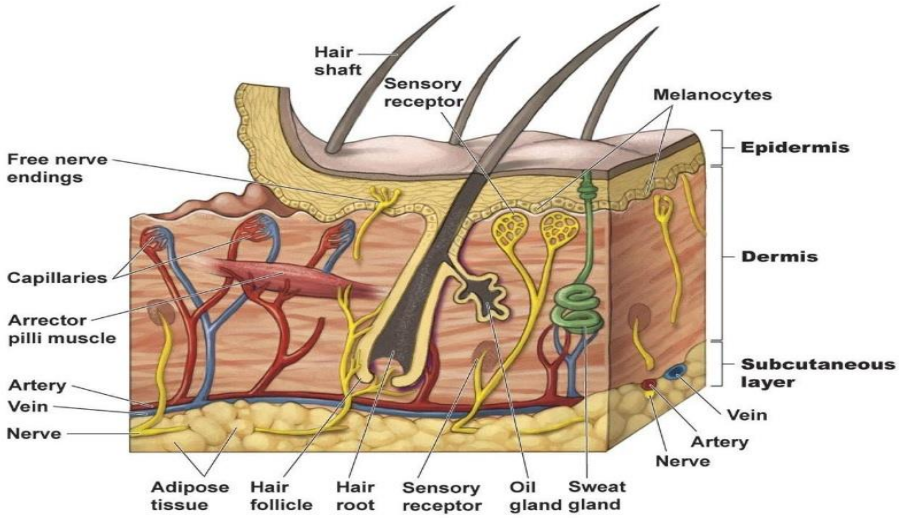

Fig. No. 1 – The Structure of Human Skin

Skin Microbiome: The skin microbiome is a mixed community of microorganisms that lives on the surface of the skin. Microorganisms such as bacteria, fungi, viruses and so on live in and on the skin. The skin microbiome plays a vital role in maintaining skin health. Different skin surfaces have different microbial communities. The interaction between different microorganisms contributes to the overall recovery of the skin. The skin microbiome acts as a protective barrier for the skin to protect it from harmful pathogens (shown in fig. no. 2). [2]

Microorganisms can influence the skin's pH which helps in the growth of good microorganisms and acts against harmful ones. If the microorganisms are imbalanced, they can lead to skin conditions such as acne, eczema, pigmentation, etc. The microorganisms can vary from person to person depending on age, gender, environment, diet, etc. [2,3]

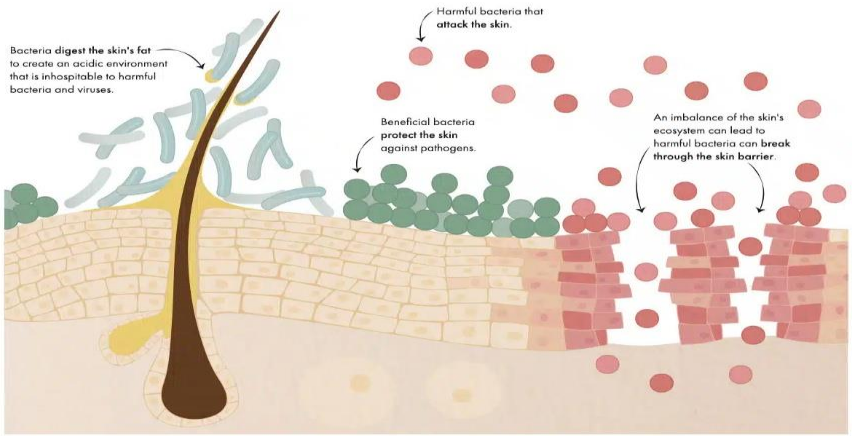

Fig. No. 2 - Skin Microbiome

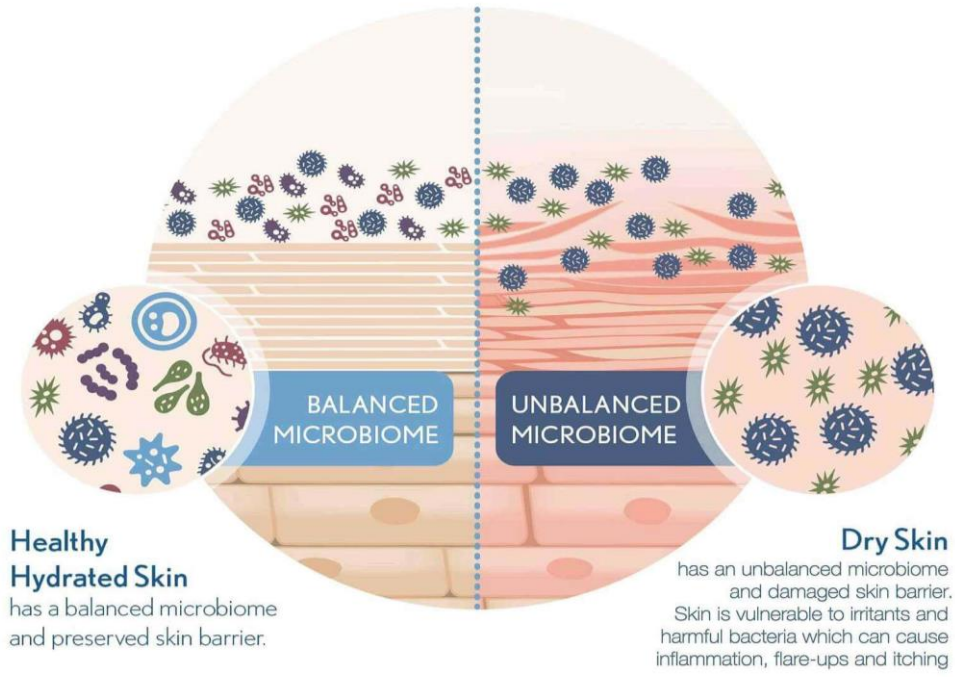

Fig. no. 3 – The difference between balanced & unbalanced microbiome on skin

External factors such skincare products, cosmetics, surroundings can influence the skin microorganisms (Refer to fig no 3). Skincare products which are not according to a person's skin, sometimes can lead to different skin conditions. The imbalance in the skin microbiome has led to the development of different skincare products which now help to balance the skin microbiomes. Skincare with prebiotics, probiotics and postbiotics are often described as that promotes the balanced microbiome. These products aim to maintain the balanced microbiome and to keep the skin healthy [5].

Interplay Between Skin Microbiome and Cosmetic Products

The interplay between skin microbiome and cosmetic products is an immensely powerful and complicated relationship that involves the impact of cosmetic products on the skin's microbes and influence of microbiome on the safety of cosmetic products. Microbial communities can be influenced by cosmetic products which contain antimicrobial agents, preservatives, or harsh chemicals. If any person has sensitive skin, then the microbiome can influence the skin's sensitivity. Cosmetic products can also disrupt the balance of microbes which may lead to skin irritation or allergic reactions [4].

Cosmetic products need preservatives to prevent microbial contamination, but harsh preservatives may impact the natural balance of microbiomes on the skin. Cosmetic products, especially cleansers, can influence the balance through their mechanism but gentle cleansing practices help maintain the microbial balance without causing any other side effects.

Table no. 1 - Skin issues, their relationship with microbiodata and ingredients to cure those issues.

Skin issues	Microorganisms	Impact on Microbiota	Active Ingredients
Acne vulgaris	*C. Acnes*	Increase in production of sebum	Benzoyl peroxide or Azelaic acid
Dandruff	*Malassezia species*	Malassezia lipase activity on sebum	Salicylic acid or zinc pyrithione
Atopic dermatitis	*S. aureus*	S. aureus becomes dominant on the skin	Hyaluronic acid or tea tree oil

Cutibacterium acnes (C. acnes) formerly *Propionibacterium acnes* is present on the skin which helps in developing acne. It grows in clogged pores and leads to inflammation. It can be treated by using cosmetic products containing retinoids, benzoyl peroxide, etc. Dandruff can happen due to overgrowth of yeast like fungus i.e., *Malassezia* and excessive oil production or sensitive to any hair products. It can be managed by using shampoos containing zinc pyrithione, salicylic acid, etc. Atopic dermatitis can be cured by using emollients i.e., moisturizers, etc. (shown in table no. 1). [2.6,11]

Staphylococcus epidermidis (S. epidermidis) is an abundant bacterial colonizer in human skin and recent studies have found that specific strains of it can help or harm the skin barrier. It can weaken the inflammatory response to accelerate wound healing. Some strains of *S. epidermidis* can also dampen *S. aureus*, an induced neutrophil and pro-inflammatory cytokine production that allows for more protection against skin infection [8,9].

A few ingredients that are known to help with maintaining the skin's ecosystems include *lactobacillus ferment lysate, Bifida ferment filtrate, saccharomyces lysate and bacillus ferment.* Every ingredient operates on a different mechanism of action. These types of ingredients should be incorporated below 40°C - 45°C at the end of an emulsion to ensure viability and stability. Additionally, with any active that is healing the skin, it can cause a bit of irritation. The use of emollient is ideal. Emollients are oils and lipids that help to protect and lubricate the skin and enhance skin softness. Some examples of emollients include (Oat) kernel oil, isopropyl myristate, sunflower seed oil, ethylhexyl palmitate and sweet almond oil.[6]

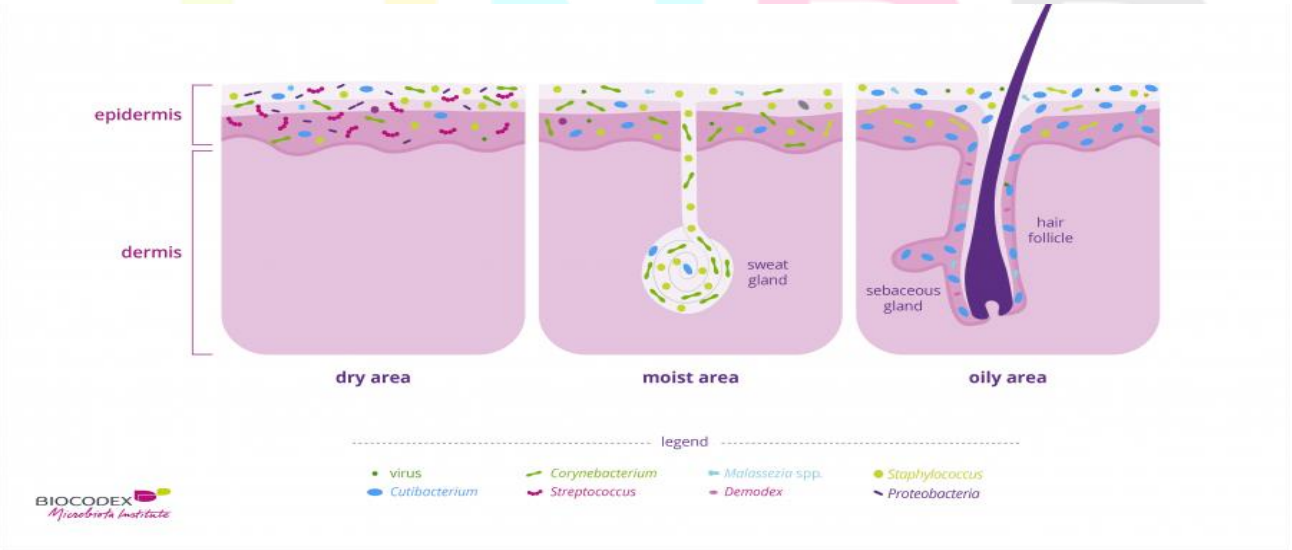

Fig. no. 4 – Composition of microbiota on different skin areas.

Compared to other skin areas, moist or oily skin are more prone to bacterial or fungal growth. Excess sebum production can lead to the growth of *Cutibacterium acne* and moist skin can lead to the growth of *Staphylococcus* and *Corynebacterium* (shown in fig. no. 4). It is always necessary to clean the skin and use cosmetic products according to the skin type. Use of antimicrobial hand sanitizers and soaps are important for hygiene, but it does contribute to various skin conditions. An imbalanced microbiome, or skin dysbiosis, is associated with many health conditions, including psoriasis, allergies, eczema, contact dermatitis, acne, poor wound healing, skin ulcers, dandruff, yeast and fungal infections, rosacea, and accelerated skin aging. Soap and sulfates, by their very nature, it is alkalinizing. That is how it works to remove dirt and microbes. But our skin microbiome prefers a pH of about 5. At this acidic pH, the healthy microbiome thrives. [7,9]

Prebiotics

Prebiotics are non-living substances in cosmetics which refer to ingredients that support the growth and activity of beneficial microorganisms (probiotics) on the skin. This may help in reducing skin problems related to imbalances in the microbiome, such as inflammation and sensitivity. Prebiotics are usually incorporated into skincare such as cleansers, moisturizers, serums, and masks. Common prebiotic ingredients used in cosmetics include several types of carbohydrates, such as *fructooligosaccharides (FOS), galactooligosaccharides (GOS), inulin, xylooligosaccharides (XOS), and arabinogalactans.* These prebiotic compounds are derived from natural sources such as plants, fruits, and grains.[11]

Mechanism of action: Prebiotics work by providing nourishment for beneficial bacteria already present on the skin, such as *Lactobacillus* and *Bifidobacterium* species. By serving as food sources for these beneficial microbes, prebiotics help support their growth, metabolism, and activity, thereby promoting a balanced and healthy skin microbiome.

Probiotics

Probiotics are living microorganisms which consist of bacteria and yeast. These are beneficial bacteria as they help in balancing the microbial community. Probiotics can be used in combination with other ingredients such as prebiotics, antioxidants, moisturizers, etc. Probiotics used in cosmetics include various strains of beneficial bacteria, such as *Lactobacillus*, *Bifidobacterium*, and *Streptococcus*, as well as certain types of yeast, such as *Saccharomyces*. These probiotic microorganisms are selected for their ability to support skin health and balance the skin microbiome [10].

Mechanism of action: Probiotics work by interacting with the skin's natural microbiome and influencing its composition and activity. They can help promote the growth of beneficial bacteria, inhibit the growth of harmful microorganisms, regulate inflammation, strengthen the skin barrier, and support overall skin health.

Postbiotics

Postbiotics are the byproducts produced by probiotics during their fermentation process. These contain organic acids, peptides, enzymes, and other bioactive compounds. Postbiotics are more stable than probiotics. It gives soothing and hydrating effects. Postbiotics encompass a wide range of bioactive compounds produced during microbial fermentation, including:

a. Organic acids (e.g., lactic acid, acetic acid) help maintain skin pH and support barrier function.

b. Enzymes (e.g., proteases, lipases) that aid in exfoliation, skin renewal, and nutrient absorption.
c. Peptides and proteins with antioxidant, anti-inflammatory, and skin-repairing properties.
d. Polysaccharides and oligosaccharides provide hydration, improve skin texture, and support microbial balance.
e. Short-chain fatty acids (SCFAs) with anti-inflammatory and immunomodulatory effects.

Mechanism of action: Postbiotics exert their beneficial effects on the skin by interacting with the skin microbiome, modulating immune responses, regulating inflammation, and promoting skin barrier function and repair. They can help support a balanced and resilient skin microbiome, improve skin hydration, texture, and alleviate various skin concerns [13].

Microbiome Modulators

Beyond conventional probiotics and prebiotics, a broad family of substances known as "microbiome modulators" affects the structure and activity of the skin microbiome. These modulators include a broad spectrum of bioactive substances that are either lab-synthesized or sourced from natural sources, and each has a distinct mode of action and possible uses in skincare.

In contrast to probiotics, which are living microorganisms known to have health benefits, and prebiotics, which provide food for good bacteria, microbiome modulators work through a variety of processes, including immunomodulation, metabolic regulation, and antimicrobial activity.

Types of Microbiome Modulators

Antimicrobial Compounds: Some bioactive substances have antimicrobial qualities that allow them to target microbial populations within the skin microbiome. Natural antimicrobial compounds, such as propolis extract, manuka honey, and tea tree oil, have been shown to prevent the growth of pathogenic bacteria while protecting beneficial germs. [16]

Immunomodulators: Certain substances can modify the activity of the skin's resident immune cells and control the skin's immunological response. These substances may have an indirect effect on the structure and functionality of the skin microbiome by affecting immune function. Beta-glucans, cytokines, and specific plant extracts with anti-inflammatory qualities are a few examples.

Metabolic Regulators: The growth and activity of microbial communities within the skin microbiome can be influenced by certain chemicals that control microbial metabolism and nutrient consumption. For example, the microbial fermentation of dietary fibers produces short-chain fatty acids (SCFAs), which function as metabolic regulators to encourage the growth of beneficial bacteria while preventing the formation of harmful species.

Application in Skincare

- Microbiome modulators are useful in skincare for a variety of purposes, including wound healing, acne therapy, anti-aging, and sensitive skin care.
- Antimicrobial substances can reduce inflammation and stop the development of acne lesions by targeting Propionibacterium acnes, a bacterium that causes acne.

- Immunomodulators can enhance antimicrobial defense mechanisms and modulate the inflammatory response, hence promoting tissue regeneration and repair during wound healing. [16]
- Metabolic regulators have the potential to enhance collagen synthesis and skin hydration in anti-aging skincare products by encouraging the growth of microorganisms that create bioactive substances with anti-aging characteristics.
- Microbiota modulators i.e. hyaluronic acid, which balance the skin microbiota and alter immune activity, can help repair the skin barrier and reduce inflammation in sensitive skin care. [17,18]

Safety and Regulatory Considerations

Microbial Contamination: The possibility of microbial contamination during production and storage is one of the main safety issues with probiotics and other living microorganisms in cosmetics. Customers who use contaminated items, particularly those with weakened immune systems, may be at risk for health problems.

Skin Sensitization: Certain probiotics or prebiotics may cause allergic responses or skin sensitization in certain people. To determine probable allergies and irritants, comprehensive safety assessments are necessary.

Microbiome Disruption: Although supporting a healthy skin microbiota is the aim of microbiome-targeted substances, if these chemicals are not thoroughly prepared and tested, there is a chance of unintended consequences like microbial imbalance or dysbiosis. [19]

FDA Regulations: Under the Federal Food, Drug, and Cosmetic Act (FD&C Act) and the Fair Packaging and Labeling Act (FPLA), the Food and Drug Administration (FDA) is responsible for regulating cosmetics. Although the FDA does not preapprove ingredients or cosmetic goods, it does require producers to make sure their products are labeled correctly and safe for consumer use. The FDA may be more interested in cosmetic items that contain probiotics or other live microorganisms because of the risk of microbial contamination and safety issues.

Safety Testing: It is the responsibility of cosmetic producers to evaluate the safety of their goods, including microbiological testing to guarantee that no dangerous contaminants are present. Testing for allergies, microbiological contamination, and possible skin sensitivity may fall under this category. [20]

Conclusion

From the above review, it can be concluded that the maintenance of skin microbiome is essential. Some cosmetics can lead to disruption or imbalance of microbiome. It is especially important to look for those cosmetics which will help in balancing and nourishing the beneficial microbial community. The good microbiome helps with healthy skin. The skin microbiome undergoes changes with age. Microbiomes can vary from person to person that means cosmetic products should be used according to individual's needs. Incorporating prebiotics, probiotics & postbiotics into cosmetic formulations aligns with the broader movement towards a comprehensive approach to skincare, recognizing the importance of supporting the skin’s natural ecosystem of overall well-being. The use of these ingredients is aimed at addressing various skincare concerns including maintaining skin barrier function, promoting hydration, and potentially mitigating inflammatory responses.

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