

Cosmetics and their role in modulating skin microbiome health. A narrative review

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Abstract

The skin microbiome plays a vital role in immune regulation, barrier function, and protection against pathogens. Cosmetics, traditionally used for aesthetic purposes, also influence skin microbiomes. Depending on their formulation, they can support microbial balance through probiotics, prebiotics and postbiotics, or disrupt it, leading to dysbiosis and conditions such as eczema and acne. Advances in nanotechnology have further altered cosmetic efficacy and microbial interactions. The current narrative review was planned to highlight the dual role of cosmetics in modulating skin microbiome health, to emphasise the need for regulatory oversight, and to explore strategies for developing safe, microbiome-friendly skincare products.

Keywords: Skin microbiome, Cosmetics, Nanotechnology, Probiotics, Prebiotics, Dysbiosis, Dermatological health.

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Introduction

The desire for healthy and attractive skin has fuelled the rapid growth of the cosmetic industry, which accounts for nearly 36% of the global market.¹ Beyond aesthetics, cosmetics increasingly contribute to skin health. The skin, as the body's largest organ, serves as both a protective barrier and a host to diverse microbial communities, including bacteria, fungi, viruses and yeasts.² These microorganisms regulate immune responses, maintain barrier integrity, and defend against pathogens.³⁻⁵ Their composition is influenced by factors such as age, body site and environment.^{6,7} Predominant bacterial phyla include actinobacteria, firmicutes, bacteroidetes and proteobacteria.^{8,9} Disruption of this balance, or dysbiosis,

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is linked to dermatological disorders, such as eczema, psoriasis and atopic dermatitis.¹⁰

Cosmetic products can positively or negatively alter this microbial equilibrium, depending on their active ingredients. Increasingly, formulations are designed to support a healthy microbiome, with probiotics, prebiotics and postbiotics gaining attention.² Educational initiatives also highlight the importance of selecting microbiome-friendly skincare.¹¹ Meanwhile, nanotechnology has revolutionised cosmetic delivery, enhancing ingredient penetration and efficacy in conditions like acne, hyperpigmentation and photoaging¹² (Figure). However, certain synthetic compounds may still pose risks, underscoring the need for continued research and regulation.¹³

The current narrative review was planned to explore how cosmetic formulations influence skin microbiomes, with a focus on both beneficial and adverse effects, and to

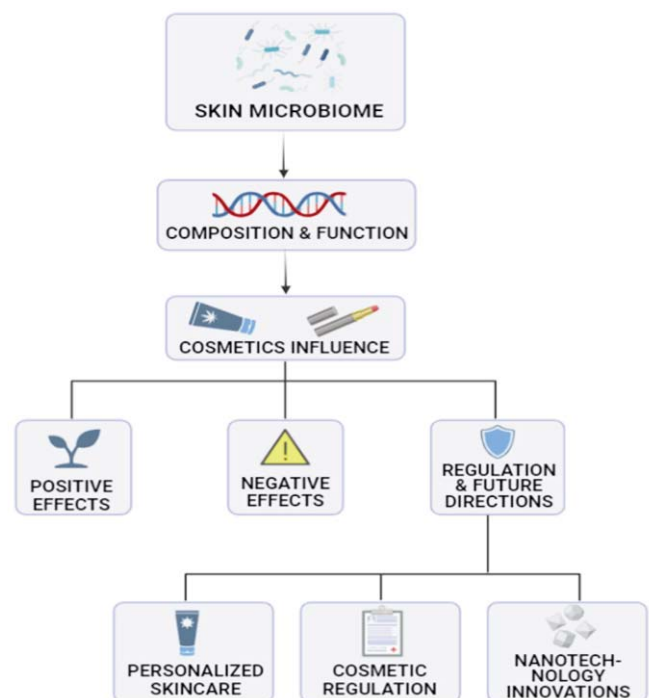


Figure-1: Graphical Abstract.

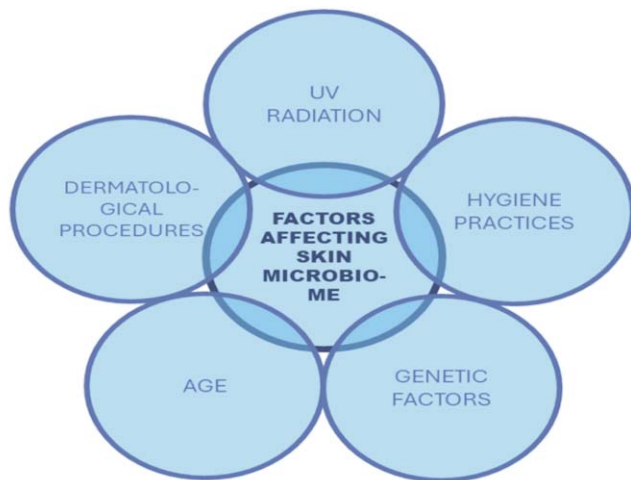


Figure-2: Factors that affect the skin microbiome.

discuss the potential for developing safer, personalised skincare products.

Skin microbiome: composition and function

The skin hosts a complex and diverse microbiome essential for maintaining barrier integrity and preventing disease.¹⁴ Its composition varies across body sites, but is largely dominated by three bacterial phyla: actinobacteria (52%), firmicutes (24%), and proteobacteria (16%), comprising nearly 1,200 species.¹⁵ Common genera

Table-1: Major phyla of bacterial and fungal communities on human skin.²¹

Bacteria				Fungi
Firmicutes	Actinobacteria	proteobacteria	Bacteroidetes	
Aerococcus	Actinomyces	Acidovorax	Chryseobacterium	Aspergillus
Bacillus	Brevibacterium	Acinetobacter	Prevotella	Aureoumbra
Enterococcus	Cellulomonas	Aeromonas	Sphingobacterium	Candida
Eubacterium	Cellulosimicrobium	Agrobacterium		Cyanophora
Gemella	Corynebacterium	Alcanivorax		Cryptococcus
Granulicatella	Dermabacter	Aurantimonas		Epicoccum
Staphylococcus	Delzia	Bradyrhizobium		Epidermatophyton
Streptococcus	Kocuria	Enhydrobacter		Gracilaria
Veillonella	Micrococcus	Enterobacter		Leucocytozoon
	Cutibacterium	Escherichia		Malassezia
	Pseudonocardia	Haemophilus		Nannizzia
	Rothia	Halomonas		Nephroselmis
		Idiomarina		Parachlorella
		Imtechium		Pyramimonas
		Klebsiella		Pycnococcus

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include micrococcus, cutibacterium, staphylococcus (S.) and corynebacterium. Archaea (notably thaumarchaeota) fungi, such as candida and cladosporium, and viruses, including propionibacterium phages and merkel cell polyomavirus, further enrich this ecosystem¹⁶.

Multiple factors shape skin microbiota, including environment (ultraviolet [UV] exposure, climate), genetics, age and lifestyle. For example, UV radiation reduces beneficial microbes and increases pro-inflammatory markers, accelerating skin aging.¹⁷

With aging, microbial diversity declines, contributing to higher disease prevalence in older populations. Cosmetic procedures, such as phototherapy or chemical peels, can also induce long-term shifts in microbial balance.^{18,19}

Host-microbiome interactions are dynamic: microbes contribute to defence through metabolite production and antimicrobial peptides, while the skin provides nutrients and habitat. Any imbalance in this ecosystem increases the risk of conditions such as eczema, psoriasis and atopic dermatitis.²⁰

Maintaining microbial equilibrium is, therefore, critical for skin health (Figure 2).

The major phyla of bacterial and fungal communities on human skin²¹ need to be looked at in detail (Table 1).

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Bacteria			Fungi
Firmicutes	Actinobacteria	proteobacteria	Bacteroidetes
		Marinobacter	Rhodotrolla
		Moraxella	Tilletia
		Neisseria	Trichophyton
		Paracoccus	Zyloseptoria
		Pasteurella	
		Pelomonas	
		Pseudomonas	
		Rasbo	
		Serratia	
		Sphingomonas	
		Stenotrophomonas	

Table-2: Alterations in skin microflora by the use of different common cosmetics.

Category of Cosmetic Product	Changes in Skin Microbiota	References
Lower foot lotion/creme application (to cure xerosis, dry conditions)	Staphylococcus epidermidis (+) Xanthomonas campestris (+) Xanthomonas spp. (+)	24
Short chain fructo-oligosaccharides (present in powders as prebiotic)	Staphylococcus epidermidis (+) at lower concentration (0.5–5 %) Staphylococcus aureus (-) Staphylococcus epidermidis (-) at higher concentration (10–15 %) C. acnes (complete halt) (-)	25
Spermidine used in lotion, cream	Staphylococcus pneumonia (+) Staphylococcus infantis (+) Staphylococcus thermophiles (-)	26
Ceramides in moisturizers	Streptococcus spp. (-)	27
Serum cosmetics containing galacto-oligosaccharides	Burkholderia (+) Bifidobacteria (+) Lactobacilli (+) Lactococcus (+) Sphingomonas (+) Thermoanaerobacterium (+) Staphylococcus aureus (-) Staphylococcus (-) Proteobacteria (-) Cutibacterium (-) Pediococcus (-) Enhydrobacter (-) Enterobacteriaceae family (-)	28
Foot powder use	Micrococcus (+) Anaerococcus (+) Streptococcus (+) Brevibacterium Acinetobacter (+) Moraxellaceae family (+)	29

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Category of Cosmetic Product	Changes in Skin Microbiota	References
Selenium in lotion, sunscreen, creams	Staphylococcus aureus (-)	30
Hydrating gels having lipids	Staphylococcus (+) Propionibacterium (+)	30

(+) = increase, (-) = decrease

Cosmetics and their ingredients

Cosmetics are widely used to improve skin health and appearance, and can be either naturally derived or synthetically formulated. Based on applications, they include creams, toners, scrubs, sunscreens and hydrating agents.

Types of cosmetics used in skin care

Herbal cosmetics, like aloe vera, turmeric and green tea, offer antioxidant and anti-inflammatory benefits with minimal side-effects. In contrast, synthetic formulations often contain preservatives and stabilisers to ensure product safety. Advances such as nanocarriers, like poly D,L-lactic-co-glycolic acid (PLGA) nanospheres, enhance delivery of active ingredients, improving outcomes in anti-aging and texture-enhancing products. While cosmetics can promote a healthier microbiome, some ingredients may disrupt microbial balance, or serve as substrates for opportunistic pathogens. High microbial diversity is associated with better skin health, but cosmetic-induced changes can extend beyond application sites, altering microbial stability.^{22,23} Common cosmetic products have both positive and negative effects (Table 2).²⁴⁻³⁰

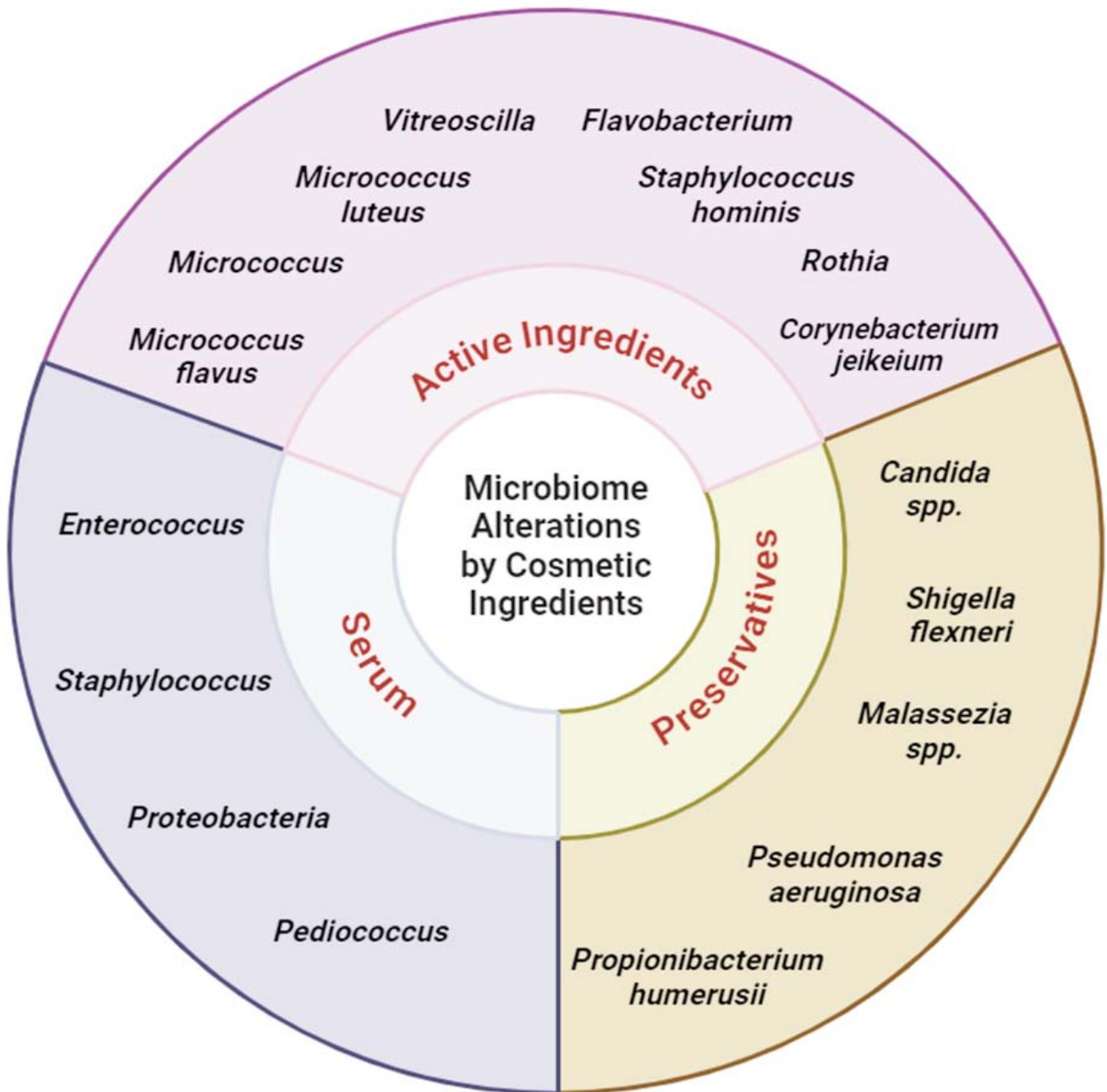


Figure-3: Alterations in skin microbial diversity due to different cosmetic ingredients.

Common ingredients in cosmetics

Cosmetic formulations typically include water, oils, peptides and carbohydrates, which can nourish skin microbes. Preservatives, such as parabens and benzalkonium chloride, prolong shelf life, but may also irritate the skin. Other common additives include microplastics, which present as exfoliating agents or packaging residues; UV filters, like titanium dioxide and zinc oxide, to protect against radiation; antioxidants, like vitamins C and E, for free-radical defence; humectants,

like hyaluronic acid, maintain hydration and elasticity; and zoocuticals which are animal/plant-derived agents, like marine collagen and lanolin, with anti-aging effects.

Growing consumer demand for “clean beauty” is driving a shift towards safer, natural alternatives over synthetic formulations.³¹

Consumer behaviour and cosmetic usage patterns

Cosmetic use and brand preference are influenced by multiple factors, including age, skin type, gender, social

media and marketing strategies. Environmental awareness has also shaped consumer choices, with sustainability and recycling trends gaining importance. Brand trust and perceived quality enhance customer loyalty, while curiosity and competitive markets drive brand switching. Notably, cosmetic use among men has risen sharply due to increasing social pressures, and gender-specific formulations further shape purchasing behaviour.³²

Impact of cosmetics on the skin microbiome

Cosmetic ingredients can modulate skin microbiota both positively and negatively, influencing microbial balance, defence mechanisms, and overall skin health.

Positive modulations

1. Enhancing beneficial microbes:

o Probiotics, prebiotics and postbiotics in cosmetics improve hydration, reduce wrinkles and acne, and restore microbial balance.

o Microbial surfactants (e.g., glycolipids) provide antimicrobial protection while supporting microbiome stability.

2. Protective roles against pathogens:

o Ingredients such as 12-hydroxystearic acid stimulate antimicrobial peptide (AMP) production, strengthening innate immunity.

o Beneficial commensals (*Staphylococcus* [S.] *epidermidis*, *Cutibacterium* [C.] *acnes*) help suppress pathogens when incorporated in formulations.

o Lipid-based compounds (e.g., rhamnolipids, sophorolipids) counteract environmental stressors and aid skin repair.

o Preservatives (e.g., parabens, organic acids) maintain product safety and extend shelf life.^{33,34}

Negative impacts

1. Disruption of microbial balance:

o Ingredients such as sodium lauryl sulphate (SLS) reduce beneficial microbes and promote pathogen growth, weakening skin defences.

o Some preservatives inhibit commensals (*S. epidermidis*) while favouring pathogens (*S. aureus*), leading to dysbiosis.

o Overuse of antimicrobial products can disturb commensal-pathogen equilibrium and impair barrier function.^{33,34}

Different ingredients in cosmetics alter the microbes differently (Figure 3).

2. Microplastic contamination:

o Surveys show widespread presence of microplastics in personal care products.³⁵

o Microplastics (e.g., polyethylene, polystyrene fibres) alter bacterial populations, reducing actinobacteria while increasing genera, such as *Gordonia*.¹⁶

Potential risks of antimicrobial agents in cosmetics

Cosmetic products often include antimicrobial agents to prevent contamination and extend shelf life. However, their widespread use raises safety and environmental concerns. A major risk is antimicrobial resistance, which develops when microbes are repeatedly exposed to sub-lethal concentrations. Compounds such as methylparaben, phenoxyethanol and methylisothiazolinone can persist in the environment, promoting resistance in pathogenic organisms.³⁶ Current European Union (EU) regulations require no environmental risk assessment for cosmetic preservatives, unlike biocidal products, resulting in unmonitored release into ecosystems and potential disruption of microbial communities.³⁷ Moreover, antimicrobial preservatives do not fully prevent contamination in shared applicators, creating transmission risks in both personal and professional use.³⁸

Allergic reactions and sensitisation

Cosmetic ingredients can trigger allergic reactions and sensitisation, with symptoms ranging from redness and itching to severe dermatitis. Natural or "organic" products are often perceived as safer, yet they may still contain harmful additives. For example, methylisothiazolinone (MI), even in "organic-labelled" items, has been linked to microbial imbalance, allergies and neurotoxicity. Despite these risks, MI remains common in products like baby wipes, powders and moisturisers. Other agents, such as alcohol and fatty acids, can promote *Malassezia* overgrowth, contributing to atopic dermatitis. Prolonged exposure to allergens intensifies immune responses, especially on sensitive skin with impaired barriers, increasing risk of sensitisation. Allergen-free formulations are, therefore, critical for maintaining skin microbiome balance.³⁹

Mechanisms of interaction between cosmetics and skin microbiome

Cosmetics influence skin microbiota through effects on potential of hydrogen (pH), barrier function and occlusion. Skin microbes thrive at an acidic pH (4.5-5.5), which supports commensals, like *S. epidermidis*, while suppressing pathogens like *S. aureus*. Ingredients such as glycolic acid can lower skin pH and strengthen the barrier without irritation⁴⁰. In contrast, occlusive moisturisers

may trap moisture, creating low-oxygen environments favourable for anaerobes, such as propionibacterium (*P.*) acnes. This promotes biofilm formation, which enhances bacterial resistance to antimicrobials.⁴¹ Certain compounds (e.g., quaternary ammonium compounds, polyol fatty acid polyesters) further stabilise biofilms [86]. Transepidermal water loss (TEWL) also compromises defence, but formulations enriched with para-probiotics and natural humectants restore hydration, strengthen the barrier, and support commensal growth.⁴⁰

Innovations in cosmetic formulations for skin microbiome health

Recent advances aim at supporting a balanced skin microbiome. Nanotechnology enables efficient delivery of active ingredients via carriers, such as nanoemulsions, liposomes and solid-lipid nanoparticles, improving stability and efficacy. The SkinCom model allows in-vitro and in-vivo testing of microbial interactions under controlled conditions, guiding development of safer formulations. Additionally, products enriched with prebiotics, probiotics and postbiotics are increasingly popular. Encapsulation techniques, such as microspheres, protect probiotics from antimicrobial destruction, ensuring their survival and functional benefits.⁴²

Recommendations

- Strengthen regulations: Implement stricter safety and environmental risk assessments for cosmetic antimicrobials and preservatives.
- Promote transparency: Ensure accurate labelling of ingredients, particularly in products marketed as “natural” or “organic.”
- Encourage research: Conduct long-term clinical studies to evaluate the impact of cosmetics on skin microbiome health.
- Develop safer formulations: Prioritise allergen-free, microbiome-friendly products containing prebiotics, probiotics and postbiotics.
- Adopt innovative models: Utilise advanced testing systems, such as SkinCom, to assess cosmetic-microbiome interactions before commercialisation.
- Educate consumers: Increase awareness about safe cosmetic use, hygiene practices, and risks of sharing applicators.

Conclusion

Cosmetics can significantly influence the skin microbiome, offering both benefits and risks. While certain formulations support commensal growth and

strengthen the skin barrier, others may disrupt microbial balance, leading to dysbiosis and dermatological concerns. Emerging innovations, such as nanotechnology, probiotics and synthetic microbial models, hold promise for microbiome-friendly skincare. However, rapid commercialisation without adequate testing raises concerns about long-term safety and efficacy. Future research should focus on longitudinal studies, ethical considerations in microbial manipulation, and development of evidence-based personalised skincare solutions.

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MF & HO: Concept, design, data acquisition and agreement to be accountable for all aspects of the work.

NN: Concept, design, data acquisition, final approval and agreement to

be accountable for all aspects of the work.

SI: Data analysis, interpretation, drafting, revision, final approval and agreement to be accountable for all aspects of the work.