

Review

Microbial and Botanical Innovations in Sustainable Cosmetics: A Review of Natural Approaches to Skin Health

Amina Tariq¹, Muhammad Arslan Ayub², Urooj Fatima¹, Samra Zulfiqar¹, Mahnoor Javed¹, Kinza Hafeez¹

¹Department of Microbiology and Molecular Genetics, University of Okara, Okara, Pakistan. *Corresponding author: M. Arsalan Ayub (drarslan07@gmail.com)

²Department of Biosciences, COMSATS University, Islamabad, Pakistan.

Abstract

Demand for natural and sustainable cosmetics is growing as a result of growing public consciousness of ethical consumption, environmental preservation, and health. This review explores the integration of components generated from microbes and plants to create environmentally friendly and productive organic beauty products. It accentuates how botanicals like aloe vera, green tea, turmeric, jojoba oil, and essential oils act in concert with probiotics, postbiotics, and fermented microbial metabolites improve skin health. Currently, knowledge from ethnobotany, microbiology, and dermatology is being utilized to develop natural products-based cosmetics. Microbial fermentation, bioactive extraction, and actual user trials are among the techniques used to assess the acceptability, efficacy, and safety of the products. Synthetic inhibitors and detergents are being substituted by biosurfactants and peptides with antibacterial properties derived from bacteria like *Lactobacillus plantarum* and *Bacillus subtilis*. High safety and quality criteria have been adopted for face washes, moisturizers, serums, and lip balms. The future of the beauty business is being shaped by the innovations in this area which will promote personal wellbeing.

Keywords: Organic cosmetics, skin microbiome, herbal skin care, consumer perception, biocosmetics, dermatological safety

Introduction

In recent years, the global interest in organic beauty products has grown substantially, mainly due to rising consumer awareness regarding personal health, environmental conservation, and the safety of the products they use [1]. These organic cosmetics are typically seen as healthier alternatives to traditional ones because they are made from natural sources and contain fewer synthetic substances [2]. However, the science behind these products, especially their interaction with the skin's natural microbes and

formulation stability, is more intricate than it may seem.

The human skin harbors a wide range of microorganisms collectively referred to as the skin microbiome, which plays a vital role in skin protection and immune regulation [3,4]. This delicate microbial balance can be affected by the use of skincare products. Studies have shown that some synthetic compounds in conventional cosmetics can disrupt this balance [5]. Consequently, there is growing interest in organic skincare products that help maintain or restore the

natural microbiome, particularly those enriched with prebiotics, probiotics, and postbiotics [6,7].

Manufacturing and Preserving Cosmetics:

Nonetheless, manufacturing and preserving organic cosmetics poses certain difficulties. Since these products usually avoid strong synthetic preservatives, they are more susceptible to microbial contamination during storage and use [8]. This issue becomes more serious in warm or humid environments and when packaging is inadequate [9]. To address this, scientists are investigating the use of natural antimicrobial substances like essential oils, herbal extracts, and fermented ingredients that can offer microbial protection while adhering to organic standards [10,11].

Public Perception:

Public perception is also a key factor in the rising popularity of organic beauty items. While many consumers associate "natural" with "safe," there is often limited understanding of how microbes actually contribute to skin health [12]. There is a noticeable contradiction, as people seek microbiome-friendly or probiotic cosmetics while still harboring a fear of germs [13]. Moreover, inconsistencies in global certification criteria and safety regulations further add to confusion and variability in the market [14]. To overcome these hurdles, collaborative research across dermatology, microbiology, and consumer behavior is necessary to ensure the development of organic beauty products that are both safe and scientifically sound [15].

These trends, consumers are becoming more conscious of major global challenges such as environmental pollution, resource depletion,

climate change, and waste accumulation [16]. These concerns are shifting consumer behavior toward more sustainable and health-conscious lifestyles, increasing demand for natural products, especially in the cosmetic and food industries [17].

Address these environmental issues, international authorities have set ambitious targets under the 2030 Agenda for Sustainable Development [18]. This has encouraged governments to adopt stricter environmental laws—such as restrictions on plastic bag usage, bans on microplastics, mandatory labeling of hazardous ingredients, and the imposition of waste management taxes [19].

Environmental Issues:

The cosmetic industry, known for its rapid innovation and scientific advancement, is actively aligning with these global sustainability efforts [20]. A significant portion of the environmental burden in cosmetics comes from non-renewable and non-biodegradable raw materials [21]. For instance, plastic microbeads used for exfoliation, parabens for preservation, silicones for smoothness, and chemical UV filters are all examples of environmentally harmful components [20].

Moreover, preservatives in cosmetics must be potent enough to avoid the growth and resistance development of harmful microorganisms [22]. Since cosmetic products often contain nutrient-rich formulations that support microbial growth, maintaining effective preservation systems is essential to ensure product safety and longevity [23].

Types of Cosmetics

1. *Organic Cosmetics:*

With very little chemical processing, natural cosmetics are made mostly from materials found in nature, such as plants, minerals, and ingredients from animals. A major **European** certification body, the **COSMOS-standard**, states that natural cosmetics must use ingredients derived from physical processes (such as cold pressing, drying, and fermentation) and refrain from using synthetic compounds unless absolutely required for stability or safety [24] (Table 1).

Examples:

Skin and Hair Related Products;

- **Clay Masks:** Make use of natural clays (such as kaolin and bentonite) that are known for their ability to absorb substances and draw out excess oil and pollutants from the skin [25]. Mineral-rich clays and essential oils derived from plants are frequently employed in natural cosmetics to provide skincare advantages. **Bentonite clay**, which is made from volcanic ash that is high in the rock montmorillonite, is frequently used in face masks because of its ability to absorb oil and purify the skin, which is especially advantageous for skin that is prone to acne [26]. Another popular clay is **kaolin**, a soft clay mineral which forms naturally (kaolinite). It is appropriate for sensitive skin because of its mild washing and exfoliating properties [27]. Mined from **Morocco's Atlas Mountains**, Rhassoul clay is rich in silica and magnesium and has long been used in

spa treatments to cleanse both hair and skin [28].

- **Essential oils:** Plant-derived aromatic chemicals that are highly concentrated. Their scent, medicinal qualities, and skin-benefitting qualities (e.g., tea tree for antibacterial characteristics, lavender for calming) are why they are employed [29]. Lavender oil, which is derived from *Lavandula angustifolia*, is popular among essential oils for relaxing scent and anti-inflammatory, skin-soothing qualities [30]. Additionally, the oil of rosemary, which comes from *Rosmarinus officinalis*, has anti-aging and antioxidant properties and is commonly used in scalp treatments to promote growth of hair [31]. Distilled from the leaves of *Melaleuca alternifolia*, tea tree oil is valued for its potent antibacterial properties, particularly against bacteria that cause acne, such as *Propionibacterium acnes* [32]. Extracted from *Mentha piperita*, peppermint oil provides a refreshing sensation and minimizes skin and scalp irritation [33]. **Geranium oil**, which originated from *Pelargonium graveolens*, is an essential oil that is good for sensitive or aging skin since it contains anti-inflammatory compounds and controls sebum production [33]. **Frankincense oil**, which is derived directly from the resin of *Boswellia serrata*, is well known for its ability to reduce wrinkles and flatten the skin because it contains boswellic acids, which have antiinflammatory qualities [34].

Last but not least, *Cananga odorata* flowers are used to make ylang-ylang oil, which is utilized in cosmetics because of its relaxing scent as well as capacity to control sebum, which makes it ideal for oily skin types [35].

- **Aloe vera:** Well-known for its restorative, moisturizing, and calming effects [36]. The jellylike substance from aloe vera, a succulent plant, is very rich in vitamins A, C, and E along with polysaccharides and glycoproteins. Promotes moisture to parched skin without producing shine. Reduce sunburn, *psoriasis*, and *eczema* redness and itching. Encourages the development of collagen and skin renewal.

By stimulating the formation of collagen and fibroblast activity, aloe vera speeding up wound healing. Its mucopolysaccharides aid in the capacity of skin for holding moisture suppresses *Candida albican*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*. Aloe vera includes polysaccharides and anthraquinones (such aloin) which tear down microbial cell walls and avoid the formation of biofilms, so providing an antibacterial environment [37].

- **Tea Tree Oil:** Tea tree oil is prized for its antibacterial, antiseptic, and anti-inflammatory qualities; it works especially well for skin that gets acne [38] contains the antimicrobial and antifungal molecule terpinen-4-ol. Decrease colonies of *Propionibacterium acnes*. Regulate the fungus *Malassezia* on the scalp. Have a natural cleaning effect. Causes

microbial cell lysis and death by tampering with their lipid membranes. Terpinen-4-ol provides broad-spectrum efficacy against *Cutibacterium acnes*, *Staphylococcus aureus*, *Candida albicans*, and *Malassezia*. It breaks down bacterial and fungal membranes, prevents the formation of biofilms, which and eliminates acne-causing pathogens upon contact [39].

- **Turmeric:** The powerful antioxidant and anti-inflammatory compound curcumin, which is used to balance and brighten skin tone [40]. Its primary product, curcumin, has antioxidant and anti-inflammatory qualities. Boost skin tone and lessen acne. Found in psoriasis and eczema formulations. Age spots and wrinkles are slowed down by anti-aging serums. Curcumin works by regulating the NF- κ B pathway, which lessens oxidative stress and pro-inflammatory cytokines. Appropriate for *Helicobacter pylori*, *Candida albicans*, *E. coli*, *Staphylococcus aureus*, and some dermatophytes. By scavenging reactive oxygen species (ROS), which are employed by pathogens for entering host cells, altering membrane potential, and inhibiting the synthesis of virulence indicators, curcumin prevents the rapid growth of microorganisms [41].
- **Jobba oil:** It is technically a wax ester, yet it works well as a moisturizer and skin conditioner since it closely resembles the natural sebum produced by the skin [42]. Since jojoba oil ester that is very similar to human sebum, it is suitable

for every kind of skin and is non-comedogenic. It controls the amount of sebum generated from oily skin and clears contaminants and makeup without blocking pores. Prevents dry hair scalp and adds shine. It strengthens the skin's ability to absorb additional active components and creates a protective lipid layer. Jojoba oil's esters disrupt the integrity of cell membranes and penetrate microbial biofilms. They are especially useful as a carrier oil for essential oils that have higher levels of antibacterial properties [43].

- **Green Tea Extract:** Catechins, especially the highly effective antioxidant epigallocatechin gallate (EGCG), are prevalent in green tea [44]. By rescuing free radicals, it reduces wrinkles and fine lines, prevents damage from the sun by serving as a photoprotective agent and minimises oedema and skin irritation. EGCG reduces photoaging and restores skin firmness by suppressing matrix metalloproteinases (MMPs), which break damaged collagen. Inhibits the *Herpes simplex virus*, *Staphylococcus epidermidis*, and *Propionibacterium acnes* (now *Cutibacterium acnes*). Catechins such as EGCG harm bacterial membranes, preventing acne-causing bacteria from producing lipase. By blocking viral replication, they exhibit antiviral behavior [45].
- **Coconut Oil:** Medium-chain triglycerides make up the majority of coconut oil, notably lauric acid, which has antibacterial effects.

Reduces frizz, inhibits protein loss, and improves hair. Provides atopic dermatitis and swelling. Its antimicrobial properties help skin prone to acne by limiting *Staphylococcus aureus*, *Candida spp.*, *Escherichia coli*. It works by penetrating skin and hair with greater efficiency than mineral oils thanks to its fatty acids. By rupturing bacterial membranes, lauric acid has antimicrobial abilities [46].

- **Shea Butter:** The nut of the African shea tree contains shea butter, which is rich in phytosterols, tocopherols, and triterpenes. Maintains moisture and minimises water loss via the skin. Reduces dryness and itching of skin. Enhances the comfort and elasticity of the skin. Derivatives of cinnamic acid and triterpenes diminish inflammation and encourage the manufacturing of collagen, restrict capacity to inhibit *Candida albicans*, *Staphylococcus*, *Bacillus spp.* Triterpenes and derivatives of cinnamic acid have antifungal and antibacterial actions, especially when it comes to promoting skin barrier repair, which diminishes the penetration of pathogens [47].
- **Rosehip Oil:** Omega-3 and omega-6 essential fatty acids, vitamin C, and antioxidant retinoic acid (vitamin A) are abundant. Stretch marks and acne scars can be repaired with scar reduction. Promotes pigmentation and skin tone with a brightening serum. Avoids the fine lines and wrinkles (anti-aging). Fatty acids rebuild the the epidermis barrier, and

retinoic acid accelerates cell turnover. *Staphylococcus aureus*, *Candida* species, and *Malassezia species* (found in dandruff) are all inhibited. Rosehip oil, known to be high in linoleic acid, helps to repair the barrier and lessen microbial colonization, which is the primary root of dandruff and acne [48].

- **Witch Hazel:** Contains antioxidant and astringent flavonoids and tannins. Oiliness gets reduced and pores get tighter with toner. Reduced bacterial load and irritation as a cure for acne, minimises inflammation and puffiness. Bacteriocidal on *Staphylococcus aureus*, *Pseudomonas spp*, and *E. coli* [49].

Table 1: Properties of Organic Cosmetics

Organic Components	Purpose	Source	Benefits	Side Effects
Clay Mask	Oil control & detoxifying	Clays generated naturally in soil with compositions rich in minerals or volcanic ash	Decreases pollutants and acne, tightens skin, unclogs pores, and absorbs excess sebum.	Irritation & dryness [25]
Aloe Vera	Replenishing & anti-inflammatory	<i>Aloe barbadensis plant</i>	soothes, adjustments, and nurtures skin	Sensitive skin responses to allergens [36]
Green Tea Extract	Antioxidant, anti-aging	<i>Camellia sinensis</i> leaves	relieves inflammation and shields against UV ray damage	May irritate or dry out [44]
Turmeric	Brightening, antimicrobial	<i>Curcuma longa rhizome</i>	avoids dark spots, promotes skin tone, and fights acne.	may result in dermatitis or discolor the skin [40]
Jojoba Oil	Moisturizer, sebum regulator	<i>Simmondsia chinensis</i> seeds	Skinhydrating, noncomedogenic, and mimicking natural oils	Less allergic reaction [42]
Essential Oils (e.g, Lavender, Tea tree)	Scent, antiseptic	Distilled from aromatic plants	Acne reduce	Allergic opinions and photosensitivity [30]

Shea Butter	Cleansing and anti-inflammatory in nature	<i>Vitellaria paradoxa</i>	Hydrated & repair skin	Allergy [47]
Coconut Oil	Antiseptic	<i>Cocos nucifera kernel</i>	Antifungal, heals wounds	Block pores in skin that is prone to acne [46]

Organic Cosmetics and Microbes: An Expanding Field (Table 2)

Microbes are becoming more and more important in natural cosmetics, going beyond simple preservation to actively enrich and create ingredients.

Table 2: Organic Cosmetics and Microorganisms

Microbial Species	Functions
<i>Lactobacillus species</i>	Improves skin hydration and barrier function
<i>Bacillus species</i>	Generates peptides and enzymes that are good for skin health
<i>Saccharomyces cerevisiae</i>	A yeast with antioxidant qualities
<i>Clove (Syzygium aromaticum)</i>	Fermentation boosts this plant's antioxidant capacity, which makes it appropriate for anti-aging products.
<i>Camellia sinensis</i>	Stronger antimicrobial and anti-inflammatory effects.
<i>Panax ginseng</i>	skin-whitening and anti-wrinkle features of ginseng improved by fermentation.

Organic Preservatives: Antimicrobial substances derived from bacteria such as *Lactobacillus*, production of antimicrobial peptides and other chemicals by microbes,

Fermentation: Microorganisms like bacteria and fungi break down plant substrates during the biotechnological process of fermentation, producing bioactive compounds with additional skin positive aspects. Increases the bioavailability of plant-based substances (such as rice and fermented ginseng. Complex chemicals found in plant materials are broken down into smaller, more absorbable forms by fermentation, a metabolic process that microorganisms carry out. It may be result in smaller molecules are more readily absorbed by the skin, increasing the potency of the active ingredients. A higher nutrient content can result from fermentation, which allows microbes to create new nutritious compounds like vitamins and amino acids Fermentation can boost the antioxidants' strength and concentration [50].

- Fermentation reduces huge molecules into smaller, more soluble forms, improving skin absorption; it also generates organic acids and peptides, which aid in antimicrobial activity; and fermented extracts frequently have higher antioxidant capacities, defending skin from oxidative stress [52].

especially specific strains of *Lactobacillus* and other helpful bacteria, can naturally prevent the growth of spoiling

microorganisms (bacteria, yeast, and mold) in cosmetics [53].

Plant-Microbe Synergy: The enzyme activity of cosmetic components can be improved by the combination of microbial fermentation and plant extracts.

- The saponin content of soapnuts (*Sapindus mukorossi*) is increased through fermentation, which improves their antifungal and cleaning qualities.
- Fermented extracts of *Bacopa monnieri* exhibit stronger antifungal and antibacterial activity.
- Fermentation strengthens *Centaurea damascena's* antibacterial and antioxidant properties [54].

In plant extracts, fermentation can raise the quantity of active ingredients. New bioactive compounds that are absent from the original plant material can be produced via microbial digestion. The cosmetic product's overall efficacy grows by the synergistic effect [55]. Significant antibacterial activity makes fermented plant extracts (FPEs) useful in natural cosmetic composition.

- *Rosmarinus officinalis*: *Endophytic fungi* isolated from this plant have antimicrobial activity against *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*.
- *Diodella sarmentosa*: Ethanol leaf extract restricts dehydrogenase activity, which inhibits *Bacillus subtilis*, *Candida spp.*, and *Penicillium spp.*, microbiological enzyme activity inhibition, which results in compromised metabolism, breach of the membranes of microorganisms, which results in

cell death, interference with the formation of proteins and DNA in pathogens. Plant extracts contain inactive phytochemicals that microbes can enzymatically transform into bioactive metabolites. *Lactobacillus* species converted (which are found in *Panax ginseng*) into compound K, a strong anti-aging agent. Bioavailability is increased when glycosidic bonds are degraded by enzymes [56].

Benefits of Organic Cosmetics (Table 3)

- **Eco-friendliness:** Less pollution generates by substances that decay.
- **Perceived Safety:** When synthetic chemicals do not exist, allergy actions and perceived toxicity are reduced.
- **Holistic Appeal:** Frequently associated with Ayurvedic or holistic methods, particularly in Asia [57].

The limitations;

- **Expiration Life:** As natural products usually don't contain potent synthetic preservatives, they are more prone to becoming poisoned and turning bad .
- **Divergence:** Because variable growth circumstances might affect the efficacy of plant-derived products, there may be batch-to-batch variations.
- **Expenditure:** The cost of natural components usually runs higher, particularly those that are certified organic [58].

Perspective of Buyers:

Consumers that appreciate sustainability, safety, and simplicity in skincare products likely to favor natural cosmetics. A

worldwide trend toward "clean aesthetics" has increased demand for goods devoid of petrochemicals, synthetic scents, and dyes. Advertising slogans such as "natural" or

"clean" were more likely to be purchased by 58% consumers in the U.S. and Europe, according to a 2020 Deloitte survey [59,60].

Table 3: Brands Offering Organic Cosmetics and Potential Side Effects:

Name of Brand	Product	Typical Adverse Consequences
Weleda	Skin Protein	contains essential oils that could induce allergic reactions and contact dermatitis in people with allergies, such as citrus and lavender [61].
First Aid Beauty	Ultra Repair Cream (Coconut Vanilla)	recalled due tainted batches might've caused negative health consequences [62].
Original Sprout	Hair & Body Babywash	includes essential oils that could aggravate skin or cause contact dermatitis, such as peppermint and lavender [63].
Dr. Bronner's	Pure-Castile Liquid Soap	Sensitive adults may experience allergic reactions or skin annoyance from high essential oil doses [64].
Burt's Bees	Beeswax Lip Balm	incorporates essential oils and natural fragrances that might trigger dermatitis from contact or allergic reactions [61].
Lush	Dream Cream	contains components that can trigger allergic responses in those who are sensitive, such as essential oils and oat milk [61].
Herbivore Botanicals	Pink Cloud Moisture Cream	contains essential oils and natural fragrances that may cause allergic reactions or skin irritation [61].
Mama Organic	Tea tree face wash for acne, pimple control	Rare Reaction [60]
Conatural	Vitamin E face wash	Mild sensitivity [60]
Body N Body	Glow cream Acne serum	No side effects due to plantbased ingredients [60]
Bare Epitome	Camel milk cream/hair care	Mild irritation possible [60]

2. Biological Cosmetics (Table 4):

The substances used in biological cosmetics are derived from living things or biological systems and improve the functionality of products. In addition to facilitating the creation of novel and energetic substances, this strategy handles sustainability issues [65]. Being skin-compatible and environmentally safe, these products frequently don't include parabens, artificial chemicals, or artificial perfumes. Frequently, they are defined by:

- Utilizing organic and natural components.
- A focus on ethical sourcing and sustainability
- Less prone to irritate skin or trigger allergic reactions in general.
- Frequently granted by eco-labels (ECOCERT, COSMOS) [66]

Examples:

- **Face creams with probiotics:** In order to improve barrier function, lessen sensitivity, and restore the skin's natural microbiome, probiotic face creams employ live beneficial bacteria. These products frequently contain *Bifidobacterium longum*, which has been demonstrated to strengthen the skin's protective layer and lessen inflammation, making it particularly beneficial for individuals with sensitive or damaged skin. A product is Lancôme's Génifique serum, which contains a probiotic and prebiotic combination [67].
- **The brewed a nutshell such as Galactomyces Ferment Filtrate:** Yeast-derived postbiotic

Galactomyces Ferment Filtrate (GFF) is frequently found in fermented skincare essences. Vitamins, enzymes, and amino acids abound in GFF. It lessens age indications, balances sebum production, and brightens the skin. These flavors come from the fermentation technique used to make sake, which was unintentionally found by looking at the young hands of sake brewers. For instance, SK-II Facial Treatment Essence is well-known for using *Pitera™*, a patented type of GFF [68].

- **Biosurfactant-Based Cleansers** (such as *Pseudomonas aeruginosa* rhamnolipids): Natural cleaning agents called biosurfactants are made by microbes. Examples of ecologically appropriate substitutes for synthetic surfactants include rhamnolipids, which are non-toxic, biodegradable, and mild on the skin. They are perfect for delicate skin and baby care products because of their gentle nature. Sample Product: The primary cleansing feature in certain organic cleansers is biosurfactants produced through microbial fermentation
- **Fermented soybean:** Extraction is high in peptides and isoflavones and originates by microbial fermentation, such as that which occurs with *Bacillus subtilis* [69]. In along with reducing wrinkles and increasing skin elasticity, this extract has antioxidant properties. It is perfect for mature and acne-

prone skin types because it also has antibacterial properties, mainly against *Propionibacterium acnes* and *Staphylococcus epidermidis* [70].

- **Rosemary:** Another potent antioxidant utilized in cosmetics for its anti-aging and preservation properties is rosemary extract, which is derived from *Rosmarinus officinalis*. It has chemicals including carnosol and rosmarinic acid that have been established to prevent *S. aureus*, *E. coli*, and *Candida albicans*, preventing skin and preserving products from nature [71].
- **Chamomile:** Matricaria chamomilla flower extract is well-known for its anti-inflammatory, antibacterial, and relaxing

characteristics. It effectively reduces redness and irritation since it is rich in flavonoids like apigenin. Furthermore, it exhibits antibacterial activity against *Streptococcus mutans* and *Staphylococcus aureus*, two major causes of skin infections [72].

- **Hyaluronic Acid:** Despite not coming to plants, hyaluronic acid is produced metabolically by *Streptococcus zooepidemicus* fermentation. It is a well-known moisturizing ingredient that improves skin suppleness and retains moisture. Although it has no direct antibacterial properties, applying it builds up the skin's inherent barriers versus microbial invasion and irritation [73].

Biologics	Purpose	Source	Benefits	Side effects
Honey	Soothing, moisturizer	Honey bees	Treat sunburns, Hydrates skin	Itching & redness [73]
Chamomile extract	Anti inflammatory soothing	Chamomile flowers	Calms skin, Reduce redness	Ragweed allergy [73]
Milk protein (casein, whey)	Moisturizer, Nourishing	Cow & goat milk	Skin softening, rich in amino acids	Dairy sensitive [72]
Rose water	Skin toner	Steam distillation of rose petals	Refresh skin	Safe, stinging in sensitive skin [72]
Vitamin E	Antioxidant, Preservative	Vegetable oils, nuts	Promotes skin, improve elasticity	Rash, irritation [72]

Biological Cosmetics & Role of Microbes:

- **The probiotics:** *Bifidobacterium* and other live beneficial bacteria are added to skincare products to promote an ideal skin microbiome. Probiotics like these can help lower inflammation and enhance the protective layer on the skin [74].
- **Prebiotics:** Inulin and other non-digestible compounds act as nutrition for healthy skin microbes, stimulating their growth and assisting in keeping of a balanced skin microbiome.
- **Postbiotics:** These are inanimate microbial (*Lactobacillus*) products, such as peptides, enzymes, and organic acids, that can benefit the skin by reducing inflammation and improving moisture [75].

- **Fermentation by Organisms:** A method of creating important components of beauty products like collagen, hyaluronic acid, and vitamins (like B12 and B3) from *Bacillus Subtilis* & *Streptococcus Zooepidemicus*. This technique provides an environmentally friendly substitute for current method of extraction [76].

Two fundamental microorganism categories are involved in biological cosmetics:

Effective Microorganisms in Cosmetics:

The formulations for skin health or the synthetic production of bioactive substances contain microbes mentioned in table 5:

Sometimes these microorganisms undergo fermentation to produce extracts, peptides, acids, or proteins that have anti-inflammatory, moisturizing, or rejuvenating effects.

Table 5: Effective Microorganisms in Cosmetics		
Microbes	Role in Cosmetics	Cosmetic Function
<i>Lactobacillus plantarum</i>	Probiotic bacterium	Helps in the reduction of inflammation, is involved in restoring skin microbiota [77].
<i>Streptococcus thermophilus</i>	Fermentation	Role in producing acid called hyaluronic acid, hydration [78].
<i>Bifidobacterium longum</i>	Probiotic	It reduces skin sensitivity, increases skin barriers [78]
<i>Saccharomyces cerevisiae</i>	Yeast	Used as antioxidant extracts [79].
<i>Bacillus subtilis</i>	Fermenting agent	Anti-ageing agent, whitening fermented soybeans [80]

Antibiotic-resistant Skin Pathogens:

In response to exposure to synthetic cosmetics, environmental stressors, or

inadequate skin neatness, several microorganisms have acquired antimicrobial resistance (Table 6).

Table 6: Antibiotic-resistant skin pathogens		
Microbes	Infection	Resistance
<i>Staphylococcus aureus</i>	Acne, skin Infection	Resistant to antibiotics and preservatives [81].
<i>Propionibacterium acnes</i>	Acne vulgaris	The formation of biofilm develops resistance to benzoyl peroxide [82].
<i>Candida albicans</i>	Fungal infections	Resistance to the overuse of antifungals [81].

Benefits:

- **Increased Effectiveness:** Biologically active substances can enhance the hydration, flexibility, and general look of skin.
- **Decreased Irritation:** Unfavorable skin reactions are less likely when natural and biocompatible components are used.
- **Environmental Sustainability:** Through the utilization of less energy and fewer chemicals, biotechnological methods of manufacturing lessen the adverse impacts on the environment [83].

Limitations:

- **Pricing:** Because biological cosmetics include luxury pollutants and difficult production procedures, they are frequently more expensive.
- **Shelf Lifespan:** While natural products may need to be stored and utilized carefully, their shelf life may be shorter.
- **Statutes:** In certain areas, adding living creatures or unusual

additives may present regulatory challenges [84].

Perspective of Buyers:

Biological cosmetics have become more and more popular among consumers due to their supposed environmental friendliness and health advantages (Table 7). A sizable majority of respondents to surveys said they would be willing to pay more for cosmetics that are certified natural and organic. The importance for openness and education is highlighted by the fact that certain customers have doubts about the genuineness and effectiveness of these products [85].

Table 7: Brands Offering Biological Cosmetics and Their Potential Side Effects.		
Brand	Product	Potential Side Effects
Neal's Yard Remedies	Frankincense Intense Cream	comprises essential oils that sensitive people might develop problems with reaction [62].
Goop	Exfoliating Facial	Products have been challenged for their potential for skin irritation and their unproven health claims [61].
100% Pure	Fruit Pigmented Ultra Lengthening Mascara	Pigments derived from plants may irritate sensitive people's eyes [61].
Tata Harper	Resurfacing Mask for cleansing	Incorporates natural acids that may harm or cause skin sensitivity [62].
Mad Hippie	Brightening Scrub to use on the Face	Some people may experience problems with exposure to extracted [63]
Acure	Body oil	For people with fragile skin, natural exfoliants might turn out too harsh, causing irritation [63].
Marjaan Boanicals	Cold pressed oil (hair & skin oils)	Skin patches [63]
Jenpharm	Skin serums	No side effects [63]

3. Herbal Cosmetics (Table 8):

Natural oils, botanical extracts, and plant-based components are used in the formulation of herbal cosmetics. These products are a popular option for health-conscious people looking for sustainable and safe beauty solutions because they are not only kind to the skin but also provide therapeutic advantages. Cosmetics and personal care items made from natural ingredients like herbs, flowers, fruits, seeds, roots, and essential oils are known as herbal cosmetics. These products are rich in vitamins, antioxidants, and bioactive substances

that nourish, protect, and revitalize the skin and hair without the use of harsh chemicals.

- No harmful chemicals (free from parabens, sulfates, phthalates, and artificial fragrances).
- Eco-friendly and cruelty-free (biodegradable and often vegan).
- Fewer side effects (suitable for sensitive and allergy-prone skin) [86].

Examples:

- **Aloe Vera Gel:** Soothes sunburn, hydrates skin, reduces acne, and promotes healing. Key Compounds:

Polysaccharides, glycoproteins, and antioxidants.

- **Turmeric (*Curcuma longa*) Face Cream:** Anti-inflammatory, brightens skin, reduces hyperpigmentation, and fights acne. Key Compounds: Curcumin (a potent antioxidant and antimicrobial agent) [86].
- **Neem (*Azadirachta indica*) Soap:** Antibacterial, treats eczema, psoriasis, and acne. Key Compounds: Nimbidin, nimbin, and azadirachtin.
- **Amla (*Emblica officinalis*) Hair Oil:** Strengthens hair, prevents premature greying, and reduces dandruff. Key Compounds: Vitamin C, flavonoids, and tannins.
- **Hibiscus (*Hibiscus rosa-sinensis*) Shampo:** Promotes hair growth, conditions scalp, and prevents hair fall. Key Compounds: Amino acids, mucilage, and vitamins.
- **Bhringraj (*Eclipta alba*) Hair Serum:** Stimulates hair follicles, reduces baldness, and improves hair texture. Key Compounds: Wedelolactone, ecliptine, and flavonoids.
- **Shea Butter Lip Balm:** Deeply moisturizes, heals chapped lips, and provides UV protection. Key Compounds: Fatty acids (oleic, stearic) and vitamin E [87].
- **Sandalwood (*Santalum album*) Body Lotion:** Anti-aging, soothes irritation, and provides a natural fragrance. Key Compounds: Santalols (alpha and beta) [87].

Role(s) of Microbes in Herbal Cosmetics

- **Probiotics in Herbal Cosmetics:** Live microbes that enhance the function of the skin barrier and lessen inflammation, such as *Lactobacillus* and *Bifidobacterium*. Utilization of herbal creams with probiotics added (e.g., aloe vera + *Lactobacillus* ferment) for acne and eczema [88]. For increased antioxidant activity, try fermented herbal extracts (like kombucha or fermented green tea). Herbal Formulations Including Prebiotics: nondigestible fibers that nourish good skin microorganisms, such as oligosaccharides and inulin. Applications: To balance the scalp microbiome, use prebiotic herbal shampoos (such as neem + chicory root extract). Prebiotic toners that support the equilibrium of *Cutibacterium* acnes (including xylitol and aloe vera) [87].
- **Postbiotics in Herbal Skincare:** Bioactive compounds (e.g., enzymes, peptides) produced by microbes during fermentation.

Applications: Fermented turmeric serums (enhanced bioavailability of curcumin). Postbiotic herbal face masks (with *Lactobacillus lysates* + *chamomile*) [86].

Microbes in Herbal Cosmetics:

Microbes play a crucial role in enhancing the efficacy, stability, and bioavailability of herbal cosmetics. Below are the most commonly used beneficial microbes:

Lactobacillus species:

- **Role:** Balances skin pH, reduces acne, and strengthens the skin barrier.

- **Applications:** L. ferment → Used in anti-acne toners, L. reuteri → Soothes eczema and rosacea.

Bifidobacterium species

- **Role:** Hydrates skin, reduces inflammation, and supports microbiome health.
- **Applications:** B. longum → Found in moisturizing creams, B. breve → Helps with atopic dermatitis [86].

Saccharomyces (Yeast Ferment Extracts);

- **Role:** Enhances skin repair and antioxidant activity.
- **Applications:** S. cerevisiae (Brewer's yeast) → Used in anti-ageing serums.

Organic Preservation of Herbal Cosmetics

Natural preservation techniques are necessary to stop microbial contamination and spoiling because herbal cosmetics don't contain artificial preservatives like parabens [88].

i. Essential Oils:

- Tea Tree Oil (*Melaleuca alternifolia*) → Fights bacteria and fungi.
- Lavender Oil → Extends shelf life while soothing skin [88].

ii. Plant Extracts with Preservative Properties:

- a. Rosemary Extract (Rosmarinic acid) → Antioxidant + antimicrobial.
- b. Grapefruit Seed Extract (Citricidal) → Broad-spectrum preservative [89].

iii. Organic Acids:

- a. Citric Acid(from citrus fruits) → Lowers pH to inhibit bacteria.
- b. Lactic Acid(from fermented sugars) → Mild preservative + exfoliant [88].

Benefits: Natural and synthetic chemical-free:

Free from parabens, sulfates, phthalates, and synthetic fragrances Reduced risk of irritation compared to synthetic cosmetics [89].

Rich in Bioactive Compounds:

Contains antioxidants (vitamins C, E), flavonoids, and polyphenols. Anti-aging, anti-inflammatory, and antimicrobial properties [89].

Suitable for Sensitive Skin:

Gentle formulations ideal for eczema, rosacea, and acne-prone skin [90].

Therapeutic Effects:

Aloe vera(soothes burns), turmeric (anti-inflammatory), neem (antibacterial).

Limitations:

- c. **Shorter Shelf Life:** Lack of synthetic preservatives → spoilage risk (3-12 months).
- d. **Allergic Reactions:** Some herbs (chamomile, lavender, tea tree oil) may cause contact dermatitis.
- e. **Variable Efficacy:** Dependent on plant source, extraction method, and concentration.
- f. **Slow Results:** Unlike synthetic actives (e.g., retinoids), herbal

cosmetics may take weeks to show effects.

microbial growth in poorly processed herbs [89].

- g. **Contamination Risks:**
Pesticides, heavy metals, or

Table 8: Brands Offering Herbal Cosmetics and Potential Side Effects:

Brand Name	Product	Adverse effects
Himalaya herbals	Neem facewash, Almond and honey face scrub	For sensitive skin it may cause irritation and dryness [88]
Biotique	Bio almond oil , bio honey gel	For oilt skin they may cause stickness [88]
Forest essentials	Saundarya radiance cream	May trigger allergies due to essential oils [88]
Kama Ayurveda	Kumkumadi face serum	Heavy feels of Ayurveda oils [88]
Saeed Ghani	Tea tree, neem acne face wash	No side effects [88]
Hemani Herbals	Herbal hair oil, charcoal facewash	Herbal sensitivity possible [88]
Hamdard Pakistan	Herbal face tonics, safi	No topical effects [88]

4. Chemical Cosmetics:

A wide range of synthetic and natural chemicals are employed in cosmetic formulations, which are widely utilized for personal cleanliness, beautification, and personal care. These chemical components are necessary for preservation, emulsification, UV protection, and aroma enhancement, among other purposes. However, other substances have sparked worries because they may pose health dangers, such as causing skin irritation, disrupting hormones, or even causing cancer. In order to improve the stability, texture, and

effectiveness of its products, the worldwide cosmetics sector mostly depends on chemical additives Parabens, phthalates, sulfates, formaldehyde-releasing agents, and synthetic fragrances are common compounds that have been examined in scientific literature for their long-term impacts on the environment and human health (Table 9).

Functional Roles: The performance of a product depends on chemicals such as surfactants (like SLS), preservatives (like parabens), and emulsifiers (like PEGs).

Safety and Regulation: While the EU's SCCS and the US FDA assess the safety of

cosmetics, some components are still debatable.

New Alternatives: As the desire for "**clean beauty**" has grown, safer, plant-based, and

Examples:

biodegradable substitutes have been created [81].

Table 9: Chemical cosmetics			
Chemical Products	Typical Chemicals	Pros	cons
Sunscreen	Oxybenzone, avobenzone	UV protection	Hormones disruption, skin allergies [90]
Antiaging	Zinc oxide	Reduce wrinkles, increase collagen	Redness, peeling, skin irritation [91]
Shampoos	Retinol, retinoic acids, sulphates	Cleansing, rich latter, long lasting fragrance	Chemical Burns, respiratory irritation [91]
Hair Dyes	Ammonia, resorcinol	Long-lasting, variety of color shades	Allergic contact dermatitis [90]
Foundation	Parabens, phthalates	Clear skin tones	Colg skin pores [91]
Lipsticks	Synthetic dyes	Rich pigmentation	Lip irritation, swelling [90]

Chemical Cosmetics and Microbes: An Expanding Field of Research

Thanks to developments in probiotic-based beauty products, antimicrobial formulations, and microbiome research, the field of chemical cosmetics and microbial science is expanding quickly. Emerging research reveals the intricate relationships between synthetic chemicals and the skin microbiota, which are essential for the preservation and effectiveness of traditional cosmetics. In the meantime, the industry is changing due to the popularity of "microbiome-friendly" cosmetics and live probiotic skincare products [90].

• Preservatives & Their Impact on Skin Microbes:

To avoid bacterial and fungal contamination, many cosmetics contain antimicrobial preservatives (such as parabens, phenoxyethanol, and formaldehyde-releasers). These substances, however, have the potential to alter the skin microbiome, which can result in: - A decrease in microbial diversity (associated with dermatitis, acne, and eczema). The selection of pathogens that are resistant (like *Staphylococcus aureus*) [92].

Surfactants and Microbial Barrier Disruption

Sodium Lauryl Sulfate (SLS) and other common detergents remove natural oils from the skin, changing the pH and balance of the microbiota. A higher chance of developing acne is due to an excess of *Cutibacterium acnes* and disruption of *Staphylococcus epidermidis*, a helpful skin bacterium.

Microbes Involved in Chemical Cosmetics:

Microbes have two functions in cosmetics: some are useful components in contemporary

"microbiome-friendly" formulations, while others are dangerous pollutants that need to be preserved. The main microorganisms found in chemical cosmetics are broken out in depth below, with scientific sources provided [90].

Harmful Microbes in Cosmetics (Contaminants):

Chemical cosmetics must prevent microbial growth to avoid spoilage and infections. Common contaminants include:

Table 10: Harmful Microbes in Cosmetics	
Bacterial species	Adverse Effects
<i>Pseudomonas aeruginosa</i>	Causes eye/skin infections (found in water-based products) [93]
<i>Staphylococcus aureus</i>	Linked to dermatitis and wound infections [93]
<i>Escherichia coli</i>	Indicates fecal contamination (e.g. in natural products) [93]
Fungi/ Yeasts	
<i>Candida albicans</i>	Can cause fungal infections in compromised skin.
<i>Aspergillus niger</i>	Produces mycotoxins in expired creams.

Beneficial Microbes in Cosmetics (Active Ingredients)

Recent advances harness **probiotics**, **prebiotics**, and **postbiotics** for skin health.

- **Probiotics (Live Bacteria):**

Bacterial species	Advantages
<i>Lactobacillus</i> ferment/extracts	Strengthens skin barrier, reduces acne [93]
<i>Bifidobacterium longum</i>	Calms rosacea and eczema [93]
<i>Vitreoscilla filiformis</i>	Reduces inflammation [90]

Example Product: Gallinée Microbiome Cream (contains *Lactobacillus*).

- **Postbiotics (Bacterial Byproducts):**

<i>Lactobacillus lysates</i>	Boost ceramide production [91]
<i>Bifidobacterium ferment filtrates</i>	Hydrate and soothe skin [91]

Example Product: Estée Lauder Advanced Night Repair (uses bifida ferment lysate).

Benefits

- **Enhanced Efficacy & Performance**

Chemical ingredients often outperform natural alternatives in:

- ✓ **Stability**– Longer shelf life (e.g., parabens prevent spoilage).
- ✓ **Precision**– Synthetic actives (e.g., retinoids, hyaluronic acid) deliver consistent results.
- ✓ **Penetration**– Chemical enhancers (e.g., propylene glycol) improve absorption [93]

- **Broad-Spectrum Preservation**

Synthetic preservatives (e.g., phenoxyethanol, formaldehyde-releasers) prevent:

- ✓ Bacterial growth (e.g., *Pseudomonas*).
- ✓ Fungal contamination (e.g., *Candida*) [93]

- **Cost-Effectiveness & Scalability**

Conclusion:

Organic and microbiological-based cosmetics mark an upsurge in the beauty

✓ **Mass production**– Synthetic ingredients (e.g., silicones, SLS) are cheaper than natural extracts.

✓ **Consistency** – Lab-made compounds ensure uniform quality [93]

Limitations

Health Risks:

- Skin Irritation & Allergies.
- SLS, fragrances, and parabens can cause dermatitis.
- Endocrine Disruption
- Phthalates and oxybenzone may interfere with hormones [94].

Environmental Impact:

- Pollution & Toxicity
- Microplastics (e.g., in exfoliants) harm marine life.
- Oxybenzone contributes to coral reef bleaching [94]

Microbiome Disruption:

- Antimicrobial preservatives (e.g. *triclosan*)
- Reduce beneficial skin bacteria (*S. epidermidis*).
- Promote antibiotic resistance [119]

marketplace in a time when customers are more concerned about sustainability and health. In accordance to this study, these

solutions, which are based on plant extracts and healthy bacteria, not only improve skin microbiota and lessen environmental damage, but they also meet changing community demands. Widespread acceptance is nevertheless hampered by expensive costs, uneven international certifications, and popular misconceptions. The sector has to strengthen local regulatory frameworks, enhance distribution networks, and make investments in consumer education in order to secure future growth (94-120). The dynamic, scientifically supported movement of organic beauty is ready to reinvent skincare through honesty, inclusivity, and originality.

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