Herbal Cosmetics in Modern Skin Care: Bioactive Phytoconstituents, Mechanisms, Clinical Evidence, and Emerging Nanotechnological Advances

Dr. Onkar B. Doke*, Dr. Samrat A. Khedkar, Akshada A. Chavan, Chaitali R. Dhale

[1*]Associate Professor, Department of Pharmaceutics, Vidya Niketan College of Pharmacy, Lakhewadi, Indapur, Pune, Maharashtra- 413103, India

[2] Principal, Vidya Niketan College of Pharmacy, Lakhewadi, Indapur, Pune, Maharashtra- 413103, India

[3] PG Scholar, Department of Pharmaceutics, Vidya Niketan College of Pharmacy, Lakhewadi, BATU University, Lakhewadi, Indapur, Maharashtra- 413103, India

[4] Associate Professor, Vidya Niketan College of Pharmacy, Lakhewadi, Indapur, Pune, Maharashtra- 413103, India

Corresponding author:

Name: Dr. Onkar Bharat Doke

Mail Id: onkardokevncop@gmail.com

Mobile no: 8624979117

Abstract:

Herbal cosmetics are becoming increasingly important in modern skincare due to the rising demand for natural, safe, and eco-friendly products. These formulations are rich in plant-derived bioactive compounds such as flavonoids, polyphenols, terpenoids, tannins, and polysaccharides that provide multiple skin benefits. Unlike synthetic cosmetics that mainly enhance appearance, herbal cosmetics help improve skin health by offering antioxidant, anti-inflammatory, antimicrobial, photoprotective, moisturizing, and anti-aging effects. Continuous exposure of skin to UV radiation, pollution, and oxidative stress can lead to damage, making natural protective agents essential. Medicinal plants like Aloe vera, neem, turmeric, green tea, licorice, Centella asiatica, and sandalwood have proven benefits in improving hydration, elasticity, wound healing, pigmentation control, and overall skin integrity. Recent advances in nanotechnology-based delivery systems such as liposomes, phytosomes, and nanoemulsions have further improved their stability and effectiveness. This review highlights their role, mechanisms, evidence, challenges, and future prospects in skincare applications.

Keywords:

Herbal cosmetics, skin care, medicinal plants, phytoconstituents, antioxidants, cosmeceuticals.

1. Introduction:

The concept of skin care has evolved considerably over the past few decades, shifting from basic cleansing and beautification practices to scientifically designed interventions aimed at maintaining skin health and preventing dermatological disorders. In this context, herbal cosmetics have emerged as a rapidly growing segment of the global cosmetic industry owing to increasing consumer preference for natural, sustainable, and biologically active ingredients. Herbal cosmetics are formulations containing plant-derived materials that are intended to cleanse, protect, enhance, or improve the appearance and function of the skin while minimizing the adverse effects commonly associated with synthetic chemicals. [1]

Historically, medicinal plants have been utilized in traditional systems such as Ayurveda, Traditional Chinese Medicine, Unani, and Egyptian medicine for maintaining skin health and treating various dermatological conditions. Ingredients such as aloe vera, turmeric, neem, sandalwood, licorice, and green tea have long been recognized for their therapeutic properties including anti-inflammatory, antimicrobial, antioxidant, and wound-healing activities. Recent advances in phytochemistry and dermatological research have further validated many of these traditional claims, leading to the incorporation of herbal ingredients into modern skin-care formulations. [2]

The increasing prevalence of skin disorders associated with environmental pollution, ultraviolet (UV) radiation, psychological stress, and aging has stimulated growing interest in plant-based cosmetic products. Environmental stressors generate reactive oxygen species (ROS), leading to oxidative damage, inflammation, collagen degradation, and premature skin aging. Unlike conventional cosmetics that mainly provide aesthetic benefits, herbal cosmetics contain bioactive phytoconstituents capable of exerting protective and restorative effects on skin physiology. Polyphenols, flavonoids, terpenoids, carotenoids, tannins, and alkaloids contribute to antioxidant defense, photoprotection, collagen preservation, and regulation of inflammatory pathways, thereby supporting overall skin health. [3, 1, 4]

Furthermore, the emergence of the cosmeceutical concept has blurred the distinction between cosmetics and pharmaceuticals. Modern herbal cosmetics increasingly function as cosmeceuticals by combining aesthetic benefits with biologically active effects that improve skin structure and function. As a result, herbal formulations are now widely employed in anti-aging products, moisturizers, sunscreens, acne treatments, skin-lightening preparations, and wound-healing applications. [5]

Given the growing scientific evidence supporting the efficacy of plant-derived ingredients and the expanding global market for natural skin-care products, a comprehensive understanding of the role of herbal cosmetics in modern skin care is essential. This review critically examines the structure and function of the skin, the significance of herbal cosmetics, their bioactive constituents, and mechanisms of action, clinical evidence, challenges, and future prospects.

2. Skin structure and functions:

The skin is the largest organ of the human body and serves as the primary interface between the internal environment and external surroundings. It constitutes approximately 15-20% of total body weight and performs multiple physiological functions essential for maintaining homeostasis. [6]

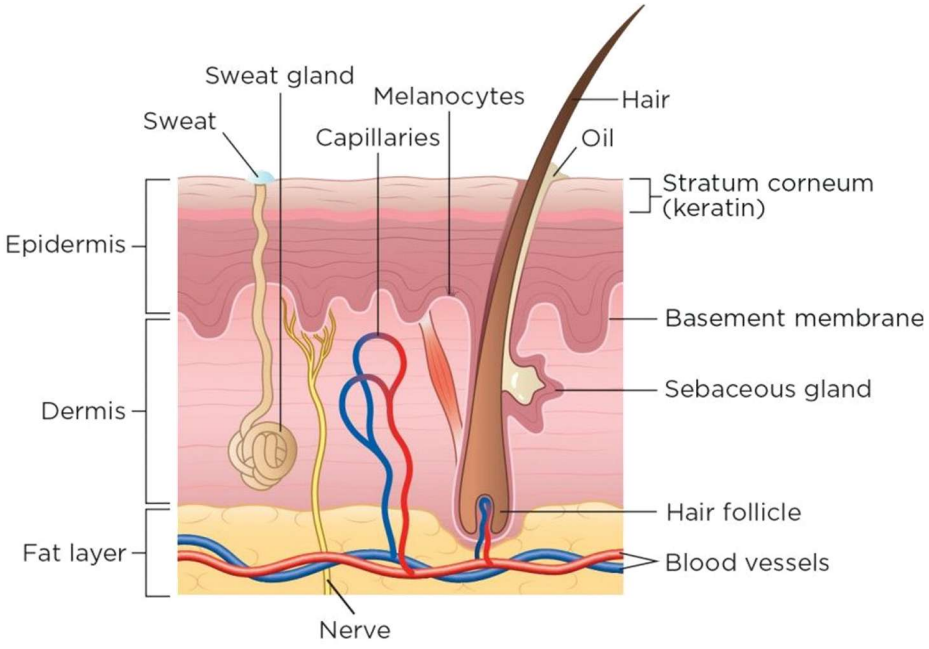

Figure 1: Basic structure of human skin

2.1 Epidermis:

The epidermis is the outermost layer of the skin and consists predominantly of keratinocytes arranged in distinct strata. The stratum corneum forms the primary barrier against microbial invasion, chemical exposure, and excessive transepidermal water loss (TEWL). Melanocytes present in the basal layer synthesize melanin, which protects the skin from ultraviolet radiation-induced damage. [6]

2.2 Dermis:

Located beneath the epidermis, the dermis provides structural integrity and elasticity to the skin. It contains fibroblasts, collagen fibers, elastin, blood vessels, lymphatic vessels, nerve endings,

sebaceous glands, and hair follicles. Type I collagen constitutes nearly 80% of dermal collagen and plays a critical role in maintaining skin strength and resilience. [7]

2.3 Hypodermis:

The hypodermis, or subcutaneous layer, is composed primarily of adipose tissue and connective tissue. This layer functions as an energy reservoir, thermal insulator, and mechanical cushion that protect underlying tissues from physical injury. [6]

2.4 Functions of skin:

a) Barrier protection:

The skin acts as a physical and biochemical barrier against pathogens, pollutants, allergens, and harmful chemicals. The integrity of the stratum corneum is crucial for maintaining this protective function. [7]

b) Prevention of water loss:

The epidermal lipid matrix regulates water retention and prevents excessive dehydration through controlled transepidermal water loss.

c) Thermoregulation:

Sweat glands and cutaneous blood vessels contribute to body temperature regulation through sweating and vasodilation mechanisms.

d) Sensory function:

Numerous sensory receptors within the skin detect touch, pressure, pain, temperature, and vibration.

e) Immune defense:

Langerhans cells, macrophages, and other immune cells located within the skin provide immunological surveillance and protection against infectious agents.

f) Vitamin D synthesis:

Exposure to ultraviolet B radiation initiates the synthesis of vitamin D, which plays a vital role in calcium metabolism and immune function. [6]

3. Overview of herbal cosmetics:

Herbal cosmetics are cosmetic preparations containing active ingredients derived wholly or predominantly from natural plant sources. These products are designed not only to improve physical appearance but also to promote skin health through biologically active phytochemicals. Depending on their composition, herbal cosmetics may provide antioxidant, anti-inflammatory,

antimicrobial, moisturizing, photoprotective, and anti-aging benefits, making them valuable components of modern skincare formulations. [8]

The increasing demand for herbal cosmetics is largely driven by growing consumer awareness regarding the potential adverse effects of synthetic ingredients such as parabens, formaldehyde releasers, phthalates, and certain artificial fragrances. Consequently, the cosmetic industry has witnessed a significant shift toward plant-based formulations that emphasize safety, sustainability, and multifunctional efficacy. [1]

Modern herbal cosmetics encompass a broad range of products, including cleansers, moisturizers, toners, face masks, anti-aging creams, sunscreens, serums, and acne treatments. Unlike traditional cosmetics that primarily provide superficial benefits, herbal formulations frequently contain compounds capable of influencing biological pathways involved in skin aging, inflammation, pigmentation, and tissue repair. [5]

The development of herbal cosmetics has been further accelerated by advances in phytochemical characterization and extraction technologies. Sophisticated analytical techniques have enabled the identification of numerous plant-derived compounds with demonstrated dermatological benefits. These include polyphenols from green tea, curcuminoids from turmeric, flavonoids from licorice, polysaccharides from aloe vera, and terpenoids from various aromatic plants. [1, 4]

Table 1: Classification of herbal cosmetics

Category	Purpose	Examples
Skin cleansers	Removal of dirt and sebum	Herbal face washes
Moisturizers	Hydration and barrier repair	Aloe vera creams
Anti-aging products	Wrinkle reduction	Green tea serums
Sunscreens	UV protection	Polyphenol-rich formulations
Anti-acne products	Control of microbial growth	Neem-based gels
Skin brightening products	Pigmentation management	Licorice formulations

Recent evidence suggests that herbal cosmetic ingredients exert beneficial effects through multiple mechanisms including antioxidant activity, modulation of inflammatory mediators, enhancement of collagen synthesis, inhibition of melanogenesis, and protection against UV-induced oxidative stress. [1, 5]

4. Importance of herbal cosmetics in modern skin care:

The growing popularity of herbal cosmetics reflects a broader transition toward preventive and wellness-oriented approaches in skin care. Modern consumers increasingly seek products that not only enhance appearance but also support long-term skin health. Plant-derived ingredients have become particularly attractive due to their multifunctional biological activities and favorable safety profiles. [1]

One of the most significant factors contributing to the importance of herbal cosmetics is the increasing exposure of human skin to environmental stressors. Air pollution, ultraviolet radiation, cigarette smoke, and psychological stress contribute to the generation of reactive oxygen species (ROS), which accelerate skin aging and promote inflammatory skin disorders. Numerous medicinal plants contain antioxidant compounds capable of neutralizing free radicals and protecting cellular structures from oxidative damage. [1]

Another important aspect is the role of herbal cosmetics in combating skin aging. Aging is characterized by collagen degradation, reduced skin elasticity, increased pigmentation, and wrinkle formation. Plant-derived antioxidants such as catechins, curcumin, resveratrol, and flavonoids have demonstrated potential in preserving collagen integrity, reducing matrix metalloproteinase activity, and improving skin appearance. [5]

Herbal cosmetics are also increasingly utilized for managing acne-prone skin. Several medicinal plants exhibit antimicrobial and anti-inflammatory properties that help control the growth of microorganisms involved in acne pathogenesis while reducing skin irritation. Botanical ingredients such as neem, tea tree, and green tea extracts are frequently incorporated into modern anti-acne formulations. [1]

In addition, consumer concerns regarding sustainability have enhanced the appeal of herbal products. The use of renewable plant resources, biodegradable ingredients, and environmentally friendly manufacturing processes aligns well with current global trends toward green cosmetics and sustainable development. [8]

Recent clinical investigations have further strengthened the position of herbal cosmetics within evidence-based dermatology. Studies have reported improvements in skin hydration, elasticity, wrinkle reduction, photoprotection, and barrier function following the use of formulations containing botanical extracts. Consequently, herbal cosmetics are increasingly recognized as an integral component of modern skin-care strategies. [3, 5]

5. Bioactive phytoconstituents used in skin care:

Medicinal plants contain a wide variety of secondary metabolites that contribute significantly to skin protection, repair, and rejuvenation. These phytoconstituents exhibit antioxidant, anti-inflammatory, antimicrobial, photoprotective, moisturizing, and anti-aging activities, making them valuable ingredients in modern herbal cosmetics. Recent dermatological research has demonstrated that the efficacy of herbal cosmetic formulations is largely dependent on the type and concentration of these bioactive compounds rather than the plant source alone.

Table 2: Principal phytoconstituents and their skin actions

Class	Major compounds	Mechanism of action	Skin benefits
Polyphenols	Catechins, EGCG, Resveratrol	Free radical scavenging	Anti-aging, photoprotection
Flavonoids	Quercetin, Kaempferol, Rutin	Anti-inflammatory activity	Skin repair, wrinkle reduction
Terpenoids	Curcumin, Carotenoids	Modulation of inflammatory pathways	Anti-aging, skin brightening
Tannins	Gallic acid, Ellagic acid	Protein precipitation, antioxidant activity	Astringent and protective effects
Alkaloids	Berberine, Piperine	Antimicrobial activity	Acne management
Saponins	Glycyrrhizin	Barrier repair and cleansing	Moisturization
Polysaccharides	Acemannan	Water retention and wound healing	Hydration and regeneration

5.1 Polyphenols:

Polyphenols are among the most extensively studied phytochemicals in skincare research due to their potent antioxidant activity. These compounds neutralize reactive oxygen species (ROS), which are major contributors to photoaging and cellular damage. Green tea catechins, particularly epigallocatechin gallate (EGCG), exhibit significant photoprotective and anti-inflammatory effects. Additionally, polyphenols inhibit matrix metalloproteinases (MMPs), enzymes responsible for collagen degradation, and help maintain skin elasticity and structural integrity. [9, 10]

5.2 Flavonoids:

Flavonoids represent a diverse group of plant metabolites characterized by potent antioxidant and anti-inflammatory effects. Quercetin, kaempferol, rutin, and apigenin have been reported to suppress inflammatory mediators such as TNF-α, IL-1β, and IL-6 while protecting dermal fibroblasts against oxidative damage. These properties contribute to improved skin elasticity and reduced wrinkle formation. [11, 12]

5.3 Terpenoids:

Terpenoids include carotenoids, curcuminoids, and essential oil constituents. Curcumin from turmeric exhibits remarkable antioxidant, antimicrobial, and anti-inflammatory activities. Carotenoids such as β-carotene and lycopene protect the skin against UV-induced oxidative stress and contribute to skin tone improvement. [13, 14]

5.4 Tannins:

Tannins possess astringent, antioxidant, and antimicrobial properties. They form protective complexes with proteins on the skin surface, reducing irritation and microbial colonization. Ellagic acid-containing tannins have also shown inhibitory effects on melanogenesis, making them useful in hyperpigmentation management. [12]

5.5 Polysaccharides:

Plant polysaccharides, particularly those derived from Aloe vera, provide moisturizing and wound-healing benefits. These compounds enhance water retention, reduce transepidermal water loss, stimulate fibroblast proliferation, and promote tissue regeneration. As a result, they improve skin hydration, elasticity, and barrier function while supporting the healing of damaged skin. [15]

6. Common medicinal plants used in herbal cosmetics: [16]

Numerous medicinal plants have been incorporated into contemporary cosmetic formulations owing to their scientifically validated dermatological benefits. These plants contain bioactive compounds capable of improving skin hydration, reducing inflammation, protecting against ultraviolet radiation, and delaying skin aging.

Table 3: Common medicinal plants used in herbal cosmetics

Plant	Family	Major active constituents	Skin benefits
Aloe vera	Asphodelaceae	Acemannan, Aloin	Moisturizing, wound healing
Azadirachta indica (Neem)	Meliaceae	Nimbidin, Azadirachtin	Anti-acne, antimicrobial
Curcuma longa (Turmeric)	Zingiberaceae	Curcumin	Anti-inflammatory
Camellia sinensis (Green Tea)	Theaceae	Catechins, EGCG	Antioxidant, anti-aging
Glycyrrhiza glabra (Licorice)	Fabaceae	Glabridin	Skin brightening
Rosa damascena (Rose)	Rosaceae	Phenolic compounds	Soothing and moisturizing
Centella asiatica	Apiaceae	Asiaticoside	Collagen stimulation
Santalum album (Sandalwood)	Santalaceae	α-Santalol	Cooling and antimicrobial

Aloe vera:

Aloe vera remains one of the most widely utilized botanical ingredients in skin-care products. Its polysaccharides promote wound healing, hydration, and fibroblast proliferation. In clinical studies, topical application has shown improvements in skin elasticity and moisture retention.

Green tea:

Green tea extract is rich in catechins, especially EGCG, which protect skin cells from oxidative stress and UV-induced damage. Green tea-based formulations are frequently used in anti-aging and sunscreen products.

Turmeric:

Curcumin possesses potent anti-inflammatory and antioxidant properties. It inhibits inflammatory cytokines and reduces oxidative stress, thereby contributing to improved skin health and reduced signs of aging.

Centella asiatica:

Centella asiatica stimulates collagen synthesis through activation of fibroblasts and increased production of extracellular matrix proteins. Consequently, it is widely incorporated into anti-aging and wound-healing formulations.

7. Mechanisms of action of herbal cosmetics: [17]

The beneficial effects of herbal cosmetics arise from their ability to interact with multiple molecular pathways involved in skin physiology. Unlike synthetic agents that often target a single pathway, phytochemicals generally exert multifunctional effects through synergistic mechanisms.

7.1 Antioxidant activity:

One of the main reasons for skin aging is oxidative stress. Plant polyphenols and flavonoids neutralize free radicals and reduce oxidative damage to cellular proteins, lipids, and DNA. Antioxidant activity also protects collagen fibers from degradation and delays wrinkle formation.

7.2 Anti-inflammatory activity:

Several phytochemicals inhibit the release of inflammatory mediators including TNF-α, IL-6, cyclooxygenase-2 (COX-2), and nuclear factor-kappa B (NF-κB). This activity reduces erythema, irritation, and inflammatory skin disorders such as acne and dermatitis.

7.3 Antimicrobial activity:

Essential oils, alkaloids, and phenolic compounds have antimicrobial effects against skin pathogens such as *Cutibacterium acnes*, *Staphylococcus aureus*, and *Candida albicans*. Such properties make them useful for treating acne and skin infections.

7.4 Photoprotective activity:

Many herbal extracts absorb ultraviolet radiation and suppress UV-induced ROS generation. This reduces DNA damage, lipid peroxidation, and photoaging processes.

7.5 Anti-aging activity:

Phytoconstituents inhibit matrix metalloproteinases and stimulate collagen synthesis. Enhanced extracellular matrix integrity contributes to improved skin firmness and elasticity.

8. Applications of herbal cosmetics in modern skin care: [18]

The incorporation of herbal ingredients into cosmetic products has expanded substantially in recent years due to increasing scientific evidence supporting their efficacy.

Table 4: Applications of herbal cosmetics [18]

Product type	Herbal ingredients	Main function
Moisturizers	Aloe vera, Rose	Hydration
Sunscreens	Green tea, Carotenoids	UV protection
Anti-aging creams	Centella asiatica, Green tea	Wrinkle reduction
Anti-acne gels	Neem, Tea tree oil	Antimicrobial activity
Skin-brightening creams	Licorice, Turmeric	Pigmentation control
Face masks	Aloe vera, Sandalwood	Skin rejuvenation

Moisturizers:

Herbal moisturizers improve hydration by enhancing skin barrier function and reducing transepidermal water loss. Aloe vera-based formulations are among the most widely studied examples.

Anti-aging products:

Plant extracts rich in polyphenols and flavonoids are increasingly utilized in anti-aging creams and serums. These products help preserve collagen and reduce visible signs of aging.

Sunscreens:

Botanical antioxidants provide supplementary protection against UV-induced oxidative stress and photoaging. Green tea polyphenols are particularly effective in photoprotection.

Anti-acne formulations:

Neem, tea tree oil, and other herbal extracts exhibit antibacterial and anti-inflammatory activities beneficial in acne management.

9. Scientific evidence and clinical studies: [19, 20]

Scientific validation is essential for establishing the credibility of herbal cosmetic products. Recent clinical studies and systematic reviews have demonstrated measurable improvements in skin health following the use of plant-derived formulations.

Table 5: Recent clinical evidence supporting herbal cosmetics

Herbal ingredient	Study type	Major findings
Green tea polyphenols	Human clinical studies	Reduced UV-induced skin damage
Aloe vera	Clinical trials	Improved hydration and elasticity
Bakuchiol	Randomized clinical studies	Reduced wrinkles and hyperpigmentation
Multi-herbal formulations	Clinical studies	Enhanced skin firmness and elasticity
Plant-based anti-aging products	Meta-analysis (2025)	Significant improvement in skin aging parameters
Rosehip extracts	Dermatological studies	Improved hydration and regeneration

Recent systematic reviews have concluded that topical plant-based formulations significantly improve skin hydration, elasticity, and wrinkle appearance while maintaining a favorable safety profile. A 2025 meta-analysis evaluating randomized controlled trials involving botanical skin-care products reported significant improvements in skin-aging markers compared with placebo controls.

Similarly, herbal cosmeceuticals containing polyphenols, flavonoids, and terpenoids have demonstrated efficacy in reducing oxidative stress and inflammatory responses associated with skin aging. Evidence also suggests that botanical extracts may enhance collagen synthesis and inhibit collagen-degrading enzymes, supporting their incorporation into anti-aging formulations.

10. Advantages of herbal cosmetics:

Herbal cosmetics have gained significant attention due to their natural origin, multifunctional properties, and growing consumer preference for safer and sustainable products. Plant-derived ingredients contain a variety of bioactive compounds such as flavonoids, polyphenols, terpenoids, alkaloids, and essential oils that contribute to skin and hair care benefits. [21-24]

a) Enhanced safety profile:

- Generally associated with lower toxicity and fewer adverse effects than many synthetic cosmetic ingredients when appropriately formulated. [21, 23]

b) Multifunctional activity:

- Have simultaneous antioxidant, anti-inflammatory, antimicrobial, moisturizing, anti-aging, and photoprotective properties. [22, 24]

c) Natural antioxidant source:

- Protect skin from oxidative stress and free radical-induced damage, thereby reducing premature aging. [24]

d) Photoprotective benefits:

- Several botanical extracts help minimize UV-induced skin damage and complement sunscreen formulations. [24]

e) Sustainability and eco-friendliness:

- Derived from renewable resources and support environmentally responsible product development. [25]

f) Consumer acceptance:

- Increasing demand for natural, organic, and clean-label cosmetics has enhanced market growth of herbal products. [25]

g) Cosmeceutical potential:

- Many herbal ingredients provide therapeutic benefits such as anti-acne, wound-healing, skin-brightening, and hair-growth-promoting activities. [23]

h) Compatibility with advanced delivery systems:

- Incorporation into liposomes, phytosomes, nanoemulsions, and hydrogels improves stability, bioavailability, and efficacy. [21, 24]

Table 6: Major advantages of herbal cosmetics [21-25]

Advantage	Benefit
Antioxidant activity	Protection against oxidative stress and aging
Anti-inflammatory action	Reduced skin irritation and inflammation
Antimicrobial effects	Acne control and skin protection
Photoprotection	Reduced UV-induced damage
Sustainability	Environmentally friendly products
Multifunctionality	Multiple benefits from a single ingredient
Consumer acceptance	Growing global market demand
Nanotechnology compatibility	Improved delivery and effectiveness

11. Limitations and challenges:

Despite their popularity, herbal cosmetics face several challenges related to standardization, stability, efficacy, and regulatory acceptance. These limitations can affect product quality, reproducibility, and commercialization. [21, 26]

a) Variability of raw materials:

- Phytochemical composition varies with plant source, climate, cultivation practices, and harvesting conditions, leading to batch-to-batch inconsistency. [26]

b) Lack of standardization:

- Differences in extraction methods and active constituent concentrations make quality control difficult. [26]

c) Stability issues:

- Many herbal constituents are sensitive to heat, light, moisture, and oxidation, reducing shelf life and efficacy. [24]

d) Poor solubility and skin permeation:

- Several phytochemicals exhibit low bioavailability and limited penetration through the skin barrier. [21, 24]

e) Microbial contamination:

- Natural raw materials may support microbial growth if appropriate preservation systems are not employed. [22]

f) Potential allergic reactions:

- Some botanical ingredients may cause hypersensitivity, contact dermatitis, or photosensitivity in susceptible individuals. [23]

g) Limited clinical evidence:

- Many herbal cosmetic claims are supported primarily by in vitro or preclinical studies rather than large-scale clinical trials. [21]

h) Regulatory and manufacturing challenges:

- Lack of globally harmonized regulations and difficulties in large-scale standardization can hinder commercialization. [25, 26]

Table 7: Major limitations of herbal cosmetics and possible solutions [21, 24-26]

Limitation	Possible Solution
Raw material variability	Botanical standardization
Stability problems	Nanoencapsulation technologies
Poor skin penetration	Liposomes, phytosomes, nanoemulsions
Microbial contamination	Improved preservation systems
Limited clinical evidence	Well-designed human studies
Regulatory challenges	Harmonized guidelines
Manufacturing inconsistency	Process optimization and quality control

The limitations associated with conventional herbal formulations have encouraged the development of innovative technologies such as nano-herbal delivery systems, phytosomes, liposomes, nanoemulsions, herbal hydrogels, artificial intelligence-assisted formulation approaches, and green extraction techniques to improve product stability, efficacy, and sustainability. [21, 24, 25]

12. Emerging trends and innovations in herbal cosmetics:

Recent years have witnessed the integration of pharmaceutical nanotechnology, artificial intelligence, and sustainable manufacturing approaches into herbal cosmetic development. These innovations are transforming traditional botanical formulations into highly efficient, scientifically validated products.

12.1 Nano-herbal cosmetics:

Nano-herbal cosmetics involve the incorporation of plant-derived bioactive compounds into nanoscale delivery systems. Reducing particle size to the nanometer range significantly enhances surface area, solubility, stability, and skin penetration. Nano-herbal formulations improve targeted delivery of phytoconstituents while enabling prolonged release and increased bioavailability. Applications include anti-aging creams, sunscreens, depigmenting formulations, and hair-care products. [21, 24]

12.2 Phytosomes:

Phytosomes are phospholipid-based complexes formed by the interaction of plant bioactives with phosphatidylcholine molecules. Unlike conventional extracts, phytosomes exhibit enhanced membrane affinity and improved dermal absorption. The technology has been extensively investigated for flavonoids, curcuminoids, catechins, and polyphenolic antioxidants. Enhanced

stability and bioavailability make phytosomes promising carriers for anti-aging and photoprotective herbal cosmetics. [24, 27]

12.3 Liposomes:

Liposomes are spherical vesicles composed of phospholipid bilayers capable of encapsulating both hydrophilic and lipophilic phytoconstituents. These vesicular carriers protect unstable herbal compounds from degradation while facilitating controlled release and enhanced penetration into skin layers. Liposomal formulations containing aloe vera, green tea polyphenols, curcumin, and essential oils have demonstrated improved cosmetic performance compared with conventional formulations. [21, 27]

12.4 Nanoemulsions:

Nanoemulsions are kinetically stable colloidal systems with droplet sizes generally below 200 nm. Their small droplet size improves dispersion, transparency, physical stability, and skin permeation. Herbal nanoemulsions are increasingly employed for the delivery of essential oils, antioxidants, and lipophilic plant extracts in moisturizing, anti-aging, and sunscreen products. Enhanced bioavailability and sensory attributes have contributed to their growing commercial relevance. [22]

12.5 Herbal hydrogels:

Herbal hydrogels represent three-dimensional polymeric networks capable of retaining large amounts of water while providing sustained release of phytoconstituents. These systems offer excellent biocompatibility, skin adherence, cooling effects, and patient comfort. Herbal hydrogels are being explored for wound healing, anti-acne therapy, anti-inflammatory applications, and skin regeneration. The incorporation of nanocarriers within hydrogel matrices has created advanced hybrid delivery systems with improved therapeutic outcomes. [23]

12.6 AI-assisted formulation design:

Artificial intelligence (AI) and machine learning are emerging as transformative tools in cosmetic research and development. Such AI-driven platforms will allow predictions for formulation stability, ingredient combinations, sensory attributes, and identification of synergistic phytochemical interactions. Predictive modeling reduces development time, minimizes experimental workload, and accelerates the discovery of personalized herbal cosmetic formulations. AI-assisted approaches are expected to play a central role in future cosmetic innovation. [25]

12.7 Green extraction technologies:

Growing emphasis on sustainability has accelerated the adoption of environmentally friendly extraction techniques. Green extraction methods such as supercritical fluid extraction, microwave-assisted extraction, ultrasound-assisted extraction, pressurized liquid extraction, and enzyme-assisted extraction provide higher yields of bioactive compounds while reducing solvent consumption and environmental impact. These technologies support the development of high-quality botanical ingredients with improved purity, reproducibility, and sustainability. [25]

Future prospects:

The future of herbal cosmetics is expected to be driven by continuous advancements in phytochemical research, formulation science, and sustainable manufacturing technologies. Increasing consumer preference for natural and environmentally responsible products will likely accelerate the development of innovative botanical formulations with enhanced efficacy and safety. Emerging technologies such as nanocarriers, phytosomes, liposomes, nanoemulsions, and hydrogel-based delivery systems offer promising solutions to challenges related to stability, bioavailability, and skin penetration of herbal bioactives. Furthermore, the integration of artificial intelligence and machine learning into cosmetic research may facilitate the identification of novel plant-derived compounds, optimization of formulations, and development of personalized skin-care products tailored to individual needs. Green extraction technologies are also expected to play a significant role by improving the yield and quality of bioactive constituents while reducing environmental impact. Future research should focus on large-scale clinical trials, standardization of herbal raw materials, establishment of quality control parameters, and harmonization of global regulatory frameworks. Such developments will strengthen scientific credibility and support the wider acceptance of herbal cosmetics as evidence-based skin-care solutions.

Conclusion:

Herbal cosmetics represent a valuable convergence of traditional botanical knowledge and modern dermatological science. Their rich content of biologically active phytochemicals provides diverse benefits including antioxidant protection, anti-inflammatory effects, antimicrobial activity, photoprotection, enhanced hydration, and anti-aging properties. Growing scientific evidence supports the role of plant-based formulations in improving skin health, maintaining barrier function, and reducing the impact of environmental and age-related skin damage. Despite challenges related to standardization, stability, quality control, and limited clinical validation, ongoing technological innovations are helping to overcome these limitations and improve product performance. The incorporation of advanced delivery systems and sustainable production methods is further enhancing the effectiveness and market potential of herbal cosmetic products. Overall, herbal cosmetics have become an integral part of modern skin-care practice and are poised to play an increasingly significant role in the development of safe, effective, and sustainable approaches to skin health and beauty.

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