RESEARCH PAPER

Sustainable Herbal Skincare: A Review of Medicinal Plants, Bioactive Constituents, and Eco-Friendly Formulation Approaches

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ABSTRACT

The concept of herbal cosmetics has now become a dynamic frontier between ancient plant-based medicine and the current cosmetic knowledge that attributed with a multidimensional combination of antioxidation, anti-inflammatory, antimicrobial, and anti-ageing properties. Adverse effect of synthetic ingredients has increased the pace of transition towards the use of safer and more sustainable green alternative skincare practices globally. The present review covers the scientific, technological, and environmental aspects of herbal cosmetics and its relation to the formulation strategies, and principles of sustainability. Medicinal plants eg. Aloe vera, Curcuma longa, Azadirachta indica, and Centella asiatica are popular for their dermatological properties and has been formulated using sophisticated formulations like nanocarriers, nanoemulsions and hydrogels, emphasised with reference to increasing bioavailability, stability and targeted delivery whilst upholding ecological and biocompatible principles by use of green solvents and eco-friendly excipients. The review deals with regulatory frameworks, standardisation issues and consumer-oriented trends that determine the green cosmetics market. The future outlook highlights the concept of combining green chemistry, biotechnology, and artificial intelligence to have sustainable innovation in the area of cosmetic science. Together, this review offers a scientific basis for creating effective, safe, and green skincare products that will meet the vision of modern green cosmetology.

Keywords: Herbal cosmetics, Green skincare, Phytoconstituents, Nanocarriers, Eco-friendly formulation, Sustainable cosmetics, Green chemistry

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1. INTRODUCTION

Herbal cosmetics are based on plants, and they are considered a holistic method of taking care of the skin, which combines the therapeutic benefits of natural bioactives with cosmetic science. Historically, herbs have been used in skin cleansing, nourishment and protection because of their dense phytoconstituents like flavonoids, alkaloids, terpenoids, as well as phenolics (1). These substances will act as antioxidants, anti-inflammatories, antimicrobials, and anti-ageing. The ever-increasing consciousness about the negative implications of synthetic components, including parabens, sulfates, and artificial scents, has altered the preference of consumers to safer and more sustainable options (2). Green skincare is a concept that is currently emerging in the cosmetic and pharmaceutical sectors and focuses on the application of environmentally friendly ingredients, green chemistry, biodegradable excipients, and environmentally friendly manufacturing processes. The mission of this paradigm is to minimise the environmental impact without compromising the product efficacy and safety (3). The research of herbal cosmetics on pharmaceuticals combines the conventional knowledge and the contemporary science of formulations by guaranteeing standardisation, reproducibility and scientific validation of the herbs. Further development of the stability, bioavailability and targeted action of herbal actives in skincare applications has been achieved through the increasing integration of advanced formulation processes, including nanocarriers, hydrogel and green emulsifiers (4, 5).

The pharmaceutical approach of herbal cosmetics research is based on the evidence-based development, the therapeutic safety, efficacy, and quality control. In contrast to traditional cosmetics, herbal compounds usually have problems with inconsistency of plant sources, extraction procedures, and stability (6, 7). Thus, there is a need to conduct systematic studies that will

maximise the formulation parameters and analyse bioactivity with in-vitro, in-vivo, and clinical methods. Moreover, the demand for worldwide natural and sustainable cosmetics is growing at an impressive rate, which leaves the pharmacist and formulation scientist with the possibility of developing something innovative and within the regulatory and environmental contexts (8, 9). Through studies on herbal preparations, green skincare products which are in line with consumer needs of natural efficacy and eco-safety are developed and this study area contributes to the pharmaceutical industry with new ideas on drug delivery and green formulation technology (10).

Green cosmetics also known as green beauty, natural cosmetics, clean cosmetics and sustainable cosmetics focus on ingredients, processes and packaging that are as harmless to human health and the environment as possible (11). Their most important principles are borrowed from green chemistry and sustainable product design: renewable and traceable botanical raw materials, no known and controversial synthetics (some parabens, persistent microplastics, etc.), minimal processing or "eco-extraction, and labelling that allows the consumer to make an informed choice (12, 13). Other special considerations found in green formulations are biodegradability of ingredients, less use of energy and solvents in the formulation, and lifecycle assessment source all the way to end-of-life). These principles aim to compromise functionality and safety with an ecological responsibility (14).

In this paper, the scientific and technological features of herbal cosmetics and green skincare are reviewed, focusing on the formulation's strategies and evaluation parameters, and sustainability practices. It will provide an overview of the recent progress in herbal-based preparations, barriers to standardisation and regulation, and further opportunities associated with the use of nanotechnology, AI, and green chemistry in the creation of effective, safe, and environmentally friendly skincare preparations.

2. SUSTAINABILITY AND ENVIRONMENTAL ASPECTS

Sustainability in the skincare is applied at raw materials, formulation chemistry, production, packaging, and disposal (15). Green skincare solves such environmentally problematic areas as: non-renewable petrochemical-based ingredients, microplastic abrasives and glitter, which remain in the water body after usage, solvent-heavy extractions, and one-time use plastic packaging (16). Recent analyses record the ecological/ human health hazards of traditional cosmetic ingredients and the necessity to switch persistent or bioaccumulative compounds with biodegradable ones; they also note that the industry has a role to play in the development of microplastic pollution and chemical burdens in wastewater (17). Sustainable measures that are currently getting more popular include green extraction e.g. eco-solvents, cold extraction), biotechnological production of actives (precision fermentation), reformulation to eliminate microbeads, use of post-consumer recycled (PCR) materials more frequently, lightweighting of packaging and the introduction of circular-design programs (refill systems, take-back programs) (18, 19). Lifecycle analyses however demonstrate trade-offs including that some so-called natural ingredients use large amounts of water or land unless responsibly managed, which means that to have credible sustainability claims evidence-based transparent impact analysis is needed (20).

3. CONSUMER PERCEPTION AND MARKET TRENDS

The major force behind the growth of green skincare is consumer demand: surveys and market research claim that there is a high and rising readiness to pay a premium to products that are believed to be natural, safe, and ethically sourced, and efficacy and transparent labelling are the key factors defining consumer loyalty (21). The natural/green cosmetics market has grown fast (the global natural cosmetics market is estimated by industry to be in tens of billions USD as of 2023), and brands, both indie clean-beauty startups and multinationals, are reacting accordingly with reformulation, sustainability map, and communication strategies, which focus on credentials (organic, cruelty-free, biodegradable, PCR packaging) (22). At the same time, regulators and NGOs are pushing to have rigid definitions and stricter labelling that will reduce greenwashing, more scientific substantiation (standardized phytochemical profiling, stability/safety testing, and environmental impact data) is demanded to substantiate marketing claims. Online platforms and influencer networks speed up the spread of trends, but also increase the level of questioning; the consumer is more demanding of a brand to post quantifiable sustainability goals and third-party accolades rather than idealistic phrases (23, 24).

4. HERBAL INGREDIENTS USED IN SKINCARE

4.1 Overview of Commonly Used Medicinal Plants

The cornerstone of green skincare formulations is herbal ingredients due to their wide range of therapeutic action, safety and cultural acceptance. Plants have been long utilized in traditional systems, including Ayurveda, Traditional Chinese Medicine and Unani, to take care of skin, wounds, infections and inflammatory diseases (25). These traditional assertions have been confirmed by modern studies, which indicate that a variety of medicinal plants have bioactive phytochemicals possessing antioxidant effects, anti-aging effects, anti-inflammatory effects, antimicrobial effects and photo protective effects (26). These bioactive have a synergistic effect that helps in shielding the skin against oxidative stress,

environmental pollutants and ultraviolet (UV) radiation. Typical skincare ingredients are Aloe vera, Curcuma longa, *Azadirachta indica*, *Camellia sinensis* and *Centella asiatica*, which have been shown to provide various biological benefits, such as skin hydration and skin restoration, as well as antipremature aging qualities (27). The selection of herbs used as ingredients in cosmetic formulations is determined by the desired effect: moisturising, depigmenting, anti-acne or anti-ageing, and whether it will be compatible with the formulation base, creams, gels or serums. Phytochemical-based extracts in recent years have also found their way into the sophisticated formulations like liposomes, nanoemulsions and hydrogels to improve bioavailability and stability, and retain their natural integrity (28). Table 1 presents a summary of the most frequently used medicinal plants in herbal skincare, their botanical names, common names, and most important dermatological properties. These plants have antioxidant, anti-inflammatory, antimicrobial, wound-healing, and skin-brightening effects, which justifies their use in green cosmetic formulations.

Table 1: Overview of Commonly Used Medicinal Plants in Herbal Skincare

S. No	Botanical Name	Common Name	Major Phytoconstituents	Key Dermatological Benefits	Ref.
1	*Aloe vera*	Aloe	Aloin, aloesin, polysaccharides	Moisturising, wound healing, and anti-inflammatory	(2)
2	*Curcuma longa*	Turmeric	Curcumin, demethoxycurcumin	Antioxidant, anti-ageing, skin brightening	(3)
3	*Azadirachta indica*	Neem	Azadirachtin, nimbidin	Antimicrobial, anti-acne, antifungal	(4)
4	*Camellia sinensis*	Green tea	Catechins, EGCG	UV protection, anti-ageing, antioxidant	(5)
5	*Centella asiatica*	Gotu kola	Asiaticoside, madecassoside	Collagen synthesis, wound healing	(7)
6	*Ocimum sanctum*	Tulsi	Eugenol, ursolic acid	Antimicrobial, anti-inflammatory	(10)
7	*Rosa damascena*	Rose	Geraniol, citronellol	Skin soothing, toning and fragrance	(12)
8	*Glycyrrhiza glabra*	Licorice	Glabridin, liquiritin	Skin lightening, anti-inflammatory	(13)
9	*Lawsonia inermis*	Henna	Lawsone, tannins	Cooling, antimicrobial, hair and scalp care	(15)
10	*Santalum album*	Sandalwood	α- and β-santalol	Anti-acne, soothing, antiseptic	(18)
11	*Calendula officinalis*	Marigold	Flavonoids, triterpenoids	Anti-inflammatory, wound healing	(19)
12	*Allium sativum*	Garlic	Allicin, sulfur compounds	Antimicrobial, antioxidant	(20)

13	*Mentha piperita*	Peppermint	Menthol, rosmarinic acid	Cooling, anti-itch, antimicrobial	(23)
14	*Rubia cordifolia*	Manjistha	Anthraquinones, purpurin	Detoxifying, complexion-enhancing	(24)
15	*Terminalia chebula*	Haritaki	Chebulinic acid, tannins	Antioxidant, rejuvenating, anti-wrinkle	(25)
16	*Phyllanthus emblica*	Amla	Ascorbic acid, gallic acid	Antioxidant, collagen synthesis, brightening	(25)

4.2 Bioactive Phytoconstituents and Their Dermatological Benefits

The science of herbal skincare is based on the diverse bioactive phytoconstituents that have antioxidant, anti-inflammatory, antimicrobial and regenerative properties and help in promoting skin health. These are flavonoids, phenolic acids, alkaloids, terpenoids, saponins, tannins, polysaccharides, carotenoids, and essential oils among others (29). A summary of fifteen frequently used phytoconstituents, their sources in plants, and their dermatological effects is given in Table 2. The flavonoids in green tea and neem, as an example, have antioxidant and anti-ageing effects, whereas saponins in Centella asiatica and liquorice have wound healing and hydrating effects (30). Phenolic acids and curcuminoids are also helpful in skin brightening and photoprotection, whereas terpenoids and essential oils have antimicrobial and relaxing effects (31). It is hoped that the combined action of these phytochemicals leads to higher efficacy of herbal preparations and contributes to the creation of safe, effective, and natural skin care products (32).

Table 2: Major bioactive phytoconstituents, their plant sources, and dermatological benefits

S. No	Phytoconstituent	Plant Source(s)	Key Dermatological Benefits	Ref.
1	Flavonoids (quercetin, catechins)	Green tea (*Camellia sinensis*), Neem (*Azadirachta indica*)	Antioxidant, anti-ageing, photoprotection	(33)
2	Phenolic acids (gallic acid, caffeic acid)	Amla (*Phyllanthus emblica*), Turmeric (*Curcuma longa*)	Antioxidant, anti-inflammatory, skin brightening	(34)
3	Alkaloids (berberine, piperine)	Berberis species, Black pepper (*Piper nigrum*)	Antimicrobial, anti-inflammatory	(35)
4	Terpenoids (santalol, eugenol)	Sandalwood (*Santalum album*), Tulsi (*Ocimum sanctum*)	Anti-inflammatory, antimicrobial, soothing	(36)
5	Saponins (asiaticoside, glycyrrhizin)	Centella asiatica, Licorice (*Glycyrrhiza glabra*)	Wound healing, hydration, collagen synthesis	(37)
6	Tannins (ellagitannins, chebulagic acid)	Haritaki (*Terminalia chebula*), Henna (*Lawsonia inermis*)	Astringent, antimicrobial, tissue repair	(38)
7	Polysaccharides (acemannan, glucomannan)	Aloe vera, Ginseng (*Panax ginseng*)	Moisturizing, barrier protection, regeneration	(39)

8	Carotenoids (β-carotene, lycopene)	Carrot (*Daucus carota*), Tomato (*Solanum lycopersicum*)	Photoprotection, antioxidant, skin nourishment	(40)
9	Essential oils (menthol, citronellol)	Peppermint (*Mentha piperita*), Rose (*Rosa damascena*)	Cooling, soothing, antimicrobial	(41)
10	Coumarins (umbelliferone, esculetin)	Parsley (*Petroselinum crispum*), Centella asiatica	Anti-inflammatory, skin lightening	(42)
11	Curcuminoids (curcumin)	Turmeric (*Curcuma longa*)	Antioxidant, anti-inflammatory, photoprotection	(42)
12	Glycosides (liquiritin)	Licorice (*Glycyrrhiza glabra*)	Skin lightening, anti-inflammatory	(43)
13	Anthraquinones (aloin, purpurin)	Aloe vera, Manjistha (*Rubia cordifolia*)	Wound healing, skin rejuvenation	(44)
14	Sterols (β-sitosterol)	Neem (*Azadirachta indica*), Shea butter (*Vitellaria paradoxa*)	Anti-inflammatory, barrier restoration	(44)
15	Vitamins (vitamin C, vitamin E)	Amla (*Phyllanthus emblica*), Wheat germ (*Triticum aestivum*)	Antioxidant, collagen synthesis, skin brightening	(45)

4.3 Mechanism of Action of Key Herbal Actives

The dermatological effects of the herbal actives are multiple and often complementary on the molecular and cellular levels, which is why they are highly versatile in application in skincare.

Antioxidant effect: Several phytochemicals, including flavonoids, phenolic acids and polyphenols, neutralise reactive oxygen species (ROS) either generated by ultraviolet (UV) radiation or pollution, or by the metabolism. These compounds prevent lipid peroxidation, protein oxidation and DNA damage in the skin cells by scavenging the free radicals, weakening oxidative stress, delaying collagen deterioration and reversing the impact of early ageing. The prominent examples of the potent antioxidants are, in their turn, green tea catechins, curcumin, and quercetin (46).

Anti-inflammatory effects: The effect of the herbal actives is that of an anti-inflammatory effect, where they inhibit pro-inflammatory cytokines (e.g., IL-1, IL-6, TNF-α), enzymes (e.g., cyclooxygenase, COX; lipoxygenase). These compounds are curcumin (Curcuma longa), eugenol (*Ocimum sanctum*) and asiaticoside (*Centella asiatica*), which inhibit erythema, swelling, and irritation, which means that they can be used in the treatment of acne, dermatitis, and skin sensitivity (47).

Antimicrobial, antifungal action: Some of the herbal extracts interfere with the cell wall of the microbes, the development of biofilms, or the metabolism of bacteria. Neem (*Azadirachta indica*), tulsi (*Ocimum sanctum*), and tea tree oil (*Melaleuca alternifolia*) have been demonstrated to possess anti-acne properties on Propionibacterium acnes, and other pathogenic microbes, and hence the use of these ingredients in treatment and the cosmetic sector is justified (48).

Wound healing: The herbs contain actives that stimulate fibroblast multiplication, collagenation and angiogenesis, which accelerate wound healing and increase skin elasticity. Asiaticoside and aloin (Aloe vera) augment the reorganisation and repair of the extracellular matrix barriers that assist in decreasing the scars and restoring the skin (49).

Depigmentation and photoprotection: Following phenolic ones (curcumin, glabridin (Glycyrrhiza glabra), and catechins) inhibit the action of tyrosinase, which leads to melanin formation. Combined with antioxidant action, these actives inhibit hyperpigmentation and photoaging of the skin due to UV radiation, which leads to a smooth skin surface and greater protection against the sun (50). Figure 1 shows multifunctional skin-protective mechanisms of phytoactives

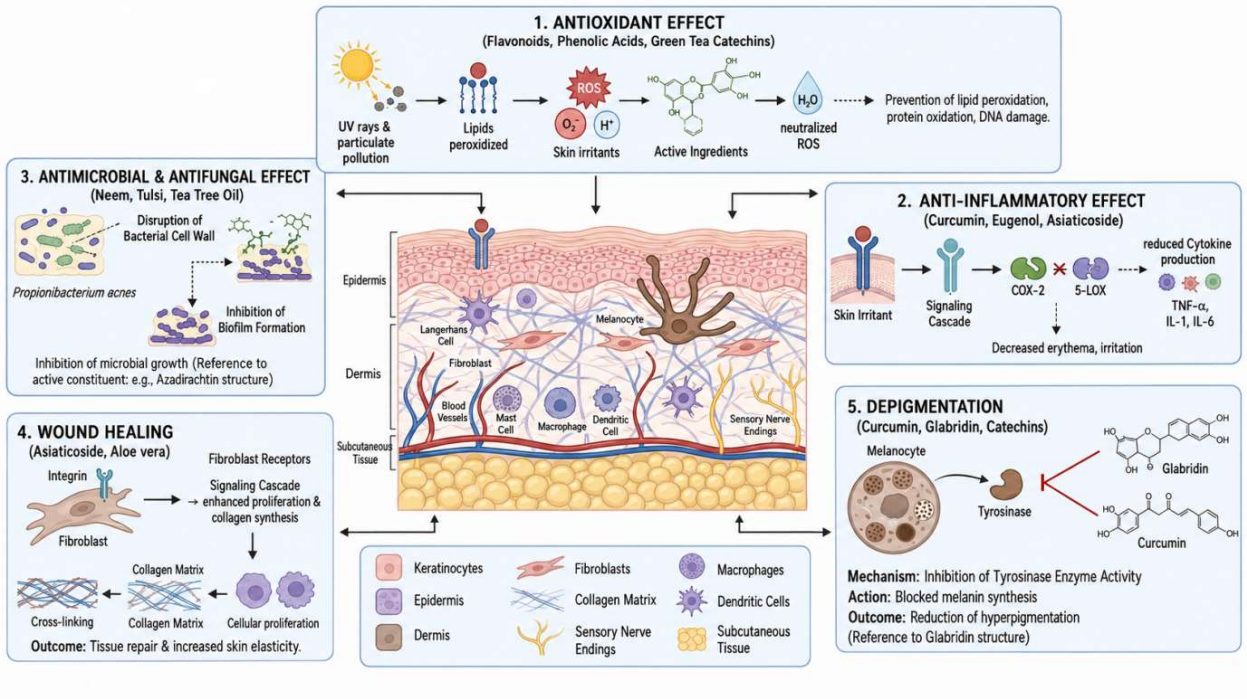

Figure 1: Multifunctional Skin-Protective Mechanisms of Phyto-actives

Figure 2: Overview of Conventional and Novel Formulation Strategies in Herbal Skincare

5. FORMULATION APPROACHES FOR HERBAL SKINCARE PRODUCTS

The objective of the herbal skincare preparations is to provide bioactive compounds to the skin that are of plant origin and ensure stability, safety, and acceptability to the consumer. The physicochemical characteristics of the herbal extracts, targeted therapeutic effect and targeted skin layer determine the choice of formulation strategy. However, recent studies have focused on the effectiveness of these formulations as well as on their compliance with green and sustainable practices (Figure 2).

5.1 Conventional Formulations (Creams, Lotions, Gels, Masks)

The most popular way to deliver herbal actives to the skin is still with conventional formulations because of their simplicity and affordable nature, not to mention their application (Table 3) (51, 52). Creams are usually oil-in-water (O/W) emulsions, which are good in keeping the skin hydrated and penetration of lipophilic phytochemicals (53, 54). Lotions, which have lower viscosity, are applicable to large areas and suitable for formulations that have light herbal extracts. Semi-solid water-based gels are especially applicable when extracting hydrophilic solutions and have a cooling effect on application (55. 56). Clay-based or sheet masks are types of masks that are utilised as topical delivery systems, which provide more time in contact with the skin and increase the absorption of active ingredients or agents (antioxidants or anti-inflammatory agents). Stability, spreadability, and sensory parameters are some of the parameters that are important in determining consumer acceptance in these traditional systems (57, 58).

Table 3: Marketed conventional herbal Skincare formulations and their key Ingredients

Brand	Product Name	Formulation Type	Key Ingredients	Official Website
Dr. Hauschka	Rose Day Cream	Cream	Rose, Marshmallow, Avocado Oil	drhauschka.com
Eminence Organics	Turmeric Energising Treatment	Mask	Turmeric, Citrine Gemstones, Zeolite	eminenceorganics.com
Ursa Major	Golden Hour Recovery Cream	Cream	Calendula, Aloe, Chamomile	ursamajorvt.com
Fresh	Lotus Youth Preserve Dream Face Cream	Cream	Lotus, Super 7 Complex	fresh.com
Sekkisei	Herbal Gel	Gel	Job's Tears, Melothria, Angelica	sekkiseibeauty.com
Acure	Radically Rejuvenating Whipped Night Cream	Cream	Argan Oil, Chlorella, Echinacea	acure.com
Glow Recipe	Avocado Ceramide Recovery Serum	Serum	Avocado, Ceramide, Peptides	glowrecipe.com
Kora Organics	Turmeric Glow Brightening Moisturizer	Cream	Turmeric, Noni Fruit, Licorice	koraorganics.com
True Botanicals	Ginger Turmeric Hydraglow Cream	Cream	Ginger, Turmeric, Green Tea, Aloe	truebotanicals.com
HimPharm	Aloe Vera Gel	Gel	Aloe Vera	himpharm.com
Naturopathica	Sweet Clover Cleansing Milk	Lotion	Sweet Clover, Aloe, Chamomile	naturopathica.com

L'BRI	Aloe Vera Moisturizer	Cream	Aloe Vera, Vitamin E	lbri.com
RainShadow Labs	Herbal Facial Mask	Mask	Lavender, Chamomile, Rosehip Oil	rainshadowlabs.com
Live Botanical	Rose + Aloe Gel	Gel	Rose, Aloe Vera, Chamomile	livebotanical.com
Credo Beauty	Ursa Major Fortifying Gel Moisturizer	Gel	Aloe, Chamomile, Green Tea	credobeauty.com

5.2 Novel Formulation Strategies (Nanocarriers, Emulsions, Hydrogels)

5.2.1. Nanocarriers for Enhanced Delivery and Stability

The system with nanocarriers (liposomes, solid lipid nanoparticles (SLNs), nanostructured lipid carriers (NLCs), ethosomes, phytosomes, and polymeric nanoparticles) are actively used in the herbal skincare industry to improve the solubility, stability, and skin penetration of herbal ingredients (61-63). These carriers can be used to deliver the sensitive bioactives including polyphenols, flavonoids, and terpenoids without oxidation and degradation and without release and controlled skin deposition.

Cheng et al. were able to prove that the photostability and dermal absorption of herbal antioxidants increased with the use of liposomal encapsulation. In their review of nanocosmetic delivery vehicles (64-66), Maghraby et al., discovered that nanoscale encapsulation highly improved the bioavailability and safety to users of plant extracts (67-69). On the same note, Talebi et al., also indicated that phytosomes enhanced the permeability and bioefficacy of phytosomalized curcumin and green tea polyphenols in topical preparations (70-72). The design parameters include particle size (less than 200 nm), surface charge, and lipid composition, which have significant roles in the control of the release kinetics and skin localisation.

Altogether, nanocarriers are a breakthrough in herbal skincare as they allow high efficacy with low toxicity and enhanced aesthetic value, but the regulation will still require validation of nanotoxicity and biocompatibility.

Table 4 summarises commonly used nanocarrier systems in herbal skincare and their role in improving the stability, solubility, bioavailability, and skin penetration of herbal actives. These systems help protect sensitive phytoconstituents and enhance their controlled delivery to targeted skin layers.

5.2.2. Emulsion-Based Systems for Improved Penetration and Stability

Emulsion-based systems (macro and micro emulsions, Nano emulsions and pickering emulsions) are a newer but flexible system to deliver both hydrophilic and lipophilic actives of herbs (Table 5). Specifically, nanoemulsions have been found to improve the dispersal of poorly soluble essential oils and phenolic compounds, which results in improved transdermal penetration and product stability. Their small droplets (20-200 nm) enhance uniformity, texture and absorption, which is ideal in herbal creams, serums and sunscreens.

Herbal nanoemulsions that were developed by Iskandar et al., exhibit increased activity as antioxidants and anti-inflammatory agents because important oils are more soluble (73-74). The article by Saari et al., developed a curcumin nanoemulsion to show that it had better skin permeation and hydration properties than the traditional emulsions (75). Similarly, Enayatifard et al., have developed stable essential-oil nanoemulsions that could be found to be stable in the long run and had enhanced antimicrobial activity (76).

Natural emulsifiers include lecithin, saponins, and plant polysaccharides, which are becoming more popular in order to satisfy the requirements of green cosmetics. Nonetheless, such formulation issues as Ostwald ripening and phase separation should be streamlined to provide consistency to the products and shelf stability. Therefore, nanoemulsions and Pickering emulsions are the most promising cosmeceutical technologies based on herbal actives.

5.2.3. Hydrogels as Biocompatible Carriers for Herbal Actives

Biopolymers like chitosan, alginate, gelatin, and cellulose derivatives are getting more and more attention in terms of topical herbal delivery owing to the high content of water, softness and biocompatibility (Table 6). They create a protective and moisturising matrix that permits prolonged release of herbal actives in addition to skin healing and comfort, thus being applicable in anti-ageing, anti-acnes and wound-healing preparations (77).

Che et al. emphasised that chitosan-based hydrogels were the best choice of scaffolds in herbal wound-healing systems because of their antimicrobial and film-forming characteristics (78). Zahra et al., documented that a polyherbal chitosan hydrogel can be used to increase the wound closure rates and collagen deposition in vivo (79).

Likewise, Mathew et al. prepared marigold-extract-impregnated hydrogels that had enhanced antioxidant and anti-inflammatory properties with high biocompatibility properties (80).

The strength, porosity, and release kinetics of the gel are affected by crosslinking methods (ionic/ covalent/ or physical) as well as polymer composition. Natural crosslinkers like genipin and citric acid are used to ensure the formulation is natural (81). In general, next-generation herbal skincare can utilise hydrogels effectively due to their strong efficacy, safety, and comfort to consumers.

Table 4: Nanocarriers for Enhanced Delivery and Stability of Herbal Actives

S. No.	Nanocarrier Type	Herbal Actives/Examples	Key Advantages in Herbal Skincare	Application
1	Liposomes	Curcumin, green tea catechins, Aloe vera extract	Improve penetration, protect bioactives from degradation, enhance hydration	Anti-ageing creams, serums, moisturisers
2	Solid Lipid Nanoparticles (SLNs)	Neem oil, turmeric extract, essential oils	Enhance stability, provide controlled release, reduce irritation	Anti-acne gels, creams, protective skincare
3	Nanostructured Lipid Carriers (NLCs)	Saffron, manjistha, licorice extract	Improve loading capacity and skin deposition of herbal actives	Brightening creams, anti-ageing formulations
4	Ethosomes	Curcumin, flavonoids, herbal polyphenols	Enhance deep skin penetration due to flexible vesicular structure	Transdermal herbal gels and serums
5	Phytosomes	Green tea polyphenols, curcumin, silymarin	Improve bioavailability and permeability of plant-based compounds	Antioxidant and photoprotective skincare
6	Polymeric Nanoparticles	Aloe vera, Centella asiatica, calendula extract	Provide sustained release and improve stability of herbal extracts	Wound-healing and skin-repair formulations
7	Nanoemulsions	Tea tree oil, sandalwood oil, turmeric oil	Improve solubility, spreadability, and absorption of lipophilic herbal ingredients	Herbal sunscreens, creams, lotions, serums

Table 5: Examples of marketed herbal skincare emulsion formulations

Product Name	Brand	Key Herbal Actives	Formulation Type	Purpose	Official Link
VLCC Snigdha Skin Whitening Cream	VLCC	Saffron, Mulberry, Liquorice	Oil-in-water emulsion	Skin whitening & hydration	Link
Patanjali Aloe Vera Moisturizing Cream	Patanjali Ayurved	Aloe vera, Wheat germ, Shea butter	Macro-emulsion	Deep moisturising & soothing	Link
Khadi Natural Sandal & Olive Nourishing Face Cream	Khadi	Sandalwood, Aloe vera	O/W Emulsion	Cooling massage cream for rejuvenation	Link
Soultree Anti-Ageing	Soultree	Saffron, Ashwagandha,	Pickering Emulsion	Wrinkle reduction	Link

Cream		Turmeric	(natural emulsifiers)	& nourishment	
Herbline Essentials Cucumber Sunblock Cream SPF 40	Herbline (UAE-India)	Cucumber, Aloe, Green tea	Nanoemulsion sunscreen	UV protection + soothing	Link
Biotique Morning Nectar Flawless Skin Lotion	Biotique	Honey, Wheat germ, Seaweed	Emulsion lotion	Daily nourishment & flawless skin texture	Link

Table 6: Commercial herbal hydrogel masks and gels marketed during 2000–2026

S. No.	Year/Period	Product Name	Brand	Key Herbal Actives	Formulation Type	Purpose	Ref
1	2000–2026	Soothing & Moisture Aloe Vera 92% Soothing Gel	Nature Republic	Aloe vera	Aloe-based hydrogel	Soothing, moisturising, face/body hydration	(82)
2	2000–2026	Aloe 99% Soothing Gel	Holika Holika	Jeju aloe vera	Aloe hydrogel	Cooling, calming, hydration for irritated skin	(83)
3	2000–2026	Aloe Revitalizing Soothing Gel	Innisfree	Aloe vera, madecassoside	Natural polymer hydrogel	Hydration and soothing for tired-looking skin	(84)
4	2000–2026	Aloe Real Cool Soothing Gel	Benton	Aloe vera, botanical complex	Soothing hydrogel	Cooling, calming, moisturising	(85)
5	2000–2026	Aloe Turmeric Gel	Mamaearth	Aloe vera, turmeric, vitamin E	Herbal gel / hydrogel	Anti-acne, soothing, healing, skin and hair care	(86)
6	2000–2026	99% Pure Aloe Vera Gel	WOW Skin Science	Aloe vera, vitamins C and E	Aloe hydrogel	Moisturising, calming, multipurpose skin and hair care	(87)
7	2000–2026	Green Tea Clear Face Mask	Plum Goodness	Green tea	Gel/clay-based herbal mask	Acne control, oil control, exfoliation	(88)
8	2000–2026	Real Nature Calendula Sheet Mask	The Face Shop	Calendula, green tea extract	Serum sheet mask / hydrogel-type mask	Moisturisation, soothing, nourishment	(89)
9	2000–2026	Fresh To Go Aloe Mask	TONYMOLY	Aloe vera	Natural cellulose sheet mask	Moisturising and refreshing skin	(90)
10	2000–2026	Deep Nourishing Sheet Mask	Skinella	Fig, green maple	Herbal sheet mask	Hydration, nourishment, glow enhancement	(91)
11	2000–2026	Radiance Boost Sheet	Skinella	Manuka honey, vitamin C	Herbal sheet mask	Brightening, hydration,	(92)

		Mask				radiance	
12	2000–2026	Aloe Propolis Soothing Gel	Benton	Aloe vera, propolis	Herbal soothing gel	Hydration, calming, post-acne skin support	(93)

Sources: Product information was compiled from official brand webpages and verified retail product listings for commercial herbal gels and sheet masks.

5.3 Eco-Friendly Formulation Approaches using Green Solvents and Excipients

This is due to the increased focus on sustainability and safety in the field of cosmetic science which has led to the incorporation of green solvents and environmentally friendly excipients into herbal skincare formulations. Green solvents, derived from renewable resources like plant-based alcohols, glycerol, ethyl lactate and deep eutectic solvents (DES), are an ecologically benign alternative to petroleum-based or organotoxic organic solvents. They minimise ecological footprints while increasing the extraction of bioactives such as polyphenols, flavonoids, and terpenoids, among others, in herbs. Indicatively, Rosarina et al. have shown that extraction using the DES of curcumin produced a more antioxidant effect as opposed to using ethanol. On the same note (94), Shahbaz et al., also indicated a higher recovery of catechins when using glycerol-water mixtures, which is of great benefit because of the excellent biocompatibility and safety of the solvent on the skin (95).

Natural lecithin, saponins, chitosan, alginate, cellulose derivatives, and biodegradable surfactants are examples of eco-friendly excipients that are crucial in formulation stabilisation as they reduce environmental effects. Indicatively, Singh et al. came up with a chitosan-stabilised herbal hydrogel, which has a sustained release and a high skin permeation (96). Similarly, Chaiwut et al., developed the green emulsions based on the sugar esters and natural oils which gave good sensorial and skin tolerance (97).

Altogether, the implementation of green chemistry principles in the development of skincare not only guarantees the biocompatibility, biodegradability, and compliance with the regulations, but also adherence to greener consumer trends of safe, sustainable, and ethically created cosmetic products.

5.4 Regulatory and Standardisation Aspects

The same structures are now mostly applied to the herbal skincare products as to the conventional cosmetic products, though there are extra requirements in regard to safety evaluation, quality control, and labelling transparency due to the use of botanical materials (98). An example is Regulation (EU) No. 1223/2009 of the European Union, which demands that all cosmetic products fulfil the duties of a Cosmetic Product Safety Report (CPSR), ingredient lists are required to be written in INCI, and that prohibited/restricted substances (Annexe II/III) be complied with. Skincare botanical extracts are thus still expected to comply with these universal safety and labelling guidelines. In India, cosmetic products containing herbal ingredients are regulated by the Central Drugs Standard Control Organisation (CDSCO) and the Ministry of AYUSH in the event that claims tend to move to Ayurvedic medicines. This type of dual status increases the necessity of the distinction between the cosmetic and the medicinal use (99).

Along with safety, botanical standardisation and traceability are also important. Transparency in the supply chain, particularly when dealing with recent regulations like the Corporate Sustainability Due Diligence Directive (CSDDD) in the EU, focuses on ethical sourcing, origin of ingredients and environmental effects of raw materials, which include raw materials used in herbal cosmetic products (100). It implies that manufacturers are required to apply Good Manufacturing Practices (GMP, ISO 22716), assure the identity and properties of herbal extracts, and make claims (including the claim of being an anti-ageing or natural) scientifically supported instead of being marketing-driven. The non-compliance is also increasingly being enforced through post-market surveillance and enhanced enforcement (as is the case with ASEAN countries) (101).

6. CHALLENGES AND FUTURE PROSPECTS

Despite the growing popularity of herbal and green skincare formulations due to their natural origin, therapeutic potential and environmental compatibility, the development of herbal and green skincare formulations continues to face a number of scientific, technical, regulatory and commercial challenges. The variable and complicated character of plant-based raw materials is one of the most crucial restrictions. In contrast to synthetic ingredients, which typically have a fixed chemical structure and predictable activity, herbal extracts are composed of a large number of bioactive compounds that can act individually or synergistically. The levels of these phytoconstituents may differ significantly based on plant species, geographical source, soil quality, climatic factors, harvesting season, cultivation, part of plant used, drying process, storage and extraction process. Consequently, it becomes challenging to ensure consistent quality, safety and efficacy in each batch. Hence, successful development of herbal skincare products depends on botanical authentication, selection and standardisation of extracts, proper selection of raw materials.

The other significant problem is that most natural bioactive compounds are unstable. Phytochemicals like flavonoids, phenolic acids, carotenoids, essential oils, vitamins and terpenoids tend to be sensitive to light, oxygen, heat, pH changes and microbial contamination. These compounds can degrade during processing and storage resulting in loss of biological activity, change of colour, unpleasant odour, phase separation or short shelf life. This has the potential to directly influence consumer acceptance and product performance. In order to address this challenge, appropriate preservatives, antioxidants, protective packaging and innovative formulation strategies are needed. Nevertheless, the preservatives and stabilisers employed should also be safe, biodegradable and also compatible with the idea of green skincare.

Another vital area that needs to be optimised is formulation development. A lot of herbal extracts are not very water soluble, have low skin permeability and low bioavailability. Certain extracts can also cause irritation, staining, strong odour or incompatible with other formulation ingredients. The use of advanced delivery systems like liposomes, phytosomes, nanoemulsions, solid lipid nanoparticles, nanostructured lipid carriers, ethosomes and hydrogels have demonstrated a promising potential in enhancing solubility, stability, penetration and controlled release of herbal actives. Such systems have the ability to prevent degradation of sensitive phytoconstituents and increase their deposition in specific layers of the skin. Nonetheless, their commercial use involves elaborate safety analysis, nanotoxicity analysis, cost-effective manufacturing, scalability and regulatory acceptance. Moreover, these technologies should be developed in such a manner that they do not affect the natural and environmentally friendly image of herbal cosmetics.

The standardisation and quality control are still one of the largest obstacles in the research of herbal cosmetics. Currently, there is no universally recognized technique to extract, phytochemical profile and assess herbal ingredients. Ineffective bioactive characterisation and lack of validated marker compounds can result in unreliable efficacy. Modern analytical techniques such as high-performance liquid chromatography, gas chromatography–mass spectrometry, liquid chromatography–mass spectrometry, Fourier-transform infrared spectroscopy, nuclear magnetic resonance, DNA barcoding and metabolomics can play an important role in authentication, detection of adulteration and quality assurance. Standardised phytochemical libraries, herbal monographs and international quality guidelines would contribute to enhance reproducibility and international acceptance.

Also important are regulatory challenges. In various countries, herbal skincare products can be categorized as cosmetics, cosmeceuticals, traditional medicines or over-the-counter products. This brings confusion in product approval and international marketing. In addition, the terms natural, organic, green, clean beauty, chemical-free and sustainable are frequently used without any clear scientific or legal definitions. These practices can lead to greenwashing and decrease consumer confidence. Thus, there is a need to have transparent labelling, appropriate disclosure of ingredients, safety data, substantiation of claims and compliance with Good Manufacturing Practices. Toxicological tests, dermatological tests, irritation tests, sensitisation tests and clinical tests should be conducted to support safety and efficacy claims.

Ethical and environmental issues are also significant in future development of green skincare. The high demand of herbal ingredients can result in overharvesting, loss and exploitation of natural resources. It is necessary to have sustainable cultivation, fair-trade sourcing, traceability of raw materials and conservation of endangered medicinal plants. Also, it should promote eco-friendly packaging, refillable containers, biodegradable materials and reduced plastic waste. The life-cycle assessment can be used to assess the total environmental impact of a product during the collection of raw materials up to the ultimate disposal of the product.

The future of herbal and green skincare is very promising. Green chemistry can facilitate the application of less toxic solvents, energy-efficient extraction processes and biodegradable excipients. Bioactive compounds can be produced in a controlled and sustainable way with the assistance of biotechnology, plant tissue culture, fermentation and metabolic engineering. Artificial intelligence and machine learning can help predict ingredient compatibility, formulation stability, skin response and personalised skincare solutions. Omics technologies may help to gain more insights into the way herbal actives affect the skin cells, microbiota and molecular pathways.

All in all, the future success of the herbal skincare will be based on combining the traditional knowledge with the modern scientific validation. Close cooperation between researchers, formulation scientists, dermatologists, regulatory agencies, farmers and cosmetic companies will be necessary. Herbal and green skincare formulations can be safer, more efficient, environmentally friendly, and globally acceptable with better standardisation, improved delivery systems, sustainable sourcing and transparent regulation.

7. CONCLUSION

The increasing popularity of herbal cosmetics and green skincare indicates the development of a new trend in the world of safer, sustainable and scientifically proven beauty products. This review outlines the synergy between ancient herbal knowledge and current

formulation science in terms of how bioactive phytonatural constituents (flavonoids, terpenoids and phenolics) can be used in promoting skin health via antioxidant, anti-inflammatory and regenerative activities. Emerging technologies such as nanocarriers, nanoemulsions and hydrogel have played a central role in enhancing the stability, bioavailability and delivery, which involved the targeted delivery of herbal actives, and the use of green solvents and eco-friendly excipients ensures cosmetic innovation is kept up-to-date by giving attention to environmental responsibility. Nevertheless, these problems as variability in phytochemicals, absence of regulatory harmonisation and insufficient toxicological information remain to be obstacles to commercial scale. These challenges are likely to be resolved in the future with the advancement of green chemistry, biotechnology, and AI-directed formulation design, which will allow one to make safe, effective, and eco-conscious skincare products. The introduction of scientific standardization, sustainable sourcing, and clear labelling will become the main factors in enhancing consumer confidence and guaranteeing the sustainability of the herbal cosmetic industry in the long term.

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