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Herbal Remedies for Skin Tanning and Pigmentation: A Review on Natural Ingredients for Melanin Control and Skin Brightening

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ABSTRACT

Skin pigmentation disorders, such as hyperpigmentation and uneven skin tone, are common dermatological conditions that affect both cosmetic appearance and psychological well-being. Conventional synthetic depigmenting agents are effective but often associated with safety concerns including irritation, cytotoxicity, and long-term side effects. In contrast, herbal remedies, rich in bioactive compounds such as polyphenols, flavonoids, vitamins, and carotenoids, offer safer and more sustainable alternatives for pigmentation control and skin brightening. This review summarizes the role of major herbal agents including Aloe vera, Licorice (glabridin, liquiritin), Curcumin, Green Tea polyphenols, Mulberry, Soybean extracts, Vitamin C (ascorbic acid), Niacinamide, and Citrus-derived compounds. These agents act through multiple mechanisms: inhibition of tyrosinase activity, reduction of melanogenesis, scavenging of free radicals, and modulation of inflammatory pathways, thereby promoting skin lightening and even tone. The review further highlights advanced strategies designed to enhance herbal efficacy, including nanoformulations for improved stability and delivery, polyherbal combinations for synergistic action, and personalized phytocosmetic approaches tailored to skin type and microbiome. Limitations such as variability in extract composition, lack of standardized trials, and potential allergenicity are acknowledged. Future directions emphasize the exploration of novel bioactive compounds, advanced delivery systems, and personalized formulations. Overall, herbal remedies represent a promising and safer alternative for pigmentation management, bridging traditional medicine with modern dermatological innovations.

Key Words *Skin Pigmentation Disorders, Hyperpigmentation, Herbal Depigmenting Agents, Tyrosinase Inhibition, Melanogenesis, Phytocosmetics, Nanoformulations*

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INTRODUCTION

The structure of the skin is a complex network that acts as the body's first defense against infections, UV rays, toxins, and mechanical harm. The amount of water discharged into the environment and temperature are also controlled by this organ[1]. Living things include a basic, inexpensive biopolymer called melanin, which is the general word for a class of naturally occurring, dark-colored pigments. Melanin means

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"black," a term borrowed from the Greek word melanos. Melanins are a class of complex pigments. The process known as melanogenesis, which involves the oxidation of the amino acid tyrosine and subsequent polymerization, is how organisms make melanin. The main types of melanin are eumelanin, allomelanin, pheomelanin, and pyomelanin." Because of its functional groups and structural similarities, eumelanin, one of the most prevalent forms of melanin, has some physiochemical characteristics with polydopamine . The visible wavelengths of 400–700 nm and the UV wavelengths of 100–400 nm are both included in the wide absorption spectrum of eumelanin . The most prevalent melanin product is eumelanin, a brown or black pigment that results from the oxidation of the amino acids l-tyrosine and/or l-dihydroxyphenylalanine (l-DOPA). Numerous living things need eumelanin for vital biofunctional purposes. Because it is generated from catechol, allomelanin, a nitrogen-free pigment, is often referred to as catechol-melanin[2]. When a person is ill, their skin colour can change. Sometimes it becomes lighter than usual, which is called hypopigmentation (Figure 1). In other cases, the skin may become darker, known as hyperpigmentation (Figure 2) . The pigment responsible for skin colour is melanin. When the body produces less melanin, the skin appears lighter (hypopigmentation). On the other hand, when melanin production increases, the skin becomes darker (hyperpigmentation) [3].

Figure 1 Hypopigmentation of the skin[4]

Figure 2 Hyperpigmentation of the skin[5]

Tanning means the skin gets darker when we stay in the sun or under UV light for a long time. It protects the skin from sun damage, but too much tanning can harm the skin, cause early aging, and even skin cancer. Knowing why tanning happens helps in making ways to prevent and treat it [6].

Cause of Skin Pigmentation

1. Genetics: Unexpectedly, 125 genes can influence skin tone. The production of melanin, as depicted in, is governed by genes and hormones. A person has control over his or her skin's ability to function and live, as well as how much pheomelanin or eumelanin they produce by, for instance, deciding how much sun exposure they receive or the amount of drugs and

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cosmetics they use. These elements could alter the tone of skin over time. Thus, one of the most frequent reasons for skin color is genetics. Genetics may be able to predict how many melanocytes each individual will have. It is melanocytes, which are skin cells, that make melanin. However, during hyperpigmentation and tanning, melanosomes (the organelles that contain melanin) must be transported and expanded, but during hypopigmentation, melanosomes decreas. Melanin, the pigment that gives skin its color, is more likely to be present in larger concentrations in people with darker skin tones. For example, individuals with darker skin tones frequently have higher melanin levels than those with lighter skin tones[7].

Sun Exposure: It is a common cause of skin pigmentation. The body produces more melanin, in order to defend itself against UV rays.. This may make the skin more pigmented, to shield it from the sun's rays. The following phases make up the pigmentation formation mechanism[8,9]:

1. UV radiation exposure
2. Activation of melanocytes
3. Melanin synthesis (melanogenesis)
4. Melanin transfer to keratinocytes
5. Accumulation of melanin in the epidermis, resulting in visible skin pigmentation

UV radiation produces free radicals. The free radicals and UV light activate biological agents that impact melanocytes, the cells responsible for creating pigment. The enzyme tyrosinase transforms the amino acid tyrosine into melanin pigments, which can be either red or brown in color. Biological substances act to increase the activity of the enzyme Tyrosinase, which generates pigment. Melanin is lost from the skin, as skin cells travel to the surface layers and are shed during the skin's natural exfoliation process. Melanin is delivered as granules from nearby keratinocytes, to give the skin its color.

Medications: Some drugs change skin color. Example: Antibiotics can increase melanin; birth control pills can cause pigmentation [10].

Post-inflammatory hyperpigmentations and hypopigmentations can be treated by regulating local inflammatory factors

In clinical practice, a variety of therapies that affect inflammatory factors can be useful for post-inflammatory hyperpigmentations and hypopigmentations. For instance, chloasma is a postinflammatory hyperpigmented condition that can be brought on by a variety of things, including hormone treatment, cosmetics, pregnancy, UV light, genetics, and phototoxic medications. Common treatments for melasma include tranexamic acid, hydroquinone, and kojic acid. It is commonly recognized that the decolorization process is caused by their inhibition of tyrosine activity or melanocyte-specific cytotoxicity. It has recently been shown that kojic acid also suppresses melanogenesis in melanocytes by encouraging keratinocytes to produce IL-6. It was discovered that resveratrol effectively reduces inflammatory damage in HaCaT cells and reduces inflammation in general, including skin inflammation. Additionally, research has shown that resveratrol

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can cure hyperpigmented disorders by blocking the manufacture of melanin. Because resveratrol controls inflammatory variables, it may potentially have an impact on melanogenesis [11].

Skin Pigmentation and Melanogenesis

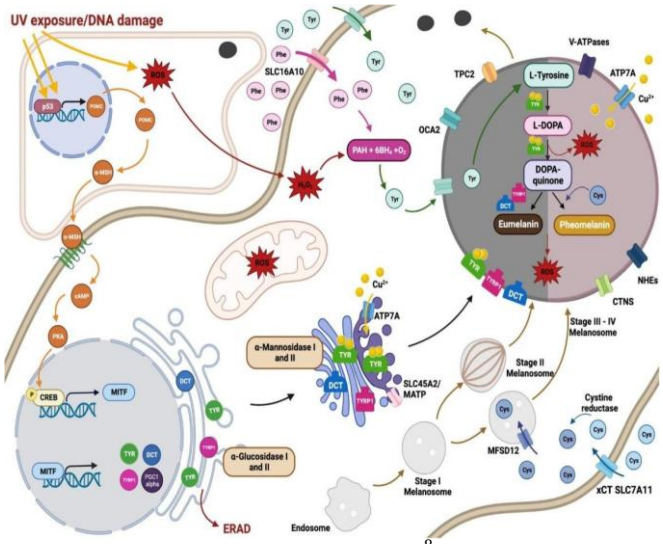

Figure 3Melanin biosynthesis pathway[8]

The Role of tyrosinase in the melanin biosynthesis:

Melanin is the major pigment that gives color to human skin, hair, and eyes, and it is produced in melanocytes through the process of melanogenesis. This pigment plays a protective role by shielding the skin from harmful ultraviolet (UV) radiation and reducing the risk of photo-carcinogenesis. When melanin production is reduced or lost, it leads to depigmentation, which can cause cosmetic as well as dermatological concerns. On the other hand, excess melanin synthesis and accumulation are associated with several disorders such as acanthosis nigricans, cervical poikiloderma, melasma, periorbital hyperpigmentation, lentigines, and even neurological conditions like Parkinson's disease, in addition to increasing the risk of skin cancers.

Melanogenesis is a complex process involving multiple chemical and enzymatic reactions, in which tyrosinase and tyrosinase-related proteins (TYRP1 and TYRP2) play central roles. Tyrosinase, a copper-containing metalloenzyme, acts as the rate-limiting enzyme in melanin biosynthesis. Apart from skin pigmentation, this enzyme is also responsible for the enzymatic browning of fruits and vegetables, as well as hyperpigmentation disorders in humans.

Because of its key role, tyrosinase inhibitors have gained importance for medical and cosmetic applications, particularly in managing pigmentation disorders. They are also widely studied in the food, agriculture, and environmental industries to prevent undesired browning. In medicine, some inhibitors are considered potential anti-melanoma agents, but only a few have been proven both safe and effective for clinical use [9,12].

Regulation Factors of Skin Pigmentation and Melanogenesis:

1. **Promoting (Stimulatory) Factors**

- α-MSH (α-melanocyte stimulating hormone) – via MC1R, cAMP/PKA pathway → ↑ MITF, TYR, TRP-1, TRP-2
- Stem Cell Factor (SCF) – via c-KIT/MAPK pathway → ↑ melanogenesis enzymes
- Interleukin-18 (IL-18) – ↑ tyrosinase activity, ↑ TYRP-1, TYRP-2 via p38/MAPK & PKA pathways
- Interleukin-33 (IL-33) – ↑ MITF, TYR,

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TRP-1, TRP-2 (via MAPK & PKA)

- Granulocyte-Macrophage Colony Stimulating Factor (GM-CSF) – promotes melanocyte proliferation & melanin synthesis
- Prostaglandins (PGE2, PGF2α) – stimulate melanocyte dendrite formation & melanosome transfer via cAMP-dependent pathway
- Keratinocyte-derived paracrine factors – IL-18, IL-33, GM-CSF, PGE2, PGF2 promote melanogenesis
- Fibroblast-derived paracrine factors – IL-33, PGE2, PGF2 promote melanogenesis [10].

2. Inhibitory Factors

- Interleukin-1 (IL-1α, IL-1β) – downregulates MITF via NF-κB/JNK pathways → inhibits melanogenesis
- Interleukin-4 (IL-4) – via JAK2-STAT6 pathway → ↓ MITF, TYRP-1, TYRP-2
- Interleukin-6 (IL-6) – decreases tyrosinase activity
- Interleukin-17 (IL-17) – inhibits melanin formation (via PKA & MAPK pathways, often synergistic with TNF)
- Tumor Necrosis Factor (TNF-α) – inhibits melanogenesis via PKA & MAPK pathways (synergistic with IL-17)
- Interferon-γ (IFN-γ) – blocks melanosome maturation, ↑ STAT1 phosphorylation, induces melanocyte apoptosis[10].

Clinical studies on topical agents for hyperpigmentation

1. Hydroquinone:

In a double-blind, randomized, prospective study conducted on 30 melasma patients with skin types III–V, treatment with 4% topical hydroquinone showed significant improvement in hyperpigmentation in 76.9% of patients compared to placebo; however, adverse effects such as itching and skin eruptions were reported in nearly 25% of the cases, indicating both efficacy and tolerability concerns.

Arbutin:

In a paired comparison, vehicle-controlled, double-blind study involving 50 Caucasian and dark-skinned patients with solar lentigines, treatment with 3% arbutin was found effective in reducing pigmentation in lighter-skinned individuals; however, it failed to demonstrate a significant therapeutic response in patients with darker skin types, highlighting variability in efficacy across different skin tones.

2. Tretinoin:

A randomized, double-blind, vehicle-controlled trial on 40 Caucasian patients reported that 0.1% tretinoin was more beneficial in reducing photoaging-related hyperpigmentation, especially in darker skin types, when compared to vehicle. However, some patients experienced side effects such as retinoid dermatitis [11].

3. Azelaic Acid:

In a randomized, double-blind study involving 155 patients of Indo-Malay and Hispanic origin, treatment with 20% azelaic acid cream showed better improvement in hyperpigmentation compared to 2% hydroquinone cream, indicating

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its higher therapeutic potential in these skin types[12].

4. Niacinamide:

A split-face, double-blind, paired design study in 18 Japanese women with different types of brown pigmentation showed a marked reduction in facial hyperpigmented spots when compared with vehicle[13].

5. Fluocinolone acetonide:

In a long-term, multicenter, open-label study lasting 12 months and involving

228 patients with facial melasma, the triple combination of fluocinolone acetonide (0.01%), hydroquinone (4%), and tretinoin (0.05%) led to complete or near-complete clearance of melasma in over 90% of cases, with no major safety concerns reported[14].

Herbal Remedies for Tanning and Pigmentation

Skin tanning and pigmentation are mainly caused by UV exposure, melanocyte overactivity, hormonal changes, or post-inflammatory reactions. While chemical agents like hydroquinone can lighten skin, they often cause irritation or long-term side effects, leading consumers to prefer gentler herbal alternatives.

Natural ingredients such as Liquorice, Turmeric, Aloe vera, Green Tea, and Papaya offer antioxidant, anti-inflammatory, and melanin-regulating benefits, making them effective for managing tanning and pigmentation in a safer way.

Market data also supports this trend. The global herbal beauty products market size is calculated at USD 97.28 billion in 2025 and is predicted to increase from USD 101.95 billion in 2026 to approximately USD 158.12 billion by 2035, growing at a CAGR of 4.98% from 2026 to 2035.. The Asia-Pacific region is leading this growth due to strong traditional use of herbal remedies and rising demand for chemical-free cosmetics [15].

Herbal Remedies for Skin Brightening

Natural extract

Over many years of clinical practice, researchers have gained extensive knowledge about using natural medicinal extracts to treat pigmentation. Most natural whitening ingredients are obtained through extraction using various solvents. They mainly work by inhibiting tyrosinase activity to reduce melanin production or by acting as antioxidants to prevent skin pigmentation caused by oxidative stress. These extracts usually contain multiple active compounds working together rather than a single ingredient, and their pharmacological mechanisms are still not fully understood, requiring further research using advanced molecular techniques.

Many natural products have been developed or have potential for development. Components like coumaric acid, cinnamic acid, ferulic acid, and coumarin, which belong to phenylpropanoids, show strong inhibition of human tyrosinase. Anthraquinone compounds, such as Aloe-emodin and Rhodopsin, can inhibit tyrosinase in mushrooms, mice, and humans. Polysaccharides from sources like Ganoderma lucidum, Bletilla striata, and Poria have antioxidant properties. At

the cellular level, these polysaccharides act by scavenging free radicals, enhancing antioxidant enzyme activity, reducing lipid metabolites, protecting cell organelles, and modulating signaling pathways to prevent cell death.

Flavonoids, including flavonols, isoflavones, flavan-3-ols, flavanones, and chalcones, exhibit multiple mechanisms of action. They act as antioxidants, inhibit tyrosinase, and can absorb ultraviolet light. Polyphenols such as curcumin, rosmarinic acid, and tea polyphenols provide antioxidant and anti-aging benefits by scavenging harmful radicals, boosting the body's superoxide dismutase (SOD) activity, and improving peroxidase function [1,5].

Aloe vera

Aloe vera is well known for its skin-brightening properties, largely due to its high content of flavonoids. Aloesin acts as a natural inhibitor of tyrosinase, the key enzyme responsible for melanin production, thereby reducing pigmentation. Studies have shown that Aloe vera gel can effectively lighten skin by suppressing melanin formation, particularly in the epidermis and mucilage, while the pulp shows minimal activity. Its antioxidant properties further contribute to preventing oxidative damage, making Aloe vera a promising ingredient in whitening skincare products.In addition to brightening, Aloe vera provides natural sun protection. It can reduce UV-induced skin damage, inflammation, and pigmentation by inhibiting tyrosinase activity and suppressing inflammatory factors. Active compounds like aloin protect against both UVA and UVB radiation, while formulations such as gels, emulsions, or nanoparticles enhance its photoprotective effects. Aloe vera not only minimizes skin pigmentation but also supports immune function in the skin, making it a safe and effective natural option for protecting and brightening the skin [16].

Niacinamide (Vitamin B3)

- Niacinamide is a bioactive form of niacin found in yeast and certain vegetables.
- Acts as a safe and effective agent to reduce hyperpigmentation.
- Mechanism: Inhibits melanosome transfer from melanocytes to keratinocytes, thereby decreasing skin darkening.

Curcumin

- Curcumin and its derivatives reduce melanin synthesis through two main mechanisms: directly inhibiting tyrosinase and modulating MITF-mediated gene expression. In α-MSH-stimulated cells, curcumin lowers melanogenic gene activity, decreasing melanin production by up to 60%. Optimized derivatives, such as CMC2.24, show even stronger inhibition without cytotoxicity. Curcumin's effects are also redox-sensitive, suppressing melanogenesis under normal conditions but exhibiting variable effects under oxidative stress.
- By competitively binding to tyrosinase and disrupting the MITF-TYR/TRP transcriptional axis, curcumin effectively controls melanin overproduction. Future studies focusing on

improving its bioavailability through nanoformulations and validating its in vivo dose-response will further establish its potential as a natural agent against hyperpigmentation and photoaging [17].

Licorice

- Glycyrrhiza glabra (licorice) offers multiple skin benefits due to its antioxidant, anti-inflammatory, and UV-protective properties. Its flavonoids, including glabridin, glabrene, isoliquiritigenin, licochalcone A, and liquiritin, exhibit depigmenting effects by inhibiting tyrosinase, the key enzyme in melanin production. This activity helps prevent hyperpigmentation disorders such as melasma, age spots, and UV-induced pigmentation. Licorice extracts also

scavenge free radicals and protect skin cells from oxidative stress, although isolated glycyrrhizin shows limited antioxidant activity.

- Topical application of compounds like glabridin and 18β-glycyrrhetinic acid can reduce melanogenesis, protect DNA from UVB-induced damage, and mitigate skin inflammation. Additionally, licorice extracts have been used safely in formulations for atopic dermatitis and even promote hair growth, making it a versatile ingredient in both cosmetic and therapeutic skincare products [18].

Tea

- Tea is one of the most widely consumed beverages, rich in polyphenols, particularly catechins such as epigallocatechin (EGC), epicatechin (EC), epigallocatechin gallate (EGCG), and epicatechin gallate (ECG), with EGCG being the most abundant. Green tea is steamed or pan-fried to preserve these compounds, white tea is made from young buds shielded from sunlight, and black tea undergoes fermentation, forming complex polyphenols like thearubigins and theaflavins.

- Many tea polyphenols act as tyrosinase inhibitors because their structures resemble tyrosine, allowing them to reduce melanin formation. Additionally, their strong antioxidant properties help scavenge free radicals, chelate metal ions, and prevent oxidative stress, making tea polyphenols effective agents for skin brightening and protection against photoaging [19].

Vitamin C (Ascorbic Acid)

- A well-known natural antioxidant widely used in cosmetic formulations.
- Prevents hyperpigmentation by regulating UV-induced signaling pathways.
- Functions as a non-toxic skin lightening agent and protects against oxidative stress.

Lemon

- Rich in antioxidants, particularly ascorbic acid and hesperidin.
- Hesperidin neutralizes free radicals and supports melanin inhibition.
- Mechanism: Suppresses melanin biosynthesis, leading to lighter skin tone.

Mulberry

- Traditionally used across Asia for its multiple health benefits: antioxidant,

immunomodulatory, anticancer, and neuroprotective effects.

- Contributes to skin lightening by inhibiting melanogenesis.

Soybean

- Contains bioactive compounds that improve skin appearance and dermatological outcomes.
- Serine protease inhibitors in soybean extract reduce melanosome transfer by suppressing PAR-2 expression, helping to prevent pigmentation[20].

Evaluation Methods

Currently, there is no single standard to measure how well whitening or spot-lightening products work. In clinical studies, researchers usually look at changes in skin pigmentation before and after treatment. However, these observations can be subjective, which makes it hard to judge effectiveness accurately.

To study how treatments reduce pigmentation, scientists use both in vitro (lab-based) and in vivo (live animal) models. In vitro studies often test how substances like tyrosinase inhibitors or antioxidants reduce melanin. More advanced lab studies use cultured cells such as melanocytes, fibroblasts, and keratinocytes to see how treatments affect melanin production and transfer at the cellular level.

For in vivo research, animal models like zebrafish embryos, transgenic mice with human-like skin, and guinea pigs with melasma are commonly used. While many natural compounds show promising results in lab studies, only a few have been tested successfully in clinical trials.Because of this, there is a strong need to discover new agents to treat pigmentation disorders and to develop safer, more reliable ways to evaluate these products. Improving these methods is crucial for the future development and testing of whitening and spot-removing treatments [21].

Herbal nanotechnology

Combining nanotechnology with herbal extracts has shown great promise in improving the effectiveness of plant-based medicines. These tiny delivery systems—like liposomes, nanoparticles, and liquid crystals—help the active ingredients absorb better, work longer, and reduce side effects. They also allow lower doses, improve stability, and protect sensitive compounds from heat and light.

Nanotechnology doesn't just improve how active ingredients work; it also makes it possible to include compounds that were previously hard to use in formulations. This helps target specific organs or tissues, improving how the medicine acts in the body.

For example, adding green tea and ginseng extracts to lipid-based systems has been shown to boost absorption. Liposomes with plant extracts helped active compounds cross viral barriers, improving their antiviral effects. Nanoparticles made from holy basil extract showed stronger antibacterial action than regular extracts. Other innovations include natural transfersomes for treating skin infections and scars, gels for anti-

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aging, and microemulsions from plant oils that protect the skin against UV rays[22].

Lin and colleagues studied liposomes containing camptothecin that were designed to target melanoma cells by attaching α-melanocyte-stimulating hormone (α-MSH). These special liposomes allowed for controlled release of camptothecin and showed much higher uptake by melanoma cells compared to non-targeted liposomes or free drug. Fluorescent microscopy revealed that the α-MSH liposomes were mostly absorbed into the cytoplasm, helping the drug reach its target more effectively. This targeted delivery improved camptothecin's ability to fight melanoma[23].

An alcohol-based extract of Curcuma longa was prepared in different vesicle types—ethosomes, liposomes, and transferosomes. The most effective cream was the one containing Curcuma longa transferosomes loaded with curcumin, followed by ethosomal, liposomal, and plain extract creams. When applied, these formulations helped the skin recover better from UV damage, with the transferosomal cream showing the best results[24].

Table 1 Traditional treatment Vs Nanotechnology based treatment[25,26]

Parameters	Traditional Treatment	Nanotechnology-Based Treatment
Drug Delivery	Conventional formulations deliver drugs systemically with limited targeting.	Uses nanoscale particles, nanofibers, and nanodevices for targeted delivery directly to specific cells, improving therapeutic outcomes.
Bioavailability	Often has lower bioavailability due to poor absorption and degradation.	Provides enhanced bioavailability, leading to improved absorption and effectiveness.
Onset of Action	Generally slower onset of therapeutic effect.	Faster onset of action due to efficient cellular uptake and controlled release.
Dose Consistency	Drug absorption may vary among individuals and can be influenced by food intake.	Offers more consistent dosing with reduced variability and improved pharmacokinetic profiles.
Target Specificity	Limited ability to selectively target affected tissues, which may affect healthy cells.	Enables precise targeting of diseased cells while minimizing damage to normal tissues.[25]
Cosmeceutical Applications	Conventional herbal formulations are used for skin care but may have limited penetration and efficacy.	Nano cosmeceuticals enhance skin penetration and are widely used for wrinkles, acne, photoaging, and hyperpigmentation.
Herbal Bioactive Delivery	Herbal compounds often show poor stability and limited skin penetration.	Improves the stability, penetration, and controlled release of phyto compounds such as vegetable oils and curcumin.
Skin Benefits	Provides antioxidant and anti-inflammatory effects but with comparatively lower efficiency.	Enhances antioxidant activity, reduces oxidative stress, prevents premature aging, and improves overall skin health.
Examples	Conventional herbal creams, lotions, and plant extract formulations.	Nano-enabled products such as Skin Caviar Ampoules, Hydra Zen Cream, and Revitalift, containing nanosized phyto compounds.
Overall Advantage	Effective but limited by poor targeting, lower efficacy, and reduced bioavailability.	Offers improved efficacy, targeted drug delivery, enhanced stability, better skin penetration, and multifunctional therapeutic benefits.

Polyherbal combination

Polyherbal formulations are commonly preferred in both traditional and modern skin care because a combination of herbs usually shows better activity than a single plant extract. This synergistic approach helps to enhance skin benefits while lowering the chances of side effects. In hyperpigmentation and tanning, such

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formulations work through multiple pathways including tyrosinase inhibition, antioxidant defense, melanin regulation, and skin repair [27]. For instance, blends of Aloe vera, Licorice, and turmeric show good antioxidant and anti-tyrosinase properties that help in reducing dark spots. Similarly, sandalwood, saffron, and manjistha are widely used in Ayurveda for complexion improvement and sun-tan reduction [28]. Modern formulations often include combinations like green tea, mulberry, and arbutin, which provide skin brightening effects, while neem, tulsi, and amla contribute anti-inflammatory and detoxifying actions [29]. Recent clinical and experimental studies also suggest that polyherbal creams, gels, and even oral formulations demonstrate stronger skin-lightening and antioxidant effects compared to single-herb preparations, making them a promising and safe strategyto manage pigmentation and achieve an even skin tone [30].

Comparative Analysis

Herbal agents for pigmentation, such as arbutin, licorice, and curcumin, act mainly by inhibiting tyrosinase, reducing oxidative stress, and soothing inflammation [31]. They are safe, eco-friendly, and suitable for long-term use, though results are slower and depend on extraction quality [32]. In contrast, synthetic agents like hydroquinone, tretinoin, and corticosteroids show faster and stronger effects by directly inhibiting melanin synthesis or promoting cell turnover [33]. However, their use is often limited by side effects, including irritation, rebound pigmentation, and long-term safety concerns. Thus, herbal remedies are better for mild to moderate pigmentation, while synthetic agents are preferred in severe cases under medical supervision [34].

Advantages of Herbal

1. **Safety:** Herbal remedies for tanning and pigmentation are generally considered safe for long-term use because they are plant-based and associated with fewer side effects than synthetic depigmenting agents. Mild irritation or allergic reactions may occur in sensitive individuals, but serious adverse effects are uncommon when products are properly formulated and of good quality. Quality control is essential, as contaminated or adulterated herbal products may pose safety risks [33,34].

2. **Efficacy:** Herbal agents typically produce gradual and moderate improvements, with visible results developing over several weeks. Bioactive compounds such as **arbutin, kojic acid, and liquorice** inhibit tyrosinase activity, reduce melanin synthesis, and provide antioxidant protection [31].They are most effective for mild to moderate hyperpigmentation and are commonly used alongside sunscreen to maintain treatment outcomes. Severe pigmentation disorders may require stronger medical therapies [35].

3. Cost: Herbal products are generally affordable, widely available, and suitable for long-term use. Basic plant extracts are relatively inexpensive, whereas standardized extracts and branded phytocosmetic formulations may be more costly [32]. Overall, herbal remedies are

considered cost-effective compared with prolonged synthetic treatments or clinical procedures, while also offering greater sustainability.

Limitations of Herbal Remedies

1. **Limited Clinical Evidence** – Most studies are in vitro or short-term, with very few large, long-duration clinical trials in humans.
2. **Variability in Potency** – The strength of herbal extracts changes due to differences in plant source, growing conditions, harvesting, and extraction techniques.
3. **Stability Issues** – Many herbal compounds (e.g., polyphenols, kojic acid) are unstable and degrade when exposed to light, air, or heat, reducing effectiveness.
4. **Safety Concerns** – Long-term safety data are lacking. Some "herbal" creams are adulterated with steroids or hydroquinone, which can cause harmful effects.
5. **Regulatory Problems** – Weak regulations in many regions result in poor labeling and unsupported claims about efficacy .
6. **Slow Onset of Action** – Results from herbal treatments are usually visible only after weeks or months, which may reduce patient compliance .
7. **Uncertain Cost–Benefit** – Although many products are affordable, advanced or branded herbal formulations are often costly without strong evidence of better efficacy [36,37].

Future Prospects of Herbal Remedies for Skin Pigmentation and Tanning

1. Nanoformulations for Enhanced Delivery

Herbal active compounds like curcumin, glabridin, arbutin, and kojic acid often face challenges such as low stability and poor skin penetration. Nano-based delivery systems (liposomes, solid lipid nanoparticles, nanostructured lipid carriers, and nanoemulsions) can enhance chemical stability, improve epidermal penetration, and provide controlled release, resulting in better efficacy and reduced irritation. This approach allows lower doses and safer topical application [38].

Bioprospecting and Personalized Phytocosmetics

Discovery of new plant-derived tyrosinase inhibitors and antioxidant combinations, guided by high-throughput screening and metabolomics, offers a path to more effective pigmentation control. Combining multiple herbal compounds (e.g., arbutin with polyphenols) can produce synergistic depigmenting effects. Personalized formulations, considering skin type and microbiome, may further improve outcomes and reduce side effects [39].

CONCLUSION

Herbal remedies for skin pigmentation and tanning present a safe and effective alternative to synthetic agents due to their diverse mechanisms, including tyrosinase inhibition, antioxidant activity, and regulation of melanogenesis. Compounds like glabridin, curcumin, arbutin, and polyphenols show notable depigmenting potential, while advancements in nanotechnology, polyherbal formulations, and

personalized approaches further enhance their efficacy and delivery. However, challenges such as extract standardization, formulation consistency, and limited clinical validation remain significant barriers. Future research should focus on novel bioactive discovery, improved delivery systems, and personalized phytocosmetics to ensure reliable therapeutic outcomes. By combining traditional knowledge with modern scientific advances, herbal remedies can be established as sustainable and holistic strategies for safe and effective management of pigmentation disorders.

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