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Review Article

Therapeutic and Dermatological Potential of *Ganoderma lucidum* (Reishi/Lingzhi) in Cosmeceutical Formulations: A Comprehensive Review

Pankaj Sharma*

Department of Pharmaceutics, Government College of Pharmacy, Rohru, Shimla, Himachal Pradesh, INDIA.

ABSTRACT

Ganoderma lucidum (Reishi) is a widely utilized medicinal mushroom in Asia, recognized for its hepatoprotective, antioxidant, immunomodulatory, and anticancer properties. The present review aims to systematically evaluate its cosmeceutical potential by examining bioactive composition, mechanistic dermatological effects, formulation strategies, and translational challenges. A comprehensive analysis of published *in vitro, in vivo*, and emerging clinical evidence was conducted, focusing on phytochemical constituents and advanced delivery approaches relevant to dermal applications. Key bioactive compounds including triterpenoids, polysaccharides, phenolics, sterols, peptides, and UV-enhanced Vitamin D_2 demonstrate significant antioxidant, anti-inflammatory, anti-melanogenic, and skin-regenerative activities. Triterpenes and phenolics contribute to oxidative stress reduction and pigmentation control, supporting anti-aging and melanin disorder management. Polysaccharides enhance skin hydration, barrier integrity, and wound healing, while Vitamin D_2 promotes photoprotection and epidermal renewal. Recent advances in green extraction technologies and nanocarrier-based delivery systems (e.g., lipid nanoparticles and nanoformulations) have improved bioactive stability, dermal penetration, and controlled release, thereby strengthening formulation performance. Despite promising preclinical evidence, limitations persist, including insufficient large-scale clinical validation, variability in phytochemical standardization, and regulatory constraints affecting commercialization. Addressing these gaps through harmonized quality control, robust clinical trials, and optimized delivery systems is essential for global acceptance. Overall, *G. lucidum* emerges as a scientifically grounded and sustainable candidate for next-generation cosmeceutical development, aligning with increasing consumer demand for safe, effective, and environmentally responsible dermocosmetic innovations.

Keywords: Anti-aging, Anti-inflammatory, Antioxidant, *Ganoderma lucidum*, Skin whitening, Wound healing.

Correspondence:
Dr. Pankaj Sharma
Assistant Professor (Pharmacy),
Department of Pharmaceutics,
Government College of Pharmacy, Rohru,
Shimla-171207, Himachal Pradesh, INDIA.
Email: pankajsharmadrugs@gmail.com
ORCID: 0000-0001-7640-5766

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INTRODUCTION

The cosmeceuticals industry represents a dynamic convergence of cosmetics and pharmaceuticals, integrating bioactive compounds with demonstrated pharmacological activity to enhance both skin health and aesthetic outcomes (Gao *et al*., 2003). Unlike conventional cosmetics that primarily address superficial appearance, cosmeceuticals provide therapeutic benefits supported by mechanistic evidence. Increasing consumer demand for safe, effective, and sustainably sourced ingredients has accelerated the exploration of natural bioactives, particularly fungi, plant extracts, and marine-derived compounds recognized for their antioxidant, anti-inflammatory, antimicrobial, and photoprotective properties (Wasser 2002; Lin 2005). These biological activities are essential for mitigating oxidative stress, preventing premature skin aging, preserving dermal extracellular matrix integrity, and promoting tissue repair. Among medicinal fungi, *Ganoderma lucidum* holds particular significance. Traditionally revered in Traditional Chinese Medicine (TCM) as a symbol of longevity and vitality, it has gained substantial global scientific attention for its dermatological potential (Boh *et al*., 2007). Its diverse secondary metabolites- including triterpenoids, polysaccharides, phenolic acids, and steroids exhibit immunomodulatory, antioxidant, anti-inflammatory, and skin-regenerative activities, providing a strong mechanistic rationale for its incorporation into cosmeceutical formulations (Bishop *et al*., 2015). Despite increasing commercialization of mushroom-based skincare products, systematic scientific evaluation of *G. lucidum* in cosmeceuticals remains limited. Therefore, this review critically examines its phytochemical

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composition, biological activities, and dermal mechanisms relevant to skin health. Furthermore, it discusses formulation strategies, current industrial applications, and challenges related to standardization, stability, and regulatory compliance, thereby positioning *G. lucidum* as a promising and scientifically substantiated cosmeceutical ingredient.

Overview of *G. lucidum*

G. lucidum is a *Basidiomycota* mushroom (order Polyporales, family Ganodermataceae) that grows on decaying hardwoods such as oak and maple. It is identified by its hard, woody texture and kidney-shaped, reddish-brown varnished cap. Considered a benchmark species within its genus, it contains diverse secondary metabolites including triterpenoids, polysaccharides, sterols, and peptides responsible for its therapeutic and cosmeceutical relevance (Xu *et al*., 2019). Revered for over 4,000 years in Eastern medicine as the "mushroom of immortality," its classification follows the standard taxonomic hierarchy from kingdom to species (Figure 1).

Morphological Characters of *G. lucidum*

G. lucidum is a member of the fungus family Ganodermataceae. In addition to its therapeutic purpose, its morphology is described by particular traits and developmental stages that define its life cycle.

Phase One

Mycelium - When *G. lucidum* produces a white mycelial network made up of tiny, anastomosable branches known as hyphae, vegetative activity begins. As they spread across the woody substrate (logs, stumps, or sawdust), these filamentous threads take up nutrients and lay the groundwork for the growth of fruiting bodies. In *G. lucidum*, mycelium plays a crucial role in the formation of polysaccharides and triterpenoids through submerged or solid-state fermentation (Thakur *et al*., 2015).

Second Phase

Primordia (Fruiting Initiation) - Primordia are tiny nodular outgrowths that appear on the substrate when nutrients are properly assimilated. These indicate the start of the fruiting body. Primordia elongate and differentiate into fruiting bodies when the humidity, temperature, and aeration are all conducive (Sudheer and Gangaprasad, 2017).

Phase Three

Basidiocarp (Fruiting Body/Equivalent to Stroma) - The kidney-shaped to semicircular basidiocarp with a reddish-brown varnished and glossy covering is the most noticeable and culturally acceptable type. It has a rough feel, similar to wood, and can reach a diameter of several centimeters. It is commonly collected for medicinal purposes in extracts, decoctions, and contemporary cosmeceutical formulations (Yue *et al*., 2008).

Fourth Phase

Basidiospores - Instead of gills, its underside is composed of tiny pores where basidia grow and create basidiospores. The sexual reproductive units of *G. lucidum* are called basidiospores. After being released into the environment, they germinate under the right conditions, develop into new hyphae, and initiate a new stage of the fungus' life cycle (Akihisa *et al*., 2007).

Additional Feature

Lucidum Varnished Surface - The formation of pigment and secondary metabolites, especially triterpenoids, gives *G. lucidum* its glossy, lacquered appearance, which is another characteristic that sets it apart. It contributes to its medicinal character and distinguishes it morphologically from some other Ganoderma species.

Therefore, *G. lucidum* morphological stages such as mycelial colonization that results in a traditional varnished woody fruiting body with an abundance of bioactive compounds, *G. lucidum* has cosmeceutical value.

Profile of phytochemicals

The main source of *G. lucidum's* bioactivity is its wide range of secondary metabolites, some of which have been thoroughly studied and linked to both pharmacological and cosmetic effects.

Major classes of compounds

Polysaccharides

The majority of polysaccharides are β-glucans, which have immunomodulatory, moisturizing, and wound-healing properties. For an anti-aging impact, these high molecular weight compounds increase collagen synthesis and improve the skin's barrier function (Shiao, 2003).

Triterpenoids

A broad class of compounds with anti-inflammatory, anti-allergic, antioxidant, and anti-proliferative properties that includes lucidenic and ganoderic acids. These chemicals are crucial for protecting the dermis from external assaults and early aging because of their capacity to modulate oxidative stress pathways (Baby and Johnson, 2017).

Sterols

Its primary sterol, ergosterol, possesses special cosmeceutical interest since it can photoconvert into vitamin D_2 upon exposure to light, besides providing photoprotection (Zhang *et al*., 2019).

Phenolic compounds

G. lucidum is rich in a multitude of phenolic acids with strong antioxidant and protective activities. Protocatechuic acid, p-hydroxybenzoic acid, and caffeic acid are illustrative examples. Such phenolic compounds impart *G. lucidum* cosmeceutical value as it can preserve dermal health, enhance medicinal potential, and avoid oxidative stress.

These molecules collectively provide antioxidant, anti-inflammatory, whitening, barrier-repair, and environmental protective effects, supporting their incorporation into innovative cosmeceutical formulations.

Characterization of *G. lucidum*

Phytochemical profiling of *G. lucidum* employs advanced analytical techniques for precise bioactive characterization. High-Performance Liquid Chromatography (HPLC) quantifies triterpenoids and phenolics, while LC-MS/MS enables sensitive detection and structural elucidation of primary and secondary metabolites at trace levels. Nuclear Magnetic Resonance (NMR) spectroscopy further supports comprehensive structural analysis of complex triterpenoids, sterols, and polysaccharides.

Mechanisms of Action in Skin Health

G. lucidum exhibits multilayered dermo modulatory effects via polysaccharides, triterpenoids, phenolic acids, and ergosterol derivatives. These bioactives regulate oxidative stress, inflammation, barrier integrity, pigmentation, and skin regeneration, supporting its strong potential in cosmeceutical and dermatotherapeutic formulations (Hsu *et al*., 2020).

Antioxidant Activity

Reactive Oxygen Species (ROS), which are produced in reaction to UV irradiation and environmental contaminants, cause accelerated oxidative stress that significantly accelerates skin aging. Triterpenoids and phenolic chemicals found in *G. lucidum* are strong radical scavengers that reduce lipid peroxidation and stop DNA fragmentation in fibroblasts and keratinocytes. Photoaging and wrinkle development are postponed by this antioxidant defense (Yuen and Gohel, 2005).

Anti-inflammatory Activity

Prolonged inflammation leads to extrinsic aging, dermatitis, and acne. *G. lucidum* inhibits Nuclear Factor-Kappa B (NF-κB) signaling, which lowers the expression of inflammatory enzymes like COX-2 and iNOS as well as pro-inflammatory cytokines like TNF-α and IL-6. As a result, cutaneous inflammatory tissues experience reduced erythema, inflammation, and edema (Joseph *et al*., 2011).

Moisturization and Barrier Restoration

Polysaccharides increase skin moisture and chelate hydrated molecules to exhibit their hygroscopic activity. Additionally, polysaccharides promote the production of ceramides, which restores the function of the stratum corneum barrier. This makes *G. lucidum* a potential cause of atopic disorders and xerosis (Kim *et al*., 2012).

Wound Healing and Regeneration

Polysaccharides and triterpenoids promote collagen deposition, increase fibroblast proliferation, and upregulate Transforming Growth Factor-beta (TGF-β), all of which lead to improved tissue regeneration and increased wound contraction. Anti-aging and post-acne scar treatment benefit from this regenerative action (Xu *et al*., 2010).

Whitening and Anti-Pigmentation

Triterpenoids and phenolic acids, which are tyrosinase inhibitors, work on the primary melanogenesis enzyme to reduce melanin manufacture and suppress hyperpigmentation. This results in whitening and anti-pigmentation. These work effectively for skin

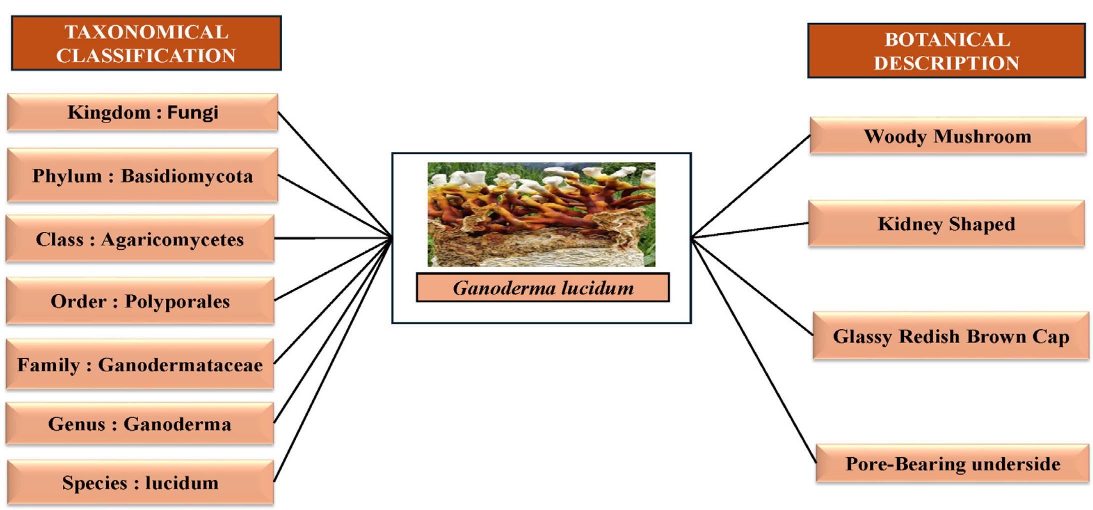

Figure 1: Shows the taxonomical and botanical description of *G. lucidum*.

whitening procedures, cosmetic whitening products, and evening out the complexion (Wasser 2014).

UV Protection and Vitamin D_2 Modulation

When *G. lucidum* is exposed to UV-B light, its ergosterol is photoconverted to Vitamin D_2. Vitamin D_2 improves cutaneous immunity, reduces photodamage, and encourages keratinocyte differentiation when applied topically. Both protection and nutritional support for the skin are provided by this dual action (Table 1).

Pharmaceutical and Cosmetic Applications

G. lucidum bioactives are increasingly incorporated into pharmaceutical and cosmetic formulations for immunomodulatory, moisturizing, whitening, anti-inflammatory, antioxidant, and UV-protective effects, highlighting its broad dermocosmetic potential (Figure 1).

To further highlight their composition and functional role, various dosage forms have been systematically summarized in Table 2.

G. lucidum modulates melanogenesis, inflammation, oxidative stress, and hydration, bridging therapeutic and cosmetic skincare applications.

Scientific Evidence Supporting Cosmetic Use

A growing body of *in vitro, ex vivo*, and *in vivo* research supports *G. lucidum* for cosmetic use, demonstrating anti-aging, anti-inflammatory, and antioxidant mechanisms, with clinical and consumer studies confirming its safety and dermatological efficacy (Figure 2).

In vitro/Ex vivo Evidence

G. lucidum demonstrates strong antioxidant, anti-inflammatory, and collagen-protective effects in *in vitro* and *ex vivo* studies, supporting its potential for skin rejuvenation and regeneration. However, further clinical validation is required for confirmed cosmetic applications (Table 3).

In vivo/Clinical and Consumer-Use Evidence

There is little clinical data on *G. lucidum's* topical use; consumer research and small-scale trials have indicated good tolerance and some skin benefits, but thorough randomized controlled trials are still required to verify safety and efficacy summarized in Table 4.

Patents

Recent filings and grants of new patents in *G. lucidum* research demonstrate the plant's many uses. According to Table 4, the authorities have also granted other patents, which are anticipated to increase demand for *G. lucidum* as a promising natural cosmeceutical agent with extensive potential in the pharmaceutical, medical, and personal care sectors summarized in Table 5.

Comparative Value with Other Medicinal Mushroom

The bioactive compounds found in medicinal mushrooms are abundant and have important cosmeceutical applications. Each of these compounds has its own mechanisms that support skin health and anti-aging benefits (Figure 3). Most notably, *Cordyceps sinensis* is known for its anti-aging peptides, which support cellular viability, skin regeneration, and the prevention of dermal senescence. β-glucans, which are plentiful in *Trametes versicolor*, have immune-modulatory actions and protect the integrity of the epidermal barrier. *Pleurotus species* are characterized by the presence of antioxidant chemicals that reduce oxidative stress

Table 1: Phytochemical of *G. lucidum* and Their Reported Skin-Related Bioactivities.

Phytochemical group	Representative compounds	Skin-related bioactivities	Analytical methods	References
Triterpenoids	Ganoderic acids, Lucidenic acids	Anti-inflammatory, anti-aging, antioxidant, skin brightening	HPLC, LC-MS, NMR	(Wasser, 2010)
Polysaccharides	β-glucans, heteropolysaccharides	Moisturizing, barrier repair, wound healing, collagen promotion	GC-MS, HPSEC, NMR	(Baby *et al*., 2019)
Sterols	Ergosterol	Photoprotective (Vitamin D_2 precursor), skin health	HPLC, UV spectrophotometry, NMR	(Zhang *et al*., 2019; Chen *et al*., 2012)
Peptides and proteins	Fungal Immunomodulatory Proteins (FIPs), antioxidant peptides	Antioxidant, moisturizing, protective	LC-MS, SDS-PAGE, NMR	(Paterson and Lima, 2014)
Phenolics	Caffeic acid, p-hydroxybenzoic acid, Protocatechuic acid	Antioxidant, anti-inflammatory, photoprotection	HPLC, LC-MS/MS	(Chan *et al*., 2007)

Table 2: Representative pharmaceutical and cosmetic formulations of *G. lucidum* and their associated benefits.

Formulation Type	Benefit	Active Ingredient(s)	References
Pharmaceuticals			
Supplements (Syrup)	Support immune system function	Polysaccharides, triterpenoids	(Sanodiya *et al.*, 2009)
Capsules	General health promotion, antioxidant	Standardized extracts	(Lin *et al.*, 2003)
Spore powder	Enhance vitality, immune regulation	Spore-derived bioactive fractions	(Guo *et al.*, 2019)
Cosmetic Formulations			
Cream/Lotion	Moisturizing, soothing	Triterpenoid-rich fractions	(Yue *et al.*, 2013)
Liquid Cleanser	Deep cleansing, detoxifying	Polysaccharide-enriched extracts	(Yue *et al.*, 2013)
Face Mask	Brightening, hydration	Ganoderma polysaccharide gel	(Yue *et al.*, 2013)
Moisturizing Cream	Long-lasting hydration, barrier repair	Polysaccharide-peptide complexes	(Yue *et al.*, 2013)
Toner	Pore tightening, anti-acne	Alcoholic extract enriched with anti-inflammatory agents	(Yue *et al.*, 2013)
Sunscreen Additive	UV protection, Vitamin D enhancement	Ergosterol-enriched fractions	(Yue *et al.*, 2013)
Serum	Anti-aging, antioxidant	UV-treated Ganoderma extract (Vitamin D_2 enriched)	(Yue *et al.*, 2013)

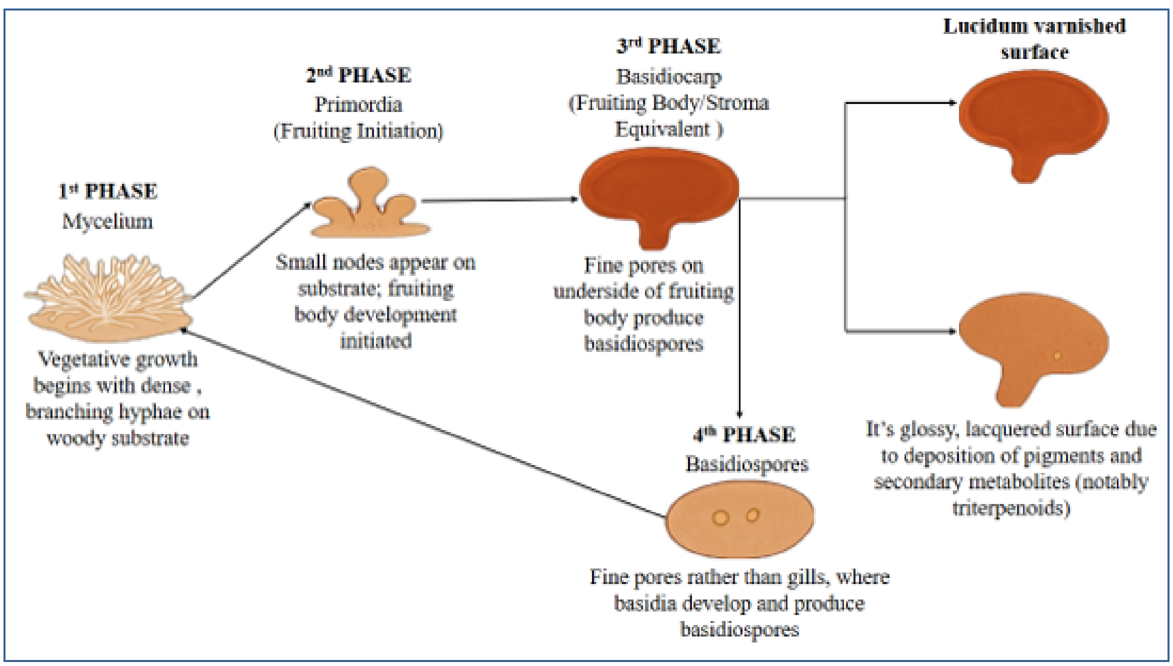

Figure 2: Showing the distinct structures and developmental phases.

and guard against photodamage. Polysaccharides, triterpenoids, and peptides are only a few of the many bioactive compounds found in *G. lucidum* that have strong cosmeceutical potential. Numerous patents and new product advancements support its uses in dermatological formulations, anti-aging, and skin rejuvenation summarized in Table 6.

Challenges and Research Gaps

Despite its rich bioactive profile, *G. lucidum* faces significant translational challenges in cosmeceutical applications. Variability in strains, substrates, and cultivation conditions leads to inconsistent levels of polysaccharides, triterpenoids, and ergosterol, complicating standardization, extraction reproducibility, and quality control. Ergosterol-derived Vitamin D_2 is thermolabile and prone to photodegradation and oxidative instability, while triterpenoids exhibit limited dermal bioavailability. Advanced delivery systems, including solid lipid nanoparticles, liposomes, and nanogels, are under investigation to enhance stability and skin permeation. Regulatory constraints, particularly in the US and EU, stem from insufficient human clinical evidence supporting anti-aging, anti-inflammatory, and depigmenting claims. Additionally, limited data on excipient-extract interactions restrict formulation optimization, underscoring the need for rigorous clinical validation and mechanistic studies (Figure 4).

Future Prospectives

Future research on *G. lucidum* emphasizes advanced formulation and sustainable production strategies to address current

Table 3: Showing the *in vitro*/*Ex vivo* Evidence of *G. lucidum*.

Study model	Intervention (*G. lucidum* form)	Primary cosmetic-relevant outcomes	Key notes	References
Enzymatic/chemical assays (DPPH, FRAP, tyrosinase)	Ethanolic/aqueous extracts from multiple *G. lucidum* varieties	Strong radical scavenging (DPPH/FRAP) and tyrosinase inhibition; activity correlated with polyphenol content.	Recent macrofungal survey includes *G. lucidum* among top performers	(Liu *et al*., 2022)
Mycelial culture extracts	Antioxidant and anti-tyrosinase screening	Antioxidant activity and tyrosinase inhibition confirmed for cultured mycelium fractions.	Supports scalable cosmetic sourcing from mycelium	(Sliva *et al*., 2002)
Human Dermal Fibroblasts (HDFs)	Polysaccharide-rich extracts (GL-PS)	Protection from UVB-induced photoaging, reduced ROS, preserved collagen.	Mechanistic evidence for anti-photoaging	(Zhao *et al*., 2019)
Human Dermal Fibroblasts (HDFs)	Polysaccharide-rich extract (aqueous)	↑ Proliferation and migration, ↑ collagen synthesis.	Direct pro-regenerative signal for wound/anti-aging claims	(Chien *et al*., 2004)
Human keratinocytes and fibroblasts	Ethanol extract	Antioxidant cytoprotection, pro-migration, modulation of MMP-2/9 and stress kinases (AKT/ERK/p53/p21).	Supports re-epithelialization and anti-oxidative defense	(Yeh *et al*., 2009)
Pigmentation models (cell-based and zebrafish)	GL-polysaccharides / phenolic-rich fractions	Anti-melanogenic effects; tyrosinase pathway modulation.	Multiple datasets indicate whitening potential	(Hapuarachchi *et al*., 2018)

Table 4: Showing the *in vivo*/Clinical and Consumer-Use Evidence.

Population / design	Formulation	Outcomes	Key Notes	References
Narrative/umbrella reviews of clinical and cosmetic applications	Various cosmetic products containing *G. lucidum* extracts	Reports of improved brightness and reduced pigmentation, supportive of cosmeceutical positioning.	Secondary evidence synthesizing small studies and product data; calls for RCTs	(Zhu *et al*., 2007)
Dermatocosmetic safety/cosmetic properties review (mushroom extracts)	Multiple macrofungi including *G. lucidum*	Good tolerability profiles cited; antioxidant/whitening mechanisms summarized.	Human safety within cosmetic use discussed; not an RCT	(Bao *et al*., 2001)
Topical potential (review)	*G. lucidum* extracts as bioactive in topical formulations	Supports anti-aging/whitening rationale; highlights formulation strategies.	Methodological guidance; urges clinical validation	(Xu *et al*., 2011)
Combination cosmetic extract study (includes *G. lucidum*)	Multi-botanical formula stability and efficacy endpoints	Explores stability/efficacy; not *G. lucidum* monotherapy.	Useful for real-world product context; limited attribution	(Jiang *et al*., 2008)

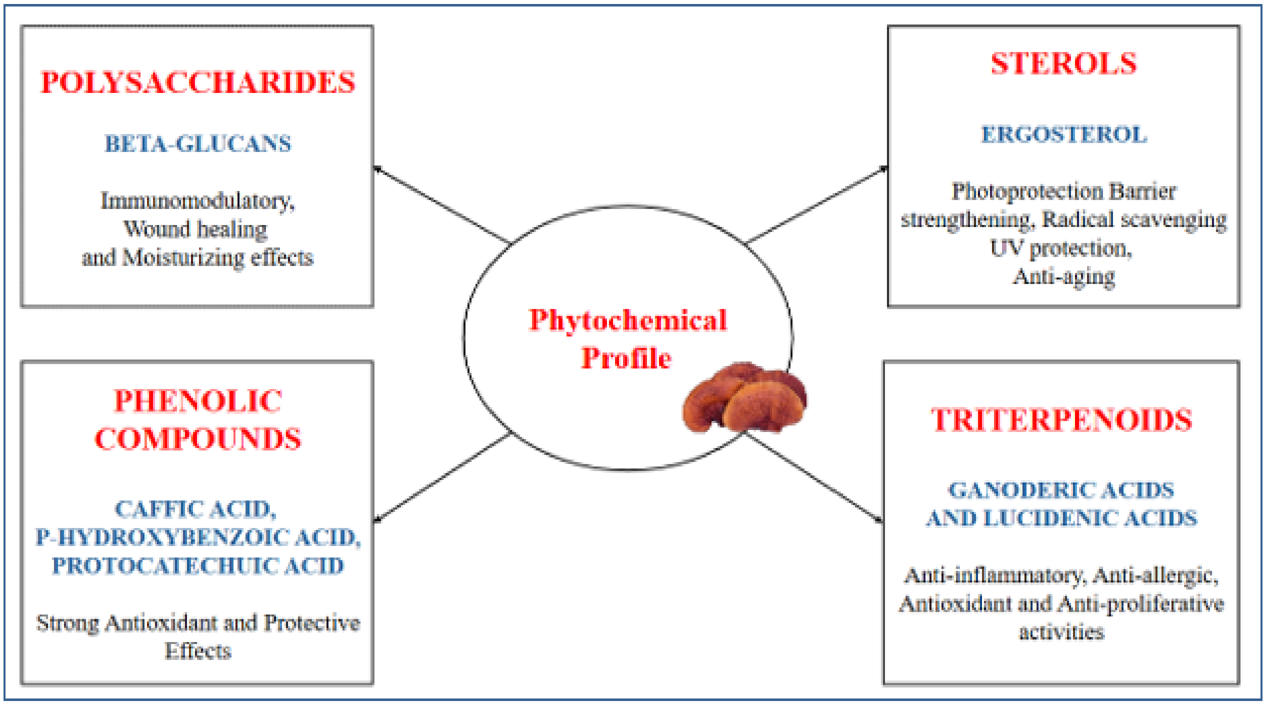

Figure 3: Showing the phytochemical constituents.

Table 5: Showing the patent in recent year.

Sl. No.	Patent title	Patent / Grant number	Inventor(s)	Grant / Publication Date	Country
1.	Eco-friendly extraction of *G. lucidum* using aqueous cyclodextrin solution.	US11,433,019B2	Amorepacific Corp. inventors	06.09.2022	USA
2.	Cosmetic composition comprising *G. lucidum* extract for anti-aging.	US2020/0253859A1	Amorepacific Corp. inventors	13.08.2020	USA
3.	Cosmetic composition for skin whitening comprising ganodermanondiol from *G. lucidum* mycelia.	KR10-2013-0050751	Korean inventors (Han *et al.*)	08.05.2013	Republic of Korea
4.	Novel *G. lucidum* strains (M2-100-02, M2-102-02) with high ganoderic acid and β-glucan yield.	US2024/0349663A1	Korean inventors (Choi *et al.*)	31.10.2024	USA
5.	*G. lucidum* polysaccharide GLP-2 for reducing cisplatin toxicity and treating cancer.	US2025/0134922A1	Chinese inventors	01.05.2025	USA
6.	Extraction and preparation method of *G. lucidum* polysaccharide GLP-3.	US2025/0144130A1	Chinese inventors	08.05.2025	USA
7.	Mutant recombinant *G. lucidum* immunomodulatory protein.	US2023/0212233A1	Taiwanese inventors	06.07.2023	USA
8.	Biologically active compounds from *G. lucidum* (ergosterol peroxide derivatives) for anticancer use.	PCT/US2020/017053	Revive Therapeutics inventors	13.02.2020	International (PCT)

Table 6: Comparative cosmeceutical potential of major medicinal mushrooms.

Sl. No.	Mushroom Species	Key Bioactive Compounds	Cosmeceutical Relevance	References
1.	Cordyceps sinensis	Anti-aging peptides	Supports skin regeneration, cellular vitality	(Xu *et al.*, 2011)
2.	Trametes versicolor	β-Glucans	Immune modulation, skin barrier support	(Bishop *et al.*, 2015)
3.	*Pleurotus* spp.	Antioxidant compounds	Reduces oxidative stress, protects against photodamage	(Zhu *et al.*, 2006)
4.	Ganoderma lucidum	Polysaccharides, triterpenoids, peptides	Broad-spectrum bioactivity, anti-aging, dermatological applications, cosmeceutical patents	(Tang *et al.*, 2006)

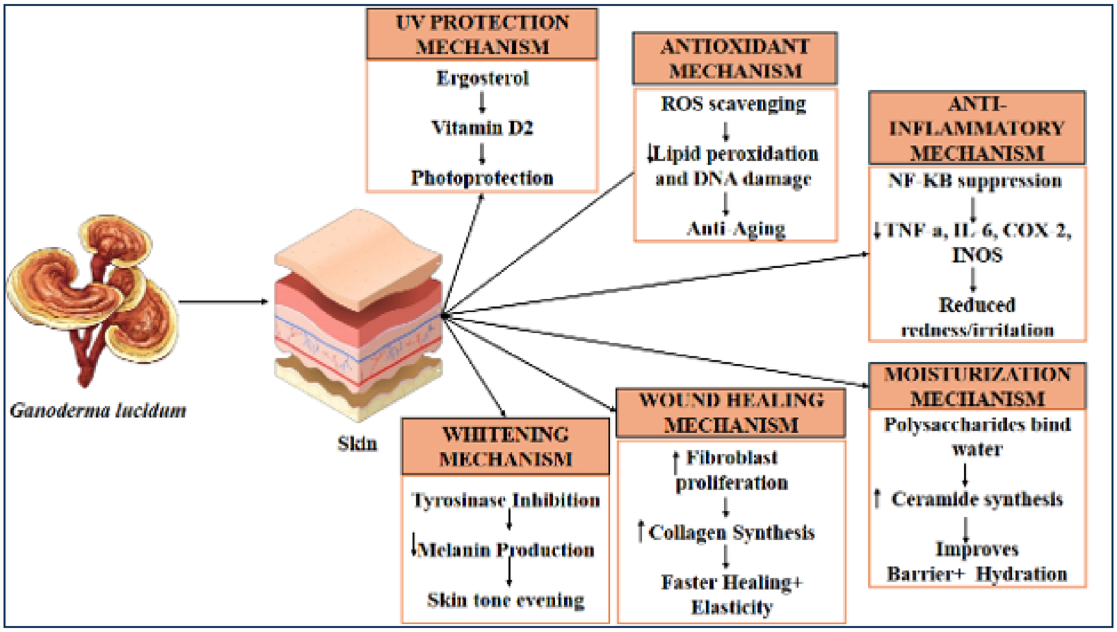

Figure 4: Showing the Mechanisms of Action in Skin Health *G. lucidum*.

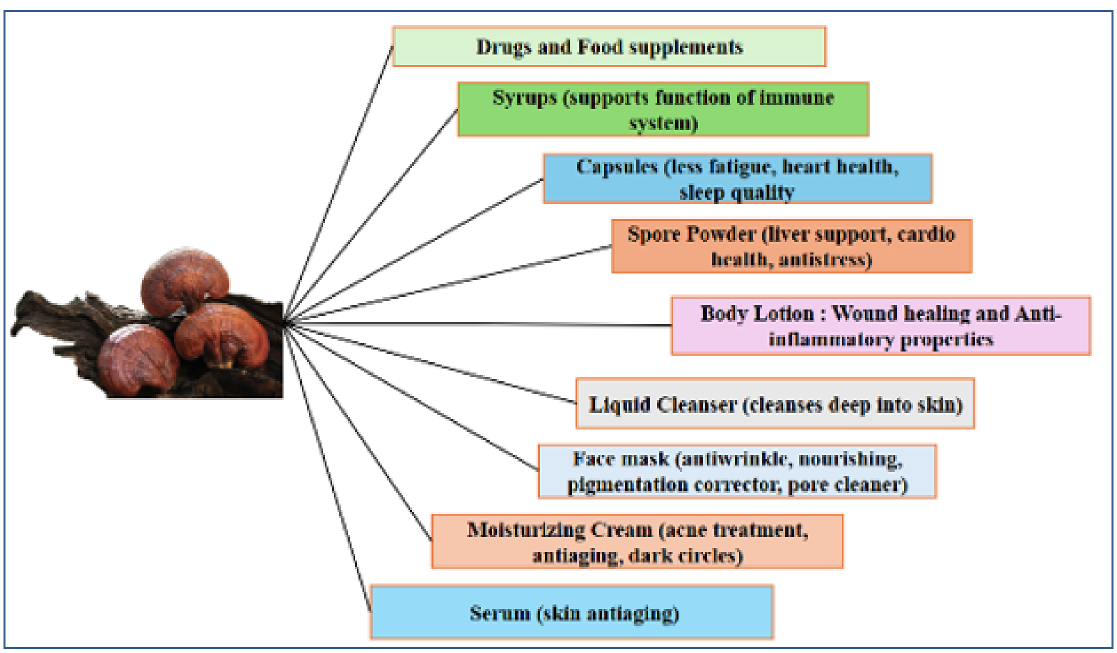

Figure 5: Representative pharmaceutical and cosmetic formulations of *G. lucidum* and their associated health/skin benefits.

limitations. Omics-driven approaches, including proteomics and metabolomics, support extract standardization and identification of novel bioactives. Smart delivery systems liposomes, nanoemulsions, solid lipid nanoparticles, microneedles, and transdermal patches are being developed to enhance vitamin D_2 stability, dermal penetration, and controlled release for conditions such as psoriasis, eczema, and photodamage. Polysaccharide-based films demonstrate potential for sustained release and improved therapeutic efficacy. Synergistic formulations combining *G. lucidum* with retinoids, peptides, hyaluronic acid, niacinamide, and botanical antioxidants may amplify anti-aging benefits, including hydration and elasticity. Prebiotic polysaccharides also support microbiome-friendly skincare. Sustainable cultivation using agro-waste substrates and green extraction technologies, such as enzyme-assisted and supercritical CO_2 methods, promotes eco-friendly production, while regulatory harmonization and clinical validation remain essential for global commercialization and consumer confidence (Figure 5).

CONCLUSION

G. lucidum has emerged as a versatile and scientifically promising bio-resource in cosmeceutical research due to its diverse bioactive constituents, including polysaccharides, triterpenoids, phenolic compounds, and peptides. These metabolites collectively exert antioxidant, anti-inflammatory, anti-melanogenic, and collagen-protective effects, supporting skin rejuvenation, barrier integrity, and photoprotection. UV-enhanced Vitamin D_2 further strengthens its dermatological relevance, reinforcing its multifunctional role in skin health management. Advances in green extraction technologies and nanocarrier-based delivery systems have improved stability, dermal penetration, and formulation performance, enhancing its translational potential. However, significant challenges remain, including variability in phytochemical standardization, limited large-scale clinical validation, and evolving regulatory frameworks. Future research should prioritize harmonized quality control protocols, well-designed randomized clinical trials, mechanistic pathway elucidation using omics technologies, and optimization of smart delivery systems for targeted and sustained release. Sustainable cultivation practices and life-cycle assessments should also be integrated to ensure eco-friendly commercialization. Interdisciplinary collaboration among mycologists, dermatologists, formulation scientists, and regulatory authorities will be essential to transform *G. lucidum* from a promising natural extract into a globally accepted, evidence-based cosmeceutical ingredient.

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ABBREVIATIONS

CO_2: Carbon Dioxide; **DNA:** Deoxyribonucleic Acid; **EU:** European Union; **G. lucidum:** *Ganoderma lucidum*; **HPLC:** High-Performance Liquid Chromatography; **IL-6:** Interleukin-6; **iNOS:** Inducible Nitric Oxide Synthase; **LC-MS/MS:** Liquid Chromatography–Tandem Mass Spectrometry; **NF-κB:** Nuclear Factor-Kappa B; **NMR:** Nuclear Magnetic Resonance; **ROS:** Reactive Oxygen Species; **TCM:** Traditional Chinese Medicine; **TGF-β:** Transforming Growth Factor-beta; **TNF-α:** Tumor Necrosis Factor-alpha; **US:** United States; **UV:** Ultraviolet; **UV-B:** Ultraviolet-B.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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