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Review Article

Bioactive components of *Ganoderma lucidum* and their efficacy and application in cosmetics

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Abstract: At present, the pursuit of cosmetics requires naturalness, greenness, safety, and high efficiency. *Ganoderma lucidum* has shown many biological effects, indicating that its application in cosmetics will produce many beneficial effects. Thus, the development of cosmetic products containing *G. lucidum* has become a research hotspot. Given the biologically active components of *G. lucidum*, such as polysaccharides and total triterpenoids, different traditional and combined extraction methods are identified. In addition, the efficacy of *G. lucidum* as an antioxidant, anti-aging, whitening, spot-reducing, anti-sensitivity, anti-inflammatory, anti-radiation, anti-frostbite, water replenishment, and moisturizing component, as well as in combating scalp problems, is described in detail. Cosmetic products containing *G. lucidum*, which are already available in the market, are also summarized. We believe that studying the effects of *G. lucidum* other than being an antioxidant and anti-aging component, as well as their proteins and other biologically active ingredients, potential biotransformation, and union with other disciplines, can expand the market of cosmetic products containing *G. lucidum* and provide insights into the development of cosmetic research on *G. lucidum*.

Keywords: *Ganoderma lucidum*; cosmetics; bioactivity; efficacy; application

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1 Introduction

Ganoderma lucidum is a fungus belonging to the genus *Ganoderma* and which are widely distributed in China. A large number of modern studies have proven that *G. lucidum* has antioxidant[1], hypoglycemic[2], antitumor[3,4], and anti-inflammatory[5] activities, and they have shown great application potential in improving bread quality[6], lowering lipid levels[7], and protecting liver function[8,9]. Utilizing the wealth of *G. lucidum* resources to the fullest and actively and successfully creating derivatives of *G. lucidum* can help the industry flourish in a variety of ways and the market for *G. lucidum* to keep growing. At present, *G. lucidum* has been successfully applied in some healthy foods or medicines, such as *G. lucidum* tea[10], *G. lucidum* coffee[11], *G. lucidum* wine[12], and *G. lucidum* pressed tablet confectionery[13]. However, the application of *G. lucidum* as a cosmetic ingredient is rarely reported. With the development of social and economic conditions, people's requirements for quality cosmetics have gradually increased, and the cosmetics required to be used will not have an impact on the skin and body, but also possess certain skincare and beauty effects. However many of the cosmetics sold in the market are made of chemical raw materials. The emulsifiers, flavors, fragrances, colors, and preservatives added to cosmetics can increase the performance, quality, value, and service life of the cosmetics, but long-term use of cosmetics containing such additives may lead to adverse effects on the skin[14]. Therefore, there is an urgent need to find some safe and effective cosmetic ingredients to meet people's current demand for natural and green cosmetics.

G. lucidum, as a popular traditional Chinese herb, has many effects in cosmetics, such as anti-aging, whitening, spot-reducing, anti-sensitivity, hydrating, and moisturizing[15]. Factors such as oxidation, inflammation, radiation, etc., may cause certain problems in the skin, and adding reishi to cosmetics can improve these conditions[14]. In addition, *G. lucidum* has low irritation, mild action, and remarkable effect when used. Some famous cosmetic brands have used products such as *G. lucidum* extract and *G. lucidum* spore oil in their cosmetics. *G. lucidum* is regarded as an ideal and beneficial ingredient for the human body in the fields of food, traditional Chinese medicine, and cosmetology. Therefore, in this study, the constituents of *G. lucidum*, such as polysaccharides and total triterpenes, and their main efficacies in cosmetic products were reviewed. *G. lucidum*-related cosmetic products were also outlined. We are looking forward to the future development of *G. lucidum* in light of the domestic and international research results.

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2 Bioactive components in *G. lucidum*

With the in-depth study of *G. lucidum*, many domestic and foreign researchers have isolated many kinds of effective bioactive components from *G. lucidum* with certain theoretical basis. The main active components of *G. lucidum* are polysaccharides, triterpenoids, *G. lucidum* proteins, and other effective components.

2.1 *G. lucidum* polysaccharides

G. lucidum polysaccharides (GLPs) are highly active natural polymers with a helical three-dimensional conformation similar to that of DNA and RNA with helical layers held together by hydrogen bonds and with molecular weights ranging from several thousand to hundreds of thousands[16]. More than 200 types of GLP have been isolated to date. Natural *Ganoderma* polysaccharides, which can be isolated from substrates or spores obtained from wild or commercial cultivation, are formed by combining glucose, mannose, galactose, xylose, fucose, and arabinose in different ratios and glycosidic bonds[17]. Based on modern separation analysis and detection methods, the traditional methods of extracting *Ganoderma* polysaccharides include hot-water extraction, microwave-assisted extraction, ultrasound-assisted extraction, enzymatic extraction, ultrasound-microwave synergistic extraction, and low-eutectic solvent extraction. The main principles and process of these methods are shown in Table 1. Modern pharmacological studies have shown that *Ganoderma* polysaccharides have unique antitumor, immunomodulatory, hypoglycemic, lipid-lowering, and antioxidant properties, regulating and improving intestinal barrier function, microbial community diversity, and many other nonbiological activities[18-21]. Various types of polysaccharides are isolated and extracted from *G. lucidum* of different origins, parts, species, growth periods, and forms, and the variability in their chemical structures and compositions may affect their specific biological functions[22-25].

2.2 *Ganoderma* triterpenoids

Ganoderma triterpenoids are the main constituents of *G.* lucidum and are highly oxidized lanosterane derivatives with molecular weights ranging from 400 Da to 600 Da[37]. Some triterpenoids are bitter, and their content varies depending on the species, growth conditions, and reproduction stage, with bitter *G. lucidum* containing a higher content of triterpenoids. Triterpenoids are first isolated from the seed bodies of *G. lucidum* by Kubota *et al.*[38] in 1982. Since then more than 300 triterpenoid species have been detected from *G. lucidum* based on the gradual improvement of isolation and detection methods[39]. Ganoderic and ganoderenic acids are the unique triterpenoid species found in *G. lucidum*, particularly ganoderic acids A, B, C2, D, F, G, and H and ganoderic acids B, C, and D, which have evident anticancer effects[40]. The methods currently used for extracting *Ganoderma* triterpenoids are shown in Table 2. Most *Ganoderma* triterpenoids are isolated and purified from *Ganoderma* mycelium, spore powder, substrates, and fermentation broth. Domestic and international studies have shown that *Ganoderma* triterpenoids have a slightly bitter taste and various activities, such as antioxidant properties[41], prevention of ultraviolet damage[42], antiviral[43], hepatoprotection[44], anti-inflammatory[45], and regulation of intestinal flora, thereby lowering blood glucose and blood lipid levels[46].

2.3 Other biological activities

Apart from polysaccharides and triterpenes, *G. lucidum* contains a wide range of active ingredients such as proteins, sterols, nucleosides, and alkaloids. *G. lucidum* contains a variety of proteins and amino acids at high levels, which have immunomodulatory and antitumor effects because of their special immunogenicity. The basic steps of protein extraction are in the following order: washing tissues lysing cells centrifugation to remove membrane fractions obtaining protein extracts[58]. The most researched *G. lucidum* protein is the immunomodulatory protein LZ-8. Cheng *et al.*[59] verified that recombinant LZ-8 alleviated oxidative stress and inflammatory responses in Parkinson's disease by establishing a Parkinson's disease model in mice. Sterols are secondary metabolites of *G. lucidum*, among which ergosterol was found to be the most abundant. Researchers and scholars have shown that *Ganoderma* stanols have some anti-inflammatory and antibacterial properties, and they protect cells

Table 1 Extraction methods of GLPs

Extraction method	Theory	Process examples	Reference
Hot water extraction method	Polysaccharides can precipitate when dissolved in water and meet ethanol	Optimal extraction conditions: 90 °C hot water extraction for 90 min, material (g) liquid (mL) ratio 1:20, extracted twice	[26, 27]
Microwave-assisted extraction method	The use of microwave radiation increases the temperature inside the cell and evaporation of liquid water leads to rupture of the cell membrane and cell wall and release of polysaccharides from the cell	The optimal extraction conditions were as follows: 1.5 h of pre-soaking, pH 8.0 of the aqueous solution, 1:70 ratio of water to material, 400 W of microwave power, 20 min of microwave time, and 2 times of extraction	[28, 29]
Ultrasound-assisted extraction method	The mechanical effect and cavitation of ultrasound is used to destroy biological tissues and increase the mass transfer efficiency within the cells, thus promoting polysaccharide release and extraction	Optimal extraction conditions: ultrasonic power of 81 W, irradiation time of 52 min, and temperature of 33 °C	[30, 31]
Enzymatic extraction	The polysaccharides are hydrolysed using specific enzyme catalysts to separate them from the solvent for the purpose of polysaccharide extraction	The optimum enzyme complex ratio: cellulase 3.5%, hemicellulase 4.0%, papain 3.0%; conditions were: pH 5.70, temperature 50 °C and time 81 min	[32]
Ultrasound-Microwave synergistic extraction method	The simultaneous action of ultrasound and microwaves stretched the conformation of the polysaccharides in the fractions and prevented their degradation	Optimal conditions: ultrasonic power 638.17 W, material-liquid ratio 1:45.24 (g/mL), microwave power 400 W, temperature 90 °C, number of times 2, time 30 min	[33, 34]
Low eutectic solvent extraction	Polysaccharide solubilisation and improved derivatisation efficiency is achieved by breaking existing hydrogen bonds in the polysaccharide and forming new ones	Optimal extraction conditions: 34% deep eutectic solvents (DESs-5) content, 1.9 h extraction time, 7.3 h alcohol precipitation time	[35, 36]

Table 2 Extraction methods of *G. lucidum* triterpenoids

Extraction method	Theory	Process examples	Reference
Solvent extraction	Different organic solvents were used for extraction and separation according to their solubility	Optimal process: ethanol volume concentration 73%, extraction temperature 76 °C, extraction time 120 min, liquid-feed ratio 16:1	[47, 48]
Ultrasound-assisted extraction method	Ultrasonic waves can make the bubbles in the extracted liquid rupture immediately, forming a jet, while forming small droplets, thus accelerating the mass and heat transfer between the solid and liquid phases and improving the extraction efficiency	Optimal extraction conditions: sonication time 27 min, power 160 W, ethanol volume fraction 87%	[49]
Microwave-assisted extraction method	The microwave energy is used to promote the chemical reaction and material migration process in the sample in order to improve the extraction efficiency and speed of the target components in the sample	Optimal conditions: solvent 95% ethanol, liquid/feed ratio 25 mL/g, time 5 min, temperature 90 °C	[50]
Supercritical CO_2 fluid extraction	When the liquid is at a critical point, small changes in temperature and pressure in the separation unit can result in large changes in the solubility of the target component	Optimal extraction conditions: pressure 85 MPa, temperature 50 °C, time 4 h	[51, 52]
Enzymatic extraction	Enzymatic digestion is utilised to loosen the structure of Ganoderma lucidum and reduce the binding force with the raw material, thus allowing the leaching of triterpenoid components	The optimal conditions were: time of 80 min, pH of 5, and temperature of 50 °C. The optimal enzyme ratio was 2.11:0.86:2.09 for cellulase:pectinase:neutral protease	[53]
Ultrasound-Microwave synergistic extraction method	Making full use of the high-energy action of microwaves as well as the cavity action of ultrasonic vibration, overcoming the shortcomings of both when used alone	Optimal conditions: ethanol content 75%, microwave power 650 W, ultrasonic power 730 W, time 20 min	[54]
Ultra high pressure assisted extraction method	At room temperature, hydrostatic pressure is applied to the material and maintained for a certain period of time, followed by a rapid reduction to atmospheric pressure, which creates a pressure differential and a rapid transfer of active ingredients into the extractant	Extraction conditions: pressure 378 MPa, liquid-solid ratio 20 mL/g, holding time 6 min, ethanol 75%	[55-57]

against oxidative damage[60, 61]. *G. lucidum* contains a variety of nucleoside analogs such as uracil, adenine, and *G. lucidum* purine[7]. Sheng *et al.*[62] established micellar electrokinetic chromatography for the determination of 10 nucleosides and bases in different batches of *G. lucidum* and found that the different geographical origins primarily influence the nucleosides and bases in *G. lucidum*. Alkaloidal components are low in *G. lucidum*. Zhao *et al.*[63] extracted four new alkaloids from *G. lucidum* substrates with some antibacterial and anti-inflammatory effects.

A variety of biological components of *G. lucidum*, such as polysaccharides, triterpenes, proteins, and sterols, each with different activities, have been used in medicines, health foods, and cosmetics. At present, *G. lucidum* has become an important medicinal and food material in China, according to the Notice on the Pilot Management of nine Substances such as *Codonopsis pilosula* that are Traditionally Used as Both Food and Chinese Herbal Medicinal Materials, which was jointly issued by the National Health and Health Commission and the State General Administration of Market Supervision.

3 Main effects of *G. lucidum* in cosmetology

As shown in Fig. 1, domestic and international studies have indicated that *G. lucidum* possesses a variety of cosmetic and skin care benefits such as antioxidant, anti-aging, anti-inflammatory, anti-allergy, anti-radiation, whitening, and light spotting, thereby increasing the overall value of *G. lucidum* in cosmetics. In recent years, the pursuit of green and harmless cosmetic products has directly increased the demand for *G. lucidum*. Consumers often purchase Lingzhi products for its biological activity, but its complex structure and chemical composition result in more cosmetic benefits of Lingzhi that are still being explored.

3.1 Antioxidant

Free radicals are generated in the normal metabolic process of organisms and are produced in large quantities after being subjected to various stimuli (temperature, machinery, pathogens, etc.)[64]. Large quantities of free radicals primarily cause oxidative stress, sub-health, and a decline in productive function in people. Studies have shown that *G. lucidum* water-soluble polysaccharides, fermentation broth polysaccharides, and alkali-extracted polysaccharides can prevent lipid peroxidation and reduce the production of hydroxyl, ABTS, and DPPH free radicals to varying degrees[65-68]. The mechanism of the antioxidant effects on organisms is shown in Fig. 2[69]. These polysaccharides have three main pathways. First, in the Kelch-like epichlorohydrin-associated protein 1-nuclear factor E2-related factor 2/antioxidant response element (Keap1-Nrf2/ARE) pathway, GLP upregulates the expression level of the *Nrf2* gene and downregulates the expression level of the *Keap1* gene, which improves the content and vitality of antioxidant enzymes and scavenging of free radicals. Second, GLP scavenges excess free radicals and alleviates the oxidative damage by increasing the content and vitality of endogenous enzymes. Third, GLP reduces the oxidative effect of reactive oxygen species (ROS) on the body and blocks lipid peroxidation[69]. Zhao *et al.*[70] found that GLP fermented with *Lactobacillus plantarum* was structurally the same, but the antioxidant activity increased, with a stronger ability to regulate the Nrf2-ARE pathway in cells. Milovanovic *et al.*[71] extracted wild and cultivated *G. lucidum* with supercritical carbon oxides and compared the antioxidant capacity and enzyme inhibition potential between the two samples. The results revealed that the cultivated sample contained higher total phenolic content than wild *Ganoderma* and possessed higher antioxidant capacity and relatively weak lipase activity, indicating that cultivated *Ganoderma* may be an important source of natural bioactive agents for the preparation of health products.

In general, multiple indicators are used to evaluate the antioxidant capacity of substances. At present, the evaluation of the antioxidant capacity of substances has not established a unified evaluation system, although there is a theoretical guidance. In the future, a complete system of the antioxidant effect of *G. lucidum* should be established, and the system must be improved in

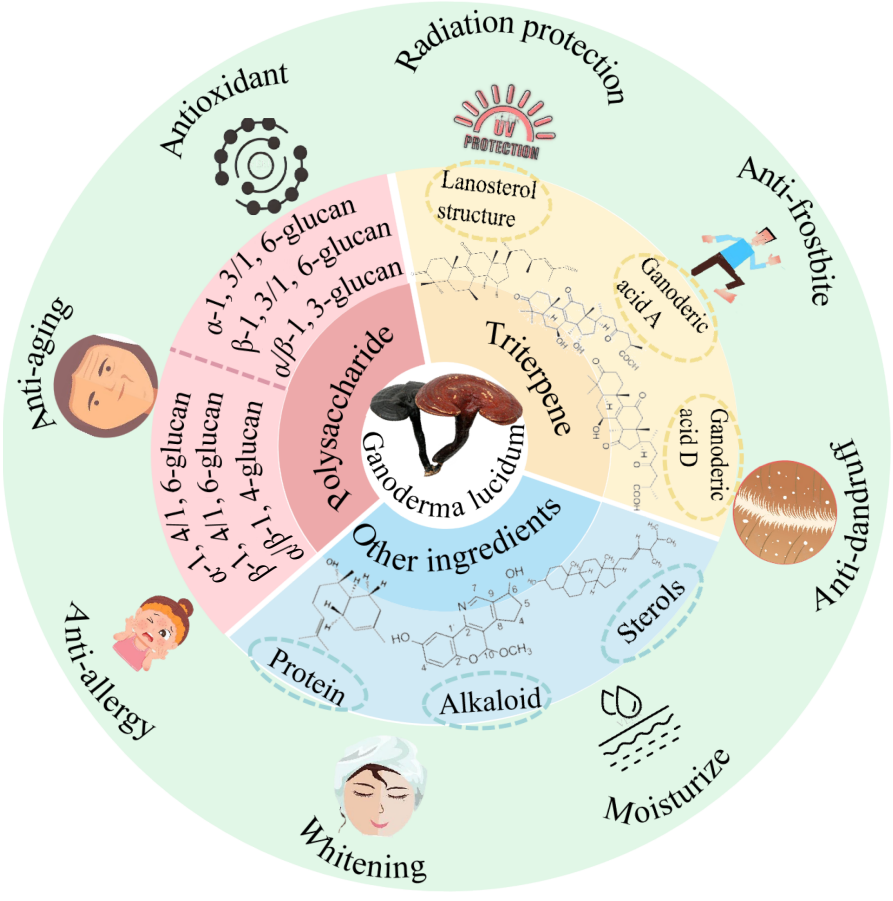

Figure 1 Main effects of *G. lucidum* in cosmetology.

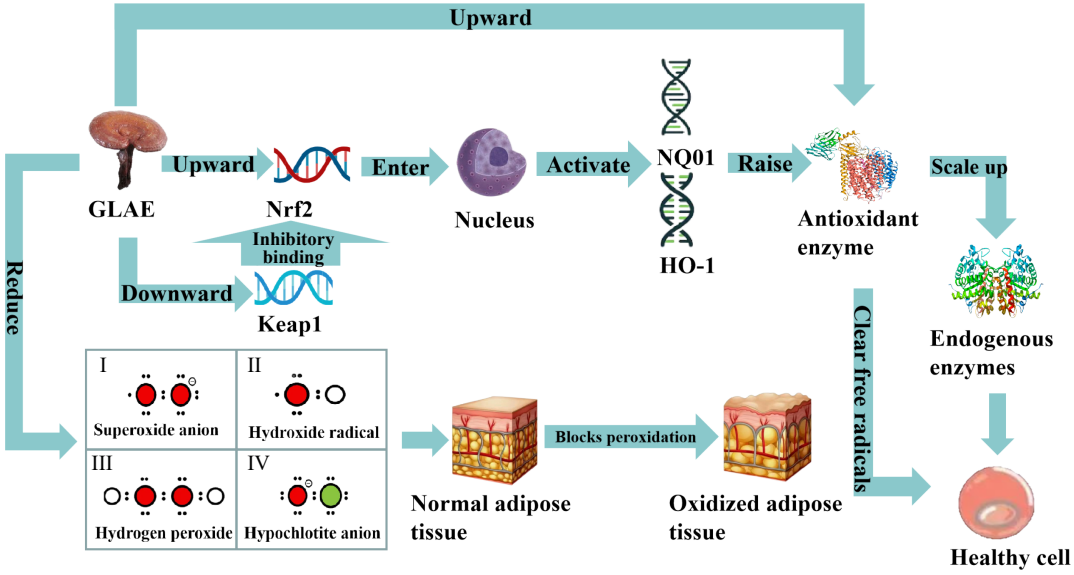

Figure 2 Mechanism of modulation of antioxidant effects of *G. lucidum* on the organism[69].

accordance with the development of science and technology, so as to form the use of practice.

3.2 Anti-aging

Aging is a complex natural physiological process, and skin aging is primarily affected by endogenous and exogenous factors. Endogenous factors include gene doctrine, free radical doctrine, non-enzymatic glycosylation aging doctrine, etc., whereas exogenous factors include photoaging, smoke, pollution, etc. The anti-aging efficacy of *G. lucidum* has been well established in a large number of studies, and its pharmacological mechanism is shown in Fig. 3[72]. The anti-aging effect is achieved by inhibiting the production of β-galacturonic acid and ROS and enhancing the expression level of 14-3-3ε protein, thereby promoting Nrf2

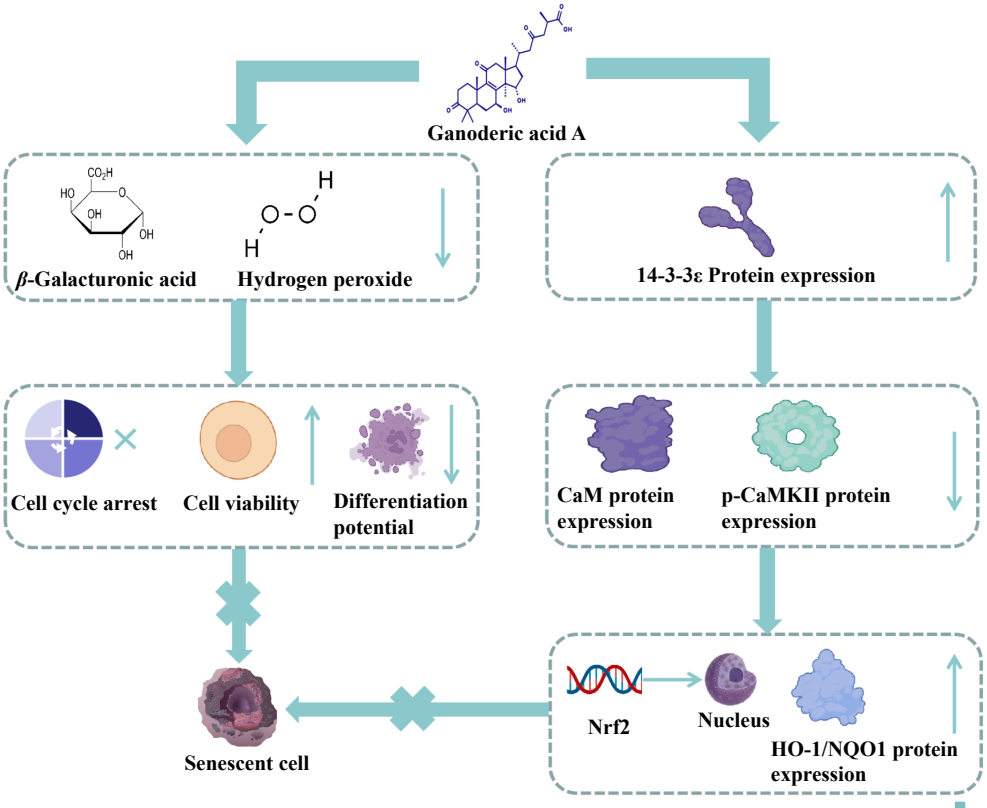

Figure 3 Regulatory mechanism of the anti-aging effect of *G. lucidum* on the organism. ↓ inhibition; ↑ enhance; × clog up; ⟷ obstacles.

nuclear translocation and Heme Oxygenase-1/NAD(P)H:quinone oxidoreductase 1 (HO-1/NQO1) protein expression. Xu *et al.*[73] found that *β*-1, 3 glucan synthase (GLS) and glucose pyrophosphorylase (ugp) were simultaneously overexpressed in *G. lucidum* for the first time during their study, and the simultaneous expression of both genes can increase the production of polysaccharides, while demonstrating a stronger anti-aging activity. In investigating the anti-oxidative stress and anti-aging effects of the aqueous extracts of *G. lucidum*, Cuong *et al.*[74] used the nematode *Cryptobacterium hidradenii* as a model to elucidate its specific pharmacological mechanisms. The results showed that the aqueous extract of *G. lucidum* could effectively increase nematode resistance to paraquat and heavy metal–induced oxidative stress and prolonged the lifespan of wild-type nematodes; however, this effect was dependent on glucagon-like peptide-1 (GLP-1) but not entirely on DAF-16 (the only forkhead box transcription factors class O (FoxO) homolog in *Caenorhabditis elegans*). Thus, further studies are necessary.

In future studies, a more in-depth analysis of the interactions of the active substances within *G. lucidum* must be conducted to find better ratios and to optimize the anti-aging effects of *G. lucidum*, as well as to explore the effects of different signaling pathways on the subjects.

3.3 Whitening and lightening

The color of the human skin, eyes, and hair depends on the production of melanin, which, depending on its quantity, quality, and distribution, plays an important role in protecting the skin from the harmful effects of UV radiation and oxidative stress from various environmental pollutants[75]. Most organisms naturally synthesize melanin, where tyrosinase, catecholase, and phenol oxidase catalyze the formation of melanin from a substrate called DOPA (dihydroxyphenylalanine)[76]. However, excessive melanin in the body can cause pigmentation, resulting in dark skin or freckles, which affects beauty, and tyrosinase inhibition is a common whitening method. Li *et al.*[77] found that the inhibition rate of the fermentation broth on complexinase reached 95.1% by optimizing the composition of the *G. lucidum* fermentation medium and fermentation conditions, and metabolomic analysis of the fermentation broth was performed using mass spectrometry. Liu[78] investigated the anti-aging and skin-whitening effects of recombinant the *G. lucidum* immunomodulatory protein (rLZ-8) on *D*-galactose-induced senescent mice and found that the recombinant protein inhibited the proliferation of melanoma cells, reduced the activity of the rate-limiting enzyme TYR during melanin synthesis, and destroyed melanoma cells, thereby achieving skin-whitening effects.

3.4 Anti-inflammatory and anti-sensitization

Inflammation is the body's defense response to stimuli, and it manifests as redness, swelling, heat, pain, and dysfunction. In general, inflammation is beneficial and is the body's automatic defense response, but local damage caused by inflammation cannot be ignored. Skin allergy can eventually cause an inflammatory reaction when allergens enter the body, prompting the body to produce the corresponding antibodies, thereby triggering an antigen–antibody reaction[79]. Some studies have proven that *G. lucidum* plays an important role in the treatment of inflammation and allergic reactions. Fan *et al.*[80] investigated whether GLPs had a protective effect against inflammatory damage and determined its mechanism. The results showed that GLP can effectively reduce lipopolysaccharides (LPS)-induced *α*-tumor necrosis factor (TNF-α), interleukin-6 (IL-6), and interleukin-1β (IL-1β) production as well as prevent inflammatory

cell injury. Liu *et al.*[81] investigated the therapeutic effects of different molecular weights of *G. lucidum* β-*D*-glucans on ulcerative colitis and their corresponding mechanisms. The results of the study showed that lowering the molecular weight of *G. lucidum* by degradation could effectively improve its anti-inflammatory activity. After certain studies, *G. lucidum* extract has been proven to play an important role in the treatment of histamine-mediated allergic reactions and block histamine release[22].

3.5 Radiation protection

Radiation refers to the phenomenon in which a portion of the electromagnetic energy emitted by an emitting source propagates away from the field source and does not return to the field source, and the energy spreads outward in the form of electromagnetic waves or particles. It is widely present in the daily life environment. Radiation pollution has become a major invisible factor endangering human health, which can lead to diseases of the immune system or metabolism, and in serious cases, cause cancer. Domestic and international studies have shown that *Ganoderma* components such as polysaccharides, glycoproteins, and total triterpenoids play an important role in protecting against radiation and in combating photoaging. Smina *et al.*[82] evaluated the application potential of *Ganoderma* total triterpenoids in preventing γ-radiation-induced damage to hepatic mitochondrial and microsomal membranes as well as to DNA strand breaks in rats and found that *Ganoderma* triterpenoids exhibited a protective effect against DNA and membrane damage caused by the deleterious effects of radiation. Yu *et al.*[83] investigated the preventive effect of GLP and its serum metabolomic mechanism on radiation-damaged mice. The results of the study indicated that platelets in the GLP group were higher than those in the control group, and low-taurine metabolism and glycerophospholipid metabolism were identified as potential biomarkers in GLP-treated mice. Zhou[84] investigated the mechanism of *G. lucidum* glycoproteins (Gl-Gp) on photoaging repair by studying the viability of superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px), the content of malondialdehyde (MDA) and hydroxyproline (HYP), and the expression level of related factors in the homogenates of rat back skin tissues. The results indicated that Gl-Gp repaired the erythematous ulceration of rat back skin after UV irradiation, restored the orderly arrangement of tissue structure and elastic fibers, repaired collagen and elastin, and inhibited the expression level of tumor necrosis and inflammatory factors. The above studies show that the effective biological activity in *G. lucidum* has a certain effect on radiation protection and the treatment of photoaging, and has a certain prospect for the development of sunscreen and other related cosmetics.

3.6 Protection against frostbite

Studies have shown that *G. lucidum* contains ingredients that can treat frostbite, but the effect is not good because of its poor solubility and drug penetration, so improving its penetration to the skin is necessary. Shen[85] constructed a *G. lucidum* triterpene nanogel transdermal drug delivery system by combining nanosuspension and gel to improve the solubility of the drug. This system was validated to have remarkably improved *in vitro* permeation, retention, and anti-frostbite effect, which is an effective method to improve the transdermal absorption of insoluble active sites, thereby enhancing the efficacy of the drug. Shen *et al.*[86] prepared a topical gel of *G. lucidum* triterpenoids and evaluated its effect on frostbite. The result showed that the penetration rate of the gel was higher than that of the emulsion, whereas the gel was more effective than the emulsion for the treatment of frostbite. Thus, this gel could be used as a novel carrier for the topical treatment of skin diseases.

3.7 Hydration and moisturization

When the temperature decreases, the skin stratum corneum cannot regulate enough moisturizing factors in time. Consequently, the sebaceous gland activity decreases; the face oils up; the moisture decreases; the skin becomes tight, and fine lines appear under the eyes and beside the nose. Thus, skincare and skin nourishing products with similar effects are used to moisturize the skin, prevent water evaporation, improve microcirculation, and improve the moisturizing properties of the skin. Most of the *G. lucidum* with moisturizing function are GLPs. Liu *et al.*[87] have proven that polysaccharides have a good moisturizing effect because of the hydroxyl group inside the polysaccharides. Liu *et al.*[88] made a nanofiber film containing *G. lucidum* fermentation broth, which was confirmed to be moisturizing, antioxidant, and safe for the skin. Liu *et al.*[89] compounded *G. lucidum* deep culture fluid with various natural additives to prepare skin care products with moisturizing and synergistic functions. The experimental results showed that *G. lucidum* deep culture fluid can improve the water-locking function of the skin barrier structures and increase the water content of the skin stratum corneum. *G. lucidum* deep culture fluid also has a moisturizing and synergistic effect, which indicates its great application potential in the development of skincare products.

3.8 Prevent dandruff, hair loss, and growth

Dandruff and hair loss are primarily due to seborrheic dermatitis, neurodermatitis, and fungal infections. *Malassezia* spp. are lipophilic fungi that are part of the normal flora of the human skin and are pathogens of dandruff and seborrheic dermatitis[90]. *G. lucidum* has remarkable antibacterial effects[91], and it can promote blood circulation and damaged cell repair in the head skin to promote hair growth. Chen[92] treated 40 cases of patchy baldness with compound *G. lucidum* hair growth tincture, with a cure rate of 70%, confirming the efficacy of *G. lucidum* topical hair growth solution.

In recent years, *G. lucidum* in cosmetic products still has several unknown effects and mechanisms other than the abovementioned effects. In the future, increasing the breadth and depth of *G. lucidum* in cosmetic skin care is necessary, and experimental research and product manufacturing must be combined, so that it is no longer used solely for scientific research and can be combined with industry, academia, and research in the future to adapt to the trend of the general public[93].

4 *G. lucidum* in cosmetics

In the pursuit of green and safe cosmetics and with the development of traditional Chinese skincare concepts, *G. lucidum* has gradually become a popular product in the cosmetic industry because of its unique efficacy[94,95]. A summary of *G. lucidum*-related cosmetics and their claimed efficacy in the market is shown in Table 3. The table illustrates that the majority of cosmetic goods containing *G. lucidum* are made in China due to the fact that the herb is a commonly used traditional Chinese medicine in that

Table 3 *G. lucidum*-related cosmetic products in the market and their efficacy

Brand	Products	Ingredient	Efficacy
ORIGINS	Mega-Mushroom relief and resilience soothing treatment lotion	*G. lucidum* extract	Inhibits intracellular stimulus signaling and robust redness fading
YUE SAI	Red radiance brightening essence lotion	Erythrina stem extract	Accelerates cell renewal, strengthens and repairs skin, and revitalises skin cells
Histoire Naturelle	Moisture daily sun lotion	*G. lucidum* extract	Spot whitening
LAN	Time orchid miracle age-defying oil	*G. lucidum* extract	Antioxidant, activates the barrier repair switch peroxisome proliferators-activated receptors (PPAR) to enrich barrier lipids and stabilise barrier structure
Herbeast	Reishi repair oil serum	*G. lucidum* cell oil	Repairing the keratinous and biological barriers to enhance skin self-care
BONOSIDAN	Ganoderma truffle soothing moisturizing waterless spray	*G. lucidum* extract	Promotes collagen synthesis; slows down oxidation and builds a strong muscle screen for firmness and resilience
gN Pearl	Black ganoderma cream	*G. lucidum* peptidoglycan	Improvement of lipid peroxidation proceeds
GOOBEN	*G. lucidum* oil	*G. lucidum* extract	Strengthens the skin barrier from the inside out, plumps and firms the skin, and gently smoothes lines
SUPER SEED	Black Reishi oily scalp treatment shampoo	Black *G. lucidum* extract	Revitalises and tones the scalp and reduces moisture loss
VITA LIXIR	Dual essence enzyme wake-up Reishi water	Purple Ganoderma extract	Hydration with water, fast absorption, deep repair, skin conditioning
Imperial Mud Flower	Jiangnan smoke and rain *G. lucidum* drinking mask	Black *G. lucidum* extract	Simple to absorb, increases the activity of cells, and provides internal moisture
TONGYANJI	Black Reishi mask	Black *G. lucidum* extract	Antioxidant, skin conditioning
READ YOUNG	*G. lucidum* facial mask	Chinese *G. lucidum* extract	Repairing, hydrating and softening the skin
Green field fairy	White rose orange blossom *Ganoderma* essence renewal mask	Black *G. lucidum* extract	Antioxidant
Maxam	Reishi long lasting moisturising cream	Purple *Ganoderma* extract	Quickly penetrates dry skin, replenishes and retains moisture, providing long-lasting, effective hydration
BEME	*Ganoderma* recovering toner	*G. lucidum* extract	Strengthens the skin's defences, both internally and externally
RNW	*G. lucidum* nourishing mask	Erythrina stem extract	Antioxidant
Natural melody	Lucid *Ganoderma* mushroom essence cream	*G. lucidum* complex	Bionic barrier technology to soothe and moisturise the skin
MINISO	*G. lucidum* dual essence emulsion	*G. lucidum* extract	Improve skin roughness and restore moisturised, supple and youthful-looking skin
PIANZAIHUANG	*G. lucidum* skin toning lotion	*G. lucidum* extract	Reduces fine lines, lifts and firms
HUQINGYUTANG	Reishi eye cream	*G. lucidum* extract	Reduces dry eye lines, softens dark circles, firms and refines skin, hydrates and brightens skin tone

country. Traditionally, people have been highly evaluating *G. lucidum*; therefore, it is easier to accept *G. lucidum* cosmetic products. Given their geographic location and cultural development, foreign countries have little understanding of *G. lucidum*, and most of the cosmetic products they develop cater to the Chinese market; thus, they do not truly reflect its efficacy and add less *G. lucidum*. The development of *G. lucidum* focuses on *G. lucidum*, *Ganoderma purpureum*, and *Ganoderma nigrum*[96], and only *G. lucidum* and *G. purpureum* are recorded in the Chinese Pharmacopoeia at present, which states that *G. lucidum* or *G. purpureum* can tonify qi, tranquilize the mind, and relieve cough and asthma. In addition, *G. lucidum* or *G. purpureum* is often used in cases of restlessness of mind and spirit, insomnia and palpitation, shortness of breath, and loss of appetite. At present, the development of *G. lucidum* focuses on the substrate, and fewer studies have been conducted on the addition of spore powder and mycelium. *G. lucidum* is used in cosmetics mostly in essence water, lotion, and mask and less in color cosmetics. Therefore, actively developing products with combined efficacy based on the existing *G. lucidum* series of cosmetics on the market is necessary.

5 Developmental trend of *G. lucidum* application in cosmetics

The active ingredients and functional properties of *G. lucidum* have been extensively studied in food and medicine. His antioxidant, anti-aging and other functions have a great future in cosmetics, and other effects are also promising. The cosmetic industry is a sunrise industry. People are now more aware of green safety, and *G. lucidum* has a variety of effective activities, which can carry out multi-angle and multi-dimensional skin care[97-100]. As a kind of cosmetic with developmental potential and efficacy, *G. lucidum* cosmetics must be continuously and deeply researched, developed, and applied. Some cosmetic products containing *G. lucidum* are already available in the market, but some aspects still need to be improved. Thus, in-depth research must be conducted as follows: 1) the efficacy of *G. lucidum* can be targeted to expand the scope of the research and develop more *G. lucidum* cosmetics with effects other than antioxidant and anti-aging; 2) further research should be carried out on GLPs, total triterpenoids, as well as proteins, nucleosides, and alkaloids to better apply their bioactive ingredients to cosmetics; 3) the additive mode of *G. lucidum* cosmetics is mostly in the form of extracts, which can be processed by biotransformation, which is a green and safe method; 4) cosmetic products and other disciplines can be combined, such as bioengineering and pharmaceutical engineering, to create safer and more effective *G. lucidum* cosmetics. Overall, the research of *G. lucidum* in cosmetics remains to be further studied, but cosmetics with multi-functionality is still worthy of attention, and its market and potential are still considerable.

Conflicts of interest

The authors declare that there are no conflicts of interest in this work.

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