INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES
[ISSN: 0975-4725; CODEN(USA): IJPS00]
Journal Homepage: https://www.ijpsjournal.com

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Review Article

Health Benefits of *Ganoderma Lucidum* (Reishi Mushroom)

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ARTICLE INFO

Published: 01 Oct 2025
Keywords:
Mushrooms; Functional foods; Bioactive compounds; Medicinal properties; Nutritional value; Sustainable development
DOI:
10.5281/zenodo.17241382

ABSTRACT

This review highlights the nutritional, medicinal, and additional applications of mushrooms, emphasizing their long-standing significance in human culture as food, medicine, folklore, and even in spiritual traditions. Traditionally valued for their unique taste and texture, mushrooms are now increasingly recognized as functional foods with health-promoting benefits and as promising sources for drug discovery. Numerous higher fungi contain bioactive compounds with diverse pharmacological activities, including antitumor, Neuro-Protective Effects, Anti-HIV Activity , antiviral, antibacterial, a. Nutritionally, mushrooms occupy a position between vegetables and meat, providing an excellent source of proteins, vitamins, and minerals, while being low in fat (2–8%), which makes them an ideal low-calorie dietary component, particularly beneficial for individuals suffering from hypertension, atherosclerosis, diabetes, and obesity. Beyond their nutritional and therapeutic value, mushrooms also contribute to environmental applications such as bioremediation and water purification, where fungal systems are employed to reduce microbial contamination. Overall, the review underscores the untapped potential of mushrooms in developing countries, where their cultivation and utilization could enhance public health while also contributing to economic growth. It is anticipated that this synthesis will enrich current knowledge and stimulate further exploration of mushrooms as versatile resources for both human health and sustainable development [1]

INTRODUCTION

Ganoderma lucidum (G. lucidum), a member of the Ganodermataceae family, is traditionally known as “Lingzhi” in China and “Reishi” in Japan. It has earned titles such as the “mushroom of immortality,” the “mushroom of spiritual potency,” and the “plant of spirit” due to its revered status in ancient medicine [2]. The antitumor properties of polysaccharides derived from *Ganoderma lucidum* were first identified in studies involving subcutaneously transplanted sarcoma-180 ascites in mice. The biologically

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

active compounds were primarily β-D-glucans, with the branched (1→3)-β-D-glucans showing the strongest antitumor activity. Research suggests that these polysaccharides exert their effects through the complement receptor type 3 (CR3 receptor), which specifically recognizes and binds β-glucan structures[3].Because of its remarkable therapeutic properties—including its tonic effects, ability to enhance vital energy, and role in supporting cardiac health—Ganoderma lucidum has been employed in Traditional Chinese Medicine (TCM) for thousands of years as a remedy to promote overall well-being, vitality, youthfulness, and longevity [4]. The pharmacological efficacy of *G.* lucidum is primarily attributed to its potent immune-modulating properties, which enhance overall immune function. This activity is due to the presence of more than 200 bioactive compounds, broadly classified into water-soluble, organic-soluble, and volatile components. Key bioactive constituents include polysaccharides, polysaccharide-peptide complexes, β-glucans, lectins, organic germanium (Ge), adenosine, triterpenoids, and nucleosides—each contributing distinct medicinal property [5]. Reishi mushroom (G*a*noderma lucidum), also known as *ling Z*hi, has been revered for over 2,000 years in Chinese and Japanese traditions for its medicinal and spiritual significance. It was valued by Taoist monks for promoting calmness, longevity, and vitality, and in Japan recognized as the most important medicinal polypore. Historical texts such as the Shen Nung Ben Cao Jing (206 BC–AD 8) classified reishi as a "superior tonic," believed to prolong life, enhance *qi*, prevent aging, and improve heart health, memory, and overall vitality. Often called the "mushroom of immortality," it was also regarded as a means of cultivating both health and virtue [6]. *Ganoderma lucidum* has gained significant attention for its pharmacologically active components. Studies have shown that its extracts, particularly polysaccharides and triterpenoids, exhibit antitumor and immunomodulatory activities. Polysaccharides from *G. lucidum* have been reported to enhance immune function both in vivo and in vitro, while its antitumor effects are thought to result from immune-mediated mechanisms or direct cytotoxic actions [7]. Ganoderma lucidum is officially documented in both the American Herbal Pharmacopoeia and the Chinese Pharmacopoeia. In the Chinese Pharmacopoeia, it is described as a medicinal agent that replenishes Qi (vital energy in Traditional Chinese Medicine), calms the mind, and alleviates respiratory disorders such as cough and asthma. Accordingly, it is prescribed for conditions including dizziness, insomnia, palpitations, and dyspnoea [8]. Consequently, Ganoderma lucidum has traditionally been employed in the management of a wide range of chronic disorders, including liver disease, kidney inflammation, high blood pressure, arthritis, migraine, sleep disturbances, bronchitis, asthma, diabetes, and various forms of cancer [9]. Ganoderma lucidum is rich in diverse bioactive constituents, including glycoproteins, polysaccharides, triterpenoids, meroterpenoids, sesquiterpenoids, steroids, alkaloids, as well as benzopyran and benzoic acid derivatives [10]. Analysis of the non-volatile components of Ganoderma lucidum reveals it contains 1.8% ash, 26–28% carbohydrates, 3–5% fat, 59% Fiber, and 7–8% protein. Its major bioactive constituents—polysaccharides, triterpenes, and peptidoglycans—are present in the fruiting body, mycelium, and spores. Different extraction methods and plant parts yield various preparations, most notably ethanol and aqueous extracts, as well as extracts from the mycelia and spores. Among these, polysaccharides, triterpenes, and peptides are recognized as the principal compounds contributing to its anti-aging and related biological activities [11] Ganoderma lucidum

polysaccharides (GLP) exert anticancer effects by suppressing tumour growth and metastasis while simultaneously enhancing host immune responses. These activities are mediated through multiple mechanisms, including antiproliferative, pro-apoptotic, anti-metastatic, anti-angiogenic, anti-inflammatory, antioxidant, and immunomodulatory pathways [12].

HABITAT:

Ganoderma lucidum typically grows annually on a wide range of dead or dying deciduous trees such as oak, maple, elm, willow, sweet gum, magnolia, and locust, though it is less commonly found on conifers in Europe, Asia, and the Americas. In the Orient, it predominantly occurs on plum trees. It is also observed on stumps near the soil surface and occasionally on soils formed from buried roots [13].

TAXONOMY:

The taxonomical profile and physical appearance of Ganoderm lucidum mushroom was shown in below table 1 and figure 1 respectively,

Table 1: The taxonomical profile of Ganoderm lucidum mushroom

Synonyms	Reishi Mushroom
Botanical name	Ganoderma lucidum
Kingdom	Fungi
Phyllum	Basidiomycota
Class	Agarocomycota
Order	Polyporels
Genus	Ganoderm
Species	Ganoderm Lucidum

Figure 1: Ganoderma lucidum

PHYTOCHEMICAL CONSTITUENTS OF GANODERM LUCIDUM MUSHROOM

Ganoderma lucidum, commonly known as Reishi or Lingzhi mushroom, contains a wide range of phytoconstituents responsible for its medicinal properties. The most important group is polysaccharides, particularly β-D-glucans and heteropolysaccharides, which exhibit strong immunomodulatory, antioxidant, and anti-tumor activities. Another major class is the triterpenoids, including ganoderic acids, lucidenic acids, ganoderiols, and ganodermanontriol, which are lanostane-type compounds known for their anticancer, hepatoprotective, anti-inflammatory, and cholesterol-lowering effects. Proteins and peptides, such as Ling Zhi-8 (LZ-8), fungal immunomodulatory proteins, and lectins, contribute to immune regulation, antimicrobial action, and anti-allergic properties. The mushroom

also contains sterols like ergosterol and fungisterol, which act as antioxidants and cholesterol-lowering agents. In addition, phenolic compounds (caffeic acid, gallic acid, ferulic acid) and trace flavonoids provide antioxidant and neuroprotective effects. Nucleotides and nucleosides such as adenosine and guanosine support cardiovascular health by inhibiting platelet aggregation and promoting vasodilation. Other minor constituents include alkaloids, choline, betaine, organic acids, essential amino acids, and minerals like selenium and zinc. Altogether, these bioactive components make Ganoderma lucidum a potent medicinal mushroom with anticancer, immunomodulatory, hepatoprotective, hypoglycaemic, and neuroprotective benefits.

PHARMACOLOGICAL POTENTIAL OF GANODERM LUCIDUM MUSHROOM

1. Anti-HIV activity:

Human immunodeficiency virus (HIV) is a globally prevalent and highly transmissible pathogen responsible for acquired immunodeficiency syndrome (AIDS). Current therapeutic strategies for HIV infection do not eradicate the virus but instead delay the progression to AIDS [14]. Studies have shown that several bioactive compounds derived from Ganoderma lucidum possess inhibitory activity against HIV progression. Isolated triterpenoids such as ganoderic acid β, lucidumol B, ganodermanondiol, ganodermanontriol, and ganolucidic acid A demonstrated potent anti-HIV-1 protease activity, with IC_{50} values ranging from 20 to 90μM [15]. In an early investigation, El-Mekkawy and colleagues isolated thirteen distinct compounds from Ganoderma lucidum, all of which demonstrated potent inhibitory activity against HIV-1 protease [16].

Laccase enzymes isolated from Ganoderma lucidum have been reported to exert inhibitory effects on HIV-1 reverse transcriptase, and although further research is needed to fully validate the potential of Ganoderma lucidum isolates as anti-HIV agents, triterpenoids appear to be the primary class of compounds responsible for the observed antiviral activity. A mathematical analysis of spontaneous mutation probabilities within the HIV-1 genome revealed that mutational emergence is not uniformly distributed but instead depends on gene length, functional constraints, and structural complexity. Among the viral genes, the pol gene exhibited the highest probability of spontaneous mutations (0.098; 32.8%), consistent with its large size and enzymatic roles, followed by the env gene (0.077; 28%), reflecting the high variability of envelope glycoproteins, particularly gp120, while accessory genes such as tat, vpr, and vpu showed significantly lower mutation probabilities (<3%), indicating stronger conservation and essentiality for replication fitness. Within pol, reverse transcriptase (RT) emerged as the most mutation-prone region (0.067; 22.63%), whereas integrase (0.015) and protease (0.01) exhibited lower mutation probabilities, a finding of clinical importance since RT inhibitors form the backbone of first-line antiretroviral therapy but are highly impacted by resistance due to RT's mutability, while the lower variability of protease aligns with the sustained efficacy of protease inhibitors that typically require multiple mutations for resistance. Analysis of structural genes further highlighted variability, with the gag-encoded capsid protein P24 (0.022; 7.54%) showing higher mutation probability than matrix (P17) or nucleocapsid proteins (P7, P6), whereas in env, gp120 (0.047; 15.7%) was more susceptible to mutation compared with gp41 (0.034; 11.26%), consistent with gp120's antigenic diversity enabling immune evasion and

gp41's conservation due to its critical role in viral fusion [17].

Docking studies on Ganoderma-derived compounds such as ganolucidic acid A, ganoderat acid B, ganoderat acid β, and ganodermanondiol revealed significant inhibitory potential against HIV-1 protease (HIV-1 PR) and Plasmodium falciparum plasmepsin I (PM I). Among them, ganoderat acid B and ganodermanondiol demonstrated strong binding affinities through multiple hydrogen bonds with catalytic residues Asp25, Thr26, Gly27, and Ile50 in HIV-1 PR, comparable or superior to the standard inhibitor nelfinavir. Similarly, in PM I, these compounds interacted with the catalytic Asp32 and Asp215 residues, with ganodermanondiol exhibiting higher affinity than the reference inhibitor KNI-10006. Statistical analysis confirmed that ganolucidic acid A and ganodermanondiol showed the closest similarity in binding modes to the standard inhibitors, indicating moderate to substantial agreement, whereas ganoderat acid B and β displayed weaker associations. Collectively, these findings suggest that specific Ganoderma triterpenoids, particularly ganodermanondiol and ganolucidic acid A, hold promise as competitive inhibitors of viral and parasitic proteases, supporting their potential as leads for novel antiretroviral and antimalarial drug development [18].

2. Anti-Oxidative effect:

Free radicals and reactive oxygen species (ROS), generated as by-products of various metabolic pathways, can inflict significant cellular damage via oxidative reactions. Prolonged exposure to elevated levels of these species contributes to accelerated aging and the development of numerous age-related diseases [19]. Zhu et al. investigated the antioxidant properties of Ganoderma lucidum using in vitro assays. The crude mushroom material was subjected to hot water extraction, followed by separation of the aqueous extract into terpene- and polysaccharide-rich fractions. Evaluation of these fractions revealed that the terpene fraction exhibited the strongest antioxidant activity. This fraction was found to be particularly enriched with ganoderic acids A, B, C, and D, lucidenic acid B, and ganodermanontriol [20].

3. Neuro-Protective effects:

In recent years, increasing attention has been directed toward the detrimental effects of oxidative stress in the human body. Oxidative stress is recognized as a major contributing factor in the progression of several neurodegenerative disorders, including Parkinson's disease, Huntington's disease, amyotrophic lateral sclerosis, and Alzheimer's disease (AD). One therapeutic strategy for AD involves regulating acetylcholine levels in the brain by inhibiting acetylcholinesterase (Ache) [5]. Zhang et al. demonstrated that triterpenoid compounds derived from Ganoderma lucidum promoted neuronal survival and alleviated fatigue. Moreover, research on the neuroprotective potential of G. lucidum suggests that its continuous intake may slow the progression of Alzheimer's disease.[17].

Research into acetylcholinesterase (AChE) inhibition by Ganoderma lucidum has demonstrated that both aqueous polysaccharide extracts and supercritical CO_2 (SC-CO_2) extracts exert inhibitory effects, with inhibition percentages recorded up to 22.54% [21]. Hasnat et al. investigated the acetylcholinesterase (AChE) inhibitory potential of hot water extracts of Ganoderma lucidum. Their findings revealed that crude aqueous extracts produced nearly 50% inhibition of AChE activity. This relatively high level of inhibition was attributed to the presence of bioactive constituents such as polysaccharides,

phenolic compounds, and flavonoids, which are well-documented for their AChE inhibitory properties [22].

Alzheimer's disease (AD) is a chronic progressive neurodegenerative disorder with no effective cure, and current therapies mainly focus on improving cognition by controlling acetylcholine levels through acetylcholinesterase (AChE) inhibition, although such treatments often cause side effects. Alternative strategies using compounds from Ganoderma lucidum (G. lucidum) have shown promise in mitigating AD progression. Studies have reported that triterpenoid mixtures from G. lucidum enhance neuronal viability, reduce fatigue, and improve memory and learning in animal models, with rats fed water extracts demonstrating better spatial perception and shorter search times (Rahman et al., 2020). Furthermore, extracts of G. lucidum inhibit AChE activity by 22.5% to 50% (Hasnat et al., 2013; Cör et al., 2014), while alcoholic extracts were found to regulate DNA methyltransferases and DNA methylation, pathways associated with slowing AD progression (Lai et al., 2019). Active compounds such as ganoderic acid, lucidone A, meroterpenoids, and alkaloids have also exhibited strong neuroprotective effects against corticosterone-induced PC12 cell damage and anti-inflammatory effects by reducing LPSinduced nitric oxide production in RAW264.7 macrophages (Lu et al., 2019). Collectively, these findings highlight G. lucidum as a potential therapeutic and preventive agent for Alzheimer's disease by exerting neuroprotective, anti-inflammatory, and epigenetic regulatory effects. [23]

4. Antimicrobial effects:

The methanolic extract of Ganoderma lucidum (MEGL) demonstrated notable multifunctional bioactivities, including antioxidant, antidiabetic, and antibacterial effects. In free radical scavenging (DPPH) assays, MEGL exhibited concentration-dependent antioxidant activity comparable to the synthetic standard butylated hydroxytoluene (BHT), achieving ~94% inhibition at 500 µg/mL versus ~95% for BHT, with EC50 values of 22.14 µg/mL and 16.26 µg/mL, respectively, indicating potent natural antioxidant potential largely attributed to polysaccharides and their complexes that act as proton donors and inhibit lipid peroxidation. In terms of antidiabetic effects, MEGL showed dose-dependent α-amylase inhibition, reaching ~81% suppression at 500 µg/mL compared with ~88% by acarbose, with EC50 values of 22.60 µg/mL and 14.45 µg/mL, respectively, suggesting moderate activity likely linked to ganoderic acids and polysaccharides and supporting its potential in controlling postprandial hyperglycaemia. Regarding antimicrobial properties, MEGL displayed significant dose-dependent inhibition of Staphylococcus aureus at concentrations between 30–240 mg/mL, though no activity was observed at lower levels (5–10 mg/mL); these results corroborate earlier findings where methanolic, aqueous, and organic extracts of G. lucidum were also effective against S. aureus, E. coli, and P. aeruginosa, with antibacterial activity attributed to a synergistic action of polysaccharides, phenolics, triterpenoids, glycosides, and tannins. Collectively, these findings highlight MEGL as a promising natural source of bioactive compounds with strong antioxidant capacity, moderate hypoglycaemic potential, and effective antibacterial activity, underscoring its value for nutraceutical and therapeutic applications [24].

Polysaccharide fractions obtained from Ganoderma lucidum fruiting bodies cultivated on different sawdust substrates (birch, maple, alder with wheat bran supplementation) were evaluated for antibacterial activity against eight reference

strains using the micro-dilution broth method. Thirty-six samples from four strains (GL01–GL04) were analysed. Substrate type influenced polysaccharide yield: GL04Kl3 (grown on maple sawdust with 30% bran) exhibited the highest polysaccharide content, while GL03 showed the lowest. Growth parameters such as substrate pH, C:N ratio, incubation temperature, and carbon source type significantly impacted polysaccharide production. Antibacterial assays revealed broad-spectrum activity of all polysaccharide samples, with MIC values ranging from 0.62 to 5.0 mg/mL and MBC values of 2.5–5.0 mg/mL, indicating bactericidal potential (MBC/MIC ratio: 1–8). Among tested strains, Micrococcus luteus was the most sensitive (MIC = 0.62–1.25 mg/mL). No major differences were observed between strains or cultivation substrates in terms of antibacterial efficacy, suggesting a consistent moderate inhibitory effect. Overall, these findings confirm that polysaccharides are the key bioactive components responsible for the broad, moderate antibacterial spectrum of G. lucidum, effective against both Gram-positive and Gram-negative bacteria, with stronger activity against Gram-positive strains like M. luteus.[25]

The antibacterial potential of polysaccharide fractions isolated from G. lucidum fruiting bodies cultivated on different sawdust substrates was evaluated against eight reference bacterial strains using the broth micro-dilution method. Results demonstrated a broad spectrum of activity covering both Gram-positive and Gram-negative bacteria, with MIC values ranging from 0.62 to

5.0 mg/mL and MBC values between 2.5 and 5.0 mg/ml. Micrococcus luteus was found to be the most sensitive strain (MIC = 0.62–1.25 mg/mL), while other Gram-positive and Gram-negative strains displayed moderate susceptibility. The low MBC/MIC ratio (1–8) confirmed that the polysaccharide fractions act as bactericidal agents rather than merely bacteriostatic. This indicates that G. lucidum polysaccharides contribute significantly to its antimicrobial properties, though their strength remains moderate compared to standard antibiotics. Similar findings have been reported by Yoon et al. and other authors, confirming the consistent broad-spectrum but moderate antibacterial activity of G. lucidum polysaccharides.[26]

The antibacterial activity of EPS extracted from G. lucidum was evaluated against seven pathogenic bacteria including E. coli, S. aureus, Proteus sp., B. subtilis, P. aeruginosa, Klebsiella sp., and B. cereus. Both malt and basal medium-derived EPS exhibited broad-spectrum antibacterial effects. The most pronounced inhibition was observed against Bacillus cereus, with inhibition zones of 23 ± 0.61 mm (malt EPS) and 18 ± 0.38 mm (basal EPS). Moderate inhibition was recorded against S. aureus and E. coli, while comparatively lower activity was observed against P. aeruginosa. These findings indicate that EPS from G. lucidum possesses significant antimicrobial activity, likely attributed to its carbohydrate-rich and sulphate-containing structural components, which enhance membrane interaction and bacterial growth inhibition.[27]

5. Antiviral activity:

Several studies indicate that Ganoderma lucidum (G. lucidum) possesses strong antiviral potential, making it a promising candidate for developing novel antiviral agents. Genomic and pharmacological investigations have shown that G. lucidum can act against a wide range of viruses, including herpes, influenza, Epstein–Barr, hepatitis, dengue, enterovirus 71 (EV71), HIV, and even emerging pathogens like SARS-CoV-2. Liposome-encapsulated polysaccharides (Lip-GLP) from G. lucidum enhanced immune

responses against porcine circovirus type 2 by modulating CD4+/CD8+ ratios and stimulating cytokine secretion (Liu et al., 2019), while computational and in vitro studies revealed triterpenoids such as ganodermanotriol as potential inhibitors of dengue virus protease (Bharadwaj et al., 2019) and certain triterpenoids capable of blocking EV71 adsorption (Zhang et al., 2014). Additionally, protein-bound polysaccharides and solvent extracts of G. lucidum exhibited strong inhibitory effects on HSV-1, HSV-2, influenza A, and vesicular stomatitis virus (Eo et al., 2000). Isolated compounds including ganoderic acids, lucidumol B, ganodermanondiol, and ganolucidic acid A demonstrated inhibitory activity against HIV-1 protease (El-Mekkawy et al., 1998; Min et al., 1998), while ganoderic acids also inhibited hepatitis B virus replication (Wachtel-Galor et al., 2011; Sharma et al., 2019). More recently, nutraceuticals such as triterpenoids, polysaccharides, and β-glucans from G. lucidum were reported to enhance protective immune responses against SARS-CoV-2, with studies showing increased lymphocyte levels and impaired coronavirus replication and absorption (Hetland et al., 2021; Al-jumaili et al., 2020). Collectively, these findings suggest that G. lucidum triterpenoids and polysaccharides exert direct antiviral effects while also boosting host immunity, highlighting its therapeutic potential as a broad-spectrum antiviral agent [28].

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HOW TO CITE: Bhavana M R, Dr. Suresh B S, Siddaraju, Jeevan Kumar T S, Sindhu Y P, Health Benefits of Ganoderma Lucidum (Reishi Mushroom), Int. J. of Pharm. Sci., 2025, Vol 3, Issue 10, 92-101. https://doi.org/10.5281/zenodo.17241382