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Bioactive Compounds of *Ganoderma lucidum* and their Therapeutic Applications

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Abstract
Ganodermalucidum(GL), a renowned medicinal mushroomhas been traditionally used in Korea, China and Japan to promote longevity, enhance vitality, and treat various ailments. It is referred to as "God's herb" in ancient China, and has been cultivated extensively on sawdust and wood logs in response to demand in global market. Extensive *in vivo* and *in vitro* investigations have elucidated the manifold metabolic activities of GL. It has been found to contain a wide array of biochemical compounds such as fatty acids, triterpenoids, nucleosides, polysaccharides, amino acids, proteins, and enzymes, all of which possess significant pharmacological properties. Triterpenoids and polysaccharides from*G. lucidum* have exhibited antiangiogenic, cytotoxic, anti-allergic, hepatoprotective, antioxidant, anti-hypertensive, hypocholesterolemic, hypoglycemic, antimicrobial, anti-inflammatory, antitumor, immuno-modulatory, and antihistamine effects. *G.lucidum*alongwith array of medicinal properties also possess certain limitations to be addressed. Clinical trials frequently encounter obstacles concerning the absence of pure constituents and the precise identification of obtained compounds, which can pose challenges in the research process. Furthermore, most of the included studies were of small scale, raising concerns about their methodological quality. Although *Ganoderma* has shown promising potential in cancer prevention and treatment, it should not be considered as a first-line therapy for cancer.*G. lucidum*extracts and active compounds formulation have undergone patenting, development, and application as cosmeceuticals, pharmaceuticals and nutraceuticals. This review highlights the potential of *G. lucidum*as an untapped natural medicine in the management of emerging infectious diseases. However, this study does not delve into the specific chemical compounds or mode of action of each bioactive component against different emerging diseases.

Key words:*Ganodermalucidum*,bioactive compounds, medicinal, therapeutic, properties

1 Introduction

Nutraceuticals, also known as functional foods, consist of natural substances that are extracted from various tissues and offer a broad spectrum of beneficial effects alongside their nutritional content. Traditional Chinese medicine has long utilized extracts derived from medicinal mushrooms. These mushrooms' fruiting bodies, spores, and mycelium contain numerous bioactive constituents, which contribute to their medicinal properties [1]. *G.lucidum*, a mushroom that has been known for more than 2,400 years, is renowned for its ability to enhance overall health, promote longevity, and support cognitive development. Additionally, it has been acknowledged as a potent immune system enhancer, offering robust protection for the entire body [2]. The mushroom contains a variety of substances such as fatty acids, sterols, nucleotides, peptides, polysaccharides, steroids, triterpenoids and proteins. These components possess multiple medicinal properties and effects[3], [4]. The polysaccharides and triterpenoidsare the primary bioactive compounds found in *G. lucidum*with significant pharmacological activity . Its bioactive compounds indicate, anti-viral activity [5], [6], antitumor [7], hypolipidemic[8], anti-inflammatory [9], [10], antiatherosclerotic, anti-fungal, and antimicrobial (Karwa, 2012 n.d.). Numerous studies have demonstrated that *G. lucidum*has immunostimulatory and potent antioxidant properties. It is now being utilized as a complementary therapy to combat cancer and to mitigate the side effects of chemotherapy [12]. *G. lucidum*polysaccharides (GLPs) possess a variety of biological activities, including but not limited to anticancer, immuno-modulatory, anti-inflammatory, antineurodegenerative, anti-diabetic, and antibacterial effects. β-d-glucans are widely recognized for their biological and physiological activities [2]. Triterpenoids exhibit a range of beneficial effects, including, antihistaminic properties, antiangiogenic activity, hepatoprotective, and antihypertensive, as well as antitumor and hypocholesterolemic. Extracts of *G. lucidum*contain more than a hundred triterpenoid compounds, which are classified as Ganoderma acids or Ganoderma alcohols. Lucidenoic acids are abundant in several triterpenoids[13].

Fig.1 *Ganodermalucidum*

2 Bioactive Compoundsof *G.lucidum*

2.1 Triterpenoids

G. lucidum's fruiting bodies, spores, and mycelia have been found to contain over 200 confirmed triterpenoids[14]. Thesetriterpenoids are typically divided into two categories: Ganoderma alcohols (containing carboxylic side chain) and Ganodermaacids (without carboxylic side chain). The majority of these triterpenoids are lanostane-type, with some being classified as lucidenic acids [15], [16]. *G. lucidum*triterpenes are classified into several subgroups depending upon their side chains and functional groups, including ganolactone, ganoderiol, ganoderone, ganoderal and ganoderic acid [14], [15]. Various ganoderic acids, such as B, F, C and GA-A are present in *G. lucidum*. Spores contain more terpenoids as compared to other parts of *G. lucidum*[17], [18]. The bioactive compound production can be affected by the location and the cultivation condition of Ganoderma[19], [20].

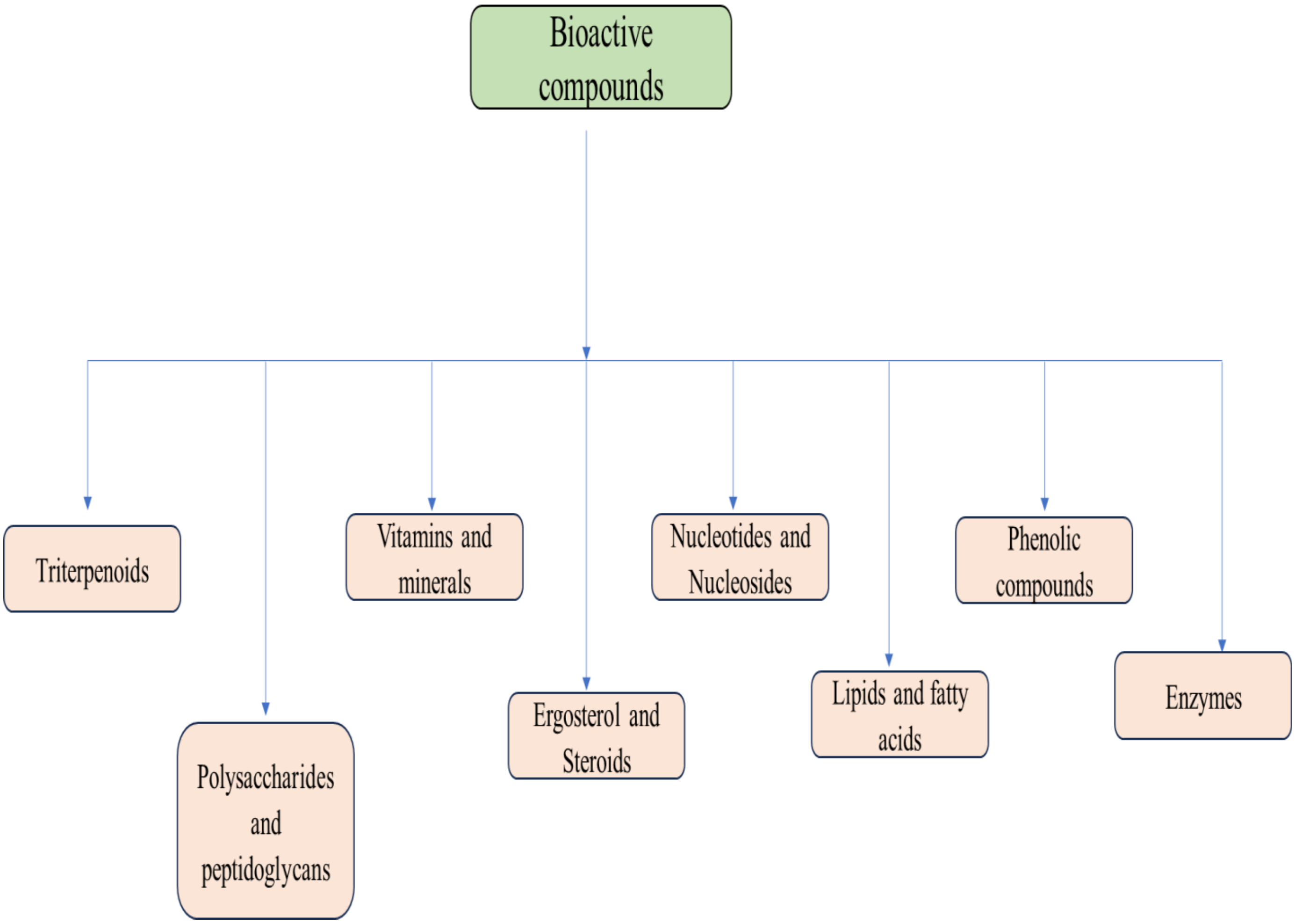

Fig.2 Various Bioactive Compounds of *G. lucidum*

2.2 Polysaccharides and Peptidoglycans

Numerous studies have reported the presence of more than hundred types of polysaccharides in *G. lucidum*. It has been found to be an excellent source of polysaccharides and glycopeptides. Multiple monosaccharides linked by glycosidic bond forms polysaccharides and most of the polysaccharides in *G. lucidum*belong to the β-glucan group. These β-glucans have a linear β-(1,3)-D-glucopyranosyl groups backbone having C-6 position varying branching [18], [21]. Different growth phases of *G. lucidum*exhibit various effects on its polysaccharides, molecular weights, structures, and components. The mycelium of *G. lucidum*contains highest amount of polysaccharides, while the fruiting body has the lowest content. Fruiting bodies contains galactose and glucose as a primary sugars, while mycelium and spores have glucose as main monosaccharide. The fundamental structure of *G. lucidum*polysaccharides (GLPs) consists of β-(1→3)-D-glucan with (1→6)-β-D-glucosyl branches having high molecular weight, and rhamnose, galactose, glucose, and mannose are primary sugar components [2], [22].

2.3 Ergosterol and Steroids

Sterols are triterpenoid derivatives, but *G. lucidum* contain 26-oxygenosterols, 24-methylcholesta-7, 8,9-epoxyergosta-5,22-dien-3,15-diol, 22-trien-3-ol and ergosterol[14], [23], [24]. Vitamin D precursor ergosterol is very essential in pharmaceuticals industries. Ergosterol is required for maintaining the fungal cell membrane integrity, producing cellular energy, and is a important biomass production parameter [25].

2.4 Fatty acids and Lipids

*G. lucidum*contains phosphatidic acids, which are lipids that are not present in significant quantities in living organisms. However, theyhelp in transporting materials across membranes andshielding the body from harm and fending off infections amidst the occurrence of inflammation. Due to the presence of these lipids, *G. lucidum* is considered crucial medicinal mushroom species [26], [27]. Stearic acid, linoleic acid, oleic acid, and Palmitic acid are fundamental fatty acids of *G. lucidum*. Fatty acids present in spores have been found to inhibit the proliferation of tumor cells. The highest inhibitory property was found in Nonadecanoic acid followed by heptadecanoic acid, while potent apoptotic agents are stearic acid and palmitic acid [28]–[30].

2.5 Enzymes

*G. lucidum*contain various enzymes, such as β-N-Acetylhexosaminidase, β-1,3-glucanase, glutamic protease, endo-β-1,3-glucanase, and α-1,2-mannosidase. Glutamic protease is the predominant protein enzyme present in extracts derived from*G. lucidum*.[31], [32].

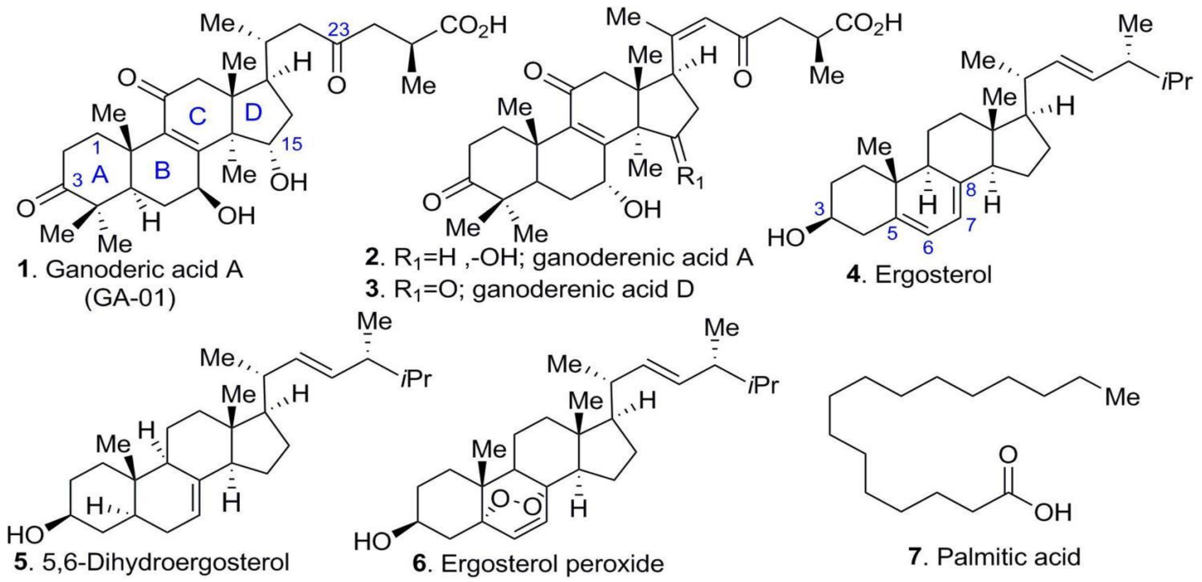

Fig.3Structure of Bioactive compounds of *G. lucidum*[33]

2.6 Nucleotides and Nucleosides

Nucleotides and nucleosides hold significant importance as nitrogen-containing compounds help in regulating hemopoiesis and metabolism. Researchers have studied that *G. lucidum*harbors nucleosides, including, thymidine, cytidine, guanosine, adenosine, uridine, and inosine, as well as nucleotides like hypoxanthine, adenine,thymine, uracil and guanine . Adenosine extracted from *G. lucidum*has demonstrated the ability to inhibit platelet aggregation and safeguard against cardiac arrests and thrombosis[34].

2.7 Vitamins and Minerals

*G. lucidum*contain various types of vitamins, including vitamins C, B6, B1, D, B2, β-carotene and E. Additionally, numerous mineral elements like potassium, arsenic, calcium, carbon, phosphorus, sodium, chromium, zinc, iron, magnesium have been identified [32], [35].

2.8 Phenolic compounds

Phenolic compounds, researched in *G. lucidum*, can be divided into two groups: polyphenols and phenolic acids. Some instances of phenolic acids comprise syringic acid, chlorogenic acid, gallic acid, and benzoic acid, on other hand tannins, flavonoids, and stilbenes are among the polyphenols found in *G. lucidum*. These compounds have been confirmed to be present in *G. lucidum*of significant medicinal importance [18], [36], [37].

3 Therapeutic properties of *G. lucidum*

3.1 Antioxidant Activity

Under normal physiological conditions, there is a balance between the production of reactive oxygen species (ROS) and their elimination through the system of scavenging free radicals, indicating a harmonized system. Nonetheless, elevated ROS levels can disrupt the equilibrium of redox and result in oxidative stress to tissues. Oxidative stress resulting from DNA, lipid and protein damage which is caused by elevated levels of ROS is crucial in diseases progression and onset. Properties like antioxidant and prooxidative of *G. lucidum*, have potentiality to be used in trearmentof diseases [38], [39]. The polysaccharides derived from *G. lucidum*have demonstrated antioxidant activity, aiding in the protection of tissues against the harmful effects of ROS and contributing to maintain oxidative balance of body[40], [41]. Chinese Food and Drug Administration (CFDA). Currently,this is only used in China to treat conditions such as muscular dystrophy, dermatitis, and polymyositis[39], [42]. Through in vivo experiments, it has been observed that polysaccharides derived from *G. lucidum*possess anti-inflammatory properties and provide protection against oxidative stress in different organs, such as the skeletal system, spleen, muscles, liver, and heart.

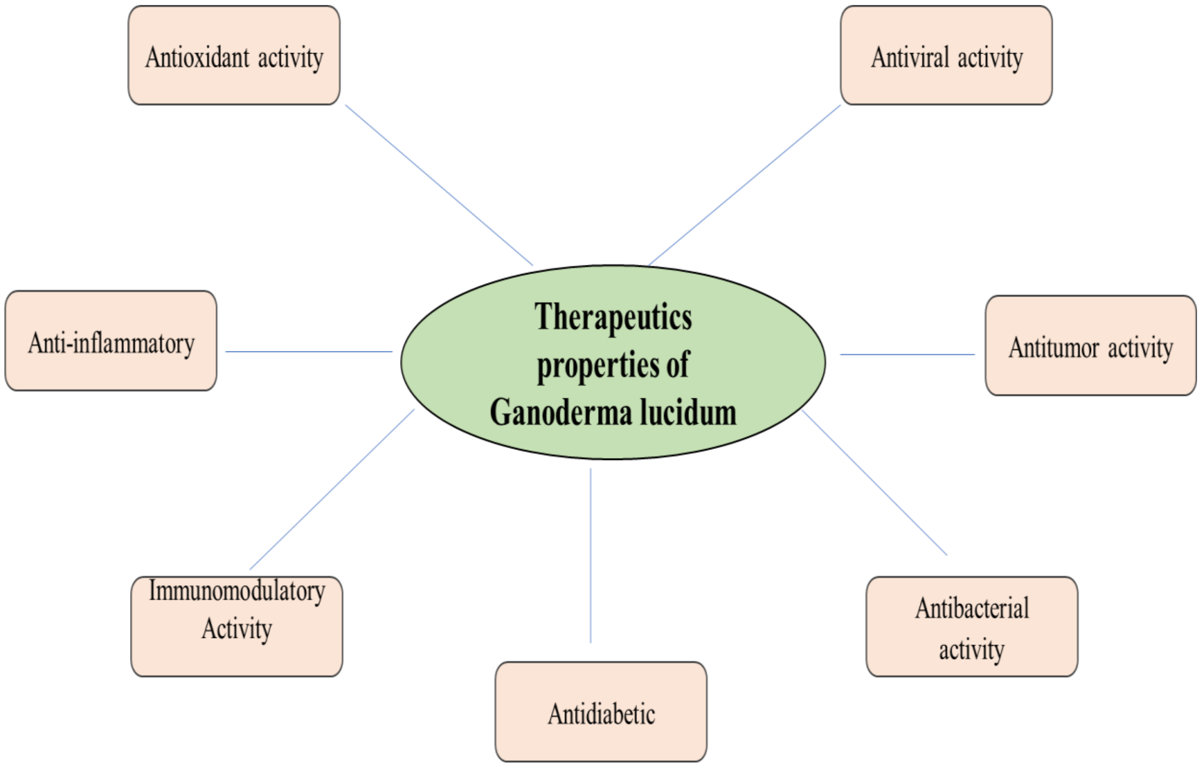

Fig. 4 Different Therapeutic Potentials of *G. lucidum*

A medicine containing a extract of *G. lucidum*polysaccharides spores has been approved by the These polysaccharides help in synthesis of various enzymes, including catalase, glutathione peroxidase, reduce glutathione, glutathione S-transferase, superoxide dismutase and mitochondrial succinate dehydrogenase to protect the endothelium of blood vessels [38], [43]. On the other hand, these polysaccharides have been found to reduce the activity of enzymes such as xanthine oxidase, myeloperoxidase, cytochrome P450, and nitric oxide synthase (NOS), which have significantly affected vascular endothelium dysfunction and induced atherosclerosis. The role of oxidative stress is evidentin the onset of numerous metabolic diseases,adversely affecting the normal functions of multiple organs,. Prolonged oxidative stress can contribute to aging processes within the body and the emergence of various age-related ailments[44]–[46]. *In vivo* studies have demonstrated that *G. lucidum*polysaccharides have a positive antioxidant effect, which increase enzyme antioxidant activity and reduction in lipid peroxidation level [44], [47]. The antioxidant properties of *G. lucidum*polysaccharides were tested in mice exposed to radiation and rats with cervical carcinoma, and the results varied depending on the dose of GLP used [48], [49]. Additional studies conducted in living organisms have shown that polysaccharides having low molecular weight, more specifically GLP-2 and GLP-1, possessedimmunomodulatory and antioxidantactivity .Cyclophosphamide induced immunosuppressed mice were administered these polysaccharides, has been found to have an increase in white blood cell and lymphocyte counts. This had a beneficial impact on hematopoiesis, the process of blood cell formation. The levels of serum immunoglobulins IgG and IgA were assessed, revealing an increase in IgA levels [50]. This study provided evidence for the immunomodulatory properties of endogenous polysaccharides derived from medicinal mushrooms.

3.2 ImmunomodulatingActivity

Recent clinical and biochemical research have indicated that GPL are powerful immunomodulators. The effects of these polysaccharides are linked to their impact on effector cells, including B and T lymphocytes, dendritic cells, natural killer cells, and macrophages [51]–[53]. These GLPs have capability to enhances proliferation of T and B cells by interacting with Toll-like receptor 4 (TLR4). This interaction leads to signal induction through p38 MAPK pathway, which is also activated by TLR2 receptors [54], [55].Lin *et al*. has research that GLP can activate and fully develop human dendritic cells, originating from monocytes, undergo maturation through the signaling of nuclear factor κ-light-chain-enhancer of activated B cells (NF-kB) and MAPK protein kinases. Furthermore, it has been reported that GLP can augment the chemotaxis and phagocytosis abilities of neutrophils, which involve the phosphorylation of protein kinase, p38 MAPK, phosphatidylinositol 3-kinase (PI3K), proto-oncogene tyrosine-protein kinase Src (Src), and tyrosine kinases [56]. Studies have demonstrated that cellwall polysaccharides extracted from *G. lucidum*can stimulate the production of innate immune cytokines, including interleukin-2, tumor necrosis factor-α, and interferon γ in human peripheral blood mononuclear cells (PBMCs) [57], [58]. Macrophages helps in engulfing the pathogens by responding to chemokines that lure them to the site of tissue injury.The activation of macrophages is primarily regulated by serine-threonine kinases, with Akt1 and Akt2 playing significant role [59]. The polarization of macrophages can be categorized into M1 or M2 based on various factors such as signaling pathways, activation stages, and stimuli within the cellular environment. M1 macrophages, which are classically activated, produce cytotoxic and pro-inflammatory molecules such as interleukin-1β, ROS, tumor necrosis factor-α, chemokines, nitric oxide, and interleukin-6 (IL-6) [60], [61].

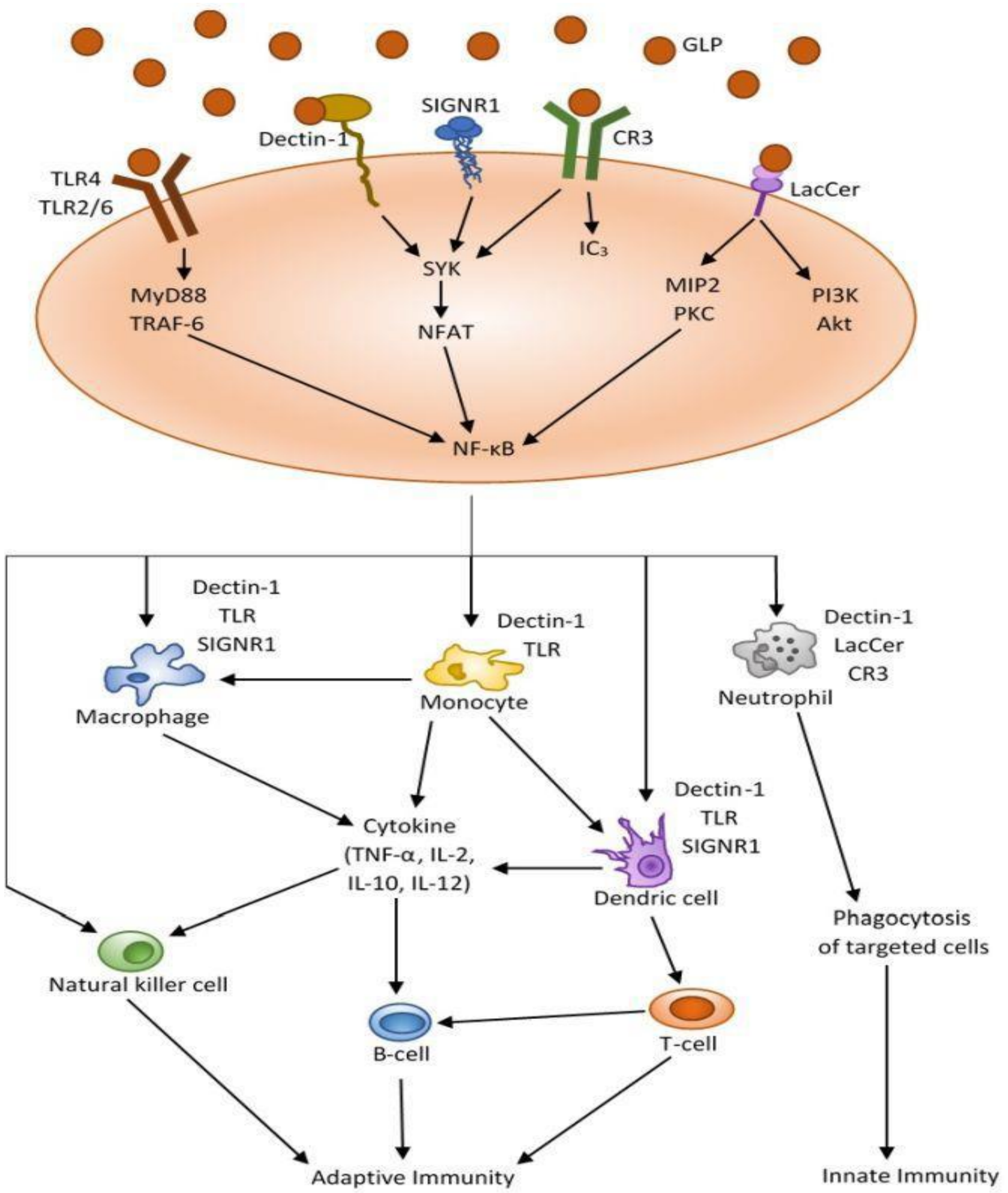

Fig.5 *G. lucidum*PolysaccharidesImmuneActivation mechanism [1]

3.3 Anti-diabetic Property

The impacts of diabetes expose the malfunction and deterioration of numerous organs. Several studies have demonstrated that animals induced with diabetes exhibit elevated levels of oxidative stress, and the imbalance in redox processes is intricately linked to the progression of the disease [62], [63]. The body possesses its own antioxidant systemfor maintaining a equilibrium between the generation of ROS and scavenging of free radicals. The *G. lucidum*derived polysaccharides exerted exogenous antioxidant effects and restored intracellular redox equilibrium by reducing the level of malondialdehyde and inducing expression of enzymes responsible for antioxidant activity. Animal studies involving diabetes induced by streptozotocin have revealed significant impairments in both enzymatic and nonenzymatic antioxidant systems. This involveddiminished function of the free radical scavenging enzymes like superoxide dismutase, glutathione peroxidase, and catalase, along with increased oxidative stress [63]–[66]. Research examining the microscopic alterations in pancreatic β cells has provided evidence of cellular damage in animals experiencing diabetes and oxidative stress. External oxidative stress had a notable impact on the redox equilibrium and resulted in mitochondrial impairment. However, administering ofGLPs to a cohort of animals have maintained mitochondria structure in pancreatic islet cells, effectively reinstating the redox equilibrium. Large amount of generation of ROS within cells leads to detrimental effects on the mitochondrial membrane, protein oxidation, and DNA mutations, ultimately leading to mitochondrial dysfunction [62], [63], [67]. The GLP extract also demonstrated the ability mitigate harm to pancreatic islet cells and to decrease insulin resistance. Furthermore, it effectively reversed the progression of diabetes development and exhibited long-lasting therapeutic effects [63]. The aforementioned studies indicate the need for future clinical trials to investigate the effects of polysaccharides from *G. lucidum.* Factors such as the level of oxidative stress, polysaccharide dosage, and duration of its action on specific tissues should be considered. In recent studies conducted on rats induced with diabetes, it has been observed that the addition of GLP as a supplement leads to a reduction in inflammation and promotes the growth of beneficial intestinal microflora, thereby enhancing the body's defense against infections. These findings have provided valuable insights into the positive impacts of GLP on metabolic regulation and the modulation of intestinal dysbiosis[68], [69].

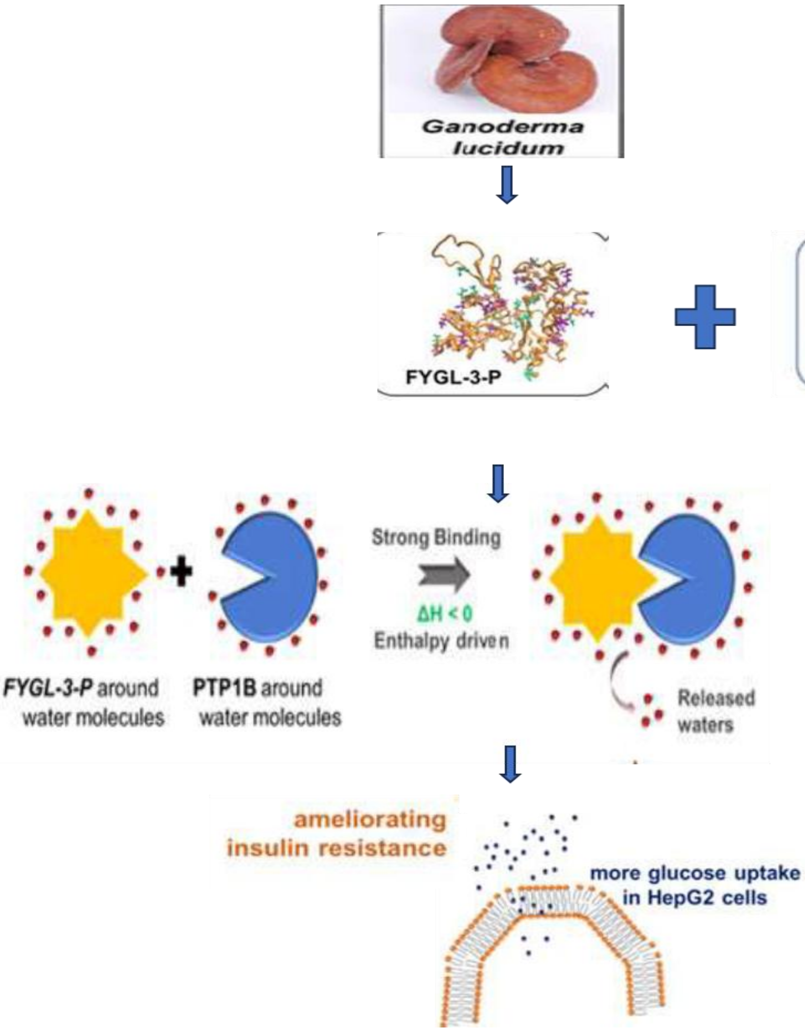

Fig.6Anti-diabetic properties of *G. lucidum*[70]

The formation of advanced glycation end products (AGEs) resulting from nonenzymatic reactions between glucose and proteins or lipids disrupts the biochemical and physiological functions of the body. Existing therapies exhibit limited efficacy, reliability, and notable side effects. Consequently, there is a growing interest in natural remedies. Particularly noteworthy is the findings that GLP are not only safe but also exhibit antioxidant properties comparable to conventional antioxidants [71], [72]. In a study researchers haveshown that *G. lucidum* extract containing proteoglycans FYGL inhibits the PTP1B protein which is insulin negative regulator and *in vivo* decrease the blood glucose level. These proteoglycans ameliorate the PTP1B-induced insulin resistant in HepG2 cells [70]

3.4 Antibacterial activity

Antimicrobial properties are attributed to various compounds present in *G. lucidum*, including terpenes, lectins, and polysaccharides. These compounds exert their effects on the bacterial cytoplasmic membrane. The constituents found in*G. lucidum* exhibit inhibitory effects against gram-negative bacteria and gram-positive bacteria. As an example, the growth inhibition of 15 diverse bacterial species, including both gram-negative and gram-positive types, has been demonstrated by an aqueous extract of*G. lucidum*. Specific compounds, including ganomycin and triterpenoids, exhibit a wide range of antibacterial activity[73].Cultured fluids derived from *G. lucidum*haveexhibited antibacterial properties against bacterial pathogens affecting plants. To assess the anti-proliferative activity, the efficacy of *G. lucidum* extracts was evaluated through employment of methods like microdilution plate method and sulforhodamine B staining method. These findings have demonstrated that all five extracts displayed a significant inhibition zone, with the methanolicextract showing the most potent activity against *Pseudomonas aeruginosa*and *Escherichia coli*. [74]. In a study, a hot water extract of *G. lucidum*was prepared and utilized in the creation of novel kombucha products with potential health benefits. The liquid beverage containing*G. lucidum* exhibited inhibitory effects against *Rhodococcusequi*, *R. equi*, *Staphylococcus epidermidis*, *Bacillus spizizenii*, *B. cereus*. A compound called Ergosta-5,7,22-triene-3β,14α-diol was extracted from*G. lucidum* . This component has been shown to possess notable activity against *Streptococcus pyogens*and Methicillin-Resistant *Staphylococcus aureus*[75], [76]. The researchers have examined different extracts of *G. lucidum*, prepared using acetone, methanol, aqueous extracts and chloroform. They have noticed that these extracts exhibited antibacterial activity against various bacteria, including *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Corynebacteriumdiphtheriae*, *Enterobacteraerogenes*, *Salmonella species*, *Bacillus subtilis*,and *Escherichia coli*[77].

3.5 Anti-tumorActivity

For a tumor to survive, it requires a continuous nutrient supply. The spread of invasive cancer cells occurs through blood and lymph vessels. As a result, it becomes necessary to utilize agents that can hinder angiogenesis. Additionally, factors related to cell adhesion, invasion, and migration must be targeted to control metastasis. Chemotherapy plays a role in inhibiting angiogenesis, thereby reducing blood vessels formation that supply the tumor, thus the nutrient supply to the tumor is diminished [47]. Researchers have demonstrated the chemopreventive and antitumor properties of polysaccharides and triterpenes derived from*G. lucidum* . Various studies have highlighted the efficacy of different compounds extracted from*G. lucidum*for acting as inhibitors of cancer growth on diverse cancer cell lines like, lung [78], colon, pancreas [79], breast [80], [81], skin [82], prostate [83] and liver[77]. GA-H and GA-A have been found to inhibit the breast cancer cells growth and invasion by influencing the signaling pathways of AP-1 and NF-κB. Additionally, GLPs have capacity to enhance the immune response of the host by stimulating macrophages, natural killer cells, and T lymphocytes. In a study by Pan *et al.* GLPs, have potency to increase the response of our immune system against tumors by augmenting the cytotoxic T lymphocytes and natural killer cells activity [84], [85]. In a study conducted by Sun *et al.*, the researchers have examined the effect of polysaccharides on lymphocyte activation.They have found that incubation of polysaccharides with a tumor cell line exhibited deficient antigen presentation. The results demonstrated that polysaccharides have the ability to stimulate the proliferation of lymphocytes in melanoma cells. Furthermore, in mice the β-glucan extracted from *G. lucidum*exhibited significant inhibition of S180 tumor growth [86], [87]. In these studies, it was found that α-D-glucans possessed cytotoxic properties against HeLa cancer cells, which are human epithelial cells [88]. Suarez-Arroyo *et al.* (2013) explored the potential therapeutic application of *G. lucidum*for treatment of inflammatory breast cancer through the utilization of both *in vivo* and *in vitro* IBC models.This research have revealed that*G. lucidum* can suppress growth of tumor and inhibit synthesis of protein by influencing signaling pathways related to cell survival and proliferation [89]. In a study by Song et al. , GLP activate macrophages which induces the cytokines and others inflammatory factors to regulate the apoptosis. It was also demonstrated that GLP have impact on mitochondrial apoptotic pathway by activating PI3K/AKT signaling to induce tumor cell apoptosis [90]

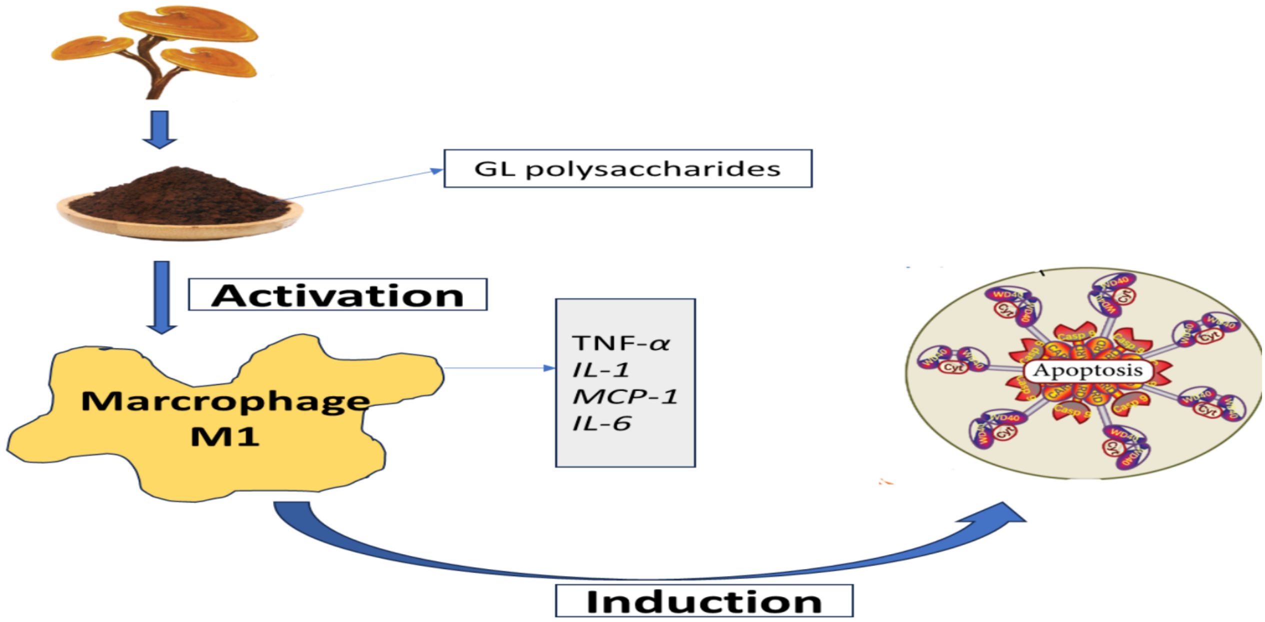

Fig.7 *G. lucidum* Polysaccharides activated the Macrophages by inducing Apoptosis[90]

3.6 Antiviral Activity

The findings from multiple studies reported that *G. lucidum*holds promise as a potential source for diverse antiviral agents development [91]. Genome sequencing analysis has revealed the potential of *G. lucidum*in combating a wide range of viruses, including herpes, Epstein-Barr, hepatitis, influenza, and H1N1 strain of flu. The researchers have investigated the impact of liposomes (Lip) containing *G. lucidum*polysaccharides on porcine circovirus type 2 (PCV2) inactivation. These results have demonstrated that Lip-GLP treatment increased the CD4+ to CD8+ T cell ratio, enhanced immune response and stimulated cytokine secretion in mouse serum [77]. Dengue virus (DENV) infection is associated with severe health complications. The triterpenoids derived from *G. lucidum*, ganodermanotriol have inhibited virus infection [13]. Enterovirus 71 is a primary culprit behind mouth, hand and foot disease as well as severe systemic and neurological complications in children. Zhang *et al.*conducted a study for assessmentof antiviral properties of various triterpenoids against EV71 infection. The research findings have revealed that certain tested triterpenoids effectively hindered virus infection by impeding the attachment of the virus to host cells [2]. Protein-bound polysaccharides of *G. lucidum*exhibited antiviral properties against herpes virus (HSV-1 and HSV-2) [92]. Several compounds extracted from *G. lucidum*, including ganoderic acid beta, ganodermanontriol, lucidumol B, ganolucidic acid A, and ganodermanondiol have been found to possess inhibitory properties against human immunodeficiency virus protease activity [93], [94]. Further extensive research is required to establish the foundation for utilizing bioactive compoundsfrom *G. lucidum*as anti-HIV agents. However, it has been observed that triterpenoids hold significant potential as the primary compounds with anti-HIV activity [27], [95]. The inhibitory effects of ganoderic acid on replication of the hepatitis B virus have been documented. Different ganoderic acids (GAs), including GA-Q, Ganoderol A, GA-B, GA-β, ganodermanondiol, GA-C2, GA-H, ganodermanontriol, GA-C1, Ganoderol B, GA-T, GA-A, and have demonstrated antiviral potency [77]. The current global public health crisis caused by the emergence of the novel coronavirus (SARS-CoV-2) presents a significant threat. Although clinical data is limited, there is substantial evidence in the literature suggesting that specific nutraceuticals derived from *G. lucidum*, such as triterpenoids, polysaccharides, nucleotides, sterols, steroids, fatty acids, and proteins/peptides, have potential utility in the treatment of COVID-19 [96]. According to the findings, supplementation of *G. lucidum*to COVID-19 patients resulted in an increase in lymphocyte levels. The β-glucans in*G. lucidum*enhanched signals from pattern recognition receptors (PRRs), lead to the stimulation of defensive inflammatory reactions, having the capacity to prevent infections caused by pathogens, including coronaviruses[6], [97].

3.7 Anti-inflammatory Activity

Notable anti-inflammatory effects were observed in *G. lucidum*that was cultivated on germinated brown rice. Furthermore, the study demonstrated that the use of *G. lucidum*have significantly reduced the severity of colitis. The effects of *G. lucidum*polysaccharides (GLPs), anti-inflammatory activities were assessed through carrageenan-induced edema and formalin-induced edema inflammation tests. The findings have indicated that GLPs efficiently suppressed both prolonged inflammation caused by formalin and immediate inflammation triggered by carrageenan[10]. Sheena *et al.* (2003a) conducted a study that yielded comparable findings, demonstrating the significant anti-inflammatory activity of methanol extracts and ethyl acetate of*G. lucidum* in both chronic and acute inflammatory mice models [98]. The extracts derived from*G. lucidum* have shown anti-inflammatory properties, primarily attributed to their ability to effectively suppress various cytokines, immunomodulatory molecules as well as chemokines[99]. The examination focused on investigating the anti-inflammatory effects of chemically sulfated polysaccharides. These polysaccharides exhibited inhibitory effects not only on L-selectin-mediated inflammation but also on the overall inflammatory response [51].

4 Conclusion

The abundant availability of bioactive compounds in *Ganoderma* species, particularly*G. lucidum*, deserves the significant attention it has garnered over the years, including recent times. The mushroom's prominence in traditional Chinese medicine, which has a long-standing establishment, further underscores its value. The extensive range of diseases that can potentially be treated or managed using the bioactive compounds found in this mushroom highlights its immense potential for discovering constituents or medicines to combat various emerging or reemerging diseases. In nutshell,*G. lucidum* stands out as the most valuable mushroom for exploring and prospecting bioactive compounds capable of combating diseases worldwide.

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