LINGZHI (*GANODERMA LUCIDUM*): "LINGZHI (GANODERMA LUCIDUM): A POTENTIAL SOURCE OF NUTRACEUTICALS AND PREBIOTICS"

Abstract

The current research highlights the urgent need for the scientific community to promote Ganoderma lucidum as a potential source of nutraceutical and prebiotic products. To characterise the active component (s) of this alleged medicinal mushroom, as well as to discover mechanisms of action, techniques for improving quality control systems are required to define and standardise G. lucidum formulations. The current review will result in a new generation of foods and will undoubtedly encourage both their dietary and therapeutic benefits.

Keywords: Lingzhi, Ganoderma lucidum, Nutraceuticals, Prebiotics

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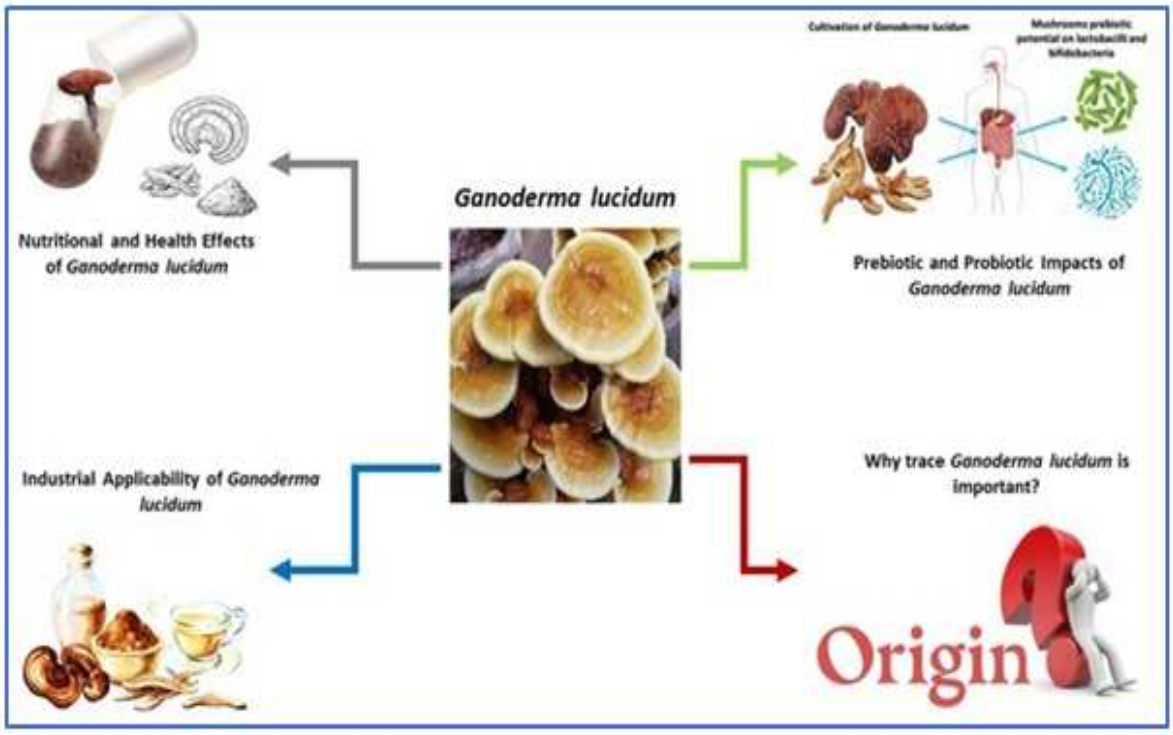
Graphical Abstract



I. BACKGROUND

In Asian nations, Ganoderma lucidum, often known as lingzhi, has been used to generally promote health and lifespan. With high-quality proteins, amino acids, nucleosides, vitamins, critical minerals, and dietary fibres (quitin, polysaccharides), ganoderma lucidum is a highly nutritious, low-calorie food. A significant and underutilised source of nutraceuticals and prebiotics is ganoderma lucidum.

The development of mushrooms is beneficial to the food, pharmaceutical, and nutraceuticals industries in developing nations like China, Japan, Korea, and India. Ganoderma lucidum has long been regarded as the best nutritious meal for obese people and for diabetics to prevent hyperglycemia due to its high fibre, low fat, and low starch content. It is mostly made up of dietary fibres and polysaccharides that encourage the growth of good bacteria. It is mostly made up of dietary fibres and polysaccharides that encourage the formation of good bacteria in the digestive tract. They are maintaining intestinal health, preventing cancer, enhancing immunity, lowering cholesterol, and preventing obesity, among other positive effects. Its potential as a nutraceutical and prebiotic is attributed to the presence of a wide range of phytoconstituents, including tocopherols, phenolics, flavonoids, carotenoids, dietary fibres, ascorbic acid, selenium, germanium, luecine, lysine, adenosine, and uracil. There is no proof of liver, kidney, or DNA toxicity with consumption of Linngzhi, according to the toxicity study on human clinical trial.

Present Overview: The current research highlights the urgent need for the scientific community to promote Ganoderma lucidum as a potential source of nutraceutical and prebiotic products. To characterise the active component (s) of this alleged medicinal

mushroom, as well as to discover mechanisms of action, techniques for improving quality control systems are required to define and standardise G. lucidum formulations. The current review will result in a new generation of foods and will undoubtedly encourage both their dietary and therapeutic benefits.

II. INTRODUCTION

A nutraceutical is a substance that has health or medical benefits, such as the prevention and treatment of diseases, and may be regarded as food or a component of diet. The spectrum of nutraceuticals may include isolated ingredients, nutritional supplements, genetically modified "designer foods," herbal items, and processed foods including cereal, soups, and drinks. Dietary fibre, Polyunsaturated Fatty Acid (PUFA, fish oil), proteins, peptides, amino acids, ketoacids, minerals, antioxidative vitamins (tocopherols), and other antioxidants (flavonoids, glutathione, selenium, etc.) are a few examples of nutritive nutraceuticals or "functional food ingredients." According to epidemiological research, eating fruits and vegetables reduces your chance of developing cardiovascular disease and several types of cancer [1]. Plant phenolics may possibly play a substantial role, even though the protective benefits have mostly been related to well-known antioxidants including ascorbic acid, tocopherols, and beta-carotene. Overweight, obesity, diabetes, cardiovascular disease, and cancer are only a few examples of the metabolic disorders that are brought on by the westernisation of our diet and the heavy intake of carbohydrates-rich foods and soft drinks, etc. Poor nutrition, smoking, and drinking contribute to an increase in morbidity and mortality. The demand for prebiotics has therefore increased. Due to their antioxidant, anticancer, and antibacterial characteristics, mushrooms have gained popularity as a functional food and as a source for pharmaceutical and nutraceutical research [2]. In addition to their medicinal properties, mushrooms are becoming more significant in our diets because of their high protein and low fat/energy contents, which contribute to their nutritional worth.

In China, Japan, and other Asian nations, the oriental fungus ganoderma lucidum (Figure 1) has a huge history of use for fostering health and longevity. It has a huge, black, glossy, and woody outer mushroom. The word lucidus, which is Latin for "shiny" or "brilliant," alludes to the mushroom's surface's varnished appearance. G. lucidum is known as lingzhi in China whereas reishi or mannentake is the name for the Ganodermataceae family in Japan [3]. Emperors of the great Japanese and Chinese dynasties consumed G. lucidum along with their special teas and mushroom connections to increase their energy and lengthen their lives. It was revered as a form of herbal therapy. Additionally, G. lucidum was said to be present in the "elixir of eternal youth" that the ancient Taoists relentlessly sought after. G. lucidum has made significant contributions to the treatment of many ailments, but it has also gained popularity due to its potential for extending life and improving health [4]. The Chinese word lingzhi, which means "herb of spiritual potency," connotes a combination of spiritual strength and the essence of immortality. It stands for success, happiness, divine power, and longevity. G. lucidum is distinct among farmed mushrooms in that its medicinal rather than nutritional value is of utmost importance. Commercial G. lucidum products come in a wide range of shapes and sizes, including powders, dietary supplements, and tea. These are made from several mushroom components, such as mycelia, spores, and fruit bodies [5]. The specific uses and claimed health advantages of lingzhi include regulating blood sugar levels, immune system regulation, hepatoprotection, bacteriostasis, and more. Recent research has also shown the existence of neuroactive substances in "Lingzhi" extracts that

mediated the neuronal differentiation and neuroprotection of rat PC12 cells. Currently, the dried powder is consumed as dietary supplements all over the world. It has earned a reputation in the East as the top herbal substance due to its purported health advantages and apparent lack of adverse effects [6]. The American Herbal Pharmacopoeia and Therapeutic Compendium has now been expanded by Lingzhi. On the basis of preclinical and clinical investigations, the goal of the current review is to encourage the use of Ganoderma lucidum as a possible source of nutraceutical and prebiotic products [7]. In order to characterise the active component(s) of this claimed medicinal fungus and to discover mechanisms of action, techniques for improving quality control procedures are also required to define and standardise G. lucidum preparations.

III. LITERATURE REVIEW

Worldwide production and usage of goods above 90 brands of G. lucidum goods were registered and sold abroad ten years ago. Several thousand tonnes are currently thought to be consumed globally, and the industry is expanding quickly. The projected yearly market value for ganoderma products, according to various commercial sources, was US$1628 million in 1995, despite the fact that there are no contemporary figures available [8]. There are numerous G. lucidum products on the market right now, each manufactured from a different mushroom component. In terms of manufacture, the most basic variant consists of complete fruiting bodies that have been powdered and then turned into capsule or tablet form. Additional "non-extracted" goods are made from the following three sources: • Dried and powdered mycelia harvested from submerged liquid cultures grown in fermentation tanks; semisolid medium inoculated and incubated with fungal mycelia; dried and powdered mixtures of substrate, mycelia, and mushroom primordia; intact fungal spores or spores mechanically broken or with the spore walls removed. Although spore preparations have recently been intensively researched and promoted, it is still unclear if any further medical effects can be linked to them. Other products are made using substances (such as polysaccharides and triterpenes) that have been extracted, typically using hot water or ethanol, from fruiting bodies or mycelia that have been taken from submerged liquid cultures. These substances are then evaporated to dryness and tabulated or encapsulated, either separately or in combination with other substances in predetermined ratios. Due to the low processing temperature required by supercritical fluid CO2 extraction technologies, the range of extracted chemicals has increased [9]. Powdered Ganoderma, other mushrooms (such as Lentinula edodes, Agaricus brasiliensis, Grifola frondosa, Pleurotus spp., and Flammulina velutipes), and even other medicinal plants (such as spirulina powder or flower pollen grains) have been used to make other products. These combinations can be binary, ternary, or even more complex. The primary pharmacological and physiologically active components in Ganderma lucidum Most mushrooms contain 90% water by weight. The remaining 10% is made up of 10%-40% protein, 2%-8% fat, 3%-28% carbohydrate, 3%-32% fibre, 8%-10% ash, and a few vitamins and minerals; potassium, calcium, phosphorus, magnesium, selenium, iron, zinc, and copper are the most common minerals. According to study on the nonvolatile constituents of G. lucidum, the mushroom contains 1.8% ash, 26%-28% carbohydrate, 3%-5% crude fat, 59% crude proteins. These are just a few of the many bioactive substances found in Ganoderma lucidum, which also includes a wide range of terpenoids, phenols, steroids nucleotides and their derivatives, polysaccharides and glycoproteins. All of the necessary amino acids are present in the proteins found in mushrooms (Ganoderma lucidum), which are particularly high in lysine and leucine [10]. An

important factor in the health benefits of mushrooms is thought to be their low total fat content and high proportion of polyunsaturated fatty acids in comparison to their total fatty acid composition. Polysaccharides and terpenoids are the main phytoconstituents in G. lucidum that are pharmacologically active. Terpenoids/steroids: The triterpenes in G. lucidum have a molecular structure based on lanostane, a metabolite of lanosterol whose formation depends on the cyclization of squalene. Ganoderic acids A and B are the first triterpenes to be isolated from G. lucidum. Since then, it has been discovered that G. lucidum contains very large amount of terpenes (more than 100 triterpenes) with recognised chemical structures and molecular arrangements. More than 50 of them were discovered to be new and exclusive to this fungus. Although ganoderic and lucidenic acids make up the most majority, other triterpenes including ganoderals, ganoderiols, and ganodermic acids have also been discovered [11]. Triterpenes, which are abundant in G. lucidum, are what give the herb its bitter flavour and are thought to provide a number of health advantages, including antioxidant and lipid-lowering properties. However, the mushroom's triterpene concentration varies depending on the region and stage of growth [12]. This therapeutic fungus can be distinguished from other taxonomically related species using the profile of its various triterpenes, which can also be utilised as classification support. The triterpene content of various Ganoderma samples can also be used to gauge their quality. Sterols, which are present in Ganoderma, are closely related to triterpenoids. Mycelium and basidiocarps both exhibit strong cytotoxic properties. Ergosterol peroxide from G. lucidum increases linoleic acid's ability to inhibit mammalian DNA polymerase. The results of an in vitro study on the effects of Ganoderma total Sterol (GS) and its primary components (GS) on rat cortical neuronal cells exposed to Hypoxia/Reoxygenation (H/R) show that GS may be helpful in treating H/R-induced oxidative stress and inflammatory response. [13]. In addition, pre-treatment with GS1significantly attenuated the decline of neuron viability and the formation of reactive oxygen species.

Figure 1: A typical Ganoderma basidiocarp

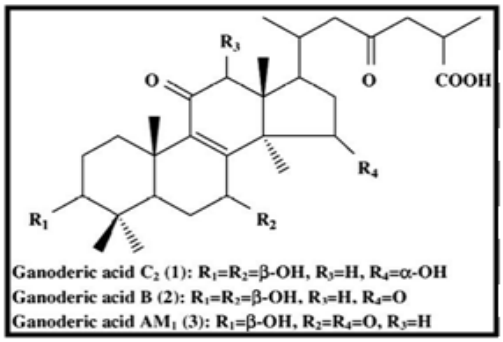


Figure 2: Chemical Structure of some Ganoderic Acids

Polysaccharides: Different polysaccharides have been isolated from the fruit body, spores, and mycelia of lingzhi. These polysaccharides are formed by fungal mycelia cultivated in fermenters and can vary in their molecular weight, peptide contents and sugar in G. lucidum. According to reports, polysaccharides (GL-PSs) have a variety of bioactivities, including those that are, hypoglycemic, anti-inflammatory, anti-ulcer, anti-tumorigenic, and immune-stimulating [14]. Although they can also be extracted using water and alkali, polysaccharides are often removed from the mushroom by extraction with hot water followed by precipitation with ethanol or methanol. GL-PSs' structural analysis show that the main sugar in these compounds is glucose. GL-PSs can also contain mannose, xylose, , galactose, and fucose in various conformations, including 1-3, 1-4, and 1-6-linked and -D (or L)-replacements, but these are heteropolymers. According to certain theories, these polysaccharides' antitumorigenic capabilities are influenced by their solubility qualities and branching conformation. In addition, the mushroom contains a matrix of the polysaccharide chitin, which is largely indigestible by humans and contributes to the mushroom's physical toughness [15]. Today, a variety of refined polysaccharide treatments derived from G. lucidum are sold over-the-counter for chronic conditions like cancer and liver disease. G. lucidum proteoglycan, G. lucidum immune modulating substance, PGY (a water-soluble glycopeptide fractionated and purified from aqueous extracts of G. lucidum fruit bodies), GL-PS peptide, and F3 (a fucose-containing glycoprotein fraction) are among the other bioactive peptidoglycans that have been isolated from the plant. Ganoderma lucidum's primary bioactive ingredients for nutraceuticals Minerals and trace elements that are necessary: Phosphorus, sulphur, silica, potassium, calcium, and magnesium were found to be the principal mineral components of G. lucidum's log-cultivated fruit bodies according to an elemental analysis. Additionally, the heavy metals lead, cadmium, and strontium, as well as iron, sodium, zinc, copper, manganese, and strontium, were found in smaller quantities, as were the heavy metals lead, cadmium and mercury [16]. A 10.2% mineral content was found in the freeze-dried fruit bodies of unnamed Ganoderma species that were collected in the field. The main minerals were calcium, potassium, and magnesium. It's noteworthy that neither cadmium nor mercury was found in these samples. Additionally, G. lucidum has a selenium content of up to 72 g/g dry weight and has the ability to biotransform 20–30% of the inorganic selenium contained in the growth substrate into proteins that contain selenium. Ganoderma species' germanium content has received some attention. In terms of concentration, germanium ranked sixth among the minerals found in G. lucidum fruit bodies that were gathered from the wild (489 g/g). In addition, this mineral can be found in ginseng, aloe, and many other plant-based foods in amounts of parts per billion [17]. Although

germanium is not a necessary element, it has been shown to have immune-boosting, anticancer, antioxidant, and anti-mutagenic properties in low amounts. There is no concrete proof connecting the germanium content of G. lucidum with the specific health advantages connected to the mushroom, despite the fact that this element has been exploited to sell G. lucidum-based goods. Amino acids, peptides, and proteins: Proteins and lectins are a couple of the additional substances found in G. lucidum that may help explain its purported medical effects. Compared to many other mushrooms, the protein level of dried G. lucidum was determined to be between 7% and 8%. According to reports, bioactive proteins from G. lucidum, such as LZ-8, an immunosuppressive protein extracted from the mycelia, contribute to the plant's therapeutic capabilities [18]. Mushroom (Ganoderma lucidum) proteins contain all the essential amino acids and are especially rich in lysine and leucine (as shown in Table 1).

Table 1: Amino acid content of *G. Lucidum*

Amino acid	Relative abundance
Aspartic acid	117
Threonine	66
Serine	54
Glutamic acid	120
Proline	60
Glycine	108
Alanine	100
Valine	61
Methionine	6
Isoleucine	36
Leucine	55
Tyrosine	16
Phenylalanine	28
Histidine	12
Lysine	21
Arginine	22

1. **Nucleosides, Nucleotides and RNAs:** Adenine, adenosine, uracil, and uridine were initially isolated from the mycelia of a Ganoderma species, G. capense, and reported by Yu and Zhai in a specialised journal. Nucleosides, uridine, and uracil were among those that were discovered to have the ability to reduce the blood aldolase level of mice with experimental myotonia. It has also been demonstrated that adenosine prevents platelet aggregation. Contrarily, Gau discovered that the administration of raw Ganoderma extracts, which are known to contain a large amount of adenosine, had no impact on platelet aggregation in HIV-positive haemophiliac patients. A 5'-deoxy-5'-methyl sulphinyladenosine epimer was discovered to prevent platelet aggregation in a test tube.

2. **Carbohydrates:** When the dried mushroom's carbohydrate and crude fibre contents were measured, it was discovered that they were 26%–28% and 59%, respectively. The majority of sugar molecules are made up of glucose, with smaller amounts of xylose, mannose, galactose, and fucose [19]. The fruit body and mycelium of the mushroom were

also used to isolate lectins, one of which was a unique 114 k Da hexameric lectin that was later found to be a glycoprotein with 9.3% neutral sugar and hemagglutinating activity on pronase-treated human erythrocytes.(shown in Table 2).

Table 2: Carbohydrate content of G. lucidum

Sugar components	Percentage (%)
d-Glucose	58
d-Mannose	15.5
d- Galactose	9.3
d-Xylose	5.4
l-fucose	9.7
d-GlcNAc	1
l-Rhamnose	0.5

3. **Alkaloids, Vitamins, Flavours and Fatty Acids:** Cyclooctasulfur and oleic acid, which were both found to be present in the culture broth of G. lucidum, were both shown to decrease histamine production, which is a crucial process for treating inflammation, allergies, and anaphylactic shock. Choline, betaine, and alkaloids were extracted from G. lucidum spores. Different "Lingzhi" "species" have been used to isolate vitamins (including b-carotene) and critical minerals. G. applanatum has produced aroma chemicals that may have new biotechnological uses. There have been over 120 discovered volatile taste compounds, the majority of which are alcohols, aldehydes, ketones, esters, and phenols. Last but not least, trace quantities (1%–2%) of very long chain fattyacids with more than 23 carbon atoms have been seen in G. applanatum.

4. **Dietary Fibres:** The non-digestible dietary fibres glucan, chitin, and hetro polysaccharides are abundant in G. lucidum. By promoting the growth of probiotic bacteria in the large intestine, it may also prevent viral infection. Given that it contains nutrients such chitin, hemicelluloses, - and -glucan, mannans, xylans, and galactose (as shown in Table 3), G. lucidum polysaccharides are a possible source of prebiotics.

Table 3: General compounds and effects of Ganoderma reported in the literature until 2004

Compound	Effect	References
Adenosine	Antiplatelet aggregation	Kawagishi, et al.; Shimizu, et al.
Lectins	Mitogenic	Ngai, et al.; Nag, et al.
Polysaccharides	Anti-fibriotic	Park, et al.
	Anti-herpetic	Eo, et al.; Kim, et al.
	Anti-inflammatory	Ukai, et al.
	Hepatoprotective	Zhang, et al.
	Hypoglycaemic	Zhang and Lin
	Immunomodulatory- anti-tumour	Gao, et al.; Li, et al.

	Miscellaneous (radiation protection, DNA damage, anti-oxidant)	Kim and Kim, et al.; Lee, et al.
Protein (‘‘LZ-8’’)	Immunomodulatory	van der Hem et al.
	Immunosuppressive	van der Hem et al.
Terpenoids	Anti-bacterial	Smania et al.
	Anti-inflammatory	Kleinwachter et al.
	Anti-oxidant	Zhu et al.
	Antiplatelet aggregation	Shiao
	Antiviral	Mothana et al.
	Cytotoxicity	Gao et al.
	Enzyme inhibitors	Lee et al.
	Hepatoprotective	Chen and Yu, et al.; Kim, et al.
	Hypolipidemic	Komoda et al.; Shiao, et al.
	Hypotensive	Morigiwa et al.

IV. DIETARY SUPPLEMENTS OR NUTRACEUTICAL POTENTIAL OF GANODERMA LUCIDUM

The majority of preparations and compounds made from mushrooms are used as innovative classes of dietary supplements (DS) or nutraceuticals, which fit the idea of functional food quite well. In addition to offering traditional therapies for the treatment of human cancer, dietary chemotherapeutic drugs may act as powerful agents to increase the therapeutic effect of chemotherapy and radiotherapy. G. lucidum has been utilised in several clinical trials on both humans and animals, yielding positive outcomes. Numerous businesses advertise their goods in India. These businesses import the medication in tablet or capsule form into India and market it as a high-end treatment for conditions like cancer and AIDS that are chronic or terminal. G. lucidum capsules come in 100-capsule packets and can be used on their own or in combination with other therapeutic mushrooms such as shitake, caterpillar, and other mushrooms. These products are marketed by Fungi Perfecti in the USA, Mycology Research Laboratory in the UK, NAMMEX (North American Medicinal Mushroom Extra) in the USA, Core Nutritional Products in the USA, among other companies. China, Japan, Korea, and India all offer these drugs as "over the counter" goods. . Kerala, a state in southern India, and parts of northern India (Delhi-Chandigarh), are notable for their consumption of it. Due to the higher per capita income of the residents of these places, consumption is high. Additionally, only wealthy households are allowed to consume. The Ganoderma lucidum products are prescribed in a variety of ways, including as syrup or an injection of a spore-powder solution. It can be consumed as tea, soup, tinctures, pills, or boluses. The dosage for tinctures is 10 ml administered three times per day. Syrup dosage ranges from 4 to 6 ml per day. Three to five times a day is the suggested dosage for the dried mushroom (200 g to 300 g), which is mixed in water and given as a drink. Ganoderma is a popular supplement in Japan for the treatment of the cancer. The patient experiences improved sleep, a better feeling, and an increased appetite as a result of the application, and Reishi also relieves angina pectoris. Spore powder injections are beneficial in treating atrophy, muscular stiffness, and gradual deterioration. Tablets containing mushroom spores have been used to both prevent and treat the effects of elevation changes. Additionally, G. lucidum treats lung and

cardiac problems. G. lucidum tablets were administered to 200 patients with chronic bronchitis in clinical research in China, and 60–90% of the patients had significant improvement, including an increase in appetite. In patients with hyperlipidemia who were also hypertensive, it also decreased blood and plasma viscosity [20]. This mushroom's extracts have reportedly been shown to alleviate arrhythmia, lower blood pressure, and lower cholesterol levels. Additionally, G. lucidum exhibits hypolipidemic and hypoglycemic behaviours. In a study, the highest outcomes were seen in 71 patients with type II diabetes mellitus who were cured. This study proved that ganopoly is an effective and secure method for decreasing blood glucose levels. Potential for probiotics in Ganoderma lucidum A fungus called Ganoderma lucidum is frequently employed in traditional Chinese medicine. The presence of polysaccharides in G. lucidum contributes to its high value. In comparison with 1 g of G. lucidum crude, 0.57 g of GLCP is present. The probiotic bacteria Bifidobacterium longum BB536, Bifidobacterium pseudocatenulatum G4, Lactobacillus acidophilus, and Lactobacillus casei shirota were used to assess the prebiotic potential of GLCP. The prebiotic potentials were investigated in 10 mL of basal Trypticase Phytone Yeast (abbreviated as bTPY) medium (without glucose) that had been treated with GLCP at different doses (0.5%, 1.0%, 1.5%, and 2.0%). As a benchmark, glucose- and insulin-supplemented bTPY medium (abbreviated as bTPYglu and bTPYinu, respectively) were utilised. The pH of the medium and the number of bacteria with viable cells were measured during anaerobic incubation periods of 0 h, 12 h, 24 h, and 48 h at 37°C. Cultures displayed varying degrees of growth acceleration in the presence of a supply of carbohydrates. BTPYglu, BTPYglu+glcp, BTPYglcp, and BTPYinu were ranked first, second, third, and fourth, respectively, in terms of the growth boosting property. Intriguingly, when cultured for 24 hours in bTPYglcp medium, bacterial growth accelerated with rising GLCP concentrations. B. longum BB536 came in first place in terms of growth in this medium (10.53 log cfu/mL). With 10.40 log cfu/mL, B. pseudocatenulatum G4 growth came in second. This study demonstrates that the tested bacteria may grow in the presence of GLCP.

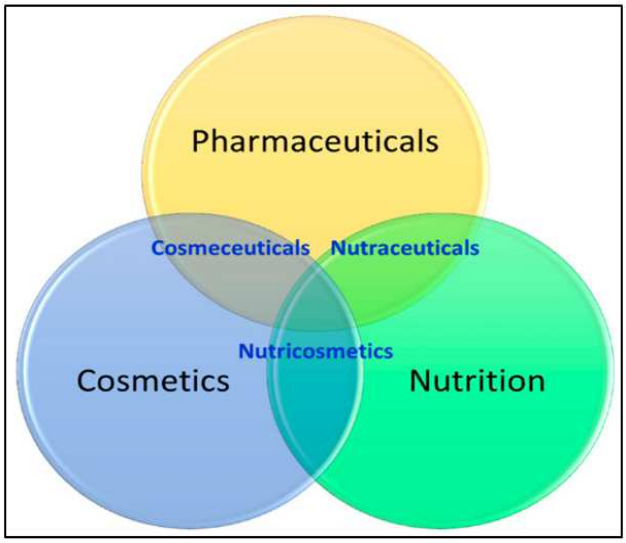


Figure 3: Wide-scale applications of mushrooms including *Ganoderma lucidum*; i.e., pharmaceuticals, nutraceuticals, and cosmetics. [21].

V. FUTURE TRENDS

Many questions have so far been raised about the rationale behind and best methods for utilising G. lucidum and its derivatives, as well as what to do with the novel uses and cutting-edge methods that have been put out in this context. The following three axes will be used to discuss these points.

1. **Do the Beneficia-l Medical Properties of G. lucidum Need More Scientific Evidence?**

   G. lucidum and its active components are still widely used as commercial supper food supplements because numerous articles have suggested that the plant's multifarious bioactive constituents, including triterpenes, polysaccharides, and proteins, may have a variety of useful therapeutical properties. Therefore, it is still thought that there are gaps in our understanding regarding the effectiveness and safety of consuming G. lucidum. In vitro/in vivo research published by Western scientists over the past three decades has demonstrated the health benefits of G. lucidum, which has assisted in popularising this fungus in the West. To fully comprehend the associated biomechanistic processes and hence open the door to their biotherapeutic application, there is still an urgent need. To understand the bioactivity of these compounds inside G. lucidum's nutraceutical and pharmaceutical products, the separation, purification, and identification of its active components is required. When adopting the commercial standardisation procedures of G. lucidum goods, this element is a significant barrier [23–25].

   There is still a pressing need to thoroughly understand the related biomechanistic processes in order to enable their biotherapeutic use. Separation, purification, and identification of the active ingredients in G. lucidum's nutraceutical and pharmaceutical products are necessary to comprehend the bioactivity of these substances. This component is a substantial hurdle to using the commercial standardising processes for G. lucidum goods [23–25].

   The biosynthesis of the therapeutically useful substances produced by G. lucidum, such as the rare triterpenoid anticancer ganoderic acids (GAs), will be clarified by further genetic research of this fungus. By building functional genes for GA biosynthesis in this mushroom, the clustered regularly interspaced short palindromic repeats and CRISPR-associated protein 9 (CRISPR-CAS9) technology has positively identified active curative components in G. lucidum, acting as a crucial platform for metabolic engineering in G. lucidum. Therefore, the CRISPR-CAS9 method can serve as the foundation for all G. lucidum biotechnological applications, including molecular breeding. Therefore, a thorough comprehension of the G. lucidum genome will open the door for its potential roles in industrial and medical applications in the future [26–28]. Large-scale studies on *G. lucidum* mushrooms will be conducted with standard scientific methods in the near future.

2. **Future of the G. lucidum Mushroom in the Food Industry:** Nutraceutical versions of a number of Ganoderma lucidum-based products are now readily available. In many nations, including the United States, they are commonly consumed and some of them are sold as nutritional supplements. They are often blended with many other foods, such as coffee and tea. The consistency of the quality of dietary supplements made from G. lucidum is rarely assessed because there is no appropriate toolbox. G. lucidum may also

be used as a source of food preservatives[29]. To validate *G. lucidum*'s nutraceutical usage, more research on this mushroom is needed

3. Is Tracing the Species and Geo-Origin of G. lucidum Essential?

Research by Loyd and others revealed that manufactured G. lucidum-based items, such as dietary supplements, that are labelled as being derived from G. lucidum really include multiple Ganoderma species in addition to G. lucidum and are regrettably offered for therapeutic purposes. Of course, not all Ganoderma species generate the same types, qualities, or quantities of medicinal chemicals. This calls into question how crucial it is for the industry that mushroom species can be traced and are real. Therefore, this query has to be covered in later studies that concentrate on G. lucidum and its byproducts [30,31].

The geographical-origin traceability of mushrooms and their products is essential to guaranteeing their quality and safety, as stated by Qi et al. In fact, depending on the geo-origins, different mushroom species have different nutritional and medicinal qualities. This was demonstrated by Lu et al. in their study of G. lucidum samples obtained from various geographical locations, where they discovered that each sample's concentration of ganoderic acids A and B, polysaccharides, and triterpenoids varied depending on the location (including differences in cultivation and environmental conditions). Therefore, G. lucidum's geo-origin traceability will increase its worth on a worldwide scale at all levels, whether industrial or economic.

What is the most effective technique for achieving targets for species and geo-traceability? In order to greatly improve food traceability generally and for mushrooms in particular from the field to the table, El Sheikha and Hu recommended the DNA barcoding approach as a new "cutting edge" technology [32].

VI. INFORMATIONAL GRAPHIC ABOUT GANODERMA LUCIDUM: CURRENT SITUATION AND FUTURE PROSPECTS

Research on G. lucidum and its products has made significant strides recently, drawing the interest of the scientific community in various domains. The biological traits, chemical make-up and active ingredients, pharmacological effects and associated mechanisms, and clinical applications based on G. lucidum have all been thoroughly studied from a variety of angles. Furthermore, G. lucidum has achieved some advances in the industrial sphere.

Future research goals for G will include new chemical formulations and active ingredients (as potential functional foods), cellular and molecular mechanisms of biological activities (such as prebiotic effects), quick and conclusive methods to identify effective ingredients, fermentation and cultivation methods, double-blind large-scale clinical trials, and pr, and quality control monitoring of product will be the aims of *G. lucidum* research (see figure 4).

Figure 4: Infographic for *Ganoderma lucidum*: current scenario and future perspectives

VII. DISCUSSION

A well-known Asian herbal treatment called G. lucidum has an extensive and astonishing range of uses. The amount of G. lucidum consumed globally is significant, and there are numerous food supplements with G. lucidum as bio-active ingredient that are already patented and commercially available. These products comprise extracts and isolated ingredients in a variety of formulations that are sold all over the world as pills, lotions, syrups, and hair tonics. The G. lucidum has many beneficial nutraceuticals that can be isolated and employed as prebiotics and functional food ingredients, including UFA,

phenolics, tocopherols, and carotenoids. Nutraceuticals can be used as a potent tool for maintaining and enhancing health, longevity, and quality of life, according to public health authorities. Nutritional therapy will surely be impacted by G. lucidum's positive properties, which also constitute a developing sector of the modern food market. Additionally, by utilising the additive and synergistic effects of all the bioactive chemicals present, these G. lucidum could be directly employed in diet to promote health. In order to characterise the bio-active component(s) of this claimed medicinal fungus and to discover mechanisms of action, techniques for improving quality control procedures are also required to define and standardise G. lucidum preparations.

VIII. CONCLUSION

We may conclude that Ganoderma lucidium is a mushroom that is deserving of all the attention it has received recently and over the years after establishing the high concentration of bioactive chemicals present in Ganoderma species, particularly G. lucidium. Now that traditional Chinese medicine has been firmly established throughout the years in China, it is readily evident why this fungus has received so much attention there. The variety of ailments that these bioactive compounds can be used to manage or treat suggests the enormous potential of this mushroom for the discovery of ingredients or medications that can be used to treat many newly or reemerging ailments in Africa, where the mushroom is thought to be native. The conclusion is that it is the most useful mushroom when it comes to searching or prospecting for bioactive compounds to combat any disease in the world.

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