REVIEW

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REVIEW

Ganoderma lucidum: production, nutritional and medicinal value in comparison with other edible mushrooms – A review

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Ganoderma is a well-known mushroom. China and other Asian countries are the primary users. It's also used as a tea or broth for medicinal purposes. The fungus is believed to be the immortal mushroom in many stories. Many illnesses have been shown to be healed by the mushroom. Because of the huge number of dynamic mixtures, it has a wide scope of antimicrobial structure. The fungus is mostly eaten by people from the east. However, the use of this fungus as an antibiotic is a relatively recent development in medicine. It's also a mushroom with a high yield.

Key words: Antibiotic, anti cancer, edible mushroom, *Ganoderma lucidum*

INTRODUCTION

Herbal remedies have been increasingly common in recent years. People are turning to herbal medicine as a result of antibiotic resistance and chemical side effects. Herbal drugs are also simple to prepare and consume, with no negative side effects. They're commonly used to treat human illness. Herbal medicine is becomingincreasingly common in eastern countries, but it emerged thousands of years ago on the Indian subcontinent. Most people think of herbs as they think of herbal medicine, but edible mushrooms take the lead when it comes to herbal medicine (Thakur and Singh, 2013).

Because of their antimicrobial, antiviral, and anti-inflammatory properties, some edible mushrooms can help to reduce microbial infections and diseases. Several fungi, such as *Pleutotus* sp., oyster mushroom, *Volvariella volvacea*, paddy straw mushroom, *Calocybe indica*, milky mushroom and *Agaricus bisporus*, button mushroom, have been discovered to be edible and useful to humans (Thakur, 2014; Chakraborty *et. al*., 2016; Barman *et al*., 2017, 2018; Thakur, 2021). They're chock-full of vitamins, fats, and other chemicals. Microbial development is influenced by edible mushrooms in a number of ways. Potential of macrofungi in waste management, human health and social upliftment also critically reviewed by Thakur and Singh (2020). The fungus *Ganoderma lucidum* (Reishi) is one of the most common among them. These fungi can be present in the China and Korea regions. It is used as a therapy for acute and chronic illnesses in old Chinese culture. The *Ganoderma lucidum* is a type of edible mushrooms, common in Japan, china and other Asian nations. The colour of this mushroom is black. It often has a broad exterior woody pattern. *G. lucidum* is known in China as Lingzhi, and in Japan as Reishi or Mannentake. Lingzhi, which means "herb of divine potency" in Chinese, simply reflects a mixture of faith and immortality. The fungi are thought to represent success, fitness, divine strength, well-being, and immortality. Many mushrooms are cultivated, but the *G. lucidum* is unusual among edible mushrooms in terms of medicinal applications. Biochemical constituents of mycelium and fruiting bodies of reishi mushroom (*Ganoderma* spp.) have been determined by Jha and Thakur (2020). It has been suggested to have potential

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for Biotechnological production of Anti-Cancer and Immunomodulatory drugs (Boh, 2013) and also anti-tumour properties (Ferriera *et al.* 2010). Its nutrient importance has also been discovered to be extremely important. *G. lucidum* can be purchased as consumer items in the form of pills, powders, herbal supplements, or tea of any form. For commercial items, the mycelium of an edible mushroom is used, but in the case of *G. lucidum*, various sections are used. Mycelium, seeds, and even the mushroom's fruiting bodies have all been included in the past. Another research found that the *G. lucidum* mushroom is beneficial against elevated blood glucose levels, a weakened immune system, hepatic defence, and a variety of other bacterial infections. Some fungi, on the other hand, may minimise bacterial infections and provide nutrients. *G. lucidum* is a fungus with a long tradition in medicine. Many scientists believe that *Ganoderma lucidum* have been utilized for over 2000 years. We believe it has been used for over 4000 years based on ancient scripts. According to some scientists, the fungi were used during the time of Taoism. Scientists also found that the cultivation and development of these fungi was first done artificially around 1400 BC. Furniture, painting, decorations, and sculpture from the past show that fungi have been used for centuries, although the use of fungi to cure illness is a recent phenomenon. In several texts, such as the Nong Ben Cao Jing, composed during China's Eastern Han administration *G. lucidum* was described as a medicine (25-220 AD). The genus *Ganoderma* is believed to be a well-known traditional remedy. Their popularity is spreading across the globe. We attempted to provide an overview of the comparative study of *G. lucidum* and other edible mushrooms based on their dietary and productive benefits in this study.

Taxonomy

The polypore Basidiomycetous fungus that can form a double-walled basidiospore belong to the Ganodermataceae family. There are 219 species in the variety *Ganoderma* that have been countered to the family, with *G. lucidum* (W. Terse.: Fr.) P. Karsten as the species type. Basidiocarps of this variety is containing a laccate (sparkly) surface partner with the presence of thick-walled pilocystidia that is implanted in an extracellular grid made of melanin (Fig.1). Fruit body exhibits various qualities, like shape and shading (yellow, red, blue, green, white, dark, and purple). Characters may incorporate host explicitness, and topographical source. They primarily are utilized to distinguish singular individuals from the species. The morphological qualities are dependent upon variety coming about structures. Development in various topographical regions with various climatic conditions, for example, can induce variations in natural genetic production. Human species variations and recombination are involved in genetic growth. Macroscopic features are used to identify this mushroom's confused, conflicting, and ambiguous taxonomy, resulting in a wide number of synonyms. Some taxonomists believe that macro morphological characteristics are only somewhat useful in identifying *Ganoderma* species. It has a high degree of phenotypic plasticity. Spore form and scale, background colour and consistency, and the microanatomy of the pilear crust are considered to be more accurate morphological characteristics for *Ganoderma* specimens. Differentiating morphologically related organisms has often relied on chlamydospore development and structure, enzymatic analyses, also, less significantly, the reach and ideal development temperatures.*Ganoderma* species taxonomy has also used biochemical, genetic, and molecular approaches such as Recombinant (rDNA) sequencing, random amplified polymorphic DNA-PCR (RAPD; PCR stands for polymerase chain reaction), internal transcribed spacer (ITS) sequences, sequence-related amplified polymorphism. Different ways to deal with the issue of *G. lucidum* scientific classification incorporate non-dangerous close to infrared (NIR) techniques consolidated with chemometrics atomic attractive reverberation (NMR)- based Metabolomics and elite

Fig. 1 : Fruiting body of *Ganoderma* sp.

fluid chromatography (HPLC) for creating synthetic fingerprints. *Ganoderma* is placed under Family Ganodermataceae, Order Polyporale, Class Agaricomycetes and Division Basidiomycota. Species of *Ganoderma* include *G. alba, G. annularis, G. atrum, G. aurea, G. australe, G. amboinense, G. applanatum, G. boninense, G. brownie, G. colossus* and *G. cupreum.*

Nutritional value

In comparison with other mushroom *G. lucidum* is considered as healthier for its active compounds which possess several healing properties and antimicrobial activity. For these compounds this edible mushroom can cure many chronic diseases. For this reason it is considered more healthy and effective.

Active compounds of G. lucidum

Triterpenoids, fatty acids, steroids, polysaccharide, triterpenoids, nucleoside, amino acids, alkaloids and proteins have all been discovered in *G. lucidum* in recent research. Due to the higher contents in the fungi, complex structures, and important bioactivities, triterpenoids and polysaccharides have gotten a lot of publicity.

Polysaccharides

The fermentation liquid, mycelium and fruit shells *G. lucidum* are used to remove polysaccharides. Different elements, shapes, molecular weights, and symptoms of GLPs (*Ganoderma lucidum* polysaccharides) are associated with different stages of growth in *G. lucidum*. The mycelium has the highest polysaccharide content, while the fruiting body has the lowest. The fruiting body containing monosaccharides are mostly galactose and glucose, while the spore and mycelium, monosaccharides are mostly glucose. GLPs derived from fruiting bodies have been shown to have anticancer properties by modulating the immune system. The mycelium and the fruiting body from the *G. lucidum* contain a variety of 1160 to 4105 D molecular weight monosaccharides. GLPs have a higher mol weight 13 -d- glucan with 16 -d- glucosyl branches and their fundamental structure and the major sugar are Rhamnose, Galactose, Glucose and Mannose (Boh*et al.* 2007).

Triterpenoids

The spores, mycelium and fruiting body of *G. lucidum* have yielded more than 200 triterpenes (Baby et al. 2015; Xia *et al.* 2014). *G. lucidum* has higher content and diversity of GTs in its fruiting body, but just a few GT species in its mycelium. In non-broken *G. lucidum* spores, no GTs have been found. Tetracyclic Triterpenes are the most common kind of triterpene (Xia *et al*. 2014). GTs are classified as Ganoderic Acid, Ganoderiol, Ganoderone, Ganolactone, and Ganoderal based on their functional groups and side chains (Baby *et al.* 2015).

Steroids

More than 20 different forms of sterols have been discovered in *G. lucidum*, and their skeletons are Ergosterols and Cholesterols, respectively.

Proteins and Polypeptide

G. lucidum has been shown to contain a number of bioactive proteins. Ling Zhi-8 (LZ-8) is a polypeptide with an acetylated amino terminus and 110 amino acid residues (Lin *et al.* 2003). LZ-8's sequence and predicted secondary structure are very similar to the variable region of immunoglobulin's heavy chain. Using chromatographic and electrophoretic methods, LZ-8 was the first immune modulatory protein isolated from *G. lucidum* mycelial extract.Antioxidant properties of the peptides isolated from *Ganoderma lucidum* fruiting body have also been reported (Girjal*et al*. 2012).

Nucleosides

Nucleosides like Adenosine, Cystidine, Guanosine, Inosine, Thymidine, and Uridine, as well as nucleotides like Adenine, Guanine, Hypoxanthine, Thymine, and Uracil, are found in *G. lucidum* (Gao *et al.* 2003).

Enzymes

Glutamic protease, B-N-Acetyl hexosaminidase, -1, 2-mannosidase, endo-1, 3-glucanase, -1, 3-glucanase, and Glutamic protease were all isolated from *G. lucidum*, and Glutamic protease was the most abundant protein in the extracts.

Table 1: Nutritional value of different mushrooms

Nutritional value	*Ganoderma* sp.	*Pleurotus* spp.	*Agaricus bisporus*	*Volvariella volvacea*
Triterpenoids	59.21%	30.45%	39.45%	51.73%
Polysaccharides	61.80%	70.91%	65.66 %	49.99%
Proteins	13.3%	10.56%	9.68%	15.55%
Amino acid	16.57%	19.25%	14.44%	22.75%
Vitamins and minerals	10.20%	5.99%	7.91%	4.49%

Data from Ahlawat *et al*. (2016)

Amino acids

G. lucidum contains eighteen different amino acids, with leucine being the most common and having significant hypoglycemic and antioxidant properties.

Vitamins and Minerals

G. lucidum Nucleosides has been shown to contain many vitamins as vitamin b6 , b2 and b1, carotene, c, d, e. *G. lucidum* has also been shown to have minerals such as calcium, sodium, potassium, phosphorus, iron, carbon, magnesium, zinc, chromium, arsenic, copper, manganese, silicon, aluminium, cobalt, molybdenum, nickel, and lead. In comparison to other mushrooms, *Ganoderma* contains a higher amount of Vitamins, Minerals and Triterpenoids (Table 1).

Global production

Current status of global *Ganoderma* cultivation, products, industry and marketing has been reviewed by Hapuarachchi *et al.* (2018). During the last decade in Europe *Ganoderma* products have attracted a heavy attention. Malaysia, North America and Singapore the *Ganoderma* is also in a great craze. *Ganoderma* products are mainly manufactured and supplied from China, Japan and Korea (Chang and Mills 2004). During 1995 the total *Ganoderma* production of Japan was estimated 500 MT. In 1997, the *G. lucidum* production was 4300 MT total in the whole World, and 3000 MT were from China single handed, while 1500 MT were exported to Japan, Korea, Singapore and Taiwan. The remaining 1300 MT were produced mainly in Japan, Thailand, US, Malaysia, Vietnam, Indonesia and Sri Lanka. In Malaysia production of 70 MT of *Ganoderma* and accounted for 1% of the global production in 2001 by DXN group (DXN Holdings' IPO listing Reports). The worth of the total World *Ganoderma* based market for natural health products was 1628 million US dollars in 1995. In 2004, *Ganoderma lucidum* worldwide production was approximately 5000-6000 MT. Of this more than half was produced by China. It was recorded that *Ganoderma* production in China was 36700 and 49200 MT in 2002 and 2003, respectively by the China Edible Fungi Association. However, due to low reproducibility and inadequate quality control, *Ganoderma*-based products have some issues. The product consistency is harmed bya variety of factors, including seasonal changes, soil conditions, and the stage of fruiting body growth. As a result, it's critical to create appropriate and repeatable manufacturing procedures to ensure high-quality, consistent, and healthy *Ganoderma* products (Chang and Mills 2004). Quality *Ganoderma* products require good laboratory, agricultural, engineering, processing, and clinical practices. Prospects and potential of *Ganoderma lucidum* in India have been highlighted by Bijalwan and his group during 2020.

Growing condition of G. lucidum

There are many stages of development, including mycelium, primordium, young and mature fruiting bodies, and so on. Each stage has its own set of nutritional requirements as well as growth parameters such as temperature, humidity, sun, and oxygen.

Nutritional factors

There are many nutritional factors that can affect the production of the edible mushrooms.

Carbon sources

It supplies energy for growth and development. Carbon sources are mainly organic like sugars, starch, cellulose, hemicelluloses, lignin etc. For cultivation of fruiting bodies hard wood saw dust,

cotton seed hull, rice straw, wheat straw, corncob powder etc. are used.

Nitrogen sources

N is one of the major components of protein. *Ganoderma* can directly absorb amino acid, urea, ammonia and other small molecules. Yeast powder and peptone are mixed with media. Common N sources are wheat bran, rice bran, corn powder, urea, ammonium sulphate etc. An appropriate Carbon and Nitrogen ratio is need which is from 15 to 45:1 for proper growth of mycelium.

Inorganic salts

Inorganic elements for *Ganoderma* growth include Potassium, Sodium, Calcium, Magnesium, Phosphorus, Sulphur and Zinc. Most important elements are Phosphorus, Potassium and Magnesium. Calcium sulphate is responsible for adjusting the pH value of the substrate, increasing ventilation,fixing nitrogen and increasing the content of Calcium and Sulphur in substrate.

Growth factor

Growth factors are important elements in during growth and development of *Ganoderma*, which are involved in metabolic processes of *Ganoderma* andincludes vitamins like B1, B2, B6 and biotin. Substrates generally contain growth factors and hence additional substance may not be needed.

Moisture content

Water is an important condition and component for growth. Artificial cultivation of *Ganoderma* requires a moisture content of the solid state substrate at approximately 60-65%. Such moisture contain can meet the needs of the mycelium growth and will not cause oxygen deficiency symptoms to mycelium. When the substrate is very loose with a larger void between materials, such as when using biogases as the substrate. The moisture content in the substrate should be increased to 70 %.

Environmental factors

Along with many nutritional factors environmental factors are also responsible for the production of fungi. They may be weather to temperature to moisture to sunlight anything some of those factors described below:

Temperature range

Temperature is a necessary condition for enzymatic reactions during the development process of the mycelium and fruiting bodies. *Ganoderma* mycelium can grow within a temperature range of 20-35^{0}C and the optimum temperature is within the range of 25-30^{0}C. The optimum temperature for the development of fruiting body is within the range of 24-28^{0}C. When the temperature is below 20^{0}C, the fruiting body will become yellow and rigid, while it will easily die when the temperature is above 35^{0}C. During the fruiting body growth and development period, it is not necessary to stimulate with different temperatures. If there is a great difference in temperature, fruiting bodies will readily grow abnormally.

Moisture requirement

During the spawn run, the relative humidity within the incubator should be maintained between 60-65 %. Moisture control is thus an important strategyfor reducing meld growth in the indoor environment. During the fruiting body growth period, the relative humidity within the mushroom house should be increased to a level of 85-95 %.

Oxygen level

Oxygen is one of the most important elements required to sustain life activities. *Ganoderma* is a kind of high temperature aerobic fungi. It is necessary to absorb oxygen and release CO_2 during the whole growing period. During development of the fruiting body in Ganodermataceae, is the concentration of CO_2 in the cultivation environment is higher than 0.1%, the cap does not grow normally and turned abnormal in shape. Only when CO_2 concentration is lower than 0.1% does the fruiting body become large, thick with a rounded cap and short stripe.

Light condition

Ganoderma is very sensitive to light/dark condition throughout growth. Light inhibits mycelia growth, but weak light can promote the primordium differentiation and pyleus formation in the early stage of fruiting body differentiation. Spawn run is usually carried out in the absence of light. Bright exposure to very little light triggers the formation

of *Ganoderma*. In other words in the absence of light individual cell of *Ganoderma* could not form the primordia and further would not easily differentiate into capsules. Even if the fruiting body does form, it will grow slowly and develop abnormally. The formation of stripe and cap is also sensitive to light. The light level is in the intensity range of 20-100 lux, a fully colonized substrate only by produces an antler like fruiting body. At an ambient light level of 300-1000 lux slanders stripe and small caps will be formed, and are strongly curved towards the direction of light. When the lighting level is in the range of 3000-10000 lux, stripes and caps are normal. Under the optimum lightning level of 15000-50000 lux, formation of stripes and caps are optimal.

CONCLUSION

Form this short review we can easily find that the *Ganoderma* mushroom is a great medicinal value holder in its class. This mushroom contains rich levels of amino acids, enzyme, nucleoside, protein, polypeptide, steroids, polysaccharide, vitamins and Minerals. The active compound of the mushroom helps to fight against many chronic disorders and disease. They are rich with dietary supplements so they are helpful in providing immunity. They are also used for the anti-aging purpose for the cosmetic world. They are even used as medicine tea even the study also summarize that the growth conditions of this fungi are helpful in humid atmosphere as Indian atmosphere. So it would be helpful to cultivate this mushroom at a high level. Even the yield of this mushroom is high. So it could help the agriculture and economy as well.

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