

Insights of medicinal mushroom (*Ganoderma lucidum*): prospects and potential in India

Abstract

Medicinal mushrooms have been used since olden days for the treatment of various diseases. *Ganoderma lucidum* or Reishi is a medicinal mushroom of significant importance which is gaining popularity due to the presence of numerous bio-active ingredients in it. Wild collection of this mushroom along with its cultivation is done worldwide to meet its ever-increasing demand in the market. Although, artificial or sawdust method of its cultivation on different woody substrates is commonly used but wood log cultivation method is also in practice. The steps for its cultivation include spawn preparation, substrate preparation, fruiting body management, harvesting and storage with their own set of requirements and precautions for each step. Several healthcare, personal care, food and beverage products made of its extract are being marketed and consumed worldwide. In this review, a general understanding about the cultivation of medicinal mushroom *Ganoderma lucidum*, current market scenario and its potential in Indian markets are discussed.

Keywords: medicinal mushroom, *ganoderma lucidum*, cultivation technique, spawn, marketing

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Arvind Bijalwan,¹ Kalpana Bahuguna,¹ Amol Vasishth,¹ Alankar Singh,¹ Sumit Chaudhary,¹ Anil Tyagi,² MP Thakur,³ Tarun Kumar Thakur,⁴ Manmohan JR Dobriyal,⁵ Rajesh Kaushal,¹ Arjun Singh,² Nandini Maithani,² Devendra Kumar,¹ Gaurav Kothari,¹ Pramod Kumar Chourasia²

¹College of Forestry, VCSG Uttarakhand University of Horticulture and Forestry, India

²Center for Business and Entrepreneurial Development (CBED), India

³Indira Gandhi Krishi Vishwa vidyalaya, India

⁴Indira Gandhi National Tribal University, India

⁵College of Horticulture & Forestry, RLB Central Agricultural University, India

Correspondence: Arvind Bijalwan, College of Forestry, VCSG Uttarakhand University of Horticulture and Forestry, Ranichauri-249199, Tehri Garhwal, Uttarakhand, India, Tel +91 9412983808, Email arvindbijalwan76@gmail.com

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Introduction

Medicines play an important role in treatment of various diseases. These medicines are consumed mostly in the form of drugs extracted from plants or other herbal sources. Among the herbal medicines, medicinal mushrooms have been used for curing several diseases as well as in maintaining good health from a long time. *Ganoderma lucidum* is one of the most popular and important medicinal mushroom which has been used for strengthening the body system since thousands of years. The name *Ganoderma* is derived from the Greek word- *ganos* "brightness, sheen", hence "shining" and *derma* "skin".¹ Its fruiting body is called "Lingzhi", Chi-zhi" or "Rui-zhi" in China, "Reishi", "Munnertake" or "Sachitake" in Japan and "Youngzhi" in Korea.^{2,3} This mushroom is often called as "Mushroom of Immortality", "Herb of spiritual potency" and "Celestial Herb" due to its various medicinal properties.^{4,5,6}

Ganoderma lucidum is known since around 2000 years and has played a very significant role as a medicine in Chinese and Japanese culture.⁷ Lingzhi, as a medicinal mushroom with various medicinal properties was also recorded in the first Chinese Pharmacopeia written in Ming Dynasty (A.D. 1590).⁸ This mushroom has often been portrayed in ancient Chinese art and literature. There also have been some assertions that the basic concept of 'Lingzhi' was originated in India as an expression of "Soma", a vedic plant "Soma-Haoma".⁹ The reports on Chinese edible and medicinal mushrooms accepted *G. lucidum* as the scientific binomial of "Lingzhi".

Ganoderma lucidum is a fungus which belongs to the family Polyporaceae (or Ganodermaceae) of class Basidiomycetes¹⁰. It grows on dead wood and various parts of the fungus viz., mycelia, spores and

its fruiting body are consumed and sold in various forms as powder, capsule, tea, coffee etc. Currently this mushroom is being used in treatment of various diseases and disorders worldwide. Cultivation of this mushroom is being done intensively in countries all around the world especially South-east Asian countries for manufacturing various health products which are being marketed and consumed worldwide. India is one of the largest market which, in recent time is flooded with herbal products including *Ganoderma* products. With increasing awareness towards *Ganoderma* based products along with easy accessibility of these products through online and multi level marketing, *Ganoderma* business is increasing continuously and creating tons of opportunities for the *Ganoderma* based businesses.

Morphology

Fruiting bodies of *G. lucidum* collected from India are kidney-shaped or irregular, mostly with thick margin along with long thick corky, hard stipe of dark brown in color (fruiting bodies also found without stipe, attached to the base of the tree with a dark thick pileus-*G. applanatum*). Basidiospores are double walled, ellipsoid with top cut flat/ovate with a rounded base and truncate to narrowly rounded apex/globose shape. Size of Basidiospores varies between 6.24 µm -9.08µm ×9.11 µm -12 µm.¹¹ Pileus of *G. lucidum* is kidney shaped, elongated, red to reddish brown with or without bright yellow and white margins when mature. Its tubes are up to 2 cm deep with white pores of 0.1 cm. and usually bruising brown in colour. The stipe is 3-12 cm. long with 1-2 cm. thickness, brown coloured spore prints and smooth, cylindrical dark red-black coloured crust.¹² According to Bhosle et al.,¹³ basidiocarp of *Ganoderma lucidum* var. *capense* is 7–12×11–19×1.5 cm, woody to corky, sub sessile to laterally stipitate with 2–3

cm long, reniform with laccate, dark red-purple upper surface which is yellowish, brittle and soft towards margin. Its basidiospores were yellowish brown and of $8.3\text{--}10 \times 6.6 \mu\text{m}$. dimensions. Basidiocarp of *G. lucidum* var. *lucidum*, as described by Bhosle et al.,¹³ was laterally stipitate or eccentric, $12\text{--}14 \times 8\text{--}9 \times 1.6 \text{ cm.}$, laccate, brittle, stipe reddish black, 7–10 cm long. Its upper surface was radially sulcate, semidull with dark reddish brown colour and yellowish to brown thin margin, basidiospore $7\text{--}8.5 \times 5\text{--}6 \mu\text{m}$. The Chinese *G. lucidum* has cream to buff colored context.¹⁴

Distribution and ecology

Ganoderma species is distributed worldwide from tropical to subtropical regions due to its likeliness towards hot and humid climate. It is a facultative parasite which can also live as saprobe by feeding off and rotting stumps and roots of trees. It is a pathogenic, wood decaying fungus which causes the butt root, root and stem rot in perennial crops and economically important trees especially in tropical countries.¹⁵ The species of *Ganoderma* have a wide host range, with more than 44 species from 34 genera of plants being identified as potential hosts.¹⁶

Ecologically, *Ganoderma* species play an important role in breaking down the woody plants for nutrient mobilization. It is effective in production of bioenergy and used in bioremediation as it contains the mechanism of lignocellulose decomposing enzyme.^{15–18} *Ganoderma* species is responsible for the loss of forestry yields by causing the root and stem rots in various tree species like, *Areca catechu*,¹⁹ *Camilliasinensis*, *Cocosnucifera*,²⁰ *Elaeisqueensis*²¹ and *Heveabrsiliensis*²² worldwide.

Chemical constituents and importance

Ganoderma lucidum is an important medicinal mushroom due to presence of various bioactive chemical constituents which reflects different biological properties and are generally used as cure of various diseases, as health tonics, cosmetics etc. Various researches have proved the therapeutic properties of this mushroom. This mushroom contains about 90% water, rest 10% of dry matter is rich in protein (10–40%), fat (2–8%), carbohydrate (3–28%), fiber (3–32%) and ash (8–10%), Calcium, minerals, Phosphorus, Potassium, Copper, Iron, Zinc, Magnesium and selenium on fresh weight basis.²³ More than 400 bioactive compounds like- polysaccharides, triterpenoid, nucleotides, steroids, fatty acids and other trace elements have been isolated and identified from its fruiting body, spores and mycelia. These ingredients have various pharmacological properties like anti-bacterial, anti-viral, anti-tumour, immunomodulation, sleep promotion, anti-ageing, anti-ulcer etc.²⁴ Various studies have shown that the chloroform extracted from *G.lucidum* have the potential to delay the scavenging activities as well as the formation of free radicles.

Photographs of medicinal mushroom *Ganoderma lucidum* (Figures 1–8).

The immunomodulatory properties of *G.lucidum* have the potential to enhance the immune system and to reduce the toxicity in the cancer patients going through the chemotherapy or the radiation treatments. Zhuang et al.,²⁵ reported the similar activity of *G. lucidum* dietary supplement in the reduction of leucopenia, neutropenia with the improvement in NK-cells and lymphocyte count. The studies and reports presented by Wang et al.,²⁶ Lieu et al.,²⁷ Cao & Lin²⁸ and Chen et al.,²⁹ also supported the immune modulatory activities of *G. lucidum*.



Figure 1 Naturally growing *Ganoderma lucidum* fruiting body on dead wood.



Figure 2 *Ganoderma lucidum* fruiting body growing on dead and decaying wood.



Figure 3 Porous under surface of *Ganoderma lucidum* fruiting body.



Figure 4 Pinhead stage of *Ganoderma lucidum*.



Figure 7 Fully developed *Ganoderma lucidum* fruiting body.



Figure 5 *Ganoderma lucidum* fruiting body with elongated stipe.



Figure 8 Harvested and dried *Ganoderma lucidum* fruiting bodies.



Figure 6 Young growing fruit body of *Ganoderma lucidum* with yellow colour and white margin.

The anti-cancerous and anti-tumor activities of *G. lucidum* are associated with the immunomodulating effects of this mushroom as it has the potential to increase the recovery in patients recovering from cancer treatment. Polysaccharides and triterpenoids extracted from this mushroom have shown the cytotoxic activities against hepatoma cells.³⁰ The compounds extracted from *G. lucidum* have also shown the decrease in leukemic cells.³¹ The study of Sliva et al.,³² indicated the high mortality of human breast and prostate cancer cells by the effect of *G. lucidum* spores or dried fruiting bodies and is potential in cancer treatment.

In a study conducted by el-Mekkawy et al.,³³ on the various compounds extracted from *G. lucidum* fruiting bodies, anti-HIV activity of Ganoderiol F and ganodermanontriol and moderate activity of ganoderic acid alpha, ganoderic acid B, ganoderiol A& B, ganoderic acid C1, 3 beta-5 alpha-dihydroxy-6 beta-methoxyergosta-7,22-diene and ganoderic acid H were observed. Gao et al.,³⁴ observed the activity of Lucidenic acid O and lucidenic lactone extracted from *G. lucidum* fruiting bodies against HIV.

The alcohol and aqueous extract of *G. lucidum* fruiting bodies have shown the reduced blood sugar level in diabetic mice.^{35,36} Hypoglycemic effect of polysaccharides isolated from *G. lucidum* was observed by Xiao et al.,³⁷ and Zhang & Lin.³⁸ The reduction in

plasma glucose levels in steroid induced rats was concluded in the study conducted by Sarker³⁶ which confirms the anti-hyperglycemic, insulin-sensitivity and hyperlipidaemic activity of *G. lucidum*.

Kurtipek et al.,³⁹ also concluded in their research that the polysaccharides present in *G. lucidum* have anti-inflammatory property and it can be an option for treating and managing skin diseases with inflammation such as cutaneous sarcoidosis.

The activity *G. lucidum* against various gram positive and gram negative bacteria is observed in several studies. *G. lucidum* also exhibits the properties like anti-fungal, anti-allergic, anti-angiogenic, anti-ulcerogenic, anti-mutagenic, anti-proliferative activities, cardiovascular and hepatoprotective activities.

Artificial cultivation

The collection *Ganoderma lucidum* fruiting bodies from wild was unable to meet the demand for the commercial production of its products. The collection of *Ganoderma* and maintaining its quality is quite difficult in wild. Only wealthy people had the privilege for the collection of *Ganoderma* from wild and its consumption in ancient times unlike now a day where most of *Ganoderma* is cultivated and is commonly consumed by general people. Although the artificial cultivation of *Ganoderma* started in 1937, it was successfully cultivated by the technicians of Institute of Microbiology, Chinese Academy of Sciences, Beijing in year 1969 by using the spore separation cultivation method.⁴⁰ After that, *Ganoderma* cultivation became popular in Asian countries like China, Japan and Korea.⁴¹

Since 1969, the cultivation of *Ganoderma* was done by the inoculation of one meter long unsterilized natural logs and then burying them in a trench.⁹ Mainly, the broad-leaved hardwood logs are cut from living trees and can be used in *Ganoderma* cultivation.⁴² It takes around 6-24 months for its fruiting bodies to appear but the crop could be continued upto five years.⁴² Various other methods like basswood cultivation, sawdust cultivation and substitute cultivation have also been tried. Various different substrates such as- wood logs, grain, sawdust, tea wastes, cotton seed husk, farm crop residues, sunflower seed hull, cork residue, corn cobs, olive oil press cakes, wheat straw etc. are being used for the artificial cultivation of *G. lucidum*. By altering the growth conditions mainly temperature and CO₂ volume, one can attain various growth forms including antlers-like structures.⁹ As compared to sawdust synthetic log cultivation method, lower yield and extended production time can be expected in natural log cultivation method.⁴³

The cultivation technique of *G. lucidum* is divided majorly into two patterns based on the medium of cultivation. Solid state medium (SSM) cultivation method is used for the production of fruiting body, spore and mycelium biomass but the Liquid state medium (LSM) is used for the cultivation by mycelia biomass only.⁴⁴ To obtain the desired products with excellent quality of mycelial biomass along with desired biochemical products in shorter time, the advance fermentation techniques are preferred choice.² The cultivation pattern of *G. lucidum* can be divided into two parts-Solid State Fermentation (SSF) and Liquid State Fermentation (LSF) on the basis of the medium on which it is cultivated.⁴⁵

In the liquid state/submerged fermentation process, the method of cultivation is done on liquid medium with Nitrogen and Carbon as the principle nutrient source. If our product of interests is Ganoderic acid and polysaccharides one can get it in 2-3 weeks through submerged

fermentation as compared to substrate cultivation which takes 3-5 months.⁴⁵ The production is mainly done in two stages- Preparation of spawn or mother culture and preparation of substrate material for the fruiting body cultivation. Mainly two methods of substrate cultivation- wood log cultivation and substitute cultivation are used in the commercial production of *G. lucidum* fruiting bodies.

Spawn preparation

The sterilized substrate after cooling is inoculated by the seed inoculum or spawn of mainly two types: liquid spawn and solid spawn. Potato-Dextrose Broth (PDB) or other formulations are used to prepare the pure culture liquid mycelial spawn. The type of solid spawn can be identified on the basis of substrate used like: grain spawn, sawdust-bran spawn, dowels, grooved woody plugged spawn etc.⁴⁴ Spawn bags for each substrate or substrate mixtures are prepared by filling up prepared mixture or substrate like wheat, sorghum, maize, saw dust in polypropylene bags of required size (preferably 1 kg. or 5 kg.) and packed tightly using heat resistant Polyvinyl chloride (PVC) tube in the mouth of the bag. After plugging its neck with cotton, it is covered with sterile brown paper and tied with rubber band. These packets with PVC necks are then sterilized by autoclaving them at 120°C and 1.5 Kg/cm² pressure for one hour. After sterilization, these packets are transferred into clean aseptic chamber for cooling it for 24 hours.^{46,47,48,11} The polypropylene bags are then inoculated with young growing culture of *G. lucidum* under aseptic conditions by removing the cotton plug from the mouth of the bag and incubated for 8-10 days to get the bags ready for inoculation into the fruiting substrates.¹¹

Substitute/sawdust cultivation

For the cultivation of *G. lucidum*, sawdust and mixed sawdust of various tree species i.e. *Albizia sp.*, *Alnusnepalensis*, *Bombaxceiba*, *Borassusflabellifer*, *Dalbergiasisoo*, *Eucalyptus sp.*, *Mangiferaindica*, *Shorearobusta* were also used as substrate.^{49,50} Other than wood, various other substrates are also used for the cultivation of *G. lucidum*. Riu et al.,⁵¹ identified cork residues as a substrate for its cultivation along with Peksen& Yakupoglu⁵² who identified tea waste as its substrate. González-Matute et al.,⁵³ studied its growth on sunflower seed hulls. Corn cobs and olive oil press cakes were also used as a substrate for *G. lucidum* cultivation by Ueitele et al.,⁵⁴ and Gregori & Pohleven⁵⁵ respectively. Zhang& Wang⁵⁶ also cultivated it on farm crop residue.

According to Mehta et al.,⁵⁷ inoculation of spawn at the rate of 3% of dry weight of substrate results in shortest growth cycle and maximum yield. This sawdust is brought to 65% moisture by wetting after mixing it with 20% wheat bran. To obtain a pH of 5.5 Gypsum (CaSO₄) and lime (CaCO₃) is added. Just like the spawn preparation, polypropylene bags are then filled with this mixed substrate and after putting a plastic ring its mouth is plugged with cotton. Sterilization of these bags is done in autoclave at 22 psi pressure for two hours. Substrate is then cooled down and spawned with wheat grain/sawdust spawn @3% on dry weight basis as *G. lucidum* is slow growing as compared to other mushrooms. At around 28-35°C spawn run/incubation is done in closed rooms with high CO₂ and darkness.⁵⁸

Wood log cultivation

Wood log cultivation can be obtained through three methods which are by sterilizing- short wood log, wood log and stump. Among these three, short wood log cultivation method has the upper hand due to high quality fruiting body, short growth cycle and large number

of spores.⁵⁹ The cultivation on wooden billets is taken place in low cost mist chambers containing a sand bed at its base. Billets are then vertically buried in the sand bed after the complete colonization. These billets are then covered with a thin layer of garden soil inside a bamboo chamber. To maintain the 60-70% humidity and 25-30°C temperature, these sand beds are watered twice a day and will be continued throughout the growing period.¹¹

Preparation of logs and inoculation

Growth and yield of Lingzhi fruiting body depends greatly upon the tree species.⁶⁰ Due to presence of bactericidal components, Lingzhi cannot be grown on softwood species and few hardwood species like—Camphor and *Eucalyptus* species.⁴⁴ The tree segments are generally cut about 12-15 cm. long and 13 cm. diameter for good mycelial growth with each section flat.⁶¹ All freshly cut logs of equal length are dried to obtain the suitable moisture level for mycelia growth which is 35-42%. The logs needed to dry for about 15 days before tying them. These logs are tied tight and flat in plastic bags and are sterilized under high pressure steam sterilizer (0.5 Mega Pascal pressure for 1.5-2 hours). To avoid any contamination, the inoculation process of spawn should be done in properly sanitized area.⁴⁴ After inoculation, the incubated logs are put for mycelium run at 26±1°C and 60-70% RH for 15 days. Proper ventilation, humidity and contamination free conditions should be provided for good mycelial growth. Any exposure to light will trigger the initiation of primordial on the logs, which are usually formed after about 60-70 days of spawning.⁴⁴

Burying logs in soil and fruiting body management

After appearance of fruiting body primordial, these logs are embedded directly into the soil, leaving the newly formed primordia above ground level. Before embedding the logs, solarization of well drained sandy soil should be done for at least two days. These bags are transferred into fruiting room where 25±1°C temperature and 80-90% RH is maintained to promote cap formation.⁴⁴ In the initial stage of fruiting body, the soil moisture should be maintained at 20-25% and 16-18% in high humus soil and sandy soil respectively, which will further reduced up to 18% and 15% respectively to avoid any mould growth. The management of fruiting body is different in its various stages. During the pileus differentiation, it is very important to reduce CO₂ concentration by providing proper ventilation. The best quality fruiting body with dark brown colour cortex is grown at 25°C. Proper irrigation, aeration, light, protection, harvesting and drying conditions should be provided. Regular inspections and management especially regulation of ventilation, light and humidity is carried out. The fruiting body will mature in about 18 days in average temperature of 25°C and can be harvested.⁴⁴ After that, fruiting bodies are air dried at 60°C for 2-3 days and the underside of pileus should be facing down. Prolonged and improper drying of fruiting body reduces its quality and makes it vulnerable to the mould attacks.⁴²

The harvest time or number of harvest is generally termed as 'Flush'. To continue the cultivation for the second and third flush under optimum growth conditions can be carried out although the yield reduces subsequently in each flush. Second flush can be harvested after two week of spawn run. *Trichoderma sp.*, *Mycogone perniciosa* and *Neurospora sp.* are the main fungi which are harmful and required proper protection for *Ganoderma* cultivation. It should be also protected from insect pests like moths, beetles, termites and small animals such as snails and slugs.⁴⁴

Ganoderma products and its global market

The annual sale of *G. lucidum* based products was estimated to be more than 2.5 billion USD in Asian countries including China, Japan and South Korea.⁶² *Ganoderma lucidum* has given prime importance in Chinese Pharmacopeia for prevention and treatment of many diseases. It has also been included in American Herbal Pharmacopoeia and Therapeutic Compendium.⁶³

To enhance the metabolic function and body immune system, *G. lucidum* products are being commercialized as food and drug supplement. These products are commonly sold in the form of coffee, powder, tea, dietary supplements, spore products, drinks, syrups, toothpastes, soaps and lotions etc.^{61,64,65} *Ganoderma* is a part of many cosmetic products like skin lightening products in USA, Europe and Asian countries mainly in China and Korea.⁶⁶ *Ganoderma* extract is used in many facial and cosmetic products due to its tyrosinase enzyme inhibiting activity which ultimately inhibit the melanin formation in skin.^{67,68} It is also used in hair stimulators for men because it lowers the dihydrotestosterone or prostatic hyperplasia levels.⁶⁹

There are nearly 200 medicines containing *Ganoderma* along with more than 1,000 *Ganoderma* health & food products are available which are certified by Chinese government.⁷⁰ *Ganoderma lucidum* is also used as the daily life food material such as soup, tea, wine, yoghurt etc.⁷¹ After 1990s, *Ganoderma* based products are being popular in Europe, Malaysia, North America and Singapore with China, Japan and Korea being its main producers and suppliers.⁷² In 1995, the world market for *Ganoderma* based natural health care products was 1628 million US dollars⁶¹ and the total estimated *Ganoderma* production of Japan during 1995 was approximately 500 MT. The worldwide *Ganoderma* production during 1997 was 4300 MT.⁷³ During 2002 and 2003, The China Edible Fungi Association recorded about 36700 MT and 49200 MT of *Ganoderma* production respectively in China.⁷⁴ The total worldwide production of *Ganoderma lucidum* in 2004 was estimated about 5000 MT-6000 MT, more than half of which was produced by China alone.^{75,76} Three types of *Ganoderma* developmental products which are mainly based on *Ganoderma* fruiting bodies,⁷⁶ mycelia⁷⁷ and spore powder⁷⁸ have been classified. Globally, More than 100 brands and 780 products of *Ganoderma* have been commercialized and sold.^{64,65} USA is the largest market for *Ganoderma* and related products.⁷⁹ According to Li et al.,⁴¹ the largest producer and exporter of popular products of *Ganoderma* fruiting bodies, slices and spore powders among consumers is China with the capacity over 110,000 MT/year. China accounts for about 70% of global *Ganoderma* production but its exports is still low (less than 5% of total production) because of the lack of any internationally recognized GMP (Good Manufacturing Practice) certified manufacturing facilities in China.⁸⁰ More than 100 research institutes specialized in *Ganoderma* studies and more than 200 factories situated in China are producing the *Ganoderma* based drugs and nutraceuticals along with the marketing of many patented products for the preparation of anti-tumor, liver function accelerant, lysozyme as antibiotic, shampoo and body shampoo, lowering of blood pressure & cholesterol levels, hypoglycemic activity, treatment of chronic bronchitis and immunomodulator.⁷⁸ Various *G. lucidum* based products made from various parts of the mushroom are currently being sold in the market.⁸¹

In India, there is a rapid increase in *Ganoderma*-based nutraceuticals market which was estimated about \$20 million USD in

2012.⁵⁷ After China, India has the most population of internet users with 34.6% population using internet which has drastically increased the number of consumers using online marketing platform.⁸² Various *Ganoderma* based genuine and certified products are easily available on online shopping platforms like Amazon, Flipkart etc which is a game changer for the herbal based products.

Conclusion

Ganoderma lucidum is a well-known medicinal mushroom possessing numerous medicinal properties which makes it suitable ingredient for a number of preparations in various medicine systems. Its history dates back almost two thousand years and has long been used as remedy for several diseases in many cultures especially Chinese and Japanese culture. *Ganoderma lucidum* is found all over the world and naturally it can be seen in the forest as a wood decaying pathogen with a wide host range of mainly broad leaved species. Various biological properties of this mushroom make it useful in cure of diseases and improvement of overall health. These biological properties are due to the presence of bioactive constituents like polysaccharides, triterpenoid, nucleotides, steroids, fatty acids etc. in it. Mainly this mushroom is comprised of protein, fat, carbohydrate, fiber, ash, minerals and other elements. Along with its pharmacological properties like anti-bacterial, anti-viral, anti-tumor, immunomodulation, anti-ageing, anti-ulcer and many more, it is also used in daily life edible and cosmetic products. China, with almost half of total *Ganoderma* production worldwide, is the largest producer and consumer of *Ganoderma* and its products. Along with China, countries like Japan and Korea are main producers of *G. lucidum* with USA being the largest market for *Ganoderma* and related products. As far as Indian market is concerned there is a growing demand for *Ganoderma* based products. Farmers and common people are not very aware of medicinal mushrooms from business point of view yet but efforts are being made to create awareness and interest among farmers towards *G. lucidum* cultivation as an additional source of income. Despite all the challenges, there is a great potential for farmers, growers and entrepreneurs for the production, value addition and marketing of *G. lucidum* based products.

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Conflicts of interest

The author declares there are no conflicts of interest.

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