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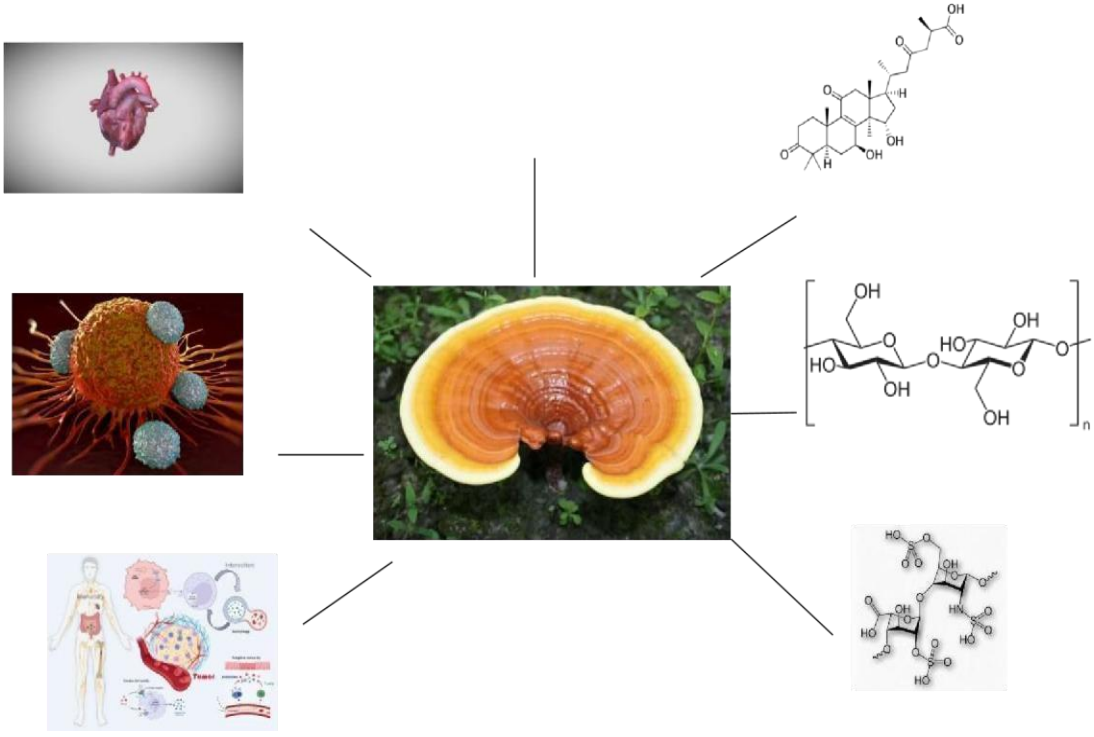
PHARMACOLOGICAL BENEFITS OF MEDICINAL MUSHROOM Ganoderma Lingzi

Sakshi Arora

Lovely Professional University

ABSTRACT :

Ganoderma lucidum is a member of the class Agaricomycetes and family Ganodermataceae. Another name for it *is Lingzii*. Numerous mushrooms, including lion mane (*Hericium erinaceus*) and cordyceps *(Ophiocordyceps sinensis*). The formulation has been combined with turkey tail (*Trametes versicolour),* shitake (*Lentinula edodes*), and maitake (*Grifola frondose*) to create an extract. The mixture is used to create an extract that has immunoregulatory and antioxidant properties. The extract, a tailored blend of natural immune modulators derived from various medicinal mushrooms, enhances the bio-intelligence of immune functions and acts on cellular biology through host defence mediation. Its functions include immunological modulation, vigour and vitality, rejuvenation and antiaging, cancer cure, and adjuvant treatment for diabetes. Beta-glucans, beta-d glucans, ergosterol, cyathane derivatives, and beta glycoprotein proflamin are examples of polysaccharides that have anti-tumor and immune-modulating properties.



INTRODUCTION

Mycology is the study of fungi. Originally considered to be part of the kingdom of plants, fungi are now classified as belonging to a distinct group of organisms. These are eukaryotes with distinct chromosomes and well-defined membrane-bound nuclei. In contrast to other plants that produce their own organic food through photosynthesis, they are heterotropic, meaning they require naturally available substances of varying degrees of complexity. Most fungi, with the exception of a few, have a distinct cell wall that all of their nutrients must flow through in a manner that is soluble (Meena et al., 2020).
It spreads widely to create a mushroom, which is a fruiting body with a vast surface area. Numerous fungus species thrive and operate in aquatic environments. Although they can grow in plants, animals, and humans and cause degradation and illness, fungi play a significant role in the soil ecosystem by decomposing decaying organic matter. Numerous fungi harm produced goods, such as food, clothing, leather, and wood, but they also play a significant role in the production of wines, beers, and other beverages (Wang et al., 2023).

Numerous causes of death or disability, including coronary artery disease, strokes, diabetes, atherosclerosis, obesity, and several types of cancer, are thought to be partially related to nutrition in the advanced nations.
A mushroom, a fruiting body with a large surface area, is produced when it spreads widely. Aquatic conditions are ideal for the growth and operation of many fungal species. By breaking down decaying organic matter, fungus contribute significantly to the soil ecology, despite the fact that they can thrive in humans, animals, and plants and cause disease and deterioration. Many fungus damage manufactured products like food, clothing, leather, and wood, but they are also important in the making of wines, beers, and other drinks (Wang et al., 2023).

In developed countries, diet is assumed to play a role in a number of causes of mortality or disability, such as coronary artery disease, strokes, diabetes, atherosclerosis, obesity, and various cancers.
The phrase "functional food" implies to any product that has the potential to be healthy, including modified foods, as well as those that may offer health advantages beyond the conventional nutrients they include. Dietary supplements, nutra or nutriceuticals, medical foods, vitamin foods, pharmafoods, and phytochemicals are only a few of the many names for them. Nonetheless, the functional foods paradigm is based on the idea that food can be used as medicine. Functional foods attempt to prevent illness rather than treat it. As a way of combating rising medical costs, functional foods are becoming more and more prominent in public health initiatives in poor countries. The kinds of foods that consumers buy are becoming more and more health concerned. An poor diet has been linked to a number of cancer types.

Numerous cultures throughout the world have traditionally regarded medicinal mushrooms as incredibly delicious and nourishing delicacies. Wild mushrooms are frequently gathered and utilised as a primary food source or added to soups, stews, and teas in many regions of the world, particularly Europe (Guo et al., 2021). The protein level of mushrooms is slightly lower than that of most meats and milk, but it is still higher than that of most vegetables, making them a decent source of digestible protein. Protein can range from 10 to 40 percent. On a dry weight basis, fresh mushrooms have 3–35% fibre and 3–21% carbohydrates. Every mineral found in mushrooms' development material is most likely present, with a higher concentration of potassium and phosphorus and a lower concentration of calcium and iron.
According to Leng et al. (2023), mushrooms seem to be a great source of vitamins, particularly thiamine (B1), riboflavin (B2), niacin, biotin, ascorbic acid, vitamin A, and active vitamin D.

Known as Fu Zheng therapy, immune system modulation has long been a part of Chinese holistic medicine. These substances lessen the severity of the illness or infection that is presenting.

Ganoderma lucidum [Lingzi or Reishi]

Lingzhi is known as the "herb of spiritual potency," signifying prosperity, well-being, divine strength, and longevity. Its name combines the essence of immortality with spiritual potency. G. lucidum stands out among farmed mushrooms in that its potent medicinal properties take precedence over its nutritional value. Commercial goods containing G. lucidum come in a range of formats, including tea, dietary supplements, and powders. These come from many components of the mushroom, such as the fruit body, spores, and mycelia. Lingzhi has several particular uses and health benefits, such as regulating blood sugar, immune system modulation, hepatoprotection, bacteriostasis, and more. Anecdotal evidence, traditional use, and cultural mores are the main sources of the variety of opinions about G. lucidum's health benefits.
However, recent evidence backs up some of the older assertions of the health advantages made by Lingzhhen et al. (2020) and Jiang et al. (2021b). When it comes to manufacturing, the most basic kind is made up of whole fruiting bodies that have been ground into a powder and then turned into capsules or tablets. The following three sources are used to prepare additional "nonextracted" products: Mycelia that have been dried and ground from submerged liquid cultures cultivated in fermentation tanks; (2) substrate, mycelia, and mushroom mixtures that have been dried and ground after a semisolid medium has been inoculated and incubated with fungal mycelia; and (3) intact fungal spores or spores that have been mechanically broken or have had their spore walls removed to produce polysaccharides.
The components (such as polysaccharides and triterpenes) are extracted, typically using hot water or ethanol, from fruiting bodies or mycelia that are harvested from submerged liquid cultures. These materials are then dried out and either tabulated or encapsulated separately or combined in specific amounts. which yielded the most number of results from because supercritical fluid CO2 extraction technologies demand a low temperature during processing, their use has expanded the range of compounds that can be removed. A number of other products have been made using powdered *ganoderma* and other mushrooms (like *Lentinula edodes, Agaricus brasiliensis, Grifola frondosa, Pleurotus spp., and Flammulina velutipes*), as well as other medicinal herbs (like spirulina powder or flower pollen grains) Shao et al. (2022).
Since wild lingzhi is so uncommon, only the wealthy were able to purchase it in the years prior to its cultivation. The sacred fungus was said to grow in the immortals' house, hence the title "three aisles of the blest." But rather than its real effects, its image as a powerful substance may have been derived largely from its uneven distribution, scarcity, and usage by wealthy, well-known Chinese society. According to Andrew et al. (2023), the Ganoderma species are still widely used in traditional medicine in Asia, and their use is expanding globally.
The mushroom and mycelium threads contains special properties remarkably steroids, lactones, alkaloids, polysaccharides and triterpenes. Pharmacologically a number of the water soluable polysaccharides present shows antitumour and immunostimulatory activities . At least 100 different alcohol soluable triterpenes have been identified including highly oxidised lanostane type triterpenoids such as ganoderenic, ganoderic, lucidenic and ganolucidic acid. The extracted compounds from triterpenoids have been shown to possess adaptogenic and antihypersensitive as well as anti allergic properties.

NUTRITIONAL COMPOSITION

As a result, almost 90% of the weight of mushrooms is water. 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. The majority of the minerals include potassium, calcium, phosphorus, magnesium, selenium, iron, zinc, and copper. According to a research of G. lucidum's nonvolatile components, the mushroom has 1.8% ash, 26–28% carbohydrates, 3–5% crude fat, 59% crude fibre, and 7–8% crude protein (Shao et al., 2022).

G. lucidum encompasses three active medicinal ingredients: polysaccharides, peptidoglycans, and triterpenes.However, in both natural and commercial products, the proportion and quantity of each component can vary greatly. The two main nutrients, triterpenes and polysaccharides, were assessed in the trials and research using 11 randomly chosen samples of commercial *lingzhi* products bought from Hong Kong stores. It was discovered that the polysaccharide content ranged from 1.1 to 5.8% and the triterpene content ranged from undetectable to 7.8%. These discrepancies may arise due to a variety of factors, such as variances in the types or strains of mushrooms utilised and changes in the techniques of production.

NUTRITIONAL PARAMETERS	**VALUE [IN PERCENTAGE]**
1. ASH	1.8%
2. CARBOHYDRATE	26-28%
3. CRUDE FATS	3-5%
4. CRUDE FIBERS	59%
5. CRUDE PROTEIN	7-8%
6. MICROMINERALS	15%
7. VITAMIN A-D	55%

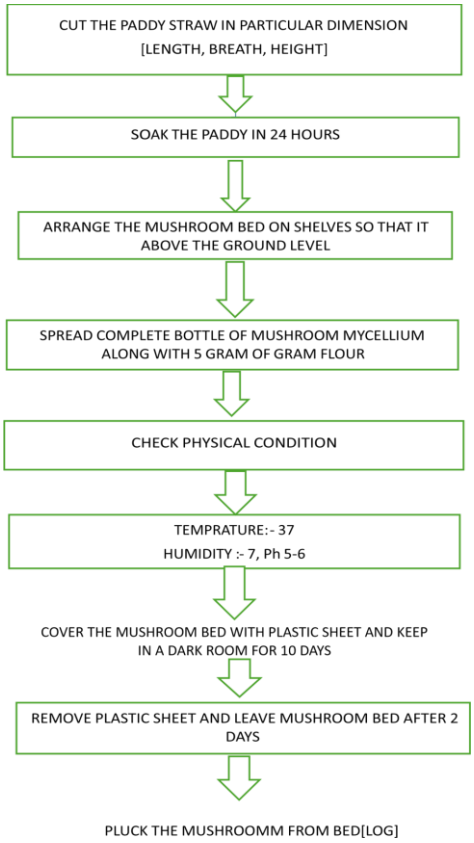
TABLE 1 :- NUTRITIONAL COMPOSITION OF MEDICINAL MUSHROOM *G.lucidium*

S.NO	MEDICINAL MUSHROOM	BIOACTIVE COMPOUND	ROLE
1.	*Ganoderma lucidium* [LINGZI OR REISHI]	• Beta and hetero beta glucans • Ling Zhi-8 protein • Ganodermic acid- triterpenes	• Anti tumor, immunostimulating • Anti allergic, immune modulating • Anti allergic agents
2.	*Lentinus edodes* [SHITAKI]	• Beta D glucans • Heteroglucan-protein • Eritadenine • Ergosterol	• Anti tumour • Immunostimulating • Cholesterol reducing • Provitamin D -2
3.	*Schizophyllus commune* [WHITISH FUNGUS]	• Beta glucans	• Anti tumor • Immunodulation
4.	*Phellinus linteus*	• Beta glucans	• Antitumor

	[SANGHWAAG]		and immunostimulation
5.	*Poris cocos* [CHINA ROOTS]	• Polysaccharides	Immune system Anticoagulant • Lowering cholesterol
6.	*Hericium erinaceus* [LION MANE]	• Beta D glucans • Ergosterol • Cyathane derivatives	• Anti tumour • Provitamin D • Nerve growth stimulation
7.	*Grifola frondose* [MAITAKE/ SHEEP/ RAM HEAD]	1,3 and 1,6 Beta glucans	Immunomodulating Anti tumour
8.	*Cordyceps sinensis* [CATERPILLAR FUNGUS]	• Galactomannans Cordycepin • sterols	• antitumor • immunostimulatory

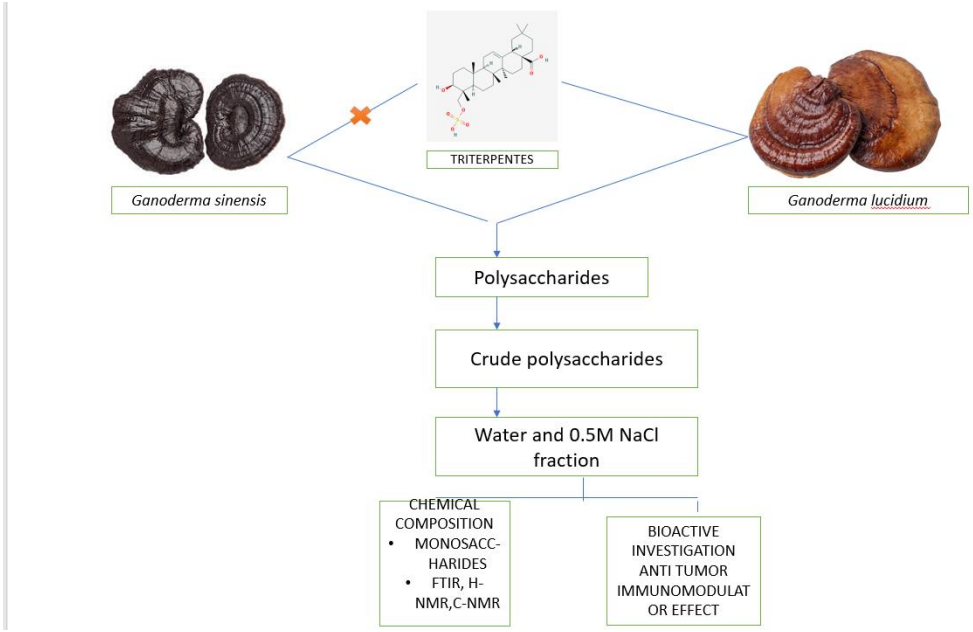
TABLE 2 :- BIOACTIVE COMPONENTS

FLOW CHART DESCRIBING THE CULTIVATION OF MUSHROOM



EXTRACTION METHODS

1. FRACTIONAL PREPARATION OF POLYSACCHARIDES FROM MUSHROOM
2. FRACTION PURIFICATION OF POLYSACCHARIEDES BY GC-MS
3. METHOD OF EXTRACTIONN IN *Ganoderma*



B. FRACTION PURIFICATION OF POLYSACCHARIEDES BY GC-MS

Pleurotus ferulae fruiting bodies serve as the starting material.

Step 1: Use 95% ethanol to induce reflux.

Filtrate and Residue are the results.

Step 2: Use water to extract the residue.

Supernatant and residue are the end results.

Step 3: Use 95% ethanol to precipitate the supernatant.

Supernatant and precipitate are the end results.

Collect the precipitate as CPFP in step four.

Step 5: Use DEAE-Sepharose CL-6B to chromatograph CPFP.

Elution is carried out with:

For PFP1, 0.1 M NaAc-buffer

For PFP2 and PFP3, a linear gradient from 0 to 1.5 M NaCl

Step 6:

PFP1: PFP1a and PFP1b are produced by further chromatography on Sepharose CL-6B.

PFP2: Following further chromatography on Sepharose CL-6B, PFP2a, PFP2b, and PFP2c are produced.

PFP3: Following further chromatography on Sepharose CL-6B, PFP3a, PFP3b, and PFP3c are produced.

PHARMACOLOGICAL EFFECT OF THE I REISHI EXTRACT ALONG WITH DIFFERENT MEDICAL MUSHROOM

S.NO	PROPERTIES	ACTION
1.	ANALGESIC	ACTION ON B CELL PROVIDING EXTRA PROTECTION
2.	ANTIALLERGIC ACTIVITIES	BETA GLUCANS ACT AS PROTECTORS
3.	BRONCHITIS PREVENTATION INCLUDING REGENRATION OF BRONCHIAL EPITHELIUM	BUILDING NEW LINING
4.	ANTI INFLAMMATORY	BETA GLUCANS
5.	ANTI OXIDANT BY ELIMINATING HYDROXYL FREE RADICLE	LING ZHI 8 PROTEIN
6.	ANTITUMOUR EFFECT	INCRAESED T AND B CELLS
7.	ANTITUMOUR	B T CELLS
8.	ANTIVIRAL EFFECTS BY INDUCING INFERONS	FLAVANOIDS
9.	CARDIOTONIC ACTION LOWERING SERUM CHOLESTROL	OXYGEN SUPPLY INCREASE
10.	INHANCHING NK CELLS	ACTION ON BONE MARROW CELLS
11.	GENERAL IMMUNOPOTENTIATION	BETA HETERO GLUCANS
12.	INCREASED PRODUCTION OF INTERLEUKIN1 BY MURINE PERITONEAL MACROPHAGES	IF CELLS INCREASE
13.	PROTECT AGAINST RADIATION EFFECT	INCREASED EFFECIENCY

REFERENCES

1. Sheng, K.; Wang, C.; Chen, B.; Kang, M.; Wang, M.; Liu, K.; Wang, M. Recent advances in polysaccharides from *Lentinus edodes* (Berk.): Isolation, structures and bioactivities. *Food Chem.* **2021**, *358*, 129883. [

2. Zhao, Y.M.; Yang, J.M.; Liu, Y.H.; Zhao, M.; Wang, J. Ultrasound assisted extraction of polysaccharides from *Lentinus edodes* and its anti-hepatitis B activity in vitro. *Int. J. Biol. Macromol.* **2018**, *107 Pt. B*, 2217–2223. [

3. Wang, K.; Guo, J.; Cheng, J.; Zhao, X.; Ma, B.; Yang, X.; Shao, H. Ultrasoundassisted extraction of polysaccharide from spent *Lentinus edodes* substrate: Process optimization, precipitation, structural characterization and antioxidant activity. *Int. J. Biol. Macromol.* **2021**

4. Mwangi, R.W.; Macharia, J.M.; Wagara, I.N.; Bence, R.L. The antioxidant potential of different edible and medicinal mushrooms. *Biomed. Pharmacother.* **2022**, *147*, 112621.

5. Morales, D.; Rutckeviski, R.; Villalva, M.; Abreu, H.; Soler-Rivas, C.; Santoyo, S.; Iacomini, M.; Smiderle, F.R. Isolation and comparison of alpha- and beta-D-glucans from shiitake mushrooms (*Lentinula edodes*) with different biological activities. *Carbohydr. Polym.* **2020**, *229*, 115521.

6. Murphy, E.J.; Masterson, C.; Rezoagli, E.; O'Toole, D.; Major, I.; Stack, G.D.; Lynch, M.; Laffey, J.G.; Rowan, N.J. β-Glucan extracts from the same edible shiitake mushroom *Lentinus edodes* produce differential in-vitro immunomodulatory and pulmonary cytoprotective effects—Implications for coronavirus disease (COVID-19) immunotherapies. *Sci. Total Environ.* **2020**, *732*, 139330.

7. Li, W.; Wang, J.; Chen, Z.; Gao, X.; Chen, Y.; Xue, Z.; Guo, Q.; Ma, Q.; Chen, H. Physicochemical properties of polysaccharides from *Lentinus edodes* under high pressure cooking treatment and its enhanced anticancer effects. *Int. J. Biol. Macromol.* **2018**, *115*, 994–1001.

8. Xue, X.; Peng, L.; Xiaofeng, L.; Zhun, X.; Chunying, D.; Jianwen, W. Identification and Biological Characteristics of Wild *Lentinus edodes*. *North Hortic.* **2021**, *4*, 118– 123.

9. Dong, Y.; Liao, X.; Jin, T.; Xie, Y. Nutrient Analysis and Safety Evaluation of *Lentinus edodes* (Beak.) *Sing*. *Edible Fungi China* **2021**, *40*, 91–96+102.

10. Hanwu, L.; Gaochao, P.; Dongsheng, Q.; Fanglun, Z.; Yan, S. Analysis of Aroma Components of a Wild Sangria Mushroom in Guizhou Province. *Edible Fungi China* **2019**, *38*, 107–108.

11. Xie, Y.; Li, P.; Lu, L.; Liao, X.; Zhang, L.; Yang, L.; Kang, C. A Kind of Cultivation Method of Masang Mushroom Returning to Nature. CN106665124A [P/OL], 17 May 2017.

12. Tang, W.; Liu, C.; Liu, J.; Hu, L.; Huang, Y.; Yuan, L.; Liu, F.; Pan, S.; Chen, S.; Bian, S.; et al. Purification of polysaccharide from *Lentinus edodes* water extract by membrane separation and its chemical composition and structure characterization. *Food Hydrocoll.* **2020**, *105*

13. Zhang, Y.; Wang, D.; Chen, Y.; Liu, T.; Zhang, S.; Fan, H.; Liu, H.; Li, Y. Healthy function and high valued utilization of edible fungi. *Food Sci. Hum. Wellness* **2021**, *10*, 408–420.

14. Wu, J.; Chen, R.; Tan, L.; Bai, H.; Tian, L.; Lu, J.; Gao, M.; Bai, C.; Sun, H.; Chi, Y. Ultrasonic disruption effects on the extraction efficiency, characterization, and bioactivities of polysaccharides from *Panax notoginseng* flower. *Carbohydr. Polym.* **2022**, *291*, 119535.

15. Sharmila, G.; Muthukumaran, C.; Suriya, E.; Muppidathi Keerthana, R.; Kamatchi, M.; Kumar, N.M.; Anbarasan, T.; Jeyanthi, J. Ultrasound aided extraction of yellow pigment from *Tecoma castanifolia* floral petals: Optimization by response surface method and evaluation of the antioxidant activity. *Ind. Crops Prod.* **2019**, *130*, 467– 477.

16. Akihisa T, Nakamura Y, Tagata M, editors. et al. Anti-inflammatory and antitumorpromoting effects of triterpene acids and sterols from the fungus Ganoderma lucidum. Chem Biodivers. 2007;4:224–31.

17. Bao X, Liu C, Fang J, Li X. Structural and immunological studies of a major polysaccharide from spores of Ganoderma lucidum (Fr.) Karst. Carbohydr Res. 2001;332:67–74.

18. Bao X, Wang X, Dong Q, Fang J, Li X. Structural features of immunologically active polysaccharides from Ganoderma lucidum. Phytochemistry. 2002;59:175–81

19. Benzie I. F. F, Wachtel-Galor S. Biomarkers of long-term vegetarian diets. Adv Clin Chem. 2009;47:169–220.

20. Boh B, Berovic M, Zhang J, Zhi-Bin L. Ganoderma lucidum and its pharmaceutically active compounds. Biotechnol Annu Rev. 2007;13:265–301

21. Borchers A. T, Krishnamurthy A, Keen C. L, Meyers F. J, Gershwin M. E. The immunobiology of mushrooms. Exp Biol Med. 2008;233:259–76.

22. Borchers A. T, Stern J. S, Hackman R. M, Keen C. L, Gershwin M. E. Minireview: Mushrooms, tumors and immunity. Proc Soc Exp Biol Med. 1999;221:281–93.

23. Budavari S. The Merck Index. elevan. New Jersey: Merck & Co., INC; 1989. p. 845.

24. Cao L. Z, Lin Z. B. Regulation on maturation and function of dendritic cells by Ganoderma lucidum polysaccharides. Immunol Lett. 2002;83:163–9

25. Cao Q. Z, Lin Z. B. Antitumor and anti-angiogenic activity of Ganoderma lucidum polysaccharides peptide. Acta Pharmacol Sin. 2004;25:833–8.

26. Cao Q. Z, Lin Z. B. Ganoderma lucidum polysaccharides peptide inhibits the growth of vascular endothelial cell and the induction of VEGF in human lung cancer cell. Life Sci. 2006;78:1457–63.

27. Cao Q. Z, Lin S. Q, Wang S. Z. Effect of Ganoderma lucidum polysaccharides peptide on invasion of human lung carcinoma cells in vitro. Beijing Da Xue Xue Bao. 2007;39:653

28. Chang S. T, Buswell J. A. Mushroom nutriceuticals. World J Microbiol Biotechnol. 1996;12:473–6.

29. Chang S. T, Buswell J. A. Ganoderma lucidum (Curt.: Fr.) P. Karst. (Aphyllophoromycetideae): A mushrooming medicinal mushroom. Int J Med Mushrooms. 1999;1:139–46.

30. Chang S. T, Buswell J. A. Safety, quality control and regulational aspects relating to mushroom nutriceuticals. Proc. 6th Intl. Conf. Mushroom Biology and Mushroom Products. 2008:188–95. GAMU Gmbh, Krefeld, Germany.

31. Chang Y. H, Yang J. S, Yang J. L, editors. et al. Ganoderma lucidum extract promotes immune responses in normal BALB/c mice in vivo. Vivo. 2009;23:755–

9. [

32. Chen Y, Bicker W, Wu J, Xie M. Y, Lindner W. Ganoderma species discrimination by dual-mode chromatographic fingerprinting: A study on stationary phase effects in hydrophilic interaction chromatography and reduction of sample misclassification rate by additional use of reversed-phase chromatography. J Chromatogr. 2010;1217(8):1255–65.

33. Fidelis, A., Wang, Z., Chen, W., Dong, L., and Peng, X. (2023). Developing Ganoderma lucidum as a next-generation cell factory for food and nutraceuticals. Trends Biotechnol. 42, 197–211. doi: 10.1016/j.tibtech.2023.07.008 Gentile, C. L., and Weir, T. L. (2018).

34. The gut microbiota at the intersection of diet and human health. Science 362, 776– 780. doi: 10.1126/science.aau5812 Guo, C., Guo, D., Liu, F., Sang, T., Jianjun, W., Guo, C., et al. (2021).

35. Ganoderma lucidum polysaccharide modulates gut microbiota and immune cell function to inhibit inflammation and tumorigenesis in colon. Carbohydr. Polym. 267:118231. doi: 10.1016/j. carbpol.2021.118231 Guo, L., Zhang, J., Kan, Q., Song, M., Hou, T., An, S., et al. (2022).

36. Extraction, structural characterization, and immunomodulatory activity of a high molecular weight polysaccharide from Ganoderma lucidum. Front. Nutr. 9:846080. doi: 10.3389/ fnut.2022.846080 Guo, W. L., Cao, Y. J., You, S. Z., Wu, Q., Zhang, F., Han, J. Z., et al. (2022).

37. Ganoderic acids-rich ethanol extract from Ganoderma lucidum protects against alcoholic liver injury and modulates intestinal microbiota in mice with excessive alcohol intake. Curr. Res. Food Sci. 5, 515–530. doi: 10.1016/j.crfs.2022.02.013 Guo, W. L., Guo, J. B., Liu, B., Lu, J. Q., Chen, M., Liu, B., et al. (2020).

38. Ganoderic acid a from Ganoderma lucidum ameliorates lipid metabolism and alters gut microbiota composition in hyperlipidemic mice fed a high-fat diet. Food Funct. 11, 6818–6833. doi: 10.1039/d0fo00436g Guo, W. L., Pan, Y. Y., Li, L., Li, T. T., Liu, B., and Lv, X. C. (2018).

39. Ethanol extract of Ganoderma lucidum ameliorates lipid metabolic disorders and modulates the gut microbiota composition in high-fat diet fed rats. Food Funct. 9, 3419–3431. doi: 10.1039/ c8fo00836a Healey, G., Murphy, R., Butts, C., Brough, L., Whelan, K., and Coad, J. (2018). Habitual dietary fibre intake influences gut microbiota response to an inulin-type fructan prebiotic: a randomised, double-blind, placebo-controlled, cross-over, human intervention study. Br. J. Nutr. 119, 176–189. doi: 10.1017/ S0007114517003440 He, X., Chen, Y., Li, Z., Fang, L., Chen, H., Liang, Z., et al. (2023).

40. Germplasm resources and secondary metabolism regulation in Reishi mushroom (Ganoderma lucidum). Chinese Herb. Med. 15, 376–382. doi: 10.1016/j.chmed.2023.01.005 Hongtao, W. (2022). Research progress on the relationship between intestinal microorganisms and human health and its influencing factors. J. Food Saf. Qual. Inspect. 1, 175–181. doi: 10.19812/J.CNKI.JFSQ11-5956/TS.2022.01.016 Imran, K., Guoxin, H., Xiaoang,

L., Waikit, L., Wenrui, X., and Wendy, H. (2018).

41. Mushroom polysaccharides from Ganoderma lucidum and Poria cocos reveal prebiotic functions. J. Funct. Foods 41, 191–201. doi: 10.1016/j.jff.2017.12.046 Isaac, T., Montiel, V. C.-P. E., Rodriguez, V., Aguirre-Moreno, A., León-Rivera, I., del Río-Portilla, F., et al. (2013).

42. Anticonvulsant and neuroprotective effects of oligosaccharides from Lingzhi or Reishi medicinal mushroom, Ganoderma lucidum (higher Basidiomycetes). Int. J. Med. Mushrooms 15, 555–568. doi: 10.1615/ intjmedmushr.v15.i6.40 Jiang, G., Lei, A., Chen, Y., Yu, Q., Xie, J., Yang, Y., et al. (2021a). The protective effects of the Ganoderma atrum polysaccharide against acrylamide-induced inflammation and oxidative damage in rats. Food \u0026amp; function, 12, 397–407

43. Jiang, Y., Zhang, N., Zhou, Y., Zhou, Z., Bai, Y., Strappe, P., et al. (2021b). Manipulations of glucose/lipid metabolism and gut microbiota of resistant starch encapsulated Ganoderma lucidum spores in T2DM rats. Food Sci. Biotechnol. 30, 755–764. doi: 10.1007/s10068-021-00908-w Jie, P., Laihao, L., and Jianwei, M. (2021).

44. Research progress of intestinal flora and human health. J. Shandong Nor. Univ. 4, 337–365. doi: 10.3969/j. issn.1001-4748.2021.04.002 Jie, Z., Xia, H., Zhong, S., Feng, Q., Li, S., Liang, S., et al. (2017).

45. The gut microbiome in atherosclerotic cardiovascular disease. Nat. Commun. 8:845. doi: 10.1038/ s41467-017-00900-1 Jin, M., Zhu, Y., Shao, D., Zhao, K., Chunlan, X., Li, Q., et al. (2017).

46. Effects of polysaccharide from mycelia of Ganoderma lucidum on intestinal barrier functions of rats. Int. J. Biol. Macromol. 94, 1–9. doi: 10.1016/j.ijbiomac.2016.09.099 Jin, X., Ruiz Beguerie, J., Sze, D. M., and Chan, G.

C. (2016).

47. Ganoderma lucidum (Reishi mushroom) for cancer treatment. Cochrane Database Syst. Rev. 4:CD007731. doi: 10.1002/14651858.CD007731.pub3 Kai, Y., Yajie, Z., Zhang, S., Ming, C., Xionge, P., Junrong, H., et al. (2020).

48. Preparation of Ganoderma lucidum spore powder oligosaccharide and its function in regulating intestinal flora. Food Ferment. Indus. 9, 37–42. doi: 10.13995/j.cnki.11

49. Xiong, Y., Zhang, F., Li, J., Peng, P.-Z., Liu, B., and Zhao, L. (2022). Ganoderma lucidum protease hydrolyzate on lipid metabolism and gut microbiota in high-fat diet fed rats. Food Biosci. 47:101460. doi: 10.1016/j.fbio.2021.101460 Xu, R. (2010).

50. Introduction to Ganoderma lucidum in 2010. p. 34–41, Nianxi Culture and Education Foundation: Taipei. Yang, J., Martínez, I., Walter, J., Keshavarzian, A., and Rose, D. J. (2013). In vitro characterization of the impact of selected dietary fibers on fecal microbiota composition and short chain fatty acid production. Anaerobe 23, 74–81. doi: 10.1016/j. anaerobe.2013.06.012 Yang, K., Zhang, Y., Cai, M., Guan, R., Neng, J., Pi, X., et al. (2020).

51. In vitro prebiotic activities of oligosaccharides from the by-products in Ganoderma lucidum spore polysaccharide extraction. RSC Adv. 10, 14794–14802. doi: 10.1039/c9ra10798c Yang, X., (2019).

52. Effect of Ganoderma lucidum polysaccharide and its hydrolysate on intestinal mucosal immune function in immunosuppressed mice. Master's degree thesis, (Shaanxi Normal University). doi: 10.27292/d.cnki.gsxfu.2019.000721 Yang, Y., Nirmagustina, D. E., Kumrungsee, T., Okazaki, Y., Tomotake, H., and Kato, N. (2017).

53. Feeding of the water extract from Ganoderma lingzhi to rats modulates secondary bile acids, intestinal microflora, mucins, and propionate important to colon cancer.

Biosci. Biotechnol. Biochem. 81, 1796–1804. doi:

10.1080/09168451.2017.1343117 Yao, C., Wang, Z., Jiang, H., Yan, R., Huang, Q., Wang, Y., et al. (2021).

Ganoderma lucidum promotes sleep through a gut microbiota-dependent and serotonin-involved pathway in mice. Sci. Rep. 11:13660. doi:

10.1038/s41598-02192913-6 Yiqiong, X., Wang, Q., Siya, S., Mengru, L., Rubin, C., and