

Mushroom: Fungus with powerful Nutritional and Medicinal value

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Abstract

As a folk medicine and a nutraceutical rich source of nutrients, mushrooms have remained an integral part of traditional cuisines for centuries due to their beneficial health attributes. They are being studied extensively today to explain their chemical nature and mechanisms of action in biomedicine and nutraceuticals. As a macrofungus, mushrooms belong to the astounding kingdom of Fungi. Mushrooms have impressive health benefits, including antiviral, antibacterial, wound healing, anticancer, immunomodulating, antioxidant, hepatoprotective, anti-hypercholesterolemia, and anti-diabetic effects, etc., all have been reported throughout the world and have generated significant interest in even further research. Consequently, they can serve as functional foods, help with the treatment of health issues that are not in optimal states, and can reduce the risk of developing life-threatening conditions. It was found that mushrooms contained a variety of polysaccharides, proteins, lipids/fats, vitamins and minerals that contributed to their therapeutic effects.

Introduction

A mushroom is a spore-bearing fruiting body of fungus that grows above ground, either on soil or on its food source. Mushrooms have been part of the diet of Greeks and Romans since ancient times. According to the Romans, they were God's food, and the Chinese termed them as elixirs of life (Bashir,2014).

For generations, mankind has cultivated and consumed mushrooms because of their delicious sensory characteristics, rich nutritional compositions, multiple functional activities (Ma,2018). As a result of different uses by consumers, the most frequently cultivated mushroom species were divided into edible mushrooms that included *Pleurotus ostreatus*, *Lentinula edodes*, *Agaricus bisporus*, *Flammulina velutipes* and *Auricularia auricular*, and medicinal mushrooms mainly include *Ganoderma lucidum*, *Cordyceps sinensis* and *Poria cocos*. Around the world, China was documented as the earliest country to cultivate mushrooms (Feeney,2014).

Over 70,000 species of fungi have been documented by different researchers. Approximately 2000 species are edible mushrooms. Nevertheless, approximately 10% of some 30 species are poisonous mushrooms and relatively small numbers are considered lethal.(Temesgen,2018).

In the past several years, knowledge about the bioactive compositions and nutritional values of different mushrooms has grown massively, thus establishing mushrooms as a potential functional food with high dietary fiber content and low fat content. In addition, mushrooms are packed with many vitamins and minerals, including most of the essential amino acids (Thatoi,2014).

The mushroom is an important natural source of both foods and medicines. As they hold the benefits of high fiber, low fat, and low starch, edible mushrooms have been recommended to people with obesity and diabetes who want to prevent hyperglycemia. In addition, mushrooms are known for their potential anti-oxidant, cardiovascular, hypercholesterolemic, anti-bacterial, and anticancer properties(Temesgen,2018).

The present study discusses different aspects of mushrooms related to human health, such as its nutritional values and its medicinal values in human health.

Nutritional values of mushrooms

Since ancient times, people have been hunting mushrooms. High-level fungi have been used as food since thousands of years ago due to their chemical composition, which makes them nutritionally beneficial (Bilal,2010).

Carbohydrates

The carbohydrate content of mushrooms varies from 35% to 70% dry weight depending on the species. On average, mushrooms consist primarily of nondigestible carbohydrates such as oligosaccharides, trehalose, and cell wall polysaccharides, such as chitin, mannans, and β -glucans(Cheung, 2013).

Mushrooms possess a significant concentration of complex polysaccharides and are pharmacologically important for their antitumor and immunomodulating properties. The most common carbohydrates in certain mushrooms that exhibit biological activity are: sucrose, xylose, rhamnose, fucose, fructose, glucose, mannose, mannitol, and maltose. Polysaccharides in mushrooms with anti-tumor activity are acidic or neutral, and their chemical structure differs significantly from one another.

A number of glycans, such as homopolymers and heteropolymers, exhibit an antitumour effect (Chatterjee, 2021).

In general, most mushrooms polysaccharides have been established as dietary fibers and presented an interaction process with colonized microbiota in gastrointestinal tracts, altering gut microbiota in various ways and affecting host health directly (Ma,2018).

Proteins

Edible mushrooms contain high levels of crude protein, ranging from 15.2 g/100 g dry weight in *Lentinus edodes* to 80.93 g/100 g in *Agaricus bisporus* . The essential amino acid content of mushrooms varies greatly depending on the species (Guillamón,2011).

The bioactive proteins in mushrooms contribute to their functional properties and also to their pharmaceutical potential. Mushrooms produce many proteins and peptides with biological activities, including lectins, fungal immunomodulatory proteins, antimicrobial protein ribonucleases, and laccases (Valverde et al ,2015)

Mushroom protein lectin is capable of inhibiting tumour growth and inhibiting viral, bacterial, and fungal infections. Some mushroom proteins are known to have antiproliferative properties towards human leukemic T cells and hepatoma Hep G2 cells, as well as breast cancer MCF7 cells (Chatterjee et al, 2021).

Lipids/Fats

It is essential to consume mushrooms because they are an important source of fatty acids, which are found primarily bound to glycerol as fats or lipids. In mitochondria and chloroplasts, they serve as membrane constituents and provide mushrooms with a source of stored energy. Most of the total lipid ranges from 1 to 4% dry weight. In addition, mushroom fat is loaded with unsaturated fatty acids (PUFA), especially linoleic acid(Cateni et al, 2021).High blood cholesterol patients are recommended to follow a diet low in fat and calories. As a result, mushrooms are perfect, because they are low in calories, low in fat, and have high essential fat levels(Gunç Ergonul et al ,2013).

Vitamins

Mushrooms are an excellent source of fiber and protein, and contain micronutrients, such as vitamins B1, B2, B12, C, D, E, niacin, and folate. Mushrooms contain significant amounts of vitamin D, which is often called "the sunshine vitamin" despite being grown in the dark and not made from animals. Vitamin D (especially vitamin D2) content in mushrooms increases when exposed to sunlight or ultraviolet (UV)-B light (Das et al, 2021). These mushrooms contain a high amount of vitamin D2, which is bioavailable during storage and cooking and relatively stable. In that sense, vitamin D-enriched mushrooms could make a significant contribution to reducing the global vulnerability to vitamin D deficiency (Cardwell et al, 2018).

Minerals

Mushrooms contain many minerals, including iron, magnesium, potassium, calcium, zinc, and manganese. Metals such as Mn, Fe, Zn and Cu play an important role in biological systems (Tel Çayan et al,2017).There are two types of elements, namely major and trace elements. Na, K, Ca, Mg, Cl, P and S are major elements with recommended daily intakes of more than 50 mg. Trace elements Fe, I, Fe, Zn, Se, Cu, Mn, Cr, Mo, Co, Ni are needed at less than 50 mg/day. Mushrooms are high in vitamins, minerals, iron, zinc, chitin, fibre, and protein. Despite containing a wide spectrum of elements and organic substances, mushrooms can also harbor heavy metals that come from the environment. In general, the mineral concentration in mushrooms was related to species, soil, location, age of fruiting bodies, and distance from pollution sources (Mleczek, Mirosław, et al, 2013).

These nutritional values play important role to increase the medicinal values of different mushroom in human health.

Medicinal values of mushrooms

For thousands of years, our ancestors used mushrooms as medicine. The Greek physician Hippocrates classified the amadou mushroom (*Fomes fomentarius*) as an anti-inflammatory and wound healer. Tao Hongjing described several medicinal mushrooms, including ling zhi (*Ganoderma lucidum*) and zhu ling (*Dendropolyporus umbellatus*), used by Shennong, probably centuries earlier. In the Alps of northern Italy, Ice Man otzi carried in his pouch amadou and a birch polypore to help him survive. In North America, both puffball mushrooms and *calvatia* are used as wound healers. Mushrooms have been used traditionally by many cultures for thousands of years (Stamets et al,2014,Bilal et al,2010).

Natural compounds found in mushrooms may have health benefits by reducing the risk of certain diseases or improving human performance. Health-promoting and disease-preventing effects of mushroom nutraceuticals can be attributed to a wide range of biological activities (Das et al,2021, Ma et al,2018)

A number of edible mushrooms and their constituent active compounds have shown to have beneficial effects on hyperglycemia and hypercholesterolemia (Bulam et al,2019. Trigos et al,2011). Several acidic polysaccharides, fibers and antioxidants in mushrooms, including vitamin C, B12, and D; folate ergothioneine; and polyphenol, are thought to reduce inflammation, lowering blood sugar, and decreasing cholesterol (Lee et al,2010),

The mushroom contains numerous constituents with prebiotic properties, including chitin, hemicellulose, β -glucan, α -glucan, mannans, xylans, and galactans (Aida et al,2009). A few important mushrooms with strong prebiotic properties are *L. edodes* (Shiitake), *Trametes versicolor* (Yunzhi), and *Ganoderma lucidum* (Reishi) (Singdevsachan et al, 2016). Mushroom nutraceuticals exhibit a wide range of biological effects, depending on their chemical structure and interactions with biochemical processes, including anti-inflammatory, anticarcinogenic, antitumor, antimutagenic, antidiabetic, antibacterial, antiviral, anti-obesity, and anti-hypercholesterolemic activities (Kumar et al,2018., Valverde et al,2015., Borchers et al,2008.,Das et al,2021., Temesgen et al,2018., Wasser et al,2002).

Anticancer activity

The history of mankind has seen the use of medicinal mushrooms to treat a vast array of diseases, including cancer.(Blagodatsk et al,2018)

It has been reported that mushrooms control cell division and, when used in cancer therapy, such as the chaga mushroom (*Inonotus obliquus*), boast anti-cancer properties (Ma et al,2013.,Arata et al,2016). A protein was isolated from *Cordyceps militaris* (CMP) by Park and coworkers. Trypsin-like activity was observed in the isolated proteins. As a result, the protein inhibits *F oxysporum* cytotoxicity in human breast and bladder cancer cellular systems (park et al, 2009). Likewise, the polysaccharides (HLP-1-1 and HLP-2-1) derived from *Helvella leucopus* showed anticancer activity against HepG2 cells (Zeng et al,2018). In human colon cancer cell lines (Caco-2), secondary metabolites of *Ganoderma applanatum* were effective (Elkhateeb et al,2018). Glutathione levels increased and morphological changes occurred. A significant increase in Bax/Bcl-2 ratio was also observed with the treatment of metabolites. A 5 day exposure to metabolites reduced the solid Ehrlich tumor mass in the in vivo study. MTT assays were used by researchers to examine the effects of *Marasmius oreades* ethanol extract on HT-29, MCF-7, and MDA-MB-231 cells.(Shomali et al, 2019).

Antioxidant and Antibacterial Activity

In many acute and chronic diseases, reactive oxygen species (ROS) play an important role. The role of antioxidants is to lower the levels of ROS in a cell environment by slowing the level of reactions. Furthermore, the mushrooms' secondary products are also crucial in scavenging ROS. Researchers exploited *Pleurotus ostreatus* and *Coprinus comatus* as ethanolic extracts for their antioxidant potential (amanu et al,2014). As a result of the study, α -tocopherol, rutin, and apigenin were extracted, which serve as antioxidants for skin protection. Researchers have demonstrated antioxidant properties of *Lentinus edodes*, *Volvariella volvacea*, *Plurotuseous*, *Pleurotus sajor-caju*, and *Auricularia auricular* (Boonsong et al,2016). ethanolic extract of *L. edodes* exhibited higher levels of phenolics and flavonoids than the others. Further, it showed the highest radical scavenging results compared to the control. Similar results have been reported for the *Lentinus edodes* and *Volvariella volvacea* (Cheung et al,2003).

Also, the acetone and methanolic extracts from *Pleurotus florida* possess inhibitive effects against linoleic acid and β -carotene (Im et al,2014). Oxidative stress was induced in RAW 264.7 cells through the production of nitric oxide and the expression of inducible nitric oxide synthase, which was inhibited to a dose-dependent extent by the extracts. Researchers extracted the polysaccharides from the mushroom called "*Odemansiella radicata* polysaccharides"(ORP)(Wang et al,2018).The three extracts were ORP-1, ORP-2, and ORP-3, respectively. Extracts differed in their chemical composition as they contained mannose, ribose, glucose, galactose, and xylose. This study showed the ORP-1 to be the most effective in scavenging DPPH radicals, and the ORP-3 demonstrated the highest activity in scavenging hydroxyl radicals, and chelating ferrous ions.

Analyses of the antibacterial properties of methanol extract from the *C. versicolor* fruiting body were conducted by Matijašević et al. (Matijašević et al,2016). MIC values for different bacteria ranged from 0.625 to 20 mg mL⁻¹. Bacteria of both Gram-positive and Gram-negative types were killed by *C. versicolor*. As well, Janeš et al. reported that extracts derived from the mushroom *Amanita virosa* had antibacterial properties. (Fr) Bertill. (*Amanitaceae*) and *Cortinarius praestans*. Cordier (*Cortinariaceae*) against *Pseudomonas aeruginosa*, and *Staphylococcus aureus*, respectively. Extract of the endophytic fungus *Trucatella hartigii*. (Tubefu) Steyaert (*Amphisphaeriaceae*) against *Enterococcus faecalis* and *S. aureus* (Janeš et al,2008). The coprophilous mushroom *Coprinopsis cinerea* has a genome-wide response to *Escherichia coli* and *Bacillus subtilis* (Kombrink et al,2019). Since the gene expression of the two bacteria were identical, the fungal effectors used by each fungus are also likely to be identical. A comparative proteomic analysis of the *C. cinerea* secretome showed that the upregulated genes encode mainly antibacterial proteins and peptides. Antibacterial activity of cysteine-stabilized-defensins (Cs-defensins) and GH24-type lysozymes (GH24-lysozymes) were assessed.

Wound Healing and anti-inflammatory activity

Throughout history, mushrooms have been used to heal wounds. A moist environment and nutrition are essential for a successful wound healing. One type of medicinal mushroom, *Auricularia auricula-judge*, has beneficial properties for wound healing (Mapoung et al,2021). An edible mushroom *Piptoporus betulinus* has been found to contain a β -D-glucan that aids in wound healing by Jesus et al.(De Jesus et al,2018)]. MTT (3- (4,5-dimethylthiazol-2-yl) -2,5-diphenyl-2H-tetrazolium bromide) assay confirmed that the derived β -D-glucan enhanced viability of caco-2 cells. Furthermore, the polysaccharide derived from mushrooms speed up the in vitro wound healing process via migration of epithelial intestinal cells. On diabetic wounds, the beta-glucan content derived from *Sparassis crispa* mushroom showed wound healing effects (Kwon et al,2009).

According to research (Chang et al,2013;Talero et al, 2012) mushrooms are known for their anti-inflammatory effects due to their effects on macrophages, which inhibit the release of prostaglandins, the production of ROS, and the activation of transcription 1 and STAT6 and NF- κ B. *Grifola frondosa* and *Ophiocordyceps* species were studied for their anti-inflammatory effects by Chien et al. Nitric oxide production affected tumour necrosis factor and increased interleukin-10 production (Chien, et al,2016). In their study, Ying et al. described the role of *Pleurotus eryngii*'s bioactive protein, PEP. It inhibited pro-inflammatory mediators as well as nitric oxide synthase expression in the colon, showing that it could fight inflammation (Yuan et al,2017). Polysaccharides derived from *Hypsizygus marmoreus* are able to inhibit LPS in the lungs according to Liu et al (Liu et al,2019).

Hepatoprotective activity

Scientists have observed that mushrooms protect against experimentally induced liver injuries. A study has reported that more mushrooms can protect the liver from ethanol and CCL4-based hepatotoxicity (Nitha et al,2013). Treatment with mushroom extract reduced glutamic pyruvic transaminase, glutamic oxaloacetic transaminase, and alkaline phosphatase concentrations in a dose-dependent manner. A similar result was reported by Wu et al. using *Ganoderma lucidum* (Wu et al,2013). In a study, Liu et al. published their results on the extraction of polysaccharides from *Oudemansiella radicata* (Liu et al,2017). As a result of administration of polysaccharides, serum alanine aminotransferase and aspartate aminotransferase were decreased and liver superoxide dismutase and glutathione peroxidase were stimulated. In hypercholesterolemic rats, Nisar et al. reported that extracts from *Lentinus edodes* provide hepatoprotective effects (Nisar et al 2017).

Anti- HIV activity

Several studies have found that mushrooms target HIV. In HIV-infected patients, mushrooms such as *Agaricus sylvaticus* reduce oxidative stress. The effect of *Auricularia polytricha* on HIV-1 was studied by Sillapachaiyaporn et al.(Sillapachaiyaporn et al,2019). Compounds isolated from hexane crude extracts of *Auricularia polytricha* (APH) have anti-HIV-1 protease activity. In their report on the anti-HIV properties of Ganoderiol F, Ganodermanontriol, El-Mekkawy et al.(El-Mekkawy et al,1988). Additionally, ganoderic acid B, ganoderiol B, and ganoderic acid C1 as well as ganoderic acid α , ganoderic acid H, and ganoderiol A showed mildly inhibited HIV-1 protease activity. From the *Ganoderma colossus*, El-Dine et al. isolated new triterpenes, including colorssolactone V, colorssolactone VI, colorssolactone VII, and colorssolactone VIII, with anti-HIV activity (El Dine et al, 2008).

Immunomodulatory Activity

An immune system is made up of individual cells and networks of proteins that are essential to keeping the body healthy. Immunity determines how healthy a person is. Active components in mushrooms help the human body fight diseases in conjunction with the immune system. Velde et al. examined the immunomodulatory properties of *Agaricus subrufescens* and *Coprinus comatus* mushroom species using THP-1 cells (Van de Velde et al,2015). The alkali-soluble and water-soluble polysaccharide-protein complex derived from *Pleurotus rhinoceros* has also been found to contain

immunomodulatory effects in mouse bone marrow-derived dendritic cells (Liu et al,2019).

Several other researchers have also evaluated the upregulation of genes by using extracts of *Ganoderma lucidum*, *L. edodes*, *Agaricus bisporus*, and *A. subrufescens* (Chan,et al,2008; Chanput et al,2012; Ellertsen et al,2006)

Conclusion

Considering the benefits of diversity, we can conclude that Mushrooms possess tremendous medicinal food, drug, and mineral values, making them a highly valuable adjunct to human well-being. A number of mushroom species have been identified as sources of bioactive compounds, in addition to their nutritional importance. The inclusion of whole mushrooms in the diet may have efficacy as possible dietary supplements. Together with the many bioactive nutrients, mushrooms are capable of being developed into functional foods based on their incredible nutritional value. Polysaccharides, terpenoids, proteins and polyphenols exhibited bioactive properties that strengthened immune strength, reduced cancer risks, and inhibited the proliferation of tumor cells. Researchers are also interested in the prebiotic effects estimated by mushrooms. It was found that mushrooms possessed a wide spectrum of health benefits activities and, with the advances in nutrigenomics and molecular nutrition, mushrooms could be considered one of the best acceptable nutraceutical foods for daily consumption.

This gives opportunity to farmers to grow mushroom and work with scientists to develop different products for human health. At swalife biotech Limited small molecules from mushrooms are used in skincare products to prevent DNA damage and also provide vitamin D. Exposure to sunlight has increased the vitamin D content in mushrooms, which is used in skincare and nutraceutical products. Moreover, small molecules from oyster and button mushroom have shown inhibition activity against DDR proteins, which play a role in a variety of cancers (unpublished data).

Mushrooms have numerous potential biological characteristics with numerous historical and novel properties, which have nutraceutical and health benefits, which should be further explored.

References

1. Aasiya Bashir, Prof. Naheed Vaida and Dr. Mushtaq Ahmad Dar (2014); Medicinal Importance of mushrooms – A review Int. J. of Adv. Res. 2 (Dec). 0] (ISSN 2320-5407).
2. Aida, F.M.N.A.; Shuhaimi, M.; Yazid, M.; Maaruf, A.G. Mushroom as a potential source of prebiotics: A review. *Trends Food Sci. Technol.* 2009, 20, 567–575.
3. Amanu, E. Antioxidant properties of mushroom mycelia obtained by batch cultivation and tocopherol content affected by extraction procedures. *BioMed Res. Int.* 2014, 2014, 974804.
4. Arata, S.; Watanabe, J.; Maeda, M.; Yamamoto, M.; Matsushashi, H.; Mochizuki, M.; Kagami, N.; Honda, K.; Inagaki, M. Continuous intake of the Chaga mushroom (*Inonotus obliquus*) aqueous extract suppresses cancer progression and maintains body temperature in mice. *Heliyon* 2016, 2, e00111.
5. Bilal, A.W., R, H.B., A, H.W., 2010. Nutritional and medicinal importance of mushrooms. *J. Med. Plants Res.* 4, 2598–2604. <https://doi.org/10.5897/JMPR09.565>.
6. Boonsong, S.; Klaypradit, W.; Wilaipun, P. Antioxidant activities of extracts from five edible mushrooms using different extractants. *Agric. Nat. Resour.* 2016, 50, 89–97.
7. Borchers, A.T.; Krishnamurthy, A.; Keen, C.L.; Meyers, F.J.; Gershwin, M.E. The immunobiology of mushrooms. *Exp. Biol. Med.* 2008, 233, 259–276.
8. Bulam S., Üstün N.Ş., Pekşen A. Health benefits of *Ganoderma lucidum* as a medicinal mushroom. *TURJAF.* 2019;7(sp 1):84–93. doi: 10.24925/turjaf.v7isp1.84-93.2728.
9. Cardwell, G., Bornman, J.F., James, A.P., Black, L.J., 2018. A Review of Mushrooms as a Potential Source of Dietary Vitamin D. *Nutrients* 10, 1498. <https://doi.org/10.3390/nu10101498>
10. Cateni, F., Gargano, M.L., Procida, G., Venturella, G., Cirlincione, F., Ferraro, V., 2021. Mycochemicals in wild and cultivated mushrooms: nutrition and health. *Phytochem Rev.* <https://doi.org/10.1007/s11101-021-09748-2>
11. Chan, W.K.; Cheung, C.C.H.; Law, H.K.W.; Lau, Y.L.; Chan, G.C.F. *Ganoderma lucidum* polysaccharides can induce human monocytic leukemia cells into dendritic cells with immuno-stimulatory function. *J. Hematol. Oncol.* 2008, 1, 1–12.
12. Chang, C.W.; Lur, H.S.; Lu, M.K.; Cheng, J.J. Sulfated polysaccharides of *Armillariella mellea* and their anti-inflammatory activities via NF-κB suppression. *Food Res. Int.* 2013, 54, 239–245.

13. Chanput, W.; Reitsma, M.; Kleinjans, L.; Mes, J.J.; Savelkoul, H.F.; Wichers, H.J. β -Glucans are involved in immune-modulation of THP-1 macrophages. *Mol. Nutr. Food Res.* 2012, *56*, 822–833
14. Chatterjee, D., Halder, D., Das, S., 2021. Varieties of Mushrooms and their Nutraceutical Importance: A Systematic Review. *Journal of Clinical and Diagnostic Research.* 15, 6.
15. Cheung, L.M.; Cheung, P.C.K.; Ooi, V.E.C. Antioxidant activity and total phenolics of edible mushroom extracts. *Food Chem.* 2003, *81*, 249–255
16. Cheung, P.C.K., 2013. Mini-review on edible mushrooms as source of dietary fiber: Preparation and health benefits. *Food Science and Human Wellness* 2, 162–166. <https://doi.org/10.1016/j.fshw.2013.08.001>.
17. Chien, R.C.; Lin, L.M.; Chang, Y.H.; Lin, Y.C.; Wu, P.H.; Asatiani, M.D.; Wasser, S.G.; Krakhmalnyi, M.; Agbarya, A.; Wasser, S.P.; et al. Anti-inflammation properties of fruiting bodies and submerged cultured mycelia of culinary-medicinal higher basidiomycetes mushrooms. *Int. J. Med. Mushrooms* 2016, *18*, 999–1009
18. Das, A.K., Nanda, P.K., Dandapat, P., Bandyopadhyay, S., Gullón, P., Sivaraman, G.K., McClements, D.J., Gullón, B., Lorenzo, J.M., 2021. Edible Mushrooms as Functional Ingredients for Development of Healthier and More Sustainable Muscle Foods: A Flexitarian Approach. *Molecules* 26, 2463. <https://doi.org/10.3390/molecules26092463>
19. De Jesus, L.I.; Smiderle, F.R.; Ruthes, A.C.; Vilaplana, F.; Dal'Lin, F.T.; Maria-Ferreira, D.; Werner, M.F.; Van Griensven, L.J.L.D.; Iacomini, M. Chemical characterization and wound healing property of a β -D-glucan from edible mushroom *Piptoporus betulinus*. *Int. J. Biol. Macromol.* 2018, *117*, 1361–1366.
20. El Dine, R.S.; El Halawany, A.M.; Ma, C.-M.; Hattori, M. Anti-HIV-1 protease activity of lanostane triterpenes from the vietnamese mushroom *Ganoderma colossum*. *J. Nat. Prod.* 2008, *71*, 1022–1026.
21. Elkhatieb, W.A.; Zaghlol, G.M.; El-Garawani, I.M.; Ahmed, E.F.; Rateb, M.E.; Abdel Moneim, A.E. *Ganoderma applanatum* secondary metabolites induced apoptosis through different pathways: In vivo and in vitro anticancer studies. *Biomed. Pharmacother.* 2018, *101*, 264–277.
22. El-Mekkawy, S.; Meselhy, M.R.; Nakamura, N.; Tezuka, Y.; Hattori, M.; Kakiuchi, N.; Shimotohno, K.; Kawahata, T.; Otake, T. Anti-HIV-1 and anti-HIV-1-protease substances from *Ganoderma lucidum*. *Phytochemistry* 1998, *49*, 1651–1657.
23. Feeney, M.J., Dwyer, J., Hasler-Lewis, C.M., Milner, J.A., Noakes, M., Rowe, S., Wach, M., Beelman, R.B., Caldwell, J., Cantorna, M.T., Castlebury, L.A., Chang, S.-T., Cheskin, L.J., Clemens, R., Drescher, G., Fulgoni, V.L., Haytowitz, D.B., Hubbard, V.S., Law, D., Myrdal Miller, A., Minor, B., Percival, S.S., Riscuta, G., Schneeman, B., Thornsbury, S., Toner, C.D., Woteki, C.E., Wu, D., 2014. Mushrooms and Health Summit Proceedings. *The Journal of Nutrition* 144, 1128S-1136S. <https://doi.org/10.3945/jn.114.190728>
24. Günç Ergönül, P., Akata, I., Kalyoncu, F., Ergönül, B., 2013. Fatty Acid Compositions of Six Wild Edible Mushroom Species. *The Scientific World Journal* 2013, e163964. <https://doi.org/10.1155/2013/163964>
25. Guillamón, E., García-Lafuente, A., Moro, C., Palacios, I., D'Arrigo, M., Alfredo, M., Villares, A., 2011. Mushroom proteins: Potential therapeutic agents. *Agro Food Industry Hi Tech* 22, 42–44.
26. Im, K.H.; Nguyen, T.K.; Shin, D.B.; Lee, K.R.; Lee, T.S. Appraisal of antioxidant and anti-inflammatory activities of various extracts from the fruiting bodies of *Pleurotus florida*. *Molecules* 2014, *19*, 3310–3326.
27. Janeš, D.; Kreft, S.; Jurc, M.; Seme, K.; Štrukelj, B. Antibacterial activity in higher fungi (Mushrooms) and endophytic fungi from Slovenia. *Pharm. Biol.* 2008, *45*, 700–706.
28. Kombrink, A.; Tayyrov, A.; Essig, A.; Stöckli, M.; Micheller, S.; Hintze, J.; van Heuvel, Y.; Dürig, N.; Lin, C.; Kallio, P.T.; et al. Induction of antibacterial proteins and peptides in the coprophilous mushroom *Coprinopsis cinerea* in response to bacteria. *ISME J.* 2019, *13*, 588–602.
29. Kumar, K. Nutraceutical Potential and Processing Aspects of Oyster Mushrooms (*Pleurotus* Species). *Curr. Nutr. Food Sci.* 2018, *16*, 3–14.
30. Kwon, A.H.; Qiu, Z.; Hashimoto, M.; Yamamoto, K.; Kimura, T. Effects of medicinal mushroom (*Sparassis crispa*) on wound healing in streptozotocin-induced diabetic rats. *Am. J. Surg.* 2009, *197*, 503–509.
31. Lee I., Kim J., Ryio I., Kim Y., Choo S., Yoo I., Min B., Na M., Hattori M., Bae K. Lanostane triterpenes from *Ganoderma lucidum* suppress the adipogenesis in 3T3-L1 cells through down-regulation of SREBP- 1c. *Bioorganic Med. Chem. Lett.* 2010;20:5577–5581. doi: 10.1016/j.bmcl.2010.06.093.
32. Liu, C.; Choi, M.W.; Xue, X.; Cheung, P.C.K. Immunomodulatory effect of structurally-characterized

- mushroom sclerotial polysaccharides isolated from *Polyporus rhinocerus* on bone marrow dendritic cells (BMDCs). *J. Agric. Food Chem.* 2019, 67, 12137–12143.
33. Liu, T.; Jiang, X.; Wang, W.; Xu, B. Optimization, characterization and antioxidant activities of selenized polysaccharides from *Hypsizygus marmoreus*. *Am. J. Biochem. Biotechnol.* 2019, 15, 138–149.
 34. Liu, Q.; Zhu, M.; Geng, X.; Wang, H.; Ng, T.B. Characterization of polysaccharides with antioxidant and hepatoprotective activities from the edible mushroom *Oudemansiella radicata*. *Molecules* 2017, 22, 234.
 35. Ma, G., Yang, W., Zhao, L., Pei, F., Fang, D., Hu, Q., 2018. A critical review on the health promoting effects of mushrooms nutraceuticals. *Food Science and Human Wellness* 7, 125–133. <https://doi.org/10.1016/j.fshw.2018.05.002>.
 36. Mapoung, S.; Umsumarn, S.; Semmarath, W.; Arjsri, P.; Thippraphan, P.; Yodkeeree, S.; Pornngarm, L. Skin wound-healing potential of polysaccharides from medicinal mushroom *Auricularia auricula-judae* (Bull.). *J. Fungi* 2021, 7, 247
 37. Matijašević, D.; Pantić, M.; Rašković, B.; Pavlović, V.; Duvnjak, D.; Sknepnek, A.; Nikšić, M. The Antibacterial activity of *Coriolus versicolor* methanol extract and its effect on ultrastructural changes of *Staphylococcus aureus* and *Salmonella enteritidis*. *Front. Microbiol.* 2016, 7, 1226
 38. Mleczek, Mirosław, et al. "Concentrations of minerals in selected edible mushroom species growing in Poland and their effect on human health." *Acta Sci. Pol. Technol. Aliment.* 12.2 (2013): 203-214.
 39. Nisar, J.; Mustafa, I.; Anwar, H.; Sohail, M.U.; Hussain, G.; Ullah, M.I.; Faisal, M.N.; Bukhari, S.A.; Basit, A. Shiitake culinary-medicinal mushroom, *Lentinus edodes* (Agaricomycetes): A species with antioxidant, immunomodulatory, and hepatoprotective activities in hypercholesterolemic rats. *Int. J. Med. Mushrooms* 2017, 19, 981–990
 40. Nitha, B.; Fijesh, P.V.; Janardhanan, K.K. Hepatoprotective activity of cultured mycelium of Morel mushroom, *Morchella esculenta*. *Exp. Toxicol. Pathol.* 2013, 65, 105–112
 41. Park, B.T.; Na, K.H.; Jung, E.C.; Park, J.W.; Kim, H.H. Antifungal and anticancer activities of a protein from the mushroom *Cordyceps militaris*. *Korean J. Physiol. Pharmacol.* 2009, 13, 49–54.
 42. Stamets, P., Zwickey, H., 2014. Medicinal Mushrooms: Ancient Remedies Meet Modern Science. *Integr Med (Encinitas)* 13, 46–47.
 43. Sillapachaiyaporn, C.; Nilkhet, S.; Ung, A.T.; Chuchawankul, S. Anti-HIV-1 protease activity of the crude extracts and isolated compounds from *Auricularia polytricha*. *BMC Complement. Altern. Med.* 2019, 19, 351.
 44. Singdevsachan, S.K., Auroshree, P., Mishra, J., Baliyarsingh, B., Tayung, K., Thatoi, H., 2016. Mushroom polysaccharides as potential prebiotics with their antitumor and immunomodulating properties: A review. *Bioactive Carbohydrates and Dietary Fibre* 7, 1–14. <https://doi.org/10.1016/j.bcdf.2015.11.001>
 45. Shomali, N.; Onar, O.; Cihan, A.C.; Akata, I.; Yildirim, O. Antioxidant, anticancer, antimicrobial, and antibiofilm properties of the culinary-medicinal fairy ring mushroom, *Marasmius oreades* (Agaricomycetes). *Int. J. Med. Mushrooms* 2019, 21, 571–582.
 46. Talero, E.; Avila-Roman, J.; Motilva, V. Chemoprevention with phytonutrients and microalgae products in chronic inflammation and colon cancer. *Curr. Pharm. Des.* 2012, 18, 3939–3965.
 47. Tel Çayan, G., Öztürk, M., Duru, M., Yabanli, M., Türkoğlu, A., 2017. Content of minerals and trace elements determined by ICP-MS in eleven mushroom species from anatolia, Turkey. *Chiang Mai Journal of Science* 44, 939–945.
 48. Temesgen, T., 2018. Application of Mushroom as Food and Medicine. *AIBM* 11. <https://doi.org/10.19080/AIBM.2018.11.555817>
 49. Thatoi, H., Singdevsachan, S.K., 2014. Diversity, nutritional composition and medicinal potential of Indian mushrooms: A review. *African Journal of Biotechnology* 13. <https://doi.org/10.4314/ajb.v13i4>
 50. Trigos Á., Suárez Medellín J. Biologically active metabolites of the genus *Ganoderma*: Three decades of myco-chemistry research. *Rev. Mex. Mic.* 2011;34:63–83.
 51. Valverde, M.E., Hernández-Pérez, T., Paredes-López, O., 2015. Edible Mushrooms: Improving Human Health and Promoting Quality Life. *Int J Microbiol* 2015, 376387. <https://doi.org/10.1155/2015/376387>.
 52. Van de Velde, J.; Wilbers, R.H.P.; Westerhof, L.B.; van Raaij, D.R.; Stavrakaki, I.; Sonnenberg, A.S.; Bakker, J.; Schots, A. Assessing the immunomodulatory potential of high-molecular-weight extracts from

- mushrooms;an assay based on THP-1 macrophages. *J. Sci. Food Agric.* 2015, *95*, 344–350.
53. Wang, Y.; Jia, J.; Ren, X.; Li, B.; Zhang, Q. Extraction, preliminary characterization and *in vitro* antioxidant activity of polysaccharides from *Oudemansiella radicata* mushroom. *Int. J. Biol. Macromol.* 2018, *120*, 1760–1769.
54. Wasser, S.P., 2002. Medicinal mushrooms as a source of antitumor and immunomodulating polysaccharides. *Appl Microbiol Biotechnol* 60, 258–274. <https://doi.org/10.1007/s00253-002-1076-7>.
55. Wu, X.; Zeng, J.; Hu, J.; Liao, Q.; Zhou, R.; Zhang, P.; Chen, Z. Hepatoprotective effects of aqueous extract from lingzhi or reishi medicinal mushroom *Ganoderma lucidum* (Higher Basidiomycetes) on α -amanitin-induced liver injury in mice. *Int. J. Med. Mushrooms* 2013, *15*, 383–391.
56. Yuan, B.; Zhao, L.; Rakariyatham, K.; Han, Y.; Gao, Z.; Muinde Kimatu, B.; Hu, Q.; Xiao, H. Isolation of a novel bioactive protein from an edible mushroom *Pleurotus eryngii* and its anti-inflammatory potential. *Food Funct.* 2017, *8*, 2175–2183
57. Zeng, D.; Zhu, S. Purification, characterization, antioxidant and anticancer activities of novel polysaccharides extracted from Bachu mushroom. *Int. J. Biol. Macromol.* 2018, *107*, 1086–1092