

# Mushrooms: A Potential Option in the Management of Deficiency and Diseases in Humans

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## Abstract

Mushrooms play essential role in preventing and treating various health issues, including, Reducing swellings due to allergy, blood pressure, and high cholesterol level". Mushrooms contain high quality, proteins, polysaccharides, unsaturated fatty acids, mineral substances, triterpenes, and secondary metabolites. Mushrooms are an excellent supplier of essential micronutrients and bioactive chemicals that may help to avoid chronic illnesses. Mushrooms have long been thought of as food that promote health. Recent research also indicates involvement of medicinal and culinary mushrooms in preventing a variety of age-related neurological dysfunctions, such as Parkinson's illnesses and Alzheimer's disease. Medicinal and edible mushrooms are rich in anti-tumor, and their antioxidant properties are extensively researched due to their various curative properties. Edible and medicinal mushrooms are used to prevent cancer to some extent and to minimize the side effects of conventional treatments like chemotherapy. Overall, mushrooms act as immunity booster, a good alternative for trace element supplement, and easily available to the consumers. In the present review, we discuss about various benefits of mushrooms using recent studies.

**Keywords:** Antioxidants, Immunity Boosters, Mushrooms, Nutrition, Supplement, Disease Management

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## INTRODUCTION

Mushrooms have existed for centuries in our diet because of their nutritional and medicinal properties they have been embraced from long back in history through traditional treatments like gastrointestinal diseases, infectious diseases, etc. Hundreds of mushroom species and about 700 species have significant medicinal properties.<sup>1</sup> Since ancient times, edible mushrooms have played a significant role in human diets, and more than 100 species have been raised for their possible health advantages.<sup>2</sup> Edible mushroom polysaccharides (EMPs) have been investigated recently for their potential benefits to fight against cancer and obesity. Evidences suggested the precise relationship between these health hazards and certain gut microbiota species.<sup>3</sup> The majority of the positive health benefits of EMPs have been linked to their ability to reverse gut microbiota dysbiosis. It illustrates how important a role EMPs play in reducing health risks by altering the gut flora.<sup>4</sup> Another major disease viz. Cardiovascular is among the most reasons for illness and deaths in the Western world. Numerous studies have demonstrated the impact of mushroom consumption on several metabolic indicators, including total, LDL, and HDL cholesterol, hypertension, and oxidative and inflammatory damage. These findings suggest that eating mushrooms may potentially lower the risk of developing cardiovascular disease.<sup>5</sup> The number of instances of neurodegenerative diseases, including dementia and Alzheimer's disease (AD), is predicted to reach 42 million in the world by 2020. The treatment of these disorders remains generally ineffectual despite the development of medicine. There are various potential health advantages of mushrooms and their extracts, including immune-modulating properties. It has been demonstrated that various edible mushrooms contain uncommon and exotic substances that have beneficial effects on brain cells *in vitro* and *in vivo*.<sup>6</sup>

Over the past ten years, the amount of metric tonnes of mushrooms have been produced by Israel and India, which ultimately resulted in sturdy market demand and developing customer information about the fitness benefits of mushrooms. Mushrooms have a high organic

process price yet are low in fat, rich in fiber, and relatively produced in macromolecules. They include quantities of vitamin B1, vitamin B12, vitamin B2, vitamin D, vitamin C, and vitamin E that are physiologically necessary. China produced more than 1.5 million metric tonnes of mushrooms in 2007, making it the world's largest producer. *Lentinula edodes*, *Pleurotus spp.*, *Flammulina velutipes*, and *Agaricus bisporus* are the most commonly cultivated mushrooms worldwide.

### Cancer Immunology

Mushrooms with medicinal properties have been offered as a new novel medicine that has the potential to improve cancer treatment and patient survival. Since at least 3000 BCE, people have been using them as medicines. Mushrooms have antibacterial, anti-inflammatory, cardiovascular, anti-diabetic, hepatoprotective, and anti-cancer properties. Mushrooms have a well-known ability to modulate the immune system, impacting blood stem cells, antigen-presenting cells, Phagocytes, thymus cells, and lymphocytes.<sup>7</sup> Cancer is a non-transmissible disease and is among the most significant causes of death worldwide, increasing day by day. Metastasis, i.e. cancer cells disseminate across the body, makes the treatment of cancer even more complicated. Chemotherapy, to some extent, can control the further advancement of cancer cells in the body but also results in various unwanted side effects that affect the quality of the patient's life. While in non-metastatic cancer, treatment is a lot easier because its location is specific and easy to treat compared to metastatic. (NCI, 2020) Cancer's ability to spread in any body organ has resisted the development of its cure but in recent years, various research developments have shown that mushrooms can boost the immune system to suppress the spread of cancer.<sup>8,9</sup> The Mushroom's medicinal ability to cure disease is well-known in the ancient history of China. The safe usage of medicinal mushrooms as single or in consortium along with chemotherapy or radiation has been carried out in Japan and China for over three decades.<sup>10</sup>

Mushrooms are rich in protein, vitamins, and minerals with low in cholesterol provides additional benefit of antioxidants, antibacterial, anti-inflammatory, and anti-tumor properties that

help improve the quality of life either during or after the therapy.<sup>11,12</sup> Mushrooms contain several substances that affect the signaling pathway of tumor-specific proliferation, apoptosis control, cancer-specific metabolism, metastasis, and essential system activities.<sup>13</sup> Different chemically structured antitumoral and immunostimulant polysaccharides from mushrooms have been studied on Pillar mushrooms, which has a variety of moderately physiologically active triterpenes, lectins, steroids like low- and high-molecular-compound fruiting bodies, mycelia and spores with possible anticarcinogenic benefits.<sup>14</sup>

The critical ingredient in mushrooms that has medical benefits is alpha-Glucan, which also contains many other roughages. Because of the fibers in their constitution, this fungus may be beneficial to intestinal function.  $\beta$ -glucan functions in the human body to enhance immune activities by stimulating natural killer large granular lymphocytes cells, Beta lymphocytes, Thymus lymphocytes cells, raising in phagocytic activity, promoting the production of antibodies and cytokines.<sup>15,16</sup>

Mushrooms have a wide range of impacts, one of which is their capacity to increase cytokine production. Small, soluble proteins called cytokines are intracellular regulators in an immune response. Characterizing a specific set of cytokines for responses to various contexts has been one strategy in the endeavor to know cytokine responses and the interactions between cytokines. Cytokine patterns are the cytokines engaged in many sorts of reactions. TH1, TH2, TH3/T regulatory (Treg) cells and the proinflammatory pathways are basic patterns in cancer research. Each of these clearly defined patterns may affect a cancer patient physiologically differently. Since the cytokines are cross-regulatory, one pattern of cytokine expression can influence another; therefore, they may have more significant effect on the body than any one kind of cytokine. T-helper 1 cell (TH1) is the cytokine pattern linked to an effective immune response against cancer. Interferon-gamma (IFN- $\gamma$ ), the predominant TH1 cytokine, triggers the cellular immune response. Since NK- LGL cells and CD8 (cluster of differentiation) tumoricidal macrophages and-T cells can eradicate tumor cells, cellular immunity is crucial in an anti-cancer response. IFN- also

enhances various cellular processes, including the presentation of tumor-specific immunogens and the creation of tumor-cancerous cytokines. Therefore, treatments for cancer patients include using mushrooms that trigger a TH1 response and boost IFN.<sup>17</sup>

A T-helper 2 (TH2) response, in contrast to a TH1 response, is not frequently connected to an immunological response to cancer. The cytokines IL-5, IL-4, IL-1(interleukin), and occasionally IL-10 are involved in TH2 responses, which are connected to allergies and asthma. The interaction between IL-4 and IFN- is crucial, as IFN- reduces IL-4 production, and IL-4 reduces IFN- production. Because a TH2 response lowers IFN- and the cellular immune response to cancer so that it can harm cancer patients. Treg cells control the T-cell response, often referred to as TH3 or Treg cells. Although there are numerous types of Treg cells, most Tregs produce transforming growth factor. This cytokine's capacity to spur tumor cell proliferation by suppressing the TH1 response led to its discovery. TGF- may lessen TH2 responses as well. TGF- is most usually linked to tolerance because it can reduce both TH1 and TH2, and it is abundant in the lungs and colon, which are regularly exposed to high quantities of harmless antigens. Although a Treg response to self-antigens is advantageous, cancer cannot be cleared due to a Treg response.<sup>17</sup>

## Medicinal values of Mushrooms

### Health of heart

The edible mushrooms are an appropriate choice for heart patients and the treatment of cardiovascular disorders since they contain low fat, no cholesterol, and a large proportion of unsaturated fatty acids. The Mushroom's high potassium and low sodium content improve salt balance while preserving human blood circulation. Therefore, mushrooms are safe for those with high blood pressure. Mushrooms like *Lentinula* and *Pleurotus* spp. should be consumed frequently to lower cholesterol levels.<sup>18</sup>

### Anti-aging properties

Mushroom polysaccharides are effective super-oxide free radical scavengers. These antioxidants stop the body from producing free

radicals, slowing ageing. For excellent and healthy eye vision, kidneys, bone marrow, skin, and liver, ergothioneine is an essential antioxidant in *Flammulina velutipes* and *Agaricus bisporus*.<sup>19,20</sup>

### Digestive system regulator

As prebiotics in the intestine, the fermentable fiber and oligosaccharides found in mushrooms attach beneficial bacteria to the colon. This dietary fiber supports good bowel function and the digestive process.<sup>19,21,22</sup>

### Low-calorie food

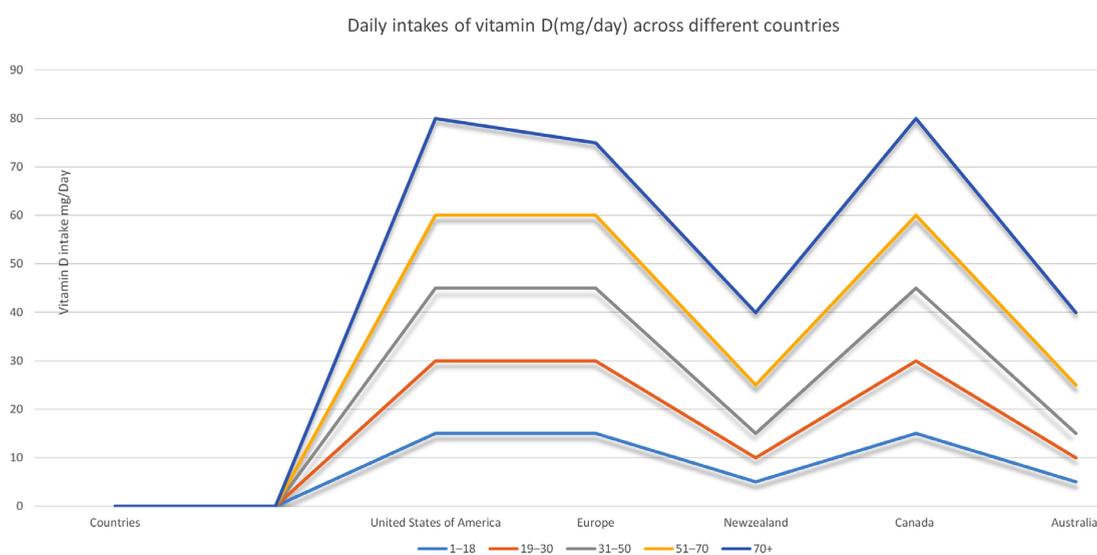
Due to their low-calorie content, lack of starch, little fat, and sugar content, and low caloric value, mushrooms are preferred as a portion of food by diabetes patients. Mushrooms include lean proteins that aid in the body's ability to burn cholesterol. As a result, it is the best food for those trying to lose additional weight.<sup>19,23</sup>

### Strengthens immunity

Mushrooms can strengthen the immune system. Beta-glucans, a broad group of polysaccharides and minerals extracted from mushrooms, is in charge of enhancing the immune system. These substances activate all immune cells, enhancing the acquired (specific) immune responses and the host's innate (non-specific).<sup>19,22</sup>

### Inflammation/ Immunity

Inflammation is thought to be a crucial component of the body's intricate biological reaction to harm or hazardous stimuli like pathogens, damaged cells, or irritation. This response causes various physiological changes, including vasodilation, increased vascular permeability, and plasma extravasation, which result in many physical symptoms like fever, discomfort, and edoema. The most often used medication to treat inflammation in the body nowadays is non-steroidal anti-inflammatory medicines (NSAIDs). However, numerous studies have demonstrated that using NSAIDs for an extended period of time may have serious adverse effects on the digestive system (GIT). These include a variety of negative consequences, such as intestine perforation, hemorrhage, peptic ulcers, and mucosal sores.<sup>21</sup> Meanwhile, some studies have found that the adverse effects of NSAIDs go beyond the GIT and include more severe problems like hypertension, acute renal failure, cardiovascular toxicity, and nephrotic syndrome. Thus, a lot of work has recently been made into finding plant-based alternative anti-inflammatory chemicals as potentially safe and natural treatments without the adverse side effects of NSAIDs.<sup>23</sup> While many different herbs have been used as medicine throughout history,



**Figure 1.** The above graph putatively represents the daily intake of vitamin D (mg/day) across different countries

mushrooms have also played a significant role in folk medicine for a long time. They have been widely used in many Asian, European, Middle Eastern, African, Australian and Indian cultures for the treatment of large number of diseases.<sup>24</sup>

### Vitamin-D

Mushrooms are one of the top sources of vitamin D due to their exposure to UV radiation. In mushrooms, vitamin D<sub>2</sub> is the most prevalent type, with more minor levels of vitamins D<sub>3</sub> and D<sub>4</sub>. Consumption of packed fresh edible mushrooms even provides 10 ng/100 g fresh weight of D<sub>2</sub>, which is quite higher than the amount found in the major foods containing vitamin D.<sup>25</sup> Mainly Ergosterol is abundant in *Agaricus bisporus* (white button mushrooms), and when exposed to UV light, it is transformed into vitamin D<sub>2</sub>. The current research study examined in rats and fresh button mushrooms using UV-C irradiation provides the information on the possibility of commercially produced button mushrooms fortified with vitamin D<sub>2</sub> to enhance consumer health (Figure 1).

### Weight management

The leading contributing cause to obesity in most situations is a mix of too many calories and not enough exercise. In addition, genetics, drugs, mental illness, and endocrine abnormalities all contribute to obesity. Additional research has demonstrated that several factors, such as hormone disruptors, smoking habits, pregnancy at a later age, insufficient sleep, cravings, use of medications (such as antipsychotics), the fluctuation of ambient temperature, inherited risk factors, and elevated Body mass index (BMI) may contribute to elevated obesity levels.<sup>26</sup>

A research study in mice found that *G. lucidum* extracts reduce obesity by regulating the microbiota, so mushrooms may be a new prebiotic to combat obesity.<sup>27</sup> Edible and medicinal mushrooms have obesity-related cellular mechanisms mediated by antioxidant action. According to research studies, mushrooms may contain antioxidant properties that boost cells' natural antioxidant defense mechanisms. They enhance anti-inflammatory responses and ward against hypertension and dyslipidemia brought on by fat. Regular consumption of

mushrooms is helpful in treating obesity and other aspects of metabolic syndrome, making it a promising option for use in upcoming pharmaceutical or nutraceutical products.<sup>26</sup> The polysaccharides or polycarbohydrates, potential importance as an anti-diabetic and anti-obesity agent is indicated by the fact that *G. lucidum* treatment of adipocytes decreases the expression of an adipogenic transcription factor, which promotes the storage of primary metabolites (lipids and glucose), induction of kinase signaling pathways, and transportation.<sup>28</sup> In both short-term (4 days) and long-term (1 year) clinical tests, individuals who were obese or had diabetes were asked to assess the effects of replacing 20% of their diet's high-energy beef with 20% of its low-energy *Agaricus bisporus* species. The observations showed that people who consumed the mushroom routine had lower BMIs, smaller waistlines, and increased satiety without losing taste.<sup>29</sup> Scientists have concluded that consuming white button mushrooms (*Agaricus bisporus*) has anti-obesity and anti-diabetic properties, and additional beneficial species of mushrooms are shiitake mushrooms (*Lentinus edodes*) and Lion's mane mushrooms (*Hericium erinaceus*).<sup>30</sup>

A compound Ergosterol peroxide in Mushrooms decreases the fatty acid accumulation in 3T3-L1 cells. This substance prevents the sterol regulatory element binding protein-1c mRNA from being upregulated (SREBP-1c). The sterol response limiting protein SREBP-1c controls how the body reacts to sterol. Additionally, treatment with ergosterol peroxide inhibits acetyl-coenzyme activity, unsaturated fat translocase, and unsaturated fat synthase. An enzyme that participates in producing and transporting long-chain unsaturated fatty acids. These studies imply that ergosterol peroxide derived from *Ganoderma lucidum* may be a promising medication for treating excess weight problem because it aids in preventing obesity and related metabolic problems.<sup>4</sup> A crucial regulator of homeostasis is AMP-activated protein kinase (AMPK). Reduced adiposity in mice resulted from increased AMPK activity's anti-hyperinsulinemic and anti-hyperglycemic actions.

The consumption of *H. erinaceus* powder showed a reduced concentration in total cholesterol and lipid levels in the mice in their

plasma.<sup>31</sup> *Pleurotus citrinopileatus*, also consists mixture of bioactives hence can treat obesity.<sup>32</sup> According to the results of clinical investigations, edible mushrooms may be utilized as a substitute for vegetables, as they contain high nutrition value and bioactive compounds. They are low in sodium and cholesterol and contain essential nutrients like vitamins and minerals. As a result, it makes a tremendous alternate food for those with high blood pressure issues. Additionally, they have trace elements like selenium, which help to enhance human health. As a result, edible mushrooms have the potential to reduce obesity and several other chronic diseases.<sup>33</sup>

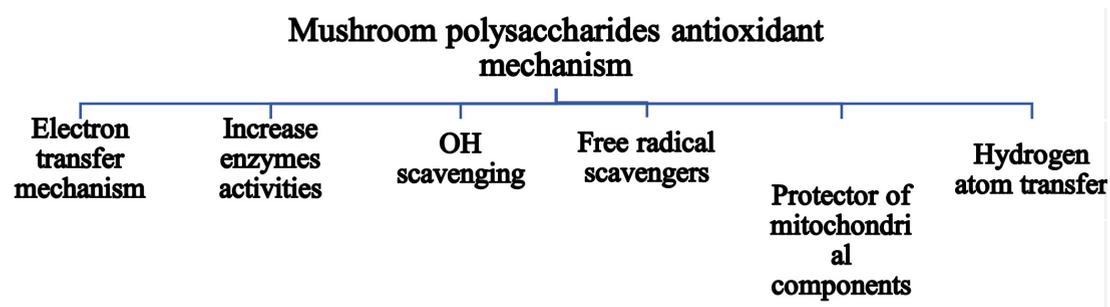
### Antioxidant

The imbalance between an organism's oxidant and antioxidant levels is known as oxidative stress. During immunological responses and different metabolic processes under physiologically normal conditions, ROS (reactive oxygen species) and free radicles are created in humans. A change in the formation of reactive free radicals and ROS causes oxidative stress.<sup>34</sup> Mushrooms can reduce oxidative stress as a natural supplement to increase antioxidant defense (Figure 2).

Mushrooms are rich in antioxidant chemicals that can be extracted from the mycelium and fruiting body of the mushrooms. Biologically active chemicals in mushrooms give mushrooms their antioxidant capabilities. Polysaccharides, phenolics, flavonoids, ABA, carotenoids, and tocopherols are some of the mushroom components with significant antioxidant qualities. Among different mushroom species, polysaccharides of *Pleurotus* spp have some unique biological functions; heteropolysaccharides exhibit anti-tumor, antioxidant properties, and anti-inflammatory.<sup>22</sup> It is essential for living things to oxidize to produce energy and perform physiological functions. A radical scavenging technique measures an antioxidant's potential in inhibiting lipid oxidation. Since free radicals contain unpaired electrons, they are highly reactive particles that can harm human health (Figure 3). These readily accessible radicals attack tissues, cells, organs, DNA, and RNA. As a result, cells can become damaged and necrosed, leading to illnesses and diseases such as cancer, improper aging, diabetes, and cardiovascular disease. Mushrooms contain a high concentration of antioxidants like glutathione and ergothioneine;

**Table.** Importance of Umami

Characteristics	Features	References
Flavor enhancement:	Additional umami present in mushrooms increases its flavor significantly.	35,36,37
Enhances satisfaction	Umami creates each craving for attractiveness and satiation, the sensation of being gratified to the fullest extent.	
Less salt use	It balances saltiness and allows up to a 50 percent salt reduction without compromising flavor.	
Brings out the best	Umami lessens the bitterness and increases sweetness.	



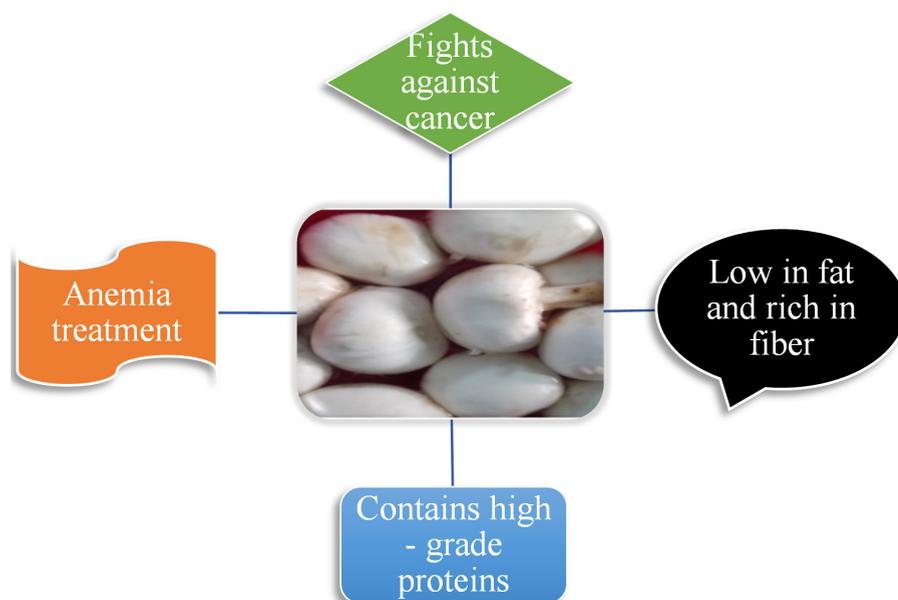
**Figure 2.** Antioxidant Activity of Mushroom Extracts Source<sup>11</sup>

their high intake protects against early death (Figure 4).<sup>20</sup>

The antioxidant ergothioneine is found primarily in mushrooms and protects mitochondrial components from oxidative damage. The release of electrons from ETS (mitochondrial electron transport system) facilitates such actions. Specific monosaccharide units contain hydrogen and are bound to side branches of compound, and mushroom polysaccharides can scavenge free radicals and increase antioxidant activity by

removing anomeric hydrogen from the internal monosaccharide units.

General health advantages of Mushrooms White button mushroom (*Agaricus bisporus*) provides several health benefits, such as anti-cancer qualities, immune system support, better digestion, protection from cardiovascular disease, and anemia treatment. High quantities of antioxidants found in white button mushrooms may be able to stop several types of cell damage. They also showed a cancer-preventive effect. They



**Figure 3.** Primary advantages of Mushrooms



**Figure 4.** Ganoderma lucidum culture

have a lot of fiber, few calories, and other minerals, including calcium, magnesium, and potassium.

Using mushrooms as a standard treatment for cardiovascular diseases and Alzheimer's disease

Cardiovascular diseases (CVD) and Alzheimer's disease (AD) have similar etiologies and preventative measures. As the number of older people increases globally, AD complications negatively impact the global healthcare system and economy. The leading cause of death worldwide is CVD, which poses a severe danger to industrialized and developing countries. Mushroom bio-components may control both disorders. One of the common connecting elements between

AD and CVD include high blood pressure, high cholesterol, and inflammation. Diabetes and oxidative stress. AD is impacted by hypertension-enhanced cerebrovascular oxidative pathogenesis stress, increased amyloid beta (Ab) formation, and decreased clearance.<sup>38</sup>

### **Mushrooms can lower the risk/probability of cardiovascular disease**

A mushroom called *Ganoderma lucidum*, sometimes referred to as lingzhi or reishi, has been used for its numerous therapeutic benefits. *G. lucidum* is gaining popularity as a supplemental treatment for cardiovascular health.<sup>39</sup> Anti-hypertensive medications have effectively lowered CVD risk from 55% to as little as 18%. Anti-hypertensive bio-components may be found in both edible and therapeutic mushrooms. The *Ganoderma* bio-actives include polysaccharides (ganoderic acids, ganoderic aldehydes, and ganoderic alcohols and triterpenoids). The results of ACE with *Ganoderma lucidum* inhibitory peptides in reducing blood pressure. *Pleurotus* species, *Hericium erinaceus*, *Pholiota adipose*, *Grifola frondosa*, *Flammulina velutipes*, *Agaricus bisporus*, *Hypsizigus marmoreus* are among the most prominent species.<sup>38</sup>

### **Mushrooms play a significant role in the treatment of neurodegenerative diseases**

A frequent neurological disorder that causes the brain or nervous system to deteriorate progressively is known as a neurodegenerative disease (ND). Comprehensive and alternative therapies have lately caught the interest of scientific researchers in treating NDs. The neutralization of numerous age-related neurological dysfunctions, including Parkinson's and Alzheimer's illnesses, depends on the consumption of edible mushrooms. The secondary metabolites of edible mushrooms like polyphenols, terpenes, sesquiterpenes, alkaloids, lactones, sterols, and chelating agents are used as ND treatments.<sup>40</sup>

### **Hericium Erinaceus function in Alzheimer's treatment**

*Hericium Erinaceus* is one of the most notable instances of a fungus that is both tasty and therapeutic. In both *in vivo* and *in vitro* model systems, HE demonstrates its neuroprotective

potential. Aqueous extract of mycelium polysaccharide from HE has anti-apoptotic action in differentiated PC12 (DPC12) cell lines stimulated by l-glucose.<sup>40</sup> The most widely utilized HE products are ethanol extracts of erinacine A-enriched HE-mycelia, erinacine S-enriched HE mycelia, and erinacine A-enriched HE-mycelia, as studied on the treated mice showed learning and memory deficiencies, and decreased discrimination in the new object recognition (NOR) using Y maze test. By increasing the amount of nerve growth factor in the hippocampus, oral treatment of HE was able to reverse the learning and memory deficits in mice that had been treated, providing evidence that it can promote hippocampal regeneration. Polysaccharide-rich aqueous HE extracts have been found to encourage neuronal development and differentiation.<sup>41</sup> Through the c-jun N-terminal kinase (JNK) pathway, the HE bioactive chemicals increase the production of NGF mRNA in the hippocampus.<sup>40</sup>

### **Potential prebiotic source: Mushroom**

Prebiotics has been discovered, and they have the potential to change the microbiota in the human gut and improve host health. Due to consumer demand from health-conscious customers, several purposeful additives have started to appear. The microbial community in the stomach may undergo minor modifications due to eating white button mushrooms, which may improve the liver's ability to manage glucose levels. Mushrooms can promote gut microbitota. Some examples of gut microbiota promoting mushrooms are *Ganoderma lucidum*, *Pleurotus tuberregium*, *Polyporus umbellatus* and *Grifola frondose*.

### **Concept of prebiotic**

The term "prebiotic" was used initially by Gibson and Roberfroid,<sup>42</sup> defined prebiotics as carbohydrates with a very short chain length. They found that the criteria of prebiotics and dietary fiber more or less overlap, except for its selectivity for particular species. Oligosaccharides like inulin and its derivatives are already on the market, are produced at a meager cost, and are frequently used as functional meal components.<sup>38</sup>

Prebiotic usage was once thought to improve colon health, immune system function,

and gastrointestinal and fecal disposal. Prebiotics promote the development of lactobacilli and bifidobacteria while also delaying the appearance of the histolyticum subgroup.<sup>43</sup> Prebiotics are demonstrated to increase the number of bacteria in the gut research by Probert and Gibson.<sup>44</sup> Bifidobacteria, also known as lactobacilli, have been shown to create vitamin B, block the growth of pathogens, lower blood ammonia and cholesterol levels, and help restore normal intestinal function. While lactobacilli help lactose-intolerant people digest lactose, they also lessen constipation and infantile diarrhea and help the body fight off diseases like salmonellae.<sup>42</sup> Mushrooms also act as immune modulator, promotes gut health supports in production of vitamins. Mushrooms contain wide nutrients such as Carbohydrate, polysaccharides, glucans, xylans which helps in enhancing health of gut.<sup>22</sup>

#### **Nutritional value and Chemical composition of Mushroom and methods of estimation**

The five most well-known kinds of farmed, fresh mushrooms have been studied for their Nutritional value and Chemical composition. Shiitake mushrooms demonstrated the highest amounts of macronutrients, except for proteins, as well as the best tiers of sugars, tocopherols, and PUFA. This search helps to enhance dietary databases for the most well-known fungus species consumed globally and allows for comparisons between them.

#### **Nutritional value**

Using AOAC International techniques, the samples' chemical composition (moisture, proteins, fat, carbs, and ash) was examined Theander et al.<sup>45</sup> by using the macro-Kjeldahl method, and the samples' crude protein content (N 4.38) was estimated. The crude fat of the samples was determined by extracting a known weight of the powdered sample with petroleum ether using a Soxhlet apparatus. The ash content was determined by incinerating the samples at 600±15°C. By using the differential, total carbs were computed. The following formula was used to calculate energy: (kcal) = 4 (g protein) + 3.75 (g carbohydrate) + 9 (g fat).

#### **Sugar composition**

Raffinose was used as an internal standard, and 40 ml of 80% aqueous ethanol was used to extract the samples for 30 min at 80°C. After that, they were analyzed using high-performance liquid chromatography (HPLC) and a refraction index detector. At a flow rate of 1 ml/min, the mobile phase was composed of acetonitrile and deionized water in a 70:30 (v/v) ratio. Sugars were determined by comparing sample peak relative retention times to benchmarks.<sup>46</sup>

#### **Fatty acids composition**

Three milliliters of ethyl ether were shaken in an extreme vortex to recover the fatty acids alkyl group esters (FAME), and the upper part also included a microcolumn of anhydrous sulfate to remove the water. Macherey-Nagel column and DANI model GC 1000 equipment with a split or without split injector, a flame ionization detector at 260°C, and these characteristics were used to conduct the analysis edible mushrooms.<sup>47</sup>

#### **Umami And Sodium**

##### **Umami**

There are five types of taste, one of which is umami, and the others are sweet, sour, salty, and bitter. Umami flavor in mushrooms comes from glutamate, naturally found in plants (Table). The umami style could be a quiet attribute remark completely different from the typical four tastes. Adding umami substances like mushrooms can amend the style characteristics of the food. Not solely the umami style but additionally different sensory characteristics like continuity, mouth fullness, impact, mildness, and thickness are inflated. Overall, they increase the palatableness of foods.<sup>48</sup> The darkness of the Mushroom increases its umami flavor. Shiitake mushrooms (dried) are a rich source of umami.<sup>49</sup> Examples of Mushrooms rich in umami are Shiitake, Portabella, Crimini, and White button.

##### **Sodium**

It is an essential nutrient that regulates blood pressure and maintains fluid balance in the body. Mushrooms are low in sodium. 100 gm of fresh Mushroom contains 4mg of sodium. Less sodium reduces the risk of stroke and risk of high blood pressure, and heart disease.

### Other Benefits of Mushroom

Humans have consumed mushrooms for their biological processes and healthful edges for a very long time. Mushrooms are low in calories and fat but high in supermolecules, macromolecules, and soluble fiber. Mushrooms are rich in minerals and trace elements such as metallic elements, copper, and vitamins such as vitamin B2, niacin, and folates. Because of their peculiar flavor, they have been utilized as food for hundreds of years. Secondary bioactive metabolites discovered in mushrooms include phenolic resin compounds, sterols, and triterpenes. In vitro and in vivo research with mushrooms and isolated bioactive ingredients have suggested that they may have hypocholesterolemic, anti-tumor, antiviral, inhibitory, and hypoglycemic properties. Implementing mushrooms or mushroom products in our everyday diet could provide a significant advantage.<sup>50</sup> Some Benefits are discussed below.

Beta glucan is a soluble fiber that regulates sterol level in human body and keeps our hearts healthy. Oriental black mushrooms and *Pleurotus ostreatus* well interacts with beta glucan and assist in glucose modulation. Beta glucans contribute to improved resistance against allergies by increasing the number of lymphocytes within the blood.<sup>51</sup> Mushrooms are supplemented with vitamin B complex, riboflavin, and water-soluble vitamin, which are sensible for our system, systema nervosum, heart, and skin. B-12 works with the B complex to boost our system and mood, and it is particularly vital for our nerve cells and genetic material.

Copper, play vital role in production of red blood cells. This is often necessary for creating sturdy bones and healthy nerve system. Potassium is important for healthy nerves and muscles. Chemical element helps to regulate force per unit area. White mushrooms have lots of metallic elements, 300 mg per serving. Mushrooms can also be used for treating anemia. Anemia is caused by an iron deficiency and is defined by headaches, fatigue, organic process issues, and decreased neural friction. Because reishi mushrooms are high in iron, they help to alleviate these symptoms. Iron aids in the development of RBC and hence keeps us healthy and efficient.<sup>52</sup> Mushrooms increase iron absorption. The copper content in mushrooms aids in the effective absorption of iron from food

and allows its well utilization by removing it from the liver, which makes a healthy liver and prevents diabetes. Copper and iron work together in Mushrooms to ensure that we have healthy bones and that they also prevent anemia.<sup>52</sup>

### CONCLUSION

In the hunt for practical, affordable solutions to meet nutritional requirement, Mushrooms are highly potential option. A variety of health problems may be prevented and treated with the help of mushrooms, which also offer a number of nutrients. Additionally, Mushrooms have powerful medicinal effects that are linked to immune enhancement, maintaining homeostasis, metabolism regulation, managing disease condition and enhancing quality of life in human life. However, in depth research is still necessary to fully understand the potential, cultivation and processing of number of edible mushrooms.

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### CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

### AUTHOR'S CONTRIBUTION

Both authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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### DATA AVAILABILITY

All datasets generated or analyzed during this study are included in the manuscript.

### ETHICS STATEMENT

Not applicable.

### REFERENCES

1. Davis R, Taylor A, Nally R, Benson KF, Stamets P, Jensen GS. Differential immune activating, anti-inflammatory, and regenerative properties of the aqueous, ethanol,

- and solid fractions of a medicinal mushroom blend. *J Inflamm Res.* 2020;13:117.
2. Bajwa R, Kausar R, Javaid A. Yield performance of *Pleurotus ostreatus* (oyster mushroom) cultivated on cereal crop residues amended with *Sesbania sesban* leaves. In: Proceedings of 2nd National Conference of Plant Pathology, September 27-29, 1999, University of Agriculture Faisalabad, Pakistan;160-164.
  3. Lee DH, Yang M, Giovannucci EL, Sun Q, Chavarro JE. Mushroom consumption, biomarkers, and risk of cardiovascular disease and type 2 diabetes: a prospective cohort study of US women and men. *Am J Clin Nutr.* 2019;110(3):666-674. doi: 10.1093/ajcn/nqz057.
  4. Ma G, Yang W, Zhao L, Pei F, Fang D, Hu Q. A critical review on the health-promoting effects of mushroom nutraceuticals. *Food Sci Hum Wellness.* 2018;7(2):125-133.
  5. Guillamon E, Garcia-Lafuente A, Lozano M. Edible mushrooms: role in the prevention of cardiovascular diseases. *Fitoterapia.* 2010;81(7):715-723.
  6. Phan CW, David P, Naidu M, Wong KH, Sabaratnam V. Therapeutic potential of culinary-medicinal mushrooms for the management of neurodegenerative diseases: diversity, metabolite, and mechanism. *Crit Rev Biotechnol.* 2015;35(3):355-368. doi:10.3109/07388551.2014.887649.
  7. Moradali MF, Mostafavi H, Ghods S, Hedjaroude GA. Immunomodulating and anti-cancer agents in the realm of macromycetes fungi (macrofungi). *Int Immuno pharmacol.* 2007;7(6):701-724.
  8. Ahn WS, Kim DJ, Chae GT, et al. Natural killer cell activity and quality of life were improved by consumption of a mushroom extract, *Agaricus blazei* Murill Kyowa, in gynecological cancer patients undergoing chemotherapy. *Int J Gynecol Cancer.* 2004;14(4):589-594. doi: 10.1111/j.1048-891x.2004.14403.x
  9. Rossi P, Difrancia R, Quagliariello V, et al. B-glucans from *Grifola frondosa* and *Ganoderma lucidum* in breast cancer: an example of complementary and integrative medicine. *Oncotarget.* 2018;9(37):24837-24856. doi: 10.18632/oncotarget.24984.
  10. Wasser SP. Medicinal mushroom science: History, current status, future trends, and unsolved problems. *Int J Med Mushrooms.* 2010;12(1):1-16. doi: 10.1615/intjmedmushr.v12.i1.10.
  11. Reis F, Lima R, Morales P, Ferreira I, Vasconcelos M. Methanolic Extract of *Ganoderma lucidum* Induces Autophagy of AGS Human Gastric Tumor Cells. *Molecules.* 2015;20(10):17872-17882. doi: 10.3390/molecules201017872.
  12. Blagodatski A, Yatsunskaya M, Mikhailova V, Tiasto V, Kagansky A, Katanaev VL. Medicinal mushrooms as an attractive new source of natural compounds for future cancer therapy. *Oncotarget.* 2018;9(49):29259-29274. doi: 10.18632/oncotarget.25660.
  13. Wasser SP, Weis AL. Therapeutic effects of substances occurring in higher Basidiomycetes mushrooms: a modern perspective. *Crit Rev Immunol.* 1999;19(1):65-96. doi: 10.1615/critrevimmunol.v19.i1.30.
  14. Wasser SP, Weis AL. Medicinal properties of substances occurring in higher basidiomycetes mushrooms: current perspectives. *Intl. J Med Mushrooms.* 1999;1(1). doi: 10.1615/IntJMedMushrooms.v1.i1.30
  15. Strong RC, Taveira VC, Novaes MR. The role of immunomodulator b-D-Glucan co-adjuvant for cancer therapy. *Revista Brasileira de Nutricao Clinica.* 2006;21:163-168.
  16. Heredia M, Canales S, Sáez C, Testillano M. The nutritional status of patients with colorectal cancer undergoing chemotherapy. *Farmacia Hospitalaria,* 2008;32(1):35-37. doi: 10.1016/S2173-5085(08)70027-3.
  17. Vanneman M, Dranoff G. Combining immunotherapy and targeted therapies in cancer treatment. *Nat Rev Cancer.* 2012;12(4):237-251. doi: 10.1038/nrc3237.
  18. Manikandan K. Nutritional and Medicinal Values of Mushrooms. *Open Journal of Forestry.* 2016;6(5)11-14.
  19. Manikandan N, Kuzhali SS, Kumuthakalavalli R. Decolorisation of textile dye effluent using fungal microflora isolated from spent mushroom substrate (SMS). *J. Microbiol. Biotech. Res,* 2012;2(1), 57-62.
  20. Mwangi RW, Macharia JM, Wagara IN, Bence RL. The antioxidant potential of different edible and medicinal mushrooms. *Biomed Pharmacother.* 2022;147:112621. doi: 10.1016/j.biopha.2022.112621.
  21. Smalley WE, Ray WA, Daugherty JR, Griffin MR. Non-steroidal anti-inflammatory drugs and the incidence of hospitalizations for peptic ulcer disease in elderly persons. *Am J Epidemiol.* 1995;141(6):539-545. doi: 10.1093/oxfordjournals.aje.a117469.
  22. Chun S, Gopal J, Muthu M. Antioxidant activity of mushroom extracts/polysaccharides-their antiviral properties and plausible AntiCOVID-19 properties. *Antioxidants.* 2021;10(12):1899. doi: 10.3390/antiox10121899.
  23. Dugowson CE, Gnanashanmugam P. Non-steroidal anti-inflammatory drugs. *Phys Med Rehabil Clin Am.* 2006;17(2):347-354. doi: 10.1016/j.pmr.2005.12.012.
  24. Oyetayo OV. Medicinal uses of mushrooms in Nigeria: towards full and sustainable exploitation. *Afr J Tradit Complement Altern Med.* 2011;8(3):267-274. doi: 10.4314/ajtcam.v8i3.65289
  25. Cardwell G, Bornman JF, James AP, Black LJ. A Review of Mushroom as a Potential Source of Dietary Vitamin D. *Nutrients.* 2018;10(10):1498.
  26. Ganesan K, Xu B. Anti-obesity effects of medicinal and edible mushrooms. *Molecules.* 2018;23(11):2880.
  27. Delzenne NM, Bindels LB. *Ganoderma lucidum*, a new prebiotic agent to treat obesity? *Nat Rev Gastroenterol Hepatol.* 2015;12(10):553-554.
  28. Thyagarajan-Sahu A, Lane B, Sliva D. ReishiMax, Mushroom based dietary supplement, inhibits adipocyte differentiation, stimulates glucose uptake and activates AMPK. *BMC Complement Altern Med.* 2011;11(1):1-14.
  29. Poddar KH, Ames M, Hsin-Jen C, Feeney MJ, Wang Y, Cheskin LJ. Positive effect of mushrooms substituted for meat on body weight, body composition, and health parameters. A 1-year randomized clinical trial. *Appetite.* 2013;71:379-387.
  30. Kim SP, Park SO, Lee SJ, Nam SH, Friedman M. A polysaccharide isolated from the liquid culture of *Lentinus edodes* (Shiitake) mushroom mycelia

- containing black rice bran protects mice against a *Salmonella* lipopolysaccharide-induced endotoxemia. *J Agric Food Chem.* 2013;61(46):10987-10994.
31. Huang HT, Ho CH, Sung HY, et al. Hericium erinaceus mycelium and its small bioactive compounds promote oligodendrocyte maturation with an increase in myelin basic protein. *Sci Rep.* 2021;11(1):1-13.
32. Hao Y, Sun H, Zhang X, Wu L, Zhu Z. A novel polysaccharide from *Pleurotus citrinopileatus* mycelia: Structural characterization, hypoglycemic activity and mechanism. *Food Bioscience.* 2020;37:100735.
33. Mustafa F, Chopra H, Baig AA, et al. Edible Mushrooms as Novel Myco-Therapeutics: Effects on Lipid Level, Obesity, and BMI. *J Fungi.* 2022;8(2):211.
34. Keshari A, Verma AK, Kumar T, Srivastava R. Oxidative Stress: A Review. *Int J Sci Technol.* 2015;3:155-162.
35. Metastatic cancer: When cancer spreads. National Cancer Institute. Published 12 May 2015. <https://www.cancer.gov/types/metastatic-cancer>. Accessed January 16.
36. Shortleeve C. Are mushrooms healthy? Here's what experts say. Time. Published online Originally published: January 31 2019. <https://time.com/5500684/are-mushrooms-healthy/>. Accessed January 17, 2023.
37. Zhao X, Wei Y, Gong X, Xu H, Xin G. Evaluation of umami taste components of mushroom (*Suillus granulatus*) of different grades prepared by different drying methods. *Food Science and Human Wellness.* 2020;9(2):192-8.
38. Rahman MA, Abdullah N, Aminudin N. Interpretation of Mushroom as a common therapeutic agent for Alzheimer's disease and cardiovascular diseases. *Crit Rev Biotechnol.* 2016;36(6):1131-1142. doi: 10.3109/07388551.2015.1100585.
39. Klupp NL, Chang D, Hawke F, et al. Ganoderma lucidum Mushroom for the treatment of cardiovascular risk factors. *Cochrane Database Syst Rev.* 2015;2021(2):CD007259. doi: 10.1002/14651858.CD007259.pub2
40. Rai SN, Mishra D, Singh P, Vamanu E, Singh MP. Therapeutic applications of mushrooms and their biomolecules and a glimpse of in silico approaches in neurodegenerative diseases. *Biomed Pharmacother.* 2021;137.
41. Yu S, Weaver V, Martin K, Cantorna MT. The effects of whole mushrooms during inflammation. *BMC Immunol.* 2009;10(1):1-13.
42. Gibson GR, Roberfroid MB. Dietary modulation of the human colonic microbiota. Introducing the concept of prebiotics. *Nutrition.* 1995;125(6):1401-1412.
43. Palframan R, Gibson GR, Rastall RA. Development of a quantitative tool for the comparison of the prebiotic effect of dietary oligosaccharides. *Lett Appl Microbiol.* 2003;37(4):281-284. doi: 10.1046/j.1472-765x.2003.01398.x
44. Probert HM, Gibson GR. Investigating the prebiotic and gas-generating effects of selected carbohydrates on the human colonic microflora. *Lett Appl Microbiol.* 2002;35(6):473-480. doi: 10.1046/j.1472-765x.2002.01223.x
45. Theander O, Aman P, Westerlund E, Andersson R, Pettersson D. Total dietary fiber determined as neutral sugar residues, uronic acid residues, and Klason lignin (the Uppsala method): collaborative study. *Journal of AOAC International.* 1995;78(4):1030-44.
46. Heleno SA, Barros L, Sousa MJ, Martins A, Ferreira ICFR. Study and characterization of selected nutrients in wild mushrooms from Portugal by gas chromatography and high-performance liquid chromatography. *Microchem J.* 2009;93:195-199.
47. Barros L, Correia DM, Ferreira ICFR, Baptista P, Santos-Buelga C. Optimization of the determination of tocopherols in *Agaricus* sp. edible mushrooms by a normal phase liquid chromatographic method. *Food Chemistry.* 2008;110(4):1046-1050. doi: 10.1016/j.foodchem.2008.03.016.
48. Mau JL. The umami taste of edible and medicinal mushrooms. *Int J Med Mushrooms.* 2005;7(1-2):119-126. doi: 10.1615/intjmedmushr.v7.i12.120
49. Dennett C. What Umami Can Do for You, and Four Foods to Help You Get There. The Seattle Times.; Published, 2016. <https://www.seattletimes.com/life/wellness/what-umami-can-do-for-you-and-four-foods-to-help-you-get-there/>. Accessed January 17, 2023.
50. Cheung PCK. The nutritional and health benefits of mushrooms. *Nutrition Bulletin.* 2010;35(4):292-299. doi: 10.1111/j.1467-3010.2010.01859.x.
51. Fan MJ, Lin YC, Shih HD, et al. Crude extracts of *Agaricus brasiliensis* induce apoptosis in human oral cancer CAL 27 cells through a mitochondria-dependent pathway. *In vivo.* 2011;25(3):355-366.
52. Firdous DH. Benefits of Mushroom and its side effects. Lybrate. <https://www.lybrate.com/topic/benefits-of-mushroom-and-its-side-effects>. Accessed January 17, 2023.