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Editorial

Edible Mushrooms Versus Health and Wellness: An Editorial

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Edible mushrooms, frequently used in traditional East Asian medicine, have recently expanded global consideration for their nutritional and medicinal ethics. They make purpose as prebiotics, indirect probiotics, or synbiotics because of their enriched β-glucans, enzymes, and secondary metabolites contents, sustain gut health and decline inflammation [1]. Mushrooms encompass bioactive compounds infrequently found in plant or animal-based foods and have been revealed to augment immunity, balance nutrition, and shield against chronic ailments. Despite their noteworthy advantages, mushrooms persist mostly absent from dietary strategies. They grip enormous latent not only for improving health but also for creating income in underserved communities. Distinguishing mushrooms as valuable functional foods could play a critical role in addressing the nutritional and economic challenges of today's global food system [2].

Various species of mushrooms hold diverse conformations and substantial nutritional worth, enabling them more than just culinary constituents [2]. Common edible mushrooms are rich in micronutrients whereas providing low caloric energy. They are particularly known for their high crude protein content, essential minerals, and complex polysaccharides. Although they are almost fat-free, they contain beneficial unsaturated fatty acids (over 75%), making them a heart-healthy food [3]. Moreover, mushrooms are excellent sources of several B vitamins-such as riboflavin (B2), folate (B9), thiamine (B1), pantothenic acid (B5), and niacin (B3)-as well as various secondary metabolites with health-promoting properties. Increasing scientific attention is nowadays focused on their potential use in natural functional foods and biotherapeutics because of their ability to curb the immune system and reduce inflammation, mostly ascribed to their high antioxidant content. Conventionally, mushrooms have been consumed for their taste and medicinal advantages long before their nutritional compensations have been understood [3]. Fresh mushrooms encompass a large percentage of water (85 - 95%), which meaningfully affects their heat transfer properties-a vital factor in food processing and investigation. For individuals following vegetarian diets, vitamin B12 can be a apprehension, as it is characteristically found only in animal products and is crucial for nerve function, perceptive ability, red blood cell production, and energy metabolism. While most mushrooms encompass little to no vitamin B12 and plants lack it completely, shiitake mushrooms stick out by providing a comparatively high amount-approximately 6 micrograms per 100 grams of dry matter-enabling them a valuable dietary accumulation for addressing B12 deficiency, predominantly among vegetarians [3,4].

Mushrooms permit them to accomplish indispensable metabolic and genetic functions with fewer controlling elements [5]. They yield secondary several metabolites i.e. lectins, phenolic acids, coenzymes, triterpenoids, β-glucans (like PSP and PSK), nucleotides, and nucleosides. These metabolites play vital roles in moderating immune responses by exciting T cells, macrophages, natural killer cells, and phagocytes, contributing to upgraded immunity and shield against infections, inflammation, and chronic disorders [5].

Mushrooms are heterotrophic organisms and lacking chlorophyll, depending instead on enzymatic breakdown of organic material for nutrition [6]. Additionally, it secrete enzymes like laccases, peroxidases, hemicellulases, and proteases, degrading complex lignocellulosic materials, enabling them ecol-friendly imperative decomposers and latent tools for bioremediation [6].

Numerous medicinal mushrooms, such as *Hericium erinaceus* (Lion's Mane), are frequently used for treating disorders like ulcers and are enriched in terms of copper-based enzymes like tyrosinase and superoxide dismutase (SOD), which hold strong antioxidant properties [6]. Mushrooms are also measured reservoirs of proteases that not only support towards nutrient recycling but also find use in food and pharmaceutical industries [6].

Mushrooms yield a extensive range of nucleotides, nucleosides, and bioactive peptides that reveal anticancer, antimicrobial, and antidiabetic properties [7]. Remarkably, some of these nucleic acids function correspondingly to microRNAs, possibly regulating human genes and assisting in antiviral responses. Compounds like cordycepin from *Cordyceps sinensis*, an adenosine derivative, and triterpenes from *Ganoderma lucidum* display fascinating immunomodulatory and anti-inflammatory activities by inhibiting cytokines like TNF-α and enzymes such as COX-2 and phospholipase A2 [7]. Mushrooms like chaga, oyster, and *Poria cocos* are recognized antioxidant and anti-inflammatory properties. The dietary fibers in mushrooms, including chitin and β-glucans (insoluble) and pectins and hemicelluloses (soluble), play role as prebiotics. These fibers are not digestible by human enzymes but are fermented by gut microbiota, aiding to gut health and immunity [6,7].

β-glucans, especially those with β(1,3) and β(1,6) linkages, are well-known for their immunomodulatory effects [8]. They bind to specific immune cell receptors like dectin-1, enhancing both innate and adaptive immunity. These glucans are absorbed through intestinal M cells, processed by dendritic cells and macrophages, and play a crucial role in immune surveillance [7,8].

Medicinal mushrooms such as *Coriolus versicolor* produce extracts like PSP and PSK that activate lymphocytes and induce cytokine production, making them effective in cancer immunotherapy [9]. Furthermore, mushrooms may support neurological health by reducing neuroinflammation and maintaining mitochondrial function. They also influence gut stem cells, potentially impacting brain health through the gut-brain axis [10].

Mushrooms are amazing organisms that offer diverse health benefits, from immune system modulation and anti-inflammatory effects to gut and brain health support [11]. Their bioactive compounds make them precious not only as functional foods but also in pharmaceutical and diagnostic applications, strengthening their function as vital agents in both traditional and modern medicine [11].

Medicinal mushrooms have been used as a form of cancer prevention and therapy for centuries in traditional Asian medicine. Majority of cancers or tumors are chronic and multifactorial in origin, concerning a complex interplay of genetic, environmental, lifestyle, medicinal, and other conducive factors [11]. In a comprehensive investigation concerning nearly 100 mushroom species, extracts meaningfully reduced the viability of several cancer types, including breast cancer. For example, extracts from *Hericium erinaceus* have revealed activity against hepatocellular carcinoma and other gastrointestinal cancers. Clinical investigations have progressively confirmed that medicinal mushrooms like *Ganoderma lucidum* and *Coriolus versicolor* can suggestively improve the quality of life for cancer patients. These mushrooms help in the eradication of harmful health effects linked with cancer and its treatments by moderating immune responses and assisting overall wellbeing. High dietary intake of common mushrooms like *Agaricus bisporus* and *Lentinula edodes* has been connected with a decreased risk of breast carcinoma, particularly in both pre- and postmenopausal women [12]. Additionally, patients administered *Grifola frondosa* (maitake mushroom) showed significant control over tumor growth, attributed to enhanced cytokine production by the spleen-specifically TNF-α and IFN-γ which synergistically boost natural killer (NK) cell activity. One of the key bioactive components in mushrooms are lectins-non-immunoglobulin, sugar-binding, cell-agglutinating proteins that are found across a wide range of organisms, including viruses, microorganisms, algae, animals, and plants. Lectins are known to act as modulators of immune and cellular functions both *in vitro* and *in vivo*. They can induce mitosis, support immune responses, and help resolve infections and inflammation. Some plant lectins serve as a defense mechanism against pests, while mushroom-derived lectins exhibit diverse bioactivities depending on how the food or extract is processed. Remarkably, mushroom lectins are also used in biotechnology as molecular adhesives and recognition elements in biosensors, making them useful in diagnostics and therapeutics. More than 100 different lectins from mushrooms have been identified, many of which show immune-modulating and direct cytotoxic activity against tumor cell lines. Certain mushroom lectins exhibit high specificity for N-acetyl galactosamine and have been found to possess strong antiviral and immune-stimulating properties [11,12]. These lectins may inhibit cancer cell growth by functioning as immunotoxins-often via fungal extracellular ribonucleases that inactivate ribosomes and halt protein synthesis, leading to cancer cell death. Importantly, the anti-tumor action of mushroom compounds is not always due to direct cytotoxicity, but rather through the activation and mobilization of the host's innate immune system. This process is mediated by toll-like receptor agonists that recognize mushroom-specific β-glucans and other polysaccharides as pathogen-associated molecular patterns (PAMPs), initiating a cascade of immune responses. Activated macrophages then release signaling molecules and cytokines such as TNF-α, IL-1β, IL-6, IL-12, and IL-23, which regulate immune tolerance and immunogenicity, and enhance detection and destruction of tumor cells [13].

Polysaccharides like chitin, α-glucans, and particularly β-glucans are the major components of Mushroom cell walls. β-1,3-glucans with β-1,6 side chains, are facilitating immune activator by immune cells [14]. Selected β-glucans-such as krestin, grifolan, lentinan, schizophyllan, and pleuran have exhibit effective immunomodulator and are being explored for therapeutic application, i.e. in COVID-19 prevention. Besides polysaccharides and other bioactive compounds such as terpenoids, carotenoids, and steroids play crucial roles in cell death regulation through apoptosis, thus they degrade tumor cells [15].

The *Inonotus obliquus* (chaga mushroom), broadly consumed in colder regions as a tea or extract, is traditionally believed to promote beauty and longevity. A group of triterpenoids, and other bioactive compounds like β-glucans, galactomannan occur adequately [16]. There are reports confirmed that its bioactive compounds exhibit strong antioxidant and immune-boosting properties, making it an anticancer effect. However, despite its traditional use and known pharmaceutical aspects, there is a lack of robust clinical trials to confirm the efficacy and safety of chaga mushroom in preventing or treating cancer, cardiovascular disease, or diabetes [15,16].

Diabetes mellitus is a widespread, non-communicable disease that poses a significant global health burden. One of the causal mechanisms contributing to the progression of diabetes is chronic, low-grade inflammation, which disrupts insulin sensitivity and action. This disruption can give rise to a spectrum of metabolic disorders, most notably type 2 diabetes and cardiovascular diseases [6,17]. Prolonged hyperglycemia-persistent elevation of blood glucose levels-along with insulin resistance, dyslipidemia, hypertension, and chronic inflammation, intensifies oxidative stress and damages blood vessels [6]. These pathological changes can lead to complications such as microvascular diseases (retinopathy, nephropathy, and neuropathy) and macrovascular diseases (coronary artery disease, stroke, and peripheral artery disease), all of which are commonly linked to type 2 diabetes [18]. Mushrooms play a valuable role in mitigating these effects due to their adequate level of soluble and insoluble dietary fiber [19]. This fiber helps in stabilizing blood glucose levels and lowering the glycemic index of foods, making mushrooms effective in glycemic control. Dietary fiber slows down the absorption of carbohydrates, leading to a gradual increase in blood sugar levels rather than sharp spikes [6.19]. Furthermore, fiber contributes to improved lipid profiles and gut health, which further supports metabolic regulation. Health authorities recommend a daily dietary fiber intake of 25-38 grams, or about 14 grams per 1,000 kcal of food consumed, to optimize metabolic and cardiovascular health [6,19].

The hypoglycemic effect of mushrooms is also attributed to their mineral composition, particularly magnesium, which is present in relatively high amounts in raw mushrooms (approximately 9% of the recommended daily intake) [19]. Magnesium is a critical co-factor for various enzymes involved in insulin and glucose metabolism, including tyrosine kinase, which plays a direct role in insulin signaling pathways. Adequate magnesium intake enhances insulin receptor function, improves glucose uptake by cells, and helps regulate vascular tone, thereby contributing to improved glycemic control and reduced vascular complications. By incorporating mushrooms into a balanced diet, individuals with or at risk of diabetes may benefit from both nutritional and therapeutic advantages that support blood sugar regulation and overall metabolic health [17-19].

Natural products and their operational analogs have played a crucial role in modern pharmacotherapy, meaningfully contributory to the development of treatments for several chronic conditions [20]. With growing concerns about synthetic drugs and their side effects, there has been a marked increase in public trust-particularly in Western countries-toward natural remedies, including mushrooms [19,20]. Mushrooms have recently been documented not only as traditional food sources but also as valuable functional foods, biochemicals, nutraceuticals, and pharmanutrients [20,21]. They are considered part of the next generation of health-promoting foods due to their diverse bioactive compounds that support wellness and help manage chronic diseases.

Despite their extensive historical use and favourable safety profiles, there remains considerable uncertainty regarding the differential effects of various forms of mushrooms such as fresh, extract-based, or biomass-derived dietary supplements-on human health [22]. The complexity is further deepened by the immense molecular diversity and biological variability among different mushroom species. Each type of mushroom may have unique bioactive components with specific therapeutic effects, but identifying these responsible biomolecules, nanoparticles, and their appropriate dosages requires further scientific investigation [20-22].

Moreover, while mushrooms are generally deemed safe and are even being explored as vaccine adjuvants due to their immune-stimulating properties, caution is necessary under certain conditions. For instance, in individuals actively infected with SARS-CoV-2, the immune-enhancing effects of mushrooms could potentially exacerbate the immune response, triggering a cytokine storm-a hyper-inflammatory condition associated with severe COVID-19 outcomes and increased mortality risk.

Conclusion and Future Perspectives

Edible mushroom production is expected to grow strongly in the coming years due to high demand. This crop generates a large amount of waste, such as stems, bases and mushrooms that are not suitable for commercialization. These by-products have the potential to be used in the food industry. The high fiber content of mushroom by-products, their micronutrient content, their antioxidant properties, and their low caloric value make them ideal candidates to become a widely used ingredient of the diet. It is relevant to highlight the use of aqueous extracts with high levels of β-glucans as functional components capable of providing foods with prebiotic polysaccharides and improved texture. Likewise, the inclusion of insoluble polysaccharides can promote a more gradual absorption of sugars, counteracting the effects of increasingly high- calorie diets. Numerous studies support these benefits *in vitro*, although *in vivo* evidence is less abundant. Nevertheless, many authors have developed various functional foods, from yogurts to cookies, with great potential to improve human health. Incorporating these by- products into feed formulations can enable mushroom producers to fully optimize crop use and pave the way toward establishing a zero-waste paradigm within the industry. They are now viewed as functional foods, offering potential benefits for disease prevention and overall well-being due to their rich content of bioactive compounds, including antioxidants, anti-inflammatory agents, and compounds with anticancer and immunomodulatory properties. Therefore, it is crucial to intensify research efforts to identify and characterize the unknown bioactive compounds in various mushroom species and to understand their therapeutic roles. This includes conducting rigorous toxicological assessments and controlled preclinical and clinical studies to ensure both the efficacy and safety of mushroom-based interventions. Only through such comprehensive evaluations can the full potential of mushrooms in modern medicine be realized, while also safeguarding public health.

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