International Journal of Research in Agronomy 2024; 7(9): 681-690

E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(9): 681-690
Received: 01-08-2024
Accepted: 05-09-2024

Yumkhaibam Ambika Devi
University Institute of Agricultural Sciences, Chandigarh University, Gharuan, Punjab, India

Sahil Raj
University Institute of Agricultural Sciences, Chandigarh University, Gharuan, Punjab, India

Saurabh
University Institute of Agricultural Sciences, Chandigarh University, Gharuan, Punjab, India

Shubham
University Institute of Agricultural Sciences, Chandigarh University, Gharuan, Punjab, India

Corresponding Author:
Yumkhaibam Ambika Devi
University Institute of Agricultural Sciences, Chandigarh University, Gharuan, Punjab, India

Comprehensive insights on medicinal and nutritional prospects of mushroom as sustainable super food

Yumkhaibam Ambika Devi, Sahil Raj, Saurabh and Shubham

DOI: https://doi.org/10.33545/2618060X.2024.v7.i9i.1643

Abstract
Edible mushrooms represent a promising future food source owing to their rich nutritional profile, encompassing proteins, dietary fibers, vitamins, minerals and bioactive compounds such as alkaloids, polysaccharides and terpenoids. These bioactive components can be extracted for nutraceutical applications and have demonstrated their potential in the treatment of various ailments including cancer, diabetes and viral infections. Furthermore, mushroom exhibits antioxidant, immune modulatory and cholesterol lowering properties, rendering them valuable as super food for both nutritional purposes and diverse biomedical applications.

Keywords: Mushroom, human health, agriculture, nutrition, medicinal properties

Introduction
Mushrooms have long been regarded as a key component of culinary delights worldwide, valued for their exceptional taste and regarded as a culinary marvel by humankind. They belong to the kingdom of Fungi, and are characterized by their fleshy texture and cap, as well as gills located beneath the cap.Mushrooms are a versatile and valuable addition to human nutrition containing a diverse range of bioactive compounds that contributes to their health promoting properties (Valverde *et al.*, 2015) [10]. Till now more than 14,000 species of mushrooms have been identified with approximately 10 percent being classified as macro-fungi and the number of mushrooms identified represents only 10 percent of the total assumed to exist (Abugri *et al.*, 2016) [1]. Mushrooms can be edible, wild, and some can be toxic. They consist of more than 90 percent water and less than 1 percent fat and contain appreciable amounts of Vitamin B, copper and selenium, while being low in sodium. Mushroom possesses high protein content (up to 44.93%), vitamins, fibers, minerals, trace elements and low calories with no cholesterol (Mhanda *et al.*, 2015) [2]. Edible mushrooms are macro-fungi that are visible to the naked eye and have already been widely utilized in food and medicine due to their delicious taste and diverse physiological activities (Qing *et al.*, 2021) [3]. They are regarded as an important source of food because of their high polysaccharide, dietary fiber, proteo-glucan, and vitamin content including riboflavin and thiamine (Ślusarczyk *et al.*, 2021) [4].
Mushrooms are considered a delicacy with high nutritional and functional value, and are also accepted as nutraceutical foods.They are of considerable interest due to their organoleptic merit, medicinal properties and economic significance.The use of edible mushrooms as a source of bioactive compounds that promote human health that is well documented in the scientific literature. For instance, studies have shown that edible mushrooms contain antioxidants (Taşkın *et al.*, 2021) [5], terpenoids, lectins (El-Maradny *et al.*, 2021) [6], phenolics/polyphenolics, polysaccharides, and ergosterols (Nowak *et al.*, 2022) [7]. The consumption of edible mushrooms has also been linked to a strengthened immune response which is critical for overall health and resilience. Additionally, some studies suggested that mushroom consumption may have a positive impact on cardiovascular health (Assemie and Abaya, 2022) [9]. While it may be challenging to distinguish between edible and medicinal mushrooms, many common edible species possess therapeutic properties, and some mushrooms used for medicinal purposes are also edible. Furthermore, mushrooms are unique among food sources in that they are a natural and abundant source of Vitamin D, which is usually obtained from animals or poultry through

irradiation or direct addition (Verma, 2023) [8]. The primary reason for this is the significant content of plant sterol known as Ergosterol. This sterol serves as a precursor for the synthesis of Vitamin D, which, when stimulated by sunlight or artificial light sources, converts to Vitamin D.

Table 1: Pre-requisites for mushroom production

Environmental Conditions	Spawn Run	Primordia Formation	Fruit body Development
Temperature	21-27 °C	10-21 °C	10-24 °C
Relative Humidity	85-95%	95-100%	80-90%
Light	50-100 lux	1000-1500 lux	1000-1500 lux
CO_2 level	5000-20,000 ppm; 1 FAE/h	500-2000 ppm; 4-8 FAE/h	<1000-2000 ppm; 4-8 FAE/h
Duration	2-8 weeks	3-12 days	5-8 days

(***Source*:** Arevalo, 2019) [38]

The nutritional value of *Agaricus bisporus* (White Button Mushrooms) is presented in detail.A well-balanced diet is an essential component of preventive healthcare, particularly in the context of combating oxidative stress. Historically, mushrooms have been used in oriental medicine to prevent and treat various diseases. Currently, mushroom extracts are marketed as dietary supplements due to their immune-boosting and antitumor properties.In this study, we aimed to examine the nutritional value, chemical composition, and potential commercial applications of the most widely cultivated edible mushrooms worldwide.

Sustainable production of mushroom

Over one hundred countries worldwide engage in the commercial cultivation of edible mushrooms employing diverse techniques and scales resulting in an annual increase in global production of approximately 7 percent. Currently, the global consumption of mushrooms stands at around 12.74 million tonnes, and it is anticipated that this figure will reach 20.84 million tonnes by 2026 (Shirur *et al.*, 2021) [36]. Mushrooms are typically classified into three categories based on their growth method: a) Saprotrophic mushrooms: which grow on decaying matter; b) Mycorrhizal mushrooms: which form a symbiotic relationship with crops or trees; c) Parasitic mushrooms: which infect and depend on their host plant before ultimately killing it (El-Ramady *et al.*, 2022) [37]. The majority of cultivated mushrooms follow a basic life cycle consisting of five stages: sporulation, spore germination and cell fusion, colonization, formation of primordia, and fruiting or maturity, which is followed by the release of spores and the repetition of the cycle (Table. 1). The cultivation process can be divided into seven stages, as depicted in Figure 1. It is crucial to cultivate mushrooms in a sustainable manner since they are considered edible foods and possess high protein content. Furthermore, the cultivation of mushrooms should be carried out in a way that protects against competing microorganisms and maintains hygiene, which can be controlled by environmental conditions as outlined in Table 1 (Arevalo, 2019) [38]. The environmental conditions controlling the most commonly cultivated species as ideal values, but certain strains may exceed them.

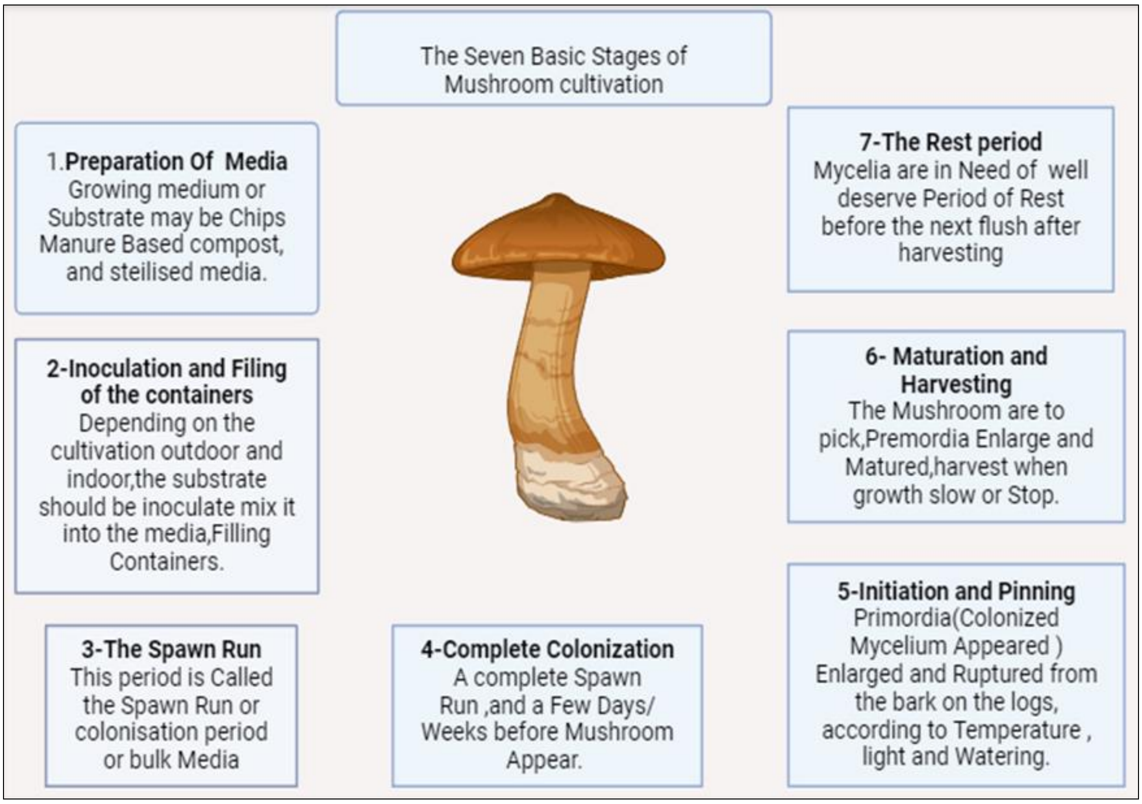

Fig 1: Basic steps of mushroom cultivation

Mushroom cultivation scenario in India

India's mushroom industry is growing, but the rest of the globe is responding to its mushroom output and consumption with lukewarmness. White button mushrooms are the main focus of the mushroom business in India; these are extremely complex and capital-intensive mushrooms. According to recent production data (official data from ICAR-DMR, Solan), button mushrooms account for the largest percentage of all mushrooms in India, accounting for 73 percent, with oyster mushrooms coming in second with a contribution of around 16 percent. In India, there are two primary categories of mushroom producers: those that cultivate white button mushrooms year-round in regulated environments and seasonal growers who plant button mushrooms in the North-Western region of the country during the winter. An estimated 94676 metric tonnes of white button mushrooms are produced in India annually from both high-tech and seasonal growing units. Approximately, 8500 metric tonnes of button mushrooms or 9 percent of the total button mushroom production were generated from the seasonal growing facilities in Punjab and Haryana (Figure. 2). Farmers in the Punjab and Haryana regions have revolutionised seasonal farming with little inputs by skilfully using seasonal fluctuations. In this area, growing white button mushrooms is a source of money and a means of subsistence. The benefits of being close to the market, having inexpensive raw materials available, and having access to high-quality spawn all contribute to this region's mushroom output.

Mushroom Producing State Share in India

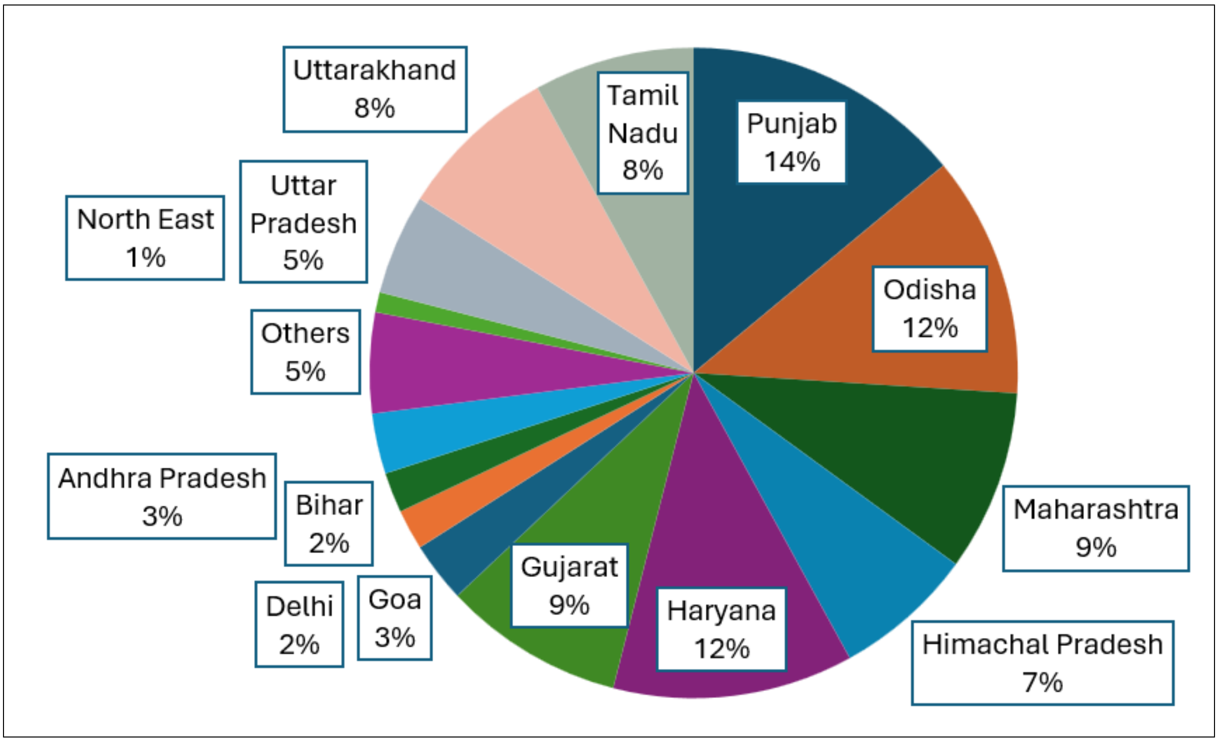

Fig 2: Mushroom Producing State Share in India

Relative contribution of different mushroom species

Five types of mushrooms are farmed commercially in India: milky (*Calocybe indica*), shiitake (*Lentinula edodes*), oyster (*Pleurotus spp*.), white button mushroom (*Agaricus bisporus*), and paddy straw (*Volvariella volvacea). Agaricus bisporus*, *Pleurotus spp*., and *Volvariella volvacea* continue to dominate the commercial markets despite the standardisation of growing techniques for many foreign species. Approximately, 96 percent of all mushrooms produced in India come from these three species.The nation's native tropical fungus is the milky mushroom (*Calocybe indica*) (Kumar *et al*., 2017) [39]. But only in the southern Indian states is commercial growing allowed, and it only makes about 3 percent of the world's total mushroom production. In the states of Odisha and Chhattisgarh, paddy straw mushroom farming has grown in popularity, accounting for 7 percent of all mushroom output. Although the ICAR-DMR in Solan standardised the short-term indoor shiitake growth technique (Sharma *et al*., 2017) [40], this valuable fungus has not yet been used on a commercial basis in India. A small number of producers in Himachal Pradesh and Uttarakhand were able to effectively cultivate the shiitake mushroom with the use of Solan's ICAR-DMR technology. On the other hand, dried mushrooms imported from Taiwan and China are currently dominating the marketplace. Growing oyster mushrooms is becoming a popular side business in the Northeastern states of Uttarakhand and Chhattisgarh.

Table 2: Mushroom production (metric tonnes) in different states of India

States	Button mushroom	Oyster mushroom	Milky mushroom	Other mushrooms	Total
Andhra Pradesh	3000	500	15	0	3515
Arunachal Pradesh	20	5	0	1	26
Assam	20	100	5	0	125
Bihar	950	1500	150	0	2600
Chhattisgarh	20	200	35	89	344
Delhi	3000	50	20	0	3070
Goa	4200	20	0	0	4220
Gujarat	10000	1200	0	0	11200
Haryana	15000	50	50	0	15100
Himachal Pradesh	9000	110	30	10	9150
Jammu and Kashmir	565	15	50	0	630
Jharkhand	200	20	0	0	220
Karnataka	700	320	160	0	1180
Kerala	0	500	300	0	800
Maharashtra	10000	2000	50	0	12050
Madhya Pradesh	10	5	0	0	15
Manipur	0	10	0	50	60
Meghalaya	25	2	0	0	27
Mizoram	0	50	0	0	50
Nagaland	0	75	0	0	325
Odisha	126	6310	0	0	15986
Punjab	16000	2000	0	0	18000
Rajasthan	100	1000	0	0	1300
Sikkim	1	2	0	0	3
Tamil nadu	6500	2000	1500	1500	10000
Tripura	0	100	0	0	100
Uttarakhand	8189	1228	819	819	10236
Uttar Pradesh	7000	100	0	0	7100
West Bengal	50	1500	0	0	2050
Andaman and Nicobar	0	300	0	0	300
Total	94676	21272	3184	3184	129782

(Source: ICAR-DMR, Solan, 2016)

Global scenario of mushroom production

Edible mushrooms are cultivated commercially in more than 100 countries on different scales and by different systems. The production of mushrooms across the world is increasing at an annual growth rate of 6-7 percent.In some developed countries of Europe and America, mushroom farming has assumed the form of a high-tech industry with mechanisation and automation in all operations. At present, China and the United States are the largest consumers of this protein-rich delicacy.

Currently, 12.74 million tonnes of mushrooms are consumed worldwide, and that number is rising at a compound annual growth rate of 6.4%.

There have been attempts to cultivate fungi such as *Auricularia*, *Flammulina*and *Lentinula* in China a century ago. Button mushrooms along with shiitake, oyster mushrooms, *flammulinaetc.*, grew in the 20th century. By the end of the 20th century, fewer than 40 percent of the world's total button mushroom crop was produced. The production of mushrooms has changed significantly in the twenty-first century. Button mushrooms continued to account for the largest portion of the world's mushroom production in 2010. The twenty-first century and especially the previous 10 years have seen quick increase in the production of mushrooms outside button mushrooms. Overall, the amount of mushrooms produced worldwide is growing exponentially. Oyster, wood ear, shiitake and flammulina production have grown at an almost unimaginable rate, especially in East Asian nations like China, Japan, South Korea, Taiwan, and so on (Figure 3 and Figure 4). As a result, these mushrooms now account for a much larger portion of the world's total mushroom production than button mushrooms, which are no longer the most popular type. The FAOSTAT database is strong of crops including mushrooms and truffles. However, this data is incomplete in many respects and does not give the complete picture (Singh *et al.*, 2017). For instance, according to FAOSTAT data from 2019, 11.9 million tonnes of mushrooms were produced worldwide (Royse *et al.*, 2017) [41] World mushroom production has been approximated species-wise using data from several sources.

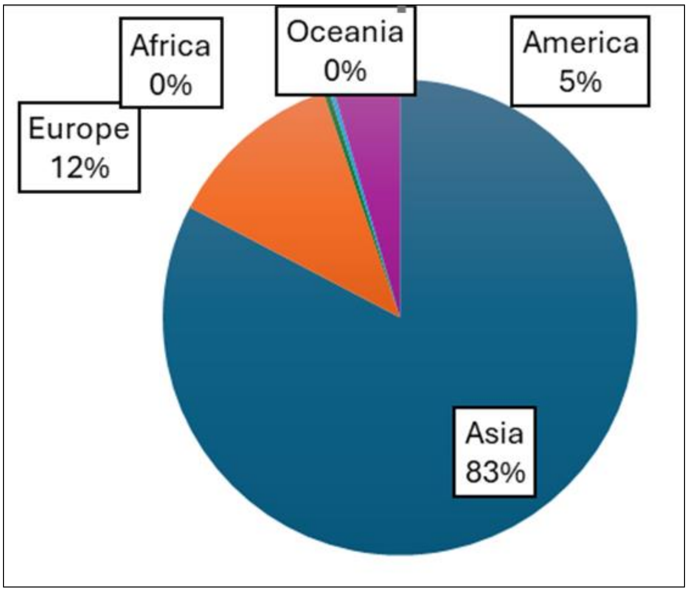

Fig 3: Continent wise total world mushroom production in 2019 (FAOSTAT, 2021)

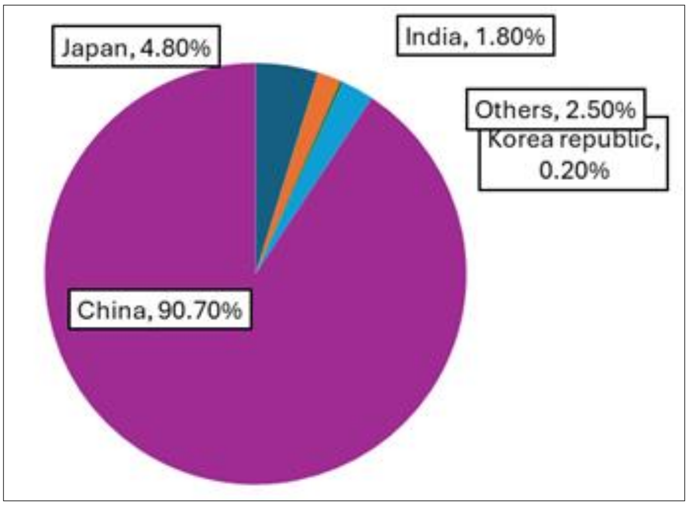

Fig 4: Mushroom production in Asia (FAOSTAT, 2019)

Significance and Importance of Mushroom

Biological, nutritional significance and active components of edible fungi

Medicinal mushrooms have been prized for their flavor, velvety texture and healing properties for thousands of years. Mushrooms are mostly made up of 10% dry matter and 90 percent water. It also possesses a physicochemical makeup that is critical to feeding. Because of their low fat content and high protein, fiber, and mineral content, mushrooms are nutrient-dense food. The human body needs all nine of the essential amino acids, all of which are found in mushroom protein. Mushrooms are being studied as a potential muscle protein replacement because of how simple they are to digest.Mushrooms are considered a healthy food because of their high nutritional value and the positive effects of the bioactive substances they contain on health. Food bioactive ingredients that promote health and reduce the likelihood of disease are becoming more and more popular. Mushrooms are an example of a food that serves both dietary and medicinal purposes. The vitamins *thiamine*, *riboflavin*, *cyanocobalamin*, ascorbic acid, and tocopherol as well as some other nutrients, are also abundant in mushrooms. They are also a great source of iron, phosphorus, and vitamins like niacin, which are rare to find in those other foods. When food analysis first began, the concept of "food supplements" was presented as something to consider in addition to nutrients. Mushrooms are nutrient-dense foods that also contain medicinal qualities that may help prevent diseases including diabetes, hypertension, high cholesterol, and cancer. Mushrooms have unique functional properties due to the presence of dietary fiber, including chitin and beta-glucans. A variety of mushrooms have antiviral, antithrombotic, immune-modulatory, and cancer-fighting properties. Some mushrooms may even be able to reduce blood glucose levels.

Types of mushrooms, their constituent parts and their biological importance

The Laetiporussulphureus species of mushrooms contains polyunsaturated fatty acids, which are known to possess antibacterial and antifungal effects. In *Ganoderma lucidum*, ganoderic acid and beta-glucan have cytotoxic and antioxidant qualities (Kolniak-Ostek*et al.*, 2022) [12]. The *Agaricus bisporous* species of mushroom contains lectins, ribotoxins, catechin, polysaccharides, galactomannan, beta-glucan, and fatty acids. These compounds also have antibacterial, antiviral, antifungal, antioxidant, and anti-diabetic characteristics, and they also increase insulin secretion activity.Other species that contain lovastatin as an active component and can lower cholesterol are *Pleurotusostreatus, Pleurotus spp., and*

Pleurotus sajor-caju. *Lentinan and eritadenine*, two species of *Lentinusedodes* that lower cholesterol, are among them (Soroko *et al.*, 2022) [13]. *Grifolafrondosa* species have lectins and polysaccharides that work to reduce blood sugar and promote the synthesis of insulin. While the Auricular species has acidic polysaccharides with analgesic effects, *Cordyceps sinensis* has an active component called cordyceptin, which has hypoglycemic and anti-depressant properties. Additionally, polysaccharide-K (Kresin), which has anti-cancer properties, is present in *Trametes versicolor* (Jędrzejewski *et al.*, 2023) [14]. The *Pleurotus giganteus* mushroom contains fatty acids, polysaccharides, and amino acids that have antioxidant and neuroprotective properties.

Pharmacological properties of edible mushrooms

Conventional medicine has recognized edible fungi for their immense health advantages since ancient times. Mushrooms provide a variety of health benefits for humans, depending on their biological makeup. The extraction of bioactive components from mushrooms to produce functional meals is attracting increasing interest (Soroko *et al.*, 2022) [13]. For a very long time, traditional medicines have used mushrooms in a variety of ways. Globally, there is an increasing trend toward the use of phytochemicals or bioactive compounds from various mushroom species as antioxidants, anti-cancer, and anti-inflammatory agents to treat a variety of human illnesses, including diabetes mellitus, cancer, bacterial and fungal infections, coronary heart disease, and diabetes mellitus. However, a large body of research on the use of mushrooms in human experimental therapy has been conducted, and those studies have shown that, generally speaking, mushrooms and their preparations are well tolerated with few discernible side effects (Asatiani *et al.*, 2021) [16].

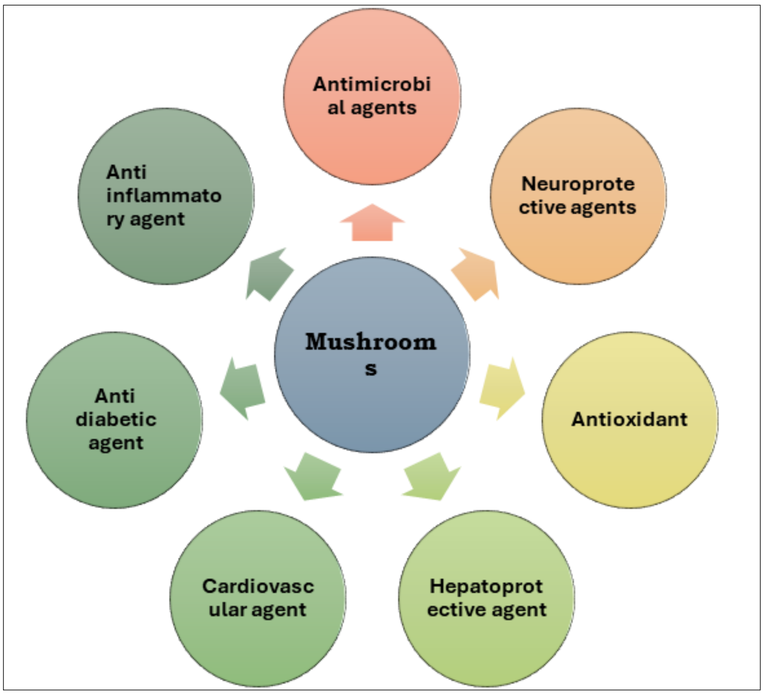

Fig 5: Medicinal properties of mushrooms.

Potential effectiveness of edible mushrooms as a cancer preventative treatment

Cancer is among the deadliest diseases in the world. According to recent studies, polysaccharides—which are naturally occurring plant active components-found in mushrooms have been shown to have strong anti-cancer properties on a variety of cancer model organisms (Panda *et al.*, 2022) [17] (Figure. 5). Additionally, *basidiomycota*, a different polysaccharide, has medicinal properties linked to its glucan. Polysaccharides, which are members of the beta-glucan chemical family, are believed to have anti-tumorigenic properties and to improve cellular immunity (Chaturvedi *et al.*, 2018) [18]. Bioactive compounds found in *Agaricus bisporus* possess both immune-modulatory and anticancer effects. The efficacy of *Agaricus bisporus* mushrooms in treating human ailments is recommended by the Canadian Cancer Society. According to the study, *Agaricus bisporus* polysaccharide has significant immune-stimulatory and anticancer bioactivity both *in vivo* and *in vitro*. The three primary polysaccharides in *Agaricus bisporus*, according to a literature analysis, are galactomannan, beta-glucan and alpha-glucan, with the latter accounting for 55.8 percent of the total. *Agaricusbisporus* can improve the mucosa's health and immunity. The secretion of immunoglobulin-A is significantly increased while consuming *Agaricus bisporus* by diet.

Agaricus bisporus fruiting body extracts promote the synthesis of interferon-gamma (IFN-γ) and have an immune-stimulant effect on activated peripheral blood mononuclear cells (PBMCs). *Agaricus bisporus* solutions have been demonstrated to induce apoptosis, which suppresses cell proliferation, in HL-60 leukemia cells as well as other human leukemia lines. Because it inhibits the growth and spread of cancer cells, arginine, which is found in *Agaricus bisporus* fruit bodies, is used as a dietary supplement for cancer patients. Furthermore, it was found that *Agaricus bisporus*inhibits aromatase, which lowers the risk of breast cancer (BC). *Agaricus bisporus* produces phytochemicals that inhibit the growth of BC cells, reduce the size of breast tumors, and decrease aromatase activity, according to *in vivo* studies. It has been reported that *Agaricus bisporus* contains unsaturated lipids such as linoleic acid and linolenic acid (LINA), including conjugates of linoleic acid (CLA) that have been demonstrated to inhibit the activity of aromatase. Additionally, a scientifically sound strategy for influencing estrogen receptor-positive tumors was found, which involves inhibiting aromatase activity and thereby lowering the amount of extracts from mushrooms that use estrogen. The average frequency of mushroom consumption and frequent use has been shown to be negatively correlated with the incidence of BC, but this correlation is most in postmenopausal women. Eating mushrooms was reported to lower premenopausal women's incidence of BC.

Efficacy of edible mushrooms as a medication

Inflammation is a complex biological response to infections and severe trauma that aids in the restoration of tissue structure and function, whereas many inflammatory diseases are influenced by chronic inflammation. The alternative anti-inflammatory pharmaceuticals derived from plants have attracted a lot of attention since they appear to be safe, natural drugs with few, if any, negative effects. It was discovered that unprocessed *Flammulinavelutipes* mushrooms have anti-inflammatory properties that stopped murine macrophage RAW264.7 from producing TNF-α and nitric oxide (NO), which are stimulated by lipo-polysaccharides and IFN-γ. Additionally, shiitake that underwent food processing steps like boiling and heating were found to have very little effective anti-inflammatory capabilities, indicating that the anti-inflammatory bioactive molecules of the treated mushroom had been eliminated. A different study found that extracts of *Flammulina velutipes* water and ethanol (EtOH) significantly reduced the generation of NO in macrophages, along with iNOS and COX-2 (*cyclooxygenase*-2).

Efficacy of therapeutic mushrooms in treating heart disease

Because they are low in fat, high in unsaturated fats, and cholesterol-free, edible mushrooms are a fantastic substitute for people with heart disease and those considering therapy for cardiovascular illnesses. The high potassium and low sodium content of the mushroom improves human blood circulation and salt balance. Thus, mushrooms are beneficial for those who have high blood pressure. It has been discovered that regular usage of mushrooms such Pleurotus species and lentinula significantly lowers cholesterol levels. Hyperlipidemia, or excessive triglyceride or cholesterol levels, is one of the most serious conditions that can affect a person and a major risk factor for atherosclerosis and heart disease. Phytosterols have the ability to reduce blood cholesterol levels, which in turn can lower LDL (low-density lipoprotein) cholesterol and total cholesterol (Ho *et al.*, 2020) [20]. *Agaricus bisporus*, often known as fungisterol, contains the sterols ergosta-7,22-dienol, ergosta-5,7-dienol, and ergosta-7-enol. *Agaricus bisporus* mushroom was found to provide anti-glycemic and anti hyper cholesterolemic properties in multiple trials on rats given a hypercholesterolemic diet consisting of 14 percent fat and 0.5 percent cholesterol (Usman *et al.*, 2021) [21]. Rats on a hyper-cholesterolemic diet benefit from daily consumption of *Agaricus bisporus* fruiting bodies, which aid to regulate antiglycemic and anticholesterolemic responses. It also improves lipid balance and liver function (Usman *et al.*, 2021; Atila *et al.*, 2017) [21, 22].

Potency of medicinal mushrooms as a superior hepato-protective agent

Because of the unique growing properties of mushrooms in ecology, a wide range of secondary metabolites, many of which have biological purposes, were created. These included phenolic compounds, carbohydrates, terpenes, and steroids). Mushrooms have a lot of potential to produce bioactive compounds that are good for human health because of a number of these mechanisms that combine. This covers their use as food as well as their importance in research facilities as sources of bio-molecules with particular medical benefits (Krittanawong *et al.*, 2021) [23]. The hepatoprotective effects of water-based extracts of Tremella fuciformis, Grifolafrondosa, Auricularia auricular, Lentinula edodes, *Volvariella volvacea*, and Tricholoma lobayense were tested in a rat model of chemical hepatitis produced by paracetamol. To investigate the impact of nutritive and medicinal mushroom bioactive components on hepatic function, animals were either given entire shiitake or non-purified preparations, or hepatocyte preparations were cultured with whole or semi-purified extracts. Fungal mycelia and basidiomata extracts based on water, alcohol, and hydrocarbon have all been examined.

Effectiveness of edible mushrooms as a medication for the treatment of diabetes

Diabetes mellitus is a metabolic disorder characterized by increased blood glucose levels that affects a large number of people. It can have fatal consequences, organ failures, and life-altering impacts if improperly regulated. Because they contain mostly natural compounds like fibers, complex carbohydrates, phenolics and alkaloids, mushrooms have been used for millennia to provide anti-diabetic, anti-oxidant, and anti-hyperlipidemic effects. This has been demonstrated to make eating mushrooms a sort of herbal remedy with anti-diabetic characteristics (Khursheed *et al.*, 2020) [24]. Furthermore, the prebiotic qualities of polysaccharides from mushrooms alter the makeup of the gut flora, reducing insulin resistance. Examining the relationship between edible mushrooms and diabetes as well as identifying prospective species of mushrooms with antihyperglycemic properties are the goals of this review. The effects of different mushroom polysaccharides on the gut microbiome of animal models of diabetes have also been studied by a number of researchers. Significant levels of dietary fiber, antioxidants (such as vitamin C, vitamin D, and vitamin B12), folates, and polyphenols are found in *Agaricus bisporus*, which may be beneficial for those with diabetes. It is said that *Agaricus bisporus* contains a number of compounds with potential anti-inflammatory and antioxidant properties. When those at risk for type-2 diabetes continue to consume certain foods, these benefits might eventually become apparent. High dosages of *Agaricus bisporus* extract administered orally to mice were shown in animal tests to mitigate the effects of streptozotocin-induced diabetes. Patients with diabetes consider mushrooms to be a good dietary choice because of their low calorie, low carbohydrate, low sugar, and low fat content. Mushrooms include lean proteins that help the body burn cholesterol. For individuals trying to cut calories, it is consequently the best diet (Enkhmaa *et al.*, 2018) [26].

Applicability of edible mushrooms as a potent antibacterial

Antimicrobial resistance is a serious concern to public health on a global scale, especially in light of the introduction of organisms that are almost immune to all antibiotics due to their multidrug resistance. Therefore, it is important to identify bioactive substances from plants and animals that can be used in place of traditional antimicrobials. According to a number of studies, *Flammulina velutipes* mushrooms may also contain antimicrobials. Mature *Flammulina velutipes* mushroom extracts from both methanol and chloroform showed excellent antimicrobial properties, especially for staphylococcal infections and Bacillus subtilis, according to research on the antimicrobial qualities of extracts from different *Flammulina velutipes* parts

(Sułkowska-Ziaja *et al.*, 2023) [28]. A methanol extract of a natural *Flammulina velutipes* fruiting body from Macedonia was also found to have antibacterial effects against both Gram-positive and Gram-negative bacteria, including *Bacillus subtilis*, *Bacillus pumilus*, Staphylococcus aureus, and *Pseudomonas aeruginosa.* To investigate the pharmacological efficacy of *Flammulina velutipes* against plant pathogens, an adversarial interaction between the pathogens and the mushroom was measured in an *in vitro* dual culture experiment (Kashina *et al.*, 2016) [30]. Discovered in *Flammulina velutipes*, enokipodins are a class of sesquiterpenoids of the cuparene type. It is now known that these compounds play a critical role in the antibacterial action of the plant. Enokipodins A-D were found to largely inhibit the growth of Gram-positive bacteria, such as Staphylococcus aureus and *Bacillus subtilis*. Although many studies have demonstrated the antimicrobial potential *of Flammulina velutipes*, such as the bioactive substances responsible for the socially constructed occurrence, a deeper comprehension of their signalling pathways is required before one of those substances can be used as nutritional supplements or drugs in the food and drug sectors.

Considerable antioxidant effects of edible mushrooms

Antioxidant qualities have been discovered in a wide variety of mushrooms. Every component included in mushroom extracts is unique to a certain kind of mushroom. For tens of thousands of years, mushrooms have been an essential part of the human diet, and recently, the consumption of a wide range of species has increased. Tocopherols, ascorbic acid, carotenoids, and phenolic compounds (phenolic acid and flavonoids) are the main bioactive ingredients of mushrooms. Polysaccharides are also physiologically active substances. The lower half maximum effective concentration (EC50) value indicates higher antioxidant activity. The plants with the highest potential for antioxidants are *Macrocybe gigantea, Phellinus linteus, Pleorotus squarrosulus, Polyporus grammocephalus, Austreus hygrometricus*, and *Fistulina hepatica.* This review will cover ROS, their deleterious effects on biological systems, antioxidant properties, and the comparative antioxidant activity of mushrooms, with a focus on a few common edible and medicinal mushrooms. In biological systems, phenolic compounds have been shown to function as oxygen scavengers, peroxide decomposers, free radical inhibitors, and metal inactivators (Shaffique *et al.*, 2021) [32]. Phenolic chemicals are present in all of the mushrooms. Mushrooms are an excellent dietary source of antioxidants and are becoming more and more significant to human health. It may surprise you to learn that mushrooms have higher antioxidant potential than most fruits and vegetables. Antioxidants help prevent diseases and aging by shielding the body from harm caused by free radicals.

When attempting to extract antioxidant nutrients from mushrooms, the ability to manipulate fruit bodies or mycelium to produce active molecules in a very short amount of time is a significant advantage. Active compounds can be produced in a relatively short amount of time. Antioxidant components of mushrooms can be isolated and utilized as functional supplements, or they can be added to diets to help minimize oxidative damage in human bodies (Sánchez *et al.*, 2017) [33]. The oxidative stress index (OSI) and total oxidant status studies were conducted on *Pholiota adiposa*, *Pholiota lubrica*, and *Pholiota squarrosa* mushroom EtOH extracts by Sevindik *et al*. Several types of mushrooms were evaluated for their total antioxidant capacity (TAS), total oxidant capacity (TOS) and OSI activity.

Mushrooms and their potential to act as a powerful neuro-protective agent

Eating mushrooms has the potentialtobe an effective neuro-protective agent.

The greatest threat to public health and the most crippling diseases are neurological and neurodegenerative disorders. Brain and nerve diseases are caused by specific pathological changes that impact both the peripheral and central nervous systems at the same time (Ambhore *et al*., 2024) [34]. Furthermore, the reduced function of neurons brought on by these illnesses impacts the structure of the nervous system and results in the degeneration or death of nerve cells all over the body.The final symptoms of multiple sclerosis, Alzheimer's disease, Parkinson's disease, Huntington's disease, and amyotrophic lateral sclerosis are ataxia and dementia. A fungus that is higher in nutrients and lower in calories and fat is called a therapeutic mushroom. They are rich in bioactive ingredients and minerals, such as vitamins, fiber, proteins, and carbs, all of which have been used for centuries to cure a variety of illnesses. All around the world, *Pleurotus giganteus* and *Hericium erinaceus* are two common medicinal and dietary supplements made from medicinal mushrooms. Apart from lectins, other substances that comprise polysaccharide-glucan or polysaccharide-protein structures include lactones, terpenoids, alkaloid compounds, antibiotics, metal-chelating components, and medicinal mushrooms and their extracts (Yadav *et al.*, 2020) [35].

The therapeutic advantages of a few medicinal mushrooms that have been demonstrated to have bioactive chemicals with a protective effect against brain dysfunction will be the main topic of this review. Drug research for neurodegenerative illnesses will benefit from this discovery (Ambhore *et al.*, 2024) [34]. Certain types of mushrooms, both edible and medicinal, may accelerate the development of neuritis in the brain by enhancing nerve growth factor (NGF) responses, imitating NGF reactivity, or protecting neurons from cell death caused by neurotoxins. These shiitake may provide neuro-protection against neurodegenerative diseases such as Parkinson’s and Alzheimer’s due to the basic properties of the neurotrophic chemicals present in the fungus. Consuming mushrooms on a regular basis may help prevent or postpone age-related neuro-degeneration.

Conclusion

As people become more aware of the possible side effects of synthetic medications and health supplements, they are searching increasingly for naturally occurring chemicals that have health benefits. Research conducted both *in vivo* and *in vitro* has demonstrated the remarkable therapeutic potential and exceptional nutritional value of mushrooms, a fungus that is abundantly available. Similar to vegetables in terms of nutrition, mushrooms of all sorts offer a good supply of carbohydrates, protein, unsaturated fatty acids, fiber, and several important vitamins. Though their gastronomic and nutritional qualities are widely recognized, little is known about edible mushrooms' potential as medicines. It has been shown that edible mushrooms contain antibacterial, anti-neurodegenerative, neuroprotective, antioxidative, anti-obesity, and anti-diabetic properties in addition to their ability to fight cancer. Subsequent research ought to focus on ascertaining the exact mechanism of action of a number of bioactive substances and biochemical formulations. This review paper will be very helpful to researchers, medical professionals, and scientists who work in the pharmaceutical research and medication development fields, as well as those who work in the healthcare industry. In addition to being a rich source of bioactive substances for therapeutic and medicinal purposes, mushrooms are a functional and nutritious food with many uses. The data in this analysis may also serve as a springboard for additional research, testing and the eventual commercialization of this peculiar fungus.

References

1. Abugri D, McElhenney WH, Willian KR. Fatty acid profiling in selected cultivated edible and wild medicinal mushrooms in Southern United States. Journal of Experimental Food Chemistry. 2016;2(01):1-7.
2. Mhanda FN, Kadhila-Muandingi NP, Ueitele ISE. Minerals and trace elements in domesticated Namibian Ganoderma species. African Journal of Biotechnology. 2015;14(48):3216-3218.
3. Qing Z, Cheng J, Wang X, Tang D, Liu X, Zhu M. The effects of four edible mushrooms (*Volvariella volvacea*, *Hypsizygus marmoreus*, *Pleurotus ostreatus*, and *Agaricus bisporus*) on physicochemical properties of beef paste. Lebensmittel-Wissenschaft & Technologie. 2021;135:110063.
4. Ślusarczyk J, Adamska E, Czerwik-Marcinkowska J. Fungi and algae as sources of medicinal and other biologically active compounds: A review. Nutrients. 2021;13(9):3178.
5. Taşkın H, Süfer Ö, Attar SH, Bozok F, Baktemur G, Büyükalaca S, Kafkas NE, *et al*. Total phenolics, antioxidant activities and fatty acid profiles of six Morchella species. Journal of Food Science and Technology. 2021;58:692-700.
6. El-Maradny YA, El-Fakharany EM, Abu-Serie MM, Hashish MH, Selim HS. Lectins purified from medicinal and edible mushrooms: Insights into their antiviral activity against pathogenic viruses. International Journal of Biological Macromolecules. 2021;179:239-258.
7. Nowak R, Nowacka-Jechalke N, Pietrzak W, Gawlik-Dziki U. A new look at edible and medicinal mushrooms as a source of ergosterol and ergosterol peroxide-UHPLC-MS/MS analysis. Food Chemistry. 2022;369:130927.
8. Verma S. Mushroom cultivation: A sustainable approach to future agriculture to ensure quality food and nutritional security of current population in India; c2023.
9. Assemie A, Abaya G. The effect of edible mushroom on health and their biochemistry. International Journal of Microbiology. 2022;1:8744788.
10. Valverde ME, Hernández-Pérez T, Paredes-López O. Edible mushrooms: Improving human health and promoting quality life. International Journal of Microbiology. 2015;1:376387.
11. Roupas P, Keogh J, Noakes M, Margetts C, Taylor P. The role of edible mushrooms in health: Evaluation of the evidence. Journal of Functional Foods. 2012;4:687-709.
12. Kolniak-Ostek J, Oszmiański J, Szyjka A, Moreira H, Barg E. Anticancer and antioxidant activities in Ganoderma lucidum wild mushrooms in Poland, as well as their phenolic and triterpenoid compounds. International Journal of Molecular Sciences. 2022;23:9359.
13. Soroko M, Górniak W, Zielińska P, Górniak A, Śniegucka K, Nawrot K, *et al*. Effect of Lentinula edodes on morphological and biochemical blood parameters of horses. Animals. 2022;12:1106.
14. Jędrzejewski T, Pawlikowska M, Sobocińska J, Wrotek S. COVID-19 and cancer diseases-the potential of Coriolus versicolor mushroom to combat global health challenges. International Journal of Molecular Sciences. 2023;24:4864.
15. Zhang M, Zhang Y, Zhang L, Tian Q. Mushroom polysaccharide lentinan for treating different types of cancers: A review of 12 years clinical studies in China. Progress in Molecular Biology and Translational Science. 2019;163:297-328.
16. Asatiani MD, Elisashvili V, Songulashvili G, Reznick AZ, Wasser SP. Higher basidiomycetes mushrooms as a source of antioxidants. In: Rai M, Kövics G, editors. Progress in Mycology. Dordrecht: Springer; c2021. p. 311-326.
17. Panda SK, Sahoo G, Swain SS, Luyten W. Anticancer activities of mushrooms: A neglected source for drug discovery. Pharmaceuticals. 2022;15:176.
18. Chaturvedi VK, Agarwal S, Gupta KK, Ramteke PW, Singh MP. Medicinal mushroom: Boon for therapeutic applications. Biotechnology. 2018;8:334.
19. Shin A, Kim J, Lim SY, Kim G, Sung MK, Lee ES, *et al*. Dietary mushroom intake and the risk of breast cancer based on hormone receptor status. Nutrition and Cancer. 2010;62:476-483.
20. Ho LH, Zulkifli NA, Tan TC. Edible mushroom: Nutritional properties, potential nutraceutical values, and its utilisation in food product development. In: Passari AK, Sánchez S, editors. An Introduction to Mushroom. London: IntechOpen; c2020.
21. Usman M, Murtaza G, Ditta A. Nutritional, medicinal, and cosmetic value of bioactive compounds in button mushroom (*Agaricus bisporus*): A review. Applied Sciences. 2021;11:5943.
22. Atila F, Owaid MN, Shariati MA. The nutritional and medical benefits of *Agaricus bisporus*: A review. Journal of Microbiology, Biotechnology and Food Sciences. 2021;7:281-286.
23. Krittanawong C, Isath A, Hahn J, Wang Z, Fogg SE, Bandyopadhyay D, *et al*. Mushroom consumption and cardiovascular health: A systematic review. The American Journal of Medicine. 2021;134:637-642.
24. Khursheed R, Singh SK, Wadhwa S, Gulati M, Awasthi A. Therapeutic potential of mushrooms in diabetes mellitus: Role of polysaccharides. International Journal of Biological Macromolecules. 2020;164:1194-1205.
25. Ng SH, Mohd Zain MS, Zakaria F, Wan Ishak WR, Wan AWA. Hypoglycemic and antidiabetic effect of Pleurotus sajor-caju aqueous extract in normal and streptozotocin-induced diabetic rats. BioMed Research International. 2015;2015:214918.
26. Enkhmaa B, Surampudi P, Anuurad E, Berglund L. Lifestyle changes: Effect of diet, exercise, functional food, and obesity treatment on lipids and lipoproteins. In: Feingold KR, Anawalt B, Blackman MR, Boyce A, Chrousos G, Corpas E, *et al*., editors. Endotext. South Dartmouth: MDText.com, Inc.; c2018.
27. Tang C, Hoo PC, Tan LT, Pusparajah P, Khan TM, Lee LH, *et al*. Golden needle mushroom: A culinary medicine with evidenced-based biological activities and health promoting properties. Frontiers in Pharmacology. 2016;7:474.
28. Sułkowska-Ziaja K, Trepa M, Olechowska-Jarząb A, Nowak P, Ziaja M, Kała K, *et al*. Natural compounds of fungal origin with antimicrobial activity-potential cosmetics applications. Pharmaceuticals. 2023;16:1200.
29. Nikolovska-Nedelkoska D, Atanasova-Pančevska N, Amedi H, Veleska D, Ivanova E, Karadelev M, *et al*. Screening of antibacterial and antifungal activities of selected Macedonian wild mushrooms. Zbornik Matice Srpske za Prirodne Nauke. 2013;124:333-340.
30. Kashina S, Villavicencio LL, Balleza M, Sabanero GB, Tsutsumi V, López MS, *et al*. Extracts from Flammulina

velutipes inhibit the adhesion of pathogenic fungi to epithelial cells. Pharmacognosy Research, 2016, 8.

31. Tabuchi A, Fukushima-Sakuno E, Osaki-Oka K, Futamura Y, Motoyama T, Osada H, *et al*. Productivity and bioactivity of enokipodins A-D of Flammulina rossica and Flammulina velutipes. Bioscience, Biotechnology, and Biochemistry. 2020;84:876-886.
32. Shaffique S, Kang SM, Kim AY, Imran M, Aaqil Khan M, Lee IJ, *et al*. Current knowledge of medicinal mushrooms related to anti-oxidant properties. Sustainability. 2021;13:7948.
33. Sánchez C. Bioactives from mushrooms and their application. In: Puri M, editor. Food bioactives: Extraction and biotechnology applications. Berlin: Springer; c2017. p. 23-57.
34. Ambhore JP, Adhao VS, Rafique SS, Telgote AA, Dhoran RS, Shende BA, *et al*. A concise review: edible mushrooms and their medicinal significance. Exploration of Foods and Foodomics. 2024;2:183-194.
35. Yadav SK, Ir R, Jeewon R, Doble M, Hyde KD, Kaliappan I, *et al*. A mechanistic review on medicinal mushrooms-derived bioactive compounds: potential mycotherapy candidates for alleviating neurological disorders. Planta Medica. 2020;86:1161-1175.
36. Shirur M, Barh A, Annepu SK. Sustainable production of edible and medicinal mushrooms: implications on mushroom consumption. In: Climate change and resilient food systems: issues, challenges, and way forward; c2021. p. 315-346.
37. El-Ramady H, Abdalla N, Badgar K, Llanaj X, Törős G, Hajdú P, *et al*. Edible mushrooms for sustainable and healthy human food: nutritional and medicinal attributes. Sustainability. 2022;14(9):4941.
38. Arevalo W. DIY mushroom cultivation: growing mushrooms at home for food, medicine and soil. 6th ed. New Society Publishers; c2019.
39. Kumar S, Sharma VP, Shirur M, Kamal S. Status of milky mushroom (*Calocybe indica*) in India - A review. Mushroom Research. 2017;26(1):21-39.
40. Sharma VP, Kumar S, Annepu SK. Technologies developed by ICAR-Directorate of Mushroom Research for commercial use. Technical Bulletin; c2017. p. 11-13.
41. Royse D, Baars JJ, Tan Q. Current overview of mushroom production in the world. In: Zied DC, Pardo Giménez A, editors. Edible and medicinal mushrooms: technology and applications. 1st ed. John Wiley and Sons Ltd; c2017. p. 5-13.