

Medicinal Mushrooms as a Source of Novel Functional Food

Review Article

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Abstract

Mushrooms are higher fungi having great taste and nutraceutical properties. They are one such dietary component that can help us in addressing the issues of quality food, health and environmental sustainability. Due to the presence of a large number of secondary metabolites mushrooms can be used as a source for biotherapeutics which in turn can help in development of new drugs. There has been a recent upsurge of interest in mushrooms not only as a health food which is rich in protein but also due to the presence of biologically active compounds of medicinal value which possess antioxidative, anticancer, antiviral, hepatoprotective, immunomodulating and hypocholesterolemic properties. Hence, mushrooms are used as a dietary supplements as well as therapeutic agents in complementary medicine. Edible items can be fortified with mushrooms owing to their high nutritive value and such food serve as a nutrient reservoir for malnourished populations. The potential therapeutic implications of mushrooms are enormous however; detailed mechanisms of various health benefits of mushrooms to humans still require intensive investigation, especially with the emergence of new evidence of their health benefit. The paper outlines the information on all such aspects of medicinal mushrooms along with their role in various diseases and in the area of clinical nutrition.

Keywords: Mushrooms; Nutraceuticals; Active Compounds; Medicines.

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Introduction

India has witnessed an enormous change in its agricultural pattern due to the continuous increase in the population rate. Henceforth, rapid rise of the population brings forward the challenge of meeting the demands of quality food and achieving nutritional security. Wide spread malnutrition necessitated the search for alternative source of protein since the production of pulses has not kept pace with the requirement of the country [1]. The rising demand for functional food free from synthetic chemicals indicates the awareness of people on quality food. The excellent texture and unique flavour of edible and medicinal mushrooms makes them universally accepted by all age groups [2]. Due to the pro-

duction of a large variety of secondary metabolites with exceptional chemical structures and interesting biological actions they are reservoir of valuable chemical resources [3]. However, there is very little awareness on mushrooms as a healthy food and as an important source of biological active substances with medicinal value [4].

For hundreds of years, medicinal mushrooms as medicinal extract and essences, and are applied as alternative medicine in Korea, China, Japan and eastern Russia [5]. According to current estimates, mushrooms constitute at least 12,000 species worldwide and out of that 2,000 species are reported as edible. About 35 edible mushroom species are commercially cultivated whereas nearly 200 wild species used for medicinal purposes [6]. The most cultivated mushroom worldwide is *Agaricus bisporus*, followed by *Lentinula edodes*, *Pleurotus spp.* and *Flammulina velutipes* [6, 7]. Mushrooms contain a high moisture percentage that ranges between 80 and 95 g/100 g, approximately. They are a rich source of protein, 200–250 g/kg of dry matter; leucine, valine, glutamine, glutamic and aspartic acids are the most abundant. They are low-calorie foods because of their low fat content, 20–30 g/kg of dry matter, being linoleic (C18:2), oleic (C18:1) and palmitic (C16:0) the main fatty acids. Edible mushrooms contain high amounts of ash, 80–120 g/kg of dry matter and are rich in minerals like potassium, phosphorus, magnesium, calcium, copper, iron, and zinc). Carbohydrates present in them include chitin, glycogen, trehalose, and mannitol; besides, they contain fiber, beta-glucans, hemicelluloses, and pectic substances [8]. The nutritive value of some commonly known mushroom varieties is listed in Table 1.

Medicinal mushrooms have been demonstrated to produce ben-

Table1. Nutritional value of some edible mushrooms (dry basis).

Mushroom species	Protein %	Fat %	Ash %	Carbohydrates %	Energy kcal/kg
<i>Agaricus bisporus</i>	14.1	2.2	9.7	74.0	325
<i>Lentinus edodes</i>	4.5	1.73	6.7	87.1	772
<i>Pleurotus ostreatus</i>	7.0	1.4	5.7	85.9	416
<i>Pleurotus eryngii</i>	11.0	1.5	6.2	81.4	421
<i>Pleurotus sajor-caju</i>	37.4	1.0	6.3	55.3	-
<i>Flammulina velutipes</i>	3.87	2.89	7.2	85.99	467
<i>Hypsizygus marmoreus</i>	21.0	5.62	8.26	65.6	-

Carneiro et al. 2013 [11]; Kalač 2013 [12]; Phan et al. 2012 [13]; Reis et al. 2012 [14].

eficial effects not only as a drug but also as a novel class of products variously known as functional food, nutraceuticals, dietary supplements that produce health benefits. Numerous studies have shown that regular intake of mushrooms or their products is effective both in preventing and treating specific diseases [9] (Table 2). Mushroom protein is comparable to muscle protein as it contains all the nine essential amino acids required by humans [9]. Since they provide all the essential amino acids they are used in the vegetarian diets and are a good option for those who do not consume meat products. The edible class of mushrooms that shows potential medicinal and functional properties includes *Lentinus*, *Auricularia*, *Hericium*, *Grifola*, *Flammulina*, *Pleurotus*, and *Tremella*. The other species known only for their medicinal properties include *Ganoderma* and *Trametes* [10].

Therapeutic Potential of Mushrooms

The knowledge of the relationship between diet and disease has led to the development of all together a new scientific discipline which is termed as “functional food science.” Functional foods can be anything like dietary supplements, medicinal foods, vita foods, phytochemicals, and myochemicals and also pharmafood, which could be used specifically to improve the health. Mushrooms falls very well into this category of functional foods as it has all the potential to ameliorate diseases. ‘Mushroom Nutraceuticals’ are the traditional preparations which were used in ancient times in the form of extracts, health tonics, concentrates, fermented beverages, tinctures, teas, soups, herbal formula, powders and arid healthful food dishes [16]. The term “Mushroom Nutraceuticals” has been coined by Chang and Buswell [17]. Due to their immunomodulatory action, they boosts the immune system [18] by the activation of dendritic cells, NK cells, T-cells, macrophages, and production of cytokines [19] and have curative actions against a lot of degenerative diseases without having any side effects; unlike the ones involved in the usage of synthetic drugs. Studies have shown that regular consumption of mushrooms or their products is effective both in preventing and treating specific diseases [7].

Edible mushrooms and their constitutive active compounds have been described to have beneficial effects on hyperglycemia and hypercholesterolemia [20, 21]. Several mushrooms have high content of acidic polysaccharides, dietary fiber, and antioxidants, including vitamins C, B12, and D; folate ergothioneine; and polyphenol [22] suggesting that the mushroom may have potential anti-inflammatory, hypoglycaemic and hypocholesterolemic effects (Table 3). The significant pharmacological effects and physiological properties of mushrooms are bio regulation (immune enhancement), maintenance of homeostasis and regulation of

biorhythm, cure of various diseases and prevention and improvement from life threatening diseases such as cancer, cerebral stroke and heart diseases. Mushrooms are also known to have effective substances for antifungal, anti-inflammatory, antitumor, antiviral, antibacterial, hepatoprotective, antidiabetic, hypolipidemic, antithrombotic and hypotensive activities [18].

Mushrooms are known to complement chemotherapy and radiation therapy by countering the side-effects of cancer, such as nausea, bone marrow suppression, anemia, and lowered resistance. Recently, a number of bioactive molecules, including anti-tumor agents have been identified from various mushrooms. Some of the identified molecules are β -glucan, proteoglycan, lectin, phenolic compounds, flavonoids, volatile oils, tocopherols, phenolics, flavonoids, carotenoids, folates, ascorbic acid enzymes, and organic acids [23], polysaccharides, triterpenoids, dietary fibre, lentinan, schizophyllan, lovastatin, pleuran, steroids, glycopeptides, terpenes, saponins, xanthones, coumarins, alkaloid, kinon, fenil propanoid, kalvasin, porisin, AHCC, maitake D-fraction, ribonucleases, eryngeolysin, and also have been effectual against various types of diseases [24, 25].

The active components in mushrooms responsible for conferring anti-cancer potential are lentinan, krestin, hispolon, lectin, calcaelin, illudin S, psilocybin, *Herichium* polysaccharide A and B (HPA and HPB), ganoderic acid, schizophyllan, laccase, etc [26]. The bioactive compounds present in mushrooms can be classified into secondary metabolites, glycoproteins and polysaccharides. Out of all these, mushroom polysaccharides are the best known and most potent mushroom-derived substances with anti-tumor and immunomodulating properties. The mushroom polysaccharide i.e beta glucans are the most versatile bioactive molecule owing to its excellent therapeutic implications and broad spectrum biological activity. Since the β -Glucans are not amalgamated by humans, so these compounds are recognized by our immune systems as non-self molecules that induces both innate and adaptive immune responses [8].

Novel Mushroom Biotech Products

Mushrooms produced are not only food but are raw material for development of functional food and dietary supplements (nutraceuticals) for health and quality life of humans. Inclusion of mushrooms as functional food can help in the early intervention of sub-healthy states in humans and it might prevent the consequences of life threatening diseases. *Trametes versicolor* contains proteoglycan constituents like Krestin (PSK) and polysaccharide peptide (PSP). Both of these glycans have been used in cancer therapy like gastric, colorectal lung cancer and breast cancer [27,

Table 2. Some commonly consumed mushrooms along with their bioactive molecules.

Biological name of mushroom	Active principle/constituents/extracts	Activity reported
<i>Agaricus bisporus</i>	Fibers, lectins	Hypocholesterolemic, Hypoglycemic
<i>Boletus edulis</i> Bull	Extracts of fruiting bodies	Antitumor
<i>Flammulina velutipes</i> (Curtis) Singer	Fibers, ethanolic extracts	Antioxidant, Hypocholesterolemic, Antiallergic
<i>Grifola frondosa</i> (Dicks.) Gray	MD-fraction, ergosterol	Antioxidant, hypotensive, Hypoglycemic, Immunotherapy, Antiinflammatory activity
<i>Ganoderma lucidum</i> (Curtis) P. Karst	Ganoderan A and B, glucans, Triterpenes, ganosporeric acid A, ganopoly, the polysaccharide-containing preparation	Hypoglycemic, antioxidant and antitumor, antiviral (HIV-1), Antiallergic Anti-inflammatory antihepatotoxic, inhibit the biosynthesis of cholesterol, antioxidative and free radical scavenging effects.
<i>Hypsizygus marmoreus</i>	Ethanolic extracts	Antioxidant, Antiallergic
<i>Lentinula edodes</i> (Berk.) Pegler	Methanolic and water extracts, eritadenine, lentinan, oxalic acid, ethanolic mycelial extracts.	Antioxidant, Hypocholesterolemic, Immunotherapy, Antimicrobial, antiprotozoal
<i>Pleurotus ostreatus</i>	Water and 30% ethanolic extract	Antioxidant, Hypocholesterolemic
<i>Pleurotus eryngii</i>	Ethanolic extracts	Antiallergic
<i>Volvariella volvacea</i>	Methanolic and water exopolysaccharides	Antioxidant, Hypocholesterolemic

Rathee et al., 2012 [15]

Table 3. Nutraceutical potential of the some important mushrooms.

Mushroom Species	Active Constituents	Type of polysaccharides	Medicinal Properties
<i>Agaricus bisporus</i>	Lectins	Heteropolysaccharides	Enhance insulin secretion, anti-aging property.
<i>Anricularia auricula</i>	Acidic Polysaccharides	Homopolysaccharides	Anti-tumour activities, lowers cholesterol, triglycerides, and lipid levels; decrease blood glucose, beneficial in coronary heart disease, immune tonic.
<i>Cordyceps sinensis</i>	Cordycepin	Heteropolysaccharides	Cure lung infections, hypoglycemic activity, cellular health properties, anti-depressant activity.
<i>Flammulina velutipes</i>	Polysaccharide, flammulin, FVP (Flammulina polysaccharide protein), peptide glycans, prolamin (active sugar protein), Proflamin (glycoprotein)	Heteropolysaccharides	Antioxidant, anti-cancer activity, anti-ageing property; immuno-modulatory, anti-viral action.
<i>Ganoderma lucidum</i>	Polysaccharides, triterpenoids, germanium, nucleotides and nucleosides, Ganoderic acid, Beta-glucan,	Heteropolysaccharides	Augments immune system, liver protection, antibiotic properties, inhibits cholesterol synthesis; immunomodulatory, anti-cancerous properties.
<i>Grifola frondosa</i>	Grifloan, Lectins	Heteropolysaccharides	Increases insulin secretion, decrease blood glucose, improves ovulation.
<i>Lentinula edodes</i>	Eritadenine, Lentinan	Heteropolysaccharides	Lower cholesterol, anti-cancer agent.
<i>P. florida</i>		Homopolysaccharides	anti-hyperglycaemic; anti-hypercholesterolemia effect
<i>Pleurotus sajor-caju</i>	Lovastatin polysaccharide	Homopolysaccharides	Lower cholesterol, prevents cardiovascular disorders.
<i>Trametes versicolor</i>	Polysaccharide-K (Krestin), Coriolon and glycoproteins	Heteropolysaccharides	Decrease immune system depression, prevents cancer, inhibits growth of <i>Candida albicans</i> , anti-viral activity by inhibiting the replication of HIV, liver protective functions.
<i>Volvariella volvacea</i>	Glycoproteins	Heteropolysaccharides	Cardio-protective, lowers blood pressure.

Lakhanpal and Rana, 2005; [5]

28]. Extract from Chaga mushroom (*Inonotus obliquus*) befungin is approved as an antitumour drug in Russia owing to its capability in curing certain cancers like breast, lung, cervical, and stomach cancers [29]. Biotech products *Hericium erinaceus* mushrooms have been extensively used in treating Alzheimer diseases. Hericenones from the fruit bodies and erinancines from the mycelium of this mushroom have induced the expression of neurotrophic factors such as nerve growth factor (NGF) in astrocytes [27]. Healthy food developed from biotechnologically cultivated mycelia of medicinal edible mushrooms and *Tremella spp.* in combination with other natural substances (medicinal plants, algae, etc.) possesses antioxidant and immune-stimulating activity and blood glucose and lipid controlling effects [29, 30]. Existing biotech-products from *H. erinaceus* help to control and bleeding. Since some mushroom products are able to decrease high glucose and lipid levels in blood they are recommended as neuro-and vasotonics, hepatoprotective and thrombolytic agents [31]. There are certain commercial mushroom dietary supplements which are produced all around the world and are consumed by the people. A list of such products is provided in Table 4.

Conclusion

Mushrooms contain numerous substances including glycoproteins, glyconutrients, lectins, etc. The compounds they contain

have been classified under the Host Defense Potentiators (HDP) which can have immune system enhancement properties. That is one of the reasons they are currently used as adjuncts to cancer treatments in Japan and China. Fungal polysaccharides are the most potent mushroom-derived substances with antitumor and immune-modulating properties. They are present in cell wall with different types of glycosidic linkages, such as (1, 3) and (1, 6)- β -D-glucans. Several different polysaccharides anti tumor agents have been developed from the fruiting body, mycelia, and culture medium of various medicinal mushrooms (*Lentinus edodes*, *Ganoderma lucidum*, *Schizophyllum commune*, *Trametes versicolor*, *Inonotus obliquus*, and *Flammulina velutipes*). Further sustainable research of natural and genetic resources of medicinal mushrooms using enhanced screening methods of genomics, proteomics and metabolomics will assist in the biotechnological cultivation and usage of their bioactive molecules to develop novel healthcare biotech products with a encouraging universal impact on human welfare and environmental conservation. In a country like ours, medicinal mushrooms can eradicate the problems of malnutrition thereby ensuring nutrition security for the coming generations by means of diet fortification and nutraceuticals.

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Table 4. Overview of some mushroom dietary supplements.

Product	Content
Organic cordyceps sinensis	C.sinensis Alohaensis hybrid strain
Gano super	Concentrated Reishi extracts
Levolar Forte	Extract of <i>C.sinensis</i> , fraction of <i>G.froncosa</i> , extract of <i>coprinus comatus</i> , cinnamon extracts
Fine Agaricus Gold	Highly concentrated micropowder active ingredients, protein bound polysaccharide of <i>Agaricus</i>
Fine Mesima	Micropulverized powder of dried <i>Pbellinus linteus</i> mushroom
Breast Mate	Phellinus lineteus fraction, Maitake PSX fraction, Glycoprotein SX fraction, Broccoli sprouts extract, Green Tea extract, Vitamin D ₃
Shiitake Gold	Lentinan, Beta glucan polysaccharide

Morris et al. 2015 [32].

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