Role of edible mushrooms as functional foods-A review

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Abstract

Mushrooms have become attractive as a functional food and as a source of drugs and nutraceuticals due to their antioxidant, antitumor and antimicrobial properties. Besides their pharmacological features, mushrooms are becoming more important in our diet due to their nutritional value, high protein and low fat / energy contents. The mushroom protein contains all the nine essential amino acids required by humans. In addition to their good protein content, mushrooms are a relatively good source of the other nutrients like phosphorus, iron and vitamins, including thiamine, riboflavin, ascorbic acid, ergosterol, and niacin. They are not only sources of nutrients but also have been reported as therapeutic foods, useful in preventing diseases such as hypertension, diabetes, hypercholesterolemia and cancer. Mushrooms are the sources of bioactive substances such as secondary metabolites (acids, terpenoids, polyphenols, sesquiterpenes, alkaloids, lactones, sterols, metal chelating agents, nucleotide analogs, and vitamins), glycoproteins and polysaccharides, mainly β -glucans. Due to the presence of biologically active compounds of medicinal value they are used as anticancer, antiviral, hepatoprotective, immunopotentiating and hypocholesterolemic agents. Present review is aimed to discuss the high nutritional and therapeutic potential of mushrooms and their applications as functional foods or as a source of nutraceuticals for maintenance and promotion of health and life quality.

Key words: Mushrooms, functional foods, bioactive components, nutritional and therapeutic agents.

Paper cited: Kumar, K. (2015). Role of edible mushroom as functional foods- A review. *South Asian Journal of Food Technology and Environment*, 1(3&4): 211-218

Received: 11/09/2015 Revised: 25/09/2015 Accepted 10/10/2015

Introduction

Mushrooms are fleshy, spore-bearing fruiting body of a fungus, typically produced above ground on soil or on its food source. Mushrooms were included in diet by Greeks and Romans since ancient times. Romans regarded them as food of God while Chinese termed them as elixir of life (Bashir *et al.*, 2014). Mushrooms have become attractive as a functional food and as a source for the development of drugs and nutraceuticals responsible with their antioxidant, antitumor and antimicrobial properties. Besides their pharmacological features, mushrooms are becoming more important in our diet due to their nutritional value, related to high protein and low fat / energy contents (Khatun *et al.*, 2012). Numerous species of mushrooms exist in nature; however, only a few are used as edibles. Many Asian countries use traditionally wild edible mushrooms as delicious and

nutritional foods and medicine (Saiqa *et al.*, 2008)

Consumers are now deeply interested in food bioactives that provide beneficial effects to humans in terms of health promotion and disease risk reduction. Detailed information about food bioactives is required in order to obtain appropriate functional food products. Therefore US, European Union and Asian countries like Japan, South Korea etc have drafted and revised various regulatory guidelines on functional foods and their health claims (Hasler, 1996). Edible mushrooms have been widely utilized as human foods for centuries and have been appreciated for texture and flavor as well as some medicinal and tonic attributes (Manzi *et al.*, 2001).

The mushroom protein contains all the nine essential amino acids required by humans. In addition to their good protein content, mushrooms are a relatively good source of the nutrients like phosphorus, iron

and vitamins, including thiamine, riboflavin, ascorbic acid, ergosterol, and niacin (Barros *et al.*, 2008). Mushrooms are not only sources of nutrients but also have been reported as therapeutic foods, useful in preventing diseases such as hypertension, diabetes, hypercholesterolemia and cancer. These functional characteristics are mainly due to the presence of dietary fibre and in particular chitin and beta glucans. Studies concluded that certain mushrooms species have antitumor, antiviral, antithrombotic and immunomodulating properties. Research has shown that some mushrooms may have potential to lower elevated blood sugar levels. But the explanation for this effect is limited, with the exception of some mushrooms (Perera and Li, 2011).

Mushrooms as a source of bioactive compounds

The bioactive substances found in mushrooms can be divided into secondary metabolites (acids, terpenoids, polyphenols, sesquiterpenes, alkaloids, lactones, sterols, metals, chelating agents, nucleotide analogs, and vitamins), glycoproteins and polysaccharides, mainly β -glucans. New proteins with biological activities have also been found, which can be used in biotechnological processes and for the development of new drugs, including lignocellulose-degrading enzymes, lectins, proteases and protease inhibitors, ribosome-inactivating proteins, and hydrophobins (Erjavec *et al.*, 2012).

Ramesh and Pattar (2010) found that methanolic extracts of 6 wild edible mushrooms i. e. *Lycoperdon perlatum*, *Cantharellus cibarius*, *Clavaria vermiculris*, *Ramaria formosa*, *Marasmius oreades*, *Pleurotus pulmonarius* isolated from the Western Ghats of Karnataka contained total phenols as major bioactive compounds which ranged from 3.20 mg/ml to 6.25 mg/ml. Average concentration of flavonoid ranged from 0.40 mg/ml to 2.54 mg/ml; followed by very small concentration of ascorbic acid

(range, 0.06 mg/mL to 0.16 mg/ml) in all the isolates. All the isolates showed high phenol and flavonoid content, but ascorbic acid content was found in traces.

Anticarcinogenic properties of mushrooms

Rajarathnam and Bano (1992) reported that the water soluble polysaccharides of mushrooms have been demonstrated to possess anti-tumour activity. Daba and Ezeronye (2003) found the anti-tumor activity in mushroom fruit bodies and mycelial extracts for different cancer cell lines. These polysaccharide extracts showed potent antitumor activity against sarcoma 180, mammary adenocarcinoma 755, leukemia L-1210 and other tumors. The antitumor activity was mainly due to indirect host mediated immunotherapeutic effect. These studies are still in progress in many laboratories and the role of the polysaccharides as immunopotentiators is especially under intense debate.

Patel and Goyal (2012) found that the mushrooms credited with success against cancer belong to the genus *Phellinus*, *Pleurotus*, *Agaricus*, *Ganoderma*, *Clitocybe*, *Antrodia*, *Trametes*, *Cordyceps*, *Xerocomus*, *Calvatia*, *Schizophyllum*, *Flammulina*, *Suillus*, *Inonotus*, *Inocybe*, *Funlia*, *Lactarius*, *Albatrellus*, *Russula*, and *Fomes*. The anti-cancer compounds play crucial role as reactive oxygen species inducer, mitotic kinase inhibitor, anti-mitotic, angiogenesis inhibitor, topoisomerase inhibitor, leading to apoptosis, and eventually checking cancer proliferation.

Phellinus is a genus of mushrooms belonging to the family Hymenochaetaceae. *Phellinus linteus* has anti-tumor, immunomodulating and anti-metastasis properties owing to its β -(1 $\rightarrow$ 3) linked glycan (Baker *et al.*, 2008). Lavi *et al.*, (2006) reported that an aqueous polysaccharide extract from *Pleurotus ostreatus* induces anti-proliferative and pro-apoptotic effects on HT-29 colon cancer cells.

Medicinal mushrooms occurring in South India namely *Ganoderma lucidum*,

Phellinus rimosus, *Pleurotus florida* and *Pleurotus pulmonaris* possessed profound antioxidant and antitumor activities. This indicated that these mushrooms would be valuable sources of antioxidant and antitumor compounds. Investigations also revealed that they had significant antimutagenic and anticarcinogenic activities (Ajith and Janardhanan, 2006)

Antioxidative Properties of Mushroom

Antioxidative activity of some edible mushrooms cultivated in Bangladesh was determined by Chowdhury *et al.*, (2015) and found that total phenols are the major bioactive component found in extracts of isolates expressed as mg of gallic acid equivalents (GAEs) per gram of fruit body, which ranged from 3.20 to 10.66 mg/ml. Average concentration of flavonoid ranged from 2.50 mg/ml to 4.76 mg/ml; followed by very small concentration of ascorbic acid (range, 0.06 mg/ml to 0.21 mg/ml) in all the isolates. All the isolates showed high phenol and flavonoid content (except *Pleurotus ostreatus*), but ascorbic acid content was found in traces.

Kosanic *et al.*, (2013) studied the *in vitro* antioxidant activity of the acetone and methanol extracts of the mushrooms *Amanita rubescens*, *Cantharellus cibarius*, *Lactarius piperatus* and *Russula cyanoxantha*. Antioxidant activity was evaluated by four different methods: free radical scavenging, reducing power, determination of total phenolic compounds and determination of total flavonoid content. As a result of the study acetone extracts from *Russula cyanoxantha* had more powerful antioxidant activities than other examined mushroom extracts. Moreover, the tested extracts had effective reducing power.

Mushrooms as hypocholesterolemic agents

Cardiovascular disease is associated with atherosclerosis, LDL oxidation, and hypercholesterolemia, and thus the regulation of the cholesterol level is important for the prevention and treatment of this disease. Edible mushrooms are an ideal food for the

dietetic prevention of atherosclerosis due to their high fiber and low fat content. Indeed, the inclusion of edible mushrooms in a natural hypocholesterolemic and antisclerotic diet is often prescribed in Oriental medicine (Ishikawa *et al.*, 1984)

The adenosine derivative lentinacin or lentysine (currently known as eritadenine [2(R), 3(R)-dihydroxy-4-(9-adenyl)-butyric acid] was subsequently isolated and identified to be one of the active hypocholesterolemic components in the shiitake mushroom. Eritadenine has also been found to reduce the serum cholesterol level in mice by the acceleration of the excretion of ingested cholesterol and its metabolic decomposition. Eritadenine affects the metabolism not only of cholesterol but also of phospholipids and fatty acids in rats. The dietary supplementation of eritadenine may therefore decrease phosphatidylcholine biosynthesis by altering the phosphatidylethanolamine concentration (Rathee *et al.*, 2012)

Nabubuya *et al.* (2010) found that consumption of *Termitomyces microcarpus* mushrooms could contribute to reduce the prevalence of diseases linked to high blood lipids and suggested that reduction in the total serum cholesterol, LDL- cholesterol and triglycerides may be attributed to the high quantities of fibre in the mushrooms.

Yang *et al.*, (2002) reported the hypolipidemic effect of exo-polymer produced in submerged mycelial culture of *Hericium erinaceus* (HE), *Auricularia auricula-judae* (AA), *Flammulina velutipes* (FV), *Phellinus pini* (PP), and *Grifola frondosa* (GF) in the experimental animals.

Hepatoprotective Effects of Mushrooms

Ganoderic acids R and S and ganosporeric acid A from *Ganoderma lucidum* has been found to exhibit *in vitro* antihepatotoxic activity in the galactosamine-induced cytotoxic test with primary cultured rat hepatocytes (Hirotani *et al.*, 1986). Chatterjee *et al.* (2011) studied the effect of ethanolic extract of a wild edible mushroom (*Calocybe indica*) against carbon tetrachloride (CCl₄) induced hepatic damage in mice. The

findings suggested that ethanolic extract of *C. indica* protects CCl_4 induced chronic hepatotoxicity in mice by restoring the liver antioxidant status.

Sumy *et al.*, (2014) found the hepatoprotective effect of Oyster mushroom (*Pleurotus florida*) against paracetamol induced liver damage in Wistar albino rats. Soares *et al.*, (2013) found that many mushroom extracts possess hepatoprotective properties against liver injury caused by toxic chemicals. Phenolics, triterpenes, polysaccharides and peptides are the main classes of compounds which could be responsible for the hepatoprotective activity of the mushroom extracts. Wu *et al.*, (2013) found that *Ganoderma lucidum* aqueous extracts (GLEs) induces hepatoprotective effects on acute liver injury induced by α -amanitin (α -AMA). These protective effects may be related in part to the antioxidant properties of GLE.

Antidiabetic Effects of Mushrooms

There is an increasing demand by patients to use natural products with hypoglycaemic activity for the treatment of diabetes mellitus. The hypoglycemic potential of methanolic extract of *Pleurotus citrinopileatus* mycelium on streptozotocin-induced type - 2 diabetes mellitus rats was studied by Rushita *et al.*, (2013). Results showed a significant reduction in fasting blood glucose level and serum catalase activity but a significant increase in serum insulin level in the high dose treated group compared to untreated diabetes mellitus experimental group. Furthermore, some histopathological changes were noticed in the kidney tissue section. This study revealed *P. citrinopileatus* had excellent antidiabetic activity and thus have great potential as an ingredient in natural health products.

Lectins isolated from mushrooms (*Agaricus campestris* and *A. bisporus*) have been shown to enhance insulin release in isolated rat islets of Langerhans (Ahmad *et al.*, 1984). Ravi *et al.*, (2013) studied the antidiabetic activity of *Pleurotus ostreatus* in normal and alloxan-induced diabetic mice.

They found that ethanolic extract of fruiting bodies of *P. ostreatus* was tested for their antidiabetic activity. Results showed that animals treated with the ethanolic extract of *P. ostreatus* showed a significant decrease in serum glucose level. The serum creatinine, urea levels were significantly reduced in post treated group. Thus, indicating that the ethanolic extract of *P. ostreatus* could be added in the list of medicinal preparations beneficial in diabetes mellitus.

Mushrooms as natural sources of Antimicrobial agents

Mushrooms are superior nutritional supplement and attributed with magnificent medicinal values. The medicinal bioactive compounds present in mushroom includes: polysaccharides, lipopolysaccharides, proteins, peptides, glycoproteins, nucleosides, triterpenoids, lectins, lipids and their derivatives. The antimicrobial properties of certain mushrooms provide human disease control that is generally safe and effective. Several mushrooms have demonstrated efficient antibacterial activity as well as antifungal activity against resistant human pathogens (Sharma *et al.*, 2014).

Chowdhury *et al.*, (2015) Determined antimicrobial activity of some edible mushrooms cultivated in Bangladesh and found that zone of inhibition against all bacteria and fungi ranged from 7 to 20 mm. Minimum inhibitory concentration values of the extracts showed that they are also active even in least concentrations ranged from 1 mg/ml to 9 mg/ml. *Lentinula edodes* showed the best antimicrobial activity than others. *Pseudomonas aeruginosa* was quite resistant and *Saccharomyces cerevisiae* was more sensitive than others microbial isolates.

In vitro antimicrobial activity of the acetone and methanol extracts of the mushrooms *Amanita rubescens*, *Cantharellus cibarius*, *Lactarius piperatus* and *Russula cyanoxantha* was studied by Kosanic *et al.*, (2013). The antimicrobial activity was estimated by determination of the minimal inhibitory concentration by using micro

dilution plate method against five species of bacteria and five species of fungi. Generally, the tested mushroom extracts had relatively strong antimicrobial activity against the tested microorganisms. It suggests that mushrooms may be used for pharmaceutical purposes in treatment of various diseases.

The culture filtrates of 27 edible mushrooms were screened for antimicrobial activity against the plant pathogens. It was found that the culture filtrates of *Lentinula edodes* and *Clitocybe nuda* were able to completely inhibit spore germination of *Colletotrichum higginsianum*. Three culture filtrates that contained substances having capacity to completely inhibit spore germination of *Alternaria brassicicola* were *Ganoderma lucidum*, *L. edodes* and *C. nuda*. These results suggest that substances from edible mushrooms have the potential to be developed into biocontrol agents for the control of plant diseases (Chen and Huang, 2011). Menaga *et al.*, (2012) found that bioactive compounds from *Pleurotus florida* mushroom extracts could be used as an alternate therapeutics as antibiotics. Alves *et al.*, (2012) reported that *Fistulina hepatica*, *Russula botrytis* and *Russula delica* are the most promising species as antimicrobial agents.

Mushrooms as natural resources of immunotherapy

In the recent years, mushrooms are distinguished as important natural resources of immunotherapy which can be used as immunomodulating and immunostimulating in the management of some immunodeficiency diseases such as cancer, tumour, HIV, tuberculosis etc. Mushroom of the genus *Pleurotus* are good sources of several bioactive compounds which are able to augment or complement a desired immune response. Such bioactive compounds are polysaccharopeptides, polysaccharide-proteins, functional proteins (ubiquinone-9, nebrodeolysin, ubiquitin-like peptide and glycoprotein), glucans, proteoglycans and many others. Most of these bioactive compounds follow the immunomodulatory

pathway mechanism of polysaccharide (β -glucan) from mushrooms by stimulating activities for both innate and adaptive immune systems (Oloke and Adebayo, 2015)

Chu *et al.*, (2002) reported that *Coriolus versicolor* (CV) is a medicinal mushroom widely prescribed for the prophylaxis and treatment of cancer and infection in China. It has been extensively demonstrated both pre-clinically and clinically that aqueous extracts obtained from CV display a wide array of biological activities, including stimulatory effects on different immune cells and inhibition of cancer growth. While very limited information is available on the physical, chemical, and pharmaco-dynamic properties of the active principles present in these extracts, there has been sufficient scientific evidence to support the feasibility of developing at least some of these constituents into an evidence-based immuno-modulatory agent.

Conclusion

Mushrooms contain various components with outstanding properties to prevent or treat different type of diseases. Because of their low fat content, mushrooms can be used in low-calorie diets. The mushroom protein contains all the nine essential amino acids required by humans. In addition they are a relatively good source of the nutrients like phosphorus, iron and vitamins, including thiamine, riboflavin, ascorbic acid, ergosterol, and niacin. Mushrooms have also been reported as therapeutic foods, useful in preventing diseases such as hypertension, diabetes, hypercholesterolemia and cancer. These functional characteristics are mainly due to the presence of dietary fibres, bioactive components, antioxidants, lectins and antimicrobial agents. Mushrooms with immune-modulating polysaccharides are used as health-promoting food supplement (nutraceuticals). The mechanism of action of various secondary metabolites isolated from medicinal and wild edible mushroom is yet to

be discovered. With respect to their high nutritional and therapeutic potential, mushrooms can find different applications, namely as functional foods or as a source of nutraceuticals for maintenance and promotion of health and life quality.

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