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Physiological, Biochemical, Biotechnological and Food Technological Applications of Mushroom: An Overview

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Abstract: *Mushrooms are a materialization of a general proverb, 'Medicines and foods have a common origin', in the constitution of both a nutritionally functional food as well as a source of physiologically advantageous medicine. This overview article mostly covers the results obtained from the broad-range studies aimed on physiological, biochemical and food technological significance of varieties and mode of nutrition of mushroom and thus may represent a comprehensive account for physiologists, biochemists and food technologists to propagate their research on still not well known nutraceutical and medicinal importance of certain edible mushrooms. Besides, it would provide new insights into development of novel mushrooms based functional foods as well as valuable medicine ingredients.*

Key words: *Anti-diabetic activity, Blood lipid lowering effects, Foods, Functional food, Medicines, Mushroom*

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I. Introduction

Aging is linked with structural and biochemical changes that are thought to outcome as motor and cognitive impairments and amplified susceptibility to neurodegenerative disorders (Ereo *et al*., 2002; Terry and Buccafusco, 2003; Sharma *et al*., 2009; Nanda *et al*., 2010). The free radical principle of aging anticipated that aging is as a consequence of accumulation of unrepaired damage from free radical attack on cellular components. Modern approaches recommend that aging is caused by a move in the balance between the pro-oxidative and anti-oxidative processes in the direction of the pro-oxidative status (Cadenas and Davies, 2000; Sharma *et al*., 2009; Nanda *et al*., 2010) . L- carnitine, a nutrient generally synthesized from methionine and lysine in the liver and kidney. L- carnitine transports long-chain fatty acids (LCFA) crosswise the mitochondrial membrane where they go through beta-oxidation to generate energy. Carnitine deficit decreases LCFA accessibility for oxidation, thus leading to LCFA accumulation in the cytosol, and decreased ketone and energy production. Other L- carnitine functions comprise the maintenance of adequate free coenzyme-A required for various metabolic cycles, the guarding of cells against toxic accumulation of acyl-coenzyme-A compounds by shuttling acyl groups out of the mitochondria, and the storage and transport of energy (Catherine *et al*., 2006). Besides, L-carnitine favors the immune system and upsurges the antioxidant system.

Mushrooms are a materialization of a general proverb, 'Medicines and foods have a common origin', in the constitution of both a nutritionally functional food as well as a source of physiologically advantageous medicine. Several centuries ago, medicinal characteristics of mushrooms have been recognized in China, Korea and Japan. Though from ancient times, mushrooms have been considered as a special category of Nutraceuticals, they have received a noteworthy attention in recent decades. Major medicinal characteristics credited to mushrooms include anti-diabetic activity, antibiotic activity, antiviral activity, anticancer activity, immune response-stimulating effects, anti-hypersensitive and blood lipid lowering effects (Kaul, 2001; Barbara *et al*., 2008). Mushroom is recognized to have elevated levels of proteins, carbohydrates and fibers and low fat contents (Yang *et al*., 2002; Barbara *et al*., 2008; Mishra and Singh, 2010; Mishra and Singh, 2013). Moreover, mushrooms have been reported to contain considerable levels of vitamins, namely thiamine, riboflavin, ascorbic acid and vitamin D_2, concomitant with minerals (Mattila *et al*., 2000). Mushroom species had been shown to hold antioxidant capacity in *in-vitro* systems (Diaz *et al*., 2000; Ribeiro *et al*., 2006; Khan *et al*., 2010). The mushroom *Pleurotus species (P. ostreatus, P. sajor-caju, P. florida)* were reported to have hypocholesterolemic and anti-diabetic activities in experimental rats (Hossain *et al*., 2003; Alam *et al*., 2009; Khan *et al*., 2010). It has been reported that the L- carnitine concentration in mushroom ranged from 130 to 533 mg/kg dried mushroom. The present overview is the assemblage of overall studies aiming at physiological, biochemical, biotechnological as well as food technological significance of mushroom under following headings foretelling the Nutraceuticals countenance for researchers to propagate the research in relevant thrust area in view of developing certain novel value added products.

(A) Changes in lipid physiology and biochemistry of mammalian system consequent to mushroom feeding

The effect of 15% dried mushroom, 450 mg mushroom extract and L-carnitine on total lipid, triglyceride and total cholesterol has been well described in studies accomplished previously (Panchamurthy and Carani, 2007). Total lipid content significantly ($P \leq 0.05$) reduced in albino rats supplemented with mushroom and L-carnitine. The reduction in the total lipids ranged from 7 to 14%. There was no significant ($P > 0.05$) difference in total lipid between rats supplemented with 400 mg L-carnitine and those supplemented with 15% dried mushroom. Albino rats supplemented with 800 mg L-carnitine had a higher ($P \leq 0.05$) total lipid content compared to those supplemented with 450 mg mushroom extract. Diet supplemented with mushroom and L-carnitine resulted in a significant ($P \leq 0.05$) decrease in triglyceride and total cholesterol level. Triglyceride was observed to reduce by 31–44%. However, total cholesterol reduced by 15.92-28.45%. Supplementation with 450 mg mushroom extract and 800 mg L-carnitine were more ($P \leq 0.05$) effective in reducing triglyceride and total cholesterol than those supplemented with 15% dried mushroom and 400 mg L-carnitine. On the other hand, supplementation with 450 mg mushroom extract and 800 mg L-carnitine were similar ($P > 0.05$) in reducing triglyceride and total cholesterol levels. Supplementation with 15% dried mushroom and 400 mg L-carnitine were also similar ($P > 0.05$) in reducing triglyceride and total cholesterol. It has been observed that rats fed a semisynthetic diet containing 0.3% cholesterol and supplemented with 5% dried whole oyster mushroom had reduced serum and liver cholesterol levels by 34 and 58%, respectively. Panchamoorthy and Carani (2007) reported that treated rats with L-carnitine caused a significant reduced in TG as compared to untreated rats. L-carnitine is known to promote the transport of cytosolic long-chain fatty acids into the mitochondrial matrix for β-oxidation, thereby providing mitochondrial energy (Eskandari *et al*., 2004; Tanaka *et al*., 2004). L-carnitine may lower plasma TG by increasing the utilization and/or oxidation of fatty acids for energy or possibly by altering very low-density lipoprotein synthesis (Tanaka *et al*., 2004).

The data gathered so far (Eskandari *et al*., 2004; Tanaka *et al*., 2004; Panchamoorthy and Carani, 2007) reflect that the high density lipoprotein in rats was not affected ($P > 0.05$) as a consequence of the supplementation with 15% dried mushroom and 400 mg L-carnitine. However, rats supplemented with 450 mg mushroom extract and 800 mg L-carnitine had a higher ($P \leq 0.05$) high density lipoprotein compared to those of the control sets. High density lipoprotein was monitored to enhance in these albino rats by 24-30%. Low density lipoprotein ($P \leq 0.05$) reduced in albino rats supplemented with mushroom and L-carnitine by 30-56%. Supplementation of rats with 450 mg mushroom extract and 800 mg L-carnitine were more ($P \leq 0.05$) effective in lowering low density lipoprotein than those supplemented with 15% dried mushroom and 400 mg L-carnitine. On the other hand, supplementation of rats with 450 mg mushroom extract and 800 mg L-carnitine were similar ($P > 0.05$) in decreasing low density lipoprotein. Supplementation of rats with 15% dried mushroom and 300 mg L-carnitine were also similar ($P > 0.05$) in lowering low density lipoprotein. Very low density lipoprotein in rats was ($P \leq 0.05$) reduced by the supplementation with mushroom and L-carnitine. Very low density lipoprotein was reduced in these rats by about 32%. Supplementation of rats with 450 mg mushroom extract and 800 mg L-carnitine were more ($P \leq 0.05$) effective in reducing very low density lipoprotein than those supplemented with 15% dried mushroom and 400 mg L-carnitine. Diet supplemented with 450 mg mushroom extract and 800 mg L-carnitine did not significantly ($P > 0.05$) differ in their effect on very low density lipoprotein. Besides, no significant ($P > 0.05$) difference was observed in very low density lipoprotein between albino rats supplemented with 15% dried mushroom and those supplemented with 400 mg L-carnitine. These results are in agreement with those reported earlier (Lofgren *et al*., 2005; Seline and Johein, 2007) highlighting that L-carnitine well stabilizes the level of lipids peroxidation, decreases concentration of total lipids, triglycerides, total cholesterol, phospholipids, and lipoproteins of low and very low density, in the Swiss albino rats' blood sera.

(B) Changes in the physiological and biochemical level of key enzymes pertaining to liver function of mammalian system as a result of feeding mushroom supplemented with L-carnitine

The aspartate amino transferase (AST) enzyme in the mammalian system was observed to considerably reduce as a consequence of the supplementation of diet with mushroom and L-carnitine (Mishra and Singh, 2010). Mushroom reduced AST enzyme by 38.64-41.46%. However, L-carnitine reduced it by 24.58-42.80%. Swiss albino rats supplemented with 400 mg L-carnitine showed a higher ($P \leq 0.05$) AST enzyme compared to those supplemented with mushroom and 800 mg L-carnitine. Diet supplemented with 450 mg mushroom extract and 800 mg L-carnitine were not significantly ($P > 0.05$) differed in their impact on AST enzyme (Mishra and Singh, 2010). Further, diet supplemented with mushroom and L-carnitine had a lower ($P \leq 0.05$) alanine amino transferase (ALT) enzyme compared to that of the control sets. Mushroom and L-carnitine reduced ALT enzyme by 36.6-45.6% and 22.4-37.1%, respectively. Diet supplemented with 15% dried mushroom, 450 mg mushroom extract and 800 mg L-carnitine

appeared to be more effective ($P > 0.05$) in decreasing ALT enzyme compared to those supplemented with 400 mg L-carnitine. No significant ($P > 0.05$) difference was found in ALT enzyme among rats supplemented with 15% dried mushroom, 450 mg mushroom extract and those supplemented with 800 mg L-carnitine. The alkaline phosphatase (ALP) enzyme in rats was observed to significantly ($P \leq 0.05$) reduce by the supplementation with mushroom and L-carnitine. Mushroom reduced ALP enzyme by 22.19-32.71%. However, L-carnitine reduced it by 22-49%. The Diet supplemented with 400 mg L-carnitine had a higher ($P \leq 0.05$) ALP enzyme compared to those supplemented with 800 mg L-carnitine. Diet supplemented with 15% dried mushroom had a higher ($P \leq 0.05$) ALP enzyme compared to those supplemented with 450 mg mushroom extract (Mishra and Singh, 2010). The diet supplemented with 15% dried mushroom and 400 mg L-carnitine were not significantly ($P > 0.05$) differed in their impact on ALP enzyme. L-carnitine and mushroom restores the changes of ALT, AST and ALP activities due to their antioxidant effects and their ability to act as a radical scavenger, thereby protecting membrane permeability. It has been observed found that ALT and AST after ethanol intoxication their activity increased by about 80%. L-carnitine partly prevented these changes. It was manifested by a statistically significant decrease in the activity of ALT and AST, by about 20% in comparison with the ethanol group (Seline and Johein, 2007; Augustyniak and Skrzydlewska, 2009).

The Data obtained from the studies (Seline and Johein, 2007; Augustyniak and Skrzydlewska, 2009) reflect that the MDA ($P \leq 0.05$) got reduced by 12-34% in albino rats supplemented with diet containing mushroom and L-carnitine. Supplementation with 450 mg mushroom extract and 800 mg L-carnitine were more ($P \leq 0.05$) effective in decreasing MDA compared to those supplemented with 15% dried mushroom and 400 mg L-carnitine. On the other hand, supplementation with 450 mg mushroom extract and 800 mg L-carnitine were similar ($P > 0.05$) in reducing MDA. Supplementation of diets with 450 mg mushroom extract and 400 mg L-carnitine were also similar ($P > 0.05$) in reducing MDA. Rats supplemented with the diet containing 15% dried mushroom had higher ($P \leq 0.05$) MDA compared to those supplemented with 400 mg L-carnitine. It has earlier been reported that administration of L- carnitine to rats intoxicated with ethanol significantly protects lipids and proteins against oxidative modifications in the serum and liver. The level of MDA was decreased by about 30%, in the blood serum in comparison to the ethanol group (Augustyniak and Skrzydlewska, 2009).

Glutathione peroxidase (GSHPx) is known to perform a key role in co-coordinating the innate antioxidant defense mechanisms. It is involved in the maintenance of the normal structure and function of cells, probably by its redox and detoxification reactions (Black, 2004). The GSHPx in rats was monitored to be significantly ($P \leq 0.05$) enhanced by the supplementation with mushroom and L-carnitine. Mushroom increased GSHPx by 58.43-85.50%. However, L-carnitine increased it by 60.15-129.69%. Rats supplemented with 450 mg L- carnitine and 15% dried mushroom had a lower ($P \leq 0.05$) GSHPx compared to those supplemented with 800 mg L-carnitine and 450 mg mushroom extract. Supplementation with 15% dried mushroom and 400 mg L- carnitine were not significantly ($P > 0.05$) differed in their effect on GSHPx. Supplementation of rats with 800 mg L-carnitine was more ($P \leq 0.05$) effective in increasing GSHPx compared to those supplemented with 400 mg L-carnitine, 15% dried mushroom and 450 mg mushroom extract. According to Augustyniak and Skrzydlewska (2009) L-carnitine has been reported to cause a significant increase in the liver and blood serum GSH level by more than 20%. An enhancement in the levels of GSHPx in aged rats treated with mushroom extract as a source of antioxidant has also been recently reported.

Taken as a whole, results outcome from the research studies (Akoma *et al*., 2002; Akoma et al., 2006; Jaikumar *et al*., 2006) highlight the effect of dried mushroom, mushroom extract and L-carnitine on food intake and body weight of Swiss albino rats. Either L-carnitine or mushroom significantly ($P \leq 0.05$) increased food intake and reduced body weight in rats. There was no significant ($P > 0.05$) variation in food intake between rats supplemented with L-carnitine and mushroom. Supplementation of rats with L-carnitine was more ($P \leq 0.05$) effective in reducing body weight than those supplemented with mushroom. Supplemented rats with 400 mg L-carnitine and 800 mg L-carnitine were not significantly ($P > 0.05$) distinct in their effect on body weight. Similar effect was monitored in rats supplemented with 15% dried mushroom and 450 mg mushroom extract. The rationale for L- carnitine supplementation as a weight-loss agent is based on the assumption that regular oral ingestion of the substance increases its intracellular concentration. This would trigger increased fat oxidation and gradual reduction of the body's fat reserves (Akoma *et al*., 2002; Akoma *et al*., 2006; Jaikumar *et al*., 2006).

(C) Application of Mushroom as food and medicine

Mushrooms are the fruiting bodies of certain types of fungi play key roles in forest ecosystems that they have unique abilities to break down wood, leaves, and other organic matter and recycle nutrients back into the system. Pleurotus species are popular and widely cultivated throughout the world mostly in Asia and Europe owing to their simple and low cost production technology and higher biological efficiency (Fekadu, 2015). Mushrooms are used as therapeutic foods, since they check diseases such as hyper-diabetes, hypertension,

hypercholesterolemia, atherosclerosis and cancer mainly due to their chemical profile (Ashagrie *et al*., 2015). According to Fekadu (2015), the higher contents of mushrooms is water (90%), protein (2-40%), fat (2-8%), carbohydrates (1- 55%), fiber (3-32%), and ash (8-10%). High fiber content, proteins, microelements, and lower caloric content are almost ideal for a nutrition program aimed to prevent hypercholesterolemia and cardiovascular diseases. Reduction of total blood cholesterol and lipoprotein cholesterol and antioxidant activities, in the regulation of blood lipid levels and reduction of blood glucose levels (Daba *et al*., 2008). Mushrooms are medicinal foods, which are rich in nutrition and globally recognized by medical professions (Fekadu, 2015). Mushrooms have eight significant amino acids, polyunsaturated fatty acids and small amounts of saturated fatty acids and have higher nutritional values than fish or beef (Fekadu, 2015).

(a) Mushroom as food

Mushrooms have a unique texture have good aroma, taste and flavor that differs mushroom from other food crops (Fekadu, 2014). Edible species of mushrooms found abundantly in indigenous forests are; Macrolepiota, Auricularia, Armillaria, Pholiota, and Coprinus. Several species of Macrolepiota and Agaricus are well known in highland grazing areas. Mushrooms found in exotic plantations such as pinus and cupressus remain unknown to the local people and are not collected for use. The most common poisonous mushroom is Chlorophyllum molybidites, a mushroom similar to other edible members of the Agaricacea and is difficult for local people to differentiate from edible one (Dawit, 2014).

Mushrooms are extremely nutritive, low-calorie food with good quality proteins, vitamins and minerals. Mushrooms are an vital natural source of foods and medicines. By virtue of having high fiber, low fat and low starch, edible mushrooms have been measured to be ideal food for obese persons and for diabetics to avert hyperglycaemia. They are also known to possess promising anti oxidative, cardiovascular, hypercholesterolemia, antimicrobial, hepato-protective and anticancer effects (Khatun *et al*., 2012). According to Barros *et al*. (2008), more than 3000 mushrooms are mainly edible species but, only 100 species are cultivated commercially, and only ten species are used at industrial scale and their global and economic worth is now escalating gradually due to increase in their value as a food as well as their medicinal and nutritional values.

(b) Nutritional composition of Mushroom

The carbohydrate content of mushrooms represents the bulk of fruiting bodies accounting for 50 to 65% on dry weight basis. Free sugars amount to about 11%. Florezak *et al*. (2004) reported that *Coprinus atramentarius* contain 24% of carbohydrate on dry weight basis. The mannitol, also called as mushroom sugar constitutes about 80% of the total free sugars, hence it is dominant (Wannet *et al*., 2000). Singh and Singh (2002) reported that, a fresh mushroom contains 0.9% mannitol, 0.28% reducing sugar, 0.59% glycogen and 0.91% hemicellose. Carbohydrates of Agaricus bisporus are Raffinose, sucrose, glucose, fructose and xylose are dominant in it.

Protein is an important constituent of dry matter of mushrooms. Protein content of mushrooms depends on the composition of the substratum, size of pileus, harvest time and species of mushrooms (Bilal *et al.,* 2010). Protein content of the mushrooms has also been reported to vary from flush to flush. Protein in A. bisporus mycelium ranged from 32 to 42% on the dry weight basis. Mushrooms in general have higher protein content than most other vegetables and most of the wild plants 14.71 to 17.37% and 15.20 to 18.87% protein in the fruiting bodies of *Lactarious deliciosus* and *Lactarious sanguiffus* respectively. Mushrooms contain all the essential amino acids required by an adult (Anon, 2007).

Fat constituent in mushroom is not high when compared with carbohydrates and proteins. The fats present in mushroom fruiting bodies are mostly unsaturated fatty acids. Fat content of mushroom is different in different species that 2.04% in *Suillus granulatus* but 3.66% in *Suillus luteus* and 2.32% in *A. campestris*. Mushrooms are rich in linolenic acid, which is an essential fatty acid. Mushrooms are considered good source of fats and minerals Fat fraction in mushrooms is mainly composed of unsaturated fatty acids (Pedneault *et al*., 2006; Yilmaz *et al*., 2006).

Mushrooms are one of the best sources of vitamins especially; wild mushrooms contain much higher amounts of vitamin D2 than dark cultivated Agaricus bisporus. Mushrooms also contain vitamin B-complex and vitamin C in small amounts, but they are poor in vitamins A, D, and E (Heleno *et al*., 2012).

Besides, Mushrooms are characterized by containing high-level mineral elements that are essential for human health. Major mineral constituents in mushrooms are K, P, Na, Ca, Mg and elements like Cu, Zn, Fe, Mo, Cd form minor. Mushrooms have ability to accumulate heavy metals like Cd, Pb, Ar, Cu, Ni, Ag, Cr and Hg (Malinowska *et al*., 2004). The mineral contents of mushroom are based on species, age and the diameter of the fruiting body of that mushroom. It also depends upon the type of the substratum that is supplied for mushroom cultivation. The mineral content of wild edible mushrooms is higher than cultivated ones (Rudawska and Leski, 2005).

(c) Mushroom as medicine

Mushrooms are not merely sources of nutrients but also as therapeutic foods, helpful in preventing diseases such as hypertension, diabetes, hypercholesterolemia and cancer. These functional uniqueness of mushrooms are mainly due to the presence of dietary fiber and specifically chitin and beta glucans. Some mushrooms species have antitumor, antiviral, and antithrombotic and immunomodulating properties and some mushrooms may have potential to decline elevated blood sugar levels (Khan and Tania, 2012; Waktola and Temesgen, 2018). According to the report of Wasser (2002), *Pleurotus* species have lofty medicinal value. Compounds extracted from these mushrooms exhibit activity against various chronic diseases including hypertension, hypercholesterolemia and they are able to possess essential antioxidant, anti-inflammatory and antitumor activities (Jose *et al*., 2002; Waktola and Temesgen, 2018).

Agaricus blazei is used general medicine against different diseases, like cancer, chronic hepatitis, diabetes, arteriosclerosis, and hyperlipidemia. Interest in the use of this mushroom and/or its extracts as dietary supplements has increased significantly, in part because of its antitumor, anticarcinogenic, antiviral, anti-inflammatory, hypoglycemic, hypocholesterolemic, and antihypertensive effects. Mushrooms are also used for chronic catarrh diseases of the breast and hinges, lower the cholesterol level of blood, improves circulation, remedy for night sweating in tuberculosis, rheumatism, gout, jaundice, dropsy, intestinal worms and have anti-tumor, anti-viral and anti-cancer agents. (Sasidharan *et al*., 2010) reported that mushrooms are very effective for patients of hypertension, renal effects and diabetics, their immune-modualatory and antitumor activities of Polysaccharide-Protein Complex (PSPC) from mycelial cultures and their immune-modualatory and antitumor activities of lectins from edible mushrooms gives them valued in medicinal value. Bracket mushroom (Ganoderma lucidum) has been repeatedly used for disease management of patients with HIV and AIDS and can be justified by the increase in body weight (Khan and Tania, 2012; Waktola and Temesgen, 2018).

(i) Mushroom versus antimicrobial action

Mushroom known as *Osmoporus odoratus* produce petroleum ether, chloroform, acetone and water extracts that are useful for their antibacterial activity against *Staphylococcus aureus*, *Streptococcus pyogenes*, *Bacillus subtilis*, *Escherichia coli* and *Pseudomonas aeruginosa*. The water extract *Osmoporus odoratus* act as antibacterial activity against the organisms and it is comparable with that of ampicillin rather than chloramphenicol (Sivakumar *et al*., 2006).

The antimicrobial activity of many solvent extracts like methanol, ethanol, acetone and aqueous extract of *G. lucidum* mushroom is applied (Quereshi *et al*., 2010) against six bacterial species *E. coli*, *S. aureus*, *K. pneumoniae*, *B. subtilis*, *S. typhi* and *P. aeruginosa*. Methanolic extracts of six wild mushrooms (*L. perlatum*, *C. cibarius*, *C. vermiculris*, *R. formosa*, *M. oreades*, *P. pulmonarius*) of Western Ghats of Karnataka, India showed significant antimicrobial activity against *B. subtilis*, *S. aureus*, *E. coli*, *P. aeruginosa* and *Candida albicans* (Ramesh and Pattar, 2010). The antibacterial and antifungal activity of methanol and aqueous extract of fruit bodies from *Phellinus* is applied by (Balakumar *et al*., 2011) against five bacterial pathogens such as *E. coli*, *P. aeruginosa*, *S. typhi*, *S. aureus* and *Streptococcus mutans* and five fungal strains *Penicillium spp*, *Aspergillus fumigatous*, *Aspergillus niger*, *Aspergillus flavus* and *Mucor indicus* (Hrudayanath and Sameer, 2014).

(ii) Mushroom versus antitumerogenic action

Four mushrooms, *Lentinus* (*Lentinula*) *edodes*, *Schizophyllum commune*, *Grifola frondo*sa, and *Sclerotinia sclerotiorum*, particularly their respective β-glucans, lentinan, schizophyllan (also called SPG, sonifilan, or sizofiran), grifolan, and SSG are known for antitumoral activity. Most of the β-(1-6)- branched β-(1-3)-linked glucans, are able to act as antitumor activity (Fekadu, 2014). *Pleurotus rimosus* produces ethyl acetate, methanol and aqueus that inhibit the Dalton's Lymphoma Ascites (DLA) cell line induced solid tumor and EAC cell line induced ascites tumor in mice whereas the antitumor effect is high in ethyl acetate extract than the other extracts. Antitumor activity of *G. lucidum* is again used by (Sheena *et al*, 2005) through the EAC cell line induced solid tumor model in mice, extracts of methanol and aqueous give significant antitumor properties by inhibiting the tumor development. Polysaccharides extracted from mycelium and fruiting bodies of L. tuberregium effectively inhibited solid tumour proliferation in mice (Manjunathan and Kaviyarasan, 2010).

(iii) Mushroom versus anti-inflammatory action

Extracted ethanol from cultured mycelium of *M. esculents* is well known for its anti-inflammatory activity and is important but based on dose to inhibit both acute and chronic inflammation in mice model that is comparable to the standard Diclofenac. The acute and chronic anti-inflammatory activities of ethyl acetate and methanolic extracts from *G. lucidum* are expressed (Sheena *et al*, 2005) through carrageen an induced acute and formalin induced chronic inflammatory models in mice. Chloroform that can extract from *G. lucidum* is significant anti-inflammatory activity (Joseph *et al*., 2009).

(iii) Mushroom versus antioxidant characteristics

Oxidation is essential in many living organisms for the production of energy to fuel biological processes. However, uncontrolled production of oxygen-derived free radicals results in the onset of many diseases, such as cancer, rheumatoid arthritis and atherosclerosis, as well as in degenerative processes associated with aging (Halliwell, 2003). Ethyl acetate, methanol and aqueous extract of G. lucidum are highly inhibit O2· and ·OH radicals, but aqueous extract cannot inhibit ferrous ion induced lipid peroxidation whereas ethanol extracts of the mycelium of G. lucidum is high as antiperoxidative activity (Lakshmi *et al*., 2003).

II. Conclusion and Future Perspectives

Mushrooms have an extensive relationship with humanity and endow with intense biological and economic impact. From prehistoric times, man has been noticed to consume wild mushrooms with probable fragile nature, for their taste and pleasurable flavor. Edible mushrooms provide elevated quality of protein that can be produced with superior biological effectiveness than animal protein, rich in fiber, minerals and various types of vitamins particularly, vitamin B- Complex and Vitamin C and have low fat content, with high proportion of polyunsaturated fatty acids relative to total content of fatty acids. Fresh mushrooms contain comparatively large amount of carbohydrate (4-5%) and fiber but, in mushrooms, starch is lacking. Mushrooms have also been reported to contain significant amount of phosphorous, sodium and potassium with lesser amount of calcium and iron. Mushrooms have numerous prospective medicinal uses. Specifically, *Ostreatus* has naturally produces isomers of lovastatin, which are well-known blood cholesterol reducing compounds. Several proteins in the *Ostreatus* mushroom have antiviral and even anti-HIV properties.

Disclosure

This article is an extended and updated version of the paper, "A Review on Physiological, Biochemical and Biotechnological Applications of Mushroom. IOSR Journal of Pharmacy and Biological Sciences (IOSR-JPBS) 8 (2): 31-34 (2013)."

Conflict of Interest

The authors confirm that this article content has no conflicts of interest.

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