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Biotechnological Significance of Mushroom: An Overview

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ABSTRACT

Background: Mushrooms are a manifestation of a common saying, 'Medicines and foods have a common origin', in constituting both a nutritionally functional food and a source of physiologically beneficial medicine. **Objective:** The review article covers the data obtained from the broad-range studies focused on physiological and biochemical worth of varieties as well as mode of nutrition of mushroom and may provide an overview for biotechnologists to propagate their research on still obscure nutraceutical significance of edible mushrooms. **Conclusion:** Conclusively, this review demonstrates that mushrooms, akin to plants, have a great prospective for the production of valuable bioactive metabolites, reflecting their prolific resourcefulness for drug formulation and/or synthesis.

Key words: Mushroom, medicines, nutritionally functional foods, physiologically beneficial medicine

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INTRODUCTION

In fact, aging is associated with biochemical and structural alterations which are thought to result in motor and cognitive impairments and in increased susceptibility to neurodegenerative diseases[1-4]. The free radical theory of aging proposed that aging is due to the accumulation of unrepaired damage from free radical attack on cellular components. Modern approaches propose that aging is caused by a shift in the balance between the pro-oxidative and anti-oxidative processes in the direction of the pro-oxidative state[1,2,5-7]. L-carnitine, a nutrient normally synthesized from methionine and lysine in the liver and kidney. L-carnitine transports Long-Chain Fatty Acids (LCFA) across the mitochondrial membrane where they undergo beta-oxidation to produce energy. Carnitine deficiency decreases LCFA availability for oxidation, thereby resulting in LCFA accumulation in the cytosol and decreased ketone and energy production. Other L-carnitine functions include the maintenance of adequate free coenzyme-A required for various metabolic pathways, the protection 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[8]. Also, L-carnitine supports the immune system and enhances the antioxidant system[9].

Mushrooms are a manifestation of a common saying, 'Medicines and foods have a common origin', in constituting both a nutritionally functional food and a source of physiologically beneficial medicine. Many centuries ago, medicinal properties of mushrooms have been recognized in China, Korea and Japan. Although from ancient times, mushrooms have been treated as a special kind of nutraceutical, they have received a remarkable interest in recent decades. Major medicinal properties attributed to mushrooms include anticancer activity, antibiotic activity, antiviral activity, immune response-stimulating effects, anti-hypersensitive and blood lipid lowering effects[10-12]. Mushroom is known to have high amounts of proteins, carbohydrates and fibers and low fat contents[13]. Furthermore, mushroom had significant levels of vitamins, namely thiamine, riboflavin, ascorbic acid and vitamin D_2, as well as minerals[14]. Mushroom species had been shown to possess antioxidant capacity in *in vitro* systems[15-18]. The mushroom *Pleurotus* species (*P. ostreatus*, *P. sajor-caju*, *P. florida*) were reported to have hypocholesterolemic activity in experimental rats[18-20]. It has been reported that the L-carnitine concentration in mushroom ranged from 130 to 533 mg kg^{-1} dried mushroom[21]. The free L-carnitine concentration in mushroom ranged from

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75 to 385 mg kg^{-1} dried mushroom, which represented 70±10% of total carnitine content. This study is an up to date review of the studies focusing at biotechnological significance of mushroom projecting the nutraceutical visage for researchers to propagate the research in relevant thrust area.

MUSHROOMS WITH ANTIMICROBIAL ACTIVITIES

Mushrooms require antibacterial and antifungal compounds to survive in their natural environment. It is therefore not surprising that antimicrobial compounds with more or less strong activities could be isolated from many mushroom and that they could be of benefit for human[22], except merely compounds from microscopic fungi are till date available in the market in the form of antibiotics. Further, of special interest are compounds with activities against multiresistant bacterial strains. We could show that new sesquiterpenoid hydroquinones produced by the European Ganoderma species Ganoderma pfeifferi Bres. and named ganomycins[23] inhibit the growth of methicillin-resistant *Staphylococcus aureus* and other bacteria[24]. Besides, we found that whole extracts of this mushroom inhibit the growth of microorganisms responsible for skin problems.

Applanoxidic acid A (2a), isolated from *Ganoderma annulare* (Fr.) Gilbn., shows weak antifungal activity against *Trichophyton mentagrophytes*[25]. Steroids like 5a-ergosta-7, 22-dien-3b-ol[26] or 5,8-epidioxy-5a,8a-ergosta-6,22-dien-3b-ol[27], isolated from *Ganoderma applanatum* (Pers.) Pat., proved to be weakly active against a number of gram-positive and gram-negative microorganisms[28]. Oxalic acid is one agent responsible for the antimicrobial effect of *Lentinula edodes* (Berk.) Pegler against *S. aureus* and other bacteria[29]. Ethanolic mycelial extracts from *L. edodes* possess antiprotozoal activity against Paramecium caudatum[30]. The antimicrobial activity of *Podaxis pistillaris* (L.: Pers.) Morse, used in some parts of Yemen for the treatment of 'nappy rash' of babies and in South Africa against sun burn[31], is caused by epicorazins[32]. These substances belong to the group of epipolythiopiperazine-2,5-diones, an important class of biologically active fungal metabolites[31]. Other antimicrobial compounds from the Aphyllophorales were summarized by Zjawiony[33].

ALTERATION IN LIPID PHYSIOLOGY AND BIOCHEMISTRY OF MAMMALIAN SYSTEM UPON 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 observed[34]. 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 7.06-14.39%. 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 31.28-43.72%. 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[35]. 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. Rajasekar and Anuradha[35] 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[36,37]. 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[38].

The data reported earlier[38] indicate 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 24.11-30.44%. Low density lipoprotein ($p \leq 0.05$) reduced in albino rats supplemented with mushroom and L-carnitine by 30.36-55.76%. 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 ($p\leq0.05$) reduced by the supplementation with mushroom and L-carnitine. Very low density lipoprotein was reduced in these rats by 32.33-42-21%. Supplementation of rats with 450 mg mushroom extract and 800 mg L-carnitine were more ($p\leq0.05$) 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[39,40] 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.

ALTERATION IN THE PHYSIOLOGICAL AND BIOCHEMICAL LEVEL OF MAJOR ENZYMES CONCERNING WITH LIVER FUNCTION OF MAMMALIAN SYSTEM UPON 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. 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 ($p\leq0.05$) 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. Further, diet supplemented with mushroom and L-carnitine had a lower ($p\leq0.05$) alanine amino transferase (ALT) enzyme compared to that of the control sets. Mushroom and L-carnitine reduced ALT enzyme by 36.59-45.61 and 22.40-36.99%, 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[40]. The alkaline phosphatase (ALP) enzyme in rats was observed to significantly ($p\leq0.05$) reduce by the supplementation with mushroom and L-carnitine. Mushroom reduced ALP enzyme by 22.19-32.71%. However, L-carnitine reduced it by 22.14-49.26%. The diet supplemented with 400 mg L-carnitine had a higher ($p\leq0.05$) ALP enzyme compared to those supplemented with 800 mg L-carnitine. Diet supplemented with 15% dried mushroom had a higher ($p\leq0.05$) ALP enzyme compared to those supplemented with 450 mg mushroom extract. 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. 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[40,41].

It has been reported that the MDA ($p\leq0.05$) got reduced by 11.92-33.79% in albino rats supplemented with diet containing mushroom and L-carnitine. Supplementation with 450 mg mushroom extract and 800 mg L-carnitine were more ($p\leq0.05$) effective in decreasing MDA compared to those supplemented with 15% dried mushroom and 400 mg L-carnitine[42]. 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 ($p\leq0.05$) 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[42].

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[43]. 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 Jayakumar *et al*.[42] L-carnitine has been reported to cause a significant increase in the liver and blood serum GSH level by more than 20%. An increase in the levels of GSHPx in aged rats treated with mushroom extract as a source of antioxidant has also been recently reported[43-45].

Further, the effect of dried mushroom, mushroom extract and L-carnitine on food intake and body weight of Swiss albino rats has been well documented by Mishra and Singh[45]. 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[45].

CONCLUSION

One species can possess a high variety of bioactive compounds and therefore of pharmacological impacts. The range of detected pharmacological activities of mushrooms is dreadfully broad. Reliant on escalating awareness of physiology, biochemistry, molecular biology and biotechnology of mushrooms as well as an up-gradation of screening methods, a rapid increase in the application of mushrooms for medicinal purposes can be expected. Prerequisition for a use as drug/medicine, nutraceutical or other rationale is the incessant production of mushrooms in elevated amounts and in a consistent quality.

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