# Medicinal And Therapeutic Aspects of Mushrooms

**Kamaljit kaur[1], Gurkirtan Kaur[2]**
[1, 2]Dept of Biotechnology
[1, 2]Khalsa College, Amritsar-143002

***Abstract***- *Medicinal mushrooms have been known to possess profound pharmacological activities. These activities are mostly attributed to the presence of bioactive compounds such as ß-glucans, heteropolysaccharides, or complexes of polysaccharides and proteins in them. They are also considered as most important functional food for humans and provide many health benefits to them beyond the traditional nutrients. In this review, an attempt has been made to exploit the chemical constituents of mushrooms and their valuable therapeutic use.*

***Keywords***- Medicinal Mushrooms, Therapeutic, Anticancer, Antitumor, Bioactive

## I. INTRODUCTION

The medicinal role of mushrooms has been known since historical times [1-5]. Gruen and Wong [6] indicated that edible mushrooms are of high nutritional value comparable to egg, meat and milk products. Till date around 100,000 mushroom species are known, out of which only 2000 species are edible and only 20 are cultivated commercially [7-9]. In order to explore their medicinal value various experiments have been conducted all over the world. They are found to be used for the treatment of numerous ailments [10, 11]. Medicinal mushroom such as *Ganoderma lucidum*, *Lentinus edodes*, *Hericium erinaceous*, *Pleurotus ostreatus* and *Grifola frondosa* are found to have anti-inflammatory activities [12-13]. *G. lucidium and Lentinus tigrinus* possess anti-cholesterolemic activity [14]. *Lentinus exodus* functions as an anti-aging agent [15]. Other beneficial properties of mushrooms includes antibacterial, hepatoprotective, cardiovascular, antioxidant, cholesterol-lowering, antitumor, antifungal antidiabetic activities [16]. Mushrooms have great potential for the production of useful bioactive metabolites and further studies are required to demonstrate the effectiveness of compounds extracted from them against various ailments. In this review an attempt has been made to focus on various medicinal mushrooms and their role in the treatment of numerous human diseases.

## II. TYPES OF MEDICINAL MUSHROOMS

Since ancient times, mushrooms have been used for medicinal purposes throughout Asia as they posses antioxidant, anti-inflammatory, anti-hypertensive, liver protective, anti-diabetic activities [16-18]. Some of the medical mushrooms which are used for treatment of various diseases are given below:

1. *Ganoderma lucidum* (Lingzhi)
2. *Lentinus edodes* (Shiitake)
3. *Hericium erinaceous* (Lion'smane)
4. *Pleurotus ostreatus* (oyster mushroom)
5. *Grifola frondosa* (Maitake)
6. *Inonotus obliquus* (*Chaga*)
7. *Agaricus blazei Murill*

### *1. Ganoderma lucidum*

*Ganoderma lucidum* is an edible mushroom, commonly known as 'Reishi' by the Japanese and 'Lingzhi' by the Chinese. It has been used for various medicinal purposes due to its anti-inflammatory and anticancer properties [12,18,19]. *Ganoderma lucidum* is also called king of mushrooms. It contains a large quantity of unique bioactive molecules namely polysaccharides, triterpenoids, amino acids, steroids, lectins and dietary fibres. These molecules activate the immune system for a multitude of defensive functions and are known to modulate the function of the immune system [20]. A variety of polysaccharides present in this mushroom provides protection against free radicals and mutagens. Triterpenoids have been reported to possess anti-hypertensive, hypocholesterolemic, hepatoprotective, anti-histaminic, antitumour and anti-angiogenic activities.

### *2. Lentinus edodes*

*L. edodes* is the second most widely cultivated mushroom in the world, commonly known as 'Shiitake' or Japanese mushroom. It is an edible mushroom which is used for medicinal and health purposes. It is called 'hsaing ku' or 'fragrant mushroom' in China. Shiitake is known to contain proteins, lipids, carbohydrates, fibres, minerals, vitamins A, B1, B2 and C and ergosterol, the D provitamin, vitamin E and selenium [21]. It is a good source of antioxidants, such as vitamin E and also contains a number of enzymes such as pepsin and trypsin that help in digestion and treatment of childhood leukemia. Zinc and selenium are the main mineral ions present in Shiitake which help in nails, skin and hair

repair. They also improve plasma testosterone levels and acts as an antioxidant [12]. Various other components found in this mushroom type include polysaccharides, eritadenine, chitin, enzymes, minerals, nucleic acids and amino acids. Due to its low calorific value and high protein and fibre contents, It is used as an ideal diet to prevent cardiovascular diseases [22,23]. Other benefits of Shiitake include improvement in stamina and circulation, preserves health, cures colds, and lowers blood cholesterol level [19]. Shiitake contains eight essential amino acids and is rich in lysine and leucine. 'Eritadenine'- an amino acid derivative of shiitake helps in lowering the cholesterol and lipid concentrations in rodents [24]. Hokama and Hokama [25] showed that *L. edodes* possesses significant anti-thrombotic activity.

***3. Hericium erinaceous***

*Hericium erinaceus* is another type of medicinal and edible mushrooms belonging to the family Hericiaceae. It has a prominent place in traditional Chinese medicine. Its fruiting body and mycelia have been reported to have a variety of pharmacological activities due to presence of different secondary metabolites. Dried powder of *H. erinaceus* fruiting body and mycelia contain proteins, carbohydrates, fat, ash, amino acids and water content. The fungal body also contains saturated and unsaturated fatty acids. Some potential bioactive compounds such as g-aminobutyric acid (GABA), ergothioneine, and lovastatin have also been reported in it. So this mushroom type can be used to improve food quality [26]

***4. Pleurotus ostreatus* (oyster mushroom)**

This edible and medicinal mushroom has 40 species and is also known as "Oyster Mushroom" because its fruiting body is of oyster shape [27]. It grows on deciduous trees in layered clusters. Bioactive compounds isolated from this mushroom posses antihypertensive, anti-inflammatory, antitumor and antioxidant activities [13, 28]. Some of these substances are lectins, phenolic compounds and polysaccharides [29].

***5. Grifola frondosa* (Maitake)**

*Grifola frondosa is* a basidiomycete polyporoid fungus commonly known as 'Maitake' in Japanese [12]. It grows from sclerotium which is an underground tuber like structure. Its major components include protein, carbohydrate, lipid, and fibers. It also contains minerals, free amino acids, organic acids, nucleotides, vitamins B1, B2 and ergosterol. It is also rich in potassium (K) and phosphorous (P), and contains lesser amounts of Mg, Ca, Na and Zn. It is very useful for spleen and stomach, treating hemorrhoids, calming nerves, blood pressure regulation, control of diabetes, reduction of cholesterol, treatment of chronic fatigue syndrome (CFS), and anti-HIV activity [19, 30-32]. This mushroom has been reported to contain useful polysaccharides such as β-glucans, α-glucans, lipids, phospholipids, sterols and nucleotides etc. The polysaccharides and polysaccharide protein complexes from this mushroom have been known to have significant anti-cancerous activity [33]

***6. Inonotus obliquus* (*Chaga*)**

*Inonotus obliquus* grows as a plant pathogen on the trunk of birch trees and also known as birch fungus. It can only be collected from living or freshly cut mature birch trees and dies on dry standing or fallen trees and their content of active compounds decreases dramatically. These mushrooms contain a high content of compounds such as β-glucans which may affect the immune system, and secondary metabolites, including phenolic compounds, melanins, and lanostane type triterpenoids. *I.obliquus* has been shown to exhibit anticancer activity in various types of tumor cells and other diseases in the absence of any unacceptable toxic side effects. *In vitro* studies demonstrated their antiviral, platelet aggregation inhibitory, antiinflammatory and analgesic properties and *in vivo* studies showed their antitumor and antioxidant activities [34].

***7. Agaricus blazei Murill***

*Agaricus blazei* Murill is also known as Mushroom of Sun, Royal *Agaricus* and God's mushroom. The main active constituents of this mushroom are polysaccharides, nucleic acids, neutral lipids, phospholipids and dietary fibres. *A. blazei* is effective against Ehlich's ascites carcinoma, sigmoid colon cancer, ovarian cancer, breast cancer, lung cancer and liver cancer as well as against solid cancer [35,36]

## III. NUTRITIONAL VALUE OF MUSHROOMS

Mushrooms are important sources of food because of their important nutritional value. They are also consumed for their innate flavor and taste. Their nutrient content varies from species to species and also depends on their growth requirement. They have a high percentage of water as compared to fresh vegetables. They contain valuable minerals such as iron, potassium, phosphorus, calcium and copper. They also contain carbohydrate and protein. Mushrooms provide a high protein and low caloric diet and can thus be recommended to heart patients. They also contain all the essential amino-acid required by an adult.

1. **Carbohydrates**

Polysaccharides such as rhamnose, fucose, mannose xylose, fructose, glucose, arabinose, mannitol, sucrose, maltose, and trehalose are the most potent mushroom derived substances with antitumor and immunomodulating properties [37,38]. Their antitumor actions are through the activation of immune response in host organism and cause around 50% reduction in tumor size [39-41]. β- Glucans are the important polysaccharides isolated from mushrooms having anticancer, immunomodulating, anticholesterolemic, antioxidant, and neuroprotective activities [42].

2. **Peptides and Proteins**

Many bioactive proteins are the essential factors of the functional component of mushrooms and have many pharmaceutical applications. These components include lectins, laccases, ribonucleases, ribosome inactivating proteins and fungal immunomodulatory proteins. Mushroom proteins consists of around 20 essential amino acids such as lysine, methionine, valine, Tryptophane, theonine, leucine, isoleucine, histidine and phenylanine [43]. Lectins bind to cell surface carbohydrates specifically and are the most studied mushroom proteins having antitumor, antiproliferative and immunomodulatory activities. They have been purified from *Pholiota adiposa, Hericium erinaceus, and Russula lepida* The ribosome inactivating proteins are the enzymes and have been found to be isolated from *Calvatia caelata, Flammulina velutipes, Hypsizygus marmoreus, Lyophyllum shimeji, and Pleurotus tuber-regium*. They are enzymes that inactivate ribosomes by eliminating one or more adenosine residues from rRNA. Laccases isolated from the mushrooms *Pleurotus eryngii, P.ostreatus*, T*richoloma mongolicum* and *Clitocybe maxima* posses antiviral activities and antiproliferative activities [44-46]. The fungal immunomodulatory proteins (FIPs) are another bioactive proteins purified from *F. velutipes, Ganoderma microsporum, Agaricus blazei, Coprinus comatus, G. frondosa, Volvariella volvacea, L. edodes, P.ostreatus, and Pleurotus citrinopileatus* having anti-tumor and immunomodulatory activities [47]

3. **Vitamins**

Mushrooms are a very good source of many essential vitamins such as thiamine, riboflavin, niacin, biotin and vitamin-C. These vitamins are present in significant amounts in mushrooms. The thiamine content ranges 0.35 mg, 1.114 mg and 1.16 to 4.8 mg in *V. volvacea, A. bisporus* and *Pleurotus species*, respectively. The niacin content was found in *L. edodes* (54.9 mg), *A. bisporus* (55.7mg), *V.volvacea* (64.88 mg) and *Pleurotus species* (46.0 - 108.7 mg) per 100g dry weight of mushroom. Mushrooms are reported to be excellent source of riboflavin and niacin and a good source of panthothenic acid. The value of vitamin C was found in *P. sajor caju* (7.4 mg), *A. bisporus* (1.8 mg), *V. volvacea* (1.4 mg) as mg/100g dry weight of edible mushroom [48]

4. **Phenolic compounds**

Phenolic compouds provide protection against variety of degenerative diseases such as brain dysfunction, cancer, and cardiovascular diseases. They exhibit antiallergenic, antiatherogenic, anti-inflammatory, antimicrobial, antithrombotic, cardioprotective and vasodilator effects. The main characteristic of this group of compounds has been related to its antioxidant activity because they act as reducing agents, free radical scavengers, singlet oxygen quenchers, or metal ion chelators [49,50]. Palacios *et al*., 2001 [51] evaluated total phenolic and flavonoids contents in eight types of mushrooms such as *Agaricus bisporus, Boletus edulis, Calocybe gambosa, Cantharellus cibarius, Craterellus cornucopioides, Hygrophorus marzuolus, Lactarius deliciosus, and Pleurotus ostreatus* and concluded that they contain 1–6mg of phenolics/g of dried mushroom and the flavonoid concentrations ranged between 0.9 and 3.0mg/g of dried matter. The main flavonoid found purified from mushrooms are myricetin and catechin. *B. edulis* and *A. bisporus* presented the highest content of phenolic compounds.

## IV. PHARMACOLOGICAL POTENTIAL OF MUSHROOMS

Mushrooms have been used in health care for treating simple and old age common diseases like skin diseases to present day complex and pandemic diseases like acquired immunodeficiency syndrome (AIDS). Scientists have investigated many health promoting principles from mushrooms for treatment of many common diseases [52]. They contain chemically diverse secondary metabolites having a broad spectrum of biological activities such as antioxidant, antimicrobial, anti-inflammatory, antitumor and other properties [53].

### 1. Antioxidative activity

Antioxidant defense in an organism depends on the endogenous antioxidant systems, and also its dietary intake. The major ROS (reactive oxygen species) defense mechanisms include the enzymatic and non-enzymatic systems. Various substances detected in the mushroom fruiting body, pure culture mycelia, and culture broth have been shown to contain compounds such as phenolics, flavonoids, glycosides, polysaccharides, tocopherols, ergothionine, and ascorbic acid having antioxidative property

[54]. There are two types of mushroom antioxidants such as primary and secondary. The former have properties such chain-breaking and free radical-scavenging whereas the later are able to deactivate metals, inhibit or break down lipid hydroperoxides, and induce regeneration of primary antioxidants. Some mushroom extracts are also found to be able to affect cellular signaling, which enable them to cause changes in gene expression and subsequently activate antioxidative enzymes [55]

## 2. Cardiovascular and Hypercholesterolemia effect of mushrooms

In the development of coronary artery disease (CAD), diabetes mellitus (DM), increased blood levels of total cholesterol, low density lipoprotein (LDL) cholesterol and very low density lipoprotein (VLDL) cholesterol as well as lowered levels of high density lipoprotein (HDL) cholesterol are the major risk factors. Mushrooms such as *Pleurotus, Lentinus, Grifola* are ideal for designing the diets to prevent cardiovascular diseases. This protection is due to their high fibre content, proteins, microelements and low caloric value. The consumption of diet supplemented with *P.florida* provides anti-hyperglycaemic as well as anti-hypercholesterolemia effect [56, 57]

## 3. Antimicrobial activity

The researchers have reported the antimicrobial activity of mushrooms [58]. Khatun *et al*., 2012 [57] observed that petroleum ether, chloroform, acetone and water extracts of *Osmoporus odoratus* have antibacterial activity against *Staphylococcus aureus, Streptococcus pyogenes, Bacillus subtilis, E. Coli and Pseudomonas aeruginosa.* The water extract of *Lentinus edodes* showed growth-enhancing effects on colon inhabiting beneficial lactic acid bacteria, *Lactobacillus brevis* and *Bifido bacteria brevis* [59]. *Hericium erinaceum* shows strong antimicrobial activity against a broad range of infectious agents. Compounds extracted from *Agaricus bisporus, Lentinus edodes, Coprinus comatus and Oedemansiella mucida* have been reported to have antifungal and antibacterial properties [60]

## 4. Immunomodulator activity

Immunomodulators are the most important medicinal mushroom drugs used especially in Japan, China and East Asian countries. Bioactive polysaccharides from mushrooms play a key role in immunomodulation. The ability of these bioactive polysaccharides bound protein to modulate immune cells that is contributed due to their structural diversity and variability of these macromolecules [23]. Substances with immense immunomodulating action have been isolated from *Ganoderma lucidum*, including polysaccharides and triterperoids [19]. Protein-bound polysaccharides PSK (Krestin) and PSP (Polysaccharopeptide) have been isolated from the mushroom *Trametes versicolor*. The Immunomodulator activity of *Schizophyllan commune* is due mainly to host mediated immune responses [61].

## 5. Anti-cancer activity

Cancer is a leading cause of death worldwide. Numerous clinical trials have been conducted to assess the benefit of using commercial preparations containing medicinal mushroom extracts in cancer therapy. 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. The active components in mushrooms responsible for conferring anti-cancer potential are lentinan, krestin, hispolon, lectin, calcaelin, illudin S, psilocybin *Hericium* polysaccharide A and B (HPA and HPB), ganoderic acid, schizophyllan, laccase, etc [62]

## 6. Hepatoprotective activity

Liver damage by hepatotoxic agents of vital consequence because chronic liver injury leads to fibrosis, end stage cirrhosis and hepato-carcinoma immunomodulating activity. Many species of *Pleurotus* contains some active compounds like β-glucan, phenol and vitamin C that increase activity of antioxidant-enzymes *viz.* catalase, superoxide dismutase; these enzymes are responsible for reduction of hepatic cell necrosis [63, 64].

## 7. Anti-inflammantory activity

Inflammation is the natural protective response of the innate immune system to tissue injury or damaging external stimuli such as pathogens, allergens, infections, irritants, and ultraviolet light irradiation [65, 66]. The anti-inflammatory activities of mushroom on macrophages are mediated through the inhibition of some signaling pathways, such as nuclear factor kappa-B (NF-κB) [67]. Extracts of *P. florida, P. pulmonarius*, etc. give a lowering response in both acute as well as in chronic inflammation [28]. Another potent anti-inflammatory agent, a polysaccharide has been extracted from the *P.pulmonarius.* It the acted against carrageenan and formalin –induced paw edema in rats [68].

## V. CONCLUSION

Mushrooms are the important natural resources which aids in improving human health and promoting quality life. To confirm their medicinal and therapeutic properties, a number of studies have been conducted. It was found that they exhibit antitumor, immunomodulating, antioxidant, radical scavenging, cardiovascular, antihypercholesterolemia, antiviral, anti-HIV, antibacterial, antiparasitic, antifungal, hepatoprotective and antidiabetic activities due to presence of bioactive components. Mushrooms are also consumed directly in the diet to promote the good heath due to their high nutritional value. However, the health benefits and novel properties provided by the mushrooms still need further investigations to ensure the high quality and safety. Exact mechanisms of their actions are still need to be explored.

## REFERENCES


[1] Breene W.M., Nutritional and Medicinal Value of Specialty Mushrooms. Journal of Food Protection,1989; 53(10): 883-94.

[2] Saris W.H., Asp N.G., Björck I., Blaak E., Bornet F., Brouns F., Frayn K.N., Fürst P., Riccardi G., Roberfroid M., Vogel M., Functional food science and substrate metabolism. British Journal of Nutrition, 1998; 80: 547-75.

[3] Diplock A.T., Charleux J.L., Functional food science and defense against reactive oxidative species. British Journal of Nutrition, 1998; 80: 577-612.

[4] Lindequist, U. Niedermeyer, T. H. J. and Julich, W. The pharmacological potentials of mushrooms e- CAM, 2005; 2:285–299.

[5] Valverde, M.E., Hernández-Pérez, T. and Paredes-López, O., Edible Mushrooms: Improving Human Health and Promoting Quality Life. Int. J. Microbiology, 2014; 2015:1-14

[6] Gruen, V. E. C. and Wong, H. X. , Immunomodulatory and Antitumor activities of a polysaccharide-peptide complex from a mycelial culture of *Trichoderma* sp. Sci., ,2005; 57; 269-281

[7] Zakia S.A., El-Kattan M.H., Husssein W.A., Khaled A.M., Chemical composition and processing potential of oyster mushroom *Pleurotus ostreatus*. Egypt. J. Agric. RES, 1993; 71: 621-631.

[8] Latifah A.L., Abu Bakar M.D., Abu B.M., Relative distribution of minerals in the pileus and stalk of some selected edible mushrooms. Food Chem.,1996; 56: 115-121.

[9] Wani B.A., Bodha R.H., Wani A.H., Nutritional and medicinal importance of mushrooms. J. Med. Plants Res. 2010; 4(24): 2598-2604.

[10] Beattie G., Lannom R., Lipsick J., Kaplan N.O., Osler A.G., Streptozotocin-induced diabetes in athymic and conventional BALB/c mice. *Diabetes.*1980; *29*: 146-150.

[11] Swanston-Flatt S.K., Day C., Flatt P.R., Gould B.J., Bailey C.J., Glycemic effects of traditional European plant treatments for diabetes: Studies in normal and streptozotocin diabetic mice. *Diabetes Res 10*: 69-73, 1989

[12] Lakhanpal T.N., and Rana M., Medicinal and nutraceutical genetic resources of mushrooms. Plant Genetic Resources. 2005; 3(2): 288–303.

[13] Ajith T.A., and Janardhanan K.K., Indian Medicinal Mushrooms as a Source of Antioxidant and Antitumor Agents. J. Clin. Biochem. Nutr. 2006; 40: 157–162.

[14] Ren L., Visitev A.V., Grekhov A.N., Tertov V.V., Tutelyan V.A. Antiatherosclerotic properties of macrofungi. Voprosy Pictaniya. 1989; 1: 16- 19.

[15] Gareth J.E.B., Edible Mushrooms in Singapore and other South East Asian countries. The Mycologist. 1990; 4: 119-124.

[16] Wasser, S.P. and Weis, A.L., Medicinal properties of substances occurring in higher basidiomycetes mushrooms: Current perspective (review). Int. J. Med. Mushr. 1999; 1: 31–62.

[17] Park, E. J., Kim, K. Y., Kim, J. B., Kim, S. W., Lee, S. Y. and Sohn, D. H. . The antifibrotic effects of polysaccharides extracted from *Ganoderma lucidum* on the experimental hepatic cirrhosis. Yakhak Hoeji. 1994; 38: 338–344.

[18] Kim M.J., Kim H.W. and Choi E.C. Anti-HIV activity of *Ganoderma lucidum*. Journal of Biological Chemistry. 1993; 264:472–478.

[19] Jong S.C. and Birmingham J.M. Medicinal benefits of the mushroom *Ganoderma*. Advancement in Applied Microbiology. 1992; 37: 101–134.

[20] Chang A.W. and Miles P.G., Biomedical research and the application of mushrooms nutriceuticals from *Ganoderma lucidum*. In: Royse DJ (ed.) Mushroom Biology and Mushroom Products. Philadelphia: Pennsylvania State University. 1996; 153–159.

[21] Ying, J.Z, Mao X.L, Ma Q.M, Zong Y.C, and Wen H.A. Icons of medicinal fungi from China. In: Xu YH, translator; Ying JZ, editor. Illustrations of Chinese medicinal fungi. Beijing: Science Press; 1987. pp. 579–85

[22] Breene, W. M. Nutritional and medicinal value of specialty mushrooms. J. Food Prot., 1990; 53: 883–894.

[23] Hobbs C. Medicinal value of Lentinus edodes (Berk.) Sing.(Agaricomycetideae). A literature review. Int J Med Mushrooms. 2000; 2:287-302.

[24] Chihara G. Immunopharmacology of Lentinan, a polysaccharide isolated from *Lentinus edodes*: Its

applications as a host defense potentiator. Int J Orient Med.1992;17:57–77.

[25] Hokama, Y. and Hokama, J. L. *In vitro* inhibition of platelet aggregation with low dalton compounds from aqueous dialysates of edible fungi. Chemical Path. Pharmacol., 1981; 31 (1):177-180.

[26] Khan, M. A., Tania, M., Liu, R., and Rahman, M. M. *Hericium erinaceus*: an edible mushroom with medicinal values. Journal of Complementary and Integrative Medicine, 2013; 10(1); 253-258.

[27] Gunde-Cimmerman N. Medicinal value of the genus *Pleurotus* (fr). P Karst (Agaricales s.l. Basidiomycetes). Int. J. Med. Mush., 1999; 1: 69-80.

[28] Jose N., Ajith T.A. and Jananrdhanan K.K. Antioxidant, antiinflammatory and antitumor activities of culinary medicinal mushroom *Pleurotus pulmonarius* (Fr.) Quel. (Agaricomycetideae). Int. J. Med. Mush. 2002; 4: 329-335.

[29] Kanagasabapathy G, Malek S.N.A, Kuppusamy U. R, and Vikineswary S. Chemical composition and antioxidant properties of extracts of fresh fruiting bodies of *Pleurotus sajor-caju* (Fr.) singer. Journal of Agricultural and Food Chemistry. 2011; 59 (6): 2618–2626.

[30] Adachi K., Nanba H. and Kuroda H. Potentiation of host mediated antitumor activity in mice by beta glucan obtained from *Grifola frondosa* (Maitake).Chemical & Pharmaceutical Bulletin. 1987; 35: 262–270.

[31] Adachi K., Nanba H., Otsuka M. and Kuroda H. Blood pressure lowering activity present in the fruit body of *Grifola frondosa*, (Maitake) I. Chemical & Pharmaceutical Bulletin. 1988; 36: 1000–1006.

[32] Kubo, K., & Nanba, H. Anti-hyperliposis effect of maitake fruit body (*Grifola frondosa*). I. Biological and Pharmaceutical Bulletin, 1997; *20*(7): 781-785.

[33] Okazaki M., Adachi Y., Ohno N., Yadomae T. Structure-activity relationship of (1-3)-β-D-glucan in the induction of cytokine production from macrophages *in vitro*. Biol Pharm Bull. 1995; 18:1320–7.

[34] Zhong, Y., Deng y., Chen Y., Chuang P.Y., and He J.C. Therapeutic use of traditional Chinese herbal medications for chronic kidney diseases. Kidney International. 2013; 84 (6) : 1108-1118.

[35] Mizuno, T., Hagiwara, T., Nakamura, T., Ito, H., Shimura, K., Sumiya, T., Asakura, A. Antitumor activity and some properties of water-soluble polysaccharides from `Himematsutake', the fruiting body of *Agaricus blazei* Murrill. Agricultural and Biological Chemistry. 1990a; 54: 2889-2896.

[36] Mizuno, T., Inagaki, R., Kanao, T., Hagiwara, T., Nakamura, T., Ito, H., Shimura, K., Sumiya, T., Asakuar, A. Antitumor activity and some properties of water-insoluble hetero-glycans from `Himematsutake', the fruiting body of Agaricus blazei Murrill. Agricultural and Biological Chemistry. 1990b; 54: 2897-2905.

[37] Zaidman B.Z., Yassin M, Mahajna J, and Wasser S.P., Medicinal mushroom modulators of molecular targets as cancer therapeutics. Applied Microbiology and Biotechnology. 2005; 67 (4): 453–468.

[38] Heleno S.A., Barros L., Martins A., Queiroz M. J. R. P., Santos-Buelga C., and Ferreira I. C. F. R., Portugal: chemical compounds with antioxidant properties. Journal of Agricultural and Food Chemistry. 2012; 60 (18): 4634–4640.

[39] Wasser S., Medicinal mushrooms as a source of antitumor and immunomodulating polysaccharides. Applied Microbiology and Biotechnology. 2002; 60 (3): 258–274.

[40] Wasser S.P., Current findings, future trends, and unsolved problems in studies of medicinal mushrooms. Applied Microbiology and Biotechnology. 2011; 89 (5):1323–1332.

[41] Zhang M, Cui S.W., Cheung P. C. K., and Wang Q., Antitumor polysaccharides from mushrooms: a review on their isolation process, structural characteristics and antitumor activity. Trends in Food Science &Technology. 2007; 18 (1): 4–19.

[42] Mayell, M. Maitake extracts and their therapeutic potential—a review. Alternative Medicine Review. 2001; 6 (1): 48–60.

[43] Xu X., Yan H., Chen J., and Zhang X., Bioactive proteins from mushrooms. Biotechnology Advances. 2011; 29 (6): 667–674.

[44] Li, Y., Zhang, G., Ng, T. B., and Wang, H. A novel lectin with antiproliferativeand HIV-1 reverse transcriptase inhibitory activities from dried fruiting bodies of the monkey head mushroom Hericium erinaceum. Journal of Biomedicine and Biotechnology.2010b; 1–9.

[45] El-Fakharany, E. M., Haroun, B. M., Ng, T. B., & Redwan, E. R. Oyster mushroom laccase inhibits hepatitis C virus entry into peripheral blood cells and hepatoma cells. Protein and Peptide Letters. 2010; 17(8): 1031–1039.

[46] Crisan E. V., and Sands A., Nutritional Value of Edible Mushroom. In: S. T. Chang and W. A. Hayer, Eds., Biology and Cultivation of Edible Mushrooms, Academic Press, New York, 1978, pp. 137-168.

[47] Mattila, P., Könkö, K., Eurola, M., Pihlava, J. M., Astola, J., Vahteristo, L & Piironen, V. Contents of vitamins, mineral elements, and some phenolic compounds in cultivated mushrooms. Journal of agricultural and food chemistry. 2001; *49*(5): 2343-2348.

[48] Balasundram N, Sundram K, and Samman S., Phenolic compounds in plants and agri-industrial by-products: antioxidant activity, occurrence, and potential uses. Food Chemistry. 2006; 99 (1): 191–203.

[49] Palacios I., Lozano M., Moro C, D'Arrigo M., Rostagno M.A., Martínez J.A, García-Lafuente A, Guillamón E, Villares A., Antioxidant properties of phenolic compounds occurring in edible mushrooms. Food Chemistry. 2011; 128 (3): 674-678.

[50] Thatoi H., and Singdevsachan S.K., Diversity, nutritional composition and medicinal potential of Indian mushrooms: A review. African Journal of Biotechnology. 2014; 13(4): 523 545.

[51] Kozarski M. S., Klaus, P.A., Jakovljevic D., Todorovic N., Vunduk J. P., and Van Griensven, L. Antioxidants of edible mushrooms. Molecules. 2015; 20(10): 19489–19525.

[52] Amirullah, N. A., Abidin, N. Z., and Abdullah, N. The potential applications of mushrooms against some facets of atherosclerosis: A review. Food Research International. 2018; 105: 517-536.

[53] Kolandaivel, P.G., Gandheeswari, P., Therapeutic potential of *Agaricus bisporus* and its antioxidant effect in hypercholesterolemic induced Albino rats. Proc. 5th Int. Medicinal Mushroom Conference, Mycological Society of China, Nantong, China. 2009; 519-525.

[54] Khatun S., Bandopadhyay S., Mitra S., Roy P., Chaudhuri S.K., Dasgupta A., Chattopadhyay N.C., Nutraceutical and antioxidative properties of three species of *Pleurotus* mushrooms. Proc. 5th Int. Medicinal Mushroom Conference, Mycological Society of China, Nantong, China. 2009; 234-241.

[55] Karwa, A., Rai, M., Mycoenhancing the potential of synthetic antibiotics using wild mushrooms: First report. Proc. 5th Int. Medicinal Mushroom Conference, Mycological Society of China, Nantong, China. 2009; 167-172.

[56] Bender S., Dumitrache C.N., Backhaus J., Christie G., Cross R.F., Lonergan G.T., A case for caution in assessing the antibiotic activity of extracts of culinary-medicinal Shiitake mushroom (*Lentinus edodes* (Berk.) Singer) (Agaricomycetidae) Int. J. Med Mushrooms. 2003; 5:31–5.

[57] Khatun S., Islam A., Cakilcioglu U., and Chatterje N. C., Research on mushroom as a potential source of nutraceuticals: a review on Indian perspective. American Journal of Experimental Agriculture. 2012; 2(1): 47.

[58] Loganathan K.J., Venkatakrishnan V., Shenbhagaraman R., Kaviyarasan V., Comparative study on the antioxidant, anticancer and antimicrobial property of *Agaricus bisporus* (J. E.Lange) Imbach before and after boiling. Afr J Biotechnol. 2009; 8: 654–61.

[59] Bobek P., Ozdin L., and Kuniak L., Effect of Oyster mushroom and on the activities of antioxidative enzymes in rats fed the cholesterol diet. J. Ntrl. Biochem. 1997; 8: 469-471.

[60] Fu H.Y., Shieh D.E and Ho C.T. Antioxidant and free radical scavenging activities of edible mushrooms. J. Food Lipids. 2009; 9: 35-43.

[61] Joseph S. V., Edirisinghe I., and Burton-Freeman B. M., Berries: Anti-inflammatory effects in humans. Journal of Agricultural and Food Chemistry. 2014; 62(18): 3886–3903.

[62] Phull A. R., and Kim, S. J., Fucoidan as bio-functional molecule: Insights into the anti-inflammatory potential and associated molecular mechanisms. Journal of Functional Foods. 2017; 38: 415–426.

[63] Chang C. W., Lur H. S., Lu M. K., and Cheng J. J., Sulfated polysaccharides of *Armillariella mellea*, and their anti-inflammatory activities via NF-κB suppression. Food Research International. 2013; 54(1): 239–245.

[64] Adebayo E.A., Oloke J.K., Majolagbe O.N., Science and Biotechnology Congress, Gumma, R.A. Ajani and T.C. Bora,. Antimicrobial and anti-inflammatory potential of polysaccharide from *Pleurotus pulmonarius* LAU 09, Afri. J. Microbiol. Res. 2012; 6(13): 3315-3323.