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Biology and Biochemistry of Mushrooms and their Importance in Medicine, Nutrition and Environmental Aspects

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Abstract:
Mushrooms are the fleshy fruiting body of some fungi arising from the group of mycelium, mushroom use as food and medicine since time immemorial. Traditional and folk medicine practitioners are using mushrooms for their healing and cleansing properties. These have been considered as the Delicacy, in the nutrition point of view mushrooms are placed between meat and vegetables and also called as vegetable meat. All varieties of mushrooms are low in calories and fat, and contain modest amounts of fiber and various nutrients. Mushrooms constitute both a nutritionally functional food as well as a source of physiologically advantageous medicine. Mushroom consumption is increasing rapidly worldwide due to their rich source of bioactive compounds such as functional protein, vitamins, minerals and dietary fibers etc. due to that considering it as precious, and functional food ingredient as food, as tonic, and as medicine to remedy and to treat numerous dangerous illnesses around the world. Mushrooms can serve as agents for promoting equitable economic growth in society. Good resource to a non-green revolution in less developed countries, and in the world at large. Mushrooms are also an important and integral component to create a clean the ecosystem.

Keywords: Bioactive Compounds, Ecosystem, Food, Medicine, Mushroom, Mycelium, Nutrition.

Introduction:

Mushrooms are a group of fleshy macroscopic fungi. They lack chlorophyll having heterotrophic mode of nutrition. The word mushroom is used through world to express the different species of fungus belongs to the order of Basidomyecets or Ascomycetes. Chang and Miles (1992) defined mushroom as a "macro fungus with a distinctive fruiting body which can be either epigeous or hypogenous and large enough to be seen with the naked eye and can be picked with hand." Mushrooms can be found everywhere in soils rich in organic matter and humus, moist wood, animals waste after heavy rain or a sudden change of temperature and soon after a few hours or day's they disappear, leaving no sign except mycelium (Chang 1999). Human use of mushrooms extent as early to 5000 BC. About 2000 species of edible mushrooms are known all over the world. For centuries, some mushrooms have been used in religious ceremonies of many ancient people and primitive tribes. Mushrooms are believed by the Romans to have properties that could produce super human strength, help in finding lost objects and lead the soul to the realm of the gods (Grube et al., 2001). Mushrooms can serve as food, as tonic, and as medicine. A regular intake of mushrooms can make you healthier, fitter, and happier. They can make

you live longer, and always look younger. Mushroom consumption is increasing rapidly worldwide due to their rich source of bioactive compounds such as functional protein, vitamins, minerals, low in calories, carbohydrates, growth promoting substances and high dietary fibers etc due to that considering it as precious, and functional food ingredient (Romi Singh 2017, Girma & Tasisa 2018). Mushrooms can serve as agents for promoting equitable economic growth in society. Good resource to a non-green revolution in less developed countries, and in the world at large. It has great potential for generating a great socio-economic impact in human welfare, at local, national and regional levels Nagaraju 2022..

Biology of Mushrooms:

Mushroom biology is the branch of mycology that deals with mushrooms. It is concerned with any aspect of the scientific study of mushrooms, such as: taxonomy; physiology; genetics; etc. Applied mushroom biology is concerned with all aspects of the application of mushroom biology. It consists of three main components: mushroom science; mushroom biotechnology; and mushroom mycorestoration. Mushrooms are seasonal fungi with fleshy, spore bearing fruiting body, typically produces above the ground of the soil or on its food source as a saprophytic fungus that grows on dead and decaying organic matter. Due to the absence of chlorophyll, it is unable to synthesize its own food and hence is dependent upon the organic matter/substrate for food. Which occupy diverse niches in nature in the forest ecosystem they predominantly occur during the rainy season and also during spring (Shubhra Shukla and A. K. Jaitly 2011). There are about 50,000 known species of fungi and about 10,000 are considered as edible ones. Of which, about 180 mushrooms can be tried for artificial cultivation and 70 are widely accepted as food. Worldwide accepted edible mushrooms are Button Mushroom *Agaricus bisporus,* Straw Mushroom *Volvariella volvacea,* Oyster Mushroom *Pleurotus ostreatus,* Milky Mushrooms *Calocybe indica,* Cremini Mushroom *Agaricus bisporus* Shiitake Mushroom *Lentinula edodes,* Portobello Mushroom *Agaricus,* Enokitake mushrooms *Flammulina velutipes,* Morel Mushrooms *Morchella esculenta* , *Lentinula edodes,* Oyster Mushrooms-*Pleurotus ostreatus,* King Oyster Mushroom -*Pleurotus eryngii,* Lion's Mane Mushrooms *Hericium erinaceus,* Enoki Mushrooms - *Flammulina velutipes,* Porcini Mushrooms -*Boletus edulis,* Maitake *Grifola frondosa,* Matsutake Mushroom - *Tricholoma matsutake* , Reishi Mushroom - *Ganoderma lingzhi,* Giant Puffball *Calvatia gigantean,* Buna Shimeji Mushroom *Hypsizygus tessellates,* Pepeao Jaws Ear Mushroom *Auricularia auricula-judae,* Straw Mushroom - *Volvariella colvacea,* Chanterelle Mushrooms *Cantharellus cibarius* and Other important edible mushrooms are *Calocybe, Coprinus, Boletus, Flammulina* and *Termitomyces* etc. Not all mushrooms are edible, wild mushrooms with white gills or a ring around the stem are considered poisonous. Some other inedible mushrooms look like edible mushrooms, also are there i.e *Amanita phalloides*(Death Cap), *Amanita muscaria, Amanita virosa* (Distroying Angel), *Clitocybe sp. Cortinarius smithi, Gyromitra sp., Paxillus involutus, Tricholoma muscarium* etc (Figure-1).

Fig. 1: Some Edible and Poisonous Mushrooms

Biochemical's of Mushroom:

Mushrooms contain moisture 85–95%, **Carbohydrates** 35–70%, includes starches, pentoses, hexoses, disaccharides, amino sugars, sugar alcohols, and sugar acids. Glycogen -α-glucans.β-glucans, **Protein** 15–34.7 protein content ranges are from 17 g to 42 g per 100 g of dried fruit bodies, significant amino acids i.e leucine, aspartic acid, valine, glutamine, and glutamic acid are found, **Lipids** little fat (4–6%) without cholesterol, important fatty acids linoleic acid, oleic acid, and palmitic acid are included, **minerals** 6–10.9% mostly potassium, calcium, iron, manganese, magnesium, copper, selenium, zinc etc, nucleic acids 3–8%, and large amount of **vitamins** such as thiamine 1.4–2.2 mg, riboflavin 6.7–9.0 mg, niacin 60.6–73.3 mg, biotin, ascorbic acid 92–144 mg , pentatonic acid 21.1–33.3 mg, and folic acid 1.2–1.4 mg/100 g in dry weight. The fruiting body contains approximately 100 different bioactive compounds such as functional protein glucans, laccase, proteoglycan (ubiquinone-9, nebrodeolysin, and lycoprotein), proteoglycans, pleuran (β-1, 3-glucan with galactose, and mannose), pleurostrin (peptide), and phenolic compounds include phenolic acids, flavonoids, hydroxycinnamic acids, hydroxybenzoic acids, lignans, tannins, stilbenes, oxidized polyphenols and dietary fibers. The fruiting bodies are high in antioxidants and anti-aging components like ergothioneine, phenolic compounds, and indole compounds like melatonin, serotonin, and selenium, and found 55 fragrance compounds in mycelium, namely, 27 esters, 9 ketones, 7 thiols, 5 alcohols, 4 terpenoids, 2 phenols, and 1 aldehyde, and also have ash, glycosides, volatile oils, tocopherols, flavonoids, carotenoids, folates, organic acids, etc. (Bhambr et al 2022, Kayode et al 2015, Sanjay et al 2021), (Table-1 & 2).

Table -1: Nutrients content in Mushrooms

Nutrient	**Average in 100gram of mushrooms**
Protein (g)	3.0
Carbohydrate (g)	5.1, including 1.9 g of sugar
Energy (calories)	28
Dietary Fibre	2.2 gm
Total Omega -2 fatty Acids	1.0mg
Total Omega -6 fatty Acids	190 mg
Calcium (mg)	6.9
Ergosterol	56mg
Iron (mg)	1.5
Magnesium (mg)	12
Phosphorus (mg)	85.6
Potassium (mg)	356
Sodium (mg)	2.3
Zinc (mg)	0.9
Copper (mcg)	0.5
Manganese	0.1mg

Selenium (mcg)	11.9
Vitamin C (mg)	4.0
Vitamin D (mg)	21 IU
Thiamin	0.1mg
Ribiflavin	0.3mg
Folate (mcg DFE)	18
Choline (mg)	19.6
Niacin (mg)	4.5
Pantathenic Acid	2.2mg
Pyridoxine (B-6)	0.104 mg

Table -2: Nutritional Value of few most widely Cultivated and Edible Mushrooms

Mushroom	Carbohydrate	Protein	Fat	Fiber	Vit-D (IU/g)	Ash	Energy (Kcal)
Agaricus bisporous	46.19	33.38	3.10	20.80	985	5.80	489
Pleurotus sajor-caju	63.40	20.13	2.70	48.60	496	6.36	426
Pleurotus ostreatus	57.60	30.40	2.30	8.70	484	9.80	275
Volvarella volvaceae	54.80	37.60	2.60	5.60	463	1.20	306
Lentinula edodes	47.60	33.23	3.75	28.90	415	5.20	395
Calocybe indiaca	64.36	17.89	4.10	3.40	486	7.45	393
Auricularia auricula	82.80	4.30	8.30	20.10	438	4.60	358
Flammulina velutipes	73.10	17.50	1.90	3.60	316	7.40	374

Mushrooms have a long association with humankind and provide profound biological and economic impact. From ancient times, man has consumed wild mushrooms with delicacy probably, for their taste and pleasing flavor. Mushrooms constitute both a nutritionally functional food as well as a source of physiologically advantageous medicine. Mushrooms are famous, precious and considered functional food ingredients for the structural and functional activities of any living being. Mushroom consumption is increasing rapidly worldwide due to their rich source of bioactive compounds, functional protein (Anmut Assemie and Galana Abaya 2022), fibers, cholesterol-free and low in calories, excellent source of vitamins, microelements, indoles, polyphenols, carotenoids, tocopherols, nine essential amino acids which required for human growth, complex carbohydrates strengthen the immune system, to increase the protein content in their diet helps lower cholesterol, Niacin can be another good supplement for vegetarians, Ergosterol performs the same function as cholesterol and Vitamin D precursor good Non Animal dietary source. as a powerhouse of minerals, **copper** help the body to absorb oxygen and create red blood cells, contain more **selenium** than any other form of produce, it act as antioxidant to neutralize free radicals, **potassium** is an extremely important mineral that regulates blood pressure and keeps cells functioning properly. ergothioneine antioxidant for the protection against cardio vascular diseases, chronic inflammatory conditions, ultraviolet radiation damages, and neuronal injuries. Alkaloids like Cordycepin, Lectins, Lovastatin for various body functions**.** high significant amino acids, low fat contents, polyunsaturated fatty acids and small amounts of saturated fatty acids are almost ideal for a nutrition program aimed to prevent hypercholesterolemia, cardiovascular diseases, reduction of total

blood cholesterol, lipoprotein cholesterol and antioxidant activities, in the regulation of blood lipid levels and reduction of blood glucose levels also used as therapeutic foods to check diseases such as hyper-diabetes, hypertension, atherosclerosis and cancer mainly due to their chemical profile. Antioxidants in mushrooms help in prevent lung, prostate, breast, and other types of cancer, choline help in muscle movement, learning, and memory, transmission of nerve impulses, reduce the risk of some types of cancer, Dietary fiber, Beta-glucans may help manage type 2 diabetes, reduce blood glucose, potassium can help regulate blood pressure, and this may decrease the risk of hypertension and cardiovascular disease (Gloria *et al.* 2021, Robin *et al.* 2021) (Table-3 & 4).

Table -3: Medicinal value of few edible Mushrooms

Mushroom	**Compounds**	**Medicinal properties**
Agaricus bisporus	Gallic acid, protocatechuic acid, catechin, caffeic acid, ferulic acid and myricetin, Lectine	Antioxidant activity
		Immune system enhancer
		Anticancer
		Enhance Insulin Secretion
Pleurotus ostreatus	Lovastatin: inhibitor of 3-hydroxy-3-methylglutaryl coenzyme A reductase	Reduction of cholesterol
	Oyster mushroom concentrate	Anti-inflammatory activity
Pleurotus eryngii	Acidic glycosphingolipids	Antitumour activity; immune system enhancer; antibacterial activity
Lyophyllum shimeji	A novel fibrinolytic enzyme: α-chymotrypsin	Blood anticoagulant
Lentinula edodes	Polysaccharides, Eritadenine, Lentinan	Antioxidant, Anticancer, Lower Cholesterol
Auricularia auricula	Acidic Polysaccharides	Decrease Blood Glucose
Ganoderma lucidum	Ganoderic acid, Beta Glucan	Liver Protection, Augments immune System, Inhibit Cholesterol Synthesis, Antibiotic Properties
Ganoderma frandosa	Polysaccharides, Lectins	Increase Insulin secretion, decrease blood glucose
Crucibulum leave	A new salfredin-type metabolites (DSM 1653 and DSM 8519	Inhibition of the enzyme aldose reductase
Cordyceps sinensis	Cordycepin	Cure Lungs Infection, Hypoglycemic activity, Anti depressant Activity, Cellular Health Properties

Mushroom	Compounds	Medicinal properties
Phallus indusiatus	A *β*-D-glucan called T-5-N	Anti-inflammatory properties
		Antioxidant capability
Flammulina velutipes	Ergotheoneine, Proflamine	Antioxidant, Anti Cancer activity
Hericium erinaceus	Glycoprotein HEG-5	Hemaglutinating activity
	Polysaccharides (HEPs)	Antibacterial activity against *Helicobacter pylori*
	Glycoprotein HEG-5	Anticancer potential against human gastrointestinal cancers
Hydnellum peckii	(2,5-dihydroxy-3,6-bis (4-hydroxyphenyl)-1,4-benzoquinone)	Anticoagulant
		Antibacterial activity atromentin and leucomelone
Trametes versicolor	Polysaccharide -K	Decrease Immune system Depression

Table -4: Enzymes produced by few edible Mushrooms

S.No	Mushroom	Enzyme
1	Agaricus bisporus	Cellulose, Endoglucanase, Cellobiohydrolase, Laccase, Tyrosinase
2	Boletus edulis	Antioxidant enzymes, Superoxide
3	Calocybe indica	Mannitol dehydrogenase, Laccase, Xylanase
4	Cantharellus cibarius	Tyrosinase, Amylase, Laccase, Cellulase Protease
5	Ganoderma lucidum	Cellulose, Hemicellulose, Laccases, Cellobiohydrolase, Haem peroxidases
6	Lentinus edodes	Catalase, Superoxide Dismutase, Ascorbate , Peroxidase and Glutathione Reductase
7	Pleurotus ostreatus	Lignin Peroxidases, Manganese Perioxidase, Cellulases, Laccase
8	Pleurotus sajor-caju	Cellulase, Xylanase, Endoglycanase, B-glucosidase, Laccase, Lignolytic enzyme
9	Ramaria botrytis	Laccase, α-amylase, Xylanase, β-glucosidase, exo-β-1,4-glucanase, Chitinase, Lipase, Protease
10	Volvariella volvacea	Cellulase, Endoglucanase, β-glucosidase, Laccase

Mushrooms have more medicinal properties it help to control many human ailments include anti-oxidant, anti-inflammatory, anti-carcinogenic, anti-microbial, antibacterial, anti-fungal, anti-diabetic, anti-angiogenic, immunemodulatory, hepatoprotective, hypoglycemic, anti-viral, anti-tumor, anti-hypercholesterolemic, anti-hypertensive, protecting the liver, promoting general fitness, anti-asthmatic,

anti-obesity, anti-atherosclerotic, and anti-ulcer, due to that fact Increased interest in consuming mushrooms as food, as tonic, and as medicine to remedy and to treat numerous dangerous illnesses around the world (Figure-2).

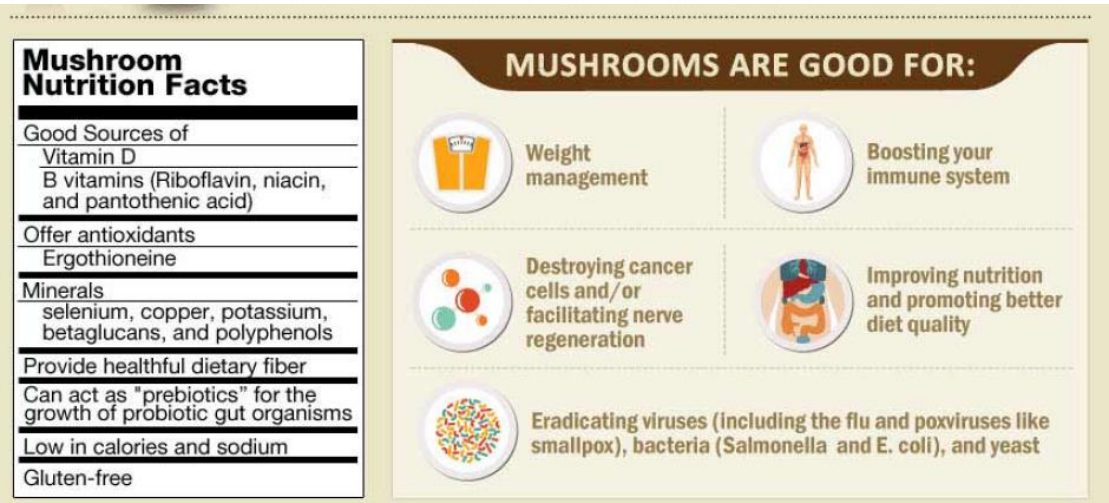

Fig. 2: Biochemical's of Mushroom and its importance for human beings.

Mushrooms are an important and integral component of the ecosystem. Mushrooms are seasonal fungi, which occupy diverse niches in nature in the forest ecosystem they predominantly occur during the rainy season and also during spring. Mushroom mycelia can produce a group of complex extracellular enzymes which can degrade and utilize the lignocellulosic wastes in order to reduce pollution. Mushroom mycelia can play a significant role in the restoration of damaged environments. Saprotrophic, endophytic, mycorrhizal, and even parasitic fungi/mushrooms can be used in mycorestoration, as like mycofiltration (using mycelia to filter water), mycoforestry (using mycelia to restore forests), mycoremediation (using mycelia to eliminate toxic waste), and mycopesticides (using mycelia to control insect pests). These are the potential to create a clean ecosystem, where no damage will be left after fungal implementation (Figure-3).Mushrooms have also been used for dyeing wood and other natural fibers. The chromosphores of mushroom dyes are organic compound and produce strong and vivid colors, and all colors of the spectrum can be achieved with mushrooms dyes. Mushrooms are potential candidates for the production of industrially important enzymes using cheap raw materials like agro-waste. .

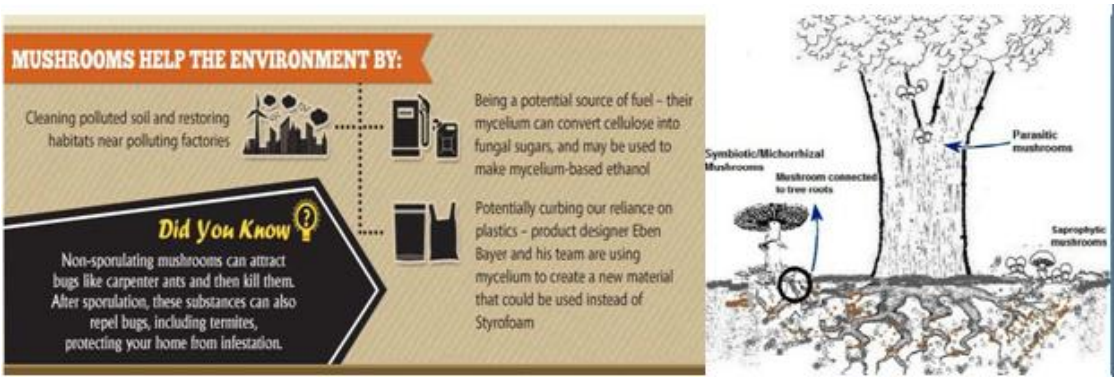

Fig. 3: Mushrooms in Environmental protection

Conclusion:

Mushroom is a general term used mainly for the fruiting body of macrofungi (Ascomycota and Basidiomycota). The edible fungi in addition to mushrooms are also known as morels, truffles, puff-balls, tudstools, morels truffles widely used as food since time immemorial. Mushrooms have a long association with humankind and provide profound biological and economic impact. Mushrooms can serve as a functional food, tonic, as medicine to control many human ailments, including antioxidant, anti-inflammatory, anti-carcinogenic, anti-viral, anti-fungal, anti-bacterial, anti-diabetic, anti-angiogenic, immuno-modulatory, hypoglycemic, and hepatoprotective. Mushrooms are the rich source of all needed material for our life. A regular intake of mushrooms can make you healthier, fitter, and happier. They can make you live longer, and always look younger. Mushrooms can serve as agents for promoting equitable economic growth in society. Mushrooms are taking part in non-green revolution in less developed countries, and in the world at large. These are great potential for generating a great socio-economic impact in human welfare and in the restoration of damaged environments.

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