Bio-active Compounds of Mushrooms: A Review

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Abstract: Mushrooms are known for its nutritional and medicinal properties form decades. In ancient Greek history mushrooms were served to soldiers for strength and in Roman Empire they were known as the "Foods of the Gods". Modern science gives a special seat to mushrooms for its Anti-allergic, Anti-bacterial, Anti-fungal, Anti-viral, Anti-cancer, Anti-inflammatory and other therapeutic uses. Food and Agricultural Organization (FAO) recommend mushrooms for the developing countries as it is full of proteins. There are various species of mushrooms around the world, among which some are edible, some are medicinal and some are highly poisonous so we must be sure about their identity before consumed. Mushrooms are packed of Vitamins, Proteins, Fibres, essential amino-acid which helps us to keep ourselves healthy and fit. Mushrooms are only non-animal food source of vitamin D which helps us to keep our bones strong. It is full of Vit-C and zinc which helps to build strong immunity.

Keyword: **Mushroom, Anti-inflammatory, Anti-fungal, Anti-cancer, non-animal food source.**

Introduction

Mushrooms are an important and diversified collection of macro fungi sharing a place within Basidiomycetes and Ascomycetes; with the arrangement of sexual spores and a cell cycle. Mushroom is being loved as a gourmet food throughout the globe since fragment for their deliciousness and unmatched flavour. It has been found that varieties of mushrooms species having little pharmaceutical production house producing thousands of unique constituents with undoubtedly important biological ownership. They have a age old history about their uses in eastern manuscripts, however their marvellous results in advancement of good health and criticalness are being upheld by present day reviews. In recent times, mushrooms have evolved as a great originator of nutraceuticals, anti-oxidents, anti-cancer, prebiotic, immune booster, anti-inflammatory, cardiovascular, anti-microbial and anti-diabetic property. Improper nutrition because of current way of life and the progress of daily life span are the two key purposes behind the growth rate of sickness everywhere on the earth. Oxidative stress produces by disproportion ofdigestion and aplenty of reactive oxygen species (ROS)result of disorders like digestive disorder, coronary diseases, several neural diseases, i.e., Parkinson's and Alzheimer's, early aging and various types of cancers. These ROS are developed inside the cellular organisms, along with different outer sources like ionizing radiation, chemotherapeutics, ultra violet, inflammatory cytokines, and environmental poisons. It's become unavoidable to breathing in poisonous chemical of environment in today's world.

Venkatesh and Sood (2009), manufactured some phenolic antioxidants contain butylated hydroxynisole, butylated hydroxytoluene and others e.g. propyl gallate, tert-butylhydroguinone, ethoxyquin, and all adequately hinder oxidation.

Ferreira *et. al.* (2009), and Kozarski*et. al*. (2014), informed that some synthetic anti-oxidants may bring antagonistic harmful impacts under specific conditions. They also brought BHA and BHT on a quick expanded interest as a natural anti-oxidant substance

BHA, which is all the time utilized as an additive in sustenance industry, can negatively affect the control the movement of mitogen-activated protein kinase (MAPK) contingent upon the dose (Kozarski*et. al.*, 2014 & Yu *et. al.*, 1997). European Union approved a few synthetic anti-oxidants to be used as an additive (Lundebye*et. al.*, 2010).

Ferreira *et. al.* (2009);Kozarski*et. al*. (2014) and Khatua*et. al.* (2013), mentioned therequirement of natural choices of anti-oxidant food substances are derived from shopkeepers.Being late, edible mushrooms now have pulled in consideration as a source of antioxidants.

They may be utilized straightforwardly in improvement of anti-oxidant guards with help of dietary supplementation to lessen the limit of stress of oxidative. Such in vitro methodologies having fewer acceptability.

Chang & Wasser (2012),described that the process inflammation in humans is thought to be a piece of the complex organic reaction that eliminates jolts, e.g. pathogens, harmed cells or disturbance. These reactions carry various side effects, for example, fever, swelling and pain, therefore of many related change, for e.g. vasodilatation, expanded vascular penetrability and plasma extravasation. Mushroom specialists are now estimated the genuine nutritive estimation of mushrooms. They also find out that Low sodium (Na) percentage of mushroom is valuable for patients having hypertensive and a higher amount of potassium (K) and phosphorus (P), which are totally imperative in orthomolecular perspective.

Along with great taste, mushrooms also have very unique mixture of high measure of total low fat, useful protein along with high extent of polyunsaturated fatty acids (PUFA), for which they are known as low calorie diets. Mushrooms also serves us all the important vitamins like B1 (thiamine), B2 (riboflabin), B3 (niacin), B9 (folate), B12 (Cobalamin), C (ascorbic acid), D (cholecalciferol), and E (tocopherols). Glycemic record in mushrooms are low along with high menintol which is very suitable for diabetic patients.

In Asian homes, mushrooms are utilized as critical wellspring of cures against different illness and sicknesses for its oxidative stress nature (**Khatua*et. al.*, 2013**).

The future progressing research tasks are planned as advancement of as a new source of craved drugs and to help in the upcoming research work to identify the novel compounds of mushroom species to help in human development.

Anti-oxidant properties of mushrooms

A great variety of wild and cultivated mushrooms were reported to having antioxidant qualities. Essenceof fungi contains many ingredients, each of these components having its own determined biological effects (**Wasser SP, 2010**). The mushroom fruiting bodies, mycelium and broth having antioxidant compounds in the form ofascorbic acid,phenolics, flavonoids, glycosides, poly-saccharides, tocopherols, ergo-thioneine, and carotenoids (**Kozarski*et. al.*, 2015**; **Chen *et. al.*, 2012**& 28–105). Different observations were used to determine the mushroom’s anti-oxidative properties and their level of activity. For example, techniques based on the exchange of hydrogen atoms and electrons, the capacity to chelate ferrous (Fe^{2+}) and cupric (Cu^{2+}) particles, the electron spin resonance (ESR) strategy, erythrocyte hemolysis and the observing of the action of SOD, CAT and GPx (**Kozarski*et. al.*, 2015**; **Chen *et. al.*, 2012**; 28–98).Mushroom agents can show cast their defensive properties by various mechanisms at various phases of the oxidation procedure. Fundamentally, there are 2 types of anti-oxidants- prime (chain breaking, free radical scavengers) and secondary or preotective (**Brewer MS, 2011**;**Ferreira *et. al.*, 2009**, **Kozarski*et. al.*, 2014**; **Kozarski*et. al.*, 2015**; 28–98, 101–103]. Secondary anti-oxidants can deactivate metals, restraint or breakdown of lipid hydroperoxides, anti-oxidants recovery, singlet oxygen ($^1O_2$) extinguishing and so on. For finding the evaluation and recognition different strategies have been used, i.e. gas chromatography (GC) and high performance liquid chromatography (HPLC) combined to reliable detection gadgets, Fourier transform infrared (FTIR), Nuclear Magnetic Resonance (NMR), UV-VIS spectroscopy and various spectrophotometric measures (**Kozarski*et. al.*, 2015**;**Chen *et. al.*, 2012**;20-103; **Suabjakyong*et. al.*, 2015**).

Analgesic and anti-inflammatory properties of mushrooms

Inflammation can be described as co-operations between cells and soluble factors that is produced in tissue in case of any injury, poisonous, diseases or post bloodlessness, or damage of immune system (**Nathan C, 2002**). In generally the information about the function and rebuilding procedure is connected to the activity of important cell. When the cells are open to safe stimulants, the pro-inflammatory cells, eg. Numerous molecular mediators’ stats by various host cells, monocytes, macrophages, to start the inflammation process. It causes many inflammation diseases like Juvenile idiopathic arthritis, multiple sclerosis, gastritis, inflammatory bowel diseases (IBD), rheumatoid arthritis, bronchitis, and artherosclerosis (**Levine TB & Levine AB, 2012**).

Mushroom is a functional food used for its high nutritional values. They also highly appreciated for their high therapeutic and medicinal applications (**Wasser SP & Weis SP, 1999**;**Chang ST & Miles PG, 2004**). Various bioactive compounds of mushrooms are tested as significant anti-inflammatory qualities (Table 1).

Table 1: Anti-inflammatory activities of different mushroom species:

Mushroom species	Plant part	Extracting solvent	references
Agaricus blazein (Himematsutake)	WM	Chloroform	115
Agaricus bisporus (Button Mushroom)	WM	Methanol	116
	FB	Ethanol	117
Agaricus subrufescens	WM	Water	118
Agrocybeaegerita	FB	Methanol	119
Agrocybecylindracea	FB	Water	120
Albatrelluscaeruleoporus	FB	Methanol	121,122
Amanita muscaria	FB	Water,Methanol, Ethanol	123
Boletus edulis (Penny bun)	WM	Methanol	116
Cantharelluscibarius (Chanterelle)	WM	Methanol	116
Cantharellustubaeformis	WM	Water	124
Cordycepsmilitaris	SC/FB	Ethanol	125
Cordycepspruinosa	FB	Methanol	126
Caripiamontagnei	FB	Methanol	127
Cyathusafricanus	SC	Ethyl acetate	128
Cyathushookeri	SC	Ethyl acetate	129
Daldiniachildiae	FB	Not mentioned	130
Elaphomycesgranulates	FB	Ethanol	131,132
Flammulinavelutipes (Enokitake)	WM	Ethanol	133
Fomitopsispinicola (Red belted conk)	SC	Ethanol	134
Grifolafrondosa (Hen of woods)	SC	Ethyl acetate, Acetone	135
	SC	Methanol, Ethyl acetate	136
Ganodermalucidum (Reishi Mushroom)	FB	Ethanol	137
	FB	Ethanol	138
Geastrumsaccatum	FB	Ethanol	139
	FB	Water, Ethanol, Ethyl acetate	140
Inonotus obliquus	FB	Petroleum ether, Ethyl acetate	141
	FB	Methanol	142
	FB	Ethanol	143
Lactariusdeliciosus	WM	Methanol	116
Lactariusrufus	FB	Water, Ethanol	144
Lentinusedodes (Shiitake)	FB	Water	145

Lentinuspolychrous	SC	Ethanol	146
Lyophyllumdecastes	FB	Methanol	147
Phellinus linteus	FB	n-butanol	148
	FB	Ethanol, n-hexane, n-butanol	149
Pholiotanameko (Nameko)	WM	Ethanol, Acetone, Acetyl ether	150
Pleurotus pulmonarius	FB	Not mentioned	151
	FB	Water, Ethanol	152
Poriacocos	SC	Ethanol	153
Termitomycesalbuminosus	SC/FB	Ethanol	154

WM: whole mushroom; FB: fruiting bodies; SC: submerged culture.

Mushrooms is a good source of analgesic medicines which are vastly use as pain relief as it a part of inflammation process. In the list given below we enlist some major edible mushrooms with their active compound (Table 2).

Table 2: Analgesic activities of mushroom species:

Mushroom species	**Active compounds**	**References**
Agaricus bisporus var. Hortensis	Fucogalactan	161
Agaricus brasiliensis	Fucogalactan	161
Agaricus macrospores	Agaricoglycerides	162-164
Cordycepssinensis	Cordymin	173-175
Coriolus versicolor	Polysaccharopeptides	168-172
Grifolafrondosa	Agarucoglycerides	180
Inonotusobliqus	Methanol extract	177
Lactariusrufus	Soluble β-glucans	179
Phellinus linteus	EtOH extract	178
Pleurotus eous	Methanol and aquous extract	160
Pleurotus florida	Hydroethanolic extract	159
Pleurotus pulmonarius	β-glucans	155-158
Termitomycesalbuminosus	Crude saponin and polysaccharide extract	176

Mushrooms: the nutrient all-rounder

Mushrooms are re-honoured globally by mankind for its unique flavour and supernatural powers. Almost 2000 mushroom species are identified and out of them only 25 species are known to be eatble and only few commercial cultivation techniques are known. Till the day, mushrooms or fungi are still underutilized compare with other conventional dietary fibre, like cereals, legumes, vegetables, and fruits (**O'Shea *et. al.*, 2012&Elleuch*et. al.*, 2010**). Mushrooms are a type of fungi that have distinctive fruiting bodies of both edible and medicinal types. The edible fruiting body of mushrooms can be consuming in fresh and dried from and medicinal mushrooms which are considered as fungi that cannot be eaten, having bio-pharmaceutical quality for having the components like triterpenoids and poly-saccharides. Novel dietary fibres (DFs) having so many beneficial effects to human health. These DFs are mainly found in plant cell, mushroom cell wall is also considered as DF. The composition of mushroom cell wall containsfibrillar (hairy like)and matrix components including chitin (straight-chain (1→4)-*β*-linked polymer of N-acetyl glucosamine) and polysaccharides like (1→3) - *β-D*-glucans and mannans, respectively (**Bartnicki-Garcia S, 1970**). The cell wall of these mushrooms are made up of non-digestible carbohydrates (NDCs) which are considered as source of Df and these are resistance to human enzymes. These mushrooms have great nutritional values with rich protein and essential amino acid, poor fat and fibre.

Table 3: Food values of different species of mushrooms:

Mushroom Species	**Protein (%)**	**Fat (%)**	**Ash (%)**	**Carbohydrates (%)**	**Energy (kcal/kg)**
Agaricus bisporus (Button Mushroom)	14.1	2.2	9.7	74.0	325
Agaricus blazei (Himematsutake)	31.3	1.8	7.5	59.4	379
Lentinusedodes (Shiitake Mushroom)	4.5	1.73	6.7	87.1	772
Pleurotus eryngii (King Oyster)	11.0	1.5	6.2	81.4	421
Pleurotus giganteus	17.7	4.3	_	78.0	364
Pleurotus ostreatus (Oyster Mushroom)	7.0	1.4	5.7	85.9	416
Pleurotus sajor-caju	37.4	1.0	6.3	55.3	_

Adopted from Carneiro*et. al*. 2013 [185]; Kala c 2013 [186]; Phan *et. al*. 2012 [186]; Reis *et. al*. 2012 [188].

Growth characteristics and post-harvest condition play a vital role in the nutritional value and chemical composition of edible mushroom. These nutritional values and composition can also be varying from species to species and within the species (**Klaus *et. al.*, 2013**&**Kozarski*et. al.*, 2012**). Moisture percentage in mushrooms is very high, ranges from 80 to 95g per kg in dry form. Eatable mushrooms means a protein package, 200-250g per kg while dry form; leucine, glutamine, valine, aspartic and glutamic acid are also found in plentiful amount (Table 3). The main fatty acid present in mushrooms are oleic (C18:1), palmitic (C16:0); and linoleic (C18:2); but still it is counted under low-calorie food as they provide low fat around 20-30 g/kg in dry form. These mushrooms contain high amount of ash, around 80-120g per kg of dry component (K, Mg, Cu, P, Zn, and Fe). Carbohydrate percentage is also very high in edible mushrooms, along with glycogen, mannitol, chitin, and trehalose; fructose and sucrose found in low percentage. They also contain fibres, hemicelluloses, β- glucans and pectic substances. Mushrooms are also rich in essential vitamins like vitamin B2 (Riboflavin), folates, niacin and vitamins like C, B1, B12, and E. In between all these vitamins mushrooms are known to be only non-animal food source of vitamin D, which it the only source of vitamin D for vegans and vegetarians. Wild mushrooms are a great source of vitamin D2, which is unavailable in cultivated ones. Mushroom need UV-B light to produce vitamin D2 but cultivated mushrooms need darkness [**Guillam'on*et. al.*, 2010**; **Mattila et. al., 2001**; 191-196].

Fatty acid content of different species of mushrooms (g/100g fresh weight)

Species	Palmitic	Stearic	Oleic	Linoleic	Linolenic
Agaricus bisporus (Button Mushroom.)	11.90	3.10	1.10	77.70	0.10
Agaricus blazei (Himematsutake.)	11.38	2.8	1.85	72.42	
Lentinusedodes (Shiitake Mjushroom.)	10.3	1.6	2.3	81.1	0.1
Pleurotus eryngii (King Oyster.)	12.8	1.7	12.3	68.8	0.1
Pleurotus ostreatus (Oyster Mushroom.)	11.2	1.6	12.3	68.9	0.1

Collected from Carneiro*et. al*. 2013 [185]; Reis *et. al*. 2012 [186].

Conclusion

Few mushroom species are put up as a source of bioactive compounds due to their dietary values and all these dietary values can bea great source food supplements if we keep mushroom in our regular eating routine. Advanced and pro-efficient biotechnological strategies could be use to obtain highest yield and metabolites from medicinal mushrooms. Studies and experiments observed that mushroom can prevent distinctive types of diseases. More dedicated research work should undertake to isolate, purify, and to know more about the novel anti-oxidant, nutraceutical, anti-inflammatory, and analgesic compounds. This review discusses the potentiality of natural anti-oxidants, analgesic metabolites, and anti-inflammatory compounds that are present in mushrooms. Apart from these uses, these metabolites can use as a cosmeceuticals as a safe and natural products without any side effects. Still we need more detail studies to understand more about these active compounds and the process which is lead us to the place where we can take these bio active compounds in place of drugs to make human life a more healthy and wealthy with less side effects.

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