Int J Biol Med Res.2018 ;9(2):6288-6295

Contents lists available at BioMedSciDirect Publications

International Journal of Biological & Medical Research

Journal homepage: www.biomedscidirect.com

Original Article

Enroll Plants in Natural Bioactive Compounds in Biological Research including their Pharmacological properties

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ARTICLE INFO

Keywords:
Mushroom,
Bioactive Compounds,
Pharmacological Properties

ABSTRACT

A mushroom (or toadstool) is the fleshy, spore-bearing fruiting body of a fungus, typically produced above ground on soil or on its food source. Mushrooms have been consumed since earliest history; ancient Greeks believed that mushrooms provided strength for warriors in battle, and the Romans perceived them as the "Food of the Gods." For centuries, the Chinese culture has treasured mushrooms as a health food, an "elixir of life". For thousands of years it has been used as a potential source of medication and also a nutrient notable supplier of fibres, proteins, vitamins etc. Many mushroom species produce secondary metabolites that can be severely toxic and may cause psychosis. Although there are only a small number of deadly species, several others can cause particularly severe and unpleasant symptoms. This review includes a brief discussion on medicinal & toxic mushrooms and also highlights on some cultivated mushrooms in Bangladesh.

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Introduction

The prevalence of high-quality nutrition and in relation to preventing numerous human health complications mushrooms are widely accepted as salubrious food and medicinal component. Mushrooms are voluminous fungi with edible, poisonous or hallucinogenic characteristics mostly from Basidiomyota, Agaricomycetes phylum of fungi containing hypogeous or epigeous fruiting body. In concern of mushroom's unprecedented health benefits, desirable aroma, taste and high nutritional content; developed countries consumption of mushroom has traditionally increased and settle down as regularly. Developed countries in the world produce countless amounts of mushrooms every year. Worldwide most of the world productions of mushrooms are from USA, UK, Canada, Italy, France, Germany, China, and Japan. Thus, in Bangladesh (one of the most developing country located in South East Asia) mushroom production is yet to come at compatible stage where still mushroom consumption has not been effectively increased even though it has decent quality atmosphere , soil and other factor that favor mushroom cultivation . However, in conformity with recent estimates, mushrooms constitute at least 12,000 species in the ecosystem and 2,000 species are reported as edible among the known. About 35 edible mushroom species are commercially cultivated and nearly 200 species were collected from wild and used for medicinal purposes [1]. A survey over Bangladesh to delineate the biodiversityof mushrooms, total of 24 species of mushrooms belonging to 17 genera and 14 families were identified. The identified genera were Agaricus sp., Ganoderma sp., Armillaria sp., Coprinus sp., Cortinarius sp., Hebeloma sp., Macrolepiotia sp., Mycena sp., Lepiota sp., Amanita sp., Daldinia sp., Tuber sp., Volvariella sp., Hypholoma sp. and Coprinellus sp and few more [4]. Seven species of edible mushrooms namely *Agaricus bisporus, ganoderma lucidum, Lentinula edodes*, *Pleurotus ostreatus, Pleurotus sajor-caju, Pleurotus florida and Pleurotus HK- 51* are the most abundant edible mushrooms found in Bangladesh [Table 1]. Due to the increasing complications of different human health hazards humans are constantly ransacking for alternative therapeutics most predominantly from natural sources. Initiative research has revealed some medicinal mushroom isolates to have cardiovascular, anticancer, antiviral, antibacterial, antiparasitic, anti-inflammatory, and antidiabetic properties [2, 3]. To approximate the nutritional content of mushrooms different study on different mushrooms has taken and in general mushrooms contain protein (7.2 – 36.6%), carbohydrates (52.3 – 88.6%,), lipid (1.7 – 3.0%,) , ash (1.4 – 9.0%) and different micronutrient [5].

Table 1: Total nutrients approximation percentage of 5 mushrooms species in Bangladesh

Species	Moisture	Protein	Carbohydrate	Fat	Fiber	Ash	Energy (kcal)	Reference
Pleurotus ostreatus	73.7	10.5	81.8	1.6	7.5	6.1	367	[6]
Pleurotus florida	91.5	18.9	58	1.7	11.5	9.3	265	
Agaricus bisporus	89.5	26.3	59.9	1.8	10.4	12	328	
Lentinula edodes	90	17.5	67.5	8	8	7	287	
Pleurotus flabellatus	91	21.6	57.9	1.8	11.4	10.7	271	

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Edible mushrooms reflect enormous food value of our quotidian diet as they may contribute both macro- and micro-nutrients. A great extent of mushroom eaters can achieve their RDA(recommended daily allowance) and DRI (daily recommended intake) for their high content of essential amino acids, vitamins, minerals and low lipid content, copper, iron, magnesium calcium, phosphorus, zinc, folate, niacin, vitamin A, B6, B12, C, E, riboflavin, thiamin, , energy, carbohydrate, fiber and protein than non-mushroom eaters. For vegetarians regular consumption of medicinal and edible mushrooms could inaugurate a functional or medicinal improvement in their health and touch the pinnacle of their nutritional requirement [7]. Medicinal component from mushroom found in Bangladesh, such as *Ganoderma lucidum*, *Lentinus edodes*, *Pleurotus ostreatus*, *Trametes versicolor*, *Tremella fuciformis* are highly potential for therapeutic and pharmaceuticals industry. Mushrooms are also been admonished for its toxicity. *Omphalotus illudens*, *Amanita muscaria*, *Amanita pantherina, Amanita phalloides*, *Amanita virosa*, *Amanita verna*, *Sarcosphaera coronaria*, *Chrysina macropus*, *Cortinarius orellanus* are the most deadly poisonous mushrooms because of their various toxins. It can be very poisonous, sometimes deadly poisonous. Common toxic compounds in mushroom include amatoxins, phallotoxins, gyromitrin, orellanine and other toxins are reported for its liver failure, renal failure, hemolysis, fever, gastrointestinal effects. Naturally toxic mushrooms can affect gastrointestinal tract, central nervous system, liver. So it is important to be more conscious to pick mushrooms. In perturbation for the upcoming challenge to battling against tremendous disease; especially from microbes it is important to look for alternative therapeutic and pharmacological components, in this concern mushroom can be a very topnotch one to research with.

Phyto-chemical screening of mushrooms:

Mushrooms accumulate a variety of phyto-chemicals and secondary metabolites, including phenolic compounds, polyketides, terpenes, steroids and many more. These metabolites could be most valuable precursor and used in the treatment against various complications such as diabetes, cancer, inflammation, cardiovascular, that occur in human body. In this concern numerous researches has been placed to describe characteristic of phytochemicals and potential uses of them. Thus, Mushrooms such as *Ganoderma lucidum* (Lactones, triterpines), *Lentinus edodes* (Lentinan, heteroglucan-protein (LEM) comprises anticancer, antitumor, immuno-stimulating, anti-allergic, anti-inflammatory bacterial and parasitic infections, hepatoprotective, cardiovascular effects activities and many more [8, 9]. Another study on *Hericium erinaceus* (Beta-D-glucans, Ergosterol and Cyathane derivatives) possesses general vigor, promote digestion, nerve growth stimulations [10]. *Boletus edulis* (ergosterol, ergosterol peroxide tocopherols) has antimicrobial and anti-inflammatory activity and cytotoxicity to various tumor cell Anti-viral activity [11]. *Inonotus obliquus* (betulin, phytosterols) has anti-inflammatory effects [12]. Study on *Grifola frondosa* (1,3 and 1,6 Beta glucans) revealed its various complex activity to improve spleen and stomach ailments, calming nerves , anti HIV, antihypertension, antidiabetic and antiobesity [13,14].

Alongside its medicinal phytochemicals it also contains toxic phytochemicals. Sometimes it can be deadly poisonous. There are some mushrooms that contain exceptionally powerful toxins that demonstrate a real hazard to health even though ingested in very trace doses. Species from the family Amanitaceae belongs to horrendous toxicity. Species of Amanita genus such as: *Amanita phalloides, A. virosa, A. verna, A. ocreata, A. bisporigera, A. subalpiacea, A. tenuifolia and A. hygroscopica* contain (amatoxin, phallotoxin that includes phalloin, phalloidin, phallisin, phallacidin, phallacin, phallisacin and Virotoxin) it can affect CNS, GIT [15, 16]. Species from Inocybe genus: *I. asterospora, I. fastigiata f. subcandida, I. gobeyi, I. lilacina, I. nappies, I. pallidicremea, I. patowillandii, I. radiate, I. repanda and I. rimosa* have toxic properties. They produce neurotoxic and psychotropic effects due to the presence of biogenic amines, muscarin, aeruginacin a thymethylammonium analogue of psylocibin which effects will be discussed later in this article [17]. Genus Cortinarius mushrooms, *C. speciosissimus and C. orellanus* are nephrotoxic due to the presence of the cyclopeptide orellanine in renal tissue may accumulate quinone compounds which bind covalently with biological structures leading to cell damage [18]. Number of intoxications are increasing day by day mainly due to misidentification of species. Perilous toxins are present in these species and are able to cause different syndromes that can be pernicious. Proper identification is important to avoid accidents through the ingestion of mushrooms.

Table 2: Antimicrobial compounds and its isolated species of mushrooms shown antimicrobial activity against various gram positive and negative bacteria.

Isolated mushrooms	Compounds	Bacteria species	Bacteria- type	Reference
Albatrellus fletti	Confluentin, Grifolin, Neogrifolin	*Bacillus cereus, Enterococcus faecalis*	gm+	19
Ganoderma pfeifferi	Ganomycin A and B	*Bacillus subtilis, Micrococcus flavus, Staphylococcus aureus*	gm+	20
Jahnoporus hirtus	3,11-dioxolanosta-8,24(Z)-diene-26-oic acid	*Bacillus cereus , Enterococcus faecalis*	gm+	19
Flammulina velutipes	Enokipodins A, B, C and D	*Bacillus subtilis, Staphylococcus aureus*	gm+	21
Lentinus edodes,	Oxalic acid	*Bacillus cereus, Staphylococcus aureus and Streptococcus faecalis*	gm+	22
		Proteus vulgaris, Pseudomonas aeruginosa and Pseudomonas fluorescens	gm-	
Xylaria intracolarata	Coloratin A	*Staphylococcus aureus*	gm+	23
	benzoic acid derivative	*Escherichia coli, Klebsiella pneumonia, Pseudomonas aeruginosa and Salmonella enteritidis.*	gm-	
Cortinarius basirubencens,	6 Methylxantho purpurin-3-O-methyl ether, Austrocortilutein, Torosachrysone	*Staphylococcus aureus*	gm+	24
		Pseudomonas aeruginosa	gm-	
Cordyceps sinensis	Antibacterial Protein-N-terminal sequence ALATQHGAP	*Staphylococcus aureus*	gm+	25
	protein CSAP	*Escherichia coli, Proteus vulgaris and Salmonella typhi*	gm-	
Pleurotus sajor-caju	Ribonuclease	*Staphylococcus aureus,*	gm+	26
		Pseudomonas aeruginosa	gm-	
Pseudoplectania nigrella,	peptide Plectasin,	*Bacillus cereus, Bacillus thuringiensis, Corynebacterium diphtheriae, Enterococcus faecium*	gm+	27
Agaricus bisporus	Methanolic compounds	*Bacillus subtilis, Micrococcus flavus, Staphylococcus aureus*	gm+	29
Agaricus bitorquis	Methanolic compound	*Yersinia enterocolitica, Klebsiella pneumoniae and Proteus vulgaris*	gm-	30
Leucopaxillus albissimus	Quinoline	*Achromobacter xyloxidans, Acinetobacter baumannii, Burkholderia cenocepacia, Burkholderia cepacia*	gm-	28

Antimicrobial profile:

Mushrooms occupied an important role in several aspects of the human activity. Most remarkably its bio-molecules diversity development favored to accelerate many of its pharmacological activity. Thus, its antimicrobial study transpired that Mushrooms shows its antimicrobial property against microorganism such as bacteria, fungi including their innocuous, noxious and resistant species. Mushrooms possess plenty of antimicrobial phenolic, ethanolic, methanolic compounds and researcher has produced plenty of antibiotics by using their extract. Following table 2 succinct a short list of microbial compounds from mushrooms with their isolated species shown antimicrobial property against gram positive and negative bacteria.

An expedient experimentation on a study over 3 common mushroom found in Bangladesh (*Pleurotus ostreatus, Lentinula edodes, Hypsizigus tessulatus*) assured its wide ranges antimicrobial activity against various bacteria by using minimum inhibitory concentrations (MICs) technique. The extract was incorporated into nutrient agar media in a concentration ranging 0.39 mg/ml to 25 mg/ml, then 10 CFU/ml of test microorganisms were inoculated the plates at 37°C. All of the experimented mushrooms transpired antimicrobial activity by showing different MICs for each microorganism [31]. Phenolic compound of mushrooms which shows strong antimicrobial activity against B. cereus, B. subtilis, E. coli bacteria [Table 3].

Table 3: Phenols amount of 3 mushroom species against *B. cereus, B. subtilis, E. coli* bacteria.

Mushrooms species	Total phenols (mg/g)	MIC mg/ml		
		B.cereus	*B.subtilis*	*E.coli*
L.deliciosus	17.25±0.65	10(++++)	100(++++)	300(−)
S.imbricatus	3.76±0.11	10(+++)	300(−)	300(−)
T.portentosum	10.80±0.47	100(++++)	300(++++)	300(−)
Note: No antimicrobial activity (−), High antimicrobial activity (+++).				

However, the infectious diseases by pathogenic bacteria is becoming a worldwide problem, thus to subvert the upcoming challenges and keep control over the resistance pathogens a newish exertion should be made to seek antimicrobial agents fruitful against pathogenic microorganisms. Therefore, the attempt for new yielding with antimicrobial peculiarities is a very active realm of research, and herein we suggest natural resources for that propose.

Antioxidative profile:

Medicinal mushrooms with robust anti oxidative peculiarities appears in Bangladesh namely *Ganoderma lucidium, Pleurotus florida, Pleurotus pulmonaris, Hypsizigus tessulatus* and few more. These mushrooms and its anti-oxidative bioactive compounds such as (terpenoids, steroids, polyphenol, polyketides, polyglucan, flavonoids, alkaloids, polysaccharides and dietary fibers etc) [32] possesses diverse pharmacological, therapeutical, scavenging activities that is exigent to threatening disease such as cancer, stroke, heart diseases, anti-inflammatory, antiviral, hepato-protective, antidiabetic, hypolipedemic, hypotensive, antithrombotic, antineoplastic and many more activities [33]. However, Antioxidants are chemical bioactive compounds that protect cells from damage by free radicals through inhibiting oxidation or reactions promoted by oxygen or peroxides. Ethanoic, Phenolic compounds, ascorbic acid found in mushrooms [Table 4] are most significant antioxidants that possesses plenty of activity against various radical [34].

Table 4: Bioactive antioxidative components found in 3 most edible mushrooms in Bangladesh [34].

Mushroom sample	Total Phenols (mg/ml)	Total Flavonoids (mg/ml)	Ascorbic acid (mg/ml)
H. tessulatus	5.65±0.05	2.50±0.008	0.11±.01
Pleurotus ostreatus	3.20±0.05	00	0.06±0.00
Lentinula edodes	10.66±0.52	4.76±0.11	0.21±0.01

Free radicals are capable of damaging all components of body including proteins, lipids, DNA and sugars. To affirm the antioxidative characteristic IC value has been used. The IC50 value, defined as the concentration of antioxidant required for 50% scavenging of DPPH radicals in this specified time period, is a parameter widely used to measure antioxidant activity; a smaller IC50 value corresponds to a higher antioxidant activity of the plant extract, In a study over mushrooms to point out its antioxidative activity using stable radical 1, 1-diphenyl;-2-picrylhydrazyl (DPPH) has performed. The 0.1 ml of mushroom ethanol extract, at various concentrations was added to 3 ml of a 0.004% methanol solution of DPPH and was allowed to stand for 30 min for the reaction to occur. The free radical scavenging activity was measured for different concentrations of sample [Table 5].

Table 5: 4 most common mushrooms with antioxidative activity against DPPH radicals [34].

Sample	Value
H. tessulatus Extract	105.0 ± 1.23
Lentinula edodes Extract	110 ± 1.24
Pleurotus ostreatus Extract	100 ± 1.20
Standard Ascorbic Acid	5.25 ± 0.21

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Proper identification is important to terminate the accidents through the consumption of mushroom. So more studies have to be conducted cautiously. Careful experimental and clinical investigations are required to identify the possible side effects of edible and medicinal mushrooms and enable their safe consumption.

Anti-cancer and anti-tumor peculiarities:

Cancer is the most skyrocketed cause of death worldwide now and its spreading grievously. For the concern about mushrooms intrigued researcher to identify drugs that can be effective against cancer. The current anti-cancer drugs available in market are not

effective enough because of their several side-effects and complications in clinical management of various forms of cancer. Which highlights the expeditious need for unprecedented effective and less-toxic therapeutic approaches. Numerous clinical trials have been conducted to assess the benefits of using commercial preparations containing medicinal mushroom extracts in cancer therapy. It has been known for centuries that some bioactive compounds found in Basidiomycetes have anticancer and anti-tumor peculiarities. First studies concerning to the anticancer peculiarities of this class of mushrooms was carried out by Lucas and coworkers, applying an extract obtained from *Boletus edulis* in the treatment of Sarcoma 180 in mice (1957) [51]. Another study by Lucas's team revealed another product from *Calvatia gigantea* mushrooms having natural anticancer properties named calvacin [52]. Numerous clinical studies have shown that mushroom's administration increases the effectiveness of chemotherapy in patients suffering from breast, liver, prostate, stomach, lung, and colon cancer. Mushrooms is also used in veterinary medicine against sarcoma, carcinoma, mammary cancer, colon cancer, and lung cancer, adenosarcoma, fibrosarcoma, mastocytoma, plasmacytoma, melanoma [53]. Polysaccharides of different chemical composition from mushrooms possess antitumor reactions. , with most assistant of the group of -glucans; these have - (13) linkages in the main chain of the glucan and (16) branch points that are needed for their antitumor action. Mushroom polysaccharides impede allogeneic, syngeneic tumors, oncogenesis and prevent tumor metastasis. Their antitumor effects by activating different immune responses in the host, thus activity is mediated through a thymus-dependent immune mechanism [54]. List out some specific mushroom with their activity and desired compound [Table 7].

Table 6: Main sites of organ affected by specific toxins of some toxic mushrooms including mortality rate.

Scientific Name	Family	Toxins	Sites of action	Mortality	Reference
Chlorophyllum molybdites	Agaricaceae	GI irritants	GIT	Rare	35
Psilocybe cubensis	Hymenogastraceae	Psilocybin, psilocin	CNS	Rare	36,37
Clitocybe nebularis	Tricholomataceae	GI irritants	GIT	Rare	35
Omphalotus illudens	Marasmiaceae	GI irritants	GIT	Rare	35
Amanita muscaria	Amanitaceae	Ibotenic acid, muscimol	CNS	Rare	38
Amanita pantherina	Amanitaceae	Ibotenic acid, muscimol	CNS	Rare	38
Amanita gemmata	Amanitaceae	Ibotenic acid, muscimol	CNS	Rare	38
P. mexicana	Agaricomycetes	Psilocybin, psilocin	CNS	Rare	36,37
Conocybe cyanopus	Bolbitiaceae	Psilocybin, psilocin	CNS	Rare	36,37
G. aeruginosa	Pseudomonadacea e	Psilocybin, psilocin	CNS	Rare	36,37
Coprinus atramentarius	Psathyrellaceae	Coprine	CNS	Rare	36,37
Clitocybe dealbata	Tricholomataceae	Muscarine	ANS	Rare	36,37
Clitocybe illudens	Marasmiaceae	Muscarine	ANS	Rare	36,37
I. fastigiata	nocybaceae	Muscarine	ANS	Rare	36,37
Boletus calopu	Boletaceae	Muscarine	ANS	Rare	36,37
Amanita smithiana	Amanitaceae	Allenic norleucine	Kidney, GIT	Rare	36, 37
Amanita phalloides	Amanitaceae	: Amatoxins, phallotoxins	GIT, liver, kidney	2-30%	39,40
Amanita virosa	Amanitaceae	Amatoxins, phallotoxins	GIT, liver, kidney	2-30%	39,40
Amanita verna	Amanitaceae	Amatoxins, phallotoxins	GIT, liver,	2-30%	39,40

			kidney		
Amanita bisporigera	Amanitaceae	Amatoxins, phallotoxins	GIT, liver, kidney	2-30%	39,40
Galerina autumnalis		Amatoxins, phallotoxins	GIT, liver, kidney	2-30%	39,40
Galerina marginata	Hymenogastraceae	Amatoxins, phallotoxins	GIT, liver kidney	2-30%	39,40
Galerina venenata	Hymenogastraceae	Amatoxins, phallotoxins	GIT, liver kidney	2-30%	39,40
Lepiota helveola	Agaricaceae	Amatoxins, phallotoxins	GIT, liver, kidney	2-30%	39,40
Tricholoma equestre	Tricholomataceae	Unknown	Muscle	25%	41
Clitocybe acromelalga	Tricholomataceae	Acromelic acid	Peripheral nerves, skin	Rare	42
Clytocybe rivulosa	Tricholomataceae	Muscarine	Unknown	Rare	43
Pleurocybella porrigens	Marasmiaceae	Unknown	Encephalopathy	27%	44,45
Lactarius torminosus	Russulaceae	velleral	Gastroenteritis	Unknown	46,47
Pleurotus ostreatus	Pleurotaceae	Ostreolysin	Unknown	Unknown	48
Gyromitra esculenta	Discinaceae	Gyromitrin	GIT, CNS, liver, blood	0-10%	36,37
Gyromitra infula	Helvellaceae	Gyromitrin	GIT, CNS, liver, blood	0-10%	36,37
Sarcosphaera coronaria	Pezizaceae	Gyromitrin	GIT, CNS, liver, blood	0-10%	36,37
Chrysina macropus	Scarabaeidae	Gyromitrin	GIT, CNS, liver, blood	0-10%	36,37
Cortinarius orellanus	Cortinariaceae	Orellanine, orellinine, cortinarin	Kidney, GIT	Rare	49
Cortinarius speciosissinus	Cortinariaceae	Orellanine, orellinine, cortinarin	Kidney, GIT	Rare	49
Mycena pura	Mycenaceae	Orellanine, orellinine, cortinarin	Kidney, GIT	Rare	49
O. orarius	Talpidae	Orellanine, orellinine, cortinarin	Kidney, GIT	Rare	50

Table 7: Mushrooms species and their activity against cancer and tumor.

Mushroom species	compound	Activity	Reference
Schizophyllum commune	Schizophyllan	Stomach and Neck Cancer.	55
Lentinus edodes	Lentinan	Bowel, Liver, Stomach, Ovarian, Lung Cancer	53
Trametes versicolor	Krestin	Breast, Liver, Prostate, Stomach, Lung, Colon Cancer.	53
Boletus edulis	Ergosterol, Ergosterol Peroxide, Tocopherols	Cytotoxicity to various tumor cells.	55
Grifola frondosa	1, 3 and 1,6 Beta glucans.	Anti-cancer activity.	56
Agaricus blazei	Beta (1,3)-D-glucan, Beta (1-4)-D-glucan, Beta (1-6)-D-glucan .	Antitumor and Immune enhancing.	57

Discussion:

For millennia, mushrooms have been valued by humankind as an edible and medical resource. A number of bioactive molecules, including anticancer, antitumor, anti-inflammatory, analgesic, anti-oxidant, immuno-modulatory etc substances, have been identified in many mushroom species. It is also a great source of carbohydrate, protein and fatty acids. Many research had been conducted and a many more being conducted to identify the bioactive compound responsible for these activity. Also there are some toxic mushrooms which cause a lot of poisoning around the world. The following section of this article will discuss about medicinal, edible and toxic mushrooms and their effect in brief.

The bioactive compounds of mushrooms include polysaccharides, proteins, fats, ash, glycosides, alkaloids, volatile oils, tocopherols, phenolics, flavonoids, carotenoids, folates, ascorbic acid enzymes, and organic acids. 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. Findings suggest that some mushrooms in combination with commercial anti-cancer drugs work in synergy as an effective tool for treating drug-resistant cancers. The mechanisms underlying apoptosis induced by medicinal mushrooms are summarized. This compilation is expected to provide new insights into the possible therapeutic use of the mushroom extracts against different cancers. These results are significant in that they provide a mechanistic framework for further exploration of the use of bioactive compounds as novel anti-tumor agents [58]. Mushroom polysaccharides prevent oncogenesis, show antitumor activity against various allogeneic and syngeneic tumors, and prevent tumor metastasis. Polysaccharides from mushrooms do not attack cancer cells directly, but produce their antitumor effects by activating different immune responses in the host [59]. Mushroom polysaccharides exert their antitumor action mostly via activation of the immune response of the host organism. Mushroom polysaccharides are known to stimulate natural killer cells, T-cells, B-cells, and macrophage-dependent immune system responses.

Numerous synthetic antioxidants can effectively improve defense mechanisms, but because of their adverse toxic effects under certain conditions, preference is given to natural compounds. Consequently, the requirements for natural, alternative sources of antioxidant foods identified in edible mushrooms, as well as the mechanistic action involved in their antioxidant properties, have increased rapidly. Chemical composition and antioxidant potential of mushrooms have been intensively studied. Edible mushrooms might be used directly in enhancement of antioxidant defenses through dietary supplementation to reduce the level of oxidative stress [60].

Conclusion:

Several mushroom species have been pointed out as sources of bioactive compounds, in addition to their important nutritional value. The inclusion of whole mushrooms into the diet may have efficacy as potential dietary supplements as well as serve as potent medicinal agent. What is more, there are barely any side effects caused by toxicity of edible mushrooms in vitro and in vivo. The production of mushrooms and the extraction of bioactive metabolites is a key feature for the development of efficient biotechnological methods to obtain these metabolites. There have been numerous researches done mushrooms and there many era expanding researches are yet to be done. We hope that this review will be helpful to give an overall concept of medicinal, edible and toxic mushrooms to help the researches in the future.

Acknowledgement

The authors gratefully acknowledge the contribution of Professor Dr. Niranjan Kumar Sana, Department of Biochemistry & Molecular Biology, Rajshahi University to the study participants for their valuable time and assistance.

Conflicts of Interest

We declare that we have no conflict of interest between the authors.

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