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CHEMICAL COMPOSITION AND NUTRITIONAL VALUE OF EDIBLE WILD GROWING MUSHROOMS: A REVIEW

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ABSTRACT

Mushrooms were considered as special delicacy by early civilizations and are valued as a credible source of nutrients including considerable amount of dietary fiber, minerals, and vitamins in particular vitamin D. Mushrooms are also recognized as functional foods as their bioactive compounds offer huge beneficial impacts on human health. This review is summarized and discussed data available on chemical components of nutritional significance for wild growing mushrooms. We aimed to update and discuss the latest data published on ash, fat, carbohydrates, fiber, proteins, essential amino acids and nonessential amino acids, some essential (P, K, Na, Ca, Mg, Fe, Mn, Zn, Cu) and toxic elements (As, Hg, Cd, Pb), vitamins (thiamine, riboflavin, niacin, tocopherol, vitamin D), flavor and taste compounds, antibacterial and antioxidant abilities of mushroom and also on less studied organic compounds (lectin, adustin, ribonuclease and nicotine) contents of wild-grown mushrooms.

KEYWORDS: Fungi, Edible Mushrooms, Bioactive Compounds, Proximate Composition.

INTRODUCTION

The fossil record has proven the long existence of fungi as far back in time as the Paleozoic era (408 – 438 million years ago) in the Silurian period.[1] Mushrooms, as part of the fungal diversity for around 300 million years, might probably have been collected by prehistoric humans as food and possibly with medicinal aims.[2] As the civilization of mankind progressed, mushrooms have been valued as edible and medicinal resources based on the long existing history in some Asian countries like China and Japan. Asian people have collected, cultivated and consumed mushrooms for over two thousand years due to their pleasant flavor and texture. In the traditional knowledge, 'mushroom' has been defined as a fleshy, aerial umbrella-shaped, fruiting body of macrofungi.[3] In the literature, mushrooms are acceptably defined as macrofungi comprising distinctive and visible fruiting bodies which can be hypogeous or epigeous.[4]

Mushrooms can be considered as a functional food or dietary supplements for their great nutritional and medicinal values.[2] The bioactivities of mushrooms have been confirmed by extensive studies. In 1957, Lucas discovered the bioactivity of *Basidiomycetes* mushrooms for the first time by isolating a substance from *Boletus edulis* which demonstrated a significant inhibitory effect against Sarcoma 180 tumor cells.[5] Since then, numerous antitumor mushroom polysaccharides have been extracted from a variety of mushrooms. Recently, a large number of compounds isolated from mushrooms have been greatly highlighted for their sound pharmaceutical applications. These compounds, including lectins, polysaccharides, polysaccharide-peptides, and polysaccharide-protein complexes, have proven to possess effective functions such as: immunomodulatory, anticancer[6], anti-inflammatory[7], and antioxidant[8,9] effects, and lowering blood cholesterol levels.[10] In particular, the commercialization of several polysaccharides and polysaccharide conjugates has allowed patients to benefit from such anticancer therapy. They are schizophyllan, lentinan, grifolan, PSP (polysaccharide-peptide complex) and krestin (polysaccharide-protein complex).[3]

Mycological terms

The basic terminology of the fruiting body of a mushroom is represented in (Figure 1). The gathered edible mushrooms are commonly described as higher fungi or macrofungi. The fruiting body (carpophore, mycocarp) in higher fungi is found mostly above ground. A fruiting body grows from spacious underground mycelia (hyphae) by the process of fructification. The bulk of fruiting bodies have a short lifetime only about 10-14 days.[11]

Most types of mushrooms are commonly found in the shape of umbrella with pileus (cap) and stipe (stem). Nonetheless, some species additionally possess an annulus (ring), or a volva (cup), or have both. The forms of some unusual mushrooms look like pliable cups, golf balls, or small clubs.[2] Unlike green plants, mushrooms lack chlorophyll and so they cannot manufacture their own food from simple inorganic materials, such as water, carbon dioxide, and nitrates. They exploit foods from complex organic materials stored in dead or living tissues of plants and animals.[2] Generally, they can be divided into three types of fungi according to their ecology. Those growing on dead organic material are termed saprophytic fungi. Those obtaining substances from living plants and animals and causing harm to the hosts are referred to as parasitic fungi. Those living with their hosts by symbiosis to gain vital benefits from each other are called mutualistic symbiotic fungi.[2] Mycelia of ectomycorrhizal species grow within roots of plants, such as trees. Terrestrial saprobic species snatch nutrients mainly from organic compounds of the plant and animal debris.[11]

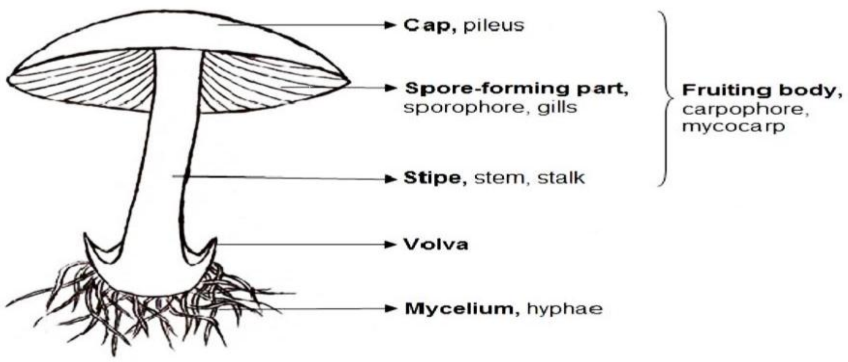

Figure. 1. Schematic image of a mushroom and basic mycological terms.

Dry matter, proximate composition and energy value

Mushrooms contain a very low dry matter in the range of 60-140 g/kg.[11] This result is supported by the study from Bano and Rajarathnam[12] who reported that the edible mushrooms contained a high moisture percentage of 81.8-94.8%. The variability of moisture content in mushrooms is dependent on the mushroom specie and other parameters related to harvest, growth, and storage conditions. Fresh mushrooms have a short shelf life due to the high moisture content.[13] Rajarathnam and Sashirekha[14] reported that mushrooms generally consist of ～ 63% carbohydrates, 25% protein, 4% fat, and 8% minerals represented by ash on a dry-weight basis. The compositions of some mushrooms are listed in (Table 1).

Table 1— Composition of mushrooms on a dry-weight basis[14].

Mushroom species	Crude protein (N×4.38)	Fat	Carbohydrate	Fiber	Ash	Energy value (kcal)
Agaricus bisporus	26.3	1.8	59.9	10.4	12.0	328
Auricularia auriculajudae	8.1	1.5	81.0	6.9	9.4	356
Boletus edulis	29.7	3.1	59.7	8.0	7.5	362
Cantharellus cibarius	21.5	5.0	64.9	11.2	8.6	353
Coprinus comatus	25.4	3.3	58.8	7.3	12.5	366
Flammulina velutipes	17.6	1.9	73.1	3.7	7.4	378
Lentinus edodes	17.5	8.0	67.5	8.0	7.0	387
Lycoperdon lilacinum	46.0	7.5	38.8	12.3	7.7	358
Pholiota nameko	20.8	4.2	66.7	6.3	8.3	372
Pleurotus florida	18.9	1.7	58.0	11.5	9.3	265
Termitomyces microcarpus	27.4	4.3	54.2	2.2	14.1	364
Tricholoma species	16.7	3.1	71.9	12.9	8.3	342
Volvariella esculenta	34.4	20.6	31.7	11.2	13.3	396

Total carbohydrates can be calculated by difference: Total carbohydrates = 100 – (g moisture + g protein + g fat + g ash). Total energy can be calculated by the following equation: Energy (kcal) = 4 × (g protein + g carbohydrate) + 9 × (g lipid); Energy (kJ) = 17 × (g protein + g carbohydrate) + 37 × (g lipid)[15].

Carbohydrates

Basically, in the composition of mushroom fruiting bodies, the predominating component is carbohydrate. The majority of carbohydrates are found in the polymeric form, glucan and hemicellulose types. However, starch as such is absent.[14] In general, glucose, mannitol and trehalose represent the major forms of monosaccharide, their derivatives and oligosaccharide groups, respectively. Usually, glucose and trehalose contents are low, in the level of g /100 g of dry matter. Mannitol that participates in volume growth and firmness of fruiting bodies shows different amounts in different species.[16]

The reserve polysaccharide found in some mushrooms is glycogen, not starch as in plants. The common content is about 5-10% of dry matter.[11] Chitin, a water-insoluble structural polysaccharide, is up to 80% of dry matter in mushroom cell walls. Chitin restricts the availability of other mushroom components and is indigestible for humans.[11] In addition to chitin, mushrooms contains considerable amount of dietary fiber. Guillamón showed that the dietary fiber supply among mushroom species exhibited a great variability.[13] In the examinations on *Boletus* group, *Agrocybe aegerita, A. bisporus, Pleurotus eryngii and ostreatus,* total fiber was reported from 5.5-42.6% of dry matter, in which β-glucans were the main fiber polysaccharides together with chitin. Mushrooms contain higher levels of insoluble dietary fiber (2.28-8.99 g/100 g edible weight) than soluble dietary fiber (0.32-2.20 g/100 g edible weight). The β-glucans account for 4-13% of the total fiber with a variability of the dietary fiber fractions depending on mushrooms species.[15] β-glucans have been regarded as functional compounds as they exhibit the abilities of stimulating the immunomodulatory response, modulating humoral and cellular immunity.[17] They therefore have been promising candidates as pharmacological agents due to their anti-infective, anti-cytotoxic, antimutagenic, and anti-tumorogenic properties. β-glucans are also used as anticoagulant agents.[13]

Proteins and amino acids

Protein is the major component next to carbohydrates in mushrooms. Wide variations occur in the content of crude protein because not only the species of mushroom differ largely but also different converting factors are used based on the determination by Kjeldahl method. Although many researchers widely used the Nitrogen converting factor of 6.25 to calculate crude protein in mushrooms, Rajarathnam & Sashirekha[14] and Barros et al.[13], used a factor of 4.38 by considering the high proportion of non-protein nitrogen, mainly in chitin. To avoid overestimating the content of crude protein, Bauer-Petrovska[18] recommended a specific converting factor of 4.16. Also, the distribution of proteins within a fruiting body is not even and changes in protein content remain unclear with the development of a fruiting body.[11] Albumins and globulins are the prevailing proteins of *Boletus edulis* and *Cantbaraellus cibarius.*[14]

The content of protein represented as a percentage in dry matter virtually did not change during air-drying of mushrooms at 40ºC or on freezing to -20ºC, whereas a significant drop was caused by boiling of fresh mushrooms.[19]

The proteins in mushrooms are composed of most of the essential amino acids. Nonetheless, some essential sulfur-containing and aromatic amino acids are scarce. The free amino acids account for nearly 20% of the total nitrogen. Even though their contents are low, they play an important role in the taste of mushrooms. Glutamic acid and alanine were found as the dominant free amino acids in *T. portentosum* and *T. terreum.*[14,20]

Vitamins

Mushrooms have been considered as a good source of vitamins because of the high levels of riboflavin (vitamin B_2), niacin, folic acid and traces of vitamin C, vitamin B_1, vitamin D, β-carotene (precursor of vitamin A), vitamin E and vitamin B_{12}.[21] Mushrooms are notable for their B-complex vitamins (niacin, thiamin, and B_{12}) and folic acid. Their ability to accumulate these vitamins eventually substantiates their biosynthetic capacities even when they are grown on lignocellulosic wastes. The fact is that folate synthetase and B_{12} synthetase enzyme systems have been proven in mushroom cells.[14] Compared to plants, mushrooms appear to have a limited occurrence of carotenoids including those which can act as precursors of retinol.[11]

Mushrooms are the only natural food source that can provide vitamin D to vegetarians since they are the only non-animal-based food containing vitamin D. There is a remarkable amount of vitamin D_2 (ergocalciferol) in numerous wild mushroom species, but is almost absent in cultivated species due to lacking exposure to sunshine.[21] It has been well known that vitamin D_2 is originated by photoirradiation from its precursor ergosterol. When exposed to UV light, ergosterol undergoes photolysis to generate various photoirradiation products, mainly previtamin D_2, tachysterol and lumisterol. The previtamin D_2 then undergoes spontaneous thermal rearrangement to vitamin D_2.[22] Jasinghe and Perera[23,24] reported that the conversion of ergosterol in mushrooms to vitamin D_2 was affected by many factors, such as the irradiation time and temperature, moisture content of mushrooms, the type and intensity of the UV irradiation. Ergosterol is distributed unevenly in different parts of shiitake mushroom. Irradiating directly on the gills could maximise the conversion of ergosterol to vitamin D_2 since this approach produced a high conversion rate that was about four times that when gills were facing away from the source of irradiation.[23] This conversion could be entirely completed when each side of the mushrooms was irradiated by UV for 1 h.[24] Irradiation of 5 g of fresh shiitake mushrooms for 15 min with UV-A, or UV-B could yield sufficient amount of vitamin D to reach the mark of the recommended allowances for adults (10 µg/day).[24] In addition, the increase in the amount of ergosterol converted to vitamin D_2 was linear with time of irradiation.

Mushrooms are rich in ergosterol as shown in (Table 2). The relatively high ergosterol content could be of significance for vegetarians and vegans who only have a limited intake of ergocalciferol from foods of animal origin.[11] In fact, ergosterol is the most abundant phytosterol in mushrooms. Generally, phytosterol can function to reduce cholesterol absorption. It thus has the capacity of lowering plasma cholesterol and LDL cholesterol with no detrimental side-effects.[25,26] More advanced fungi yield ergosterol as the major sterol which is different from the main plant sterols, for ergosterol has two double bonds in the sterol ring structure instead of one in lanosterol, the precursor to cholesterol and ergosterol. Furthermore, although fungal and plant sterols are produced through similar biosynthesis reactions, the sequence of postsqualene reactions and the stereochemistry of the main products are distinct. Most fungal sterols like ergosterol contain 28 carbon atoms.[27] A variety of minor sterols present in fungi have been identified, such as fungisterol, ergosta-5,7-dienol, 24-methyl cholesterol and methylene cholesterol.[22]

Table 2— Content of mycosterols (mg 100 g^{-1} of dry matter) in some mushroom species[11].

Species	Ergosterol	Fungisterol	Reference
Boletus edulis			22
– Complete fruiting body	489	–	
– Cap	589	–	
– Stipe	444	–	
– Sporophore	549	–	
– Dried fruiting body	241	–	28
Cantharellus cibarius			22
– Complete fruiting body	304	–	
– Cap	140	–	
– Stipe	100	–	
– Sporophore	278	–	
– Dried fruiting body	348	–	28
Cantharellus tubaeformis	173	–	28
Clitocybe nebularis	638	104	29
Hydnum repandum	628	85	30
Russula cyanoxantha	632	128	30
Russula xerampelina	655	112	30
Suillus granulatus	702	80	30
Suillus luteus	662	83	30

Lipids

Mushrooms contain relatively low amounts of fat. The fat comprises representatives of all types of lipid compounds, such as free fatty acids, mono-, di-, and triglycerides, sterols, sterol ester, and phospholipids.[14] Overall, unsaturated fatty acids prevail over saturated fatty acids, especially nutritionally undesirable saturated palmitic acid (C16:0), monounsaturated oleic acid (C18:1) and polyunsaturated linoleic acid (C18:2), while the remaining fatty acids are only found in small amounts. The exceptional case is seen in *Lactarius deliciosus* which contains an abundant amount of stearic acid (C18:0).[31] Linolenic acid (18:3) is the precursor of 1-octen-3-ol, known as the mushroom alcohol. It is the principal aromatic compound in most fungi, which contributes characteristically and distinctively to mushroom flavor.[13,32]

Pedneault and co-workers (2007) reported that fatty acid composition was dependent on ambient temperature. The growth temperatures of cultivated oyster mushroom below 17^oC led to a rise of unsaturated fatty acid proportion as compared to mushrooms produced at temperatures above 17^oC.

Minerals

A reasonable content of many mineral elements can be observed in mushrooms. Manzi et al (1999) reported that ash content of mushroom was around 6-10.5% of dry matter, this result was supported by Kalač (2009) who showed it to be about 5-12%. The principle constituents in the ash are potassium, phosphorus, magnesium, calcium, copper, iron, and zinc.[11,13] In fruiting body, the distribution of potassium is not even. Its concentration indicates a decreasing trend in the order: cap > stipe > spore-forming part > spores.[11] Some species also hold germanium that has the ability to maintain vitality in humans.[14]

Mushrooms possess a special feature to accumulate minerals that are available in their growth medium. This property can be ambivalent, for it is not only useful in providing desired minerals in good quantities but also is dangerous for consumption when toxic elements are accumulated.[11,14] Mushrooms are able to accumulate potassium and phosphorus in their fruiting bodies. The concentrations of potassium and phosphorus are respectively 20-40 folds and 10-50 folds higher than those in the underlying substrates. On the other hand, mushrooms growing in highly polluted areas or some accumulating species appear to contain considerably elevated contents of harmful elements, even one or two orders of magnitude higher than those in substrates. Great attention has been drawn regarding the accumulation of trace heavy metals in the mushroom, especially toxic elements such as cadmium, lead, mercury, chromium, arsenic, silver and tin.[11,13]

Flavor components

Based on their chemical structure, numerous identified odorous compounds can be classified as derivatives of octane and octenes, lower terpenes, derivatives of benzaldehyde, Sulphur compounds and others.[32] Kalač reviewed that the characteristic group of mushroom aroma is formed by the derivatives of octane, 1-octene and 2-octene, alcohols and their esters with volatile fatty acids, and ketones.[11] The major role is attributed to 1-octen-3-ol which is known as mushroom alcohol.[13,32] This is a characteristic process for mushrooms during drying, in which free linoleic acid is oxidised by the catalysis of lipoxygenase and hydroperoxide lyase. The compound, 1-octen-3-ol, is a secondary product in the oxidation.

Toxic components in poisonous mushrooms

Although there are thousands of mushroom species on earth, only 30-50 poisonous mushrooms species are found. However, even though no more than 10 are fatally poisonous, mushroom poisoning has caused about 70% of natural poisoning and often results in death. Learning the physical features of each species of poisoning mushrooms is the best way to avoid risk instead of conducting the convenient tests of folklore claims. For instance, it has been proven that silver spoons will not be blackened when cooked with poison mushrooms.[14]

Amanita phalloides is known as the green death cap that is the most dangerous and poisonous mushroom responsible for 90-95% of fatal mushroom poisonings. *Amanita* poisonings are resulted from the toxic compounds such as the cyclic peptides, the amatoxins, and the phallatoxins (Table 3). *Amanita virosa* is as toxic as *A. phalloides* and is described as 'destroying angel', containing an amatoxin, amaninamide. Amino acids that have the relevant structure to glutamic acid have been observed as mushroom toxins. Acromelic acids obtained from *Clitocybe acromelaga* are neurotoxins, exhibiting highly potent activity as glutamate agonists. *Amanita muscaria* presenting as a brilliant red cap flecked with white spots is the best known poisonous mushroom in the world. These mushrooms are cataloged under genus *Inocybe,* which contains abundant quantities of a toxic chemical muscarine. In addition, some alkaloids, such as psilocybin and psilocin found in most *Psilocybe* species, can act on the central nervous system since the structure and activity are similar to those of the hallucinogen, lysergic acid diethylamide (LSD).[14]

Table 3— Mushroom poisoning[14].

Mushroom species	Compounds	Nature of compound	Symptoms
Amanita phalloides	Phallotoxin	Cyclopeptide	Fatal
Amanita phalloides	Amatoxin	Cyclopeptide	Fatal
Amanita virosa	Virotoxin	Cyclopeptide	Fatal
Gyromitra esculenta	Gyromitrin	Cyclopeptide	Affects autonomic nervous system
Coprinus atramentarius	Coprine	Amino acid	Drunken sickness
	Clitidine	Novel amino acids	Neurotoxin
Clitocybe acromelalga	Acromelic acid	Novel amino acids	Neurotoxin
	Clithioneine	Novel amino acids	Neurotoxin
Amanita muscaria	Muscarine	Amino acid	Affects parasympathetic, cholinergic nervous system
Inocybe patouillardii	Muscarine	Amino acid	Affects parasympathetic, cholinergic nervous system
Clitocybe acromelalga	Muscarine	Amino acid	Affects parasympathetic, cholinergic nervous system
Amanita pantherina	Mycoatropine	Alkaloids	Psychotropic poisoning
Amanita muscaria	Mycoatropine	Alkaloids	Psychotropic poisoning
Amanita regalis	Mycoatropine	Alkaloids	Psychotropic poisoning
Psilocybe species	Psilocybin	Alkaloids	Psychotropic poisoning
Panaeolus species	Psilocybin	Alkaloids	Psychotropic poisoning
Panaeolina species	Psilocybin	Alkaloids	Psychotropic poisoning
Stropharia species	Psilocybin	Alkaloids	Psychotropic poisoning
Cortinarius orellanus	Orellanin	Polypeptide	Fatal
Ramaria formosa	Emodin		Laxative effects

Antibacterial ability

In order to better understand the abilities of mushroom polysaccharides against cancers, antibacterial and antioxidant properties of mushroom polysaccharides could be studied, as hypothetically there might be correlations among their biological mechanisms. The accumulating evidence has implied that polysaccharides are the primary markers for cell recognition. The discoveries regarding the involvement of specific polysaccharides in recognition will have practical applications to the prevention and treatment of various ailments, including cancer. As mentioned in section 1.6.2, β-D-glucans can be recognised by the human immune systems as foreign molecules because they are not synthesized by humans. These compounds can trigger both innate and adaptive immune responses.[33] It has been generally accepted that cells recognize one another via pairs of complementary structures on their surfaces. These structures on cells hold encoded biological information that the structures on the other cells can decipher, which represents an extension of the lock-and-key hypothesis.[34] For example, to cause disease, viruses, bacteria or protozoa must be able to adhere to at least one tissue surface in a susceptible host. Infectious agents without that ability are swept away from potential sites of infection by the body's normal cleaning mechanisms. Bacteria adhesion varies not only between tissues but also between species and sometimes between individuals of the same species, depending on their age, genetic makeup and health. For instance, *E. coli* prefers to stick to tissues surrounding the ducts that connect the kidneys and the bladder, while *Streptococci* colonise only the upper respiratory tract and skin.[34] Since bacterial adhesion is so crucial to infection, it has been considered to use sugars for prevention and treatment. Sugars with selective ability of inhibiting adhesion could act as molecular decoys, intercepting pathogenic bacteria before they reach their tissue targets. It has been found that bacteria do not bind solely to the ends of surface carbohydrates; they are able to sometimes bind to sugars located within the structure. Moreover, different bacteria may bind to different parts of the same carbohydrate. Considerable experimental evidence indicates that the binding of bacteria to host cell-surface sugars intitiates infection.[34]

Carbohydrate-directed interactions between cells are not restricted to pathological phenomena, they are also critical to the healthy operation of the immune system. Also, cell–adhesion molecules could play a role in other diseases, such as the spread of cancer cells from the main tumor throughout the body. In one study, melanoma cells were exposed to compounds containing lactose prior to injecting them into mice. The result demontrated that the metastatic spread of the cells was reduced.[34] Hence, antiadhesive drugs may turn out to be antimetastatic. It has been found that some polysaccharides extracted from mushrooms exhibited antibacterial activity, such as those from *Lentinula edodes* against *Bacillus cereus*, *Listeria monocytogenes*, and *Staphylococcus aureus*[35], polysaccharide extracts of *Pleurotus ostreatus* against *Bacillus subtillis*, and *E. coli.*[36] The polysaccharides from the two species of mushroom also exhibited antitumor ability as the former inhibited breast cancer[37], and the latter was effective against Ehrlich ascitic tumor.[36] Therefore, a better understanding of polysaccharides structures and their antibacterial abilities could hypothetically provide a clue for clearly describing their anticancer abilities.

Antioxidant ability

Oxidation is essential to many living organisms for the generation of energy to fuel biological processes.[38] Basically, reactive oxygen species (ROS) production is a common biological process during normal cell metabolism. Likewise, oxygen is essential for life as it plays an important role in diverse biological functions. Nonetheless, overproduction of ROS can lead to many diseases and accelerate ageing[39], and excess oxygen-derived free radicals may turn to be a harmful initiator to cause oxidative damage within cells by its transformation to more reactive form, such as superoxide radical, hydroxyl radical, and hydrogen peroxide, leading to uncontrolled chain reactions, lipid peroxidation or autooxidation reactions.[40] Moreover, they can also cause DNA damage, and eventually cause cell injury, necrosis, or apoptosis, resulting in body disorder and various diseases, such as cancer, cardiovascular, and diabetes.[41] Nearly all organisms use enzymes, including superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), to protect the body from oxidative damage.

These enzymes are the first line of defense against lipid peroxidation, and protecting cell membranes at an early phase of free radical attack through their free-radical-scavenging activity.[42,43] However, the enzyme systems are not sufficient to prevent oxidative damages, thus antioxidants are normally applied. Furthermore, many synthetic chemicals with strong radical scavengers usually present side effects.[44] As a consequence, natural antioxidants from fruits, vegetables, cererals, herbs and seeds, such as α-tocopherol, ascorbic acid, and carotenoids, are favoured in food applications to establish cooperative defense systems. Apart from a variety of plants, mushrooms have been considered as a potential source to produce effective anitoxidants that have been proven by the excellent antioxidative abilities of their bioactives, especially polysaccharides. In addition, mushroom polysaccharides are effective against cancers as detailed in part 1. Hypothetically, they might also possess the ability to present the occurence of cancer from the onset. Theoretically, it is thus necessary to find out more mushroom polysaccharides with antioxidant ability to possibly assist discovering the mechanisms which can be used to prevent cancer.

Various constituents

Numerous other beneficial components have been determined in a diverse range of edible wild-grown mushroom species. A lectin that was isolated from fresh fruiting bodies of *B. edulis* is a dimer made up of two 16.3 kDa subunits, which displays activities including mitogenic and HIV-1 reverse transcriptase inhibiting. As a result, it is possible for *B. edulis* lectin to be developed into a pharmaceutical with similar effects for cancer patients and AIDS patients.[45] A polypeptide designated as adustin was isolated from the wild-grown mushroom *Bjerkandera adusta* and also represents one of the very rare mushroom translation-inhibiting polypeptides.[46] A ribonuclease (RNase) with a molecular mass of 29 kDa was isolated from fruiting bodies of the mushroom *Boletus griseus*, its N-terminal sequence exhibited some similarity to RNases from *Irpex lacteus* and *Lentinus edodes*.[47]

Nicotine is an alkaloid that is abundant in tobacco. However, nicotine was first accidentally extracted from mushroom samples with water under the action of microwave energy. According to the European Food Safety Authority (EFSA) statement, the temporary maximum residue levels (MRLs) of nicotine are 0.036 for fresh wild mushrooms and 1.17 mg kg^{-1} for dried wild mushrooms (2.3 mg kg^{-1} for dried ceps only).[48] The determined content of nicotine in some mushrooms from China was in the range of 0.024–0.054 mg kg^{-1} fm, and for some species was higher than MRLs.[49]

CONCLUSION

The rich amount of proteins, carbohydrate, essential minerals and low energy levels make many wild grown mushrooms a good food for the consumer, which can virtually be compared with meat, eggs and milk. Potential medicinal value is also high including boosting the immune system, controlling blood lipids, antitumor function and so on. In order to preserve the nutrients further, more complete and effective storage methods and culinary treatments are necessary. In view of the current situation, the research of these components is deficient. We ought to identify more poisonous wild-grown mushroom and clear the noxious substances through testing, to ensure the safety of consumer. Owing to the unique geographical conditions, wild-grown edible mushrooms in China are abundant and varied, especially in Yunnan province. There are numerous characteristics and even undiscovered species, which can provide abundant resources for the research of wild fungi.

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