

Review Article

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## Edible Macro Fungi Consumption: Improving Human fitness and Promoting Worth of Life During COVID-19 Pandemic: A Review

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### ABSTRACT

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.” They have been part of the human culture for thousands of years and have considerable interest in the most important civilizations in history because of their sensory characteristics; they have been recognized for their attractive culinary attributes. Currently, mushrooms are popular valuable foods because they are low in calories, carbohydrates, fat and sodium, they are cholesterol free also. Moreover, mushrooms provide important nutrients, including selenium, potassium, riboflavin, niacin, vitamin D, proteins and fiber. All together with a long history as food source, mushrooms are important for their healing capacities and properties in traditional medicine. It has reported beneficial effects for health and treatment of some diseases. Many nutraceutical properties are described in mushrooms, such as prevention or treatment of Alzheimer, high risk of stroke, hypertension and Parkinson. They are also utilized to condense the possibility of cancer attack and metastasis due to antitumoral attributes. Mushrooms act as antibacterial, immune system enhancer and cholesterol lowering agents; In addition, they are important sources of bioactive compounds. As a result of these properties, some mushroom extracts are used to promote human health and are found as nutritional supplements.

#### Keywords

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### Introduction

Mushroom husbandry improves the socio-economy of the farming community through additional revenue by utilizing farm wastes. In addition to this, it paves ways for employment

generation in significant amount. The substrate remains after cultivation of mushroom is more readily digestible and palatable to livestock. Additionally, it can be exploited as a source of compost and mulch for soil and others. Mushrooms have been

considered as component of gourmet cooking across the globe; especially for their unique flavor and have been valued by humankind as a culinary wonder. More than 2,000 species of mushrooms exist in nature but around 25 are widely accepted as food and few are commercially cultivated. Mushrooms are considered as a delicacy with high nutritional and functional value and they are also accepted as nutraceutical foods; they are of considerable interest because of their organoleptic value, medicinal properties and economic impact (Ergonul *et al.*, 2013). However, there is not an easy distinction between edible and medical mushrooms because many of the common edible species have therapeutic properties and several used for medical purposes are also edible (Guillamon *et al.*, 2010).

The most cultivated mushroom worldwide is *Agaricus bisporus* followed by *Lentinus edodes*, *Pleurotus* spp. and *Flammulina velutipes*. Mushrooms production continuously increases, China being the biggest producer around the world (Patel & Goyal, 2012). However, wild mushrooms are becoming more important for their nutritional, sensory and especially pharmacological characteristics (Ergonul *et al.*, 2013).

Mushrooms could be a substitute source of new antimicrobial compounds, mainly secondary metabolites such as terpenes, steroids, anthraquinones, benzoic acid derivatives and quinolones, but also of some primary metabolites like oxalic acid, peptides and proteins. *Lentinus edodes* is the most studied species and seems to have an antimicrobial action against both gram positive and gram negative bacteria (Alves *et al.*, 2012).

They have a great nutritional value since they are quite rich in protein with an important content of essential amino acids, fiber and

deprived fat but with excellent important fatty acids content (Table 1). Moreover, edible mushrooms provide a nutritionally significant content of vitamins (B<sub>1</sub>, B<sub>2</sub>, B<sub>12</sub>, C, D and E) (Heleno *et al.*, 2010). Thus, they could be an excellent source of many different nutraceuticals and might be used directly in human diet and to promote health for the synergistic effects of all the bioactive compounds present. Coronavirus mainly effects in human immune system and decrease immune power. So after recovering from this infection, patient does not have proper immune power to protect other infections like bacterial and fungal infection (Souvik *et al.*, 2021).

A large variety of mushrooms have been utilized traditionally in many different cultures for the maintenance of health, as well as in the prevention and treatment of diseases through their immune modulatory and antineoplastic properties. In the last decade, the interest for pharmaceutical potential of mushrooms has been increased rapidly and it has been suggested that many mushrooms are like mini pharmaceutical factories producing compounds with miraculous biological properties (Patel & Goyal, 2012); (Ferreira *et al.*, 2010). In addition, the expanded knowledge of the molecular basis of tumorigenesis and metastasis has given the opportunity for discovering new drugs against abnormal molecular and biochemical signals leading to cancer. More than 100 medicinal functions are produced by mushrooms and fungi and the key medicinal uses are antioxidant, anticancer, antidiabetic, anti allergic, immune modulating, cardiovascular protector, anti cholesterolemic, antiviral, antibacterial, antiparasitic, antifungal, detoxification, and hepatoprotective effects; they also protect against tumor development and inflammatory processes (Chang & Wasser, 2012); (Finimundy *et al.*, 2013). Numerous molecules synthesized by macro

fungi are known to be bioactive, and these bioactive compounds found in fruit bodies, cultured mycelium and cultured broth are polysaccharides, proteins, fats, minerals, glycosides, alkaloids, volatile oils, terpenoids, tocopherols, phenolics, flavonoids, carotenoids, folates, lectins, enzymes, ascorbic and organic acids in general. Polysaccharides are the most important for modern medicine and  $\beta$ -glucan is the best known and the most versatile metabolite with a wide spectrum of biological activity (Patel & Goyal, 2012); (Chang & Wasser, 2012).

A balanced diet is the supporting treatment for the prevention of illness and especially against oxidative stress. In this context, mushrooms have a long history of use in the oriental medicine to prevent and fight numerous diseases. Nowadays, mushroom extracts are commercialized as dietary supplements for their properties, mainly for the enhancement of immune function and antitumor activity (Guillamon *et al.*, 2010). In this work, we aimed to review the nutritional value as well as the chemical and nutraceutical composition and commercial potentialities of the most cultivated edible mushrooms worldwide.

### **Nutritional Value**

The nutritional value of edible mushrooms is due to their high protein, fiber, vitamin and mineral contents and low fat levels. They are very useful for vegetarian diets because they provide all the essential amino acids for adult requirements; also, mushrooms have higher protein content than most vegetables. Besides, edible mushrooms contain many different bioactive compounds with various human health benefits (Kalac, 2013).

It is important to remark that the growth characteristics, stage and postharvest condition may influence the chemical composition and the nutritional value of edible

mushrooms. Also, great variations occur both among and within species (Reis *et al.*, 2012); (Erjavec *et al.*, 2012). Mushrooms contain a high moisture percentage that ranges between 80-95 g/100 g approximately. As above mentioned, edible mushrooms are a good source of protein, 200-250 g/kg of dry matter, leucine, valine, glutamine, glutamic and aspartic acids are the most abundant. Mushroom are low calorie foods since they provide low amounts of fat 20-30 g/kg of dry matter, being linoleic (C18:2), oleic (C18:1) and palmitic (C16:0) the main fatty acids. Edible mushrooms contain high amounts of ash 80-120 g/kg of dry matter (mainly potassium, phosphorus, magnesium, calcium, copper, iron and zinc). Carbohydrates are found in high proportions in edible mushrooms, including chitin, glycogen, trehalose and mannitol; besides, they contain fiber,  $\beta$ -glucans, hemicelluloses and pectic substances. Additionally, glucose, mannitol and trehalose are abundant sugars in cultivated edible mushrooms but fructose and sucrose are found in low amounts. Mushrooms are also a good source of vitamins with high levels of riboflavin (vitamin B<sub>2</sub>), niacin, folates and traces of vitamin C, B<sub>1</sub>, B<sub>12</sub>, D and E. Mushrooms are the only non animal food source that contains vitamin D and hence they are the only natural vitamin D ingredients for vegetarians. Wild mushrooms are generally excellent sources of vitamin D unlike cultivated ones; usually cultivated mushrooms are grown in darkness and UV-B light is needed to produce vitamin D (Guillamon *et al.*, 2010).

### **Nutraceuticals**

In addition to the nutritional components found in edible mushrooms, some have been found to comprise important amounts of bioactive compounds. The content and type of biologically active substances may vary considerably in edible mushrooms; their

concentrations of these substances are affected by differences in strain, substrate, cultivation, developmental stage, age, storage conditions, processing and cooking practices. The bioactive substances found in mushrooms can be divided into secondary metabolites (acids, terpenoids, polyphenols, sesquiterpenes, alkaloids, lactones, sterols, metal chelating agents, nucleotide analogs, and vitamins), glycol proteins and polysaccharides, mainly  $\beta$ -glucans. New proteins with biological activities have also been found which can be used in biotechnological processes and for the development of new drugs, including Lignin and Cellulose degrading enzymes, lectins, proteases and protease inhibitors, ribosome-inactivating proteins and hydrophobins (Erjavec *et al.*, 2012).

In China, many species of edible wild grown mushrooms, that is *Tricholoma matsutake*, *Lactarius hatsudake*, *Boletus aereus* are appreciated as food and also in traditional Chinese medicine. The rich amount of proteins, carbohydrates, essential minerals and low energy levels contributes to considering many wild grown mushrooms as good food for the consumer, which can virtually be compared with meat, eggs and milk (Wang *et al.*, 2014).

Numerous bioactive polysaccharides or polysaccharide protein complexes from medicinal mushrooms appear to enhance innate and cell mediated immune responses and exhibit antitumor activities in animals and humans. A wide range of these mushroom polymers have been reported previously to have immunotherapeutic properties by facilitating growth inhibition and destruction of tumor cells. Several of the mushroom polysaccharide compounds have proceeded through clinical trials and are used extensively and successfully in Asia to treat various cancers and other diseases. A total of 126 medicinal functions are thought to be

produced by selected mushrooms (Wasser, 2011).

## **Carbohydrates**

Polysaccharides are the best known and most potent mushroom derived substances with antitumor and immune modulating properties. Data on mushroom polysaccharides have been collected from hundreds of different species of higher basidiomycetes; some specific carbohydrates with these properties have been quantified in different mushrooms: rhamnose, xylose, fructose, arabinose, glucose, mannose, mannitol, sucrose, maltose and trehalose (Table 2) (Finimundy *et al.*, 2013).

The antitumor polysaccharides isolated from mushrooms are acidic or neutral with strong antitumor action and differ significantly in their chemical structures. A wide range of glycans extending from homo polymers to highly complex heteropolymers exhibits antitumoral activity. Mushroom polysaccharides have antitumor action by activation of the immune response of the host organism in other words; mushroom polysaccharides do not directly kill tumor cells. These compounds prevent stress on the body and they may produce around 50% reduction in tumor size and prolong the survival time of tumor bearing mice.  $\beta$ -glucans are the main polysaccharides found in mushrooms and around half of the fungal cell wall mass is constituted by  $\beta$ -glucans. This is important for the industry because many of them are excreted into the cell growth medium, making their recovery, purification and chemical characterization very simple.  $\beta$ -glucans are responsible for anticancer, immune modulating, anticholesterolemic, antioxidant and neuro protective activities of many edible mushrooms. Moreover, they are recognized as potent immunological stimulators in humans and it has been demonstrated their capacity for treating

several diseases.  $\beta$ -glucans bind to a membrane receptor and induce these biological responses.

Natural products with fungal  $\beta$ -glucans have been consumed for thousands of years and they have long been considered to improve general health.  $\beta$ -glucans are not synthesized by humans and they are not recognized by human immune systems as self molecules; as a result they induce both innate and adaptive immune responses. Fungal  $\beta$ -glucans are notably beneficial to humans; they markedly stimulate the human immune system and protect from pathogenic microbes and from harmful effects of environmental toxins and carcinogens that impaired immune systems. They also protect from infectious diseases and cancer and aid patients recovery from chemotherapy and radiotherapy. Besides, these compounds are also beneficial to middle age people, people with active and stressful lifestyles and athletes. A large variability can be observed in mushroom species and their concentration ranges from 0.21-0.53 g/100 g dry basis.  $\beta$ -glucans are well known for their biological activity, specifically related to the immune system. Therefore, activating and reinforcing the host immune system seem to be the best strategy for inhibiting the growth of cancer cells (Finimundy *et al.*, 2013).

### **Proteins**

Bioactive proteins are an important part of functional components in mushrooms and also have great value for their pharmaceutical potential. Mushrooms produce a large number of proteins and peptides with interesting biological activities such as lectins, fungal immune modulatory proteins, ribosome inactivating proteins, antimicrobial proteins, ribonucleases and lactases (Xu *et al.*, 2011).

Lectins are non immune proteins or glycoproteins binding specifically to cell

surface carbohydrates and in the past few years many mushroom lectins have been discovered. They have many pharmaceutical activities and possess immune modulatory properties, antitumoral, antiviral, antibacterial and antifungal activity. Some of them exhibit highly potent anti proliferative activity toward some tumor cell lines (human leukemic T cells, hepatoma Hep G<sub>2</sub> cells and breast cancer MCF<sub>7</sub> cells) (Xu *et al.*, 2011); (Lin *et al.*, 2010).

Fungal immune modulatory proteins are a new family of bioactive proteins isolated from mushrooms, which have shown a potential application as adjuvants for tumor immunotherapy mainly due to their activity in suppressing tumor invasion and metastasis (Lin *et al.*, 2010). Xu *et al.*, 2011) published an extensive and comprehensive review about bioactive proteins in mushrooms.

### **Lipids**

Polyunsaturated fatty acids are mostly contained in edible mushrooms; thus, they may contribute to the reduction of serum cholesterol. It is noteworthy that transisomers of unsaturated fatty acids have not been detected in mushrooms (Table 3) (Guillamon *et al.*, 2010). The major sterol produced by edible mushrooms is ergosterol, which shows antioxidant properties (Guillamon *et al.*, 2010). It has been observed that a diet rich in sterols is important in the prevention of cardiovascular diseases (Kalac, 2013).

Tocopherols found in the lipidic fraction are natural antioxidants because they act as free radical scavenging peroxy components produced from different reactions. These antioxidants have high biological activity for protection against degenerative malfunctions, cancer and cardiovascular diseases. Linoleic acid, an essential fatty acid to humans, takes part in a wide range of physiological

functions; it reduces cardiovascular diseases, triglyceride levels, blood pressure, and arthritis (Reis *et al.*, 2012).

### Phenolic compounds

Phenolic compounds are secondary metabolites possessing an aromatic ring with one or more hydroxyl groups and their structures can be a simple phenolic molecule or a complex polymer. They exhibit a wide range of physiological properties, such as antiallergenic, anti atherogenic, anti-inflammatory, antimicrobial, antithrombotic, cardio protective and vasodilator effects. The main characteristic of this group of compounds has been related to its antioxidant activity because they act as reducing agents, free radical scavengers, singlet oxygen quenchers or metal ion chelators (Heleno *et al.*, 2012).

Phenolic compounds provide protection against several degenerative disorders, including brain dysfunction, cancer, and cardiovascular diseases. This property is related to their capacity to act as antioxidants; they can scavenge free radicals and reactive oxygen species. The process of oxidation is essential for living organisms; it is necessary for the production of energy. However, the generation of free radicals has been implicated in several human diseases. The phenolic compounds in mushrooms show excellent antioxidant capacity (Finimundy *et al.*, 2013). Palacios *et al.*, (2011) evaluated total phenolic and flavonoid contents in eight types of edible mushrooms (*Agaricus bisporus*, *Boletus edulis*, *Calocybe gambosa*, *Cantharellus cibarius*, *Craterellus cornucopioides*, *Hygrophorus marzuolus*, *Lactarius deliciosus*, and *Pleurotus ostreatus*). These authors concluded that mushrooms contain 1-6 mg of phenolics/g of dried mushroom and the flavonoid concentrations ranged between 0.9 and 3.0 mg/g of dried matter; the main

flavonoids found were myricetin and catechin. *B. edulis* and *A. bisporus* presented the highest content of phenolic compounds, while *L. deliciosus* showed a high amount of flavonoids and *A. bisporus*, *P. ostreatus*, and *C. gambosa* presented low levels. Heleno *et al.*, (2012) reported proto catechuic, *p*-hydroxybenzoic, *p*-coumaric and cinnamic acids in the phenolic fraction in five wild mushrooms from northeastern Portugal.

### Main edible mushrooms worldwide

#### Agaricus

Button mushroom (*Agaricus bisporus*) is the most cultivated mushroom worldwide (Figure 1). This group of edible mushrooms is nowadays widely used and studied for its medicinal and therapeutic properties (Lima *et al.*, 2011).

A lectin from *A. bisporus* and a protein from *A. polytricha* have been found to be potent immune stimulants; thus, these macromolecules may be considered for pharmaceutical utilization and these fungi may be classified as strong food. *A. bisporus* extract has been shown to prevent cell proliferation in breast cancer (Patel & Goyal, 2012).

*A. blazei* is an edible mushroom native to Brazil and it has been cultivated especially in Japan. It is a very popular basidiomycete known as “sun mushroom” and at these days it is consumed globally as food or in tea due to its medicinal properties. Its fruit bodies exhibit antimutagenic, anticarcinogenic and immune stimulative activities (Hakime Silva *et al.*, 2013), its extracts have also shown immune modulatory, anticarcinogenic and antimutagenic properties. Additionally, it has been reported that this mushroom blocks the liver lipid peroxidation. Al Dbass, *et al.*, (2012) concluded that *A. blazei* is a natural

source of antioxidant compounds and has hepatoprotective activities against liver damage. On the other hand, (Hakime Silva *et al.*, 2013) reported that the aqueous extract of this fungus is a possible source of free radical scavengers and stated that this fungus can be used as a pharmacological agent against oxidative stress and as a nutritional source. Furthermore, it is known that this fungus is rich in  $\beta$ -glucans, steroids, tocopherols and phenolic compounds (Reis *et al.*, 2012); (Firenzuoli *et al.*, 2008). Besides, liquid extracts of this fungus inhibit cell proliferation in prostate cancer cells and oral supplementation suppressing significantly tumor growth without inducing adverse effects. *A. blazei* has been used as an adjuvant in cancer chemotherapy and various types of antileukemic bioactive components have been extracted from it (Patel & Goyal, 2012); (Hakime Silva *et al.*, 2013).

Carneiro *et al.*, (2013) reported powder formulations from *A. blazei* and *L. edodes* with proteins, carbohydrates and unsaturated fatty acids. These formulations may be used in low calorie diets and have shown high antioxidant activity with high content of tocopherols and phenolic compounds. In view of the previous studies, this fungus has been used as a healthy food for the prevention of a range of illnesses including cancer, diabetes, arteriosclerosis and chronic hepatitis (Al Dbass *et al.*, 2012).

*A. subrufescens* is called the “almond mushroom” for its almond taste and it is cultivated in the US and has been incorrectly referred as *A. blazei*. It produces various bioactive compounds that have potential to treat many diseases and has been used as a medicinal food for the prevention of cancer, diabetes, hyper lipidemia, arteriosclerosis and chronic hepatitis. Some of its beneficial properties are the reduction of tumor growth, antimicrobial and antiviral activities, immune

stimulatory and antiallergy effects. The bioactive compounds isolated from this mushroom are mainly based on polysaccharides such as riboglucans,  $\beta$ -glucans and glucomannans. The antitumor activity has been found in lipid fractions that is ergosterol (Lima *et al.*, 2011); (Wisitrassameewong *et al.*, 2012).

### **Lentinus**

Shiitake mushroom (*Lentinus edodes*) has been used for many years to investigate functional properties and to isolate compounds for pharmaceutical use; this is because of its positive effects on human health (Figure 2). It has been utilized to alleviate the common cold for hundreds of years and some scientific evidence has supported this belief. Finimundy *et al.*, (2013) have provided experimental information about the aqueous extracts of *L. edodes* as potential sources of antioxidant and anticancer compounds. These extracts significantly decreased cell proliferation on tumor as well.

*Lentinus edodes* contains high levels of  $\beta$ -glucans in the soluble fraction of dietary fiber. Shiitake produces lentinan and  $\beta$ -glucan that suppress leukemia cell proliferation and have antitumor and hypo cholesterolemic activity (Patel & Goyal, 2012); (Bisen *et al.*, 2010). Lentinan is used in clinic assays as adjuvant in tumor therapy and specifically in radiotherapy and chemotherapy. On the other hand, it has been reported that lentinan enhances host resistance against infections by bacteria, fungi, parasites and virus; it also promotes nonspecific inflammatory responses, vascular dilation, hemorrhage-inducing factors activation, and generation of helper and cytotoxic T cells (Yamaguchi *et al.*, 2011). In other studies, *L. edodes* exhibited capacity to inhibit the growth of mouse sarcoma, probably due to the presence of an unspecified water soluble polysaccharide.

Another edible mushroom is *L. polychrous*, found in northern and north-eastern Thailand, which is used as medicine in diseases like dyspepsia or envenomation caused by snake or scorpion. The methanolic extract and crude polysaccharides have antioxidative activity and inhibitory effect on cell proliferations of breast cancer (Thetsrimuang *et al.*, 2011). Additionally, mycelial extracts from this mushroom have antiestrogenic activity, resulting from a new poly hydroxyoctane and several ergostanoids (Fangkrathok *et al.*, 2013).

### **Pleurotus**

Oyster mushroom (*Pleurotus* species) has approximately 40 species (all are commonly edible and available) (Figure 3). In addition to their nutritional value, they possess medicinal properties and other beneficial effects and health promoting effects. *Pleurotus* species have been used by human cultures all over the world for many years.

These species have been used as medicinal mushrooms for long time since they contain several compounds with important pharmacological/nutraceutical properties. Some of these substances are lectins with immunomodulatory, antiproliferative and antitumor activities; phenolic compounds with antioxidant activities and polysaccharides (poly saccharopeptides and polysaccharide proteins) with immune enhancing and anticancer activities.  $\beta$ -glucans isolated from *Pleurotus pulmonarius* demonstrated an anti-inflammatory response in rats with colitis, and *P. ostreatus* inhibited leukocyte migration to acetic acid-injured tissues. An extract from *P. florida* suppressed inflammation. *Pleurotus* has also been reported with hematological, antiviral, antitumor, antibacterial, hypocholesterolic, immune modulatory activities and antioxidant properties.

Maity *et al.*, (2011) reported the stimulation of macrophages with different concentrations of

the heteroglycan isolated from *P. ostreatus*. In addition, Jedinak *et al.*, (2011) concluded that the edible oyster mushroom may be considered a functional food due to its anti-inflammatory activity and potential to control inflammation. Moreover, *P. ostreatus* exhibits hypocholesterolemic effect on rats with normal cholesterolemia or hypercholesterolemia and hereditary cholesterol disorders. Other authors reported some species of *Pleurotus* with this hypocholesterolemic effect as well (Guillamon *et al.*, 2010). *Pleurotus pulmonarius* apparently seems to be the richest source of fungal  $\beta$ -glucans. They also concluded that  $\beta$ -glucans in mushroom is distributed in the soluble and insoluble dietary fraction.

*P. citrinopileatus*, *P. djamor*, *P. eryngii*, *P. flabellatus*, *P. florida*, *P. ostreatus* and *P. sajor-caju* were evaluated by (Mishra *et al.*, 2013). The authors concluded that *P. eryngii* had the highest contents of phenolics followed by *P. djamor*. Also, *P. eryngii* had a better antioxidant activity and *P. citrinopileatus* had more ascorbic acid and chelating activity.

Kanagasabapathy *et al.*, (2011) reported antitumor effects and antioxidant properties by *P. sajor-caju*. The aqueous and butanol extracts exhibited the highest antioxidant activity and corresponded to the total phenolic content. Also, a ribonuclease from *P. sajor-caju* presented antimicrobial, antimutagenic and antiproliferative activities. However, the antiproliferative activity of this fungus may result from its specific proteins, terpenoids, steroids, fatty acids and phenolic compounds. On the other hand, Finimundy *et al.*, (2013) reported evidence that *P. sajor-caju* is a potential source of antioxidant and anticancer compounds. Water soluble polysaccharides extracted from *P. tuber-regium* a novel edible mushroom showed effective anti proliferative activity against human leukemia cells and induced apoptosis in HL-60 cells (Patel & Goyal, 2012); (Hakime Silva *et al.*, 2013).

*Pleurotus giganteus* is a culinary mushroom with outstanding sensory properties. It contains 15.4 g of protein and 33.3 g of dietary fiber/100 g of mushroom (dry weigh basis) and it also has important amounts of carbohydrates. It is rich in minerals like magnesium (67.64 mg/100 g dry weight) and potassium (1,345.7 mg/100 g dry weight). Its carbohydrate content is 4-11 times higher than other edible mushrooms (Phan *et al.*, 2012). The aqueous and ethanolic extracts from *P. giganteus* have shown antioxidant, genotoxic and liver protective properties and have a high effect on neuronal differentiation and neurite outgrowth. The high potassium level in the fruiting bodies and the presence of bioactive compounds mainly triterpenoids could be responsible for the neuro activity (Phan *et al.*, 2012); (Wong *et al.*, 2012).

### **Ganoderma**

The “mushroom of immortality” commonly known as Reishi, has been used in traditional Chinese medicine to improve health and longevity for thousands of years as well as in the treatment of neurasthenia, hypertension, hepatopathy and carcinoma (Figure 4).

It is one of the most popular medicinal mushrooms in China, Japan and Korea. It has been under modern biochemical and pharmacological research during the last decades (Zhou *et al.*, 2012). Modern pharmacological tests have also demonstrated some important characteristics of this fungus such as immune modulating, antiallergic, antiradiation, antitumor, antiinflammatory, antiparasitic and antioxidant properties.

In Asia, *Ganoderma* has been administered for centuries as treatment for cancer; it exhibits anticancer effect alone or in combination with chemotherapy and radiotherapy. *Ganoderma* decreases viability of human cancer cells, induces cell apoptosis, inhibits cell proliferation, suppresses the motility of

invasive breast and prostate cancer cells and prevents the onset of various types of cancer. Furthermore, Chen and Zhong (2011) reported the inhibition of tumor invasion, metastasis and cell adhesion, promotion of cell aggregation and suppression of cell migration in human colon tumor cell lines. Lai *et al.*, (2010) reported the suppression of epidermoid cervical carcinoma. Water soluble polysaccharides from *Ganoderma* act over more than 20 types of cancer and strongly inhibit tumor growth.

The major biologically active polysaccharides from *Ganoderma* are  $\beta$ -glucans and the anticancer and antimetastatic activities are due to its polysaccharides and triterpenoid components. These compounds may be associated with their immune stimulating activities and antioxidant capacity. It also contains a large number of proteins and peptides with biological activities such as lectins, ribosome inactivating proteins, antimicrobial proteins, ribonucleases and lactases, which are important for life activity and show immunomodulatory and antitumor effects as well (Zhou *et al.*, 2012); (Weng & Yen, 2010).

*Ganoderma* present three characteristics for prevention or treatment of diseases. First it does not produce any toxicity or side effects, second it does not act on a specific organ and third it promotes the improvement of normalization of the organ function. Modern pharmacological and clinical trials have demonstrated that this fungus shows a significant effect on the prevention and treatment of various diseases, especially cancer, including immune modulation, induction of cytokine production, antiallergic, antiradiation, antitumor, anti-inflammatory, antiparasitic and antioxidant effects, as well as benefits for the cardiovascular, respiratory, endocrine and metabolic systems (Zhou *et al.*, 2012).

A large collection of scientific information on bioactive components and pharmacological properties mainly on the anticancer potential of *Ganoderma* is available; it is focused on the anticancer effect, regulation of cell cycle and cell signaling.

Weng and Yen (2010) studied the inhibitory activity against invasive and metastatic behaviors (*i.e.*, adhesion, migration and angiogenesis) in various cancer cells *in vitro* or implanted in mice.

Currently, *Ganoderma* is recognized as an alternative adjuvant in the treatment of leukemia, carcinoma, hepatitis and diabetes as well as an immune system enhancer with health benefits. In general, it is safe to be used for a long period of time (Zhou *et al.*, 2012). The dried powder and aqueous/ethanol extracts of *G. lucidum* are used worldwide as dietary supplement.

Boh (2013) studied around 270 patents for fruit bodies and mycelia cultivation methods of *Ganoderma lucidum*, basidiomycete mushroom with strong anticancer effects.

Boh concluded that the anticancer activity of this fungus may be attributed to at least five groups of mechanisms: (a) activation/modulation of the immune response of the host (b) direct cytotoxicity to cancer cells (c) inhibition of tumor induced angiogenesis (d) inhibition of cancer cells proliferation and invasive metastasis behaviour and (e) carcinogens deactivation with protection of cells.

### **Other mushrooms**

Some other species of mushrooms are also edible and possess health benefits. *Trametes versicolor* has been shown to promote chemo preventive potential; it inhibits growth of several human cancer cell lines, acts as

adjuvant in breast cancer prevention and has a significant IC<sub>50</sub> value.

*Grifola frondosa* is promoted as anticancer agent, particularly on human gastric carcinoma such effect results from the induction of cell apoptosis and could significantly accelerate the anticancer activity.

In this context, it could be mentioned that *Cordyceps militaris* has several beneficial effects and it is used for multiple medicinal purposes. It acts as an antitumor, antiproliferative, antimetastatic, insecticidal and antibacterial compound.

More than 21 clinically approved beneficial effects for human health have been found in this mushroom (Das *et al.*, 2010). Extracts of *C. militaris* have been used for its immuno modulatory and antiinflammatory effects. Moreover, it is also a cancer preventive material and is effective against chronic bronchitis, influenza A and viral infections (Rao *et al.*, 2010).

*Cordyceps sinensis* contains substances called cordycepin, cordycepic acid with therapeutic applications like the effects of increased oxygen utilization, ATP production and stabilization of blood sugar metabolism. Besides, it has antibacterial function, reduces asthma and lowers blood pressure. On the other hand, it has been reported as organ protector, as well as with a protective effect for heart, liver and kidney diseases. Also, *C. sinensis* has sedative effect on the central nervous system.

*Antrodia cinnanomea* is a medicinal mushroom native to Taiwan with various functional compounds and a total of 105 Taiwan patent applications. Different commercial products are made with this mushroom and it has been used to treat food and drug intoxication, diarrhea, abdominal

pain, hypertension, skin itching and cancer (Chen *et al.*, 2013).

*Panellus serotinus* (Mukitake) is extremely appreciable in Japan as one of the most

delicious edible mushrooms. The use of this fungus helps to prevent the development of nonalcoholic fatty liver disease (Inoue *et al.*, 2013).

**Table.1** Proximal composition of some edible mushrooms (dry basis)

Species	Protein (%)	Fat (%)	Ash (%)	Carbohydrates (%)	Energy (kcal/g)
<i>Agaricus bisporus</i>	14.1	2.2	9.7	74.0	325
<i>Lentinus edodes</i>	4.5	1.73	6.7	87.1	772
<i>Pleurotus ostreatus</i>	7.0	1.4	5.7	85.9	416
<i>Pleurotus eryngii</i>	11.0	1.5	6.2	81.4	421
<i>Pleurotus sajor-caju</i>	37.4	1.0	6.3	55.3	
<i>Pleurotus giganteus</i>	17.7	4.3	—	78.0	364
<b>Dry powder formulations</b>					
<i>Agaricus blazei</i>	31.3	1.8	7.5	59.4	379
<i>Lentinus edodes</i>	12.8	1.0	4.3	81.9	388

**Table.2** Composition of sugars of some edible mushrooms (dry weight)

Species	Fructose	Mannitol	Sucrose	Trehalose	Total sugars
	(g/100 g fresh weight)				
<i>Agaricus bisporus</i>	0.03	5.6	Nd	0.16	5.79
<i>Lentinus edodes</i>	0.69	10.01	Nd	3.38	14.03
<i>Pleurotus ostreatus</i>	0.01	0.54	Nd	4.42	4.97
<i>Pleurotus eryngii</i>	0.03	0.60	0.03	8.01	8.67
<b>Dry powder formulations</b>					
<i>Agaricus blazei</i>	0.27	60.89	Nd	5.74	66.91
<i>Lentinus edodes</i>	Nd	23.3	Nd	13.22	38.31

Nd= Not detected

**Table.3** Fatty acids content of some edible mushrooms

Species	Palmitic (C16:0)	Stearic (C18:0)	Oleic (C18:1)	Linoleic (C18:2)	Linolenic (C18:3)
	Fatty acid (g/100 g fresh weight)				
<i>Agaricus bisporus</i>	11.9	3.1	1.1	77.7	0.1
<i>Lentinus edodes</i>	10.3	1.6	2.3	81.1	0.1
<i>Pleurotus ostreatus</i>	11.2	1.6	12.3	68.9	0.1
<i>Pleurotus eryngii</i>	12.8	1.7	12.3	68.8	0.1
<b>Dry powder formulations</b>					
<i>Agaricus blazei</i>	11.38	2.8	1.85	72.42	Nd
<i>Lentinus edodes</i>	11.78	1.09	3.28	78.59	0.59

Nd= Not detected

**Fig.1** Button mushroom (*Agaricus bisporus*)



**Fig.2** Shiitake mushroom (*Lentinus edodes*)



**Fig.3** Oyster mushroom (*Pleurotus spp.*)



**Fig 4.** Reishi mushroom (*Ganoderma lucidum*)



Most *Auricularia* species are edible and are grown commercially in China. *A. polytricha* has potential medicinal properties and is considered effective to reduce LDL cholesterol and aortic atherosclerotic plaque; it also has antitumor and anticoagulant activities. Besides, *A. auricula-judae* is a popular ingredient in many Chinese dishes; it has been used as a blood tonic and has shown antitumor, hypoglycemic, anticoagulant and cholesterol lowering properties (Yu *et al.*, 2014); (Reza *et al.*, 2014). *Flammulina velutipes* is available as fresh or canned product and it is traditionally used for soups in China. It contains biologically active components such as dietary fiber, polysaccharides and antioxidants, which reduce blood sugar, blood pressure and cholesterol (Yeh *et al.*, 2014).

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. 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. It has been shown by a wide range of studies that mushrooms contain components with outstanding properties to prevent or treat different type of diseases. Powder formulations of some species have revealed the presence of essential nutrients. They present a low fat content and can be used in low calorie diets just like the mushrooms fruiting bodies. Some formulations could be used as antioxidants to prevent oxidative stress and thus ageing. Future studies into the mechanisms of action of mushroom extracts will help us to further delineate the interesting roles and properties of various mushroom phytochemicals in the prevention and treatment of some degenerative diseases. In view of the current situation, the research of bioactive components in edible wild and cultivated mushrooms is yet deficient. There are numerous potential characteristics and old and novel properties, provided by mushrooms with nutraceutical and health benefits which deserve further investigations.

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