THE NUTRITIONAL AND MEDICAL BENEFITS OF AGARICUS BISPORUS: A REVIEW

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INTRODUCTION

Mushrooms have been recognized as important food items since the ancient times because of their nutritional values and therapeutic properties. In ancient China, people believed that the mushroom establishes human body and health, preserves the youth for as long as possible, it was used as food and medicine (Safwat and Maihara, 2012). The nutritional attributes of edible mushrooms and the health benefiting effects of the bioactive compounds they contain, make mushrooms a health food (Rodrigues et al., 2008). Mushrooms are considered as potential source of many essential nutrients and therapeutic bioactive compounds. Agaricus bisporus belongs to Basidiomycetes family and is the most important commercially cultivated mushroom in the world. The rich nutrients like carbohydrates, proteins, lipids, fibers, minerals, and vitamins present this mushroom as famous healthy food. Moreover, because of the presence of some active ingredients, such as polysaccharides, lipopolysaccharides, essential amino acids, peptides, glycoproteins, nucleosides, triterpenoids, lectins, fatty acids and their derivatives, these mushrooms have been reported to have antimicrobial, anticancer, antidiabetic, antihypercholesterolemic, antihypertensive, hepatoprotective and antioxidant activities. This study is focused on reviewing the recent studies published in the medical and nutritional properties of Agaricus bisporus. Investigations on the mushroom have accelerated during the last ten years so that only reports published after 2006 have been considered.

Proximate Compositions

Mushrooms contain a high moisture percentage depending on harvest, growth, culinary and storage conditions (Guillamón et al., 2010). Reis et al. (2012) described moisture (91–92 g/100 g), ash (0.9–1 g/100 g) and energy (29–31 kcal/100 g) in Agaricus bisporus samples. Ahlavat et al. (2016) analyzed the fruitbodies of A. bisporus for its proximate composition and they found that Agaricus bisporus fruitbody is rich in protein (29.14%), carbohydrate (51.05%), fat (1.56%) compared to Pleurotus eous, Volvariella volvacea and Lentinula edodes. Tsai et. al. (2007), it has been found that the content of the fruits from the carbohydrate 48.9-38.3%, fibers 23.3-17.7% and ash 11.00-7.77% fat 3.92-2.53% in dry A. bisporus fruitbodies.

Protein and Amino acid content

Mushrooms are considered as a good source of protein. Correa et al. (2016) suggested that mushrooms are ranked below animal meats, but well above most other foods, including milk, which is an animal product, concerning the amount of crude protein. Growing substrates (Gothwal et al., 2012), the stage of development and pre and post-harvest conditions (Guillamón et al., 2010) can influence the chemical composition and the nutritional value of the cultivated mushrooms. So nutritional composition data of mushrooms published by different authors working with even the same species are variable. The protein content of A. bisporus presented by Sadiq et al. (2008) with 11.01 %, by Muszynska et al. (2011) with 25%, by Mohiuddin et al. (2015) with 17.7%–24.7% and by Ahlavat et al. (2016) with %29.14 in different growing substrates. The amino acid composition of mushroom proteins is comparable to animal protein, which is of particular importance to counterbalance a high consumption

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of protein animal food sources, especially in developed countries (Guillamon et al., 2010). Kakon et al. (2012) reported that mushroom proteins contain all nine essential amino acids required by humans, enabling their use as a substitute for a meat diet. The amino acids found in A. bisporus in the highest amounts are alanine, aspartic acid, glutamic acid, arginine, lysine, methionine, leucine, serine, proline, tyrosine and threonine (Muzysniska et al., 2013). Moreover, Muslak et al. (2014) reported that A. bisporus contains the essential amino acids useful as a food for the human health including cystine and methionine and threonine and valine and isoleucine and leucine and lysine and tyrosine and phenylalanine.

Carbohydrate and Fiber

Mushroom carbohydrates are not a major source of energy for humans. Digestible carbohydrates include mannitol and glucose, usually present in very small amounts (less than 1% DW) and glycoxygen (5–10% DW) while undigestible carbohydrates include oligosaccharides such as trehalose and non-starch polysaccharides (NSPs) such as chitin, β-glucans and mannans, which are the major portion of mushroom carbohydrates (Cheung et al., 2010; Reis et al., 2015). Moreover, it has been reported that mushroom and trehalose are abundant sugars in the studied cultivated edible mushrooms, mannitol predominated in A. bisporus (white and brown mushrooms). Dietary fiber includes components of fungal cell walls such as chitin (Maftoun et al., 2015), hemi-celluloses, mannans and beta glucans play a key role in some healthy properties of mushrooms (Cheung, 2009; Nitschke et al. 2011) determined that chitin content of A. bisporus was 9.60 g/100 g DM. Conversely, musaeus et al. (2010) reported that A. bisporus contains 2 times more chitin than P. ostreatus. Similarly, Vetter (2007) determined that A. bisporus had higher chitin level than had P. ostreatus, L. edodes.

Mineral content

Mushrooms are known to be an excellent accumulator of minerals from the environment in which they grow. Owaid (2015) reported that A. bisporus a good source of K, Fe, Zn, Cu, Na, Se,Co and Mn. The main constituents in mushroom fruiting bodies are potassium and phosphorus and are usually followed by Ca. Mg, Na and Fe. Zn (Guillamonn et al., 2010; Falandyz and Borovička, 2013). Mohuddin et al. (2015) Agaricus bisporus fruitbodies from different locations of Bangladesh, were analysed for their minaral content profile . The mineral content of samples ranged from 0.54–1.58% for potassium and 37.2–61.9 μg/g for sodium, 143.6–396 μg/g for ferrum, 54.6–163 μg g-1 for copper, 36.6–58.0 μg/g for zinc, 5.6–91.8 μg/g for manganes. Čaglarımak (2009) determined that, that thiamin (8.1–7.0 μg/g), ferrum (7.4–7.9 μg/g), potassium (7.4–7.9 μg/g), magnesium (88.0–76.3 μg/g), potassium (213.3–238.8 μg/g), sodium (2652–2500 mg/kg) and calcium (534.2–554.8 mg/kg) contents, whereas Ahlavit et al. (2016) they found that sodium (500.8 mg/kg), potassium (4.21%) and selenium (1.34 g/kg of A. bisporus fruitbodies.

Selenium is an essential micronutrient for humans and animals (Lu and Holmgregn, 2009). Turto et al. (2010) reported that most wild growing and farmed edible mushroom species including A. bisporus are poor selenium sources with a concentration of less than 1 μg/g (dried weight). On the other hand, Maseko et al. (2013) suggested that the Se concentration in A. bisporus cultivated in growth compost irrigated with sodium selenite solution can be increased. They determined that selenium contents of mushroom proteins increased from 13.8 to 60.1 and from 14.1 to 137 μg/g in caps and stalks by irrigate A. bisporus with sodium selenite solution. Maseko et al. (2014) investigated the effect of dietary supplementation with Se-enriched A. bisporus on cytosolic glutathione peroxidase-1 (GPx-1), gastrointestinal specific glutathione peroxidase-2 (GPx-2), thioredoxin reductase-1 (TrxR-1) and selenoprotein P (SeP) mRNA expression and GPx-1 enzyme activity in rat colon and they reported that the activity of colonic GPx-1 in rats provide evidence for its potential anti-cancer use.

Vitamins

Some authors have considered mushrooms as a good source of vitamins. It was reported that the most abundant vitamin in Agaricus is niacin, followed by riboflavin. Other vitamins include vitamin B1, vitamin B3, L-ascorbic acid and β-tocopherol (Bernas & Jaworska, 2016). Çaglarımak (2009) also reported that brown A. bisporus (portobello mushroom) is a good source of folic acid (0.09–0.08 mg g–1), riboflavin(0.27–0.29 mg g–1), niacin (3.6–2.9 mg g–1), and thiamin (0.085–0.09 mg g–1), while not rich in vitamin C content. On the other hand, Furlany and Godoy (2008) determined that the mean level of vitamin B1, for fresh A. bisporus was 0.03 mg/100 g while vitamin B1 for the A. bisporus mushrooms was 0.00 mg/100 g. They reported that although Vitamin B1 contents in A. bisporus, Lentinula edodes and Pleurotus spp. with exception of mushroom in conserve, are higher than the levels present in many vegetables, mushrooms could not be considered as significant sources of B1 and B2 vitamins, since their contribution in terms of these vitamins to the diet is not significant although they may contribute to the sums of the nutrients in the diet.

Mushrooms are a natural source of vitamin D. Ahlavit et al. (2016) determined that vitamin D content of A. bisporus is 984 IU/g. It is found in larger quantities in wild mushrooms compared to cultivated mushrooms (Simons et al., 2011). The absence of vitamin D in cultivated Agaricus bisporus could be due to cultivation in dark (Reis et al., 2012). Roberts et al. (2008) reported treating ultraviolet light on the mushrooms in order to increase the vitamin D content. However, this can be problematic because it is not feasible to harvest the mushrooms in this way.

Fatty acids

Agaricus bisporus is low in fat content, but they contain some essential fatty acids such as linoleic acid. Barros et al. (2008) reported that wild Agaricus spp. contained a lower content of unsaturated fatty acids but also a higher content of polyunsaturated fatty acids than the commercial species, due to the higher contribution of linoleic acid. Total amounts of fatty acids ranged from 180 to 5818 mg/kg dry matter in the A. bisporus strains tested and almost 90% of the fatty acids in A. bisporus is linoleic acid on average (Baars et al., 2016). Sadiq et al. (2008) reported that fatty acids detected in A. bisporus were: linoleic, caprylic, palmitic, stearic, oleic, eicosan and erucic acids and linoleic acid was the major fatty acid in A. bisporus that accounts for 44.19% of total fatty acid identified. Ozturk et al. (2011) find that linoleic (61.82–67.29%) and palmitic (12.67–14.71%) acids were dominant fatty acids in A. bisporus among the 13 fatty acids detected in the oils. The fatty acid contents of A. bisporus are reported to be mainly linoleic and palmitic and stearic acids by Sha et al. (2010). Linoleic acid is essential for human health and has many beneficial effects on human health. They reduce atherosclerosis by interfering with HDL in the blood (Sadiq et al., 2008). Hassain (2007) determined that the concentration of linoleic acid in A. bisporus was 20- and 5-folds more than those in the Ganoderma lucidum and Pleurotus ostreatus, respectively.

Soluble sugar and volatile compounds

Flavor and taste represent the most important quality attribute contributing to the overall perception of mushroom products. The taste of mushroom is a component umami or palatable tastes or the perception of satisfaction, which is an overall food flavor sensation induced or enhanced by monosodium glutamate (MSG). The contents of MSG-like (aspartic and glutamic acids) and sweet components (alanine, glycine, and threonine) total soluble sugars and polysols were considerably higher in edible mushrooms and might be sufficient to suppress and cover the bitter taste arising from the contents of bitter components. The content of monosodium glutamate-like components is in the range from 10.6 mg/g to 13.5 mg/g and similar to those of sweet components (11.4–14.3 mg/g) but lower than those of bitter components (19.7–26.9 mg/g) (Tsai et al., 2007).

For A. bisporus mannitol was the most abundant sugar (Baars et al., 2016). Tsai et al. (2007) also reported that mannitol was the major soluble sugar in fresh A. bisporus fruitbodies while glucose was the second highest and its contents were in the range of 17.6–28.1 mg/g in different mature stages. Moreover, they suggested that the high amount of sugars and polysols, especially mannitol, would give rise to a sweet perception, and not to the typical mushroom taste. Taste in mushrooms is linked both to volatile and non-volatile compounds. The terpenes, lactones, amino acids, and carbohydrates of their composition determine a range of precious aromas and flavor properties to their fruiting body and mycelial biomass (Smilde et al., 2012). Štaškin et al. (2013) identified totally 28 aroma compounds of A. bisporus. In this study, alcohols were detected to be the major compounds and 1-octen-3-ol was found to be the major alcohol.

Medicinal importance of A. bisporus

There is an increasing interest in extracting bioactive ingredients from mushrooms for developing functional foods. A. bisporus have a very good history of being used for many traditional therapies. The use of A. bisporus extracts and/or its bioactive compounds as antioxidant, anti-cancer and anti-inflammation is increasing in the world against many human diseases such as coronary heart diseases, diabetes mellitus, bacterial and fungal infections, disorders of the human immune system and cancers (Dhatenharaan and Murinurali, 2010). No significant data have been reported on the direct effects of mushroom consumption in humans, those that have been completed to date indicate that mushrooms and their extracts are generally well-tolerated with few, if any, side effects. (Yolman et al., 2010). Antioxidant (Guhabremani-Majd and Dasthti, 2015) and anti-diabetic (Mio et al., 2013) antibacterial properties (Nduongate et al., 2015) of A. bisporus were reported some studies (Öztürk et al., 2011). A. bisporus extracts can be potentially applied in Alzheimer’s disease treatment reported that due to their
acetylcholinesterase and butyrylcholinesterase inhibiting activity. Mohamed (2012) determined that a total 174 significant metabolites in ethanolic extracts of Agaricus bisporus samples by using GC/MS method between 1% to 83% (w/w) classified into twelve categories. These metabolites had numerous medicinal activities such as anti-cancer, anti-cardiovascular disease, anti-hypercholesterolemia, antimicrobial, hepatoprotective, human health supporting and immune enhancer. The main medical properties of A. bisporus were presented in the following section.

Anticancer

Cancer is one of the deadliest diseases in the world. Recently, purified some natural active component from mushrooms such as polysaccharides exhibited the significant anti-cancer activity toward various cancer cell lines. Basidiomycota is known to present medicinal characteristics, which are being attributed to its glucan and other polysaccharide. The polysaccharides generally belong to the beta-gluan family of compounds and appear to exert their anti-tumorigenic effects via enhancement of cellular immunity. A. bisporus contains bioactive compounds that have been shown to exhibit immunostimulatory and antitumor bioactivity. The Canadian Cancer Society recommends consumption of A. bisporus mushroom because of its effectiveness against human diseases. Zhang et al. (2014) reported that brown A. bisporus polysaccharide possessed strong immunostimulatory and antitumor bioactivity in vitro and in vivo. A. bisporus contains three main polysaccharides α-glucan, β-glucan and galactomannan Smiedere et al. (2011) and galactomannan is main polysaccharide by 55.8% (Smiedere et al., 2013). Ren et al. (2012) reported that the most common glucans extracted from A. bisporus are (1→3), (1→6)-d-glucans. Consumption of fruit juice enriched with α-glucans from A. bisporus (5 g glucans/day) lipopolysaccharide induced tumor necrosis factor (TNFα) production by 69%. No effects on interleukin (IL)-1β and IL-6 and decreased production of IL-12 and IL-10 was observed (in vivo) (Volman et al., 2010). On the other hand, A. bisporus does not present very high β-glucan content (8–12 g/100 g dm). Low beta-glucan content in Agaricus bisporus is also reported by McCleary and Draga (2016).

A. bisporus has got potential health benefits for improving mucosal immunity. The dietary intake of A. bisporus significantly accelerates secretary immunoglobulin A secretion (Jeong et al., 2012). A. bisporus fruiting bodies express an immunostimulating effect on activated human peripheral blood mononuclear cells (PBMCs) and induces synthesis of interferon gamma (IFNγ) (Dubost et al., 2011). Extracts from A. bisporus have been shown to inhibit cell proliferation of HL-60 leukemia cells and other leukemia human cell lines via the induction of apoptosis. (Jagadish et al., 2009). Novaxes et al. (2011) reported that arginine present in the A. bisporus fruitbodies delays tumor growth and metastasis and should be used as dietary supplements for patients with cancer. Kanaya et al. (2011) reported that A. bisporus would suppress aromatase to decrease the risk of breast cancer. Moreover, A. bisporus contained the high amount of lovastatin (Chen et al., 2012). Yang et al. (2016) demonstrated that lovastatin exerts anti-cancer effects in the triple-negative breast cancer cell line MDA-MB-231. Palomares et al. (2011) reported that phytochemicals extracted from Agaricus bisporus contain anti-cancer activity, inhibits breast cancer (BC) cell proliferation and decrease mammary tumor formation in vivo. They suggested that anti-aromatase phytochemicals are present in plasma with daily consumption of 100–130g whole WBm, but not at high enough concentrations to significantly reduce estrogen levels from baseline in 12 weeks. Moreover, Chen et al. (2006) reported that the major active compounds in A. bisporus are unsaturated fatty acids such as linoleic acid, linolenic acid, and CLA which have been shown to inhibit aromatase activity. Roupas et al. (2012) also reported that an inhibition of aromatase activity and subsequent reduction of estrogen using extracts of mushroom that provide a physiologically suitable mechanism for influences on estrogen receptor positive tumors. Although Hong et al. (2008) reported that daily intake and average of consumption frequency of mushroom were inversely associated with breast cancer risk, and a strong inverse association was found in post-menopausal women. Shin et al. (2010) suggested that a decrease in breast cancer from mushroom consumption by pre-menopausal women.

Antihyperlipidemic

Hyperlipidemia, represented by increased levels of triglycerides or cholesterol, is a dominant risk factor that contributes to the progression and development of subsequent cardiovascular disease and atherosclerosis, which is one of the most serious diseases in humans (Esmaillzadeh and Azabakht, 2008). Phytosterols derive reduce cholesterol absorption, thereby having the capacity to lower plasma cholesterol and LDL cholesterol (Lin et al., 2009). The identified sterols in A. bisporus are ergosta-7,22-dienol, ergosta-5,7,22-dienol, and ergosta-7,22-dienol (fungisterol) (Teichova et al., 2007). Lovastatin is a statin drug, used for lowering cholesterol (hyperlipidemia) in those with hypercholesterolemia to reduce the risk of cardiovascular disease (Xu et al., 2013). Yang et al. (2016) demonstrated that lovastatin exerts anti-cancer effects in the triple-negative breast cancer cell line MDA-MB-231. Chen et al. (2012) reported that Agaricus bisporus contained the 563.4 mg/kg of lovastatin and suggested also that white button mushroom A. bisporus reduce the cholesterol level in serum and/or liver. Jeong et al. (2010) examined the hypothesis that intake of the fruiting bodies of A. bisporus regulates antipyogenic and anticholesterolemic responses in rats fed a hypercholesterolemic diet (14% fat and 0.5% cholesterol) and rats with type 2 diabetes induced by injection of streptozotocin (STZ) (50 mg/kg body weight) and they reported that A. bisporus mushroom had both possess anti-hyperglycemic effects in rats. Moreover, it has a positive influence on lipid metabolism and liver function.

Antidiabetic

A. bisporus contains high levels of dietary fibers and antioxidants including vitamin C, D, and B12; folates and polyphenols that may provide beneficial effects on cardiovascular and diabetic diseases (Jeong et al., 2010). Calvo et al. (2016) reported that A. bisporus contain a variety of compounds with potential anti-inflammatory and antidiabetic health benefits that can occur with frequent consumption over time in individuals predisposed to type 2 diabetes. Yamaç et al. (2010) reported that the oral application of high doses of A. bisporus extract may result in decreased severity of streptozotocin-induced diabetes in rat. The streptozotocin induced diabetic male Sprague-Dawley rats fed the A. bisporus powder (200 mg/kg of body weight) for three weeks had significantly reduced 77.8% in blood glucose (BG) and plasma glucose concentrations to 39.1% and 24.7% respectively, liver enzyme activities, aspartate aminotransferase and alanine aminotransferase to 15.7% and 11.7% respectively, and liver weight gain (Jeong et al., 2010). Volman et al. (2010) investigated the effects of alpha-glucans from A. bisporus. They reported that consumption of alpha-glucans of A. bisporus mushroom lowered producing lipopolysaccharide-induced TNFα by 69% compared to the control group, whereas no effect on IL-1β and IL-6 was observed. Calvo et al. (2016) reported that A. bisporus contain a variety of compounds with potential anti-inflammatory and antidiabetic health benefits that can occur with frequent consumption over time in adults predisposed to type 2 diabetes. Kanaya et al. (2011) suggested that Agaricus bisporus intake may be a viable dietary choice to prevent liver steatosis, which is an early reversible stage of nonalcoholic fatty liver disease in postmenopausal women.

Antioxidant

Total phenolics and antioxidant properties of A. bisporus have been reported by many authors (Ramirez-Anguiano et al., 2007; Savoie et al., 2008; Barros et al., 2008). A. bisporus mushrooms, especially portabellas (brown A. bisporus), had higher antioxidant capacity relative to Lentinula edodes, Pleurotus ostreatus, Pleurotus eryngii and Grifola frondosa. Liu et al. (2013) determined the main phenolic compounds in ethanolic extract of A. bisporus like gallic acid, protocatechuic acid, catechin, caffeic acid, ferulic acid and myricetin and suggested that the ethanolic extract of this mushroom had potent antioxidant effect, and could be explored as a novel natural antioxidant. Omó-Olíu et al. (2011) reported that phenolic content of fresh-cut A. bisporus mushrooms was 100.78–100.32 mg/100 g fw. Ergothioneine content ranged from 0.21–0.45 mg/g dw with white A. bisporus and brown A. bisporus (portobello) (Dubost et al., 2007). Phenolic compounds have been reported as the major antioxidant components in mushrooms (Barros et al., 2008). A close relationship between antioxidant activity and phenolic contents and suggested that phenolic compounds could be the foremost contributors to the antioxidant activity of edible macrofungi (Kim, 2008; Guo et al., 2012). Contrarily, Palacios et al. (2011) reported that A. bisporus presents the high contents of phenolics, although this species has got a low antioxidant activity. Chitosan NPs of A. bisporus had antioxidant effects. All potential antioxidant properties reflect on positive anticancer effect (Dhamodharan and Mirunalini, 2012). Neyrinck et al. (2009) fungal chitosan decreases feed efficiency, fat mass, adipocyte size, density and the rate of maturation of the liver and muscle. In this way it counteracts some inflammatory disorders and metabolic alterations occurring in diet-induced obese mice. Tocopherols (TCP) are fat-soluble antioxidants but also seem to have many other functions in the body. Many of them have vitamin E activity. Reis et al. (2012) determined α-tocopherol (0.25 µg/100 g fw and 0.28 µg/100 g fw), β-tocopherol (0.85 µg/100 g fw and 0.71 µg/100 g fw), γ-tocopherol (1.51 µg/100 g fw and 7.63 µg/100 g fw) and δ-tocopherol (2.60 µg/100 g fw and 2.54 µg/100 g fw) in fruit bodies of white A. bisporus and brown A. bisporus, respectively. Seratonin is a biochemical compound that has got antioxidant ability (Sariyaka and Gulcin, 2013). Antioxidant actions of serotonin and its ability to prevent the progress of Alzheimer’s disease were also referred by Quchi et al. (2009). Muszynska et al. (2011) reported that the content of serotonin in the extracts of A. bisporus was high (5.21 µg/100 g dw).
Antimicrobial


Figure 1 Biosynthesis silver nanoparticles using mushroom Agaricus bisporus

CONCLUSION

A bisporus may provide significant support against malnutrition due to high nutritional values especially in developing and undeveloped countries. Consumption of A. bisporus is not useful in case of nourishment, but also existing the medicinal benefit of mushroom, especially as anticancer, anti-cardiovascular disease, antidiabetes, antioxidant, and antimicrobial. In the last decades, edible mushroom has been used as a source of treatment or health food supplements increasingly. Most of the investigations have shown that nutraceutical therapy is a promising source of new therapeutics against many life threatening diseases. Although bioactive molecules isolated from A. bisporus may represent an important advance for their characterization as a source of drugs, more clinical data are needed for the determination of medicinal benefits of A. bisporus. REFERENCES


