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The Wondrous of Fungus World

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INTRODUCTION

Mushrooms can be defined as "macrofungi" with distinctive fruiting bodies that could be hypogenous or epigeous, large enough to be seen by naked eyes and to be picked by hand (Chang & Miles, 1992). They contain no chlorophyll, therefore, do not have leaves, seeds or roots and in real do not need any light to grow. They are a group of fleshy macroscopic fungus which propagates by releasing spores in the dark and typically grew on its food source or on soil above ground. Through the process of fructification, the fruiting bodies are developed from spacious underground mycelia (hyphae). They require a substrate agricultural waste to absorb nutrition and produce enzymes which degrade complex organic matter (Walde *et al*., 2006). The estimated lifetime of fruiting bodies is only 10-14 days (Kalac, 2009).

Cultivated mushrooms are mainly belonging to the family *Agaricaceae* of class *Basidiomycetes* (Asghar *et al*., 2007). Mushrooms constitute more than 14,000 species and possibly as many as 22 000 species, but only about 10% of them are explored and edible (Hawksworth, 2001; Mattila *et al*., 2000). Edible mushrooms can be found all over the world and have been consumed as food and food ingredient since early century primarily for their flavour, economic and ecological values (Chang & Buswell, 1996). Apart from that, the edible mushrooms have been used not only for consumption purpose but also for medicinal purposes (Yang *et al*., 2001; Chocksaisawasdee *et al*., 2010).

Between 1995 and 2005, world commercial mushroom production increased rapidly by 35.9%. Global production of mushrooms is estimated to comprise approximately 5 million tonnes of fresh weight yearly (Omarini *et al*., 2010). China is reported to be the most prominent producers for mushrooms, followed by United States, Canada and Indonesia. China produced approximately 1.6 million metric tonnes in year 2007, reporting an increment at around 65% in 10 years. In 2007, Malaysians consumed 8100 tonnes of mushrooms per year but the total mushroom production in the country is only 5500 tonnes per year. The skyrocketing production rates are probably due to increased consumer demand of mushroom and increased consumer awareness on the benefits of mushrooms (Aida *et al*., 2009).

The most cultivated mushroom worldwide is *Agaricus bisporus* (button mushroom), followed by *Lentinus sajor-caju* (oyster mushrooms), *Lentinus edodes* (shiitake mushroom), *Auricularia auricular-judae* (wood ear mushroom), *Volvariella volvacea* (straw mushroom), *Flamulina velutipes* (winter mushroom), *Grifola frondosa* (maitake mushroom) and *Tricholoma terreum* (grey-capped mushroom) (Figure 7.1). Regarding the shape and structure, the most common type is umbrella shaped that made up of a pileus (cap) and a stipe (stem). Interestingly, some mushrooms are in the form of pliable cups, in the shape of small clubs, round like golf balls, resemble coral and even very much resemble the human ear (Chang, 2008).

Lentinus sajor-caju
(Oyster mushroom)

Lentinus edodes
(Shiitake mushroom)

Agaricus bisporus
(Button mushroom)

Auricularia auricula-judae
(Wood ear mushroom)

Flammulina velutipes
(Winter mushroom)

Volvariella volvacea
(Straw mushroom)

Grifola frondosa
(Maitake mushroom)

Tricholoma terreum
(Grey-capped mushroom)

Source: Aida *et al.* (2009)

Figure 7.1 Most common cultivated edible mushrooms worldwide

Among the higher fungi, *Pleurotus* species are originated from India. These mushrooms are being paid attention nowadays and well-acknowledged as an economically important genus (Hassan *et al*., 2010). This fungus that can naturally be found in the tropical and subtropical rainforest is universally known as oyster mushroom and characterised by a white spore print, gills attachment as well as eccentric stip occasionally (Miles & Chang, 1997). Oyster mushroom, a common primary decomposer of wood and vegetal residue, basically grown on trunks and stumps of deciduous trees as well as cultivated on various agricultural residues such as sugarcane bagasse, sawdust, cereal straw and fruit straw as the carbon source in shady cultivation farms (Asghar *et al*., 2007; Pathmashini *et al*., 2008). These types of farming can act as a pivotal role in managing organic wastes and reducing environmental pollution through a biotechnological process (Sanchez, 2010). Hence, it has a high gastronomic value and can be cultivated in an easy and inexpensive way due to its shorter growth time and only a few environmental controls are required (Patrabansh & Madan, 1997). Furthermore, it owns a very delicious taste and flavour, thus greatly accepted to be used for culinary all over the world especially Asian countries.

Since last decade, cultivation of oyster mushroom is increasing tremendously all over the world (Chang, 2008). Oyster mushroom accounts for 14.2% of the total world edible mushroom production with its annual production of more than 900,000 tonnes and ranks second most popular cultivated mushrooms after button mushroom (25% of the total world cultivated mushrooms production) (Imran *et al*., 2011). Asian countries contributes 74.4% of the total world mushroom tonnage with China being the major producer of *Pleurotus* spp. because of their high adaptability (Royse, 2002). It consists of 40 species and come in a broad array of colours (white to light grey when in fresh form but light brown to golden when in dried form). The most well-known established biological species are *Pleurotus ostreatus*, *P. cystidus*, *P. flabellatus*, *P. tuber-regium*, *P. florida*, *P. eryngii*, and *P. pulmonarius* (Ragunathan *et al*., 1996).

Some mushrooms are quite palatable due to their pleasant taste but undeniably, some poisonous mushrooms (represent about 1% of the world's known mushrooms) may bring dangerous effects to individuals if being consumed (Chang, 2008). Depending on the growing environment of mushrooms, they can accumulate heavy metals particularly lead and cadmium which can lead to toxic effect. Some of the poisonous species contain phallotoxins and heptapeptides that may cause vomiting, diarrhoea and abdominal discomfort. Individuals who mistakenly pick and eat the poisonous species of mushrooms from the wild will lead to death. Hence, wild mushroom picking should be only made by or under the supervision of mycologist who is an expert in identifying mushrooms. This chapter will discuss on food and nutritional components and potential health benefits of bioactive compounds in edible mushrooms and their potential applications and future development as functional food.

FOOD AND NUTRITIONAL COMPONENTS

Nutritional qualities of edible mushrooms have been intensively studied. In general, mushrooms contain considerable amounts of protein, dietary fibre, vitamins and minerals and low fat and calories (Crisan & Sands, 1978).

Moisture content

Moisture content of mushrooms is influenced by several factors such as watering conditions during cultivation, time of cropping, postharvest period as well as relative humidity and surrounding temperature during growth (Bano & Rajarathnan, 1988). Basically, the moisture content of mushrooms ranged from 85% to 95% of their fresh fruiting weight. The moisture contents (in fresh form) of some specific edible mushrooms are listed as follows: *Pleurotus ostreatus* (85.2-94.7%), *Grifola frondosa* (86.1%), *P. pulmonarius* (87.7%), *Lentinus edodes* (81.8-90%) and *Agaricus bisporus* (92.8-94.8%) (Manzi *et al*., 1999; Manzi *et al*., 2001).

Since fresh mushrooms with high moisture content are the highly perishable (short shelf life) commodities, dehydration process is the most desirable method for ensuring a long-term storage. After drying, the moisture content is less than 10% of dry weight (DW), with a value of 8.8% for *Lentinus sajor-caju* (Wan Rosli *et al*., 2011) and 9.1% for *Dictypphora indusiata* (Longvah & Deosthale, 1998).

Calorie

Calorie content of edible mushrooms is depleted and thus, can be considered to be consumed as low-energy and weight-loss diets. Calorie is the measurable energy that derived from macronutrient including carbohydrate, protein and fat. Previous studies indicated that the calorie contents in *Pleurotus ostreatus*, *Tricholoma robustus* and *Agaricus bisporus* were 4.2, 3.0 and 4.2 kcal/g DW respectively (Aletor, 1995; Manzi *et al*., 2001). Fresh edible mushrooms with a serving of 100 g provide only 1.4-4.4% of the daily calorie requirement for an adult male (around 70 kg) who engages in a moderate physical activity (Cheung, 2008).

Macronutrients

Macronutrients are the essential components in human diet. They are carbohydrate, protein and fat. Carbohydrate is the major component in plant. Total carbohydrate content (sum of digestible and non-digestible carbohydrates) of mushrooms is ranging from 35% to 70% of DW. The carbohydrate contents of some edible mushrooms are as follows: *Lentinus sajor-caju* (60.6%), *Pleurotus indusiata* (67%), *Grifola frondosa* (58.8%), *Tricarpelema giganteum* (70.0%), *Lentinus edodes* (62.3-64.4%), *Schizophyllum commune* (61.1%) and *Pleurotus ostreatus* (61.1%) (Longvah & Deosthale, 1998; Díez & Alvarez, 2001; Mau *et al*., 2001; Wan Rosli *et al*., 2011).

Amount of digestible carbohydrates detected in mushrooms is low which include mannitol (less than 1% DW), glucose (less than 1% DW) and glycogen (5-10% DW). A major component of mushroom carbohydrate includes oligosaccharides and non-starch polysaccharides which are non-digestible carbohydrates. Mushroom's non-starch polysaccharides such as β-glucans, chitins and mannans are also the mushroom dietary fibres which may bring physiological benefits to human health (Cheung, 2010).

Dietary fibre is considered as non-digestable carbohydrate. All fungal cell walls are nonstarch polysaccharides possessing a mixture of fibrillary and matrix components which can be categorised as dietary fibre (AACC, 2001). Edible mushrooms contain a large variation of the total dietary fibre content depending on their species and morphological structure. Certain mushroom species have low level of total dietary fibre in DW (4.5% in *Tricarpelema giganteum*, 9.26% in *Dictyophora indusiata* and 8.7% in

Pleurotus cystidious) while the others have high level of total dietary fibre in DW (58.0% in *Lentinus sajor-caju*, 50.0% in *Tricholoma terreum* and 54.5% in *Tremella fuciformis*) (Cheung, 1997; Díez & Alvarez, 2001; Ng & Wan Rosli, 2015). In general, mushrooms are a great source of dietary fibre, with 100 g of fresh mushrooms providing 10-40% of the recommended dietary intake of fibre (Manzi *et al*., 2001).

Dietary fibre can be further classified according to its water solubility: water soluble and insoluble fibre fractions which can be distinguished by their solubility in aqueous solutions. In mushroom, 16.8-46.1% of total dietary fibre is found as soluble dietary fibre and 53.9-83.2% as insoluble dietary fibre (Manzi & Pizzoferrato, 2000). Glucose that composed of 43.1-82.8% of total dietary fibre is considered as the predominant sugar in mushrooms. Nevertheless, the existence of other sugars such as xylose, mannose and galactose speculated that the primary cell wall polysaccharides in most fungi are hemicelluloses such as β-glucan, pectic substances and chitin (Cheung, 1996). Apart from that, it is worth to be mentioned that mushroom sclerotia mainly composed of β-glucans (Wong *et al*., 2003).

Plant especially mushroom has low to moderate amounts of protein. As reported in the previous studies, crude protein content of mushrooms is ordinarily high (15 to 35% of DW) but varies greatly depending on the varieties, species and development stage of fruiting body (Longvah & Deosthale, 1998; Manzi *et al*., 1999; Mdachi *et al*., 2003). The crude protein contents of certain edible mushrooms are as follows: *Pleurotus ostreatus* (10.5-30.4%), *Lentinus edodes* (13.4–17.5%), *Agaricus blazei* (26.7%), *Grifola frondosa* (21.1%), *Lentinus sajor-caju* (21.0%) and *Hericium erinaceus* (22.3%) (Crisan & Sands, 1978; Mau *et al*., 2001; Tsai *et al*., 2008; Wan Rosli *et al*., 2011).

According to the Food and Agriculture Organisation (FAO) standard, the protein quality of mushrooms is more advantageous than most plant proteins (FAO, 1991). *In vivo* protein digestibility values of mushrooms are more depleted than those of animal protein (more than 90%) (McDonough *et al*., 1990). However, the percentages of protein for mushrooms such as *Pleurotus ostreatus* and *Lentinus edodes* are 73.4% and 76.3% respectively (Adewusi *et al*., 1993; Dabbour & Takruri, 2002) which are comparable with those of legumes (70-80%) (Wong & Cheung, 1998).

Edible mushrooms possess a low lipid level (less than 10% DW). The lipid contents (% DW) of some mushrooms are as follows: *Lentinus sajor-caju* (1.7%), *Dictyophora indusiata* (3.0%), *Tricarpelema giganteum* (4.3%), *Grifola frondosa* (3.1%), *Lentinus edodes* (5.7-6.3%), *Lyophyllum ulmarius* (2.1%), *Volvariella bombycina* (2.8%) and *Tricholoma terreum* (6.6%) (Mau *et al*., 2001; Yang *et al*., 2001; Wan Rosli *et al*., 2011). Their fatty acid profile favours polyunsaturated fatty acids which comprise of at least 75% total fatty acids. The most substantial fatty acids are oleic acid (8.3%), palmitic acid (19.2%) and linoleic acid (68.8-84.0%) (Cheung, 1997; Longvah & Deosthale, 1998; Díez & Alvarez, 2001). Yilmaz *et al*. (2006) documented that linolenic acid levels in mushroom were low, but despite its small amount, it contributes largely to the mushroom flavour because of its function as the precursor to 1-octen-3-ol which is the principal aromatic compound recognised as fungal alcohol in most mushrooms (Maga, 1981).

Micronutrients

Cultivated mushrooms are rich in B vitamins such as riboflavin (vitamin B2), niacin (vitamin B3) and folates (vitamin B9), with concentrations that vary within the ranges of 1.8-5.1, 31-65 and 0.3-0.6 mg/100 g DW respectively. Riboflavin content in mushrooms is generally higher than that discovered in vegetables. *Agaricus bisporus* has riboflavin content of 3.7-5.1 mg/100 g DW which is as high as that found in cheese and egg (Mattila *et al*., 2001).

Cultivated mushrooms are also rich in niacin. For instance, *Pleurotus ostreatus*, *Lentinus edodes* and *Agaricus bisporus* have niacin content of 33.8-109 mg/100 g, 11.9-98.5 mg/100 g and 36.2-57.0 mg/100 g (in dry weight) respectively (Crisan & Sand, 1978; Bano & Rajaratham, 1988; Miles & Chang, 1997). Besides, these mushrooms have an appreciable amount of folates (ranging from 300 to 1500 µg/100 g DW) that are similar to that of in vegetables. The bioavailability of mushroom folates is as great as folic acids (Clifford *et al*., 1991).

In addition to B vitamins, edible mushrooms contain small amounts of vitamins C and D. The vitamin C content of mushrooms is ranging from 17.0 mg/100 g in *Agaricus bisporus* to 40.4-59.9 mg/100 g DW in *Lentinus edodes* (Li & Chang, 1985; Beelman & Edwards, 1989; Kurzman, 1997).

Vitamin D amount is nearly negligible in cultivated mushrooms even though the quantity depends on the cultivation conditions (Mattila *et al*., 2001).

Ash content (6 to 10.9% DW) in edible mushrooms represents a wide variety of minerals (Zakhary *et al*., 1983). The ash contents (%DW) of some edible mushrooms are as follows: *Lentinus sajor-caju* (7.7%), *Pleurotus ostreatus* (6.9%), *Pleurotus eryngii ferulae* (8.6%), *Lentinus edodes* (5.3-5.9%) and *Hericium erinaceus* (9.4%) (Manzi *et al*., 1999; Mau *et al*., 2001; Wan Rosli *et al*., 2011).

Cultivated mushrooms are rich in minerals, containing macroelements such as calcium, magnesium, phosphorus, sodium and potassium as well as microelements such as iron, copper, manganese and zinc. Besides, they are recognised to contain heavy metals such as lead, cadmium and mercury which may have toxicological effects on humans (Ouzouni *et al*., 2007; Kalac, 2010). However, there is lacking of detailed evaluation on the nutritional assessment and toxicological risk of these substances in mushrooms.

HEALTH BENEFITS

Recently, mushrooms are of great interest in food science and nutrition due to the presence of their biologically active compounds which have medicinal values including complementary medicine and dietary supplements. Mushrooms have been widely used in traditional medicine since decades ago, and their medicinal properties have been continuously ascertained by intensive research conducted worldwide. Of all species of mushrooms throughout the world, approximately 200 types are known for their medicinal and pharmacological properties (Sanchez, 2004). Some of these mushrooms have therapeutic effects. The therapeutic effects include antiviral, antibacterial and antifungal, immunomodulatory, antitumour, anti-inflammatory, antiatherogenic, hepatoprotective and anti-diabetes (Wasser, 2001).

Antimicrobial Effect

Mushrooms need antifungal and antibacterial agents to survive in their natural environment. Therefore, it is not surprising that certain antimicrobial compounds have been isolated from many mushrooms; and thus, these bring benefit to human health (Lindequist *et al*., 1990). Mothana *et al.* (2000) reported whole extracts of European *Ganoderma* species, *Ganoderma pfeifferi* that grows on wood inhibited growth of microorganisms such as *Pityrosporum ovale* and *Staphylococcus epidermidis*, where these microorganisms are responsible for skin problems. Oxalic acid, an antimicrobial agent extracted from *Lentinula edodes* is responsible for acting and fighting against *Staphylococcus aureus* and other bacteria (Bender *et al*., 2003). For the species of *Podaxis pistillaris*, it is used in the treatment of 'nappy rash' of babies (in some parts of Yemen), against inflammation (in China) and against sunburn caused by epicorazins (in South Africa) (Al-Fatimi, 2001).

Antiviral Effect

Viral diseases should be managed by using specific drugs and also more appropriately isolated compounds from mushrooms. There are small and large molecular compounds with antiviral activities. Antiviral effect of smaller and complex mushroom molecules can be obtained directly (by synthesis of viral nucleic acids, inhibition of viral enzymes or uptake of viruses into mammalian cells) and indirectly (resulted by the immunostimulating activity) respectively (Brandt & Piraino, 2000).

Small molecular compounds such as triterpenes (ganoderiol F, ganoderic acid B and ganodermanontriol) which isolated from *Ganoderma lucidum* are capable antiviral agents against human immunodeficiency virus type 1 (HIV-1). Apart from that, ganodermadiol is active against herpes simplex virus type 1 which can cause lip exanthema and other symptoms (Mothana *et al*., 2003). For high molecular compounds, water-soluble lignins isolated from *Inonotus obliquus* can inhibit HIV protease (IC_{50} value of 2.5 μg/mL) (Ichimura *et al*., 1998). In the long-term trial, maitake D-fraction from *Grifola frondosa* was examined in 35 HIV patients. The results showed that 85% of patients documented an increment sense of well-being related to various symptoms and secondary diseases caused by HIV (Nanba *et al*., 2000).

Antitumour Effect

Globally, cancer is one of the main culprits of death. The fruiting bodies of *Piptoporus betulinus* and *Inonotus obliquus* have been traditionally used in Bohemia and Eastern Europe respectively for the management of both stomach diseases and rectal cancer (Molitoris, 1994). The melanin complex of *Inonotus obliquus* contains high genoprotective and antioxidant effects on peroxidase-catalysed oxidation of aminodiphenyls (Babitskaya *et al*., 2002).

Antitumour activity via lipid peroxidation inhibition has been reported by Matsuzawa (2006). The study demonstrated that fruiting body of *Hypsizygus marmoreus* exerted potential antitumour effects and resulted in an apparent decrease in lipid peroxide levels. Besides, it could induce antioxidant activity in the plasma of tumour-bearing mice, thus considered an effective mechanism for cancer management.

Apart from that, mushrooms polysaccharide is well studied for its antitumour properties. Polysaccharides isolated from *Pleurotus tuber-regium* and *Pleurotus ostreatus* are reported to have the capability to fight against human hepatic cancer cell and Hela tumour cell (Tao *et al*., 2006; Tong *et al*., 2009). Besides, antiproliferative and proapoptotic activities of *Pleurotus ostreatus* fractions have also been assessed in HT-29 colon cancer cells *in vitro*.

Antiatherogenic Effect

Control of blood lipid level mainly cholesterol level is essential for lowering risk of development of atherosclerosis or heart diseases. A pronounced hypocholesterolaemic effect of *Pleurotus ostreatus* was demonstrated in rats and rabbits. In the study conducted by Bobek and Galbavy (1999), the oyster mushroom diet containing 10% dried fruiting bodies significantly reduced the incidence and size of atherosclerotic plaques in rabbits ($p<0.05$). The possible factor contributed to the observed antiatherogenic effects of *Pleurotus ostreatus* might be due to lovastatin, the lead compound of statins (Gunde-Cimerman *et al*., 1993).

Agaricus bisporus is documented to reduce cholesterol levels in rats fed a hypercholesterolaemic diet (Jeong *et al*., 2010). In the hypercholesterolaemic rats, oral administration of the *Agaricus bisporus* powder (200 mg/kg of body weight) for four weeks had a significant decrease in plasma total cholesterol (22.8%) and low-density lipoprotein-cholestrol (33.1%). The reduction of plasma total cholesterol was accompanied by an apparent increment in plasma high-density lipoprotein concentration showing a significant hypolipidaemic activity. Thus, *Agaricus bisporus* powder possesses antiatherogenic effect in rats.

Anti-Diabetic Effect

Diabetes is a worrying chronic metabolic disorder characterised by high blood glucose level due to the insulin insensitivity (ADA, 2005). The effects of *Agaricus blazei* combined with metformin and gliclazide on insulin resistance have been demonstrated in a randomised, double-blinded and placebo-controlled clinical trial. After supplementation of *Agaricus blazei* for 12 weeks, the supplementation improved insulin resistance and increased adiponectin concentration in 72 subjects with type 2 diabetes (Hsu *et al*., 2007). Besides, the hypoglycaemic activity of *Pleurotus pulmonarius* aqueous extract has been documented (Badole *et al*., 2006). Doses of 250, 500 and 1,000 mg/kg BW of *Pleurotus pulmonarius* extract were administrated orally to different groups of alloxan-induced diabetic mice for 28 days. The results demonstrated that all doses of extracts reduced the serum glucose level after 28 days of chronic administration.

In recent years, the hypoglycaemic effect of *Lentinus sajor-caju* in streptozotocin-induced diabetic rats was reported (Ng *et al*., 2015). Different doses of *L. sajor-caju* aqueous extract (500, 750 and 1000 mg/kg BW) were given orally and their effects on fasting blood glucose and oral glucose tolerance test were examined. The result indicated that the extracts of 750 mg/kg BW reduced blood glucose level and improved glucose tolerance of the rats.

Anti-Inflammatory Effect

Mushrooms, especially from *Pleurotus* genus, have anti-inflammatory effect based on the animal studies. Methanolic extract of *Pleurotus pulmonarius* (500 and 1000 mg/kg BW) reduced carrageenan-induced and formalin-induced paw oedema in mice. The effect was similar to the reference diclofenac (10 mg/kg BW) (Jose *et al*., 2002). In another study, four-week administration of pleuran (a β-glucan) isolated from *Pleurotus* *ostreatus* in rats with acute colitis significantly decreased the disposition to colitis ($p<0.05$). The enhanced activity of myeloperoxidase in the inflammed colonic segment was reduced by the diets containing pleuran, reflecting a decrease in neutrophil infiltration (Bobek *et al*., 2001).

Immunomodulatory Effect

The activity of immunomodulators such as polysaccharides, proteins and peptides are not only for boosting immune cells to fight against infection, but also to normalise the cells when the immune system is highly activated. Hence, it acts as an agent to regulate and maintain the existing balance of system (Tzianabos, 2000). *Lentinus sajor-caju* is evaluated for its immunomodulating properties. Treatment of mice with various concentrations of *L. sajor-caju* extract for 21 days showed an improvement in CD4+/CD8+ ratio. The improvement indicates its potential immunomodulating activity (Nurul *et al*., 2014). β-Glucan is found in *L. sajor-caju* (Wan Rosli & Aishah, 2012). It has been described as a potent immunomodulator, with specific activity for T-cells and antigen-presenting cells such as macrophages and monocytes (Tzianabos, 2000). Besides, phenolic compounds present in *Agaricus bisporus*, *Agaricus brasiliensis* and *Ganoderma lucidum* extracts strongly generate reactive oxygen species in the human peripheral blood mononuclear cell (PBMC) and K 562 cells *in vitro* (Wei *et al*., 2008). *Agaricus blazei* extract is also been reported to possess immunomodulatory activities such as stimulation of serum immunoglobulin G level, splenocyte proliferation rate and delayed-type hypersensitivity (Chan *et al*., 2007).

POTENTIAL APPLICATIONS

Since last decade, there is a continuous trend of developing food products which are appealing to our taste but neglecting our health issue. The supermarkets are full of convenient processed or packaged foods that are unhealthy or lacking natural nutrients. During the refining process, important nutrients such as vitamins and dietary fibres are removed, resulting in greater number of people diagnosed with serious diseases and many types of chronic illness. However, much attention has been paid to physiological functions of foods due to increasing concerns about health in the recent years (Arihara, 2006). People are more aware of what they eat and drink as well as consuming more natural types of food rather than artificial and processed food. Hence, various health promoting products have been emerged in the market due to the increasing consumer demand.

A majority of edible mushrooms are good sources of protein and dietary fibre and contain vitamins and minerals as compared to vegetables. Moreover, these mushrooms are some of the low-calorie foods due to their low fat content and digestible carbohydrate (Mattila *et al*., 2002). Therefore, edible mushrooms can be used as daily food items and broadly incorporated into a variety of food products such as bakery products, meat-based products and soup for health benefits. The role of medicinal mushrooms as "functional foods" is known for thousands of years, particularly in the eastern countries, but these mushrooms are only recognised by modern science (Chang & Wasser, 2012; Reis *et al*., 2012).

Lentinus sajor-caju (commonly called oyster mushroom) is used for the development of food products due to its pleasant taste and nutritional value. Recently, the effects of *L. sajor-caju* on food and nutritional compositions, sensory acceptability and glycaemic index in cinnamon biscuits are reported. The increment of the incorporation level of *L. sajor-caju* powder (replace wheat flour at 0, 4, 8 and 12%) in cinnamon biscuit significantly increased dietary fibre content and reduced glycaemic index (GI) ($p<0.05$). From a sensory evaluation, consumers can accept *L. sajor-caju* powder of level of up to 8% as wheat flour replacer in the biscuit formulation. Besides, a low glycaemic index food is beneficial in controlling postprandial blood glucose level as well as reducing risks of diabetes and complications caused by diabetes. Similar results also documented in a study conducted by Wan Rosli *et al*. (2012) who added *L. sajor-caju* powder into the butter biscuits.

L. sajor-caju powder has been incorporated into wheat- and rice-based products such as rice porridge, paratha bread and creaming cake (Aishah & Wan Rosli, 2013). The addition of *L. sajor-caju* powder to partially replace rice and wheat flours at 2% and 4% enhances the essential nutritional components especially protein and ash as well as highly accepted by consumers. Apart from that, it has also been added to chicken (Wan Rosli *et al*., 2011) and beef patties (Wan Rosli & Solihah, 2012). The addition of *L. sajor-caju* at 25% to replace partially chicken meat and beef in patties is recommended for the purpose of lowering production cost and fat content while unchanging the protein content and increasing the dietary fibre content. Moreover, the study also indicated that consumers accepted the patties formulated with all level of *L. sajor-caju* powder.

Other than that, β-glucan-enriched materials produced from *Lentinus edodes* have been evaluated as wheat flour replacer at 1, 2 and 3 g per serving (100 g) in making cakes (Kim *et al*., 2011). The results indicated that the replacement at 1 g per serving could be successfully used to produce cakes with quality attributes similar to that of control. Besides, *Agaricus bisporus* is used to develop mushroom-whey soup powder to create a nutritious soup (Singh *et al*., 2003). The finding showed that mushroom-whey soup containing 4% mushroom possessed significantly higher colour, flavour, appearance, consistency and overall acceptability scores compared with the other soup formulations (2.5%, 6.0% and 7.5% of mushroom).

Edible and medicinal mushrooms have the potential to be incorporated into several food products to develop functional foods with good nutritional values and a high consumer-acceptance level. Functional mushroom-based products could be included in the populations' daily diets to benefit their general health and reduce risks of non-communicable diseases.

CONCLUSION AND RECOMMENDATIONS

Mushrooms are valuable sources of food, medicine and nutraceuticals (Lakhanpal & Rana, 2005). They are the low energy and nutrient-dense food containing several micronutrients. Mushrooms have low sodium and calories making them a great addition to low-salt diets. They are rich in potassium, phosphorus, zinc, copper and selenium. "Mushroom nutrition" is advocated by many health care professionals and mushrooms have been scientifically proven based on epidemiological as well as *in vitro* and *in vivo* clinical studies, having many health benefits. These benefits have potential implications on immune system, providing properties of antiviral, antifungal, antiinflammation and anticancer as well as controlling blood lipids and glucose levels in human body.

Interestingly, medicinal mushrooms can either be used as food ingredients or incorporated into food products, creating novel "functional foods". Hence, fruiting bodies of mushrooms and mushroom components or extracts should be formulated and applied to many other foods or food products to broaden the mushroom application. Pre-requisition for the use as functional food, drug or another purpose is the continuous production of mushrooms (fruiting bodies or mycelium) in large amounts and a standardised quality. Further necessities are the establishment of suitable quality parameters and of analytical methods to control these parameters for ensuring safety and quality of mushrooms and mushroom products. However, more attention should be paid to the legal regulations for authorisation as drug or dietary supplement for food (Wasser *et al*., 2000). Control of possible side effects particularly allergies during extensive use is also important.

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