



Mushrooms: Conventional Food and Alternative Medicine

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Most edible mushrooms have a number of properties in common. The most obvious is their high water content, which varies from 85 to 95 % of their fresh weight and makes mushrooms vulnerable for bruising and loss of storage quality. After harvest, mushrooms must be kept cool to prevent water loss and discoloration. When this is not done properly or when mushrooms are affected by bacteria or parasitic fungi, most mushrooms will have only a very short shelf life, lose their food quality and cannot be sold. The dry matter of mushrooms consists mainly of fibrous carbohydrates and further of proteins, (unsaturated) fats and a very high number of very diverse compounds: anti-oxidative polyphenols, vitamins, and inorganic elements as phosphorus (P), potassium (K) and magnesium (Mg). The diverse compounds are present at low concentrations but their biological effects may be impressive (Stojkovic *et al.* 2014)

Mushrooms contain bactericidal and fungicidal components that form a natural protection against offensive microbial, and could also be applied as protective agents in biological foods such as yoghurt (Stojkovic *et al.* 2014).

The question arises whether mushrooms are a healthy food. Shii-take (*Lentinula edodes*) is reported to have app. 14 % of its dry weight as protein (Sistani *et al.* 2007), which makes it comparable to some vegetables, wheat and rice (Chang & Buswell, 1996), but it is less than that of animal meat. Further the protein seems high in glutamic acid and aspartic acid but is low in methionine and cysteine. The answer to the question is that for vegetarian's mushrooms are not a very healthy food. Assuming a MDI (minimum daily intake) of 60 grams protein per day, it can be easily calculated that even a daily consumption of 1 kg of fresh mushrooms would not suffice. The advice is then to use a variety of lean meat and various vegetables and or mushrooms to supply the required protein.

Agaricus bisporus is a valuable source of magnesium, phosphorus and vitamin D. Vitamin D is readily available from *Agaricus bisporus* and *Pleurotus sp.* after exposure to sunlight or other sources of UV-B light, the fungal wall component ergosterol being converted to Vitamin D₂. Post-harvest drying of these mushrooms in sunlight induces high amounts of Vitamin D. Different animal studies have shown that light induced edible mushrooms are safe and that Vitamin D₂ is indeed available (Calvo *et al.* 2013). In a human experiment with 26 patients that were deficient in Vitamin D₂, Urbain *et al.* (2011) have described that UV irradiated *Agaricus bisporus* could improve their Vitamin D₂ status the

same way as synthetic Vitamin D2. The energy content of mushrooms is low which makes them suited for a low calorie diet that is much desired in the affluent India.

Mushrooms can be considered a high dietary fiber food, which relates to its non-digestible carbohydrates, mainly chitin. *Agaricus bisporus* contains 41% of its carbohydrates as dietary fiber and *Pleurotus sajor caju* 44% (Goyal *et al.* 2015). This high content of dietary fiber makes mushrooms suitable as an anti-constipation food or to be used in a diet designed to prevent this modern times' hindrance of human wellbeing. In patients with functional constipation, fiber supplements derived from *Auricularia* (ear) mushrooms significantly improved constipation related symptoms without serious side effects (Kim *et al.* 2004).

Apart from the Vitamin D2 precursor ergosterol, *Agaricus bisporus* contains significant amounts of the vitamins B2 = riboflavin (24% of recommended daily intake per 100 gram fresh), Vitamin B3 = niacin (18%) and Vitamin B5= panthotenic acid (15%). 9% of the recommended daily intake of Potassium (K) and 9% of phosphorus can be supplied by the same 100 grams of fresh product.

The polyunsaturated fatty acids (PUFA) present in mushrooms are often mentioned as contributing to good health. Up to 80% of the edible mushrooms' fatty acids are of a polyunsaturated nature (Reis *et al.* 2012), but the amount per serving of 100 grams fresh mushrooms is maximum 0.15 grams of PUFA. It seems not very likely that this small amount can play an important dietary role.

Mushrooms as an alternative medicine

Medicinal mushrooms are mushrooms or extracts from mushrooms that are thought to give treatment for various diseases, yet these effects remain unconfirmed in mainstream science and allopathic medicine.

Ganoderma lucidum also known as Reishi or Ling Zhi was used as a remedy against various cancers for over 500 years and *Lentinula edodes*, shii-take, was found to enhance "vital energy" and cure colds since the Ming dynasty (Mizuno, 1995).

Mushroom compounds that are causative in (presumed) medicinal effects are high molecular weight polysaccharides, and a variety of smaller compounds as polyphenols and triterpenes, and many molecules that have possible signalling functions but have not yet been defined. The effects of mushrooms and mushroom components on human and animal health have been studied in vitro as well as in vivo.

Effects of mushroom compounds

Bactericidal and fungicidal effects: Mushrooms can be easily colonized by bacteria and fungi. During evolution they have adapted to these threats by developing defence mechanisms. Many mushrooms extracts show antimicrobial properties. *Agaricus blazei* extracts showed MIC's and MBC's that were equal to or better for inactivation of *P. aeruginosa* than those of ampicillin and streptomycin (Stojkovic *et al.* 2014).

Anti-Quorum sensing: Many pathogens use the formation of biofilms as a defence against their host's immune system and against antibiotic treatment. Biofilms are vast bacterial populations in a host that are protected by a layer of polymeric substances. Biofilms use quorum sensing for their protection, a bacterial coordination system that allows density-dependent cell-cell communication. Considering the rapid spread of multidrug resistance, the development of new antimicrobial or anti virulence agents that act upon newly adapted microbial targets has become a very pressing priority. *Agaricus blazei* and also *Inonotus obliquus* (Chaga) were found to have anti quorum sensing compounds next to more common antimicrobials (Sokovic *et al.* 2014). Application of these findings awaits techniques for large scale production and purification of anti-quorum sensing compounds.

Antioxidant effects: Oxidative stress caused by an imbalanced metabolism and an excess of reactive oxygen species (ROS) lead to a range of health disorders in humans. Our endogenous antioxidant defence mechanisms and our dietary intake of antioxidants potentially regulate our oxidative homeostasis. Numerous synthetic antioxidants can effectively improve defence mechanisms, but because of their adverse toxic effects under certain conditions, preference is given to natural compounds, such as from mushrooms. Almost all mushrooms show considerable anti-oxidant activity. Edible mushrooms might be used directly in enhancement of antioxidant defences through dietary supplementation to reduce the level of oxidative stress. Kozarski *et al.* (2015) have recently published and extended review of antioxidants of edible mushrooms.

The diseases: Mushrooms and their components have been used during ages as a traditional medicine in the prevention and therapy of a variety of diseases.

Cancer: Although hundreds of studies were published on the curative effects of mushrooms and their extracts on various cancers in experimental animals, no convincing information is available on the effects in humans that justifies a definite conclusion. Instead many studies are biased, too small, non-randomized, and non-conclusive. The *Ganoderma lucidum* is used full for medication in cancer patients (Jin *et al.* 2016)

“Our review did not find sufficient evidence to justify the use of *G. lucidum* as a first-line treatment for cancer. It remains uncertain whether *G. lucidum* helps prolong long-term cancer survival. However, *G. lucidum* could be administered as an alternative adjunct to conventional treatment in consideration of its potential of enhancing tumour response and stimulating host immunity. *G. lucidum* was generally well tolerated by most participants with only a scattered number of minor adverse events. No major toxicity was observed across the studies.”

For Polysaccharide K (PSK) from *Coriolus versicolor* the situation is not much different. PSK may improve the immune function, reduce tumour-associated symptoms, and extend survival in lung cancer patients. PSK was reported to enhance docetaxel-induced prostate cancer tumour suppression, apoptosis and antitumor responses.

Use of *G. lucidum* and of PSK, in the fight against cancer are repeatedly mentioned to increase the quality of life of cancer patients.

In breast cancer patients quality of life increased after supplementary shii-take extract treatment; the same as for *A. blazei* extract (Ahn *et al.* 2004).

These are only a few examples of many anti-cancer assays in humans.

A possible interesting feature of *Agaricus bisporus* is its anti-aromatase activity that could be deployed in the prevention and treatment of breast cancer in postmenopausal women.

Autoimmune diseases and allergies: Mushroom polysaccharides decrease the concentration of pro-inflammatory cytokines as TNF- α and IFN- γ in lipopolysaccharide stimulated cell systems *in vitro*. This proves that mushroom polysaccharides can be immunosuppressive under certain conditions.

Neurodegenerative diseases: Neurodegenerative diseases as Alzheimer’s disease, Parkinson’s disease, dementia and stroke are mostly age dependent. Mushrooms such as *Antrodia camphorate*, *Ganoderma lucidum*, *Grifola frondosa*, *Hericium erinaceus*, *Phellinus linteus* and *Pleurotus giganteus* may improve memory and cognition functions. The mushrooms (either extracts from basidiocarps/mycelia or isolated compounds) reduced beta amyloid-induced neurotoxicity and had anti-acetylcholinesterase, neurite outgrowth stimulation, nerve growth factor (NGF) synthesis, neuroprotective, antioxidant, and anti-(neuro) inflammatory effects (Phan *et al.* 2015). *Phellinus linteus* ethyl acetate extract containing mostly polyphenols was found neuroprotective *in vitro* by reducing oxidative stress and preventing apoptosis (Choi *et al.*, 2016).

Diabetes: Diabetes type 2 is a rising problem in the modern world. Lifestyle, diet and genetics are causal in the development of obesity and diabetes type 2. As many conventional drugs show adverse side effects, a search was done for potential effects of mushrooms in treatment and prevention of diabetes. So far there is only a single statistically reliable study published on the effects in humans. Hsu *et al.* (2007) performed a clinical randomized double-blind placebo controlled trial with 72 Chinese subjects who had proven diabetes type 2 for over a year and who had been taking gliclazide and methformin for over 6 months. They showed that treatment with 1.5 grams of *Agaricus blazei* extract per day for 12 weeks improves the insulin resistance of the patients from 6.6 to 3.6 in the homeostasis model assessment for insulin resistance, blood pressure was lower and fasting triglycerides of the patients were much lower than the controls. Surprisingly, no further results have been published since.

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