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A comparative study of nutritional and non-nutritional composition of mushroom capable of growing on the different waste: Review

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Abstract
Mushrooms are basically fungi, which have a fleshy and spore-bearing fruiting body. Mushroom contain appreciable amount of potassium phosphorus copper and iron but low level of calcium. This low cost vegetable is not only packed with nutrients like vitamin D but also has properties to ward off cancer, HIV-1 AIDS and numerous other diseases. There is tremendous potential and appeal for growing a highly nutritious food with excellent taste from substrates that are plentiful and not very expensive. Also, it is very environmental friendly, capable of converting the lignocellulose waste materials into food, feed and fertilizers. Mushroom consumption and production is relatively low in comparison to other crops and investment in the mushroom industry is not very large. Mushroom protein is intermediate between that of animal and vegetables. Mushrooms contain 90 percent moisture and showed different properties such as Medicinal properties, Biochemical, Bio medicinal and antimicrobial properties.

Keywords: Cultivation, medicinal, biochemical, bio medicinal and antimicrobial properties

Introduction

Mushrooms are basically fungi, which have a fleshy and spore-bearing fruiting body. There are over 14,000 types of mushrooms in the world, out of which about 3,000 are edible. It belong to class Basidiomycetes, subclasses hollobasidiomycetidae, order agaricales. It grow wild in the forest of hilly areas. Mushroom are the source of extra ordinary power and virility and are used in the preparation of many continental dishes. (Quimio 1976) [41] Mushroom contain about 85-95% water, 3% protein, 4% carbohydrates, 0.1% fats, 1% minerals and vitamins (Tiwari 1986) [47]. The vitamins of mushrooms are not destroyed by cooking, drying and freezing (Nair, 1982) [36]. Mushroom contain appreciable amount of potassium phosphorus copper and iron but low level of calcium. (Anderson and Fallenr 1942) [2]. On exposure to UV-light, mushrooms also produce large amounts of vitamin D, which is normally difficult to obtain from a regular diet intake. In light of the growing incidences of cancer in today's world, it is high time people woke up to the beneficial effects of mushrooms and utilized their cancer-fighting qualities. This low cost vegetable is not only packed with nutrients like vitamin D but also has properties to ward off cancer, HIV-1 AIDS and numerous other diseases (Beelman *et al.*, 2003) [6]. It is an economical crop to cultivate, requiring low resources and area, can be grown throughout the world and all over the year from low-cost starting materials. There is tremendous potential and appeal for growing a highly nutritious food with excellent taste from substrates that are plentiful and not very expensive (Beetz and Kustudia, 2004) [7]. Also, it is very environmental friendly, capable of converting the lignocellulosic waste materials into food, feed and fertilizers (Hadar *et al.*, 1992; Jaradat, 2010) [23, 18]. However, mushroom consumption and production is relatively low in comparison to other crops and investment in the mushroom industry is not very large (Chang, 2006) [23]. Mushroom protein is intermediate between that of animal and vegetables. (Kurtzman 1976) [30]. In India, only 3 species, namely, *Agaricus bisporus*, *Pleurotus sajor caju* and *Volveriella* are preferred for commercial cultivation. Of the three cultivated species, the white button mushrooms have the highest consumer preference and account for about 90 percent of total mushroom production. The Oyster mushroom grows during winter months only therefore, it needs proper preservation techniques to promote their consumption among common people and excess mushroom is processed into food products acceptable to consumers. Mushrooms contain 90 percent moisture. Every year about 90 tons of mushroom are exported to Europe and Pakistan. There is a need to develop diversified agriculture in the Pakistan.

The aim of project study was to investigate the information about the Cultivation, Medicinal, biochemical and antimicrobial properties of mushroom from different areas.

Chemical compound in mushroom

Beneficial effects of wood-rotting mushrooms (that include oyster mushroom) on human being have been known for a long time. They have positive effects on blood lipid profile when consumed in large quantities because of their high content of fiber and natural production of substances suppressing the production of cholesterol. Oyster mushroom also contains many vitamins (B, D, C, K), minerals, trace elements (Na, Cr, Cu, I, Se, Zn) and some fatty acids. Beyound doubt, the oyster mushroom is found to have positive impact on the organism and is considered as component food of healthy diet. So far modulation of immune response is concerned, the effect of the oyster mushroom itself (most frequently as dry powder) is negligible. Oyster mushroom significantly reduces the hepatocellular enzyme Aspartate transaminase (AST) and Alanine transaminase (ALT) in plasma. Although the exact mechanism is not clear but it might be due to presence of various hepatoprotective substances present in *Pleurotus ostreatus*. In a study (Bobek *et al*. 1997) [8] observed a significant reduction of cholesterol in serum (31 - 46%) and in liver (25 - 30%) in Wister rats fed a diet containing 5% *Pleurotus ostreatus* for 52 weeks. These observations were supported by the findings of (Hossain *et al*. 2003) [21]. They suggested that 5% *Pleurotus ostreatus* supplementation provides health benefits, at least partially, by acting on the Atherogenic lipid in hypercholesterolaemic condition. It is now established that excess lipid accumulation in the liver causes fatty change and ultimately responsible for hepatocellular injury. In a study (Jayakumar *et al*. 2006) [24] observed that administration of the extract of *Pleurotus ostreatus* reduces significantly the plasma level of AST, ALT and Alkaline phosphatase (ALP) and increases significantly the hepatic concentration of antioxidant enzymes reduced glutathione (GSH), catalase (CAT), superoxide dismutase (SOD) and glutathione peroxidase (Gpx) on Carbon tetra chloride (CCl4) induced liver damage in male Wister rats. Although lots of study conducted in different corners of the world with *Pleurotus ostreatus* but most of them were limited in animal subjects. A study was conducted by (Choudhury *et al*. 2009) [9] among the targeted human population which is consistent with (Bobek *et al*. 1997) [8] and (Jayakumar *et al*. 2006) [24] that gives the guidelines of hepatoprotective effects of oyster mushroom demonstrated that lovastatin crosses the bloodbrain and placental barriers (25). Statins (or HMGCoA reductase inhibitors) lower cholesterol levels by inhibiting the enzyme HMG-CoA reductase, which plays a central role in the production of cholesterol in the liver. Increased cholesterol levels have been associated with cardiovascular diseases (CVD), and statins are therefore used in the prevention of these diseases. *Pleurotus ostreatus* also contains the hypocholesterolaemic agent mevinolin (monacolin K, lovastatin) which may be involved in decreasing the activity of the 3- hydroxy-3-methylglutaryl coenzyme A (HMGCoA) reductase enzyme. *P. ostreatus* contains water-soluble gel-forming substances, including b-1,3-D-glucan and pectin, which bind to bile acids, thereby inhibiting cholesterol-bile micelle formation and cholesterol absorption (Hossain *et al*. 2003) [21].

Table 1: Some chemical compounds extracted from mushrooms

Chemical compounds	Obtained from	Properties
Peptido glycans	*Lentinus, Schizophyllum, Grifola, Sclerotinia*	Anti-tumour
Ergosterol	*Agaricus blazei*	Anti-tumour
Lipid fraction	*Grifola*	Anti-oxidant
Steroids, hydroquinones	*Ganoderma pfeifferi*	Anti-bacterial
Oxalic acid	*Lentinula edodes*	Anti-protozoal
Schizophyllan	*Schizophyllan commune*	Anti-tumour
Epicorazin	*Podaxis pistillaris*	Anti-microbial
Ganoderic acid	*Ganoderma lucidum*	Anti-viral (HIV)
Ganodric acid, lucidadiol,	*Ganoderma sps.*	Anti-viral (influenza)
Lignins	*Inonotus obliquus*	Anti-viral (HIV)
Polysaccarides	*Trametes versicolor*	Anti-viral (HIV)
Velutin	*Flammulina velutipes*	Anti-viral (HIV)
Illudins	*Omphalotus olearis*	Cytotoxic
Polysaccarides	*Phellinus linteus*	Antiangiogenic
Hispolon, hispidin	*Indocalamus hispidin*	Anti-allergic
Ergosterol peroxide	*Tricholoma populinum*	Anti-allergic

Medicinal uses of mushrooms

Most of our medicines come from natural resources and scientists are still exploring the organisms of tropical rain forest for potentially valuable medical products. As the infectious microorganisms evolve and develop resistance to existing Pharmaceuticals, Bioprospecting for novel sources of medicines against bacterial, viral, fungal and parasitic diseases is now focusing on other lead sources including drugs of fungal origin. *Pleurotus* are cultured on a wide variety of agro forestry products for the production of feed, enzymes, and medicinal products (Andrew *et al.* 2007) [3]. Several medicinal properties have been reported in extracts of *Pleurotus* species. *Pleurotus* species have been used by human cultures all over the world for their nutritional value, medicinal properties and other beneficial effects. Oyster mushrooms are a good source of dietary fibre and other valuable nutrients. They also contain a number of biologically active compounds with therapeutic activities. Oyster mushrooms modulate the immune system, inhibit tumour growth and inflammation, have Hypoglycaemic and Antithrombotic activities, lower blood lipid concentrations, prevent high blood pressure and Atherosclerosis, and have antimicrobial and other activities (Gunde-Cimerman, 1999) [17]. Crude extracts of *Pleurotus* species have also been reported to have Antitumour activities. Methanol extracts of *P. florida* and *P. pulmonarius* fruiting bodies significantly reduced solid tumours in mice (Jose & Janardhanan, 2002) [26]. It has been suggested that the bioactive compounds in the extract were water-soluble proteins, polypeptides and polysaccharides (Wasser, 2002) [51]. Methanol extracts of oyster mushroom have been shown to possess moderate antioxidant activities. The antioxidant activity was positively correlated with total polyphenol content (Dubost *et al.* 2007, Elmastas *et al*. 2007) [11, 14].

Oyster mushroom can help in solving the problems of malnutrition and disease. Its protein content is second to legumes and quality is nearly equal to animal derived protein. Low fat content of oyster is mostly of the healthy unsaturated types. It contains the minerals mainly required by the human body, such as calcium, phosphorous and iron, in twice the amounts contained in beef, pork and chicken meat. It has the highest content of Vitamin B1 and B2. It is rich in folic acid content which can prevent and cure anemia and 5 to 10 times richer in niacin than any other vegetable. Oyster mushroom is also suitable for people wishing to reduce their weight. It has been used to relax muscles, to resist leakage of blood vessels and in strengthening of veins and relaxation of the tendons (Annonymous.). Folklores have provided clues for potential sources of medicine from mushrooms. Using modern approaches, scientists have isolated and identified specific components that can help prevent or sometimes cure of mankind killer diseases: heart diseases, diabetes, and cancer. As a result, a vast body of scientific literature concerning mushrooms has been published, mostly in hospitals and research institutions in Europe, Japan, China and United States. Following these leading countries Bangladesh has already started its journey to the goal. Oyster mushroom significantly reduces the hepatocellular enzyme Aspartate transaminase (AST) and Alanine transaminase (ALT) in plasma (Choudhury *et al* 2009) [9].

Cultivation of mushroom

Although there are well over 300 genera of mushrooms and related fleshy Basidiomycetes, only a few species of these fungi are cultivated commercially. This may be due to the fact that many of them are mycorrhizal and may not sporulate in the absence of the host. But many saprophytic species have been amenable to cultivation. Some of the more common cultivated species listed here (Table 2) are the button mushroom, *Agaricus bisporus* which was widely cultivated in Europe before being exported to North America by the settlers. The Shiitake mushroom (*Lentinus edodes*) which is grown for centuries in China and other oriental countries and the oyster mushroom (*Pleurotus ostreatus*) which was collected as wild specimens from forests in Florida and later actively cultivated in several countries around the world. Also grown are the oriental Enoke or velvet stem mushroom (*Flammulina velutipes*) whose major production is in Japan the paddy straw mushroom (*Volvariella volvacaea*) and ear fungus (*Auricularia auricula*) which has great medicinal value. Other cultivated mushrooms are the Reishi mushroom (*Ganoderma lucidum*) which is used as an alternative medicine and also as flavouring agent in Japan. The Nameko (*Pholiota nameko*) grown in the orient and *Tremelia fuciformis* or white jelly fungi that is grown for use as food supplements in Taiwan. Varieties of *A. bisporus* that are grown commercially include the crimini and portabello. Truffles (*Tuber* species) live in close mycorhizal association with roots of specific trees. They are considered a food delicacy and rated as one of the most expensive natural food in the world (Trappe *et al*., 2007).

Mushroom cultivation represents the only current economically viable biotechnology process for the conservation of waste plant residues from forests and agriculture (Wood and Smith, 1987). Culture of Oyster mushroom is becoming popular throughout the world because of abilities to grow at a wide range of temperatures and to utilize various lignocellulose *Pleurotus* species have extensive enzyme systems capable of utilizing complex organic compounds that occur as agricultural wastes and industrial by-products. These mushrooms are also found to be one of the most efficient lignocelluloses solid state decomposing types of white rot fungi (Baysal *et al*., 2003).

The oyster mushroom, first cultivated in Germany as a subsistence measure during World War2 is now grown commercially around the world for food. There are many different varieties of the exotic oyster mushroom which are found throughout North America, Europe and Asia. The fluted, graceful oyster shell shape and delicate, briny flavor are best praised in a poem written during the Sung dynasty that calls the oyster "the mushroom of flower heaven". In Japanese, Korean and Chinese cookery oyster mushroom is frequently used as a delicacy. It is frequently served on its own as soup, sometimes stuffed, or in stir-fry recipes with soya sauce. In Asian cooking practice oyster mushrooms are sometimes made into a sauce, which is similar to oyster sauce. (Eger 1976) [13].

Table 2: Some common commercial mushrooms

Common name	Scientific name	Origin
Button mushroom	*Agaricus bisporus*	Europe
Shiitake mushroom	*Lentinus edodes*	China
Oyster mushroom	*Pleurotus ostreatus*	Florida
Velvet stem mushroom	*Flammulina velutipes*	Japan
Paddy straw mushroom	*Volvariella volvacea*	China, Japan
Ear fungus	*Auricularia auricula*	China, Japan
Reishi mushroom	*Ganoderma lucidum*	Japan
Nameko mushroom	*Pholiota nameko*	China, Japan
White jelly fungi	*Tremella fuciformis*	Taiwan
Truffle Europe	*Tuber aestivum*	New Zealand, Australia

Mushroom as Mycoremediation tool

Remediation through fungi is also called as Mycoremediation. Mycoremediation tool refers to mushrooms and their enzymes due to having ability to degrade a wide variety of environmentally persistent pollutants, transform industrial and agro-industrial wastes into products.

Mushroom as Mycoremediation potential

Mushroom uses different methods to decontaminate polluted spots and stimulate the environment. These methods include –

(i) Biodegradation
(ii) Biosorption
(iii) Bioconversion.

Biodegradation

The term '*Biodegradation*' is used to describe the definitive deprivation and recycling of multifaceted molecule to its mineral constituents. It is the process which leads to complete mineralization of the starting compound to simpler ones like CO_2, H_2O, NO_3 and other inorganic compounds by living organisms. Many reports have been published on the compounds produced by degradation of various wastes and factor affecting the processes. Mushroom can produce extracellular peroxidases, ligninase (lignin peroxidase, manganese dependent peroxidase and laccase), cellulases, pectinases, xylanases and oxidases (Nyanhongo *et al*. 2007). These are able to oxidize recalcitrant pollutants *in vitro*. These enzymes are typically induced by their substrates. These enzymes have also been found to *degrade* nonpolymeric, recalcitrant pollutants such as nitrotoluenes (VanAcken *et al*. 1999), PAHs (Hammel *et al*. 1991, Johannes *et al*. 1996), organic and synthetic dyes (Ollikka *et al*. 1993, Heinfling *et al*. 1998), and pentachlorophenol (Lin *et al*. 1990) under in vitro conditions. Recently, it is reported that mushroom species are able to degrade polymers such as plastics (da Luz *et al*. 2013). The biodegradation mechanism is very complex. The reason is the influence of other biochemical systems and interactions of Ligninolytic enzymes with Cytochrome P_{450} Monooxygenase system, hydroxyl radicals and the level of H_2O_2 which are produced by the mushroom.

Table 3: Various waste products and the mushrooms used as their management.

Mushroom spp	Waste/Pollutant	Remarks	References
Pleurotus ostreatus	Oxo-Biodegradable plastic	Mushrooms degraded the plastic and grew on it.	da Luz *et al*. (2013)
Lentinula edodes	2,4-dichlorophenol	Mushrooms degraded 2,4-dichlorophenol (DCP) by using vanillin as an activator	Tsujiyama *et al*. (2013)
Pleurotus pulmonarius	Radioactive cellulosic-based waste	Waste containing mushroom mycellium was solidified with portland cement and then this solidified waste act as first barrier against the release of radiocontaminants	Eskander *et al* (2012)
Pleurotus pulmonarius	crude oil	crude oil was degraded	Olusola and Anslem (2010)
Coriolus versicolor	52492 PAH	Mushroom possesses ability to degrade Poly-R 478 which decides its suitability to degrade PAH. Lignin-modifying enzymes laccase, manganese-dependent peroxidase (MnP), and lignin peroxidase (LiP)was found to produce for degradation	Jang *et al*. (2009)

Biosorption

The second important process of removal of metals/pollutants from the environment by mushroom is - *biosorption*. Biosorption is considered as an alternative to the remediation of industrial effluents as well as the recovery of metals present in effluent. Biosorption is a process based on the sorption of metallic ions/pollutants/xenobiotics from effluent by live or dried biomass which often exhibits a marked tolerance towards metals and other adverse conditions (Gavrilescu 2004). Biosorbents can be prepared from mushroom mycelium and spent mushroom compost. The uptake of pollutants/xenobiotics by mushrooms involves a combination of two processes: (i) Bioaccumulation i.e. active metabolism-dependent processes, which includes both transport into the cell and partitioning into intracellular components; and (ii) Biosorption i.e. the binding of pollutants to the biomass without requiring metabolic energy. Several chemical processes may be involved in Biosorption, including adsorption, ion exchange processes and covalent binding. According to (Mar'in *et al*. 1997), the polar groups of proteins, amino acids, lipids and structural polysaccharides (chitin, chitosan, glucans) may be involved in the process of biosorption.

Table 4: Various waste pollutants and the mushrooms used for their management

Mushroom spp	Pollutants	Remarks	References
Agaricus bisporus, Lactarius piperatus	Cadmium (II) ions	Wild *L. piperatus* showed higher removal efficiency on Cd(II) ions compared to the cultivated *A. bisporus*	Nagy *et al*. (2013)
Fomes fasciatus	Copper (II)	Mushroom is efficient in biosorption of Cu (II) ions and hot-alkali treatment increased their affinity for Cu (II) ions	Sutherland and Venkobachar (2013)
Pleurotus platypus, Agaricus bisporus, Calocybe indica	Copper, Zinc, Iron, Cadmium, Lead, Nickle	Mushrooms are efficient biosorbent for the removal these ions from aqueous solution	Lamrood and Ralegankar (2013)
Flammulina velutipes	Copper	Mushroom compost used as biosorbent for removing copper ions from aqueous solution	Luo *et al*. (2013)
Pleurotus tuber- regium	Heavy metals	*Pleurotus tuber-regium* biosorb the pollutant heavy metals from the soil artificially contaminated with some heavy metals	Oyetayo *et al*.(2012)
Pleurotus ostreatus	Cadmium	Mushroom possess biosorption capacity and mechanism of biosorption was observed	Tay *et al*. (2011)

Bioconversion

Nowadays, the research on conversion of industrial or agro-industrial sludges into some other useful forms is going on. The most important bioconversion product is - Mushroom. Any lignocellulosic waste, generated by industries, can be used for cultivation of mushroom which can be further use as a product. Mushroom species cultivated on industrial and agro-industrial wastes are given in Table 5. The choice of the substrate for the cultivation of mushroom is generally determined by the regional availability of the material. Mushroom cultivation has also been successfully done on various industrial wastes (Singhal *et al*. 2005, Kulshreshtha *et al*. 2010, Dulay *et al*. 2012 and Kulshreshtha *et al*. 2013b). Applications of mushroom as mycoremediation tool in the bioconversion of these industrial wastes into protein rich mushroom carpophores (fruiting bodies of mushroom), on one hand provides mushroom and on the other hand helps in solving pollution problems, which their disposal may otherwise cause.

Table 5: Different species of mushrooms capable of bioconversion of waste.

Mushroom spp.	Bioconversion of waste	Remarks	References
Pleurotus citrinopileatus	Handmade paper and cardboard industrial waste	Successfully cultivated. Basidiocarps possessed good nutrient content and no genotoxicity	Kulshreshtha *et al*. (2013)
Pleurotus ostreatus	Extract from the sawdust	Biomass of mushroom was produced in submerged liquid culture were analyzed	Akinyele *et al*.(2012)
Volvariella volvacea	Agro-industrial residues such as cassava, sugar beet pulp, wheat bran and apple pomase	Enzyme activities were measured during the fermentation of substrates	Akinyele *et al*.(2011)
Pleurotus florida	Handmade paper and cardboard industrial waste	Successfully cultivated. Basidiocarps possessed normal morphology and no genotoxicity	Kulshreshtha *et al.* (2010)
Pleurotuseous and *Lentinus connotus*	Cotton waste, rice straw, cocoyam peels and sawdusts of *Mansonia altissima*, *Boscia angustifolia* and *Khaya ivorensis*	Waste successfully bioconverted by mushroom with good biological efficiency	Rani *et al.*(2008)
Pleurotus	Paddy straw, sorghum stalk, and banana pseudostem.	Successfully cultivated with good crude protein, crude fat and carbohydrate contents in sporophores.	Kuforiji and Fasidi (2009)

Conclusion

After study we conclude that mushroom has different properties as Medicinal properties, Biochemical, Antimicrobial properties and even these fungal fruiting bodies are capable of managing the organic waste by different mean. There are different methods for the cultivation of mushroom by using the waste around us which relies on the enzymes produced by the mushrooms. As the mushroom are useful for human health and provide a significance of nutrients having antioxidant and anti-cancerous property. As we are hemmed in by agricultural and industrialized unwanted waste that can be transformed into fuel, medicines, and edible protein. The cycle of life is a constant balance of strength and weakness. Fungi are opportunistic and can be trained to decompose specific pathogens for the waste management and can get the valuable mushrooms too for the consumption. Thus, there is a requirement for advance research in the direction of the exploitation and implement its safety characteristics for consumption as product of prospective of mushroom from waste as per its bioremediation, medicinal and nutritional properties.

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