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Case Study

DIFFERENT ASPECTS OF *LENTINULA EDODES*

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ABSTRACT
Lentinula edodes is an edible and medicinal mushroom which is very popular in the Asian and western countries for its rich taste and medicinal properties. This mushroom has a very rich history of its cultivation on oak wood log, and then it was cultivated on synthetic plastic bags with saw dusts and other agricultural wastes. The present review summarizes the available literature on *Lentinula edodes* in respect of its taxonomic position, morphological characterization and cultivation technology. It also suggests how the cultivation of this mushroom not only helps in the management of protein need in the country but also play an important role in management of agricultural wastes, hence, improving the ecology.

KEYWORDS: *Lentinus edodes,* Shiitake, substrates, agricultural wastes.

INTRODUCTION

Lentinus edodes (Berk.) Sing. or *Lentinula edodes* (Berk) Pegler, commonly known as the Shiitake mushroom, is a white rot wood-decay fungus that naturally inhabits the dead wood of many hardwood tree species in Asia. Cultivation of Shiitake on natural logs is an established industry, especially in Japan (San Antonio, 1981). Shiitake accounts for 25.4 % of total world consumption of edible mushrooms (Chang and Miles, 2004). This is a saprophytic fungus which produces edible sporophores of high value. Its commercial cultivation is being done in Japan and China on the logs. Oak is the most preferred species used as substrate (Stamets and Chilton, 1983). The cultivation of *L. edodes* (Shiitake) first began in China about AD 1100 (Nakamura, 1983; Royse *et al.*, 1985; Chang and Miles, 1987, 1989). It is believed that Shiitake cultivation techniques developed in China were introduced to the Japanese by Chinese growers (Ito, 1978). Other common names of this mushroom are the Oakwood mushroom, Japanese forest mushroom, Black mushroom and Pasania. It is a mushroom long valued for both an unique flavour and as a medicinal tonic, for even in the Ming Dynasty (1368-1644 CE) it was claimed to be a general stimulant, curing colds, increasing blood circulation and lowering blood pressure. *Lentinula edodes* is found throughout much of eastern Asia, especially China and Japan, preferring an optimal temperature of around 24°C but also extending westwards as far as Kazakhstan. It grows on the dead wood of a wide range of tree hosts, especially species of oak, beech, chestnut, hornbeam, walnut, *Elaeocarpus,* the Shii tree (*Castanopsis cuspidata*), magnolia, pines and spruce (Pegler, 2003). It is a moderately lignocellulolytic species which can produce a series of hydrolytic and oxidative enzymes used in the degradation process of the main compounds of the lignocellulosic materials (Morais *et al.,* 1999).

Taxonomic Position (Alexopoulos *et al.,* 1996; Chang and Miles, 1989 and Wasser, 2002).

Class	: Basidiomycetes
Sub-class	: Holobasidiomycetidae
Order	: Agaricales
Family	: Tricholomataceae
Genus	: *Lentinula*
Species	: *edodes*

But some workers placed it in the order Aphyllophorales (Singer, 1986; Pegler, 1983). In 1997, Guzman *et al.* placed the genus *Lentinula* in order Poriales. Kirk *et al.* (2001) described the position of *Lentinula* in order Polyporales and family polyporaceae.

Morphology

According to Purkayastha and Chandra (1985) the sporophores of Shiitake mushroom usually growing on wood of deciduous trees of Fagales such as chestnut (*Castanea* sp.), oak (*Quercus* sp.), hornbeam (*Carpinus* sp.), beech (*Fagus* sp.). These sporophores were usually concentric, sometimes centrally stipitate and characterized by its whitish lamellae which do not darken with age. The pileus upto 11.0 cm in diameter, brown at first convex, then depressed sometimes umbenate when old; scales darker in the centre, lighter towards the margin, triangular or areolate, small or large consisting of filamentous interwoven hyphae. Gills crowded, edge denticulate, at first whitish, later brownish or greyish, adenate, usually get separated from stipe and becoming free. Stipe usually 3.0-4.0 × 0.8-1.3 cm long, solid, pale and reddish brown, dark brown scales present at the joints of cortina. Broad at the middle, rarely bulbous at the base, cortina colourless to light brown, ring-like in young fruiting bodies, inconspicuous with age. Flesh of the sporophores generally white, brownish under the surface of pileus, soft, fleshy when tender, tough and coriaceous when old. Shiitake is having mild odour, taste slightly acidic, not unpleasant with hymenophoral trama regular. Basidia are 4-spored, basidiospores cylindrical to elliptical, smooth, thin walled. Hyphal system monomitic, sclerified generative hyphae present, skeletal or ligative hyphae absent, generative hyphae loosely interwoven inflating constricted at the septa with clamp connection. According to Luis (1999) Shiitake had beautiful, dark brown, fleshy basidiocarps. According to Pegler (2003) the convex to depressed, ochraceous tawny to dark vinaceous brown cap was 5-15 cm across, darker at the center, dry and smooth then breaking up into triangular scales or deeply cracking. The gills were adnate to free, crowded and whitish whilst the short, stocky stem was solid, pale reddish brown, and slightly scaly below. Gaitan *et al.* (2004) cultivated Shiitake mushroom on wheat straw substrate and got sporophores with pileus diameters ranging from 5 to 20 cm.

Cultural Characteristics

Cultural characteristics of wood-decaying fungi were studied by Long and Harsch (1918), Fritz (1923) and Davidson *et al.* (1938). Davidson *et al.* (1942) using microscopic cultural characteristics developed the first key codes for the identification of fungi that decay oak. Nobles (1948) provided an 11-character key pattern and descriptions based on cultural information to 126 basidiomycetes that decay wood. Nobles (1958) suggested the use of cultural characters in developing taxonomy of the polyporaceae that reflects natural relationships and phylogeny. Fukushima *et al.* (1991) grew *Lentinula edodes* in medium containing polypeptone (2.5 g or 5.0 g/litre of water), yeast extract (2.5 or 5.0 g/litre) and glucose (50 g/litre) with salts, either under batch culture or continuous culture conditions. They found that mycelium productivity was 14 times higher in continuous culture at a dilution rate of 0.03/h than in batch culture. Furlan *et al.* (1997) investigated mycelial growth of 7 strains of edible fungi on different growth media and under different culture conditions. They found that mycelial growth rates of *L. edodes* were higher on wheat dextrose agar (WDA) medium than on PDA at 20 to 25°C and pH 4.0. Absence of light favoured rapid mycelial development in all the strains tested. Pacumbaba and Pacumbaba (1999) grew *Lentinula* on different culture media including YMMBSA (yeast extract, malt extract, multigrain oatmeal, brown sugar, agar), YVMBSA (yeast extract, V-8 vegetable juice, multigrain oatmeal, brown sugar, agar) and YVMSA (yeast extract, V-8 vegetable juice, multigrain oatmeal, sucrose, agar) and broths YVMBS (yeast extract, V-8 vegetable juice, multigrain oat meal, brown sugar), YVMS (yeast extract, V-8 vegetable juice, multigrain oatmeal, sucrose) and MVBS (multigrain oatmeal, V-8 Vegetable juice, brown sugar) they found that formulated culture media considerably enhanced the growth of Shiitake mycelia, production of spawn and basidiocarps in less time (2.6 to 4.1 months after inoculation) in the laboratory. Rossi *et al.* (2000) developed *L. edodes* in different culture media, including aqueous sugarcane bagasse extracts at different concentrations (20 to 100 g/litre of bagasse), minimum medium and potato-dextrose agar medium (PDA). They found that PDA medium provided the highest speed, vigour and estimated biomass values. Mata *et al.* (2001) cultivated 11 strains of *Lentinula edodes* on solid media: derived from malt extract (MEA); malt yeast extract (YMEA); and YMEA plus wheat straw soluble lignin derivatives (YMEA + WSLD). The results were compared with data for mycelial growth rates, of the same strains cultivated on substrates derived from wheat straw treated at different temperatures (50,65,75 and autoclaving at 121°C). The greatest mycelial growth rate was obtained on sterilized straw at 121°C for the majority of strains. Curvetto *et al.* (2002) evaluated the nutritive agar formulations with additions of poplar (*Populus alba*) sawdust, wheat (*Triticum durum*) bran, or milled sunflower (*Helianthus annuus*) seed hulls (SSH) for mycelium cultivation of shiitake in petri dishes. The largest mycelial growth rates were 2.75, 2.88 and 2.93 mm/day for the substrates formulated with 8 SSH : 2 wheat bran, 9SSH : 1 poplar sawdust, and 8SSH : 1 wheat bran : 1 poplar sawdust by weight, respectively. Hatvani *et al.* (2003) observed that the medium containing malt extract (15 g/l), starch (3 g/l) and oak wood chips (20 g/l) proved best for mycelial growth. Xia and Qin (2003) investigated the effects of cotton stalk powder (CSP) on the hyphal growth and mushroom yield. They were media A (85% CSP + 15% wheat bran), B (70% CSP + 15% sawdust + 15% wheat bran), C (60% CSP + 25% sawdust + 15% wheat bran), D (45% CSP + 40% sawdust + 15% wheat bran) and E as control (80% sawdust + 20% wheat bran). The highest mushroom yield was recorded in medium C, followed by medium B. The mushroom appeared 87, 81, 79, 84 and 85 days after inoculation on the media A, B, C, D and E respectively and biological conversion efficiencies were 77, 84, 86, 78 and 81 %, respectively. Insignificant differences in hyphal growth speed mushroom yield and biological conversion efficiency were found among the media A, D and E, but these differences reached the significant level between the media B and E and between the media C and E. Hence, substituting sawdust with CSP was feasible for *L. edodes* production and the best medium was medium C.

Ding (1987) recommended a temperature of 20°C and a relative humidity of 85-90 % to give satisfactory colour of the fruiting bodies of *Lentinula edodes.* He also advocated that temperature changes can also cause fruiting bodies to fall. Triratana and Tantikanjana (1989) studied the effect of temperature and light intensity on various strains of *Lentinula edodes* and they found that various strains responded differently to light intensity (150-600 lux) and temperature (11-25°C). Delpech *et al.* (1991) found that good control of temperature is essential to prevent *Trichoderma* infection of the substrates. Khan *et al.* (1991) observed maximum radial growth of *L. edodes* at 25°C and pH 5.0. Khan *et al.* (1995) recorded maximum growth of *L. edodes* at 25°C 12 days after inoculation on agar medium with pH 5.0. Growth was reduced markedly at temperature below 20°C and above 30°C. The most suitable pH for growth of the fungus was 5.0. Balazs *et al.* (1996) inoculated *L. edodes* into agar media containing malt extract and different concentrations of peptones at pH 5.5-7.0. The cultures were incubated at 15-30°C for 12 days and growth was then compared. They found that temperature; pH and N requirements of *Trichoderma, Aspergillus, Penicillium, Chaetomium* and *Nigrospora* were similar to shiitake, indicating that modification of these factors would not help in control. It is recommended that the temperature should not exceed 25°C and the pH should be kept below 6. Increasing the initial shiitake inoculum dose is also suggested. Furlan *et al.* (1997) observed the higher growth rates of *Lentinula edodes* at 30°C than at 20 or 25°C. They also observed high growth rates of *L. edodes* at low pH (4.0). Absence of light favoured rapid mycelium development. Maki *et al.* (2001) observed the growth of thirty four *Lentinula edodes* strains at different three pH values (5, 6 and 7) and four different temperatures (16, 25, 28 and 37°C). They found that mycelial cultivation was successful at all pH tested, while the ideal temperature for mycelial cultivation ranged between 25 and 28°C. In 2011, Puri found that sorghum is an ideal material for Shiitake spawn production.

Substrates and supplementation for Shiitake production

Mushroom cultivation is a complicated procedure, involving a number of operations, which include the preparation of a fruiting culture, spawn and compost. It is the aim of mushroom growers and researchers to try to increase the yield from a given surface area, to shorten the cropping period and to have many more flushes with an increasingly high and regular yield (Morais *et al.,* 1999). Various species of trees have been used for the cultivation of Shiitake (San Antonio, 1981). One of the primary species used in one area of Japan in past years was the Shii-tree thus the derivation of the name Shiitake (Singer, 1961). Most production today, however, is on various species of oak (Harris, 1986; Stamets and Chilton, 1983). In an attempt to develop a more efficient and dependable method for the production of Shiitake mushrooms researchers have focused on the cultivation of *L. edodes* on synthetic sawdust substrates. Cultivation on a supplemented sawdust substrate provides a more rapid and controlled method of cultivation than is presently possible with sectioned logs as described by Ito (1978). Synthetic substrates usually consist of sawdust mixed with nutrient supplements (Ando, 1974; Mee, 1978; Mori *et al.*, 1976; Fuzisawa *et al.* 1978a, b; Fuzisawa and Hattori, 1979; Anonymous, 1980; Han *et al.,* 1981; Fergus, 1982; Farr, 1983; Leatham, 1983; Patrick *et al.,* 1983; Royse *et al.*, 1985 and Royse, 1985). Sawdust is one of the wood-sawmilling wastes which may reach 15 percent of the total volume. This material could be used for Shiitake's cultivation media (Djarwanto and Suprapti, 2000). Sawdust is the most popular basal ingredient used in synthetic formulations of substrate used to produce Shiitake (Miller and Jong, 1987). Other basal ingredients that may be used include straw and corn cobs or mixtures thereof. Presently, there is a wide range of techniques used to grow Shiitake on sawdust. One common technique involves autoclaving the substrate in heat-resistant containers followed by the inoculation of cooled substrate in each container (Ando, 1974; Mee, 1978; Mori *et al.*, 1976; Fuzisawa *et al.*, 1978a, b; Fuzisawa and Hattori, 1979; Anonymous, 1980; Han *et al.,* 1981; Farr, 1983; Patrick *et al.,* 1983). It has been reported that mycelial growth, primordia formation and productivity vary with different lines on synthetic substrates (Ando, 1974; Han *et al.*, 1981). In an effort to save time and labor, a process has been developed where the substrate can be mixed, heat treated, cooled and inoculated in the same apparatus (Royse, 1985). He used a mixture of maple and birch (60: 40) sawdust as the main substrate ingredient and found that the proportion of sawdust (80%), millet (10%) and spring wheat bran (10%) was the best formula for nutrimental components. Selection of the tree species for sawdust cultivation should proceed with caution. Fresh sawdust without aging by fermentation can be used for production of Shiitake only if it is from high quality tree species, such as chinkapin oak, hornbean, poplar, alder, iron wood, beech, birch and sweetgum, those graded 4, excellent by FAO (Oei, 1996). Schunemann (1986) studied the mycelial growth of 14 strains of *Lentinula edodes* on to substrates of compressed straw, or beech (*Fagus*), coniferous or mixed (>50% mahogany) sawdust, with or without amendments of 20 % (w/w) soybean or maize meal, used brewer's grain or dry molasses. The dry molasses amendment improved mycelial growth of nearly all the strains on all the substrates. Chen (1988) described the cultivation of *Lentinus edodes* (including the use of gypsum in substrate), the relatively low temperature requirements of the fungus, the humidity requirements, the need for ventilation, the light requirements and the substrate pH (which is most favourable at about 5). Triratana and Osathaphant (1988) cultivated the Shiitake on sawdust as a substitute for the usual log-wood cultivation. Some types of sawdust and agricultural residues available in tropical countries were examined for their suitability for mycelial growth in Shiitake production. Royse *et al.* (1990) cultivated Shiitake on synthetic substrate having sawdust, wheat bran and millet, amended or non-amended with sucrose, fructose or glucose. They found that the addition of sucrose (0.6-1.2% dry weight) and fructose at 12 % and glucose at 0.6 % to the substrate stimulated mushroom yield by 11 to 20 % or more. They advocated that regardless of the main ingredient used, starch based supplements such as wheat bran, rice-bran, millet, rye, corn, etc. are added to the mix in a 10 to 40 % ratio (dry weight) to the main ingredient. These supplements serve as nutrients to provide an optimum growing medium. Delpech *et al.* (1991) cultivated *Lentinula edodes* on available basic materials with a short production cycle (not exceeding 3 months). The substrate was wheat straw mixed with chicken feather meal. Benomyl was added to the substrate before pasteurization at 60°C for 24 h. Substrate temperature was controlled using thermodynamic sensors within the substrate blocks. Six commercial *L. edodes* strains (S 600, S 610, 4055, V084, V0122 and 072) were tested. Good control of temperature is essential to prevent *Trichoderma* infection of the substrate. A few strains only were able to give a good commercial yield on the pasteurized substrates. Khan *et al.* (1991) cultivated the Shiitake on three types of sawdust from 'shishum' (*Dalbergia sissoom*), 'kikar' (*Acacia arabica*) and poplar (*Populus alba*) were amended with wheat bran, wheat chaff, paddy straw and cotton waste and lime and used for spawn preparation. They found that sawdust from *D. sissoo* was the most suitable for spawn preparation and all sawdust amended with cotton waste were found to give optimum results for spawn running. Moyson and Verachtert (1991) studied the effect of *Lentinus edodes* on the composition of wheat straw. They observed that Shiitake grew very well on lignocellulosic substrates breaking down a considerable amount of lignin. The initial concentration of lignin is straw was halved after 12 weeks of fungal growth, doubling the enzymatic digestibility. Balazs and Kovacs (1993) studied that straw with additives made the best substrate of *Lentinula edodes*. The dry substrate was heat treated at 100°C, spawned and incubated. Fruiting bodies appeared 60-70 days after spawning and a yield of 20-25 kg mushrooms/100 kg heat treated wet substrate was produced. In India, cultivation trials of Shiitake were done and mushrooms have been developed successfully (Sohi and Upadhyay, 1988; Thakur and Sharma, 1992; Shukla, 1994). Shiitake mushroom was artificially cultivated in India on wood logs, artificial medium and saw dusts and corn cobs supplemented with wheat and rice bran (Dhar, 1976; Suman and Seth, 1982; Sohi and Upadhyay, 1988; Thakur and Sharma, 1992). Shukla (1994) firstly reported the cultivation of Shiitake mushroom in India, on oak logs. According to Shukla (1995) indole-3acetic acid treated (with 5 and 10 ppm solutions) logs gave the maximum yield while maximum number of sporophores were formed in indole butyric acid. Kaur and Lakhanpal (1995) reported for the first time in India the cultivation of *L. edodes* on various types of sawdust in polypropylene bags. They found that colonization of the substrate was most rapid in a mixture of sawdust of eucalyptus and poplar (40 days) with highest yield (360 g/kg dry substrate) and with 36 % of biological efficiency. They also found that medium containing dextrose, peptone, thiamine, manganese and gibberellic acid supported the best mycelial growth of *L. edodes*. Puri et al (2011) also observed that ten percent supplementation of wheat bran was the best among all the supplements tried. The wheat straw substrate produced the heaviest and beautiful brown sporocarps with maximum number of fruiting bodies.

Kalberer (1998) investigated the effect of substrate composition on the yield of *L. edodes*. He found that for highest yields, the substrate should contain 20 % corn meal, an additional N source (1% urea or 4% extracted soybean meal) and 2 % calcium carbonate. Aleksandrova *et al.* (1998) observed that wheat grain was best substrate for fruiting body production (upto 7 fruiting bodies per 0.5 litre of substrate). Morais *et al.* (1999) gave a methodology for production of *Lentinus edodes* based on sterilized mixed agro-residues including sawdust, bark, bagasse, cottonseed husks, maize stover and hay/straw etc. as substrate. Zhang *et al.* (1999) raised spawn of *Lentinus edodes* for cultivation on PDA medium and the substrate was a mixture of 70 % deciduous tree sawdust, 20 % bran, 1 % gypsum and 1 % sucrose. Inoculation was done at the end of February, and mushrooms were produced in autumn. They observed that there is a lack of varieties suitable for spring cropping. Some varieties rotted before cropping. Cropping lasted 38-45 days depending on variety. Pacumbaba and Pacumbaba (1999) suggested that basidiocarp production of Shiitake mushroom on amended hardwood sawdust may have excellent economic potential commercially as it takes 1 to 2 years for basidiocarps to appear in Shiitake spawn inoculated logs. Camargo (2000) studied the efficiency of some organic by-products available in Colombia as substrates for Shiitake cultivation. The artificial trunk technique was used, with eucalyptus sawdust and cotton seed hulls, wheat bran was added as nitrogenous supplement at 12, 20 and 28 % (w/w). He found that the highest total and premium quality yields were obtained with sawdust and the 20 % level of bran. Djarwanto and Suprapti (2000) cultivated Shiitake on media made of sawdust of different wood species, including *Hevea brasiliensis, Eucalyptus deglupta, Dyospiros ebenum, Castanopsis argentea, Pithecelebium viringa, Swietenia mahagoni, Ecalyptus urophylla* and *Cananga odorata* enriched with rice bran and seed of *Panicum viridae* as much as 10 % each, and then mixed thoroughly with sufficient distilled water. They found that highest fruit body's weight and BCE were obtained from the sawdust medium of *Hevea brasiliensis* i.e. 201.64 g and 96.27, respectively. Kovacsne and Kovacs (2000) investigated straw as a substrate for Shiitake growing. Heating of straw at 100°C for 45-60 minutes eliminated all unwanted fungal spores. During incubation (20-30 days), air temperature was kept at 18-22°C, substrate temperature at 25°C and relative humidity at approximately 80 %. Straw is suitable as a substrate as long as it is high quality with less than 14 % moisture. Both substrate nutrients and physical texture property aeration are important. Sawdust should not to be smaller than 0.85 mm (Royse and Sanchez, 2000). Zervakis *et al.* (2001) evaluated the mycelium extension rates on seven mushroom cultivation substrates: wheat straw, cotton gin-trash, peanut shells, poplar sawdust, oak sawdust, corn cobs and olive press-cake. They found that wheat straw was the most suitable substrate for *L. edodes.* Curvetto *et al.* (2002) cultivated Shiitake with a simple substrate composition containing 37.5 % milled sunflower (*Helianthus annuus*) seed hulls (SSH), 0.5 % calcium carbonate ($CaCO_3$), 2 % calcium sulphate ($CaSO_4$), and 60 % water and got a daily production rate of 2 kg Shiitake/100 kg dry substrate for 55 days cycle production. Grodzinskaya *et al.* (2002) studied the mycelium growth (spawn) and fruit body production of Shiitake on 20 different substrates from agricultural wastes. They found that *L. edodes* prefers a mixture of rice straw and husk with maize cobs, bagasse from sugarcane, coconut fibres and coffee wastes. The cultivation of *L. edodes* began in 1979 using Quercus logs as substrate, the use of oak sawdust started in 1997 (DeLeon, 2003). Mata and Salmones (2003) evaluated different agricultural and forest by-products as substrates for commercial cultivation of *Lentinula.* Some strains of *L. edodes* have been cultivated on pasteurized non-conventional substrates, such as coffee pulp, sugarcane bagasse, and wheat straw, showing good adaptation to this process. Philippoussis *et al.* (2003) cultivated two strains of *Lentinula edodes* (S4080 and SIEF 0231) on oak-wood sawdust (OS), wheat straw (WS) and corn cobs (CC) substrates. They found that strain SIEF 0231 colonized OS and CC earlier than WS and heavier basidiomata were produced by WS and OS substrate. Royse and Sanchez (2003) cultivated Shiitake on synthetic substrate consisting of oak sawdust (50%), white millet (28%), winter rye (11%) and soft red wheat bran (11%) was non supplemented or supplemented with 0.2, 0.4 or 0.6 % (dry weight basis) precipitated calcium carbonate ($CaCO_3$). They found that supplemented substrate with 0.6 % $CaCO_3$ gave high yields and biological efficiencies whereas mushroom size (weight) was larger with non-supplemented substrate (16.8 g). Silva *et al.* (2005)

cultivated *Lentinula edodes* in eucalyptus residues, supplemented with 5, 10, 15 and 20 % (w/w) of soya, wheat or rice brans. They found that eucalyptus residues supplemented with cereal brans supported fast grown of *L. edodes,* indicating that mycelium extension is related to the bio-availability of nitrogen.

Therapeutic Potentials of *Lentinula edodes*

Chihara *et al.* (1969) isolated from the fruiting bodies of Shiitake a water soluble antitumor polysaccharide which was named '*Lentinan'* after the generic name of this mushroom. This *Lentinan* demonstrated powerful antitumor activity, preventing chemical and viral tumor development in mice and experimental models. According to Sasaki and Takosuka (1976) the most highly researched bioactive molecule isolated from Shiitake is the pure b (la3)-D-glucan lentinan. Lentinan has an antitumour polysaccharide. *L. edodes* also contains adenine and choline, which may prevent the occurrence of cirrhosis of the liver as well as vascular sclerosis. Tyrosinase contained in *L. edodes* tends to lower blood pressure. Two other constituents which have been isolated from *L. edodes* which tend to reduce serum cholesterol are : C6H11O4N5 and C9H11O3N5, namely [2(R), 3(R)-dihydroxy-4-(9-adenyl)-butyric acid 2(R)-hydroxy-4-(9-adenyl)-butyric acid]. According to a Chinese physician of the Ming Dynasty (1368-1644), Wu-Juei, Shiitake preserves health, improves stamina and circulation, cures cold and lowers blood cholesterol (Jong and Birmingham, 1993). Yang *et al.* (1992), Wang *et al.* (1995) and Kobayashi *et al.* (1995) reported that a number of polysaccharides obtained from basidiomycetes, such as *Lentinus edodes* (LPS), *Ganoderma lucidum* (GPS) and *Coriolus versicolar* (CPS), have also been shown produce anti tumor effects, thus being potentially useful in cancer therapy.

Biochemical Make-up of *Lentinula edodes :* approximate composition of *L. edodes* : (Crisan and Sands, 1978)

Component	Percentage by weight
Moisture	90.0-91.8
Crude protein (N × 4.38)	13.4-17.5
Crude fat	4.9-8.0
Carbohydrate	
Total	67.5-78.0
N-free	59.5-70.7
Crude fibre	7.3-8.0
Ash	3.7-7.0
Energy value	387-392

Sous (1980) found that fruiting bodies of Shiitake are rich in K, P and vitamins of B complex, and have anti-viral and cytotoxic properties. Aoyagi *et al.* (1993) cultivated 37 samples of *L. edodes* on logs and 19 samples on sawdust substrates and found that carbohydrate, Ca, Cu, Mn and Hg contents were higher in the fungi cultivated on logs and moisture, protein, ash, K, P and Zn contents were higher in fungi cultivated on sawdust substrates. He found high amounts of moisture, protein, ash, K, P and Zn in *L. edoes* cultivated on sawdust substrates. Seidemann (1993) studied Shiitake cultivation in Japan based on various wood substrates and artificial nutrient media. He found that the fruiting body contains cyclic polysulphides which, together with other volatiles were mainly responsible for the odour, and guanosine-5-monophate for taste. Another constituent, *Lentinan*, a heavily branched (1< right arrow >3)-glucan had pharmacological properties. Vetter (1995) observed that the amino acid concentrations in *L. edodes* were 15.24 % in caps and 11.35 % in stipes. Longvah and Deosthale (1998) found that essential amino acid contents of *L. edodes* were 39 %. Yuang *et al.* (2001) extracted a crude polysaccharide (Le) from the fruiting body of *L. edodes* with molecular weight from 14000-954000. The glucuronic acid and protein contents (%) of the 3 fractions were 24.10 and 2.01, 34.77 and 7.38, 40.05 and 25.31 in Le-1, Le-2 and Le-3. Mattila *et al.* (2002) observed the variation in dry matter contents of mushrooms varied from 7.7 to 8.4 %. The dry matter of Shiitake mushrooms contained large amounts of carbohydrates i.e. 5.8 g/100 g fresh weight. *L. edodes* proved to be an especially good source of dietary fibres (3.3 g/100 g fresh weight). They also found that crude fat, ash and protein contents of the mushrooms varied from 0.31-2.09 g/100 g fresh weight.

CONCLUSION

Commercial production of Shiitake mushrooms is largely determined by the availability and utilization of cheap materials of which agricultural lingo-cellulosic waste represents the ideal and most promising substrates for cultivation. There are several studies suggested the production of *L. edodes* using teak sawdust, wheat straw and poplar sawdust, wheat straw and teak sawdust and poplar and teak sawdust as substrate. This review thus compiled various research works conducted in different parts of the world and explore the possibilities for the cultivation of *L. edodes* using largely available agro-industrial wastes. The substrates used in various studies for shiitake production can be considered practical and economically feasible due to their availability throughout the year at little or in large quantities with minimal cost. The biological conversion of different agriculture wastes by *L.edodes* into high protein diet not only reduces waste disposal problem but also utilizes them into the ecology.

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