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Edible Mushroom:Boon to human health and nutrition

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Edible mushrooms have long been known to be easily cultivable, affordable, protein rich food and has been referred to as poor man's meat. The most common mushrooms cultivated for edible purposes are *Agaricus bisporus*, different species of *Pleurotus*,*Lentinus* sp., *Volvariella* sp., *Calocybe indica* and some more. It is now known that besides being high in proteins, they are also good source of other nutrients and dietary fibres. They also have several medicinal and therapeutic properties such as high antioxidants, antimicrobials, anti-inflammatory, antitumor, anticancer and many others. Thus, it is indeed nature's boon to human kind where so many beneficial traits are found to occur in a single group of organism. Besides, the compost remaining after mushroom cultivation is a good biofertilizer since it still contains a number of partially biodegraded nutrients which can be used for crop improvement.

Key words: *Agaricus bisporus*, *Calocybe indica*, *Pleurotus* sp.,*Volvariella* sp., *Lentinus* sp., antioxidant. anticancer

INTRODUCTION

Mushrooms are a widely distributed food resource on earth and have been consumed because of their nutritional value and medicinal properties for over 2000 years. Besides their enjoyable flavor and taste, human health was improved by mushrooms due to their nutrients, including digestible proteins, carbohydrates, fiber, vitamins, minerals, and antioxidants (Acharya *et al.* 2017, Zhang *et al*. 2016). A wide variety of bioactive compounds from medicinal mushrooms, which are widely used in eastern Asia, have been studied extensively, and these compounds including polysaccharides, lectins, lactones, terpenoids, and alkaloids have been reviewed (Rahi and Malik, 2016; Toledo *et al*. 2016). Nagy *et al*. (2017) reviewed bioactive mushroom polysaccharide composition and their synthesis and function. Besides their pharmacological features, mushrooms are becoming more important in our diet due to their nutritional value, high protein and low fat/energy contents. The mushroom protein contains all the nine essential amino acids required by humans. In addition to their good protein content, mushrooms are a relatively good source of the other nutrients like phosphorus, iron and vitamins, including thiamine, riboflavin, ascorbic acid, ergosterol, and niacin. Mushrooms are the sources of bioactive substances such as secondary metabolites (organic acids, terpenoids, polyphenols, sesquiterpenes, alkaloids, lactones, sterols, metal chelating agents, nucleotide analogs and vitamins) glycoproteins and polysaccharides, mainly 1, 2-glucans. Due to the presence of biologically active compounds of medicinal value they are used as anticancer, antiviral, hepatoprotective, immunopotentiating and hypocholesterolemic agents. Present review is aimed to discuss the high nutritional and therapeutic potential of mushrooms and their applications as functional foods or as a source of nutraceuticals for maintenance and promotion of health and life quality.

EDIBLE MUSHROOM PRODUCTION

Pleurotus species, commonly known as oyster mushrooms, are edible fungi cultivated worldwide especially in south East Asia, India, Europe and Africa. *P. ostreatus* has been reported to bethe second most cultivated mushroom species next to *A. bisporus* in the world market (Sanchez, 2010). Mushroom cultivation is the fifth largest

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Table1. Contribution of states in mushroom production in India

States	Production (tons per year)				
	Button	Oyster	Milky	Others	Total production
Andhra Pradesh	2,992	15	15	0	3,022
Arunachal Pradesh	20	5	0	1	26
Assam	20	100	5	0	125
Bihar	400	80	0	0	480
Chattishgarh	0	50	0	0	50
Goa	500	20	0	0	520
Gujrat	0	5	0	0	5
Haryana	7,175	0	3	0	7,178
Himachal Pradesh	5,864	110	17	2	5,993
J&K	565	15	0	0	580
Jharkhand	200	20	0	0	220
Karnataka	0	15	10	0	25
Kerala	0	500	300	0	800
Maharashtra	2,725	200	50	0	2,975
Madhya Pradesh	10	5	0	0	15
Manipur	0	10	0	10	60
Meghalaya	25	2	0	0	27
Mizoram	0	50	0	0	50
Nagaland	0	75	0	250	325
Orissa	36	810	0	5,000	5,846
Punjab	58,000	2,000	0	0	60,000
Rajasthan	100	10	0	10	120
Sikim	1	2	0	0	3
Tamil Nadu	4,000	2,000	500	0	6,500
Tripura	0	100	0	0	100
Uttarakhand	8,000	0	0	0	8,000
Uttar Pradesh	7,000	0	0	0	7,000
West Bengal	50	50	0	0	100
Union Teriitories					
Andaman-Nikobar Islands	0	100	0	0	100
Chandigarh	0	0	0	0	0
Dadar&Nagar Haveli	0	0	0	0	0
Daman & Diu	0	0	0	0	0
Delhi	3,000	50	20	0	3,070
Lakshadweep	0	0	0	0	0
Pondicerry	0	0	0	0	0

Source: Mushrooms Cultivation, Marketing and Consumption, Directorate of Mushroom Research (Indian Council of Agricultural Research) Chambaghat, Solan-173213 (HP)

Table 2. Nutritive values of different mushrooms (dry weight basis g/100g)

Mushroom	Carbohydrate	Fibre	Protein	Fat	Ash	Energy k cal
Agaricus bisporus	46.17	20.90	33.48	3.10	5.70	499
Pleurotus sajor-caju	63.40	48.60	19.23	2.70	6.32	412
Lentinula edodes	47.60	28.80	32.93	3.73	5.20	387
Pleurotus ostreatus	57.60	8.70	30.40	2.20	9.80	265
Volvariella volvaceae	54.80	5.50	37.50	2.60	1.10	305
Calocybe indica	64.26	3.40	17.69	4.10	7.43	391
Flammulina velutipes	73.10	3.70	17.60	1.90	7.40	378
Auricularia auricula	82.80	19.80	4.20	8.30	4.70	351

agricultural sector in China (Zhang *et al.*; 2014). Among the numerous species of mushroom, oyster mushrooms have more advantages over other mushrooms in terms of ease of cultivation, role in biodegradation and bio-remediation, extracellular enzymes production and neutraceuticals

Table 3. Essential amino acid composition of some edible mushrooms

Mushroom species	Valine	Leucine	Isoleucine	Threonine	Methionine	Lysine	Phenyl alanine	Tryptophan
Agaricus bisporus	2.5	7.5	4.5	5.5	0.9	0.1	4.2	2.0
Lentinus edodes	3.7	7.9	4.9	5.9	1.9	3.9	5.9	Nd
Pleurotus florida	6.9	7.5	5.2	6.1	3.0	9.9	3.5	1.1
Volvariella diplasia	9.7	5.0	7.8	6.0	1.2	6.1	7.0	1.5
V. volvacea	5.4	4.5	3.4	3.5	1.1	7.1	2.6	1.5
P. ostreatus	0.91	1.1	0.62	1.10	0.28	0.71	0.73	0.15
P. sajor-caju	0.98	1.3	0.75	0.98	0.34	0.78	0.86	0.09

Note. Values are expressed on dry weight basis (µg/100g of sample)
Nd- not determined.

Table 4. Source, type, and bioactivity of some polysaccharides isolated from different edible mushrooms

Mushrooms	Polysaccharide source	Type of polysaccharide	Bioactivity
Pleurotus tuber-regium	Sclerotium, mycelium	Beta-glucan	Hepatoprotective and anti-breast cancer
Ganoderma lucidum	Fruit body, culture broth	Heteroglycan, Mannoglucan, Glycopeptides	Hyperglycemia, Immunomodulating, antitumor, antidecrepitude
Lentinus edodes	Culture broth, fruiting body	Mannoglucan, polysaccharide-protein complex, glucan, lentinan	Immunomodulating, antitumor, antiviral
Agaricus blazei	Fruit body, mycelium	Glucan, Heteroglycan, glucan protein, Glucomannan-protein complex	Antitumor
Ganoderma applanatum	Fruit body	Glucan	Antitumor
Polyporus umbellatus	Mycelium	glucan	Antitumor, immunomodulating
Pleurotus citrinopileatus	Fruit body	galactomannan	Antitumor
Pleurotus ostreatus		Glycoprotein	Antitumor, hyperglycemia, antioxidant
Volvariella sp	Fruit body,	Polysaccharides	Cardiac tonic
Trametes coriolus	Fruit body, mycelium	Polysaccharide, PSP - a glycopeptides	Antitumor and Immunostimulant
Tricholomopsis rutilans	Fruit body, mycelium	Polysaccharides	Anticarcinogenic activity Antioxidative and anti inflammatory
Morchella esculenta	Fruit body	Heteroglycan	Hyperglycemia, antitumor
Tricholoma mongolium	Fruit body	Glucan	Antitumor activity

production (Rashad *et al*. 2009).Although edible mushrooms represent an important agricultural product worldwide, only a few of them (*Agaricus*, *Lentinula*, *Pleurotus*, *Auricularia*, *Volvariella*, *Flammulina*, *Tremella* and a few others) can be cultivated. The most significant progress in mushroom cultivation occurred in France in the seventeenth century when *A. bisporus* was grown in a composted substrate. The cultivation process of *A. bisporus* is complex but highly efficient with up to 9 crops per year at modern mushroom farms, resulting in an annual crop value of about $4.7 billion worldwide (Sonnenberg *et al.,* 2011). China, the United States and the Netherlands are

Table 5. Therapeutic metabolites of different edible mushrooms and their bioactivity

Mushrooms	Compounds	Medicinal properties
Ganoderma lucidum	Triterpenes	Active against HIV
	Ganoderiol F	Cytotoxic to hepatoma cells,
	Ganodermanontriol	protection against atherosclerosis,
	Ganodermadiol	Hypoglycemic effect
	Ganopoly	Antitumor activity
	Ganoderon B	Augments immuno-system,
	Glycoprotein	antitumor activity, Liver protection, Antibiotic properties,
	Ganoderic acid B	Inhibit cholesterol sysnthesis
	Beta-glucans	
Ganoderma frondosa	Polysachharides	Increase insulin secretion
	Lectins	Decrease blood glucose
Lentinula edodes	Eritadenine (derivative of nucleotide)	Antilipidemic activity
	Lentinan	Anticancer agent
		Antibacterial activity
	Oxalic acid present on caps	Inhibits sarcoma 180 and HIV induced cytopathic effect
	Emitanin	Used in tumor/ chemo/ radiotherapy/surgery Anti HIV activity
	Soluble lignin	
Agaricus bisporus	Lectins	Enhance insulin secretion
		Immunomodulatory
		Anti-carcinogenic and
	Conjugated linoleic acid	anti-mutagenic activity
		Anti-proliferative activity
		Antioxidant activity
		Tumor-suppressive activity
Agaricus brasiliensis	L-ergothionene	Antioxidant activity
Calocybe indica	Glucan	Antiinflamatory activity
P. pulmonarius	Saponins	Antiinflamatory activity
Pleurotus florida	Glucan	Antiinflamatory activity
	Pleuran	
P. Sajor-caju	Lovastatine	Lower cholesterol
	Proteins having polysaccharide xyloglucan, xyloproteins	Antitumor activity
Pleurotus ostreatus	Aqueous Polysaccharides	Induces anti-proliferative and proapoptotic effects on colon cancer cells
	Polyphenols	Antioxidant activity
	Ubiquitine	Anti-viral activity
	Glucan	
	Pleuran	
		Antiinflamatory activity
	Ribonucleases	
	Lovastatine	Neutralize HIV by degrading genetic materiall
		Artherosclerotic activity
P. citrinopileatus	Homodimeric Lectin	Anti-tumor activity
P. tuber-regium	Water soluble Polysaccharides	Anti-proliferative activity
Pleurotus flabellatus	Phenolics	Antioxidant activity
	Lycopene, alpha-tocopherol and L-ergothionene	
Auricularia auricula	Acidic Polysachharides	Decrease blood glucose
Flammulina velutipes	Ergothioneine	Antioxidants
	Proflamin	Anticancers activity
	Velutin protein	Antitumor, antifungal and anti
	Enokipodins	bacterial activity
	Sesquiterpenes	
Trametes versicola	Polisachharide-k (kresin)	Decrease Immuno-system depression
Cordyceps sinensis	Cordycepin	Cure lung infections,Hypoglycemic activity, Cellular health properties,Antidepressant activity
	Adenosine, ergosterol	Antioxidative property
Pleurotus tuber-regium	Water insoluble Glucans	Antiviral activity
Auricularia polytricha	Antiplatetet compound	Artherosclerotic activity
	Adenosine	

the largest mushroom producers in the world and a large part of the produced mushrooms is exported. According to State Department of Agriculture/Horticulture, in India, in seventies and eighties button mushroom was grown as a seasonal crop in the hills, but with development of technologies increased understanding of the cropping systems, and mushroom production shot up from mere 5000 ton in 1990 to 1, 00,000 ton in 2006. The appropriate production based on the report is as given in Table1. In India the total production of mushroom is about 1,13, 315 tons (Wakchaure *et al*. 2013), of which 80 % share goes to button mushroom, while the rest of the 20% goes to other tropical mushroom such as oyster, paddy straw mushroom, milky mushroom. In India, at present, four mushroom species-*A.bisporus*, *Pleurotus sp*, *Volvariella spp.* and *Calocybe indica* have been recommended for year round cultivation. The Indian subcontinent is known worldwide for its varied agro climatic zones with a variety of habitats that favour rich mushroom biodiversity (Thakur *et al*. 2011).

Agaricus bisporus (Lange) Imbach is the most widely cultivated edible mushroom and presents more than 40% of world mushroom production followed by *Lentinula edodes, Pleurotus* sp and *Flammulina velutipes* (Mostafa and Ali, 2014; Sharma and Gautam, 2016).It has delicious taste, high nutritional value, high aroma or flavoring taste and is used as a food and in food industries.This mushroom also has high biological activity, low toxicity and is used in folk classical medicines, flavouring of food products, perfume, cosmetics and pharmaceutical industries, as defoaming agents and to improve the shelf life and safety of minimally processed fruits

ANTIMICROBIAL PROPERTIES

Inhibitory activity of methanolic extract of *Pleurotus sp* against *Bacillus megaterium, Staphylococcus aureus, Escherchia coli,Klebseilla pneumonia, Candida albicans,C. glabrata*, species of *Trichophyton* and *Epidermophyton w*as demonstrated to different degrees that were lower with respect to two antifungal agents' streptomycin and Nystatin (Akyuz *et al.* 2010). Ether and acetone extracts of oyster mushroom were effective against *B. subtilis*, *E. coli, Saccharomyces cerevisiae* and *Pseudomonas aeruginosa* (Nithya and Raghunathan,2009; Parashare *et al. 2013*). Extract of *A. bisporus* was shown to have antibacterial activity against a wide range of pathogenic bacteria as well as fungi (Sharareh and Hamit, 2016,Waithaka *et al*. 2017).

ANTI-TUMOR ACTIVITY

It is reported that an aqueous polysaccharide, extracted from *P. ostreatus* induces anti-proliferative and pro-apoptotic effects on colon cancer cells. The water soluble polysaccharide from *P. ostreatus* was considered as a potential candidate for developing a novel low-toxicity anti-tumor agent (Maiti *et al*. 2011). Li *et al.,* (2008a) isolated a homodimeric lectin from fresh fruiting bodies of *P. citrinopileatus* and reported as considered as potent anti-tumor activity in mice bearing sarcoma. *In vitro* anti-proliferative activities of the water soluble polysaccharides extracted from fruit body and mycelium of *Pleurotus tuber-regium* where fruit body extract showed the strongest cytotoxicity and anti-proliferative activity. Immunomodulatory, anticarcinogenic and anti-mutagenic properties of *Agaricus* sp have been reported. Lectin from *Agaricus bisporus* and *Agaricus polytrica* protein are stable immuno-stimulants (Chang *et al.* 2010). Kim *et al.,* (2014) reported that the extract from *Agaricus* sp showed the most potent tumor selective growth inhibitory activity against human leukemia. Adams(2014) evaluated the effect of *A. bisporus* extract *in vivo* and its major component conjugated linoleic acid on prostate cancer cell lines *in vitro* and reported that the extracted linoleic acid inhibited proliferation in the prostate cancer cell lines *in vitro.*

Antioxidant activity

The antioxidant activity of *Agaricus bisporus* was determined by means of DPPH and TCA, and H_2O_2 assay (Waithaka *et al*. 2017). High phenolics and flavonoid content in *Pleurotus flabellatus* have been detected by Pumtes *et al.* (2016), which have an impact on antioxidant activity. The high phenolic compounds of mushrooms are normally well correlated with antioxidant activity. The main phenolics in mushrooms are- phenolic acids, gallic acids, caffeic acid, quercetin, flavonoids and tannins, in which the phenolic hydrogen is a major contributor to antioxidant activity (Siu *et al.* 2014; Jiang *et al*. 2015). Besides, ascorbic acids, beta-carotene, Lycopene, alpha-tocopherol and L-ergothionene are also some of the main compounds with antioxidant effect in mushrooms (Vamanu, 2013). Adhiraj *et al.* (2014) reported

P.flabellatus can be a potential source of natural antioxidant to treat various oxidative stress related diseases. Antioxidant activity of *Agaricus bisporus* and *Agaricus brasiliensis* was determined by Gan *et al.* (2013).However Gil-Ramirez *et al.,* (2016) reported that the mushrooms do not contain flavonoids and those found in the hyphae could be due to the facility of these organisms to absorb many nutrients and compounds from the substrate where they grow or from neighboring plants by spreading their hyphae. All water and methanolic extracts of *Pleurotus ostreatus* possess phenolics compound and flavonoid and they suggested that the antioxidant activity could not be by poly phenol. The antioxidant activity may be as a result of the presence of others molecules which are present in the extract (Ivette and Hector,2016). They also investigated the antioxidant properties of aqueous and 95% ethanol extracts of two species of fungi, *Pleurotus ostreatus* and *P. sajor-caju*, obtained from a local farm in Thailand. The aqueous extracts showed the highest amount of total polyphenols and better antioxidant activity than ethanol extracts for both fungi. Kim *et al.,* (2014) investigated the antioxidant activity and the total polyphenol amount, of methanol extracts of mycelium and fruiting body of *P. sajor-caju*, *P. ostreatus* and *P. sapidus*. The polyphenolic compounds with antioxidant activity are multifunctional and act according to the majority of these mechanisms. Furthermore, it is known that the antioxidant properties depend on the type of solvent used in the extraction and complexity of compounds, since must involve different methods to determine their antioxidant activity. Fruiting bodies of *Pleurotus* possessed higher concentration of antioxidants than other commercial mushrooms. Oyster mushrooms are now widely used as ingredients in dietary supplements in the hope of maintaining health and preventing diseases due to their higher free radical scavenging activities. Fruiting bodies of oyster mushrooms have higher phenol concentration when compared with mycelium and fermentation broth filtrate of *P. citrinopileatus*.

ANTI-INFLAMATORY ACTIVITY

Pleuran, isolated from fruiting bodies of oyster mushroom possesses anti-inflammatory activity. Extracts of *P. florida, P. pulmonarius* give a lowering response in both acute as well as in chronic inflammation. Nozaki-Taguchi *et al.* (2008) reported that glycosphingo-lipid isolated from *P. eryngii*, induced secretion of IFN-g and IL-4 from T-cells, whereas (1-3), (1-6)-linked-glucan isolated from *P. ostreatus* inhibited leukocyte migration to acetic acid-injured tissues. Recently a nonlectin glycoprotein isolated by Chen *et al.* (2011) from fresh fruiting body of *P. citrinopileatus* down-regulated the pro-inflammatory mediators. In their experiments they also observed anti-inflammatory activity of oyster mushroomthat was mediated through the inhibition of NF-kB and AP-1 signalling. Another potent anti-inflammatory agent, a polysaccharide has been extracted from the *P. pulmonarius* which acted against carrageenan and formalin-induced paw edema in rats (Adebayo *et al.* 2014). Tannin and terpenes detected in the mushroom have been found to possess astringent properties, which hasten the healing of wounds and inflamed mucous membrane . *C. indica* extract inhibited proteinase trypsin and display the most potent inhibitory activity of proteinases as reported by Prabu and Kumudakalavalli (2014). It was reported that methanolic extracts of *Pleurotus pulmonarius* and *Pleurotus florida*cause decrease of induced paw edema and ameliorated acute inflammation in mice. Selvi *et al*. (2011) studied that the aqueous and ethanolic extracts of *C. indica* for its antilipid-peroxidative activity through *in vitro* model of goat.

ANTIVIRAL ACTIVITY

Pleurotus mushroom contain substances that exert direct or indirect antiviral effects as a result of immuno-stimulatory activity. Ubiquitin, an anti-viral protein was isolated and identified from fruiting body of oyster mushroom. Not only intracellular proteins of *P. ostreatus* but its extracellular extract also contains polysaccharides that have Immuno-modulating effects.

ANTI-AGEING ACTIVITY

Extracts of *P. abalonus and P. ostreatus* elevated levels of vitamin C and E, increased activities of catalase, superoxide dismutase and glutathione peroxidase in aged rats (Jayakumar *et al*. 2009). Different extracts (methanol, ethanol, acetone or water extract) of *Pleurotus* can improve the antioxidant status during ageing, leading to the reduction of age-associated disorders like stroke, Parkinson's disease, atherosclerosis, diabetes, cancer and cirrhosis. The polysaccharides from mushrooms are potent scavengers of super oxide

free radicals. This antioxidant prevents the action of free radicals and consequently reducing the ageing process.

Hepatoprotective activity

Chen *et al*., (2014) reported the hepato-preventive and therapeutic activity of hot-water extract of mushrooms by mechanism of inhibition through preventive regimen causing less leakage of alkaline phosphate, less pronounced increase in hepatic malodialdehyde concentration, less notable reduction in hepatic total protein, RNA and DNA contents and in contrast increased hepatic superoxide dismutase, glutathione reductase and glutathione peroxidase activities. Polysaccharides extracted from fruit body of *P. ostreatus* alleviated the thioacitamide-induced alterations, inflammation, steatosis necrosis and fibrosis in the therapeutic regimen as reported by Chen *et al*. (2014). They also observed that water soluble polysaccharides extracted from *P. eryngii* removes the free radicals and also increase the activity of the antioxidant enzyme in liver injury mouse model.

ANTI HIV PROPERTIES

Ribonucleases have been isolated and characterized from the *P. ostreatus* that has the potentiality to neutralize HIV through degradation of viral genetic material (Wang *et al*. 2012). Oyster mushrooms have been reported to have a nopvel ubiquitin-like protein having HIV-reverse transcriptase inhibitory activity . Similarly hot water extracts of *P. sajor-caju* and *P. pulmonarius* inhibit HIV-1 reverse transcriptase activity by SU2 . A Lectin isolated from fresh fruiting bodies of *P. citrinopileatus* also inhibited HIV-1 reverse transcriptase (Li *et al.* 2008).

ANTI-MUTAGENIC ACTIVITY

Extracts of 89 different mushrooms species were tested for their antigenotoxic and bio-antimutagenic activities on *S. typhimurium* and *E. coli*. Methanolic extracts of *P. ostreatus* showed significant inhibition of mutagenicity elicited through mutagens requiring activation (Lopez *et al*. 2016). Dried *P. ostreatus*, in diet, reduced pathological changes in dimethylhydrazine-induced colon cancer, in rats. Furthermore, extracts of *P. cornucopiae* significantly reduced $HO^{\cdot}$ induced DNA damage in Chinese hamster lung cells and *P. ostreatus* extract mitigated genotoxicity through suppression of DNA damage induced by different mutagens in the *Drosophila DNA* repair test. *P. citrinopileatus* fruiting body extracts have shown antioxidant activities *in vitro* and in hyperlipidemic hamster rats.

POTENTIAL HYPOCHOLESTEROLEMIC ACTIVITY

The World Health Organization estimated that 17.3 million lives were lost in 2008 and an expected 23.6 million people will die of cardiovascular diseases by the year 2030. About 80% of mortality rates were reported from the lower and middle income countries. The treatment of hypercholesterolemia is targeted by decreasing the low density lipoprotein by medications. A wide variety of biological active compounds are produced by fungi (De Silva *et al*. 2013) including statins (anti-cholesterol compounds). Lovastatin is an interesting fungal metabolite. It functions as a competitive inhibitor of the enzyme, 3-hydroxy-3methyl-glutaryl enzyme in cholesterol biosynthesis. HMG Co-A reductase is an important enzyme in the process of converting HMG CoA to mevalonate. Mushroom fruiting bodies or their extracts might be considered as a new source of compounds with potential hypocholesterolemic activity because they are rich in ergosterol-derivatives, α-glucans and HMGCoA-red inhibitors. The presence of lovastatin in the mushrooms*Pleurotus ostreatus, P. saca and P. sapidus* was confirmed by Dhar *et al.* (2015). *Agaricus campestris, C. indica, Ganoderma applanatum* and *Tricholoma giganteum* also prooduced lovastatin (Pushpa *et al.* 2016). The presence of lovastatin in *Pleurotus* has been reported by Mowsumi and Chowdhury (2013). Chowdhury *et al.* (2015) reported that the intake of *P. ostreatus* improves glycemic status and effective in controlling blood pressure in diabetic hypertensive subject

PRE-BIOTICS

The balance of intestinal flora is crucial for human health and disease prevention. In this context, prebiotics are the most promising health foods because they can regulate the structure and number of intestinal flora. Mushrooms (*P. ostreatus* and *L. edodes*) can significantly modify intestinal flora composition by promoting the metabolismandproliferation of beneficial microorganisms suchas *Lactobacilli* and *Bifido-*

bacteria, as well as by inhibiting pathogenic bacteria such as *E coli*, *Clostridium* and *Salmonella* (Zhou *et al.* 2011). The major components rendering prebiotics function in mushroom are non-digestible polysaccharides such as glucan, chitin and hetropolysaccharides. Mushrooms also prevent viral infection by enhancing the growth of probiotic bacteria in the large intestine (Villares *et al.* 2012). Several mushroom polysaccharides likepleuran, lentinan, schizophyllan, â and á-glucans, mannans, xylans, galactans, chitin, inulin and hemi-celluloses can be credited to promising prebiotics effects. Pleuran from *P. ostreatus* and lentinan from *Lentinus edodes* mushrooms are currently the most frequently used â-glucans as prebiotics. Both of them show positive effects on the intestines. They increase the resistance of intestinal mucosa to inflammation and inhibit the development of intestinal ulcers in rats Lentinan also shows a positive effect on peristalsis in weaned piglets.

SPENT MUSHROOM COMPOST AS SOIL CONDITIONER AND ORGANIC FERTILIZER

The use of organic manure such as spent mushroom substrate (SMS)or spent mushroom compost (SMC) in growing agricultural crops especially leafy vegetables has been recognised as a possible means of enhancing sustainable agriculture or sustainable production of food crops (Okokon *et al.* 2009). Jonathan *et al.* (2011) used SMC of *Pleurotus pulmonarius* as possible organic fertilizer for the improvement of growth of vegetables in Nigeria.Addition of leached SMC to growing media significantly improved the cucumber plants growth as recorded by Gonani *et al.* (2011). Jonathan *et al.,* (2012) also considered SMC as remnant substrate of mushroom cultivation for biodegradation of agricultural wastes (rice straw and sorghum stalk) into substrates of utilizable products.Tuhy *et al.* (2015) obtained healthy effect when They conducted an experiment on tomato plants. SMS contribute significantly to the number of branch, number of leaves in the vegetables depending on the rate of application (Saalu *et al.* 2010; Roy *et al.* 2015). According to Akanbi *et al.,* (2015) organic fertilizer improved cell activity, enhance cell multiplication and enlargement of fluted pumpkin. Organic manure is known to be capable of activating diverse microorganisms which release hormones like substances that stimulate nutrient absorption and plant growth. Spent mushroom compost is rich in organic matter and constitutes an important source of macro-micro nutrients for plants and microorganisms thereby increase the soil micro flora, soil biological activity and enhance soil enzyme activity. It contains calcium carbonate which provides short term buffering of the acidic water and elevates soil pH. The SMC is able to bind mineral particles together promoting a good soil structure and improving aeration and moisture retention. SMC could be applied greenhouse soil at agronomic rates without heavy metal and salinity defects. Use of SMC reduces the quantity of biodegradable waste disposed in landfill sites and also transforms them into economical useful agricultural product. The significant influence of SMS on the yield of Telfaira revealed that SMS can be used as soil amendment to promote the yield of crop (Dauda *et al.* 2008). Applications of SMS of *Pleurotus ostreatus* have a direct effect on the growth and yield of *T. occidentialis* (Orluchukwu *et al*. 2016).SMS also effect on nutritional constituents of vegetables fruits (Priadi *et al.* 2016). Their study also showed that growing media containing SMS is the best to improve seedlings growth.SMS of *Calocybe indica* has direct effect on growth parameters of leafy vegetables (Barman *et al.* 2017). Thus, the management of spent mushroom substrate (SMS) and spent mushroom compost (SMC) as soil conditioner in the agricultural field can be very effective for improvement of crop health status.

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