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Mushrooms in Service of the Society and the Environment

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ABSTRACT

Mushrooms are cosmopolitan and epigeous or even hypogeous. They produce varied morphological forms which grow either solitary or scattered to gregarious or in cespitose clusters on variety of substrates and some may even form fairy rings as well. Ecological parameters such as soil type, pH, relative humidity, temperature, altitude, association with trees, specificity, geographical coordinates, etc., play a determinate role in mushroom growth, phenology and their distribution. These are categorized as minor forest products having number of applications as for their utility in human welfare is concerned. Besides their nutritional and nutraceutical importance, they are a source of revenue and provide opportunities for the entrepreneurs to venture into the area of cultivation of nutritionally and medicinally important mushrooms and explore opportunities in value addition as a source of revenue generation. *Agaricus bisporus*, *Lentinula edodes*, *Pleurotus* spp., *Volvariella volvacea*, *Calocybe indica* are some such mushrooms which are being cultivated on commercial scale and are in use for value addition as well. There are number of them including *Cordyceps militaris*, *C. sinensis*, *Morchella esculenta*, *Termitomyces heimii*, *Coprinus comatus*, *Podaxis pistillaris*, *Phellorinia inquinens*, etc., which are collected from the wild and sold in the local markets for earning extra revenue or even dried for use in the off season. Mushrooms have been in use since times immemorial as folk medicine. Many of these including *Cordyceps militaris*, *C. sinensis*, *Grifola frondosa*, *Tramates versicolor*, *Gandoderma lucidum*, *Psilocybe mexicana*, etc., are important source of bioactive molecules having applications in therapeutics. Many of the mushrooms are saprophytic which play an important role in recycling the organic wastes and some are mycorrhizal, which help in improving the health of the plants by forming mutualistic association. Other important aspects where mushroom mycelia and their sporophores have found applications include bioremediation, mycofiltration, as objects of beauty and mystique, in the synthesis of building and packaging material, in the preparation of cosmeceuticals or nutricosmetics and as a source of natural colors. Because of such wide range of applications mushrooms are referred as special creation of God.

Keywords: Mushrooms, Nutritional, Nutraceutical, Bioactive compounds, Mycorrhizal, Lectins, Nanoparticle, Bioremediation, Biotransformation, Mycofiltration, Biocomposite.

INTRODUCTION

Mushrooms are the macrofungal sporophores of Ascomycetous and Basidiomycetous fungi which grow subterranean or epiterranean from the underground mycelium (Chang and Miles, 2004). These inhabit variety of ecological niches such as ground or soil (terrestrial), living plants or logs (lignicolous), decaying leaf litter (humicolous), foliage (folicolous), animal dung (coprophilous), in symbiotic association with plant roots (mycorrhizal) and on insects (entomogenous) or even parasitic. Many of them are edible, inedible, curative, poisonous, decorative, and even magical and mysterious.

In Chapter 2 of the fifth edition of RBG Kew's State of the World's Plants and Fungi, approximately 2.5 million fungi are estimated to be present on earth, out of these only 10% are known and about 90% fungal species still remains unknown to science. The updated estimate confirms fungi as the second only to invertebrates with regard to species diversity. The rate at which the scientists are naming fungi, it is estimated to take 750-1000 years to fully describe the World's fungi (Antonell, 2023; Niskanen, *et al.*, 2023). The number of mushrooms expected to be growing on the earth are reported to range between 1,50,000 to 1,60,000 species, out of which approximately 16000 mushroom species have been described (Cunha Zied and Pardo-Giménez, 2017). About 7000 mushroom species are reported to possess varying degree of edibility. More than 3000 species spread over 31 genera are regarded as prime edible and table delicacy because of their aroma, good taste, acceptable flavour, texture and digestibility. So far from India, 70 mushroom genera spread over about 300 edible species are documented. Out of these, about 80 mushrooms have been grown experimentally, 20 cultivated commercially and 4-5 species are being produced on large scale (Chadha and Sharma, 1995).

Mushrooms as a source of food and medicine have found mention in inscriptions, and scriptures of Mein, Mesopotamian, Egyptian, Aryan and Chinese civilization. Greeks believed them to give strength to the warriors, while Romans regarded them as food for God. Chinese referred mushrooms as the "Elixir of Life" (Chang and Buswell, 1996). Mushrooms were worshiped (mycolatry) and consumed (mycophagy) as hallucinogens by the Mexican Indians. Somrus / Soma, mentioned in the Hindu Rigveda is said to be the extract of *Amanita muscaria*, commonly referred as Fly Agaric (Wasson, 1968). Thus, there are number of evidence to support centuries of observations regarding nutritional and medicinal benefits of mushrooms (Chang, 2007). These were investigated by the nutritionist after the Second World War, when food shortage became very severe, and a need was felt to look for alternative sources of food. At the same time, increased awareness of people about their nutritional and medicinal values has stimulated their consumption and research on this minor non-timber forest products.Mushrooms contain high quality proteins, dietary fibres, vitamins, minerals and many essential amino acids and hence are important source of quality food (Barros *et al*., 2008; Kalač, 2009).To popularize and inculcate confidence in public for mushroom eating, their nutritional labeling has been made mandatory in many countries to exhibit the key nutrients present in the mushrooms so that interested persons can make a choice in accordance with their dietary requirements. There are a number of medicinally and nutraceutically important constituents present in mushrooms which provide solution against variety of ailments (Cheung, 1998). Many of these contain immunopotentiating polysaccachrides and hence can help to improve the diminishing quality of health. In the era of healthy eating, mushrooms serve as the best alternative food source especially for persons suffering from diabetes, obesity, hypertension, hypercholesterolemia, cancer, AIDS, atherosclerosis (heart ailments), etc. (Chioza and Ohga, 2014; Wasser and Weis, 1999; Lindequist *et al*., 2005).

Mushrooms play an important role in the bioconversion of organic residue, bioremediation, and microfiltration and hence act as nature's scavengers and replenishers. By forming mycorrhizal association, mushrooms form Wood Wide Web (WWW) and hence play a pivotal role in ecosystem maintenance and sustenance. Being a cash crop for marginal families as a side avocation, mushrooms have become important additional source of income and employment. This venture helps to generate direct and indirect income and employment opportunities in the areas of cultivation, marketing, processing business, value addition, etc. Being a cottage scale venture for rural areas, it helps in the economic upliftment of small and marginal farmers, landless labourers, women, and unemployed educated youth.

MUSHROOMS AS A SOURCE OF QUALITY FOOD

Sporophores of about 200 mushrooms either in fresh form or in preserved form are treated as delicacy because of their excellent culinary credentials. Mushrooms being nutritious and medicinal are now categorized as functional foods/ health foods (Srivastava *et al*., 2019).

Commercially cultivated mushrooms: There are over 20 cultivated species of mushrooms, out of which 4-5 mushrooms including *Agaricus bisporus* (White Button mushroom) are being cultivated at commercial level (Srivastava *et al.*, 2019). In overall production, different strains of *A. bisporus* occupy the dominating position followed by *Lentinula edodes* (Shiitake) and *Pleurotus* spp. (Dhingri/ Oyster mushroom). Presently, total world production of mushrooms is nearly 38 million tons, with China being the leading producer (33 million tons). As compared, India produces only small amount (1.55 lakh tons) annually (Srivastava *et al*., 2019). Out of the total mushroom production in India, *Agaricus bisporus* accounts for about 73% of the share whereas contribution of oyster mushoom and paddy straw mushroom is 12% each followed by milky mushroom (2%) and shiitake mushroom (1%) (Srivastava *et al*., 2019). In comparison to per capita consumption of mushrooms in America (2-3 kg), Europe (2-3 kg) and China (20-22 kg), in India it is very less (70-80g). India being more populated country like China, there is a need to popularize mushrooms as a good culinary option having nutritionally and nutraceutically important constituents. If India can increase the per capita consumption of mushrooms even up to 100 g, it is estimated that it will help the growers to market over 1 lakh ton mushrooms within the country itself (Srivastava *et al.*, 2019).

Wild mushrooms as food source: Besides commercially cultivated mushrooms, there are many edible species of wild mushrooms which are collected in bulk from the pasture lands and forested areas for personal consumption and even for selling in the local markets (Atri and Mridu, 2018; Kumari *et al*., 2022). In the plains, species of *Termitomyces* (*T. heimii*, *T. mammiformis*, *T. badius*, *T. medius*, *T. microcarpus*, *T. clypeatus*, *T. schimperi*, *T. umkowann*, *T. eurrhizus*, *T. globules*, etc.), *Macrolepiota* (*M. dolicaula*, *M. procera*), *Lentinus* (*L. squarrosulus*), *Volvariella* (*V. volvacea*), *Coprinus* (*C. comatus*), *Pleurotus* (*P. sajor caju*, *P. cystidiosus*, *P. sapidus*, *P. ostreatus*, *P. floridanus*, etc.) are some commonly gathered mushrooms for culinary purposes. In Goa, Chattisgarh and Northeast India, species of *Termitomyces* are gathered in bulk from the wild and are sold in the local markets during the season. In the foothills especially Shiwalik range, *Podaxis pistillaris*, *Amanita vaginata*, *Macrolepiota procera*, *Lycoperdon perlatum*, *Termitomyces heimii*, *Pleurotus* spp., *Morchella esculenta*, *M. crassipes*, *M. tomentosa*, *Tuber melanosporum*, *Lycoperdon perlatum*, etc., are commonly gathered mushrooms for culinary purposes and for local trading. In Rajasthan, *Phellorinia inquinans* and *Podaxis pistillaris* are commonly traded mushrooms from the wild. Similarly, there is an organized trade of various *Morchella* species in Jammu and Kashmir, Himachal Pradesh and Uttrakhand. Largely these mushrooms are traded in dried form in the National and International markets for a very high premium. In the middle and outer Himalayan regions, *Geopora arenicola***,** *Laetiporus sulphureus*, *Auricularia auricula-judae*, *Hericium erinaceous*, *H. corraloides*, *Sparassis crispa*, *Ramaria botrytis*, *R. botrytoides*, *Cantharellus cibarius*, *Lactarius deliciosus*, *Russula cyanoxantha*, *R. virescens*, *Boletus edulis*, *Clavatia bovista*, *Clavatia lycoperdoides*, *Astraeus hygrometricus*, etc., are some of the commonly consumed mushrooms during monsoon season and their only source is forested areas having coniferous and angiospermic components with which many of them form ectomycorrhizal association (Atri *et al.*, 2019; Atri, 2020). From Western Ghats, Karun and Sridhar (2017) reported the bulk collection of *Astraeus hygrometricus* for personal consumption.

Nutritional value of mushrooms: In general, mushrooms contain low calories, high proteins, dietary fibers, vitamins and minerals (Barros *et al.*, 2008; Atri *et al.*, 2015) with high antioxidant capacity (Kalač, 2013). The protein content in mushrooms ranges from 1.6-2.1 g/100g (Mattila *et al.*, 2002). Mushrooms sporophores are quite rich in Chitin (Polymer of N-acetyl–glucosamine) as well as non-starch polysaccharides (β-Glucans). Mainly mushrooms are low in fat and a good source of unsaturated fatty acids to the extent of 75% (w/w) of the total fatty acids. Although the fat content is as low as 0.3% but is rich in Linoleic acid, an essential fatty acid. Instead of cholesterol, mushrooms contain ergo-sterol which is transformed into vitamin D in the human system. Mushrooms are fairly a good source of vitamin C and vitamin B-complex, particularly thiamine, riboflavin, biotin and pantothenic acid. Folic acid and vitamin B-12, which are absent in most vegetables are present in mushrooms (Srivastava *et al.*, 2019). Mushrooms are also a good source of minerals, particularly Ca, Mg, Na, K, Cu, Fe, Mn, and Zn (Cheung, 2008). Because of the constituents present in mushrooms, these are treated as an important food source which can help in meeting the malnutrition problem being faced by the developing countries (Pathmashini, 2008).

Mushrooms as functional food: Functional ingredients in the mushrooms are dietary fiber, poly-unsaturated fatty acids (PUFA), proteins, peptides, amino acids, keto acids, minerals, vitamins, glutathione, selenium, etc. (Srivastava *et al*., 2019). The presence of bioactive compounds like β-Glucans, having antibacterial, anti-hypertensive, anti-hyperchlosterolemic, anti-tumor, and antiviral properties in mushrooms is reported to be yet another reason for the classification of mushrooms as functional foods (Srivastava *et al.*, 2019). β-Glucans is reported to possess the ability to maintain the blood cholesterol at the optimum level preventing cardiovascular diseases (Chioza and Ohga, 2014). Due to their immunomodulatory properties, purified β-Glucans have been used clinically as part of a combination therapy against variety of cancers (Thompson *et al.*, 2010). In view of the above, thus mushrooms serve as an ideal food even for suffering patients, old people, pregnant women and children. Thus, the role played by mushrooms as functional food in meeting the challenges of human health, malnutrition and therapeutics, has resulted manifold increase in consumer demand. Nutritional and nutraceutical potential of number of wild edible mushrooms from North India is well known (Atri *et al*., 2015; Mridu and Atri, 2017; Sharma *et al.*, 2017).

Mushroom based food products and dried mushrooms: In India, value addition of mushrooms represents only 7% of the total mushroom production. Jalali *et al.* (2003) worked on the development of value-added products from milky mushroom *Calocybe indica.* Mushroom based products are available as bakery products as biscuits, bread, cakes and as fast-food items such as burgers, cutlets and pizza, etc. (Harsh and Joshi, 2008). Drying is one of the simplest and yet most important preservation method and the market price of different dried mushrooms are quite variable which largely depend upon the mushroom variety. Shelf life of different dried mushrooms varies from 6 months to one year if stored in airtight packets. India exports dried mushrooms to USA, Germany, Switzerland, France, Canada, Denmark, Belgium, etc. (Mehta and George, 2003). Dried mushrooms can be used in a variety of preparations such as soups, sauces, pasta dishes, noodles, nuggets, papad, etc. Dried Chanterelles can also be crushed into flour and used in seasoning in various recipes such as soups, sauces (Srivastava *et al.*, 2019). Some other preparations include mushroom coffee/tea in which *Grifola frondosa, Gandoderma lucidum*, *Innonotus obliquus*, *Cordyceps sinensis*, *Hericium erinaceus*, etc., are used. Ready to eat mushroom recipes including mushroom manchurian, mushroom ravioli, mushroom risotto, mushroom chilli, mushroom biryani, mushroom curry, mushroom fry, mushroom fried rice, etc., are also prepared using *Agaricus bisporus* (Srivastava *et al.*, 2019).

Canned and frozen mushroom products: Canning is another method of mushroom preservation which can help to increase the storage period of the product. Cost of canned mushroom varies with the type of mushroom canned. Shelf life of canned white button mushroom can be increased from 1 to 3 years in comparison to canned paddy straw mushroom products which range between 1 and 2 years. Most significant buyers of canned white button mushroom are Germany and USA (Rai and Arumuganathan, 2007). Among other type of mushrooms, oyster, shiitake, etc., are also available in canned form under different brand names at variable market prices. Freezing is reported to be the best processing method for preserving natural taste and aroma of mushrooms. Button mushroom, oyster mushroom, paddy straw mushroom and milky mushroom are being sold in the markets in frozen form (Srivastava *et al*., 2019).

Mushrooms based dietary supplements: Dietary supplement refers to the substances which are used to supplement the diet with nutrients for improving the health. These are normally available in the form of tablets, capsules, powder, extracts, tonic, etc. There are number of mushrooms which have found their utility as dietary supplements and are available in the market under different trade names. Medicinally important mushrooms used as dietary supplement include *Ganoderma lucidum* (sold as Reishi Mushroom extract/powder), *Tramates versicolor* (sold as Turkey tail mushroom powder), *Grifola frondosa* (sold as Maitake mushroom extract/tonic), *Cordyceps militaris* (sold as *Cordyceps* mushroom extract/powder/capsule) and *C. sinensis* (sold as *Cordyceps* mushroom extract/ tablets) (Srivastava *et al*., 2019). All these are marketed under different brand names as immunity booster and to promote energy and health primarily because of their nutraceutically important constituents. Amongst the edible mushrooms, *Hericium erinaceus* is marketed as Lions Mane capsule which is reported to provide support to brain and nervous system. *Pleurotus sajor- caju* is marketed as Oyster mushroom powder and *Lentinula edodes* is marketed as Shiitake mushroom extract/ powder. Like other mushrooms, these mushrooms are also reported to boost energy, immunity and are reported to result in overall improvement of health of the consumers (Srivastava *et al*., 2019).

MUSHROOMS AS A SOURCE OF FOLK MEDICINE

Local inhabitants from throughout the world belonging to different civilizations possessed ethnic information regarding uses of mushrooms in their day-to-day life as source of food and as home remedies in the treatment of common ailments. Folk medicine refers to the traditional medicine practiced by local people/tribal population/traditional healers based upon the knowledge gained by them through generations of experience of their forefathers. There are number of mushrooms which have been in use for the treatment of common ailments by traditional healers in the respective areas. An exhaustive review containing information about the ethnomedicinal practices of wild mushrooms by Indian local tribes is published by Debnath *et al.* (2019). A list of some of these along with their trivial names, name of the tribe using these and the ailments against which these are used is given in **Table 1** below.

Table 1: Mushrooms in folk medicine with trivial name.

S.No.	Name of Mushroom	Folk Name of Mushroom/ Name of the Tribe using	Used Against	Reference
1.	*Phellinus rimosus*	Phansomba (Western Ghats, Kerala)	Dysentery, Angina, Diseases of Gums, Mouth, Teeth, Mumps	Vaidya *et al.* (2005)
2.	*Agaricus campestris*	Khumb (Punjabi), Koir (Sirmouri, H.P.), Maaskhel (Kashmiri), Khumbhiu (Sindhi),	Tuberculosis, Dysentery,Increase masculinity	Gogate (1972)
		Bhu Chatra Maaz hadur (Kashmir)	Leucoderma and as tonic for patients of heart disease	Pala *et al.* (2013)
3.	*Fometopsis officinalis*	Bhui kohol (Guajrat)	Diarrhoea, Vomiting, Headache Worm infection	Khory (1887) Singh (1974) Gerard (1597)
4.	*Ganoderma lucidum*	Jarh Phorh (Baiga tribe, M.P.)	Cataract, Asthma, Hydrocele, Body ache	Harsh *et al.*(1993)
		Kulu chhati (Abujmad tribe, M.P.)	Applied on Burns after mixing with mustard oil	Vaidya *et al.* (2005)
		Heand (J. & K.)	Treatment of prolonged illness	Malik *et al.* (2017)
		Gond tribe (M.P.)	Applied on Burns after mixing with mustard oil	Harsh *et al.* (1996)
5.	*Astraeus hygrometricus*	Savan Putpura (Baiga and Bharia tribes, Jabalpur, M.P.)	Treatment of burns	Rai *et al.* (1993)
		Mati tara (Kharia, Mankidi, Santal, Kolha, Munda, etc. tribes, North Odisha)	Treatment of burns	Panda and Tayung (2015)
6.	*Phallus impudicus*	Bastar Tribes (M.P.)	Typhoid	Harsh *et al.*(1996)
7.	*Microporus xanthopus*	Bastar Tribes (M.P.)	Fever, Vomiting, Ear pain	Harsh *et al.* (1996)
		Baiga, Bharia tribes (Jabalpur, M.P.)	Fever, Vomiting, Ear pain	Rai *et al.* (1993)
8.	*Xylaria polymorpha*	Bastar Tribes (M.P.)	Active lactation	Harsh *et al.* (1996)

S.No.	Name of Mushroom	Folk Name of Mushroom/ Name of the Tribe using	Used Against	Reference
9.	*Podaxis pistillaris*	Khumbi (Haryana) Koir (Morni, Haryana)	Wound treatment	Mridu and Atri (2015) Atri and Mridu (2018)
		Paliyar tribes (Tamil Nadu)	Skin burns and skin diseases	Thangaraj *et al.* (2017)
10.	*Auricularia auricula*	Bodo and Garo tribes (Assam)	Rheumatic pains and injuries	Sarma *et al.* (2010)
11.	*Daldinia concentrica*	Kath chhatu (West Bengal	Skin ailments	Dutta and Acharya (2014)
12.	*Pisolithus arhizus*	Sonajhuri chhatu, Bomb chhatu (West Bengal)	Skin ailments	Dutta and Acharya (2014)
13.	*Schizophyllum commune*	Pakha chhatu (West Bengal)	Tonic	Dutta and Acharya (2014)
14.	*Termitomyces clypeatus*	Bali chhatu, Kalunge chhatu (West Bengal)	Pox	Dutta and Acharya (2014)
15.	*Termitomyces tyleranus*	Adim (Gujarat)	General protection from chicken pox	Lahiri *et al.* (2010)
16.	*Termitomyces microcarpus*	Sita-adim, Kulambi-kunwar (Gujarat)	General health maintenance	Lahiri *et al.* (2010)
17.	*Coprinus comatus*	Ajjio (Gujarat)	Skin ailments	Lahiri *et al.* (2010)
18.	*Innonotus obliquus*	Tehaga (Maharashtra)	Chronic gastritis, ulcer, cancer	Vaidya and Rabba (1993)
19.	*Daedaleopsis flavida*	Snuff fungus (Maharashtra)	Jaundice	Vaidya and Rabba (1993)
20.	*Calvatia cyathiformis*	Putu (Chhatisgarh)	Healing of wounds	Tiwari *et al.* (2009)

Traditional ways of using mushrooms as medicine are quite interesting as well as important which are worth examining on scientific parameters. For this, the primary requirement is to document the ethnomycological information from the experienced tribal population/hakims/vaids and from all possible sources, otherwise it is going to be lost with the passing away of the individual who acquired such knowledge from the past generations.

MUSHROOMS AS A SOURCE OF BIOACTIVE COMPOUNDS

Mushrooms are an important source of large number of bioactive substances including phenolics, nucleosides, terpenoids, protein bound polysaccharides, complex starches, glucans and lectins with multifarious health benefits. Among various medicinal mushrooms, *Ganoderma lucidum* (Reishi), *Grifola frondosa* (Maitake), *Lentinula edodes* (Shiitake), *Tramates versicolor*, etc., have received great attention (Rai, 1997). Many of them possess anti-microbial, antioxidant, antiviral, hypo-cholesterolemic and immunopotentiating properties (Saini and Atri, 1999). The compounds having and immunopotentiating properties are reported to serve as Host Defense Potentiators (HDP's) and help in the revitalization of immune system against large number of pathogenic and non-pathogenic ailments. They are reported to serve as biological response modifiers with the capabilities to activate macrophages and T-cell and produce cytokines, interleukins and tumor necrosis factors (Chang, 1996). A list of mushrooms with respective bioactive component and its biological effect is given in **Table 2** below.

Table 2: Mushrooms, their bioactive components and properties.

S. No.	Name of the mushroom	Bioactive compound	Property	Reference
1.	*Agaricus bisporus*	Phenolics, quinoid, pyrogallol, hydroxybenzoic acid and derivatives, flavonoids and lectins	Antibacterial, anti-inflammatory, anti-ageing property	Vogel *et al.*(1974); Moro *et al.*(2012); Ndungutse *et al.*(2015); Lakhanpal and Rana (2005)
2.	*Clitocybe nebularis*	Nebularine	Antibacterial	Loefgren *et al.*(1954)
3.	*Sparassis ramosa*	Sparassol	Antifungal	Falck (1923)
4.	*Lentinula edodes*	Lentinan, glucan, cortinellinmannoglucan, fucomannogalactan, lentin (protein),catechin, flavonoids, eritadenine	Anticancer, anti-HIV, hypocholestrolemic, hypolepidemic, immunomodulatory, antitumour, antioxidant, anti-inflammatory, anti-virus, antifungal, antibacterial	Herrman (1962); Chedd (1967); Subramanian (1995); Tsunoda *et al.* (1970); Sujuki *et al.* (1976); Chibata *et al.* (1969); Attarat and Phermthai (2015); Chowdhury *et al.* (2015); Israilides *et al.* (2008); Ngai and Ng (2003); Sasaki and Takasuka (1976)
5.	*Flammulina velutipes*	Flammulin, peptidoglycan, polysaccharides, FVP (flammulina polysaccharide-protein),proflamin, prolamin	Anticancer, anti-inflammatory, antiviral,antitumour, antioxidant, immuno-modulatory, anti-ageing	Ikekawa *et al.*(1968); Lakhanpal and Rana (2005); Chang *et al.* (2010); Chang *et al.* (2004); Wu *et al.* (2010); Yin *et al.* (2010); Chen *et al.*(2003)
6.	*Grifola frondosa*	Proteoglucan, β –glucan (D-fraction) heteroglycan, grifolan, lectins, polysaccharides, Grifron Pro D-fraction	Anticancer, anti- HIV, anti-diabetic, immunomodulatory, antitumor, anti-inflamatory	Rai (1997); Nanba (1993); Lakhanpal and Rana (2005)
7.	*Ganoderma lucidum*	Triterpenoids, ganoderic acids, ganodermanontriol, ganoderiol, polysaccharides, germanium, nucleotides and nucleosides, Ling Zhi-8, _-glucan, ganoderans A,B,C	Anticancer, anti-metastatic, antitumour, antiviral,anti-HIV, immunomodulatory, antibiotic properties, liver protection, prevents cholesterol synthesis, hypocholestrolemic, hypolepidemic, hepatoprotective	Wang *et al.* (1997); Rai (1997); Subramanian (1995); Xu *et al.* (2010); Walton (2014)
8.	*Ganoderma applanatum*	β–Glucan, flavonoid, polysaccharides	Anticancer, anti-HIV, immunomodulatory, antibacterial	Monika *et al.* (2014)

S. No.	Name of the mushroom	Bioactive compound	Property	Reference
9.	*Auricularia polytricha*	Adenosine	Hypocholestrolemic, hypolepidemic, anti-coagulent and anti-thrombic	Markhija and Bailley (1981); Hammerschimidt (1980)
10.	*Tramates versicolor*	B-Glucans PSK	Anticancer, Autoimmune disease and humanpapilloma virus	Rai (1997)
11.	*Cordyceps militaris*	Cordycepin, polysaccharides, ergothionine, γ-aminobutyric acid (GABA)	Immunopotentiating	Jedrejko *et al.*(2021)
12.	*Cordyceps sinensis*	Nucleosides, cordycepin, adenosine, polysaccharides	Anticancer, antiviral; anti-diabetic, hypo-glycemic anti-depressant	Liu Yi *et al.* (2015); Liu Wu *et al*. (2022) Lakhanpal and Rana (2005)
13.	*Auricularia auricula*	Glucan, polysaccharides	Immunomodulatory, antitumour, anti-inflammatory, hypoglycaemic,immune tonic, and beneficial in coronary heart disease	Lakhanpal and Rana (2005); Zhang *et al.* (2007)
14.	*Pleurotus florida*	β-Glucans	Antioxidant, antimicrobial	Ganeshpurkar *et al.* (2015); Menaga *et al.* (2012)
15.	*Pleurotus ostreatus*	Ubiquinone-9, ubiquitin-like peptide, nebrodeolysin, glycoprotein, proteoglycans pleuran, pleurostrin galactose, mannose, glucans, laccase	Immunomodulatory, hyperglycemia, antitumour, antioxidant, antiviral, antifungal	El Enshasy *et al*. (2012); Tong *et al.* (2009); Chu *et al.* (2005);El Fakharany *et al.* (2010); Oloke and Adebayo (2015)
16.	*Pleurotus pulmonarius*	Polysaccharides [(1→3)glucopyranosyl, and polysaccharides(1→3), (1→6)-linked glucan	Anti-inflammatory	Lavi *et al.* (2012); Smiderle *et al*. (2008)
17.	*Volvariella volvacea*	Fip-Vvo	Immunomodulatory	Hsu *et al*. (1997)
18.	*Hericium erinaceous*	Hericenones and erinacines	Neuritogenic effects	Lakhanpal and Rana (2005)
19.	*Agaricus blazei*	Agarol, β–Glucan	Antioxidant, immunomodulatory, anti-inflamatory, antimicrobial	Aline *et al.* (2017)
20.	*Schizophyllum commune*	Phenolics, polysaccharide, β -glucan, protocatechuic acid, tocopherol	Antitumor, Immunomodulatory	Mayakrishnan *et al.* (2013); Liu, *et al.* (2015); Zhu *et al.* (2015)

From the information given in **Table 2**, it is apparent that unique chemical composition of mushrooms makes these suitable for specific groups suffering with variety of ailments including diabetes, obesity, hypertension, atherosclerosis, etc. (Rai, 1997).

MUSHROOMS IN BIOCONVERSION AND AS NATURES REPLENISHERS

Large majority of mushrooms being saprophytic, plays an important role in remediation and restoration of the ecosystem and hence serves as natures replenishers. While discussing ecology and conservation of edible Asian mushrooms, Mortimer *et al.* (2012) besides their culinary relevance also emphasized their role in sustainability of nature. Largely mushrooms being saprotrophic, play a significant role in recycling the organic debris. By doing so these adds to the fertility of the soil and healthy growth of plants on the Earth and their sustenance.

Saprophytic fungi are the premier recyclers on the planet which form a mycelia network on the organic substrate including twigs, grasses, wooden chips, logs and stumps, etc. Amongst the colonizers, primary decomposers are fast-growing which decompose the colonized substrate. Majority of these saprophytes are wood and litter colonizers, such as *Pleurotus* spp., *Lentinus* spp., *Lentinula edodes*, *Stropharia rugosoannulata*, *Marasmius* spp., etc. These are followed by secondary decomposers which typically grow on composted material degraded by the primary colonizers. Typical examples of mushrooms serving as secondary decomposer are *Agaricus bisporus*, *A. bitorquis*, *Stropharia ambigua* etc. Of these, *Stropharia ambigua*, is reported to colonize outdoor mushroom beds after the wooden chips have been decomposed by the primary colonizers. The habitats thus created by the prolonged activity of primary and secondary decomposers are subsequently colonized by tertiary colonizers like *Aleuria aurantia* which is commonly known as the Orange Peel Mushroom. Other tertiary decomposers include species of *Conocybe*, *Agrocybe*, *Pluteus*, etc. Wood and litter decaying basidiomycetes play an effective role in the degradation of environmental pollutants as well, primarily because of their capability to secrete extracellular lignolytic enzymes including manganese peroxidise (MnP) which seems to play significant role in the degradation of xenobiotics (Hofrichter *et al.*, 1997; 1999). Some of the white rot fungi (*Nematoloma frowardii*, *Clitocybula dusenii*, *Trametes versicolor*, *Phellinus pini*) and brown rot fungi (*Flammulina velutipes*, *Daedalea quercina*, *Laetiporus sulphureus*, *Serpula lacrymans*, *Fomitopsis palustris*) are reported to play an important role in recycling xenobiotics. Different species of *Pleurotus* including *P. flabellatus*, *P. citrinopileatus*, *P. cornucopiae*, *P.sapidus*, etc., also possess capability to degrade lignin which is the second most abundant complex aromatic renewable biopolymer present on the earth (Upadhyay and Fritsche, 1997; Rajarathnam *et al*., 1997).

Mushrooms are cultivated on variety of plant substrates which are lignocellulosic in composition. In India food crops alone, after harvest and separation of consumable portion, are reported to generate about 1.15 billion tons of agro-wastes which are renewable. Large amount of these are burnt in the field after harvest of crop to clean the field for growing next crop because of labour constraints. Through this, large amount of potent source of organic carbon and nutrient is lost. Growing mushrooms on lignocellulosic wastes represent the most successful example of solid-state fermentation and biotransformation to produce mushrooms (Rajarathnam *et al.*, 1997). Amongst such organic residues, wheat straw, rice straw, leaf litter, saw dust, wooden flakes, sugarcane bagasse, cotton waste, coconut coir, etc., serve as excellent substrate for mushroom cultivation. Currently, India is using only 0.03% of the crop residues for producing 1.2 Lakh tonnes of mushrooms. If only 1% of it is utilized for mushroom cultivation, India can become a major mushroom producing country. All commonly cultivated species of mushrooms including *Agaricus bisporus*, *A. bitorquis*, *Pleurotus ostreatus*, *P. floridanus*, *P. sajor-caju*, *Volvariella volvacea*, *Lentinula edodes*, *Lentinus squarrosulus*, *Calocybe indica*, etc., grow well on pasteurized/ unpasteurized agricultural and other organic residues and gives excellent biological efficiency through biotransformation.

MUSHROOMS IN BIOREMEDIATION

Mushroom mycelia produce extracellular enzymes which break down recalcitrant molecules such as lignin and cellulose, the primary component of woody plants. During decomposition lignin peroxidases play an important role in dismantling the long chains of hydrogen and carbon into simpler forms. These enzymes are also capable of breaking the hydrocarbons which form the base structure of oils, petroleum, pesticides, and many other pollutants. Numbers of enzymes produced by mushroom mycelia are known to play a role in bioremediation (Adenipekun and Lawal, 2012). *Phanerochaete chrysosporium* produce laccases, polyphenol oxidases and lignin peroxidases which can degrade lignin, organopollutants synthetic dyes, pesticides, degrades toxic xenobiotics which otherwise take long time for complete mineralization (Barr and Aust,1994). Mycelia of another species *Phanerochaete flavido-alba* produce manganese peroxidase which can decolorize olive oil mill wastewater and result in 90% decrease in the phenolic content of olive oil mill wastewater (Adenipekun and Lawal, 2012). The lignolytic enzymes produced by the mycelia of *Trametes versicolor* possess the capability to degrade lignin, polycyclic aromatic hydrocarbons, polychlorinated biphenyl mixture and number of synthetic dyes quite efficiently. The enzymes are used to dechlorinate, decolorize and bleach kraft pulp effluents and as biocatalyst for decolourization of different industrial dyes and in wastewater treatment (Amaral *et al.*, 2004). Although *Pleurotus ostreatus* is an edible mushroom, its mycelia produce enzymes which are reported to degrade polycyclic aromatic hydrocarbons in the contaminated soils from a manufactured gas facility and abandoned electric cooping plant (Sack and Günther, 1993). *Pleurotus pulmonarius* mycelium is reported to possess utility in the management of cement and battery polluted soils (Adenipekun *et al*., 2011b). A general increase in carbon, organic matter, phosphorus and potassium content and significant decrease in copper, manganese, nickel and polyaromatic hydrocarbon content has been reported where this mushroom was used. Enzymes from *Lentinus tuber-regium* have ability to ameliorate crude oil polluted soil. The fungus is reported to bring about an improvement in the nutrient status of the soil, bioaccumulation of heavy metals, degradation of lignin and increased activity of polyphenol oxidase and peroxidase primarily due to biodegradation of cutting fluids and other crude oils (Adenipekun *et al*., 2011b). *Lentinus squarrosulus* mycelium has been reported to mineralize the soil contaminated with various concentrations of crude oil resulting in the increased nutrient contents in the treated soil. It can degrade the engine oil from the polluted soil resulting in reduced heavy metal concentration, increased organic matter, carbon and available phosphorus in the treated soil (Adedokun and Ataga, 2006). *Lentinula edodes*, commonly known as shiitake, has got the potential to degrade pentachlorophenol (PCP) from the soil. Many white rot mushrooms possesses the capability to uptake and concentrate heavy metals in their mycelia. Examples of some such species are *Pleurotus ostreatus* (Cd, Cu, Zn), *Ganoderma lucidum* (Al, Cd, Pb, Ca), *Volvariella volvacea* (Cu), *Pleurotus pulmonarius* (Pb, Cu), etc. (Adenipekun and Lawal, 2011; Dowalti *et al*., 2021). Fungal mycelia either live or in dried form possess very effective biosorption potential for metals. They also hold the potential to transform recalcitrant pharmaceutical compounds and pesticides (Boamponsem *et al*., 2013)

Mushroom mycelia in mycofiltration: Microfiltration is an environment friendly technology which involves treatment of contaminated water by passing through a network of fungal mycelia (Mnkandla and Otomo, 2021). The mushroom mycelia form a fabric of interconnected, interwoven strands resulting in a well-knit network. One such colony of fungal mycelia can range from the size of a miniature coin to many acres. The fungal mycelia network works like a filtration membrane. The use of fungal mycelia as a mycofilter is currently being studied for the removal of biological contaminants from surface water passing directly into sensitive watersheds (Taylor *et al.*, 2015). By placing sawdust colonized by mushroom mycelia in drainage area downstream from livestock farms, the mycelia act as a sieve, which traps fecal bacteria and thus reducing the impact of a farm's nitrogen-rich outflow into aquatic ecosystems substantially (Taylor *et al.*, 2015)**.** Mushrooms mycelia can also be used to filter contaminants like *Escherichia coli* from agricultural run-off water. Mehta *et al.* (2017) reported the reduced outflow of *E. coli* by about 20% per cubic foot through mycofiltration using *Stropharia rugoso-annulata* mushroom mycelia bed as mycofilter. Several species of fungi are reported to have demonstrated an exceptional ability in the uptake and removal of metals and other pollutants from waste and runoff water (Akpaj and Olorunfermi, 2014)).

MUSHROOMS IN EMPLOYMENT AND REVENUE GENERATION

Mushrooms are playing a major role in employment generation and as a side avocation for generation of extra income. A year-round mushroom cultivation cycle is operative now a days in different parts of the country in which *Agaricus bisporus* (Button mushroom) is being grown from mid-November to mid-March, *Pleurotus sajor-caju* (Dhingri mushroom) is grown from February to mid-April, *Volvariella volvacea* (Paddy straw mushroom) from mid-June to mid-September and *Pleurotus sajor-caju* and *P. floridanus* from September to November. Besides, there are other mushrooms including *Lentinula edodes* (Shiitake) and *Calocybe indica* (Milky mushroom) which are also adding to the income of various mushroom entrepreneurs, who have taken up this venture on large scale. Fresh milky mushroom is being sold for Rs. 100-120/kg in places such Bangalore and Hyderabad (Krishnamoorthy, 2003).

Local people/tribals collect number of mushrooms from the wild and sell them in the Local/National/International markets at variable prices. *Cordyceps sinensis*, considering its medicinal properties in China, is reported to cost USD 20,000 to 40,0000 per kg in the markets (Jang *et al.*, 2015; Lo *et al.*, 2013). Because of its high cost, the fungus is regarded as “Soft Gold”. In high altitudes of the Uttrakhand Himalayas, it is commonly referred as “Keera Jari/ Keera Ghas”. Depending upon the quality and size of the larval host, the cost of this medicinal mushroom is reported to vary in the Indian markets between INR 4-5 lakhs (i.e. INR 200-500/kg). Uttrakhand State Government is reported to purchase it from the local collectors through Van Panchayats and Forest Development Corporation at INR 50,000/kg (Bhandari *et al.*, 2012). *Termitomyces heimii*, *T. mammiformis*, *Phellorinia inquinans*, *Podaxis pistillaris*, *Coprinus comatus*, etc., are some commonly gathered mushrooms from the wild, which are sold fresh in the local markets of Northeast, Chattisgarh, Rajasthan, Goa, etc., for high premium.

There are number of mushrooms which can also be sold in dried form and these fetch variable price in the National and International markets and thus serve as an important source of revenue (Srivastava *et al.*, 2019). As per the details given by Srivastava *et al.* (2019) dried oyster mushroom sporophores (*Pleurotus florida)* are sold at a market price ranging between Rs. 1500 and 2500/kg. In powder form, it is reported to fetches a higher market price ranging between Rs.2000 and 4250/kg. Shiitake (*Lentinula edodes*) in dried form can be sold @ Rs. 2000 – 4000/kg., while in powder form its market value is reported to be much higher which ranges from Rs. 10,000 -14,000/kg. Dried fruit bodies of morels (*Morchella esculenta* and other species of *Morchella*) are reported to fetch a market price ranging from Rs.20,000 – 40,000/kg. Dried wood ear mushroom (*Auricularia auricula-judae*) can be sold at Rs.4000 – 5000/kg, while dried porcini fruit bodies (*Boletus edulis*) are sold at a market price of about Rs.13,000 – 15,000/kg. Canterelle (*Canthrallus cibarius*) mushrooms when dries can be sold for Rs. 25,000 – 30,000/kg in the international markets in Italy (Srivastava *et al.*, 2019). The shelf life of these dried mushrooms is reported to vary from 6-12 months and the markets for selling these are available in Bombay, Delhi, Guru gram, Goa, Ghaziabad, Italy, China, etc. (Srivastava *et al.*, 2019).

As for preservation of mushrooms is concerned, canning is reported to increase the storage time of mushrooms by up to 2 years (Srivastava *et al.*, 2019)**.** Cost of canned mushroom is reported to vary with the type of mushroom canned (Srivastava *et al.*, 2019). Market price of canned white button mushrooms is reported to range from Rs. 200-400/kg with shelf life of 1-3 years. Canned paddy straw mushroom products are sold at a market price of Rs. 400-700/kg with shelf life of 1-2 years. Among other type of mushrooms, oyster, shiitake, etc., are also sold in canned form under different brand names at variable market prices. Mushroom pickles, mushroom sauce and spread, mushroom soup, bakery products such as biscuits, bread, cakes and fast food items such as burgers, cutlets and pizza, ready to eat mushroom products, etc., are some more mushroom based options available as a source of revenue (Srivastava *et al.*, 2019).

MUSHROOMS AS SOURCE OF LECTINS

Mushrooms are reported to be the potential source of novel lectins (Singh *et al.*, 2019a). About 80% of the fungal lectins are isolated from mushrooms (Singh *et al.*, 2010; Varrot *et al.*, 2013). Wide range of lectins is extensively distributed in sporophores and vegetative mycelia of mushrooms (Nikitina *et al.*, 2017). Some of such mushroom genera which have been investigated for the potential occurrence of lectins include *Lactarius*, *Russula*, *Agrocybe*, *Coprinus*, *Lentinus*, *Panaeolus*, *Pleurotus*, *Schizophyllum*, *Termitomyces*, *Volvariella*, etc.

Mushroom lectins are reported to exhibit preferential haemagglutination activity with potential biotechnological and therapeutic applications (Singh *et al*., 2016, 2019b). Lectins from mushrooms can help in the identification of various glycoconjugates and are known to mediate different biological responses associated with cell surface. Based on their carbohydrate specificity, lectins are reported to act as potential diagnostic agents used to analyze various biological functions with cell surface (Singh *et al*., 2019b). Mushroom lectins are reported to act as important tools for therapeutic applications due to their anticancer, immunomodulatory, antimicrobial, antiviral and antioxidative properties (Singh *et al.*, 2016, 2019b).

MUSHROOMS AND PLANT HEALTH

About 95% of world's species of vascular plants are known to form ectomycorrhizal association with fungi (Trappe, 1977). As compared less than 2% of the fungal species including both ectomycorrhizal and endomycorrhizal fungi are reported to form mutualistic association (Brundrett and Tedersoo, 2018; Van der Heijden *et al*., 2015). Estimate suggest that there are 50,000 fungal species that form mycorrhizal associations with about 2,50,000 plant species and play a major role in overall growth and development of associated plants in particular and forest ecosystem in general. So far, ECM studies are exclusively focussed on temperate and boreal ecosystems, whereas there is little information on ECM communities of tropical and subtropical ecosystems (Kumar and Atri, 2018). The economically and ecologically most important forest trees forming ECM association belong to plant families such as *Pinaceae*, *Fagaceae*, *Salicaceae*, *Betulaceae*, *Nothophagaceae*, *Myrtaceae*, *Casalpiniaceae* and *Dipterocarpaceae* (Kumar and Atri, 2018). Larger fungi, particularly some of the mushroom genera belonging to *Ascomycota* (*Tuber*, *Morchella*) and *Basidiomycota* (*Russula*, *Lactarius*, *Lactifluus*, *Inocybe*, *Aspiroinocybe*, *Amanita*, *Boletus*, etc.) are known to form ectomycorrhizal association with vascular plants. While working in the Northwest Indian Shiwaliks, Kumar and Atri (2019, 2020, 2021) identified and characterized species of *Russula* and *Aspiroinocybe* forming ectomycorrhzal association with *Shroea robusta*. The fungal partner in the plant root-fungus mutualistic association play an important role in the growth and development of the associated plants by facilitating nutrient management and their increased tolerance against drought, high temperature, extremes of pH, heavy metals and protection from infection by the root pathogens (Singh and Lakhanpal, 2005). In return, associated fungi get supply of carbon from their plant hosts. In fact most mycorrhizal fungi depends on their host for survival, just as many plants depend on their fungal partner (Kohler *et al*., 2015). In an experimental set up, Kumar and Atri (2023) recorded improvement in the growth, biomass, nutrient uptake and protection from heavy metals in infected Sal seedlings which were infected with cultures raised from natural mycorrhizal associates, namely *Russula kanadii*, *R cyanoxantha* and *Lactarius shiwalikensis*. Thus mushrooms serve as an important component in the establishment and proliferation of natural forest ecosystem.

MUSHROOMS AS SOURCE OF COSMETIC PRODUCTS

There are number of mushrooms which are in use in the preparation of cosmetic products throughout the world. Mushrooms, which are incorporated in topical creams, lotions, ointments, serums, and facial preparations as cosmetic ingredients, include Shiitake (*Lentinula edodes*), Maitake (*Grifola frondosa*), Reishi or Lingzhi (*Ganoderma lucidum*), Fu Ling (*Wolfiporia extensa*), Yartsa Gunbu (*Cordyceps sinensis*), Cauliflower mushroom (*Sparassis latifolia*, formerly *Sparassis crispa*), and Jelly fungi (*Tremella* spp.) (Wu *et al.*, 2016). All such mushrooms are reported to be traditionally in use for these purposes in Eastern Asian countries such as China, Japan and Korea (Choi *et al.*, 2014; Liu, 2002; Zhang *et al*., 2002). Portobello mushroom (*Agaricus bisporus*), oyster mushroom (*Pleurotus ostreatus*), elm oyster mushroom (*Hypsizygus ulmarius*) and tinder fungus (*Fomes fomentarius*) are highly recognized in this regard in Western countries (Van Griensven, 2009; Wani *et al.*, 2010; Wasser, 2010). Other popular mushrooms include *Agaricus subrufescens*, *Coprinus comatus*, *Hericium erinaceus*, *Mycoleptodonoides aitchisonii*, *Phellinus linteus*, *Schizophyllum commune* and *Volvareilla volvacea* (Chandrasekaran *et al.*, 2012; De Silva *et al.*, 2012; Lee *et al*., 2011). There are numerous potential mycochemicals from all these mushrooms that has potential utility in cosmeceuticals or nutricosmetics. Some of such specific examples in this regard are *Lentinula edodes* (Shiitake) used in the preparation of face cream, skin lotion (U.K.), skin serum (U.S.), face cleanser (Italy), body lotion (U.S.A.); *Ganoderma lucidum* in the preparation of body lotion, face mask (U.S.A.), face gel, hair cream (U.K.), anti-aging cream (France, Korea), hair polish (France), massage oil, soap, shampoo (Malaysia), hair oil (Kerala, India), face cleanser (Italy), serum (Japan, U.S.A.); *Cordyceps sinensis* in face cream (Japan); *Schizophyllum commune* in face cream (Spain) and moisturizing cream (Korea); *Innonotus obliquus* in face mask (U.S.); *Tremella fuciformis* in moisturizing lotion (Switzerland), face mask (U.S.A.); *Pleurotus ostreatus* in anti-aging cream (Korea); *Hypsizygus ulmarius* in skin lotion, etc.

MUSHROOMS AS OBJECTS OF BEAUTY AND MYSTIQUE

Some mushrooms because of their fascinating colour and unique architecture are an objects of beauty and mystique because of which these can be used both in fresh and dried form for ornamental/decoration purposes (Pandey and Veena, 2007). *Trametes versicolor*, *Pycnoporus cinnabarinus*, *Laccaria amethstia*, *Sarcoscpha coccinea*, *Ganoderma lucidum*, etc., are some examples of such mushrooms which have been favorite subjects for painters and sculptors. Not much has been done to popularize mushrooms for ornamental purposes. Mushroom laboratory at Indian Institute of Horticultural Research (IIHR), Bangalore has initiated work to utilize such mushrooms for commercial horticulture with simultaneous objective of conserving these beautiful microbes having fascinating fruiting structures (Pandey and Veena, 2007).

MUSHROOMS IN SYNTHESIS OF NANOPARTICLES

Synthesis of nanoparticles using edible and medicinal mushrooms has emerged as an interesting field of research as these act as eco-friendly bio-factories which secrete enzymes exogenously and play a pivotal role in the reduction of metal ions into zerovalent or nano-form. Such nanoparticles produced using mushrooms are reported to exhibit higher stability, with longer shelf life and enhanced biological activities. A variety of mushrooms (*Pleurotus florida*, *P. ostreatus*, *Agaricus bisporus*, *Flammulina velutipes*, etc.) are reported to have been used in the synthesis of metal (Au, Ag, Fe, Pt) and non-metal (Se, Cd, S, etc.) nanoparticles. These nanoparticles have found applications in advanced biomedical and industrial ventures (Khan *et al*., 2018; Kalia and Kaur, 2019, 2022).

MUSHROOM IN SYNTHESIS OF BUILDING AND PACKAGING MATERIAL

Mushroom mycelia can colonize the agro-waste and by doing so, the mycelia bind the matrix of the substrate to form biodegradable bio-composite material. This colonized bio-composite material can be easily molded into shock resistant packaging, construction and insulation material. For this purpose, cost effective raw material is used to form bio-composite using mycelia of oyster mushrooms like *Pleurotus ostreatus*. The material so developed after colonization serve as a sustainable substitute to synthetic materials like expanded polystyrene (EPS). Such features make the mycelia-based bio-composite a material of choice in packaging applications (Rejeesh, 2022). Mycelia bricks prepared using bio-composite material are reported to have been used to build a tower as high as 40 feet and it is reported to be the largest structure made using such material. Few architectural projects such as Hy-Fi Tower, the Mycotecture alpha, MycoTree are reported to have been built using bio-composite material (Abhijith *et al*., 2018; Mojumdar *et al*., 2021). Even insulation boards and Myco boards (wood substitute) are some of such bio-composite products which are being produced using mushroom mycelia and agro-waste (Abhijith *et al*., 2018).

HALLUCINOGENIC MUSHROOMS AND THERAPEUTIC POTENTIAL

The existence of hallucinogenic mushrooms is known since long time. There are number of references of use of such mushrooms during ceremonies. Wasson and Wasson (1957) in one of the most fascinating book “Mushrooms, Russia and History” described the ceremonies during which certain Mexican tribes are reported to use the sacred mushrooms which produced ecstatic effects when consumed. Majority of the hallucinogenic species are found in genus *Psilocybe* (Heim and Wasson, 1958; Heim, 1963). One of its species, *P. mexicana* along with some related species were collectively referred as “sacred mushrooms”. These were used by Mexican Indians for centuries in certain religious rites (Alexopoulos *et al*., 1996). Some other mushrooms having hallucinogenic properties include *P. strichfer*, *P. caerulescens*, *P. zapotecorum*, *Amanita muscaria* and species of *Panaeolus* and *Stropharia*. All such mushrooms affect the nervous system in such a manner that the hallucination symptoms start appearing 2-4 hours after ingestion. *Amanita muscaria* var *muscaria* is particularly known for its hallucinogenic properties with main psychoactive constituents being muscimol and its nurotoxic precursor ibotenic acid. It is reported to be in use as entheogen by indigenous people of Siberia (Carboué and Lopez, 2021). Wasson (1968) proposed *A. muscaria* to be a source of ‘soma’ referred in Rigveda. Ingestion of fly agaric is also documented by Wasson (1980) in the Lithuanian festivities and religious uses in Eastern Europe. There are number of similar instances of use of hallucinogenic mushrooms during religious rituals and festivities.

Nearly all species of *Psilocybe* contain psychedelic compounds, psilocybin and psilocin which are responsible for hallucinogenic properties. There is a possibility of use of these compounds in psychiatric medicine (Guzmán, 2008). Psilocybin has anti-depressant and anti-anxiety effects that last for several months. It has been in use for religious and spiritual ceremonies as well as therapeutic option for treating the neuropsychiatric condition (Lowe *et al*., 2021).There can be a possibility of psychedelic-assisted therapies providing significant opportunities to current issues in the conventional treatment of psychiatric disorders. For detailed information and the possibility of use of bioactive molecules from hallucinogenic mushrooms in therapeutics and possible risks, reference can be made to Lowe *et al.* (2021).

MUSHROOMS AS ASOURCE OF NATURAL COLOUR

Mushrooms are reported to be an important eco-friendly source of natural pigments (Lagashetti *et al*., 2019; Ahmad *et al.*, 2022). These pigments find their utility in textiles, pharmaceuticals, cosmetics, food and beverage industries as colorants, color intensifiers, additives, antioxidants, etc. (Lagashetti *et al.*, 2019; Ahmad *et al.*, 2022). In the early 1970s Miriam Rice, reported large number of wild mushrooms which can serve as a source of natural colour pigments which can be used to dye wool, etc. Miriam Rice (1974) published first book describing mushrooms as a source of natural colors entitled ‘*Let’s Try Mushrooms for Color*’. Subsequently, Miriam Rice and Dorothy Beebee (1980) published second book on the subject ‘*Mushrooms for Color*’. A more recent book ‘*Mushrooms for Dyes, Paper, Pigments and Myco-stix*’, which is more comprehensive, was published by Miriam Rice with illustrations by Dorothy Beebee in 2007. Mushrooms belonging to ascomycetous and basidiomycetous fungi (mushrooms) and lichens, particularly those belonging to families *Nectriaceae*, *Xylariaceae*, *Hymenochaetaceae*, *Polyporaceae*, *Tremellaceae*, *Agaricaceae*, *Russulaceae*, etc., are non-conventional sources of dyes which produce an extraordinary range of colors representing several chemical classes of pigments such as carotenoids, melanins, azaphilones, flavins, Grevilins**,** azulenesanthraquinone, etc. (Mortensen, 2006; Lagashetti *et al.*, 2019; Ahmad *et al.*, 2022). Their pigmentation is reported to vary depending on age. Mushrooms are reported to produce safe and functional pigments having application in food processing as well. Some common examples of mushrooms as a source of dyes are *Daldinia concentric* (Daldinin-A,B,C (Azaphilones)-Yellow pigment), *Suillus* (Grevilins-Orange to Dark Blue pigment), *Lactarius indigo* (Azulenes-Brilliant Blue pigment), *Lactarius lilacinus* (Lilacinine-Red pigment), *Cortinarius sanguines* (Anthraquinone-Red Pigment), *Auricularia auricula* (Melanin-Yellow Reddish pigment), *Cantharellus cibarius* (Carotenoid-Yellow orange pigment), etc. Yellow dyes extracted from mushrooms are reported to be in use in bread making (Ahmad *et al.*, 2022).The dyes from mushrooms are reported to provide health promoting factors when introduced as food colorants. These dyes are completely biodegradable safe and environment friendly (Ahmad *et al.*, 2022). Lot of work needs to be carried out in this area since mushrooms are still insufficiently researched as a natural source of dyes.

CONCLUSION

Mushrooms are unique creation of God having varied texture and shapes and multifarious applications. They find their relevance in human welfare and in the well-being of the environment. Mushrooms have high fiber content, unique chemistry, ability to revitalize immunity and nutritionally and neutraceutically important constituents because of which edible mushrooms should be made permanent part of the dietary recommendations. Value addition in mushrooms is an important aspect which can add to the fruitful utilization of this perishable commodity. Some of the mushrooms find their utility in bioremediation and others which are under cultivation play an important role in biotransformation thus converting huge quantity of agro-wastes into utility food. There are number of other applications in which mushroom finds their use in solving number of issues the mankind is facing besides their importance in ecosystem sustenance. India is a rich repository of this bio-resource which needs to be tapped for various applications. Mushrooms having utility in the welfare of society and in the sustenance of the ecosystem needs to be identified, inventoried, evaluated and conserved so as to mitigate the challenges being faced by mankind and the environment.

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