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Mushroom: A Review on Multipurpose Fungi and its Commercial Utilization

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Abstract: This paper reviews multifunctional nature of mushrooms. Besides being an essential source of nutrition, they are being extensively exploited by man in various ways. Not only are they admired for their exceptional flavor and texture but this fungus can replace a number of resources that we are currently utilizing. Higher mushrooms contain bioactive components that show antibacterial, antitumor, immunostimulator, antiparasitic, antidiabetic, anticarcinogenic properties. Simultaneously they are useful for people and woodlands by recycling nutrients, managing plastic waste and agricultural residues as they can act as natural decomposers . Mushroom farming is the best method to meet sustainable development goals set up by UNO. Mushrooms play an important role in biofuel generation, textile, footwear, furniture, dying and tanning industries. It is hoped that this paper would add to existing information on versatile attributes of mushrooms to make it feasible for humans to utilize mushrooms to a more prominent extent other than just a food ingredient, which makes them not just edible but a multi-functional fungi.
Keywords: Mushroom, pharmaceuticals, Cosmetics, bioactive components, vegan leather, mycelium.

Introduction:

Mushrooms are fruiting bodies that belong to kingdom Fungi, division Basidiomycotina and Ascomycotina with distinctive fruiting bodies of sufficient size to be noticeable with naked eyes. It is estimated that on earth only 10% of 140,000 mushroom species have been named until now. (Bal et al. 2017). Mushrooms can be classified into edible, poisonous & medicinal mushrooms. All over the world it is documented that there are about 3000 edible species of mushroom and about 700 are known to have therapeutic values (Li et al. 2021). 10% of total mushroom species are poisonous and considered as fatal .In Asian countries mushroom cultivation initiated around a thousand years ago but in India it is comparatively a new viewpoint.(Sharma et al. 2017)

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Most common species of mushroom are mushrooms are *Agaricus bisporus*, *Pleurotus ostreatus*, *Volvariella volvaceae*, *Ganoderma lucidum*, *Morchella esculanta*, *Lentinulla edodes* and *Calocybe auricula*. They can be grown very easily in contrasting habitats, mainly on dead and decaying matter.

They are consumed not only for their delicious taste but also for their nutritional values such as good quality protein, low calories, vitamins and minerals. Mushrooms can be a better alternative to animal based proteins. The use of mushrooms has been extended to a number of fields such as pharmaceuticals, cosmoceuticals, nutraceuticals, leather industry, tanning and dye industry, Bioremediation for the environment , curing various diseases, maintaining a healthy diet, making dishes, etc. Today with increasing number of diseases medicinal mushrooms can be alternative to synthetic medicines .Some clinical studies explicitly revealed that large number of mushroom species have medicinal and therapeutic potential in curing cancer, viral diseases, HIV AIDS, hypercholesterolemia, hypertension (Woldegiorgis et al. 2015). Mushrooms now aren't just limited to basic cooking and medicinal purposes, but they have shown a great potential to be utilized in various commercial uses. The mycelium part of the mushroom, which is often considered waste, is the most versatile part of the mushrooms. Various researches have shown a potential to develop different products using mushrooms mycellium like packing material, construction material, leather , decorative house products , textile and footwears（ Attias et al. 2017). SMS (Spent mushroom substrate) of mushrooms like *Flammulina velutipes* and *Pleurotus eryngii* can be used to produce methane gas which can be used as fuel (Grimm and Wosten 2018). Mushrooms plays an significant role in keeping up with the forest ecosystem by breaking down organic waste like woods , leaves and recycling nutrients back to the ecosystem. (Waktola and Temesgen , 2018). With an increasing population, interest in cultivation and consumption of mushrooms is also increasing. Mushroom cultivation industry is presently a billion dollar industry with yearly turnover of around US$ 41920 million in 2021. As per the report released by market world report, the global mushroom market is relied upon increment at CAGR of approximately 5.6 % during 2022-2028 (marketreportsworld.com).

During pandemic SARS-COV -2 consumption of mushroom was increased because there was no any specific treatment available for it but only by regular consuming of mushrooms species like *Lentinula edodes*, *Inonotus obliqus* and *Grifola frandosa* having antiviral and anti-inflammatory properties can be prove to be very effective in reducing the deleterious effects Covid – 19 (Shahzad et al. 2020). This review paper tries to give a comprehensive view on different functions of mushrooms by which it can revolutionize the world, saving the environment and lives of people and the role of mushrooms in overcoming challenges like food insecurity, malnutrition , environmental crisis, economy, industries etc.

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I) **Different ways of exploitation of mushrooms:**

(A) Mushroom as a potential source of food and nutrition.

The most standard use of mushrooms is to be utilized as food. Mushrooms are fitted to provide a number of nutrients, they have various health perks as food. According to the Global Hunger report 2021 , Worst affected country from hunger and malnutrition was Somalia. Around 516.5 million people in Asia and pacific area are malnourished , whereas 239 million people living in Asia are malnourished (Szmigiera M , 2021) . Various species of edible mushrooms like *Agaricus bisporus*, *Calocybe indica* , *Pleurotus ostreatus* , *Volvariellla volvaceae* can be used to solve the problem of malnutrition. By expanding the cultivation of mushrooms , its price can be reduced and hence it can safeguards food insecurity. According to The Great Courses Daily by Wandrium Food trend forecasters predicted that 2022 will be ‘’Year of the Mushroom’’(Lupsha J, 2022). Mushroom are highly nutritious containing 50 to 65% of Carbohydrate on dry weight basis, 32-42% protein in species like *Agaricus bisporus* (Table 1) , unsaturated fatty acids, several important vitamins i.e Vitamin B complex, C and D2 in wild mushrooms . and also some major minerals like K, P, Na, Ca, Mg(Waktola and Temesgen, 2018). They have low fat content, , calories , sodium and carbohydrates and are utilized in the manufacturing of dietary supplements. Protein from mushrooms is estimated to have a higher nutritional content than vegetables, meat, eggs, and milk. In mushrooms the Protein content is comparatively less than animal meat protein but higher than food like milk .Mushrooms are a superfine replacement to fulfill the protein needs of vegans and vegetarians who depend on plant-based sources of protein such as pea, rice, and legumes.

Due to its nutritive and therapeutic properties , the trend in fortification of muscle food with edible mushrooms is increasing rapidly . Nowadays , customers are cordially accepting muscle foods which are incorporated with mushrooms , because it has fibrous structure which imitates the texture of meat and offers distinctive taste and flavor (Das et al , 2021) . Dried forms of mushrooms are also a key ingredient of packaged food products like instant soup, cup noodles, sauce , nuggets , biscuits , murraba and other snacks (Sufer et al, 2016) . For their great taste and incredible nutritional content, they are acknowledged as “super-food”.

There are many startups working on mushrooms to harness its goodness by making different products out of it. A California based startup FOUR SIGMATIC is working on drinking mushrooms like mushroom coffee & super blended food .They prepare Mushroom coffee by mixing Lion’s Mane and Chaga (https://us.foursigmatic.com). Another Company EMERGY FOOD startup is working on Mushroom to create plant based protein that have taste, texture and nutrition similar to animal derived meat and they are using mushrooms for this purpose. Their 1st product is ‘’Meati ‘’(https://meati.com) which is prepared in large tanks by fermentation process and harvested in a way similar to cheese making. MYCOVATION, a

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company established in Singapore (2020) aims at replacing animal proteins with mushrooms that will sustain our food system and make it affordable and healthier for vegans(https://www.mycovation.asia/) .

Table 1 : Nutritional value of various mushrooms .

Mushroom species	% of Carbohydrate	% of Fibre	% of Protein	% of Fat	% of Ash (%)	Energy in K Cal
Pleurotus sajor caju	63	48	19	2.70	6.32	412
Agaricus bisporus	46.17	20.90	33.48	3.10	5.70	499
Lentinula edodes	47.60	28.800	32.94	3.73	5.20	387
Vovarella volvaceae	54.80	5.50	37.50	2.60	1.10	305
Auricularia auricula	82.80	19.80	4.20	8.30	4.70	351
Flammulina velutipes	73.10	3.70	17.60	1.90	7.40	3.78
Calocybe indica	64.26	3.40	17.69	4.10	7.43	391

Source : Manikandan k ,2011

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B) *Medicinal and Therapeutic potential of Mushrooms :*

Many mushrooms have shown significant results in curing a number of diseases. Medicinal mushrooms such as reishi mushroom, shiitake mushroom, caterpillar mushroom , chaga mushroom , turkey tail and maitake possess antimicrobial, antidiabetic , antitumor , antiparasitic, immunostimulatory properties. *Agaricus bisporus* has the potential to defend the body against type 2 Diabetes. When the rat's body was treated with extract of *Agaricus bisporus* results that there is increase in insulin production with considerable decrease in glucose concentration (Ekowati et al. 2020) . Some polysaccharides like Mannogalactan , Fucomannogalactan , Fucogalacton can be derived from *Agaricus bisporus* which shows analgesic and anti-inflammatory properties (Komura et al.2010). Ganoderma is called ‘’King of Medicinal Mushrooms ‘ as it can be used to treat a number of diseases like cancer , diabetes , HIV AIDS . Reishi mushroom or *Ganoderma lucidum* is known to reduce free radical mechanisms and is also believed to diminish insomnia . It fortifies both the mind & body of a person . Several studies shows that *Ganoderma lucidum & Poria cocos* act as prebiotics which can promote growth of beneficial microbes in intestine .Drugs like Psilocybin and Psilocin can be extracted from *Psilocybe mexicana* used in treatment of mental disorders. Chaga mushroom contains Betulinic acid toxic to cancer cells and this mushroom also increases.

P – coumaric & cinnamic acids present in *Pleurotus* species , lentinan in *L.edodes* , ganoderol, ganoderma control & ganodermic acid in *G.lucidum* are some anti HIV substances and possess anti reverse transcription activities (Duru and Cayan, 2015;Lindequist et al. 2005) . There is ongoing Placebo controlled clinical trial , MACH-19 (Mushroom and Chinese Herbs for COVID -19) by University of California to assess 2 two mushrooms *Fomitopsis officinalis*(Agarikon) and *Trametes versicolor*(Turkeytail) (FoTv) in treatment of COVID -19 positive patients having mild to moderate symptoms .This study is expected to complete by December 1 , 2022. This trial was sanctioned by Food and Drug Administration (FDA) in which they are investigating how medicinal mushrooms can be used as complementary to COVID-19 vaccines. The 1st trial is studying the effect by combining two different mushrooms ; Turkeytail and Agarikon (Jamsnetwork.com) .

C) *Mushrooms as splendid gift for cosmetic industries :*

Over the most recent couple of years a great deal of consideration has been given to capability of mushrooms in treatment of skin . Different Skin products are being launched based on mushroom technology (refer table 2). Mushrooms are known to have anti-aging , anti-wrinkle,

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skin whitening , moisturizing , hair treatment and hyperpigmentation properties. Extract from Agaricus bisporus can be used to formulate shampoos because it contains vitamin D and minerals like Cu , Fe , Se which plays an important role in making hair strong and healthy (Wu and Choii , 2016) . *Agaricus bisporus* plays an important role in curing skin aging because ethanolic extract obtained from it exhibits strong antioxidant properties. In skin , the Melanin production is controlled by Tyrosinase enzyme. *Agaricus bisporus* contains bioactive compounds (2 – Amino – 3H – phenoxazin -3 - one) which inhibits the synthesis of melanin when utilized in specific concentration for example at 0.5 , 1 and 2 micrometer (Miyake et al , 2010). Kojic acid is a compound having anti- Tyrosinase activity that acts as a Tyrosinase inhibitor and is used commercially to inhibit melanin production . Hence it is known as Skin whitening agents (Alam et al. 2010). Mycellium extract obtained from *Tricholoma matsutake* (Pine mushroom) decreases the activity of the elastase enzyme and reduces the level of MMPs (Kim et al , 2014) . Reishi mushroom contains beta-glucans , a chain of antioxidant glucose molecules that can attract moisture from the environment to the skin and keeps the skin deeply hydrated *Agaricus bisporus ,L. edodes , P.ferulae and P.ostreatus* are rich in vitamin D2 (ergocalciferol), which plays significant role in protecting the skin's immune system (Morales et al.2017). When the experiment was conducted to study the antiwrinkle properties of culture broth of *Hygrophoropsis aurantiaca* through ROS–scavenging mechanism, procollagen production in HDF- N cells (Human primary dermal fibroblast – neonatal cells) and elastase inhibitory activities, it was seen that clitocybin A , an functioning compound secluded from this mushroom declines elastase action by 8.31% and invigorate procollagen synthesis capacity by 167.9% (Lee et al.2017) .

Table 2 : Mushrooms applied in cosmetic products.

Mushroom	**Product**	**Function/unique benefits**
Pleurotus ostreatus	Hankook Firming cream	Enhances elasticity and tightening of skin
Tremella fuciformis	Eminence organic skin-care product	Antioxidant, enhances elasticity
Polyporus umbellatus	Serum	Revitalization Of kin

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Schizophyllum commune	Alqvimia face cream	Skintone brightening agent
Lentinula edodes	Griffin skincare	, Skin brightening and anti inflammatory agent
Ganoderma lingzhi	Birch Water purifying Essence Shiseido: Ultimate Powder Infusing concentrate	Anti-aging and provides hydration to skin Anti-aging and anti-inflammatory properties

Source : (Sujarit et al. 2021).

(D) *Mushroom based leather : a sustainable substitute for animal skin.*

Leather is a well-known material used in the field of clothing , footwears , accessories and furniture. Raw material for leather is animal skin .Leather industries around the world slaughters around more than billion animals per year. Rearing animals for skin (raw material) may take 3 years to produce a fragment of leather . Leathers are tanned and processed under several conditions which release toxic chemicals and lead to greenhouse gases emissions . One of the sustainable alternatives to animal skin is mushroom based leather. Watch straps produced from mushroom leather are preventive against skin annoyance due to eczema . The cost of raw material associated with fungi leather is lower than synthetic and bovine leather and the production process is not much complicated as only basic understanding of mycology is needed . Water required for mushroom leather processing is upto 99% less as compared to animal leather.

With the constantly evolving technologies , the leather alternative is expected to have an extraordinary market in future . In current times , the mycelium obtained from oyster mushrooms are used in vegan leather production. But there are some companies who are working on new species of mushroom for leather production. For example MuSkin is one of the innovative materials that can be made from *Phellinus ellipsoideus*, a large parasitic fungus that attaches itself to trees and can be found in subtropical forests. Another company MycoWorks is using mycelium of *Ganoderma lucidum* which gives a very similar texture to animal skin. Bolt

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Threads is also a big company that is testing several types of fungi for leather production .Mylo is their most popular leather alternative till now. In march 2021 , a French luxury brand Hermes produced a new version of their Victoria bag by using mushrooms. Name of this mushroom leather is Sylvania

(https://www.veganfirst.com).Adidas in partnership with Bolt Threads produced Stan smith biodegradable shoes (www.smithsonianmag.com).

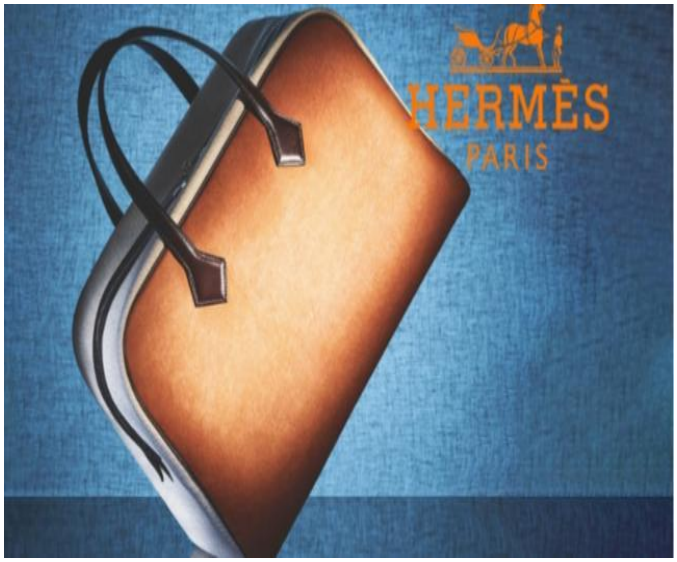

Fig 1 : Products Prepared from mushroom leather

Source : https://www.veganfirst.com. Source : https://www.designboom.com

(E) Novel application of Mushroom derived mycelium in designing and architecture

Nowadays , architects are focusing on the potential of mushrooms to be utilized as designing and building material . Cell wall of fungus comprised of chitin which is made out of N – acetylglucosamine units which is also present in up in insect's exoskeleton. (Jones et al. 2017) . Chitin have nanofibrils tensile strength between 1.6 and 3GPa because of strong hydrogen bonding and high dipole moment between macromolecules. This property provides primary support to the cells of fungus that architecture has displayed (Jones et al. 2020) . Mushroom

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materials are naturally fire resistant and can be easily molded to any shape as they have high durability . Mycelium composites of mushrooms have been employed in making buildings using mycelia of the mushrooms as a building material. Mycelium composites were produced by mixing mycelium with farm substrates such as rice hulls, walnut shells (Yang , 2020) .The mushroom spores are added to a nutrient medium which is then put into molds to get shaped. The composites are then demoulded and units are formed in order to form a structure (Dahmen , 2017) .

The potential of mycelium as building material is shown in a number of architectures like MycoTree, Hy-Fy , Shell mycelium etc. Architect named Dirk Hebel designed a Mycotree (Fig 2, c),a tree like installation prepared from mycelium based composites with addition of sugarcane and cassava root waste to show how mycelium can be utilized to make self supporting designing structures (Fearson , 2019) . While another organization The Living principal head David Benjamin designed a 40 – foot Hy – Fi tower (Fig 2, d) and installed it at MoMa (Museum of modern art) PS1 , Newyork in 2014 to demonstrate the potential of mushroom bricks by using mycelium grown on agriculture waste (Fearson , 2019) . Ecovative , a startup company, is dedicated to providing mycelium based bricks for tower projects . Pascal Leboucq in collaboration with Erik Klarenbeek prepared a Growing pavilion (Fig 2 ,a) produced by using bio-based materials and it was featured at Dutch design week. Its outer panels were made up of mycelium . During design week , This mushrooms growing were collected and used for cooking purposes (Pownall , 2019) Designer Eric Klarenbeek prepared and printed a chair (fig 2, b) by using powdered straw and mycelium to show that machine and nature can be brought together to create a new material (Yang , 2020).

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Fig 2 : Mushroom based building materials .

a)Source : (Pownhall, 2019)

b) Source : (Yang, 2020)

c)Source: (Fearson, 2019)

d) Source : (Fearson,2019)

E)Mycoremediation - A sustainable approach in Solid waste management:

The most prominent environmental dilemma encountered by the planet now is the deterioration of soil because of industrialization and unlimited utilization of chemical fertilizers in agriculture. A suitable and cost-effective method of treating polluted soil is "mycoremediation," which allows mushrooms to deteriorate lethal pollutants. The mushrooms species like *Agaricus bisporus*, *Pleurotus ostreatus*, *P. tuberregium*, *P. ostreatus*, *P. pulmonarius Phanerochaete*

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chrysosporium and *Trametes versicolor* are suitable for bioremediation of contaminated soil is (Malik et al. 2021) . Mushrooms can degrade various forms of pollutants , agricultural wastes , heavy metals because of extracellular stimulants they possess as described in Table 3. They have potential to change the waste into organic matter and into the food of prime quality and texture .

A study published in Biotechnology Reports in 2020 found that mycoremediation of agricultural wastes like pesticides, cyanotoxins and herbicides is more cost effective and eco friendly (Gallagher, 2021) Scientists have discovered many species of microorganisms that can assume a significant role in ridding the planet of plastic. The mycelium of *Psetalotiopsia microspora* has the ability to eat plastic products as its primary food source. This mushroom species can even survive at the bottom of heavy landfills . Researchers have now observed that there are numerous species which are fit for plastic bioremediation including the consumable Oyster mushroom. Mushrooms produce some enzymes like lignin peroxidase , manganese peroxidase and by releasing these enzymes it penetrates , breaks and digests or mineralizes harmful substances present in waste material. When mushroom mycelium is exposed to cadmium , copper , lead ,mercury and zinc , there is increase in production of laccase enzyme which can decolorizes and ingest the heavy metals (Jebapriya, 2013).

Table 3 : Stimulants released by mushrooms for degradation of contaminants.

S.No.	**Name of Contaminant**	**Stimulants released**	**Mushrooms involved**
1.	2,4-Dichlorophenol	Ligninolytic stimulants-develop vanillin	*Lentinula edodes*
2.	Crude oil	Ligninolytic stimulants	*Pleurotus tuber-regium* and *Pleurotus pulmonarius*
3.	Plastics	Lignocellulolytic stimulants	*Pleurotus ostreatus*
4.	Malachite green	Enzymatic degeneration and biosorption	*Schizophyllum commune*, *Polyporus sp.*, *Auricularia sp.*

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5.	Green polyethylene	Laccase	*Pleurotus ostreatus*
6.	Polycyclic aromatic hydrocarbons	Manganese peroxidase , lignin peroxidase, laccase.	*Coriolus versicolor*

Source: Das et al. 2021

From 2010 to 2020, the global plastic production was expanded from 270 MMT to 370 MMT . It is estimated that the global production of plastic in 2025 would be 445.25 MMT. Therefore, the efficient management of plastic waste should be conducted and mushrooms are discovered to be of big aid in reducing plastic waste without oxygen and can be used for cleaning up landfills .

Fungi Mutarium – It is a system invented by Katharina Unger of Utrecht University . She used two species: Schizophyllum Commune and Pleurotus Ostreatus. Mushrooms are cultivated in specially designed capsules shaped known as FU. Agar is mixed with starch and sugar provided to the mushroom for its nutrient requirement. The plastic is then filled in the capsules and mushrooms will utilize it as food for its growth. At the end Mushrooms will grow and can be used for edible purposes. If this system is used on a large scale , it will reduce plastic pollution and also people will get mushrooms as a food source (https://katharinaunger.com/fungi-mutarium) .

Fig 3: Fungi Mutarium System developed by Katharina Unger.

Source : (https://katharinaunger.com/fungi-mutarium)

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F) *Efficient way of recycling spent mushroom substrate for fuel generation and yield enhancement*

Spent mushroom substrate is characterized as extra biomass generated after production and harvesting of mushrooms. Substrates of tremendous quantity is additionally expanding. 1 kg of mushrooms brings out the production of 4 to 5 kg of SMS . It is expected that its generation from commercially edible fungus is probably to surpass 110 billion tonnes in future(Mahari et al. 2020). The management of such a quantity of SMS has become a new challenge since random discard would prompt ecological issues like water and soil contamination. Therefore efficient techniques for retrieving and using SMS are very necessary . SMS can be used in a number of ways , for example in improving agriculture fertility, casing soil , biofuel production etc.

Production of Biofuel from SMS :

Production of biogas in the mushroom farm using SMS and animal manure produced nearby is eco-friendly and will offset the use of fossil fuel and benefit the environment by reducing greenhouse gas emissions. SMS have lignocellulosic compounds which are suitable for pyrolysis, gasification and torrefaction (Alves, 2021). Shiitake mushrooms grown on birch can be used for production fermentable sugars through enzymatic saccharification process (Chen et al. 2020) . It was depicted that Bio -coke can be produced from SMS of Pleurotus species at temperature of 130 – 190 degree Celsius and it is more economical and profitable than other fuels (Baharin et al. 2020). It has a longer combustion period and high mechanical strength. Produced Biocoke can be potentially utilized as a source of fuel for boilers to produce steam for substrate warming and pasteurization of mushroom ranches (Baharin et al. 2020). Smartmushroom, an EU supported project has developed a process by which biogas can be generated from fresh SMS to dry a mixture of digestate and conversion of SMS into pelletised fertilizer. Their new methanogenic technique was hydrolysis followed by anaerobic digestion . Biogas produced from this process facilitates the drying process and water removal from SMS . The dried SMS is further enriched with NPK fertilizers and converted into pellets .

Role of SMS in enhancing agricultural yield:

Due to high cation exchange capacity and slow mineralization and major minerals like calcium, nitrogen, phosphorus and protein SMS plays a key role in Adding soil organic matter and nutritional content in soil (Zhu et al. 2012). It contains 1.3 – 4.2 % N , 0.1 – 0.4 % P , 0.5 – 1.8 %

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K, 0.05 – 0.2% Na , 0.2 – 0.4% Mg(Jasinska, 2018). Spent mushroom substrate of Pleurotus spp. has been assessed in interplantings with cabbage and lettuce (Muchena eta al . 2021). In a recent experiment , it was proved that yield of baby spinach increments with expansion in application of SMS of button mushroom (Muchena et al. 2021) . *Agaricus bisporus* spent substrates have proved to be effective against zinc toxicity of soil , mining contaminated soil, and treatment of hazardous waste (Rinker , 2017) . *Agaricus bisporus* spent mushroom compost have been examined against different plant diseases including damping off disease in tomatoes , apple scab , dry bubble disease in commercial mushrooms , stem necrosis in chilies and root knot nematodes (Rinker , 2017) . A.bisporus spent substrate is additionally used to grow numerous vegetables including , cauliflower, cucumber onion , potato , radish , spinach , tomato , capsicum, lettuce , asparagus etc.

G) Other applications :

Mushrooms in making dyes : Extraction of dyes from mushrooms is a safer , cheaper and eco- friendly method than other expensive and hazardous chemically synthesized dyes (Mandlik and Hedawoo, 2020). The number of mushrooms are being identified for making dyes as shown in fig .including *Phaeolus schweinitzii* , *Hydnellum aurantiacum* , *Hydnellum spongiosipes* ,*Phellodon alboniger* , *Cortinarius semisanguineus* , *Cortinarius sanguineus* (https://namyco.org). *Phaeolus schweinitzii* commonly known as Dyer's polypore can create a beautiful range of colors from yellow to green to orange to brown depending on its life stage (bloomanddye.com). When it is cooked with alum - mordanted wool in 1:1 ,it would give a bright yellow or golden color. *Halophiles' nidulans* , a little wood decaying polypore grows on oak and birch commonly found in Scandinavia and northeastern North America . It gives a shade of purple color when utilized in 1:2 of dry mushroom to wool using alum mordanted wool. *Inonotus hispidus* is a huge yearly polypore grows on oak in North America , when it is at its mid age , it will give a strong burnt orange color to wool (https://namyco.org). Grey-green dye can be extracted from grey oyster mushrooms (Pleurotus ostreatus) and Shaggy pink cap (*Coprinus comatus*) . Brown dye from Dye ball (*Pisolithus tinctorius*) and Turkey tail (*Trametes versicolor*) . *Ganoderma lucidum* is a source of Rusty dye , *Calvatia cyathifor*mis of rust red dye and *Agaricus campestris* produce yellow tan color (Mandlik and Hedawoo , 2020).

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Fig 5 : Dyes extracted from different mushroom species.

Source : https//:bloomanddye.com

II) Mushrooms in footwear industry:

Another unique use of mushroom leather is in the footwear industry. Shoes built from mushrooms have become a trend because they are biodegradable and gentle to the environment. Certain types of shoes are often called "vegan shoes". Renowned footwear companies like Adidas have also launched vegan shoes which are mycelium developed leather .These shoes can assist in diminishing environmental waste by replacing harmful footwear making material. Shoe sole composed of mycelium will not be a part of landfills and will provide nutrients back to the soil which will be supportive for natural metabolism. A Brand named ZVNDER which prepare mushroom leather embellishments has intrigued with Nat-2 for Making vegan shoes (https://designboom.com).

Conclusion:

There is a great deal of fervor in advancement of new and value-added items from Mushrooms. The versatile nature of mushrooms shows the potential of fungi in replacing a number of resources. Mushrooms can assist in fulfilling human demands and can be a sustainable approach for maintaining a healthy environment. The applications of mushrooms in various fields of economy like architecture, medicine, replacing plastic, bioremediation, fuel generation , dying

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and textile industries etc. makes it an excellent choice for executing several processes. Recent work has exhibited the sufficient chances in improvement of novel advances from mushrooms. Future work should focus on studying the properties of mushrooms more extensively and more potential applications of mushrooms should be discovered to support mankind.

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