JOURNAL OF CRITICAL REVIEWS

ISSN-2394-5125 VOL 11, ISSUE 01, 2024

BENEFITS OF MUSHROOMS FOR THE ENVIRONMENT AND HUMANS

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Abstract
Mushrooms are popular for their taste and flavor as a food. It is well established that they are excellent sources of nutrients and bioactive compounds. They are also known for their medicinal properties. Mushrooms demonstrate great impact on environment as well as on agriculture. They have been explored not only for their medicinal and edible uses, but also as sustainable materials and its applications in other fields and for their ecological importance. Many benefits of human welfare are associated with mushroom cultivation. An increasing number of the eco-friendly entrepreneurs are looking at mushroom fungi as an eco-friendly material for buildings as well as the textile industry. Present review highlights it's ecological and economical importance and as an emerging sustainable material for many uses.

Keywords: Mushroom cultivation, environmental impacts, biodegradable fibers, waste recycling, agro-industrial residues, bio-remediation and biodegradation, MycoTex.

I. Introduction

Mushrooms are considered as one of the most remarkable invisible organism of the Earth. They mostly expand underground thus creating a web connecting entire global ecosystem and considered vital for cycle of life [1, 2]. No doubt, fungi kingdom played the critical role during evolution of life previously [3]. Even today no one can ignore its important place in the ecosystem. They are known to degrade almost everything in the atmosphere. They consume some of the most hazardous pollutant and make entirely new material from it [2, 4]. They are remarkable and exceptional in themselves in many ways. What they are actually? They are known for their underground existence (Figure 1.). They are reproductive structure of fungi, taken as a food, grow on rotten veggies and very common in the forest. They have their own realm different from animals and plants. However, the mushroom we see on the surface is the only fruit of something vaster present in the underground. The real growth happens beneath the surface where mycelium form root like web of the fungi. It is largest grown organism on the plant. There are reports from Oregon (USA) that mycelium of 'humongous fungus' spread through the area of 9 km^2 and estimated to be 8650 years old. '*Armillaria ostoyae'* (Honey fungus) hold the title for world's largest organism [5]. They are considered biggest even than blue whale (Largest animal) [6]. It contains massive underground filament. In 1998, this fungus was discovered when an enormous tree died in Oregon forest. They have high adaptability to any environment [4]. As we know their restricted life over billion years ago and with evolution this group become pioneer. They excavate nutrient from the rocks and distribute to the plants thus assist them to grow and produce life essential gas oxygen making lives possible today. After million years these minute forms expand into huge forms. In Arab Peninsula (Arabia), archeologist found fossils that was thought to be tree initially. Later, it turned out an eight-meter mushroom that grew 500 million years ago [7].
Many benefits associated with mushrooms are-

II. Role in soil conservation

They play an important role to keep soil healthy and known for their astonishing capabilities. They maintain carbon stock of the soil and help to maintain carbon cycle through food web of the soil [2]. As they form the association with plants so play role in soil carbon segregation and store them in the soil therefore, improves soil fertility. Studies on them indicate that they arrest almost 10 tons of CO_2 per year [8]. Fungi which produce mushrooms are critically important in different ecosystems as they provide life sustaining minerals and nutrients to plants and recycling throughout the biome as they grow and reproduce. Many ecologists are realizing now that mushrooms really run the world. We are mostly focused on things which are visible. But plants are closely associated with them and wouldn't be there without them. In fact, diversity and composition in a place really reflect what happens there ecologically, both in terms of plant composition and productivity. Fungi below ground is actually driving force of many things that we actually care start off in the ground [7].

III. Environmental protection

ISSN-2394-5125 VOL 11, ISSUE 01, 2024

As we know that many forms of mushrooms help in the degradation of a living things which have more complex organic make up. Therefore, they are also capable to breakdown any organic pollutant present in the environment. Several studies on different species like *Pleurotus tuber-regium* (PTR), *Pleurotus pulmonarius*, *Lentinus squarrosulus* have shown that they are capable of clearing the land of oil pollution [9]. Almost 44000 oil fields are known to be contaminated due to leakage and illegal extraction worldwide [10]. Wide range of pollutants are found in fuel and crude oils. One of the most vicious pollutant is PAH (Polycyclic aromatic hydrocarbon). It is known to be harmful for flora and fauna and known for its cancerous activities in humans and animals. All the organic pollutants like fuel oils derives from the dead organic matter. So these fungal species degrade them with the same enzyme which are known to degrade the wood and leaves. So it is helpful to degrade the contaminants and convert them into less harmful compounds so that they can enter back into nutrient cycle. Sometime, degradation may result into CO_2 and water. Addition of mushroom to degrade the pollutants in contaminated area is a very promising route [10, 11]. But it doesn't end with organic matter. As mushroom species are known to reduce the metal toxicity they can be used to treat the soil contaminated with metals like Arsenic, Lead and Mercury from mining [12, 13 14].

IV. Degradation of radiation

They are also used to treat radioactive elements [15]. In 1986, a nuclear reactor in Chernobyl was lapse and resulted spread of radioactive contamination due to explosion. Therefore, making surrounding areas uninhabitable till now. Mushrooms were first discovered on the wall of reactor in 1991 (five years after Chernobyl disaster). They were named as radiation fed mushrooms [*Cryptococcus neoformans*] with high amount of melanin pigment [16]. Melanin pigment is known for absorbing light and distributing UV rays. This radio trophic fungi use radiation as an energy source. In another trial near the nuclear reactor, mycelium with host sunflower plants were used. Studies have shown that sunflower have capability to take radioactive substance. Therefore taken up half of the radioactive substances like Strontium were taken up in the 12 weeks of growth [17]. Later contaminated plants were burned and ashes containing Strontium was stored safely. The significant radioactivity free soil was observed. Mycelium actually assist in mobility of the elements either by fixing them in the soil by absorbing itself or helping plants to take them up. In another study it was shown that mushrooms accumulate 40 times more Nickel and Cobalt than the soil in the sample taken from Russian Industrial site [18]. So it might be solution to treat heavily polluted soil. Treating soil with fungus could be one of the promising alternative. It is convenient to treat the soil of small area as it is environment friendly and economical even better than conventional methods like removing and burning. But for large area like entire forest or mining regions, it is not feasible. Moreover, every ecosystem have its own characteristics. It's not necessary that external fungi grow in them. Encouraging local species can be alternative of it.

V. Mushroom in plastic degradation

A recent study has shown that human have produced 8300 million metric tons of plastic till date. It does not decompose, therefore all plastic produced accumulated in environment and present there in different forms. It is 25000 times more than the weight of Empire building [19]. 79% of that plastic ended up in landfill or in ocean. Plastic contaminant are showing up in the drinking water worldwide wiping out and causing illness including in human [20, 53]. Even now for the first time, plastic traces reported in human blood [21]. According to one study published in Journal of Environment International in 22 anonymous samples 80% people had plastic particle in their blood. Source to enter the plastic in a blood could be air, food and drink [22]. In 2011, a group of research students of Yale University under the guidance of Professor Scott Strobel discovered the mushroom variety *Pestalotiopsis microspore* in Amazon rainforest. They found fungi is capable of surviving just eating the plastic (Table 1). It can convert polyurethane into organic matter [23]. They can survive without oxygen and are found to be perfect creation to degrade the plastic. Later many other species like Oyster were discovered for their plastic degrading capabilities [24,54,55,56]. Another variety of mushroom i.e. *Asperigillus tubingenesis* was identified in 2017 that eat plastic and break them into small pieces [25,57]. It is grown on the surface of plastic where it secretes enzymes that break the chemical bond between plastic molecules.

VI. Sustainable materials to make the bricks

No doubt mushroom fungi can degrade any organic material from agriculture and food industry. This power to degrade can be used to build the blocks of our future buildings i.e. homemade up of mushroom. It's not about the mouldy walls. It may sound odd but, it's true. In 2014, twelve meter tower by height was made by architectural team 'The Living' [27]. Instead of using stone, bricks or concrete they used special type of 10000 mycelium bricks. These bricks were inexpensive and can be grown and created in almost any conditions. To prepare them, no specialized equipment is needed. David Benjamin (Associate Professor in Architecture department) from Columbia University headed the project on it. Studies have shown that production of concrete and steel for construction are responsible for carbon dioxide emission worldwide which is almost 10% [27]. Apart from it, construction industry is facing sand shortage [28]. On the other hand, crop remains are often burned all around the world. In Delhi for example crop residue is burned which result increase in pollution [29]. Using crop residue in useful construction can be an alternative to it. Instead of wasting, it can be used to create solid organic brick from creating a new and low priced carbon building construction material [30]. It is non-fireproof and its cushioning properties are exceptionally good. Quality wise it is equivalent to

ISSN-2394-5125 VOL 11, ISSUE 01, 2024

concrete material as well as those of polystyrene and plastic, In case of project headed by Professor Benjamin, bricks later destroyed after destruction of the house. The bricks were not as firm concrete [31]. However, when mycelium was mixed with replaceable material like bamboo and constructing a skeleton to spread pressure uniformly scientists from University of Karlsruhe appeared that concrete's superiority can be reduced [32]. One of the drawback with mycelium brick is its ability to last for long as it have capability to absorb moisture in case it is damaged [31]. That mean to make it practical approach for housing, new techniques are needed to protect it from the moisture. The idea of fungus to make a house, is still in early stage, but the potential is huge. Apart from architectural structure, mycelium can be also used for thermal and auditory insulation [33, 34]. We know that mushroom contain long thread like material in them. These thread like white filament develop and for complex web. Mycelium have capacity to for glue and cement the material, when it is installed in a suitable place with the substrate. Different substrates composed of straw, sawdust, ground wood and agricultural waste can be used which otherwise get wasted. So using different mycelium strain and substrate, we can use them to make many things like insulating panels, furniture, accessories, thermal and acoustic material. Many studies have shown that mycelium made material resemble with polystyrene in terms of physical and mechanical characteristics but with biodegradable properties [35, 36.] Evocative Design Biomaterial Company headquartered in New York focused on the development of innovative material that provides, sustainable alternative to plastic for packaging and building materials by using mushroom technology [37]. Evocative used these unconventional materials to produce objects used in wrapping. During this process substrate is mixed with mushroom mycelium in a solution than added in the container. Within five days material get modified if supplemented with suitable temperature, moisture and light. High temperature treatment to it, demilitarize the microbes completely if existing therefore permitting it to be used as good quality wrapping material [36].

VII. Architectural structure made up of mushrooms

One of the architectural structure made up of mushrooms was developed by the Carlo Ratti Association in partnership with the energy company Eni and demonstrated in exhibition at Milan Design Week, 2019 [38]. This circular garden was consist of series of dome shaped structure composed of almost one kilometer in the length. They added the mushroom spores of mycelium into organic material and allowed it to grow further. This was an experiment with a sustainable structure that allowed to increase in size organically and then get back to nature in a ring shaped structure. However now some of the mushroom based mycelium products are available commercially in the market, still it is a new production method. Lot of research is needed to improve it and make stronger [39]. The main reason for switching to it is: 1. It can be produced anywhere with organic waste. 2. Grows fast. 3. It doesn't need soil to prepare it.. Ecovative has also created Mycoflex foam which is 100 % compostable and can be used in anything from makeup sponge to single-use slippers and masks [40]. Researchers are still figuring out new ways to use the mycelium.

VIII. Mushroom in textile industry

Mycelium used in textiles is known as Mycelium textile or MycoTEX [41]. Mushrooms obtained from mushrooms and mycelium has a leather-like texture. The transition from growing them to producing a fabric has involved a lot of trial and error. This fabric is biodegradable by nature. Although mushroom textile for clothing is in its initial stage, the future of it is bright. It is already used in clothing, bags and even durable furniture. First mushroom made clothing was started by Stella McCartney using mylo in 2016, but she did not make her debut. Mycelium can be dyed into any color it is Carbon negative. Fabric made by mushroom mycelium is harmless, nonflammable with soft texture. Both thin sheets as well as thick forms are used [42]. Both forms are flexible and strong. The process of making mushroom leather has an advantage over animal leather as less water is needed. The mushroom leather was made by different methods but still there are lot of scope to improve it [41]. Leather made by mushroom is natural and free from any chemical and colored by velvety exterior. It has high absorbing, antibacterial and antiseptic properties. It is better than animal leather as less pollution is created, no killing of animals is required, mushroom leather needs less resources, it can be used again and again, less time is needed to grow it, and leather is good in quality. This eco-friendly mushroom fiber has some unique properties that are not found in sustainable fiber. Clothing made from this fiber is very thin, flexible and comfortable. The fabric is strong, breathable and durable [41]. It is possible to make various things like caps, dresses, bags and jackets by processing the fibre ingredient of mushrooms. However, due to low production, the price remains high. The possibilities of mushroom leather are unlimited. Still, mushroom leather is perhaps quite a new material. It will take time to gain acceptance and fame.

IX. The unexploited potential of Mushrooms

They can be used as herbicides [43]. Growing little known entophytic fungi inside the plants protects them against disease and does not damage the plants. The mycorhizal fungi play a significant role in restoration of degraded lands [8, 44]. Degrade toxic pesticides [48]. Mushroom mycelium is capable of filtering wastewater [45]. Because of these beneficial attributes, conversion of wasteland into green plantations is possible in some cases. Species like *Aleurodiscus, Clitocybe, Maraminus, Polyporus, Tricholoma* and contain poly acetylene are known for their antibacterial effect. *Lantinus edodes, Cortenellin, Coprinus comatus, Oudemansiella mucida* show anti-fungal effects. *Omphalotus olearius* active against *Plasmodium gallinaeum* has anti-protozoal an effect.

ISSN-2394-5125 VOL 11, ISSUE 01, 2024

X. Importance of Mushroom as fire starter (Tinder fungi)

Archaeological evidence reveals that at least 7000 years ago humans were using several dried tree fungi, for their fire starting properties. Fire was an essential element of early human evolution. Not only for cooking and heating, but also in various social rituals. Tinder fungus is a polypore and decaying fungus living on deciduous and dead trees. It has a hoof like a hard perennial fruit body. Its upper surface looks zone like grey or brown in colour. The lower surface called the pore layer, is dirty white or purple in colour. The spores are released when the outer shell is damaged. They attach themselves to the host tree. It grows commonly on Betula (Birch) or Alnus (Alders) spp. Tinder fungus has been used for thousands of years as kindling for fire [46]. In folk medicine, it has been used to treat various pains [47]. It forms white rot and decays wood quite quickly. They are also known as serious tree pathogens.

XI. Importance of mushrooms as a natural dye and writing material

There are a large number of mushrooms that produce dye and how you actually get them to produce the dye is different from mushroom to mushroom. *Gomphus floccosus* (scaly vase) is a mushroom that appears not to produce any dye, even after soaking the fiber in the mushrooms overnight. In the presence of iron (mordant), fibre turns into a purple color [48]. *Phaeolus schweinitzii* a fungal pathogen known to cause butt rot in conifers. One of the best mushrooms for color is also known as "the dyer's polypore"[49]. It is used to get different color of the dye like green, gold and brown with mordant. From ancient time humans were interested in writing. For that purpose they tried various materials like mushrooms, plants, minerals even squid. Shaggy ink cap [*Coprinus comatus*] is known to cover with fluffy scales, resembling a lawyer's wig. Commonly it is eaten but if kept for long time they turn black and start secretions. Actually by this process it releases its spores and starts a new round of life cycle [50].

XII. Conclusion

Mushrooms are known for various nutrients as well as medicinal properties. Bioactive compounds in them are reported to exhibit immunomodulation properties [51]. Mushroom cultivation is economical as it is grown on inexpensive agricultural or forest waste [52]. Mushrooms are a tremendous boon to the idea of using several processes as a real world solution. They are discovered over a long time, but they are still not explored well. Mushroom cultivation is one of the best alternative for environmental remediation with lost cost investment. In-depth studies are needed to explore the prospective and ecology of large number of edible mushrooms. The research related to its biotechnological application is still in its infancy stage. Production of new cultivars with modified traits will provide a boost for many industries, like textiles and their antipollution activities. Many limitations which need to work out to take the benefit of its applications in several fields. Mycoremediation through mushroom cultivation will alleviate major problems like waste accumulation and oil spoilage. Thus, there is a need for further research towards the exploitation of the potential of mushrooms in several fields. Another field is mushroom fiber and it's potential for textile performance. However, it is in the initial challenging stage. As fiber is made of completely organic ingredients without using any chemicals. With proper research and studies, the expected results of this fiber can be achieved. According to studies in the United States, even fashion industry is known to emit the carbon which contribute 10% of it and 20% of global wastewater [46]. So studies are needed to find sustainable and eco-friendly alternative functions. There are few reports on its plastic degrading capabilities. As known for its plastic degrading capabilities still many things are needed to explore. Detailed research should be done to utilize its biotechnological applications for plastic waste decomposition.

Author's Contribution: RJ and PG prepared Figure and Tables; KBN, JM, KB and RJ drafted manuscript; KBN and KB edited the manuscript and approved the final version of the manuscript.

Funding Information: This study is not funded by any funding agency.

References:

1. 1 Anne Bhambri, Malay Srivastava, Vivek G Mahale, Sushma Mahale, Santosh Kumar Karn. Mushrooms as potential Sources of active metabolites and medicine. Front Microbial, 2022, 13, 837266
2. Hassan Tagab WI Ramady, Neama Abdalla,, Zakaria Fouad, Khandsuren Badgar. Green biotechnology of Oyster mushroom (*Pleurotus ostreatus*): A sustainable strategy for Mycoremediation and Bio-fermentation, Sustainability, 2022, 14, 6, 3667
3. Miguel A Naranjo-Ortiz Toni Gabaldon. Fungal evolution: Major ecological adaptation and evolutionary transitions, Biol Rev Camb Philos Soc., 2019,94,4, 1443-1476
4. Weldesemayat Gorems Woldemariam, Mushroom in the Bio-remediation of waste from soil, Advances in Life Sciences and Technology, 2019, 201976, 41-47
5. Linh Anh Cat. The Largest organism in the world is not what you think It is, 2019, Forbes http://www.forbes.com/sites/linhanhcat/2019/02/22/largest-organism-in-the-world/

6. Craig L Schmitt, Michael L Tatum. The Malheur National Forest –Location of the World's Largest Living Organism [The Humongous Fungus], 2008, United States Department of Apiculture 1-8
7. Francis M Hueber Rotted wood-algae-fungus: The history and Life of Prototaxites Dawson 1859, Review of Palaeobotany and Palynology, 2001, 116,123-158,
8. Sardar Singh Kakraliya Economic importance of Mushroom and their uses, Just Agriculture. 2020, 1, 3, http://justagricultural.in
9. Shweta Kulshreshtha, Nupur Mathur, Pradeep Bhatnagar, Mushroom as a product and their role in mycoremediation, AMB express, 2014,1,4,29
10. Farzaneh Roshandel, Saadatmand S, Iranbakhsh A, Ardebili ZO Mycoremediation of oil contaminant by *Pleurotus florida* in liquid culture, Fungal biology, 2021 125,9,667-678 http://doi.org/10.1016/j.funbioahderijani2021.04.002
11. M.M. Mohammadi-Sichani, M.Mazaheri Assadi, A. Farazmand, M.Kianirad, AM Ahadi, H. Hadian Ghahderijani. Bioremediation of soil contaminated crude oil by *Agaricomycetes*, J Environ Health Sci Eng, 2017, 15,8
12. Fereshteh Mohamadhasani, Rahimi M, Growth response and mycoremediation of heavy metals by fungus Pleurotus sp, Scientific Reports, 2022, 12, 19947
13. ET Ogbomida ET, Omofonmwan K, Aganmwonyi I, Fasipe IP, Enuneku A, Ezemonye LIN. Bioactive profiling and therapeutic potential of mushroom (*Pleurotus tuberregium*) extract on Wistar albino rats (*Ratus norvegicus*) exposed to arsenic and Chromium toxicity. Toxicol. Rep. 2018 ,15,5,401-410
14. Huma Vaseem An ecofriendly approach to decontaminate toxic metals from coal washery effluent using the mushroom *Pleurotus ostreatus*, N Applied Sciences, 2020, 2,1588
15. Makiko Orita, Yuko Kimura, Yasuyuki Taira, Toshiki Fukuda, Jumpei Takahashi, Oleksandr Gutevych, Serghii Chornyl, Takashi Kudo, Shunichi Y, Noboru T. Activities concentration of radio cesium in wild mushroom collected in Ukraine 30 years after the Chernobyl power plant accident, Peer J, 2018, 6, 4222
16. Mihai Andrei. This Chronobyl fungus thrives in radioactivity and eats radiation, 2023, Environment, http://www.zmesience.com/ecology/chrnobyl-fungus-radiotrophic-08122011
17. Alexandra de Castro. Sunflowers, Cleaners of Nuclear Disasters, United Academics Magazine, 2022, http://www.ua-magazine.com/2022/03/27/sunflowers-cleaners-of-nuclear-disasters/#
18. Martin D Hasen, Therese H Nost, Eldjorg S H, Anita E, Alexey AD, Arja R, Paivi M, Eugenia VD, Marta J, Guttorm NC, Erik EA, Magritt B, Torkjel . The impact of a Nickel-Copper Smelter on concentration of Toxic elements in local wild food from the Norwegian, Finnish and Rusian border region, International Journal of Environment Research and Public Health, 2017,14,7,694
19. John McKenna. Picture this: all the plastic we have produced weighs the same as 25000 Empire State Building, Wold Economic Forum, 2017, http://www.weforum.org/agenda/2017/07.picture-this-all-the-plastic-we-have-produced-weighs-the-sa...
20. Isabella G, Francesco B, Tiziana G, Alessanda P, Antonella De D. Occurrence of micro plastic in Tap and Bottled water: Current knowledge, Int.J. Environ Res Public Health, 2022, 19, 9, 5283
21. Damian Carrington. Micro plastics found in human blood for the first time, The Guardian, 2022, http://www.theguardian.com/environment/2022/mar/24/microplastics-found-in-human-blood-for-the-first-time
22. Heather A Leslie, Martin JM van velzen, Sicco H. B, A Dick V, Juan J Garcia-Vallejo, Marja H. L Discovery and quantification of plastic particle pollution in human blood, Environment International, 2022, 163,107199
23. Jonathan R.Russel, Jeffrey H, Pria Anand, Kaury Kucera, Amanda G Sandoval, Kathleen W Dantzler, DaShawn Hickman, Scott A Strobei. Biodegradation of Polyester Polyurethane by Endophytic Fungi. Appl. Environ Microbial, 2011, 77, 17,6076-6084
24. JM Rodrigues da luz, Sirlaine AP, Karla VGR, Igor RM, Maria CMK. Degradation of Green Polethylene by *Pleurotus ostreatus*, PLoS ONE,2015, 10,6 , e0126047
25. Sehroon Khan, Sadia N, Zia U S, Aamer AS, Samantha CK, Jianchu Xu, Afsar K, Shazad M. Biodegradable of polyester polyurethane by *Aspergillus tubingesis.*Environmental pollution, 2017, 225, 469-480
26. Eduardo Souza. Mushroom Buildings? The possibilities of using mycelium in Architecture 2020 http://www.archdaily.com/949007/mushroom-buildings-the-possibilities-of-using-mycelium-in-architecture
27. Rana Ghoneim, Gokce M, Anthony H. Steel and cement can derive the decade of action on climate change. This is how. Newsletter, 2022, Industrial Analtytics platform. http://iap.unido.org/article/steel-and-cement-can-drive-decade-action-climate-change-how
28. Sam Meredith. A sand shortage? The world is running out of a crucial-but under-appreciated-commodity,2021 http://www.cnbc.com/2021/03/05/sand-shortage-the-world-is-running-0ut-of-a-crucial-commodity.html
29. Lan R, Eastham SD, Liu T, Norford LK, Barett SRH. Air quality impacts of crop residue burning in India and mitigation alternatives Nat Commun,2022,13,6537
30. IIvy Bonnefin Emerging material: Mycelium brick, Development of Bio-fabricated materials in the construction industry 2022 http://www.certifiedenergy.com.au/emerging-materials/emerging-mareials-mycelium
31. Digafe Alemu, Meslin Tafesse and Ajoy Kanti Mondal. Mycelium based Composite: The Future Sustainable Biomaterial. Int J Biomater, 2022, 8401528

32. 32 Cultivated building materials for cities of the future,Karlsohe Institute of Technology, Press Release 121/ 2017 http://www.kit.edu/kit/english/pi_2017_121_cultivated-building-material-for-cities-of-thefuture.php
33. Mathew Pelletier ,Greg H, John D Wanjura. An evaluation study of mycelium based acoustic absorbers grown on agricultural by products substrates, 2013, 51,480-485
34. Natalie Walter and Benay Gursoy. A study on the sound absorption properties of mycelium based composites cultivated on waste paper based substrates, 2022,7,3,100
35. 35.GV Angelova, Brazkova MS, Krastanov AI. Renewable mycelium based composite-sustainable approach for lignocellulosic waste recovery and alternative to synthetic material-a review, Zeitschrift fur Naturforschung C, 2021.76,11-12
36. Simon Vandelook, Elise Elsacker, Eveline Peeters. Current status and future prospectus of pure mycelium materials, Fungal Biology and Biotechnology, 2021, 20
37. 37.Ecovative Company Packaging from mushroom plastic 2007 http://ellenmacarthurfoundation.org/circular-examples/packaging-from-mushroom-plastic-ecovative
38. Niall Patrick Walsh Carlo Ratti. Unveils Structure Grown from mushrooms at Milan Design week, 2019 http://www.archdaily.com/914704/carlo-ratti-inveils-structure-grown-from-mushroom-at-milan-design-week
39. Jonathan Dessi-Olive Strategies for growing large scale mycelium structure, Biomimetic (Basel), 2022, 11,7,3,129
40. Jillian Silverman, Huantian Cao, Kelly Cobb. Development of mushroom mycelium composites for footwear products, 2020, 38, 2,119-133
41. Aniela Hoitink MycoTEX-3D produced sustainable textile from mushroom roots, 2021, http://hollandcircularhotspot.nl/case/mycotex-3d-produced-sustainable-textile-products-from-mushrroms
42. 42 Marz Sustainable fabric series: All about mycelium fabric 2021 http://hollandcircularhotspot.nl/case/mycotex-3d-produced-sustanable-textile-products-from-mushroom/
43. Tamer Elsakhawy, Muneera DFA,,Ali AHS, Kotb AA, Yaser MH, Khaled AAA. Efficacy of mushroom metabolite (*Pleurotus ostreatus*) as a natural product for the suppression of Broomrape Growth (*Orobanche crenata Forsk*) in Faba Beans Plants, Plants, 2020, 9,1265,
44. Yuwei Hu, Peter EM, Kevin DH, Pattana K and Naritsada T. Mushroom cultivation for soil amendment and bioremediation, Circular Agricultural Systems, 2021, 1,1,1-14
45. 45. Reyna L Camacho-Morales, E Sanchez. Biotechnological use of fungi for the degradation of recalcitrant Agro pesticides, Mushroom biotechnology- Development and applications, 978-0-12-802794-3, 2016, 203-214
46. Mitchell Jones, Tanmay B, Everson K. Thermal degradation and fire properties of Fungal Mycelium and mycelium biomass composite material, Sci Rep. 2018, 8, 17583
47. Liudmila Katitukha and Miriam Sari. Fascinating Vital Mushroom. Tinder Fungus Fomes formentarius (L) Fr as a dietary supplement, International J of Res Studies in Sci, Engineering and Technology. 2019, 6, 1, 1-9
48. 48.Michael Kuo Turbinellus floccosus 2021 http://www.mushroomexpert.com/turbinellus_floccosus.html
49. JA Simpson and TW . *Phaeolus Schweinitzii* in Australia, Australian Plant Pathology, 2002,31,99-100
50. Cao H, Qin D, Guo H, Cui X, Wang S, Wu Y, Zheng W, Zhong X, Wang H, Yu J, Zhang H, Han C. The shaggy ink cap medicinal mushroom, *Coprinus comatus* (Agariconycetes) a versatile functional species: A review Int J Med Mushrooms, 2020, 22, 3,245-255
51. 51.Valverde ME, Hernandez-Perez T, Paredes Lopez O (2015) Edible mushrooms: Improving human health and promoting quality life, Int J Microbiol,2015, 376387
52. Bulti Kumera Fufa , Belsti Atnkut Tadesse and Mestawot Merid Tulu. Cultivation of *Pleurotus ostreatus* on Agricultural waste and their combination, International Journal of Agronomy, 2021, Vol 2021, 1465597
53. 53.Russel JR, Huang J, Anand P, Kucera K, Sandovel AG, Kathleen WD, Hickman D, Scott a Strobel Biodegradation of polyster polyurethane by endophytic fungi. Appl Environ Microbiol, 2011, 77, 17, 6076-82
54. Khan S, Nadir S, Shah ZU, Shah AA, Karunarathna SC, Xu J, Khan A, Munir S, Hasan F. Biodegradation of polyster polyurethane by *Asperigillus tubingensis,* Environmental Pollution,2017. 225, 469-480,
55. Da Luz JMR, Sirlaine AP, Denise MSB, Marcos RT, Antonio JD, Maria CMK. Abiotic and biotic degradation of Oxo-biodegradable plastic bags by *Pleurotus ostreatus*, PLoS ONE, 2014. 9, 11, e107438
56. 56.Charu Gupta and Dhan Prakash. Mushroom as plastic eaters. Acta Scientific Pharmaceutical Sciences, 2019,3,10
57. 57.Munuru Srikanth. Sandeep TSRS, Sucharitha K .Biodegradation of plastic polymer by fungi: a brief review, Bioresour. Bioprocess, 2022 9, 42

Table 1. Various mushroom species known for plastic degradation properties.

S. No.	Form of mushroom	Role	References
1.	*Pestalotiopsis microspora*	Break down plastic in anaerobic condition	53
2.	*Aspergillus tubingensis*	Effective degradation of plastic	54
3.	*Pleurotus ostreatus*	Effective degradation of plastic	55
4.	*Schizophyllum commune*	Effective degradation of plastic	55,56
5.	*Aspergillus nidulans*	Effective degradation of plastic	57
6.	*Aspergillus oeyzae*	Effective degradation of plastic	57

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7.	*Aspergillus nomius*	Effective degradation of plastic	57
8.	*Pleurotus abalones*	Degradation of plastic	57
9.	*Pleurotus ostreatus*	Degradation of plastic	57
10.	*Agaricus bisporous*	Degradation of plastic	57
11.	*Pleurotus eryngii*	Degradation of plastic	57

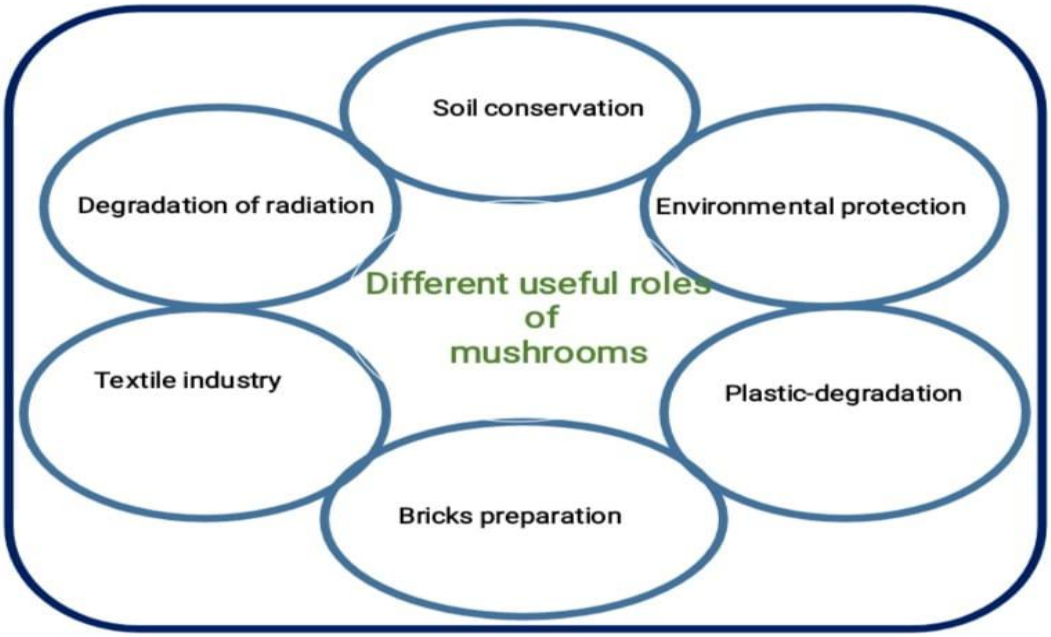

Figure 1. Different biotechnological role of the mushrooms.