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Plastics Meet Their Nemeses: Exploring the Role of Plastic Eating Fungi

Debjeet Sharma[1*], Dharmesh Gupta[1], Pratibha Sharma[2] and Shubham Sharma[1]

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Corresponding Author
Debjeet Sharma
e-mail: debjeet19@gmail.com

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Abstract

Plastics take generations to naturally break down because of their chemical makeup, which causes a huge buildup of plastic trash in the environment. Since they use enzymes they release into their surroundings to break down organic matter, fungus are essential decomposers in natural environments. Researchers have recently found that some fungi can decompose far more difficult materials, such as plastic. Enzymes like hydrolases, laccases, and peroxidases are produced by these decomposer fungus and are capable of breaking down the lengthy polymer chains present in plastics. They break down complicated materials like wood using a similar process. The scientific community is very interested in using these fungi to break down plastic trash because of their special capabilities. Utilizing fungi that consume plastic has a lot of potential for trash management.

1. Introduction

Nowadays, plastics are necessary for daily life and are produced in large quantities worldwide. Its product portfolio consists of building supplies, industrial goods, tote bags, and wrapping and packaging materials. Plastic has evolved over the past century from a fantastic time-saving substance to a contemporary scourge that clogs landfills, kills marine life, and swirls around our oceans in enormous garbage gyres the size of nations (Greene, 2023). Over 8.3 billion tons of plastic have been created since the 1960s, with packaging that is used just once and then thrown away accounting for 40% of this total. Polystyrene (PS) and polyethylene (PE) typically account for about 40% of global plastic production. In instance, polymers with a carbon-carbon (C-C) backbone are less likely to break down since they don't include hydrolyzable groups (Zhang et al., 2022). Landfill handling of plastic waste results in secondary environmental deterioration. Around 70–80% of plastic garbage is transported by rivers to the ocean, where it is dispersed

Author's Address

[1]Dept. of Plant Pathology, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh (173 230), India
[2]Faculty of Agricultural Sciences, DAV University, Jalandhar, Punjab (144 012), India

across the seafloor, coastline, and remote locations that are remote from populous regions (Quero and Luna, 2017). Polymers, pigments, additives (plasticizers, antioxidants), and contaminants make up microplastic surfaces. When plastics are made, used, and weathered, these chemicals are readily discharged into the environment (Silva et al., 2016). Researchers are searching for ways to break down plastic in order to address the growing issue of plastic pollution. As a result, fungi that consume plastic were found.

2. Fungi as an Important Consideration for Mitigating Plastic Stress

The alarming rise of plastic pollution has driven the search for innovative, sustainable solutions beyond conventional recycling and disposal (Balraj et al., 2025). Developing sustainable and environmentally friendly methods to address microplastic contamination requires a thorough understanding of the mechanics and effectiveness of fungus-driven microplastic remediation. Fungi convert polymeric polymers from monomers by using intracellular and extracellular enzymes (Figure 1). This mechanism produces methane under anaerobic conditions and carbon dioxide and water under aerobic settings. Furthermore, hydrophobins—surface proteins secreted by fungi—are essential to the bioremediation process because they improve substrate mobility and bioavailability. The biodegradation of polyethylene (PE) by microorganisms, especially fungus, depends heavily on microbial enzymes. Through the production of extracellular enzymes, these enzymes aid in the oxidation or hydrolysis of PE. Microorganisms are essential

Figure 1: AI generated image of mushrooms showing potential to degrade plastics

to the processes of mineralization, assimilation, and depolymerization. Microbial enzymes have the ability to increase PE's hydrophilicity, which makes it easier for microbes to adhere to its surface. Numerous microbial enzymes that can break down polyethylene (PE) have been discovered in recent years. Laccases, manganese peroxidase, and lignin peroxidases are a few examples. These enzymes are involved in fatty acid metabolism, chain cleavage, and terminal oxidation, among other aspects of degradation. *Aspergillus carbonarius* and *Eurotium* sp. were the fungal species found to have the highest capacity for degrading microplastics at the study areas along the Tigris River, according to research studies conducted (Shaymaa et al., 2024). It was discovered that these species could break down HDPE more effectively than PS.

The ability of several dozen fungi to break down polyester polyurethane (PUR), a synthetic polymer used in plastic, was evaluated in 2011 by Yale University researchers. They discovered that PUR could be broken down and transformed into organic matter in both solid and liquid solutions by a number of fungi belonging to the *Pestalotiopsis* species. In both aerobic (oxygenated) and anaerobic (oxygen-free) conditions, two species of this genus were able to live only on PUR (Vasarhelyi, 2021).

Landfills nowadays are oxygen-poor and arid. Anything, including organic material, cannot effectively decay as a result. However, *Pestalotiopsis* fungi are a perfect fit for landfills since they can break down plastic under anaerobic circumstances. *Pestalotiopsis's* capacity to endure and break down PUR in soil and liquid solutions suggests that they may one day be employed to remove plastic from the ocean, particularly from the Great Pacific Garbage Patch. More research on the degradation of plastic by fungi was conducted once it was discovered that *Pestalotiopsis* could break down plastic. Numerous species, including the common edible oyster mushroom, are now known to be capable of plastic bioremediation, according to research. The oyster mushroom can break down plastic and yet produce a tasty mushroom. This makes it possible to utilize it as a recycling system at home.

The "Fungi Mutarium" is a prototype of an oyster mushroom recycling device that Austrian researcher Katharina Unger developed. The oyster mushroom would be enclosed in capsules with plastic fragments in the "Fungi Mutarium." After that, the fungus would develop on the capsule, where it could be removed and eaten. The fungus takes several months to completely break down the plastic, leaving behind a puffed, mushroom-shaped cup that tastes sweet and smells like liquorice. According to scientists, community recycling centers will have larger systems, while homes would possess a smaller model to recycle their plastic garbage (Greene, 2023). Cutting back on plastic use is the most crucial thing you can do to address the plastic issue. However, plastic eating mushrooms provide an organic solution to removing the plastic that is already polluting our environment.

Several species of the genus *Pestalotiopsis* were included in the active organisms in the synthetic polymer polyester polyurethane (PUR-A) media clearance screen (Russell et al., 2011). Within the genus, there were species with moderate activity, some with high activity, and some with no discernible activity. Although it is noteworthy that certain strains of *Pestalotiopsis microspora* exhibited some of the greatest levels of activity, the levels varied greatly among the different isolates. It has previously been demonstrated that isolates of *Pestalotiopsis microspora* are prone to horizontal gene transfer. In one noteworthy instance, a strain of *Pestalotiopsis microspora* that was isolated as a fungal endophyte from the plant *Taxus wallachiana*, which produces taxol, developed the capacity to synthesis taxol. The capacity of a subset of these isolates to break down polyester polyurethane as a single carbon substrate may have been facilitated by this tendency for horizontal gene transfer, or it may indicate a high degree of phenotypic variety within the genus.

3. Some Major Plastic Eating Fungi

There are several genus and species of fungi that have shown potential ability to degrade various kinds of plastics present in the environment.

a. Dothideomycetes: Certain Dothideomycetes species have the ability to degrade plastic. A small number of taxa are known from the Dothideales and Botryosphaeriales, however the majority of the Dothideomycetes species are found in the Pleosporales order. *Thyrostroma jaczewskii*, *Stagonosporopsis citrulli*, *Leptosphaeria* sp., *Guignardia mangiferae*, and numerous more Dothideomycetes are plastic degraders that may break down LDPE, PUR, PS, PCL, PEA, PPA, PBA, HDPE, PVC, PE, PU, and Sky-Green polymers.

b. Eurotiomycetes: The Eurotiomycetes are responsible for the majority of plastic-degrading fungus records. *Aspergillus* and *Penicillium* are the two most prevalent fungus genera that break down plastic. HDPE, LDPE, PCL, PE, PVC, PS-PUR, PEA, PPA, PBA, PHB, Poly[3HBco-(10 mol%) 3HV], Sky-Green, PHV, PBS, PLA, and PVC are the plastic types that they are said to break down. Additional eurotiomycetes that have been demonstrated to break down plastics include *Eupenicillium hirayamae*, *E. rubidurum*, *Exophiala jeanselmei*, and *Monascus* sp.

c. Sordariomycetes: The second largest class in the phylum Ascomycota is Sordariomycetes. Their biological range is broad, encompassing both aquatic and terrestrial environments. Numerous Sordariomycetes have been found by researchers to be capable of breaking down plastics. PE, PS, PHB, Poly[3HB-co-(10 mol%) 3HV], PUR, PS-PUR, HDPE, LDPE, PVC, PCL, PEA, PPA, and PBA are the plastic kinds that they are said to breakdown. *Chaetomium globosum*, *Bionectria* sp., *Acremonium* sp. and *Emericellopsis minima* are among the crucial organisms that are known to break down plastics.

d. Agaricomycetes: They comprise pathogens, mycorrhizal symbionts, and saprobes and are ecologically diverse. There have been numerous reports of agricomycetes that can break down plastics. Poly[3HB-co-(7 mol%) 3HV], LDPE, PVC, polyethylene, and PHB are all said to be degraded by them. Examples include *Pleurotus ostreatus*, *Polyporus circinatus*, and *Phanerochaete chrysosporium*.

e. Tremellomycetes: The Tremellomycetes are saprobic yeasts, dimorphic taxa, and species that generate complex fruiting bodies and/or hyphae. They are categorized under the Basidiomycota. The ability to degrade plastic has been identified mostly in the genera *Cryptococcus* and *Papiliotrema* (Tremellales), which can break down PCL, PBS, and PBSA.

f. Mucoromycetes: The phylum Mucoromycota contains the class Mucoromycetes, which is primarily made up of filamentous fungi that live saprobiotic lives. Several Mucoromycetes fungus that can break down plastics have been found through studies. The genera *Rhizopus* and *Mucor* contain all of the known plastic-degrading Mucoromycetes. PHB, HDPE, LDPE, PVC, PCL, polyalkylene dicarboxylic acids, PPA, and PET copolymers containing dicarboxylic acids can all be broken down by these fungi (Ekanayaka et al., 2022).

There are also many marine fungi like *Parengyodontium album* who can break down complex plastics into simpler substances (Figure 2).

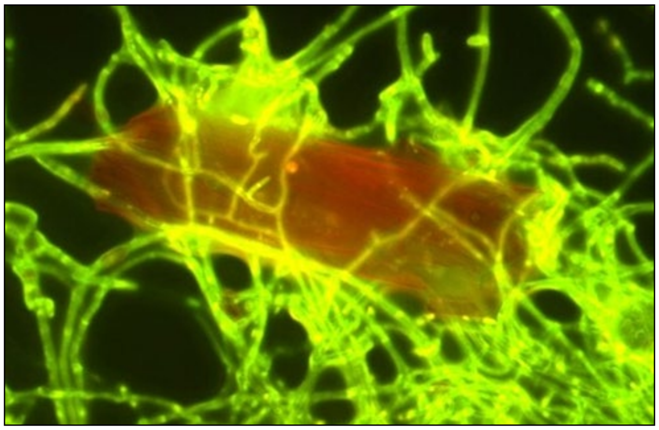

Figure 1: Marine fungus *Parengyodontium album* can break down polyethylene in the ocean when exposed to UV light

4. Conclusion

An inventive and organic solution to the world's plastic waste problem is the use of plastic-eating mushrooms. These fungus may provide a sustainable waste management and bioremediation solution by dissolving complicated plastic polymers. However, more investigation and technological advancement are needed before they may be used widely. Even though they have drawbacks and restrictions, such as particular growing conditions, varying rates of decomposition, and possible environmental effects, plastic-eating mushrooms offer a lot of promise as solutions to reduce plastic pollution.

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