Systematic Review on Mycodegradation of Plastic

Abstract

Since plastic is versatile, durable, and easy to make, this material has widely been applied in almost every sector. Unfortunately, the big exertion of this material on the environment led to pollution, which is a world green disaster. Scientists have found that many living organisms, especially bacteria and fungi, can degrade many plastic polymers. In doing so, this paper shall be poised to highlight the possibility of fungi as a feasible approach to managing plastic waste, an environmentally conscious means. The research scope will extend to publications that have been made on plastic degradation for 30 years; and papers have been chosen for this analysis. The review explores three crucial aspects of the relationship between fungal species and plastic degradation, specifically: the diversity of the identified fungal species in specific plastic degradation, place of isolation, and the methods applied to analyze the plastic degradation of fungi.

Keywords: plastic, fungi,degradation, weight loss, SEM, FTIR, CO_2.

Highlights

- Plastic pollution and its environmental impact
- The potential of fungi as a viable, eco-friendly method for degrading plastic waste.
- Analysis of 30 years of scientific publications of fungalinvolvement in plastic degradation.
- Diversity of fungal species is involved in plastic degradation with place of isolation.
- Analytical methods used to study the degradation process.

Introduction

Plastic has been widely utilized because of its exceptional physical characteristics, such as its versatility, pliability, chemical and physical durability, and simplicity of manufacturing in comparison to alternative materials (Khruengsai et al., 2022). It contributes to managing population surges and promoting economic prosperity for human beings. The durability of plastics makes them suitable for use in disposable products (Kim et al., 1994). It is employed in several industries such as refrigeration insulation, packaging, electronics, aircraft, building, and construction (Khan et al., 2017). Plastic materials are used in many fields, which leads to the significant amounts of plastics waste. Plastic waste formation is a serious issue worldwide without an effective solution, threatening ecosystems and human health(P. Perera et al., 2023). Microplastics (MPs)are fine plastic particles which have recently surfaced as another major area of concern in environmental research. (Bernat et al., 2023).The present level of plastic pollution is alarming, and thus innovative and lasting methods need to be put into practice to reduce plastic waste.

Various methods for plastic degradation are in work by scientists across the globe. Biodegradation is the chemical or organic degradation of chemicals and substrates in the presence of a living entity. The scientists are now overcoming this challenge by applying various micro-organisms like bacteria, fungus, actinomycetes, or cyanobacteria either alone or in combinations with each other or as biofilm(Vimal Kumar et al., 2017). The soluble products of biodegradation are absorbed or assimilated by enzymes or other compounds secreted by microorganisms (Zeghal et al., 2021).Besides secreting degrading enzymes like cutinase, lipase, and protease, which constitute a part of lignocellulolytic enzymes, fungi also enhance the rate of plastic biodegradation by accelerating it with the help of pro-oxidant ions. This enzymatic activitybreaks them into various functional groups and consequently let their degradation into low molecular weight oligomers(Napoli et al., 2023).This capability is ascribed to their enzymatic activities, which has developed to break down intricate organic substrates. Recently, numerous scientific studies have shown that different types of fungi can break down plastics, providing a promising solution to the problem of plastic pollution.

Hence, in the very first systematic review of this kind, we undertook a comprehensive overview of plastic degradation by fungi. The rationale behind this study is to make an overall assessment of all the current knowledge on the topic of fungal decomposition of plastic. Our purpose for investigating all literature so far available is to show the possibility of fungi as a sustainable and eco-friendly manner in managing plastic waste, contributing towards the broader discourse on environmental conservation and the circular economy. In this comprehensive review, we dig into three crucial sides of the remarkable interaction between fungal species and plastic degradation. Initially, we compiled the remarkable range of fungal species that have been recognized as crucial participants in the breakdown of different kinds of plastics.We have also studied a wide range of plastics that have been selected in particular for their degradation. A list of some of the most used substances comes under this category: polyethene, polypropylene, polystyrene, and others. The successful degradation of such plastics by fungi could perhaps be the answer to the global plastic pollution crisis. Finally, we discuss the methods applied for the assessment of plastic biodegradation by fungi, which include laboratory experiments that explain the mechanisms of degradation, field studies oriented at evaluating feasibility in realistic conditions, and environmental applications where fungi are applied for plastic biodegradation. Together, they form a complete view of the promising realm of plastic biodegradation through fungi.

Methodology:

To write a systematic review on plastic degradation by fungi, we used a well-known database ‘SCOPUS’. With its strategic feature, we searched different combination of keywords related to our topic of interest to make a script. Among the nine scripts, we selected the following script which showed the largest number of publications. By the following script we could successfully get 680 research articles in the SCOPUS database until the date of March 4, 2024. Abstracts of all articles were screened for systematic review. Among which 355 papers were excluded in view of not meeting the criteria for inclusion. So, the total text of 325 papers was analyzed to evaluate the whole article. 120 were excluded as they had no focus on fungal plastic degradation, nor plastic degradation in general. Instead, the studies mainly focused on the degradation of polyaromatic hydrocarbons (PAHs), pesticides and dyes, or undertook a general review of plastic degradation. Finally, 205 papers were closely considered for this systematic review(Fig. 1).

Script:

TITLE-ABS-KEY (((plastic OR polythene OR polyethylene OR ldpe OR hdpe) AND (degradationOR degrading OR mycodegradation) AND (fungi OR fungus OR fungal))) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (DOCTYPE , "ar"))

AND (LIMIT-TO (LANGUAGE , "English"))

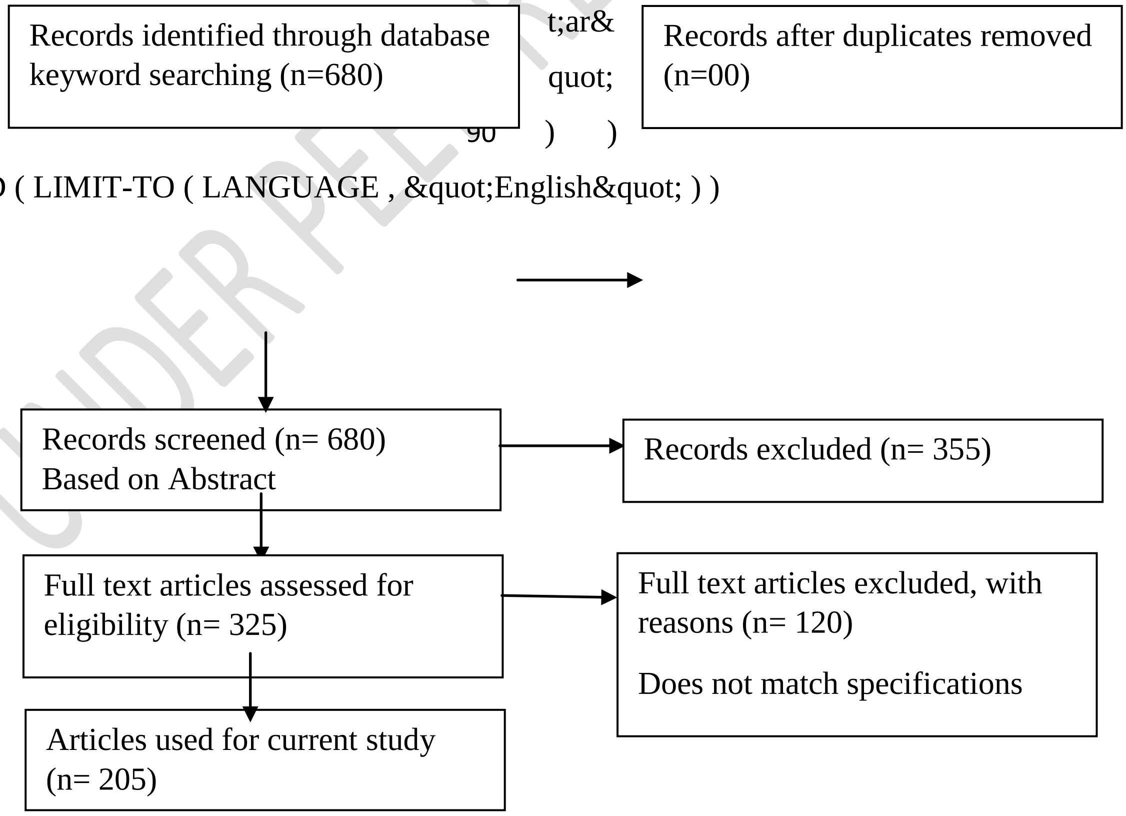

Fig. 1. Flow chart of data collection and analysis

Results and Discussion

After gathering and processing all the data, observations were categorized based on the kind of plastic degraded by fungi.

Polyethylene (PE)

Degradation of PE was observed to be up to 140 days by an adapted strain of *Aspergillus niger*. The characterizations were carried out using Differential Scanning Calorimetry (DSC) and Fourier Transform Infrared Spectroscopy (FTIR). In the FTIR analysis, thebio-treated PE sheet exhibited the presence of double bonds, which were detected by using absorbance at 1640 cm^{-1} and 940 cm-1. Whereas in abiotically treated PE sheets, the ketonic carbonyl group was associated with an absorption band observed at a wavenumber of 1715 cm-1 (Raghavan & Torma, 1992). Interestingly, the lignin-degrading fungus IZU-154showed a significant decrease of 73% in tensile strength within a span of only 12 days (Iiyoshi et al., 1998). Within a one-month period, *A. glaucus*, was able to break down 28.80% of polythene bags and 7.26% of plastic cups which was isolated from mangrove soil (Kathiresan, 2003).In 30 days, polythene bags ranging in thickness from 0.5 to 5 mm were broken down by the *A. oryzae* that was isolated from the soil. Weight reduction served as confirmation of it(Kannahi & Rubini, 2012).Plastic cups and polythene bags were tested in Mangrove soil (M), Petroleum soil (P), and Molasses soil (MS) as well as in Lab (L) for 9 months. The recorded weight loss for*A. niger*wasL – 13.25, M – 15.5, P – 4.62, MS – 3.37 for plastic cups, and L – 14.75, M – 10.75, P – 6.75, MS – 3.25 for polythene bags. Also, L – 17.25, M – 12, P – 3.5, MS – 2.25 for plasticcupsand L – 16, M – 11, P – 6.37, MS – 2.25 for polythene bags by *A. glaucus.* SEM analysis observed the physical alterations of the surface, and the degradation was confirmed (Sugana Rani & Prasada Rao, 2012).

Pleurotus ostreatus PLO6 brought from Laboratory of Mycorrhizal Associations/DMB/BI OAGROU/FV degraded oxo-biodegradable plastic bags in 45 days. The confirmation was done by X-Ray Diffraction (XRD), scanning electron microscopy (SEM), FTIR and enzymatic assay(da Luz et al., 2013). *P. ostreatus* PLO6 collected from the Department of Microbiology degraded oxo-biodegradable polyethylene in 90 days. The confirmatory tests were SEM, FTIR, mechanical properties, and CO_2 measurement(Da Luz et al., 2014).*Curvularialunata*, *Alternaria alternata*, *Penicilliumsimplicissimum*, and *Fusarium sp.* were isolated in a garbage site. Each of these fungi showed a decrease in weight of 1.2, 0.8, 7.7, and 0.7% respectively. However, when all of them were combined as a consortium, they experienced a weight loss of 27% after being kept for three months(Sowmyaet al., 2015). *P.simplicissimum*from a dumpsite exhibited a diverse degradationrate for each treatment. Compared to autoclaved (16%) and surface-sterilized (7.7%) polyethylene, the treated PE (38%) exhibited a rapid weight reduction over a three-month period. Further confirmation was provided by nuclear magnetic resonance (NMR),SEM, FTIR and analysis (Sowmya, Ramalingappa, Krishnappa, et al., 2015).

The marine fungus, *Zalerionmaritimum*isolated from its soil,successfully decomposed microplastic (MP) span of only 28 days. This degradation was tested and verified with Attenuated Total Reflectance-Fourier transform infrared (ATR-FTIR) and NMR(Paço et al., 2017).*Candida sp.* consumed a polythene bag of 20 Grams per Square Meter (GSM) with a weight loss of 2.3 percent, while *Aspergillus sp.* isolated from landfill soil degraded a polythene bag of 40 GSM with a weight loss of 6%. FTIR verified the change in condition(Ratna Kumari & Kulkarni, 2018).*Avicenniamarina*'s rhizosphere contained *A.sydowii* strain PNPF15/TS which reduced 94.4±42.40% tensile strength and *A.terreus* strain MANGF1/WL reduced 50% of weight in 60 days. This decomposition was evidenced by SEM and FTIR(Sangale et al., 2019).Additional sources of *A. niger, A. flavus*, and unidentified fungi have been found to include cooking oil, grease, and petroleum products. The black polyethylene exhibited degradation by weight at the rates of 38, 27, and 64%, while the white polyethylene showed degradation at rates of 26, 16, and 45%, respectively. SEM visuals confirmed the breakage of plastic surface(Padmanabhan et al., 2019).*Aspergillus strain*MH119104.1 was isolated from marine water and showed that around 22% of the plastic bottle strip decomposed within a period of 6 weeks. FTIR, SEM and XRD were used to verify degradation(Sarkhel et al., 2020).The degradation percentage of weight of PE in liquid media (L) by *A. niger* (NG_065763.1) and *A. glaucus* (NG_063391.1) during a period of 28 days was 40±3.3 and 25±3.3%, respectively. Whereas the rate of degradation in soil (S)was as low as 12±3 and 15±3%(Saeed et al., 2022).*A.alternata* FB1, isolated from marine sediment, efficiently degraded commercial PE bags, including additive-containing (type ET3113, 0.25 mm thick) and additive-free (type ET3111, 0.025 mm thick) plastics in 120 days. The degradation was confirmed by gel permeation chromatography(GPC), gas chromatography-mass spectroscopy (GC-MS), FTIR, XRDand SEM analyses(Gao et al., 2022).

Zone formation was observed in plastic-rich Mineral Salt Media (MSM) plates among the following species: *A. terreus* (F4), *A terreus* (F5), *Talaromycesislandicus* (F6), *A.terreus* (F8), *Aspergillus sp.* (F7), *Phoma* sp. (F2), *Eupenicilliumrubidurum* (F1), and *Neosartorya fischeri* (F3) from different soils of Morogoro, Tanzania. After 13 days, the visibility zone varied between 30 and 66.3 mm of all the organisms tested, *Aspergillus* sp. (F7) had the best performance in breaking down PE bags (Nakei et al., 2022).*A. flavus*found in the Gut of *Galleriamellonella* larvae,degraded PE when the larvae fed on PE of freezer, garbage, and shopping bags. The consumed PE were scanned with SEM and Atomic Force Microscopy (AFM) for confirmation of the degradation(Riabi et al., 2023). From soil that had been contaminated with plastic, *Trichoderma harzianum* was isolated and treated with PE, and showed 3.39 ± 0.3% weight loss after 30 days. This consumption was supported by SEM, FTIR and GC–MS analysis (Ruan et al., 2023). Several microorganisms were identified from the municipal waste disposal site and were found to degrade the PE in 90 days. These included *Fusarium solani* (OL919442, OL919446), *F.oxysporum* (OL91944, 3OL919445), *Lecanicilliumaraneicola* (OL919438, OL919441), and *T.lixii* (OL919447). The SEM analysis showed presence of fungal shreds of varying lengths on the external surface of granules, confirmed the micro-damage. The degradation studies are also supported by FTIR (Wróbel et al., 2023)(Table No. 1).

Low Density Polyethylene (LDPE)

Prior to being subjected to biodegradation, plastic sheets were photo-oxidized for 0 to 100 hours. *A. niger*wasprocured from the National Chemical Laboratory (NCL), India, successfully decomposed the pre-treated LDPE in compost for over a period of 6 months, resulting in a weight reduction of 22% whereas, the untreated LDPE film was degraded less than 15%. The degradation was confirmed using Variation in Viscosity, Chain Scission, FTIRand SEM(Pandey & Singh, 2001). Thermally oxidizedLDPE was decomposed in a period of 31 months in a culture of *A. niger* and*P.pinophilum* and verified by DSC, SEM, FTIR and XRD(Volke-Seplveda et al., 2002). The consortium of *A. niger*(ATCC 9642,7), *Gliocladiumvirens*(ATCC 9645,9), *P.pinophilum*(ATCC 11,797,7), and *Phanerochaetechrysosporium*(H2896) efficiently breakdown the physico-chemically pretreated LDPE within a period of 9 months. Wide angle X-ray scattering (WAXS), Gas Chromatography (GC), DSC, FTIR, and SEM were used for verification (Manzur et al., 2004). *A. niger* and *P.funiculosum*were extracted from the waste,modified with 60% (wt/wt) Bionolle within a period of 90 days. *P.funiculosum* completely degraded LDPE whereas*A. niger* exhibited a weight reduction of 7.53%. It showed tensile strength of 17.9 ± 0.6 MPa andfurther studied by SEM and FTIR(Łabuzek et al., 2004).*Fusarium sp.* AF4 isolated from soil has been degraded LDPE in 3 months which was confirmed by FTIR(Shah et al., 2008).*A. fumigatus*, *A. terreus*, and *F.solani*, which were obtained from solid waste, decomposed LDPE over a period of 100 days. Molecular weight changes of polyethylene were measured byhigh-temperature gel-permeation chromatography (HT-GPC). And further it was verified using FTIR and SEM (Zahra et al., 2010).*P. Chrysosporium and T. Wortmannii* obtained from culture collection at the Federal University of Brazil degraded LDPE/modified starch in 90 days, which were examined by XRD, SEM, and FTIR(Ferreira et al., 2010).

The most significant decrease in both elongation percentage (62%) and tensile strength (51%) was observed in the pro-oxidant manganese stearate (MnS)treated with *A. oryzae* with weight loss of 47.2%.This treatment involved UV irradiation and incubation in soil for a period of 3 months. In comparison, other pro-oxidant treated LDPE films showed elongation percentage, loss of tensile strength and weight [45, 45, 41.6% for titanium stearate (TiS)], [43, 40 and 36.1% for iron stearate (FeS)], and [41, 39 and 34% for cobalt stearate (CoS)]. LDPE treated with UV irradiation and *A. oryzae* showed 18, 21 and 24% weight loss, tensile strength and elongation percentage; whereas LDPE incubated with only *A. oryzae*(UT) showed 5, 26 and 3% respectively (Konduri et al., 2011).In a study conducted by (Nowak et al., 2011) LDPE that had been modified with bionolle was immersed in waste coal, a forest and an extinct volcano craterover a period of 225 days. *A. awamori*, *Mortierellasubtilissima*, and *G. viride* were identified on the buried plastic film. The weight loss for films 0 (pure LDPE), 1 (modified), and 2 (polyester)was 0.26, 0.25, and 5.76% in waste coal; 0.13, 0.52 and 2.02% in forest and 0.28, 0.26 and 17.03% in soil,respectively. The tensile strength measurements for film 0 and film 1 obtained from waste coal were 13.7 and 6.7 MPa, forest 13.7 and 6.9 MPa and crater 13.2 and 7.3 MPa, respectively. Film 2 was determined to be the most delicate among all the sites because of elongation at break of 98%. The findings were further supported by SEM and FTIR.

*A. niger*along with five other species of the same genus, as well as two species of *Fusarium* found in municipal solid waste were able to adhere on the surface of LDPE film and togrow in the synthetic medium supplemented with 0.1% LDPE as they utilized it as a sole carbon and energy source.The fungal strains caused considerable degradation of LDPE within a 30-day period. (Kumar et al., 2013).*T. harzianum*isolated from soil of dumpsite degraded UV- treated, autoclaved and surface- sterilize LDPE with 40, 23 and 13% by weight in 15 days respectively. The confirmatory tests were SEM, FTIR and NMR(Sowmya et al., 2014).*Aspergillus sp.* F1- 16S isolated from soil of municipal landfill site degraded LDPE 20 µm films (25 days UV pre- treated) and powdered plastic in 56 days. The confirmatory tests were SEM, FTIR and XRD(Esmaeili et al., 2014).After 30-day incubation period, *Saccharomycessp.*, *A. niger*, *A.flavus*, and *Streptomyces sp.* exhibited weight reductions of 43%, 72%, 11%, and 40%, respectively. Furthermore, *A. niger* exhibited a respiration and breakdown process, as evidenced by the production of 4.2 g/L of CO_2just in a week(Muthumani & Anbuselvi, 2014).Strains of *Aspergillus sp.* and *Fusarium sp.* were isolated from municipal solid waste. Amongst them, FSM-3, FSM-5, FSM-6, FSM-8 and FSM-10 were found to be degrading LDPE with weight loss of 8, 5, 7, 7 and 9% and CO_2 evolution of 20.26, 18.47 17.93, 17.84 and 19.38g/L respectively. Further confirmation was added by testing change in pH, SEM and FTIR(Das & Kumar, 2014). LDPE and sago starch filled LDPE (70/30) was degraded by *A. niger* in 30 days with recorded weight loss of 0.09 and 6.52% respectively. It was additionally confirmed by SEM(Beg et al., 2015).*Lasiodiplodiatheobromae* isolated from*Psychotriaflavida, Aspergillus sp.*, and *Paecilomyceslilacinus* isolated from *Humboldtiabrunonis* has degraded LDPE (20 µm) in 90 days as confirmed by the FTIR, DSC, SEM and changes in viscosity tests(Sheik et al., 2015).*P. ostreatus* PLO6 procured from collection of the Department of Microbiology of the Federal University of Viçosa, MG, Brazil degraded LDPE with 50% green polymer plastic in 90 days. The confirmatory tests were tensile strength, CO_2 evolution, SEM and FTIR(Da Luz et al., 2015). Within a span of 90 days, two distinct microorganisms, namely *A. nomius* JAPE1 and *Streptomyces sp.* AJ1, effectively decomposed LDPE which were isolated from waste disposal site. The study showed that the weight losses of by fungi were 4.9% and 5.2% respectively. Additionally, the rate ofCO_2 evolution wasrecorded as 2.85 and 4.27 g/L after 4 weeks of incubation(Gajendiran et al., 2016a).*A. clavatus* JASK1 (KT148627) reduced the weight of LDPE by 35% within a span of only 90 days. The degradation also confirmed by the CO_2 evolution after 4 weeks at the rate of 2.32 g/L (Gajendiran et al., 2016b).In 90 days, *Chamaeleomycesviridis*, which was isolated from the dumping site soil, consumed LDPE, causing a weight loss of 14.8%, which was further verified by SEM, AFM and FTIR(Gajendiran et al., 2016c). The study conducted by (Awasthi et al., 2017) demonstrated that *Rhizopusoryzae* NS5(KT160362) have the ability to break down thermally (hot air oven at 70°C for 10 days) pretreated LDPE. The tensile strength had a 60% decrease within a month, whereas the weight fell by 8.43%. SEM, FTIR, and AFM techniques were used to further validate the findings.

Two *Penicillium* speciesare isolated from a plastic landfill, *P. oxalicum*NS4 (KU559906) and *P. chrysogenum*NS10 (KU559907), wiped out LDPE within 90 days. For each fungus, weight degradation of 36.60 and 34.35% was observed. AFM, FTIR and Field Emission Scanning Electron Microscopy (FESEM)were used for further confirmation(Ojha et al., 2017). *A. oryzae* strain A5, 1 (MG779508) was discovered in a dumpsite and has been found to decompose approximately 36.4±5.53% of plastic by weight within a 16-week period. It was further tested and confirmed with FTIR, GC-MS(Muhonja et al., 2018).To obtain plastic degrading fungus, plastic bags were buried in soil for a duration of six months. *A.oryzae*was identified as a plastic degrading organism. It was further used to degradegreen LDPE. Weight losses of 25 and 32.5% were observed inpotato dextrose broth (PDB) and Czapek dextrose broth (CDB)for surface-sterilizedplastic sheet, whereaspre-treated plastic sheet with palmitic acidshowed decreased in weight by 30 and 40% respectivelyafter 90 days (Jayaprakash & Palempalli, 2018). Gómez-Méndez et al., (2018) implemented chemical, physical, biological and combined treatments. Among them *P.ostreatus*pretreated with glow discharge plasma degrade LPDE in 150 days and noted that fungus colonized 88.72 %. The degradation was also confirmed by SEM and FTIR(Gómez-Méndez et al., 2018)(Gómez-Méndez et al., 2018).*A. flavus* and *A. versicolor*, as well as *F.solani*, were obtained from a municipal garbage yard in Chennai, India. They exhibited the capacity to decompose LDPE during a span of 60 days. They achieved a reduction in plastic weight of 17, 19, and 13% respectively. The levels of CO_2 evolution were correspondingly 20.8, 20.98, and 19.22 g/L. Additional confirmation was obtained using FTIR and FESEM(Das et al., 2018).*Mucorcircinelloides*(MTCC No. 3945) significantly reduced LDPE weight by 1.328±0.27% without pre-treatment after 45 days, whereas thermally pre-treated samples lost weight by 0.770333%. FTIR added further confirmation(Sharma et al., 2019).In 11 weeks, *A.terreus* and *A. niger*that were isolated from the soil on the Santay Island mangrove, broke down LDPE of 100 µm, resulting in a 22.4 and 35.3 % weight loss that was verified by SEM(Sáenz et al., 2019a).

A. flavus and *A. terreus*isolated from soil, when exposed to LDPE, caused its degradation within 4 months in a laboratory condition and 9 months in soil. The weight loss of plastic by *A. flavus* and *A. terreus* in soil were measured to be 30.6 and 11.4%, respectively. In media, 14.3% for *A. flavus* and 13.1% for *A. terreus*(Verma & Gupta, 2019). After a period of 77 days, *A. terreus* and *A. niger*, which were obtained from mangrove, degraded LDPE by 35.3% and 22.14% in terms of weight, respectively. The study was supported by SEM(Sáenz et al., 2019b).*T.hamatum* FR87271, obtained from a plastic-contaminated environment, decomposed virgin, UV/T60and γT150-pretreated LDPE by 0.5 ± 0.4%, 1.3 ± 0.4% and 0.9 ± 0.1% during a span of 7 days, respectively.The experiment was facilitated by the use of FTIR, Thermogravimetric Analysis (TGA), GPC, and SEM techniques(Malachová et al., 2020).The blackuntreated LDPE(U-LDPE)degrading fungus *A.carbonarius* MH 856457.1 and *A. fumigatus* MF 276893, isolated from landfills, exhibited degradation rates of 3.8 and 2.267%, respectivelyover a period of 16 weeks. However, when these fungi were cultured together, the degradation rate increased to 5.01%. The percentage of degradation was 39.1after subjecting the plastic sheets to thermal pretreatment(80 °Cfor 30 days, T-LDPE). The application of chemical treatment with 65% HNO_3(C-LDPE)ledto a degradation of 17.76%. Gamma radiation (22KGy, γ-LDPE)showed the least degradation (5.79%) as determined using mixed culture analysis (El-Sayed et al., 2021).Khruengsai et al., (2021) obtained the strains viz., *Diaportheitaliana*, *Thyrostromajaczewskii*, *Collectotrichumfructicola*and*Stagonosporopsiscitrullicola*, from the Institute of Excellence in Fungal Research, Mae Fah Luang University, Thailandand *A. niger*ATCC 10254 as reference fungal strain acquired from Thailand Institute of Scientific and Technological Research, Bangkok, Thailand.Over a span of 90 days, they observed decline in tensile strength of 1.56, 1.78, 0.43, 1.86, and 3.34%, respectively. Additionally, there was a corresponding weight loss in LDPE of 43.90, 46.34, 48.78, 45.12, and 28.78%. The measurement of CO_2 evolution ranged from 0.45 to 1.45, 0.36 to 1.22, 0.45 to 1.45, 0.33 to 1.26, and 0.37 to 1.27 g/l. Five different fungal strains were isolated from soil at a disposal site, in which *Fusarium spp.*, *A. fumigatus* and *Penicillium spp*. degraded LDPE in 40 days with weight loss of 7.08±0.05, 21.88±0.03 and 19.17±0.02 % respectively. The biodegradation was also confirmed through SEM-EDAX and FTIR(Lakshmi & Selvi, 2021).The production of laccase enzyme using bio efficacy assay confirmed the degradation of LDPE by *T. viride* in 5 days (Johnnie et al., 2021).

Within a span of 30 days, *Thermomyceslanuginosus*(NCIM 1394)procured from NCL, effectively degraded LDPE (9.21±0.84% weight loss) that had been subjected to UV radiation (15 W and 50 Hz), high temperatures (100 °C), and chemical treatment (69%nitric acid) each for 7 days.The confirmation was also obtained by SEM and FTIR (Chaudhary et al., 2021).*Purpureocilliumlilacinum*, *P. chrysogenum*, *F. oxysporum*, *T. brevicompactum*and *F. falciforme*were recovered from an abandoned dumpsiteand degraded LDPE in 30 days, as proven by SEM and FTIR analysis(Spina et al., 2021).Two strains of *P.simplicissimum* derived from plastic debris collected from municipal sources and evaluated on LDPE sheets for 150-day. The untreated sheets achieved weight reduction of 58.0 ± 4.04 and 24.78 ± 3.94%, while the pre-alcohol treated sheets achieved weight loss of 60.1 ± 3.56 and 25.58 ± 2.72%. The strains F1 (Bar2) and F2 exhibited CO_2 evolution rates of 20 ± 3.45 and 05 ± 1.67 g/L, respectively(Ghosh & Pal, 2021).The plastic decomposition process was carried out by *Fusariumsp*, *Penicilliumsp*, and *A. fumigatus*, which were found in waste disposal site. Over a period of 40 days, these species caused weight losses of 7.08, 19.17, and 21.88%, respectively. Other techniques like Plate assay method, Zone method, SEM-EDAX, FT-IR were also used to screen and confirm the degradation(Lakshmi & Selvi, 2021).*Cephalosporiumsp.*NCIM 1251, which was procured from NCL, caused 12.22±0.82% reduction in weight of nitric acid pretreated LDPE over a period of 8 weeks. FTIR, SEM, XRD were used to study the surface and change in material nature (Chaudhary et al., 2022).*R.oryzae* MT259131, obtained from a landfill, achieved a 60% degradation efficiency of LDPE within a span of 60 days. The degradation was verified by SEM and FTIR(Seenivasagan et al., 2022).*P.chrysogenum*, *R.nigricans*,*Chaetomium murorum*, *Memmoniella echinata*, *A.fumigatus*,*Stachybotryschartarum*, *A. niger*,*C.globosum* and *A.flavus*, which were isolated from polyethylene waste, showed the degradation of LDPE in 30-day period. The weight reduction of the plastic was 8, 6, 2, 3, 7, 2, 9, 5, 7 and 3% in comparison to biodegradable plastic, which experienced weight reductions of 23, 14, 5, 8, 15, 7, 28, 10, 18 and 8% respectively. The study was also supported by SEM analysis(Saxena et al., 2022).

T. harzianum KKP 534 consumed LDPE MPs in a matter of nine days which was studied with enzymatic activity (Bernat et al., 2023). The wood-decaying fungus *Phlebiopsisflavidoalba*had successfully degraded LDPE with CO_2 emissions of 3.07 ± 0.13% mg/L and percent weight loss 46.79 ± 0.67 after 45 days. SEM and FTIR provided further confirmation (P. Perera et al., 2023).The untreated LDPE was degraded by *Cladosporium* sp.

CPEF-6 showed 0.30±0.06% by weight after 30 days, while the heat-treated LDPE showed a rise of 0.4±0.0%. Environmental scanning electron microscopy (ESEM) and FTIR corroborated the findings (Gong et al., 2023).The yeasts isolated from the gut of wood feeding termite identified as *Sterigmatomyceshalophilus*SSA1575, *Meyerozymaguilliermondii*SSA1547, *M.caribbica*SSA1654successfully degraded LDPE in 45 days. They showed tensile loss of 43.6, 19.2, 32.0 and weight loss of 18.6, 11.1 and13.3 % respectively. The maximum tensile and weight loss of 63.4 and 33.2 % respectively was detected in the yeast consortium(Elsamahy et al., 2023).*C.cladosporioides* (strain Clc/1, Gen. bank: OP729904) found from agricultural field successfully degraded LDPE in 90 days. The structural changes of the LDPE were screened by using SEM, ATR-FTIR, normal Raman and with an unconventional Surface-enhanced Raman scattering (SERS) (Puliga et al., 2023).FE-SEM, FTIR, and TGA verified that, *P.citrinum*isolated from the soils of a plastic waste dump yard in Bhopal, India, broke down LDPE (51 μm) in 90 days. For untreated LDPE, the weight loss was 38.82±1.08, while for nitric acid-treated LDPE, it was 47.22±2.04(Khan et al., 2023).

Aspergillus sp. 1, *Aspergillus sp. 2*, *Trichoderma sp.*, *Rhizopus sp.*, *Penicillium sp*., *Alternaria sp.*, and *Candida parapsilosis*were isolated from the activated sludge, river sediment, and compost. They experimentedwith LDPE, 20 % thermoplastic starch (TPS), LDPE + TPS, LDPE + TPS + styrene-ethylene-styrene degradation (SEBS). The fungi isolated from activated sludge and river sediment showed 3.3184%, 14.1152%, and 16.0062% weight loss. Whereas 3.9625%, 20.4520% and 21.9277% degradation were observed in fungi isolated from compost. SEM, FTIR/ATR data demonstrated that degradation was more intense in fungi isolated from compost than in activated sludge and river sediment(Kučić Grgić et al., 2023).After being examined for degradation, *Geotrichumcandidum* HAU-F1 (OQ940537), *F. oxysporum* HAU-F2 (OQ940538), and *Trichoderma sp*. HAU-F3 (OQ940550) were discovered on the residual mulch film (RMF) of PE from a vegetable field that had been mulched. After ninety days, the weight loss percentages were 1.5809, 1.7823, and 1.8398, in that order. A consortium comprising all fungi demonstrated a weight decrease of 1.6239%. SEM confirms that surface LDPE film wrinkles and holes are the result of biodegradation(Lin et al., 2024) (Table No. 2).

High Density Polyethylene (HDPE)

Aspergillus and *Penicillium* have been shown to break down HDPE in three months, as demonstrated by DSC and FTIR tests.(Ojeda et al., 2009). *A. niger* consumed HDPE in 6 months, as demonstrated by SEM, FTIR and viscosity variation(Alariqi & Singh, 2010).*A. niger* ITCC 6052, obtained from a waste disposal site, decomposed plastic within a span of 30 days. The sheet had a reduction in weight of around 3.44%, accompanied by a loss of 61% in tensile strength. SEM and FTIR supported the study(Mathur et al., 2011). The plastic was destroyed *A.terreus* MF12, collected from a garbage yard, within a period of 30 days. The HDPE sheet was exposed to heat at 50 °C for 72 h. further they programmed for alternate exposure of UV (312 nm) and humidity for 5 cycles per day. A reduction in weight of 9.4±0.1% was observed and verified byusing FTIR, SEM, and GC-MS(Balasubramanian et al., 2014).Consortium of fungi isolated from compost, degraded HDPE 80/Starch 20 (pretreated UV for 500 hrs) in 20 and 200 days. The confirmatory tests were Synchrotron-

FTIR microscope (SFTIR- M), SEM, FTIR and tensile testing(X. Liu et al., 2013). In 30 days, duration *A.tubingensis* VRKPT1 and *A. flavus* VRKPT2 isolated from plastic waste dump site in Gulf of Mannar, India has degraded HDPE (40 µm) with 6.02 ± 0.2 and 8.51 ± 0.1% weight loss for both fungi respectively. The degradation was confirmed by FTIR analysis(Sangeetha Devi et al., 2015).*P.oxalicum* KU559906 and *P.chrysogenum* KU559907 were obtained from a location where plastic waste was dumped. They showed 55.34 and 58.59% weight reduction of HDPE respectively, within a period of 90 days. FE-SEM and AFM were used to study the surface morphology whereas FTIR was used to analyze functional changes(Ojha et al., 2017).Polyethylene bags were kept in soil for 6 months to get plastic degrading fungus from which *A.oryzae*was obtained. It showed complete degradation of black HDPE within 90 days.The weight loss for surface sterilized plastic was 22.6 and 28% for PDB and CDB, respectively. Pre-treated plastic sheet with palmitic acid in PDB and CDB lost 24% and 33% of their weight. Additional confirmation was added in support with SEM and FTIR(Jayaprakash & Palempalli, 2018).

Bjerkanderaadusta TBB-03, which was isolated from the Ohgap Mountains in North Chungcheong Province, South Korea, decomposed HDPE (0.05 mm thick) in 90 days. SEM and Raman spectroscopy were used for conformation(Kang et al., 2019). *M.circinelloides* (MTCC 3945) degraded HDPE of 10 and 38 µ sheet for a period of 45 days, resulting in weight reductions of 1.428± 0.51 and 0.709±0.14 % for untreated plastic strips, and 1.13 and 0.610% for pre-thermally treated (80^{o}C) plastic strips respectively. The sample was obtained from a pure culture and the findings were validated using FTIR analysis (Sharma et al., 2019).The digestive tract of a wax moth (*G.mellonella*) was shown to harbor *A. flavus* PEDX3, which may degrade polyethylene MPs within a span of only 28 days. FTIR measurements confirmed the breakdown of HDPE due to the presence of microplastic carbonyl groups and ether groups (Zhang et al., 2020).*A.fumigatus*, *A.flavus*, and *F.solani*, were collected from soil and degraded plastic over a period of 90 days. The weight reduction of polyethylene following physical(UV 300 nm wavelength for 10 days), thermal (80°C for 120 hours), and chemical treatment (concentrated nitric acid for 10 days)was 2.12, 1.38 and 2.58%, respectively. In contrast, untreated (UT) polyethylene experienced weight loss of 1.43, 1.31 and 1.84%. The findings were supported by SEM and FTIR(Rani et al., 2020).*A. flavus*isolated from farm sludge (FS), soil, wax and meal worms' excretaand degraded 5.5% and 2.5% of the weight ofHDPE plastic sheets, after a span of 100 days. SEM and FTIR was used for confirmation of degradation(Taghavi et al., 2021).*C.parapsilosis* ATCC 96144, encountered for its ability to degrade HDPE, was found in the sediments of the deep sea. The degradation of plastic was observed within 96 hours, as evidenced by FTIR and SEM analysis(M. M. Oliveira et al., 2022).The*Cephalosporium* strain NCIM 1251, obtained from NCIM, NCL, India, reduced HDPE 18.22% by weight in 56 days following 6 hours of drying at 60°C, 7 days of exposure to UV light in a laminar flow, and 69% exposure in nitric acid. TGA, FTIR, and SEM provided further evidence(Chaudhary et al., 2022).Within 20 days, the powdered form of HDPE could be consumed by *C. halotolerans*, which was isolated from the digestive tract of *G. mellonella* larvae. An SEM analysis was performed on the particles. This was further validated by FTIR, enzyme and protein analysis (Napoli et al., 2023) (Table No. 3).

PolyesterPolyurethane (PS-PU)

Five strains of *Nectriagliocladioides*, *P. ochrochloron*, and seven strains of *Geomycespannorum* derived from PS-PU soil degraded within 44 days. The maximum reduction in tensile strength of PS-PU was recorded by 60%. This study was supported by SEM analysis(Barratt et al., 2003).The fungal communities (*G.pannorum*and *Phoma sp*.) in soil showed degradation of PS-PU in just five months. It was confirmed by tensile strength in soil and reviled up to 95%(Cosgrove et al., 2007).(Ibrahim et al., 2011) isolated different fungi from soil, wall paints (Latex), plastic debris and shields of street light posts for degradation of PS-PU. In shaken liquid (L) culture, *F. solani* (FsM-6) completely degraded (100%) followed by *A.solani* (FsH-3) and *A. terreus* (FsH-8) with 71.8%; *A. fumigatus* (FopI-4) accounts for 40.5%; *A. flavus* (FopI-2) by 26.1% and *Spicaria sp.* (Fp-7) with 12.7% of PS-PU weight loss in 21 days. Similarly, in petriplate (P)tests 72.5%, 22.9%, 63.6%, 58.0%, 94.8%, and 39.5%weight loss was observed respectively. Clear zone test was performed in addition to confirm the growth and degradation.

Pestalotiopsismicrospora completely decomposed the plastic within a span of 14 days. The degradation was confirmed by the utilisation of zone clearance, enzyme activity, and FTIR analysis (Russell et al., 2011).*L.theobromae, P.janthinellum, F.verticilloides* and *P.puntonii* isolated from forest soil degraded PS-PU in 15 days. It was authenticated with biomass determination and clear zone formation(Urzo et al., 2017).*Papiliotremalaurentii* 5307AH, isolated and identified during a microbiome analysis of an aircraft. Polyethylene succinate (PES) and polyethylene adipate (PEA)along with thermoset PS-PU andIrogran,were used to decomposed during a span of 8 days. The highest concentration of CO_2 (1.2 ± 0.2 mol%) was observed in PES. The reduction was also confirmed using IR microscopy techniques (Hung et al., 2019).Within a short span of fourteen days, *Embarriaclematidis*, obtained from Institute of Excellence in Fungal Research, Thailand, caused the degradation of PS-PU. The presence of degradation was evidenced by a quantification of 0.85 g/L of CO_2. Additionally, enzymaticactivity assay, FTIR and GC-MS analyses were conducted (Khruengsai et al., 2022)(Table No. 3).

Polystyrene (PS)

P.variabile, showed degradation of polystyrene in 16 weeks. It was screened and verified by SEM, FTIR, and GPS(Tian et al., 2017). PS is an artificial polymer made from styrene monomers.*T.hamatum* FR87271 originated from a buried plastic fragment, decreased the amount of virgin PS by 0.9±0.4% within a span of 7 days. Additional confirmation was conducted using FTIR, TGA, GPCand SEM(Malachová et al., 2020).*P. glaucoroseum* was isolated from soil, farm sludge, activated sludge, and worm dung, could degrade 1.8% of PS within a span of 100 days. Due to colonisation of fungus and penetrationof microbial metabolites into the PS, surface deteriorationand formed cavities on the incubated PS could be seenby AFM and SEM. FTIR results were also in support of the study(Taghavi et al., 2021).*Cephalosporium sp*. (NCIM 1251) procured from NCL, had a degradation rate of 12.22±0.82% on nitric acid-treated PS over a period of 56 days.It was further confirmed by SEM, FTIR, XRD, TGA.(Chaudhary et al., 2022).In just 35 days, the PS weight was reduced by 19.7 % using *P. chrysosporium* (BKMF-1767, CCTCC, No. AF-96007) which was obtained from the China Centre for Type Culture Collection, China. Further verification was carried out using GC-MS, FTIR and SEM (F. Wu et al., 2023)(Table No. 3).

Polyurethane (PU)

The fungus *P.chrysosporium*ME446 (ATCC34541) demonstrated the production of lignin peroxidase when immobilized on polyurethane (PU) foam. Within 10 days, under multiple operational conditions like number of polyurethane foam cubes, glucose concentration and temperature. Also, it showed various amount of enzyme production on addition of various additives(Nakamura et al., 1997). Weight loss, FTIR and SEM have verified that the culture of *C.globusom* from the biological research institution Romania's microbiology department, has effectively broken down the polyurethane in 130 days(Oprea, 2010). Three fungal species, namely *Monascus sp*., *M.ruber*, and *M.sanguineus* were obtained from the soil at the dumping site. *M. ruber*had the most elevated esterase concentration, with *M. sanguineus* following closely behind. Production of esterase by *M. ruber*, SEM, and Zeta analysis, showed that the PU was completely degraded within a span of 5 days (El-Morsy et al., 2017).According to an enzymatic essay, *Pestalotiopsis sp.*, which was isolated from *Nepenthes ampullaria*, broke down polyurethane in three weeks.(Bong et al., 2017).The fungi *Xepiculopsisgraminea*, *C.cladosporioides*, and *P.griseofulvum*, along with the plant pathogen *Leptosphaeria sp*., were detected in plastic waste from the shoreline of Lake Zurich. These organisms were observed to possess the ability to decompose PU within a span of 6 days. Also, they observed that the *Agaricusbisporus* and *Marasmiusoreades*from fungal culture can decompose PU around 14 days. The degradation was validated using GC-MS(Brunner et al., 2018).*A. fumigatus* S45 (KF961003), obtained from waste dumping site soil, decomposed PU film within a span of 28 days. The degradation was indicated by a measurement of 10.05 g/L of CO_2, and a weight loss of 15-20%. FTIR, DSC, SEM and Esterase Activity Assay were used for verification of breakdown(Osman et al., 2018).SEM, GC-MS, and liquid chromatography-mass spectroscopy (LC-MS) confirmed that PU cubes were degraded in 12 weeks by uncultured *Arthrographis, Apiotrichum, Aspergillus, Thermomyces*, and compost-derived *Arthrographis, Thermomyces, Apiotrichum, and Mortierella*(Gunawan et al., 2020a). *Cladosporium* SI3, and *P.chrysogenum* SIO2 were isolated from PU rich site in an ocean, examined for consumption of PU for 15/30 weeks and it was screened by SEM, FTIR, and GC-MS (Gunawan et al., 2022b). The PU degrading strains, *R. oryzae* P2072 and *A.alternata* P2073 were isolated from the soil,showing a degradation rate of 2.7% and 3.3% weight loss respectively after incubation of 2 months.SEM and enzymatic analysis also supported the results(K. Y. Wu et al., 2023).

Liu et al., (2023) isolated *Cladosporium sp*. P7 from an activated sludge. The fungal strain degraded 32.42% of PU on Poly(1,4-butylene adipate- Polyurethane (PBA-PU) whereas it increased up to 43.91% along with PDB after 28 days. Similarly, fungus cultured with PU foam on MSM and PDB medium showed 15.3% and 83.8% degradation respectively after 14 days. It was further confirmed by SEM and FTIR(J. Liu et al., 2023).In the liquid media (L), PU was consumed by fungal strains *Clonostachy* PB54 (38%), PB62 (36%) and *Purpureocillium spp.* PB57 (33%) whereas on solid media (S), strains PB54, PB57 and PB49 produced the highest average weight loss of 45%, 42% and 39% after 90 days of incubation. These strains were isolated from the landfill. The degradation was further confirmed by

FTIR, LC-MS and X-ray photoelectron spectroscopy (XPS)(Bhavsar et al., 2024).*L.iraniensis* (ZHKUCC 22–0282), *M.alpina* (ZHKUCC 22–0283) which were found growing on PU foam, degraded 13.55 on malt extract agar (MEA) and 26.30% on malt agarmedium containing chloramphenicol (CMEA) by mass in four months. The results of the SEM analysis corroborate the confirmation (Xu et al., 2024)(Table No. 3).

Polyvinyl Chloride (PVC)

Soilcontaining *P.chrysosporium* combined with municipal sewage sludge showed degradation of PVC sheets (treated with cellulose (1:1)) in three months. FTIR was used to confirm it(M. I. Ali et al., 2009). The degradation of PVC occurs during a span of 10 months when it is subjected to *P.chrysosporium* EU543990, *Lentinustigrinus*EU543989, *A. niger* EU543987, and *A. sydowii*EU543988 found in soil. The maximum production (7.31g/L) by *P.chrysosporium* and (6.02g/L) of CO_2 by *A. niger*after 4 weeksThe analytical techniques of SEM, FTIR, GPC, and NMR also demonstrated a notable adaptation in biotransformation(M. I. Ali et al., 2014).*Cochliobolus sp.* isolated from soil of plastic industry has degraded PVC in 7 days, as confirmed by FTIR, GC-MS and SEM(Sumathi et al., 2016). A 75% reduction in the weight of PVC was seen within a period of 28 days by *C.globosum* ATCC 16021 from a culture collection. Further it was supported by SEM analysis(Vivi et al., 2019).*PhanerocheateChrysosporium* isolated from plastic waste and wood material which degraded PVC sheets in 2 months with the weight loss of 31%. FTIR and SEM confirm the breakdown(Khatoon et al., 2019).

T.hamatum FR87271,*Trichaptumabietinum* J768676, *Byssochlamys nivea* FK1 and *B. nivea*JM5 broke down PVC within a period of 2 months, with rates of 20.0±0.5, 17.5±0.7, 18.4±0.7, and 15.5±0.9 respectively in liquid medium. The sample was derived from soil collected from different localities and subsequently subjected to analysis utilizing FTIR, TGA, GPC, and SEM techniques(Malachová et al., 2020).*A. niger* NG_065763.1 exhibited a degradation rate of 10±3.3% and *A. glaucus*NG_063391.1 showed a degradation rate of 32±3.3% when exposed to liquid media containing PVC over a period of 28 days. The changes in surface topography were confirmed by SEM and the changes in functional groups intensity was observed using the FTIR(Saeed et al., 2022).*Fusarium sp., T.viridae, A. flavus, A. fumigatus, A. niger, P.glandicola,* and *P. chrysogenum* were found in a dump site. Over a period of 42 days, these fungi degraded PVC by 6%, 12%, 6%, 2%, 10%, 6%, and 10% by weight, respectively (Emmanuel-Akerele & Akinyemi, 2022).Weight reduction analysis showed that when *A. fumigatus-3*was isolated from landfill,showed highest reduction (2.15 ± 0.42%), followed by *A. fumigatus-2, Malassezia sp*. and *A. fumigatus-1*, with reduction percentages of 1.92±0.51, 1.46±0.7 and 0.718±0.1 respectively after 30 days. SEM analysis revealed that *A. fumigatus3, A. fumigatus2* and *Malassezia sp*. strains could create surface cracks on the PVC strips, with the most prominent erosion observed in the *A. fumigatus-3* strain. Whereas SEM images of control PVC strips displayed no surface erosion. The degradation study was also supported by enzymatic activity(El-Dash et al., 2023)(Table No.4).

Polypropylene (PP)

Phanerochcetechrysosporium ME-446 (ATCC34543) DSM has degraded PP with lignin in the duration of 30 days, which was confirmed by elongation at break and enzymatically(Mikulášová & Košíková, 1999). *A. niger,* when exposed to compost for a duration of six months, demonstrated the ability to decrease the size of a unirradiatedisotactic-PP sample by 22% weight loss. This finding was also supported by SEM and FTIR(Pandey & Singh, 2001).*A. niger* consumed isotactic polypropylene (i-PP) in 6 months, as demonstrated by SEM, FTIR and viscosity variation(Alariqi & Singh, 2010).The blends of PP/TPS with 6 wt % of ethylene-(vinyl acetate) copolymer (EVA) were degraded by *Trichoderma* sp. in 3 weeks. The confirmatory tests were Small Angle X-ray Scattering (SAXS), Transmission Electron Microscopy (TEM), TGA, SEM and FTIR(Hanifi et al., 2014). *L.theobromae* isolated from *P.flavida, Aspergillus sp.,* and *Paecilomyceslilacinus* isolated from *H.brunonis* has degraded PP (20 µm) in 90 days as confirmed by the FTIR, DSC, SEM and changes in viscosity tests(Sheik et al., 2015).*Trametes villosa, T. versicolor, Pycnoporus sanguineus, Fuscoporia ferrea* degradedPP and EVA blended with wood flour of *Eucalyptus grandis* and *Pinus elliottii* in 12 weeks with a coupling agent (CA). The observed weight loss by *F. ferrea* for PP-EVA-Eu-CA was 14% and for PP-EVA-Pi-CA was 16.5%. SEM and CO_2 production served as confirmation of degradation(Catto et al., 2016).According to SEM, FTIR, AFM, and static contact angles (SCA), *B.adusta* from the Research Laboratory for Fungi with Applications in Ecological Reconstruction of Polluted Soils with Heavy Metals (RECOSOL) degraded PP, PP/*E. globulus* (PP/EG), PP/*Pinecones* (PP/PC), and PP/*Brassica rapa* (PP/BR) in 49 days(Butnaru et al., 2016).An investigation was conducted to assess the capacity of culture collected *Aspergillus* and *Penicillium* to decompose pure PP. The degradation rates of both neat PP 1 cycle (-0.262 % mass loss) and neat PP 7 cycle (-0.620 mass loss) (temperature profile of 175, 180 and 190˚C at a screw speed of 60 rpm), were observed to be 30 days. The SEM and FTIR offer supplementary support for the findings(T. A. De Oliveira et al., 2020).After being isolated from a solid waste disposal site, *A. fumigatus* consumed polypropylene (PP) cups in six months, causing an 18.0% weight loss. Additionally verified by FTIR and SEM(Oliya et al., 2020).PP was consumed by *Coniochaetahoffmannii* and *Pleurostomarichardsiae,* isolated from hydrocarbon-contaminated environments in two months. The PP films were checked for degradation by SEM, Raman spectroscopy, FTIR-ATR and Enzymatic activity (Porter et al., 2023).The PP sheets were treated with *C.halotolerans* SUK PRAKASH (ON024632) which was isolated from soil of solid waste dumping siteand was examined for weight loss after 8 months. The maximum weight loss was found in sunlight-exposed PP sheets (8.6%), followed by UV-exposed PP sheets (6.1%), and without pre-treated PP sheets (4.2%). FTIR spectroscopy showed the variance in the intensity of bands at the different locations (Parit et al., 2023).*A. flavus*OL919436 and OL919440, *A. fumigates* OL919439 and OL919437, *F.oxysporum*OL919444 and *P.granulatum*OL919448were isolated from municipal waste landfill siteand found to successfully degrade the PP in 90 days. The SEM images showed that the surface of the granule was covered with fungal shreds of different lengths. The empty spaces in the images visibly demonstrate delicate pits in the granule structure. Microdamage to the outer layer of the structure was clearly visible. The degradation studies are also supported by FTIR (Wróbel et al., 2023).

Polyethylene Terephthalate (PET)

Pseudomonas fluorescens, A. niger, and *P. pinophilum*wereemployed to degrade PET (225-275 µm)that included nitrated units. Both were obtained from uncontaminated cultures. Molecular weight loss by using SEC and SEM were used to validate the experiment. The degradation process lasted for duration of three months(Marqués-Calvo et al., 2006a).*A. niger* (CECT 2700), *P.pinophilum* (2912) isolated from Coleccio´nEspan˜ola de Cultivos Tipo has degraded PET in the duration of 3 months which is confirmed by optical imaging profiler (OIP)(Marqués-Calvo et al., 2006b). *P.funiculosum* was obtained from a landfill and studied for a period of 84 days to assess its ability to degrade PET. Various doses of Bionolle were used to test the polymer. The polymer composition was characterized by the following weight ratios: 100/0, 90/10, 75/25, 50/50, and 0/100, with corresponding weight loss percentages of 0.08, 0.07, 0.21, 0.19, and 90.28, respectively. The deterioration was enhanced to a greater extent with the assistance of SEM, FTIR, and XPS techniques(Nowak, PająK, et al., 2011).In a study conducted by (Nowak et al., 2011) PET, a type of a polyester was buried in waste coal, a forest and an extinct volcano crater over a period of 225 days.*A. awamori, M. subtilissima*, and *G. viride* were identified on the buried plastic film. The weight loss recorded in waste coal was 5.76%, 2.02% in forest and 17.03% in soil. The tensile strength revealed to be the most delicate among all the sites because of elongation at break of 98%. The findings were further supported by SEM and FTIR.*Thielavia terrestris* CAU709, isolated from soil, demonstrated the ability to hydrolyze PETwhen incubated with a low molecular mass cutinase for 24 hours(S. Yang et al., 2013).*Aspergillus sp., Penicillium sp.,* and *Fusarium sp.*which were isolated from sewage, degraded PET flakes and foam in 70 days as confirmed by FTIR(Umamaheswari et al., 2014).Fungal strains displaying possibilities for converting PET nanoparticles were *A. oryzae* [CBMAI 2034] C361 (1.0 ± 0.1), *Trichoderma sp.*[CBMAI 1932] C65 (1.7 ± 0.3), *Trichoderma sp.*[CBMAI 2032] C68 (1.1 ± 0.2), *Trichoderma sp.*L1239 (7.1 ± 0.2), *M. arundinis*L43 (2.4 ± 0.4), *M. arundinis*L84 (4.1 ± 0.5), *Fusarium sp.*L1269 (1.4 ± 0.2) detected by fluorescence after 15 days. Other low-capacitydegradable fungi found to be*R. miehei*C357 (0.3 ± 0.1), *P. brevicompactum*C360 (0.2 ± 0.1), *Aspergillus sp*. C362 (0.1 ± 0.0), *Aspergillus sp.*C363(0.4 ± 0.1), *Trichoderma sp.*C64 (0.4 ± 0.1), *Trichoderma sp*. [CBMAI 2033] C70 (0.2 ± 0.0), *Neopestalotiopsis sp.*[CBMAI 2030] F053 (0.4 ± 0.1), and *E. sorghinum* F057 (0.5 ± 0.1). All the findings were confirmed with SEM analysis(Chaves et al., 2018).Freshwaters isolates of*Microsphaeropsisarundinis (2), Mucor, Trichoderma, Westerdykella, and Pycnidiophora sp.* have successfully degraded PET and further verified byhigh-performance liquid chromatography with UVdetector(HPLC-UV), FTIR, SEM, and fluorescence examination(Malafatti-picca et al., 2019). The degradation of PET was attributedfrom the culture collected*Clitocybe sp*. and *L.laccata.*for over a period of six months which was confirmed by SEM and EDX analysis(Janczak et al., 2020).

Pseudomonas sp. could degrade PET films 0.6% by weight within 100 days which was isolated from AS, FS and soil. The colour of PET film changed from shiny-brown to matte-white. The AFM and SEM analysis showed cavities and surface deterioration. FTIR analysis confirmed the degradation(Taghavi et al., 2021).Dry weight measurement, titration assay, and SEM analysis verified that *Moniliophthoraroreri,* which was isolated from cacao pods, produced cutinase that broke PET by 43 % by weight in 21 days(Vázquez-Alcántara et al., 2021).*A.tamarii*and *P.crustosum,* isolated from soil on the premises of Rajalakshmi Engineering College, India, degraded PET through cutinase activity in 30 days as confirmed through terephthalic acid (TPA), FTIR, and SEM analysis(Anbalagan et al., 2022). *Lecanicillumaphanocladii*(IBPPM 542) and *F.oxysporum*(IBPPM 543) from the IBPPM Collection of Rhizospheric Microorganisms, originally isolated from oil-polluted samples, *T. harzianum*(IBPPM 664) from the Institute of Ecology and Evolution, Russian Academy of Sciences and *T.sayulitensis* (IBPPM 665), isolated from the rhizosphere of *Miscanthus* grown in Zn-polluted soil successfully degraded PET in 30 days and showed 11.6 ± 2.9, 22.0 ± 2.2, 17.2 ± 3.8, 10.0 ± 3.3 percent weight loss respectively. Production of enzymes like cutinase, peroxidase and oxidase supported the degradation of PET(Pozdnyakova et al., 2023).*P. ostreatus* from the University of Ibadan, Nigeria and *P. pulmonarius*, provided by Zero Emissions Research Initiative (ZERI), Namibia, successfully degraded the PET flakes after 60 days. There was a color fading of the PET flakes due to increased carboxyl-terminated species because of enzymes secreted by the fungi. The biodegradation was studied with the help of FTIR and GC-MS analysis(Odigbo et al., 2023) (Table No. 5).

Poly(ε-caprolactone) (PCL)

Pochonialilacinus (formerly *Paecilomyceslilacinus*) isolated from soil and activated sludge, demonstrated the ability to degrade PCL by 10% in 10 days. It was further confirmed with HPLC(Oda et al., 1995). The culture of *A. fumigatus* was introduced to PCL for 49 days. After 14 days, PLC films showed weight reduction and change in tensile properties. The degradation was studied by DSC(Albertsson et al., 1998).In 45 days, PCL was breached apart by *P.simplicissimum*and*A. fumigatus*. SEC, DSC, FTIR, SEM, and ESCA were used to corroborate the observed 50–55% weight decrease(Renstad et al., 1998).In aerobic soil study, *Paecilomyces sp., Thermomyces sp.,* were found at 30^{o}C degrading PCL 30 days. It was confirmed by weight measurement and analysis of soil (Nishide et al., 1999). In 50 days, the SEM test verified that *Penicillium spp*. isolated from soil had effectively broken-down PCL(Kamiya et al., 2007). Seo et al. (2007) conducted a fascinating study where they broke down PCL utilizing a unique cutinolytic-ustilaginomycetous yeast,*Pseudozymajejuensis*OL71,discovered on orange leaves. They confirmed the degradation by measuring the total organic carbon (TOC) concentration, which showed a fivefold increasein Yeast and Mold medium with 10 g/l PCL within a span of 12 days. It also showed the best growth on YM medium with 10g/l cutin(Seo et al., 2007).mass loss and SEManalysis confirms that the soil-isolated *A. fumigatus, A. niger, A.versicolour, Aspergillus spp., P.simplicissimum, Penicillium spp.,* and *C.cladosporioides* have effectively broken-down blend of PCL with cellulose acetate (CA) 25%, reduced the tensile strength by 38, 25, and 13% in the blends of 80/20, 60/40, and 40/60 in nine months respectively(Rosa et al., 2009).*P.oxalicum* strain DSYD05-1, isolated from soil, demonstrated the ability to degrade PCL within 6 days, confirmed through enzymatic assay and weight loss analysis(Li et al., 2012).*T. terrestris* CAU709, isolated from soil, demonstrated the ability to hydrolyze PCL when incubated with a low molecular mass cutinase enzyme for 24 hours(S. Yang et al., 2013). Enzymatic degradation and SEM confirm that in 7 days, *P. antarctica* JCM 10317, *Ustilago maydis* MAFF 236374, 236375, 236376, 236377, 236378, and *S. cerevisiae* BY4741 from culture collections of Japan, NIAS General Bank Japan, and EUROSCARF, Germany, degraded PCLfilm(Shinozaki et al., 2013).*P. japonica* is a newly discovered yeast belonging to the ustilaginomycetous group. It was found on the *Hyoscyamusmuticus* plant, often known as Egyptian henbane. This yeast could break down PCL in the form of film and foam. They reviled a significant weight reduction of 93.33% for PCL film and 43.2% for foam over a period of 15 and 30 days respectively (Abdel-Motaal et al., 2014).Agricultural soils collected from Chiang Mai and Lampang provinces in northern Thailand were screened for PCL degradation by the agar diffusion method. Among the several isolates, *Amycolatopsis sp.* Strain SCM_MK2-4 produced enzymes like protease, esterase and lipase and showed 0.023 U/mL activity in 30 days(Penkhrue et al., 2015). Soil of western and central parts of Spitsbergen, Svalbard Archipelago, *Trichoderma sp*. (16H) and *Clonostachys rosea* (16G) isolated and showed weight loss of 21.54 and 52.91% of PCL respectively. *C. rosea* also showed degradation of 34.5% at 20^{O}C in liquid medium. The experiment was further validated by SEM(Urbanek et al., 2017).*A. fumigatus* and *T. lanuginosus* showed complete degradation of PCL when buried in compost and incubated at 50˚C after 91 days. They also observed significant reduction in tensile strength within a 2 week at below 45˚C. Further thy recorded abundant growth of *A. fumigatus* at 25 and 37˚Cwhereas *Neocosmosporaramose*, *F.solani*and*A. fumigatus*reviled at 25˚C in compost and *F. solani* alone in soil at same temperature(Al Hosni et al., 2019).A culture of *C.globosum* obtained from a collection was utilized for the degradation of PCL with significant reduction of 75% in mass over a period of 28 days and supported by SEM analysis (Vivi et al., 2019).Clear zone formation indicates that the Korean Agricultural Culture Collection (KACC)'s *Apiotrichumporosum* (83034BP), *P.samsonianum* (KNUF-20-PPH03), *T.pinophilus* (KACC 83035BP), *P.lilacinum* (KNUF-20-PDG05), and *Fusicollaacetilerea* (KACC 83036BP) degraded PCL in 45 days(Lee et al., 2021).In just one month, PCL, was successfully degraded by consortium of*Geomyces sp.* (B10I), *Sclerotinia*, *Fusarium sp.* (B30M), *Mortierella*, and *Hansenulaanomala*which were isolated from soil, as demonstrated by the establishment of a clear zone(Urbanek et al., 2021).Dry weight measurement, titration assay, and SEM analysis verified that *M.roreri*, which was isolated from cacao pods, produced cutinase that broke down PCL 43 % by weight in 21 days(Vázquez-Alcántara et al., 2021)(Table No. 5).

Polyhydroxy Butyrate (PHB) and polyhydroxybutyrate co-hydroxyvalerate) (PHBV)

P.simplicissimum, *Verticillium leptobactrum*, and *A.fitmigatus*degraded PHB and PHBHV in compost in 98 days. Weight loss and loss of mechanical properties verified the degradation(Mergaert et al., 1994).*P.lilacinus* isolated from soil and activated sludge, demonstrated the ability to degrade 100% of PHB in 10 days. It was further confirmed with HPLC(Oda et al., 1995). In aerobic soil study, *Mucor sp.* was found at 30^{o}C degrading PHB/HVin 23 days. It was confirmed by weight measurement and analysis of soil (Nishide et al., 1999).From garden soil, *Penicillium*, *Cephalosporium*, *Paecilomyces*and *Trichoderma* has degraded PHB in 30 days, confirmed by mass loss and mechanical tests(Savenkova et al., 2000). *A. fumigatus* LAR 9, *P.farinosus* LAR 10 and*F.solani* LAR 11 were isolated form PHB buried in activated sludge for 25 days.It showed weight loss of 98.9 ± 4.0% at 37°C.

Whereas, *A. fumigatus* LAR 9, *Curvulariaprotuberata* LAR 12 and *P. simplicissimum* LAR 13 found on Sky-Green1 (SG) with 77.5 ± 2.4% at 28°C and *A. fumigatus* LAR 9 and *A. parasiticus* LAR 26 on Mater-Bi1 (MB) with 72.1 ± 2.2% at 60°C weight loss in 55 days. Further it was confirmed by SEM and Sturmtest (Kim et al., 2000). PHB has been broken down by the soil-isolated *Trichoderma spp*. in 50 days, as shown by FTIR(Râpă et al., 2014). *A. fumigatus* (KP724998.1) in soil whereas *A. fumigatus* (KR527135.1) in compost at 37°C, *F. solani* (KX929306.1) in compost at 25°C and *T. lanuginosus*(KT365229.1), *Sordarialessp.* (JN659492.1), *S. thermophilum*(AB085928.1) and *C. thermophilum*(AB746179.1) in compost at 50°C showed significant weight loss around 300 days(Al Hosni et al., 2019).*A. niger* (soil contaminated with oil wastes) obtained from the Department of Biotechnology, Ministry Science, degraded PHB on solid media with a 100% weight loss in 12 days whereas it took 14 days to consume in liquid medium(Iman et al., 2019). *P. oxalicum* strain SS2 has broken downPHB and PHBV from soil in emulsion and films within 36–48 hours at 30 °C in a lab-built soil environment within a week, as confirmed by SEM, NMR, DSC, FTIR, Gel Filtration Chromatography (GFC), and Molecular Weight Determination (MWD)(Satti et al., 2020)(Table No. 5).

Polylactic Acid (PLA)

Enzymatic degradation and SEM confirm that in 7 days, *P. antarctica* JCM 10317, *U. maydis* MAFF 236374, 236375, 236376, 236377, 236378, and *S. cerevisiae* BY4741 from culture collections of Japan, NIAS General Bank Japan, and EUROSCARF, Germany, degraded PLAfilm(Shinozaki et al., 2013).Several isolates were collected from northern Thailand, *Amycolatopsis* sp. SCM_MK2-4 exhibited 36.7 % degradation of PLA film after seven days. They also reported protease, esterase and lipase enzymes, which were responsible for biodegradation(Penkhrue et al., 2015). *T. lanuginosus*was prominently identified in compost and soil under controlled conditions. PLA at 25 and 37˚C showed no significant weight reduction, whereas, after approximately 18 weeks, rapid weight loss was observed at 50˚C in compost(Al Hosni et al., 2019).Clear zone formation indicates that the Korean Agricultural Culture Collection (KACC)'s *A.porosum* (83034BP), *P.samsonianum* (KNUF-20-PPH03), *T. pinophilus* (KACC 83035BP), *P.lilacinum* (KNUF-20-PDG05), and *F.acetilerea* (KACC 83036BP) degraded PLA in 45 days(Lee et al., 2021). *P.chrysosporium*(BKMF-1767, CCTCC, No. AF-96007) procured from China Center for Type Culture Collection, China, degraded 19.7% PLA by weight in 35 days. Additional confirmation was done with the help of FTIR, SEM (F. Wu et al., 2023)Table No. 6.

Polybutylene Succinate (PBS)

In 50 days, the SEM test verified that *Penicillium spp*. isolated from soil had effectively broken-down PBS (Kamiya et al., 2007). *F.solani* isolated from farmland soil has degraded the polybutylene succinate in 14 days. It was demonstrated by measuring CO_2 evolution(Abe et al., 2010).Within ten days enzymatic activity and a SEM test have indicated that *Paraphomachrysanthemicola* (FJ426987), which was isolated from healthy leaves of wheat, barley, and rice grown in fields, successfully wiped out PBS film (Bionolle 1001 G) (20 µm)(Koitabashi et al., 2012). *T. terrestris* CAU709, isolated from soil, demonstrated the ability to hydrolyze PBSwhen incubated with a low molecular mass cutinase enzyme for 24 hours(S. Yang et al., 2013). Enzymatic degradation and SEM confirm that in 7 days, *P.antarctica* JCM 10317, *U. maydis* MAFF 236374, 236375, 236376, 236377, 236378, and *S. cerevisiae* BY4741 from culture collections of Japan, NIAS General Bank Japan, and EUROSCARF, Germany, degraded PBS film(Shinozaki et al., 2013). *Cryptococcus magma, C. magnus* JCM 9038 (CBS 140),*Filobasidiumfloriforme* JCM 10631 (CBS 6241), *P. antarctica* JCM 10317 procured from Japan Collection of Microorganisms of the Riken Bio-resource Center, Japan which were isolated from larval midgut of a stag beetle (*Aeguslaevicollis)* showed degradation of PBSin 4 days. The confirmation was done on the basis of enzyme production(Suzuki et al., 2013). Previously isolated *Paraphoma sp*. from barley, successfully degraded PBS films in 7 days as proved by the enzymatic degradation test(Koitabashi et al., 2016). *P. antarctica* (PaE) and *Paraphoma sp*. B47-9 (PCLE) have degraded PBS (Bionolle #1020)in 1-4 hrs, which was confirmed using LCMS(Sato et al., 2017). Enzymes synthesized by SCM_MK3-3 isolate and *A. thailandensis* CMUPLA07showed PBS degrading activity which further confirmed by SEM (Penkhrue et al., 2015).Al Hosni et al., (2019) incubated *T. pinophilus* (MF686817.1)*, A. cellulolyticus* (AB474749.2), *P. pinophilum* (AB474749.2) and *A. fumigatus* (KF494830.1) in compost and soil. They recorded moderate degradation of PBS at 50˚C in compost and 37˚C in soil within 300 days. In just one month, PBS was successfully degraded by *Geomyces sp.* (B10I), *Sclerotinia*, *Fusarium sp.* (B30M), *Mortierella*, and *H.anomala* isolated from soil, as demonstrated by the establishment of a clear zone(Urbanek et al., 2021)Table No. 6.

di-(2- ethyhexyl phthalate (DEHP)

*F. oxysporum*and *M. alpina*isolated from soil in central Manchester, UK, *P. pulmonarius,* two strains of *P. ostreatus* and *P. florida*procured from the Chinese University of Hong Kong Collection, American Type Culture Collection and Universidad Autonoma de Tlaxcala collection respectively. In the DEHP-containing medium, *F. oxysporum*and *M. alpina*produced the utmost amounts of biomass, 200 and 82 mg/cm2, respectively(Suárez-Segundo et al., 2013).*F.culmorum,* a culture from Research Centre for Biological Sciences (CICB) at Universidad Autónoma de Tlaxcala, Mexico degraded 99% of DEHP (1000 mg/L) after 144 h of incubation whereas at 500 mg/L, it showed 93% and nearly 98% degradation within 84 h and 144 h of incubation, respectively. The experiment was confirmed by GC-MS analysis(Ahuactzin-Pérez et al., 2016).*P. ostreatus, P.seryngii, Lentinula edodes,* and *A. bisporus*were procured from the market. The manganese peroxidase activity (MnP) confirmed the degradation of DEHP after 20 days(Hock et al., 2020).The soil of garbage dumps was investigated and isolated *A. niger* (MZ832174), *A. nidulans* (MT919276), and *R. nigricans*. After 20 days, the fungal species with the highest DEHP degradation rate in urine bags was *A. niger*, followed by *R. nigricans* and *A. nidulans*. The most DEHP-degrading fungus species in blood bags was *A. niger*, followed by *A. nidulans* and *R. nigricans*. SEM was employed to understand the deterioration of DEHP (E. A. M. Ali et al., 2023).*F. culmorum*was procured from the Research Centre for Biological Sciences culture collection at Universidad Autónoma deTlaxcala, Mexico. For the degradation of a high concentration of DEHP (3 g/L) as the only carbon and energy source, the fungus was grown in solid-state fermentation (SSF), where the biodegradation reached 96.9% in 312 hours. In cultures treated with DEHP, this fungus developed an esterase activity three times higher than in control cultures (1288.9 and 443.2 U/L, respectively). Using zymography, nine bands exhibiting esterase activity (24.6, 31.2, 34.2, 39.5, 42.8, 62.1, 74.5, 134.5, and 214.5 kDa) in DEHP-supplemented cultures were detected. These bands differed from control cultures(Hernández-Sánchez et al., 2024) (Table No. 6).

Linear Low-DensityPolyethylene (LLDPE)

The mix culture of *A. niger*, *P.funiculosum*, *C.globosum*, *G. virens*, and*Pullularia pullulans* demonstrated the ability to biodegrade LLDPE and maleated LLDPE with corn starch blends (>30%) in 28 days. The recorded weight loss was 0.37% and 0.20% for LLDPE and MA-g-LLDPE respectively. It was further confirmed by SEM, DSC, TGA, FTIR(Chandra & Rustgi, 1997). *Aspergillus* and *Penicillium* have been shown to break down LLDPE in three months, as demonstrated by DSC and FTIR tests.(Ojeda et al., 2009). *P.chrysosporium*ATCC 34541, procured from Deutsche Sammlung von Mikroorganismen und Zellkulturen (DSMZ), demonstrated the ability to degrade oxo-biodegradable LLDPE films (12 microns) designed for mulching applications over 180 days, confirmed through FTIR, DSC, TGA, and GPC analysis(Corti et al., 2012). According to enzymatic activity, *A.terreus*, *A.wentii*, and*Emericellanidulans* which were isolated from waste material soil, decomposed LLDPE and LLDPE mixed with High Molecular Weight (HmHDPE) in three months(Poonam et al., 2013). *T. hamatum*FR87271 decomposed LLDPE within seven days after being extracted from plastic waste found in the soil. The weight reduction for untreated virgin plastic and LLDPE treated with γ irradiation followed by 90°C temperature showed 2.2±1.2% and 3.9±0.5%, respectively. The test was supported by FTIR, TGA, GPC and SEM (Malachová et al., 2020).Among the microbes tested, the most active plastic-consuming fungus was*Debaryomyceshansenii*(MK394103.1), found in agricultural soil. Compared to plastic film, it reduced LLDPE MPs by 2.5-5.5% in 30 days when it was in powder form. Some other, as-yet-unidentified fungi also demonstrated plastic-consuming capabilities up to some extent. FESEM validated it further (Salinas et al., 2023) (Table No. 6).

Poly (butylene succinate adipate (PBSA)

In aerobic soil study, *Aspergillus sp.*, *Cunninghamella sp.* and*Thermomyces sp.* were found at 30^{o}C degrading PBSA in 25 days. It was confirmed by weight measurement and analysis of soil(Nishide et al., 1999).In 50 days, the SEM test verified that *Penicillium spp*. isolated from soil had effectively broken-down PBSA (Kamiya et al., 2007). Within ten days enzymatic activity and a SEM test have indicated that *P.chrysanthemicola* (FJ426987), which was isolated from healthy leaves of wheat, barley, and rice grown in fields, successfully wiped out PBSA film (Bionolle 3001 G) (20 μm)(Koitabashi et al., 2012). Enzymatic degradation and SEM confirm that in 7 days, *P. antarctica* JCM 10317, *U. maydis* MAFF 236374, 236375, 236376, 236377, 236378, and *S. cerevisiae* BY4741 from culture collections of Japan, NIAS General Bank Japan, and EUROSCARF, Germany, degraded PBSA film(Shinozaki et al., 2013). *C. magma*, *C.s magnus* JCM 9038 (CBS 140),*Filobasidiumfloriforme* JCM 10631 (CBS 6241), *P. antarctica* JCM 10317 procured from Japan Collection of Microorganisms of the Riken Bio- resource Center, Japan which were isolated from larval midgut of *A.laevicollis* showed degradation of PBSA in 4 days. The confirmation was done on the basis of enzyme production(Suzuki et al., 2013). Previously isolated *Paraphoma sp*. from barley, successfully degraded PBSA films in 7 days as proved by the enzymatic degradation test(Koitabashi et al., 2016). *Paraphoma* sp. Strain B47-9 degraded PBSA of 20µm in 8 hours by enzyme production. It was analysed and confirmed by gel electrophoresis(Sameshima-Yamashita et al., 2016). *P. antarctica* (PaE) and *Paraphoma sp*. B47-9 (PCLE) have degraded PBSA (Bionolle #3020) in 1-4 hrs, which was confirmed using LCMS(Sato et al., 2017). Previously isolated rice leaf-derived *P. antarctica* strain NRL-A and rice husk-derived *P. antarctica* strains GB-4(1) Wand GB11-W as well as *P. antarctica* JCM 10317 from the Japan Collection of Microorganisms (JCM) of the Riken Bio Resource Centre degraded PBSA film (20 mm) in three days, as confirmed by SEM(Kitamoto et al., 2018). In just one month, PCL, PBS, and PBSA were successfully degraded by *Geomyces sp.* (B10I), *Sclerotinia*, *Fusarium sp.* (B30M), *Mortierella*, and *H.anomala*isolated from soil, as demonstrated by the establishment of a clear zone(Urbanek et al., 2021).PBSA films were damaged in 28 days by *A. fumigatus* L30 and *A.terreus* HC (78 % weight loss) which were isolated from farming soil. This was verified by SEM, NMR and enzymatically(Chien et al., 2022). *Fusarium sp.* grown in *in-situ* soil degraded PBSA in 55 days. The production of CO_2 and enzymatic activity were used to verify the degradation(Tsuboi et al., 2024) (Table No. 6).

Other types of Plastic

P. ostreatus, *P.chrysosporium*, *T. versicolor* (ATCC11235), cultures from culture collection of the Institute of Forstbotanic of The Universitat Gottingen, 3400-Gottingen, Germany and *Gloeophyllumtrabeum*, *Phlebia radiata* from Collection of Bundesanstalt fur Materialforschungundprufung, Berlin, Germany, Lignin/styrene products 10.3 (LPSl0), 32.2 (LPS32), and 50.4 (LPS50) wt% lignin and lignin/ methyl methacrylate (1 1 to 18 wt% lignin) in 68 days. The significant weight loss was recorded for LPS 50 and LPS 32 by 50.41 and 32.17, respectively. SEM analysis, UV-spectrometry, and synthesis of polymerizates served as degradation confirmation(Milstein et al., 1996).In 15 days,*Phanerochetechrysosporium* degraded PVA successfully. It was confirmed by GPC, FTIR, HPLC(Betty Lucy López et al., 1999). In 12 weeks, *Fusarium* L023 degraded polylactic co-glycolide (PLGA43/57)91.1% b weight, which was confirmed by DSC, SEM and change in viscosity tests(Cai et al., 2001). The biodegradation of E-P copolymers was conducted using *A. niger* obtained from the NCL, India. Weight losses of 10% for E-P (F 30R), and less than 15% for E-P (Q 30R) were observed after 6 months of being exposed to 100 hours of UV-irradiation in compost(Pandey & Singh, 2001).The process of decomposing polyamide-6 involved utilization by a lignolytic fungus,*P.chrysosporium*MZKI B223 which was procured from the Fungal Culture Collection of the National Institute of Chemistry. It exhibited a 50% reduction in weight after 5 months. The deterioration was further supported by DSC, relative viscosity and SEM analysis(Klun et al., 2003). GPC and SEM tests has confirmed that *Inonotus hispidus* has degraded ploysteramides and caprolactone in 32 to 90 days(Šašek et al., 2006).*A.clavatus* isolated from both dry and moist soil, completely metabolisedPES in 20 to several days, as shown by the SEM and enzyme production assays(Ishii et al., 2007).A pure culture of *A. niger*, degraded PS: PLA (30%) PS: PLA: OMMT (5%) by 4.9% and 6% reduction in tensile strength in 28 days respectively. The confirmatory tests were TGA, SEM, FTIR and XRD(Barkoula et al., 2008)**.** Synthesized copolymers of lactic acid, terephtalic acid, and ethylene glycol were degraded in 60 days by *A. niger, A.versicolour, A.clavatus, A. fumigatus, A.alternata, Mucor sp., Penicillium sp.,* and *Rhizopus sp.* FTIR and SEM tests verified the change in condition(Soni et al., 2009).*A. niger* consumed ethylene-propylene copolymer (EP)in 6 months, as demonstrated by SEM, FTIR and viscosity variation(Alariqi & Singh, 2010).*A. niger* ATCC 9642, *P.pinophilum* ATCC 11, 797, *Chaetoomiumglobsum* ATCC 6205, *G. virens* ATCC 9645, and *Aureobasium pullulans* ATCC 15, 233 were procured from Guangzhou institute of microbiology. Consortium of these fungal strains degraded starch-based elastomers, polyethylene-octene (POE),starch and grafted POE-g-MAH (acid anhydride) and starch copolymer blends in 28 days, which were confirmed by tensile strength and SEM(Z. Yang et al., 2010).

TGA and SEM tests have verified that in 45 days, thermoplastic grafted starch (TPGS) and ungrafted starch (TPS) was degraded by *A. niger*(Canché-Escamilla et al., 2011). Within 24 days *Fusarium sp*. DMT-5-3 and *Trichosporon sp*. DMI-5-1, which were isolated from mangrove sediments, have been shown to degrade dimethyl phthalate (DMP), dimethyl isophthalate (DMI), and dimethyl terephthalate (DMT) as per an enzymatic assay(Luo et al., 2012). *Fusarium sp.* isolated from garden soil and waste leachate degraded Polycarbonate (PC) in 15 days. The confirmatory tests were clear zone formation and AFM(Arefian et al., 2013). *Chaetomium sp.* isolated from agricultural soil, demonstrated the potential for breaking down biodegradable mulch films (BDM) used in agriculture, as indicated by clear zone formation and SEM analysis after 10 weeks(Bailes et al., 2013).*P. pulmonarius*, two strains of *P. ostreatus*, and *P. florida*were obtained from the Chinese University of Hong Kong Collection, the American Type Culture Collection, and the Universidad Autonoma de Tlaxcala Collection, respectively. *F. oxysporum*and *M. alpina*were isolated from soil in central Manchester, UK. Media containing 500 mg per liter DBP showed the highest biomass production by *F. oxysporum* and *M. alpina*, with quantities of 160 and 65 mg/cm^2 in 7 days respectively (Suárez-Segundo et al., 2013). *T. versicolor* ATCC 42530, taken from the American Type Culture Collection and *L. tigrinus* CBS 577.79 procured from Central Bureau Voor Schimmel Cultures [Utrecht, NL], demonstrated the ability to degrade highly recalcitrant PAHs in industrially polluted soil within 60 days(Lladó et al., 2013). *Fusarium, Ulocladium, Chrysoporium,* and*Penicillium*were isolated from a PC-contaminated garden, and waste leachate exhibited a degradation of PC within a week. Further confirmation was done by a clear zone of amylase and lipase, and AFM(Arefian et al., 2013). *Candida guilliermondii* and *A. fumigatus* taken from Culture Collection of Basidiomycetes, Czech Republic, degraded Polyester amides in 6 weeks. Enzyme production (lipase and esterase) served as confirmation of degradation (Novotný et al., 2015). The label "70 TPF" refers to the combination of thermoplastic unripe banana flour and polyethene in a 70:30 ratio. It remained buried in compost for 125 days. The fungus *M. elongata* was shown to thrive on plastic, leading to a decrease in its weight (45.23%) and tensile strength(Vieyra et al., 2015). *T.versicolol* procured from National Collection of Biology Laboratory, University of Tehran, Iran has degraded TPS, Cellulose Nanofibers (CNFs) in the duration of 2 months, which was confirmed by SEM and dynamical thermal analysis (DMA)(Babaee et al., 2015). *P. antarctica* (PaE) and *Paraphoma sp*. B47-9 (PCLE) have degraded poly(butylene adipate) (PBA) in 1-4 hrs, which was confirmed using LCMS(Sato et al., 2017).Through enzymatic degradation, *Coriolopsisbyrsina*, which was isolated from the Wonorejo Mangrove soil in

Indonesia, broke down syntheticplastic in six weeks, resulting in a 22.7% weight loss(Kuswytasari et al., 2019).The degradation of hexadecane, derived from municipal trash, was seen to occur within a period of 14 days by the action of *A. flavus* MH503926 with 52.92±8.81% weight loss. This deterioration was confirmed through the use of both GCMS and SEM(M. Perera et al., 2019).SEM and EDX analyses revealed that *Clitcybe sp*. and *Laccarialaccata*, exhibited the ability to degrade polylactide within a period of 6 months (Janczak et al., 2020).The PBAT-thermoplastic starch underwent effective degradation by the *Aspergillus sp.* and *Penicillium sp*. cultures in 30-day period, resulted in degradation rates of 1.04% and 2.32% respectively. The test confirmation was conducted using SEM and FTIR techniques (T. A. De Oliveira et al., 2020).

Dry weight measurement, titration assay, and SEM analysis verified that *M.roreri*, isolated from cacao pods, produced cutinase that broke down polyethylene succinate (PES) 59% by weight in 21 days(Vázquez-Alcántara et al., 2021). By producing enzymes, *P.sordida* YK-624, which was obtained from a culture, broke down Bisphenol F (BPF) in 14 days. Transcriptome analysis under ligninolytic conditions, was used to identify the ligninolytic enzymes(Wang et al., 2021).As demonstrated by increased esterase activity during liquid fermentation, *F.culmorum* and *F.oxysporum* degraded dibutyl phthalate (DBP) in 7 days(González-Márquez et al., 2021).*Myrothecium roridum* IM 6482, retrieved from a culture, eradicated Bisphenol A (BPA) in 72 hours, as demonstrated by cellular and subcellular enzyme production and LC-MS/MS analysis(Jasińska et al., 2021).*A. flavus*found in the field soil, degraded compostable microplastic films in a year, as demonstrated by ATR-FTIR analysis(Pedrini, 2022).A single species of fungus, specifically *Acremonium sp*., was identified as capable of decomposing three PAHs, phenanthrene, anthracene, and pyrene within a 30-day period, which was found inside plastic fuel bottles. The deterioration was confirmed by ultra-high-performance chromatography (UHPLC) (Héctor et al., 2022).DBP was catabolized in 15 days by *A. flavus,* an isolate from the sanitary landfill soil. The GC-MS characterizations revealed the formation of intermediate metabolites such as benzyl-butyl phthalate, dimethyl-phthalate, di-iso-butyl-phthalate and phthalic acid (Puranik et al., 2023).*P.lilacinum* strain BA1S isolated from farmland soil degraded biodegradable PBAT 15% by weight in 30 days. It was confirmed by SEM, FTIR and LCMS (Tseng et al., 2023).*Phanerochaete sp*. H2, an endophytic fungus isolated from the leaves of *Handroanthusimpetiginosus*, was used to remove BPA. Polyacrylonitrile nanofibrous membrane (PAN NFM) used as a scaffold to accomplish BPA degradation in just seven days.SEM was used to detect the deterioration(Conceição et al., 2023) (Table No. 7).

Conclusion

In this presented phase of our inquiry, we focused on the advantages, consequences, and environmental impacts of fungal plastic degradation. We find out its remarkable ability to substantially reduce plastic waste andconserve natural ecosystem. This review opens the doors for understanding the plastic as a problem as well as using fungi as its mitigation. We have also focused on the understanding of the dynamic and promising area of fungal plastic degradation and its crucial role with the hope of a better future.

Considering an extensive review of the literature, we can confirm that fungi can be used to decompose plastic, which is one of the worst wastes of time. Also, we concluded that LDPE was the most common substance that degraded. Whereas, on the other hand PBS and PBSA appeared to be the fastest degrading polymer with the degrading time as low as 1-4 hours. The most promising fungal strain is found to be the various species of *Aspergillus* primarily isolated from dumpsite and soil. The most convenient screening and confirming technique appeared to beweight loss and FTIR. It can also be said that fungi degrade faster when they are set together for work.

However, in addition to its promise, we must also consider the difficulties and limitations associated with employing fungi for plastic degradation. These concerns include the ability to handle increased size or capacity, ensuring precision in targeting particular types of plastics, managing the rules that regulate the release of genetically modified fungi into the environment.As we look to the future, we understand how crucial it is to preserve a balance between progress and environmental conservation.

Acknowledgements

The authors are gratefulto Dr. Aniket Gade for his valuable help in collection of data.We are thankful to MAHAJYOTI for their financial assistance. we sincerely thank the authorities of Homi BhabhaState University, The Institute of Science, Mumbai, and Elphinstone College for providing resources to carry out this work.

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Glossary

- Microplastics (MPs)
- Polyaromatic hydrocarbons (PAHs)
- Polyethylene (PE)
- Differential Scanning Calorimetry (DSC)
- Fourier Transform Infrared Spectroscopy (FTIR)
- Mangrove soil (M)
- Petroleum soil (P)
- Molasses soil (MS)
- Lab (L)
- X-Ray Diffraction (XRD)
- Scanning Electron Microscopy (SEM)
- Nuclear Magnetic Resonance (NMR)
- Attenuated Total Reflectance-Fourier Transform Infrared (ATR-FTIR)
- Grams per Square Meter (GSM)
- Gel Permeation Chromatography (GPC)
- Gas Chromatography-Mass Spectroscopy (GC-MS)
- Mineral Salt Media (MSM)
- Atomic Force Microscopy (AFM)

- Low Density Polyethylene (LDPE)
- National Chemical Laboratory (NCL)
- Wide angle X-ray scattering (WAXS)
- Gas Chromatography (GC)
- High-Temperature Gel-Permeation Chromatography (HT-GPC)
- Manganese Stearate (MnS)
- Titanium Stearate (TiS)
- Iron Stearate (FeS)
- Cobalt Stearate (CoS)
- Field Emission Scanning Electron Microscopy (FESEM)
- Potato Dextrose Broth (PDB)
- Czapek Dextrose Broth (CDB)
- Thermogravimetric Analysis (TGA)
- Untreated LDPE (U-LDPE)
- Thermal pretreatment (T-LDPE)
- Environmental Scanning Electron Microscopy (ESEM)
- Thermoplastic Starch (TPS)
- Styrene-ethylene-styrene degradation (SEBS).
- Residual Mulch Film (RMF)
- High Density Polyethylene (HDPE)
- Polyester Polyurethane (PS-PU)
- Polyethylene succinate (PES)
- Polyethylene adipate (PEA)
- Polystyrene (PS)
- Polyurethane (PU)
- LiquidChromatography-Mass Spectroscopy (LC-MS)
- X-ray Photoelectron Spectroscopy (XPS)
- Malt Extract Agar (MEA)
- Chloramphenicol Malt Extract Agar (CMEA)
- Polyvinyl Chloride (PVC)
- Polypropylene (PP)
- Isotactic Polypropylene (i-PP)
- Ethylene-(vinyl acetate) (EVA)
- Small Angle X-ray Scattering (SAXS)
- Transmission Electron Microscopy (TEM)
- Coupling Agent (CA)
- Static Contact Angles (SCA)
- Polyethylene Terephthalate (PET)
- Optical Imaging Profiler (OIP)
- High-Performance Liquid Chromatography with UVdetector (HPLC-UV)
- Energy Dispersive X-ray analysis (EDX)
- Zero Emissions Research Initiative (ZERI)
- Poly(ε-caprolactone) (PCL)
- Total Organic Carbon (TOC)
- Polyhydroxy Butyrate (PHB)
- Polyhydroxybutyrate co-hydroxyvalerate) (PHBV)
- Gel Filtration Chromatography (GFC)

- Molecular Weight Determination (MWD)
- Polylactic Acid (PLA)
- Polybutylene succinate (PBS)
- Di-(2- ethyhexyl phthalate (DEHP)
- Linear Low-Density Polyethylene (LLDPE)
- Poly (butylene succinate adipate (PBSA)
- Polylactic co-glycolide (PLGA)
- Polyethylene-octene (POE)
- Thermoplastic grafted starch (TPGS)
- Dimethyl phthalate (DMP)
- Dimethyl isophthalate (DMI)
- Dimethyl terephthalate (DMT)
- Polycarbonate (PC)
- Biodegradable Mulch (BDM)
- Cellulose Nanofibers (CNFs)
- Dynamical Thermal Analysis (DMA)
- Poly(butylene adipate) (PBA)
- Bisphenol F (BPF)
- Dibutyl phthalate (DBP)
- Ultra-High-Performance Chromatography (UHPLC)

Supplementary Data

Table No.1: Biodegradation studies on PE using fungi

Sr. No.	**Name of Fungus species**	**Collection Site**	**Type of plastic**	**Incubation Time**	**TS (%)**	**WL (%)**	**CO_2** (g/L)	**Other Plastic degradation test**	**Reference**
1	*A. niger*	Adapted strain	PE (10.16 µm)	140 days	-	-	-	DSC, FTIR	Raghavan and Torma, 1992
2	IZU-154	Kobe Steel	PE	12 days	73	-	-	Manganese peroxidase activity	Iiyoshi et al., 1998
3	*A. glaucus*	Mangrove soil	PE bags	1 month	-	28.8	-	-	Kathiresan, 2003
			Plastic cups			7.26			
4	*A. oryzae*	Soil	polythene bags 0.5 to	30 days	-	-	-	Weight loss	Kannahi& Rubini,

			5cm						2012
5	*A. niger*	Soil from mangrove (M), petroleum (P) and molasses (MS)	plastic cups	9 months	-	L: 13.25 M: 15.5 P:4.62 MS:3.37	-	SEM	Sugana Rani & Prasada Rao, 2012
			polythene bags			L: 14.75 M: 10.75 P: 6.75 MS: 3.25			
	A. glaucus		plastic cups			L: 17.25 M: 12 P: 3.5 MS:2.25			
			polythene bags			L: 16 M: 11 P: 6.37 MS: 2.25			
6	*P.ostreatus*	Laboratory of Mycorrhizal Associations/DMB/BIOAGRO/UFV	Oxo-biodegradable plastic bags	45 days	-	-	-	XRD, SEM, FTIR, Enzymatic assay	da Luz et al., 2013
7	*P. ostreatus*	fungal collection of the Department of Microbiology of Universidade Federal de Vicosa	Oxo-biodegradable ployethylene	90 days	-	-	-	SEM, FTIR, mechanical properties, CO_2 measurement	Da Luz et al., 2014
8	*C. lunata*	Dumpsite	PE	3 months	-	1.2	-	FTIR, SEM	Sowmya et

	A. alternata					0.8			al., 2015a
	A. glaucus					7.7			
	Fusarium sp.					0.7			
	Consortium of all fungi					27			
9	*P.simplicissimum*	Dumpsite	PE: autoclaved	3 months	-	16	-	FTIR, SEM, NMR	Sowmya et al., 2015b
			PE: surface-sterilized			7.7			
			PE: UV-treated			38			
10	*Z. maritimum*	Marine water and soil	PE microplastic pellets	28 days	-	-	-	FTIR-ATR, NMR	Paço et al., 2017
11	*Aspergillus sp.*	Landfill soil	polythene bag (40 GSM)	2 months	-	0.6	-	FTIR	Ratna Kumari & Kulkarni, 2018
	Candida sp.		polythene bag (20 GSM)			2.33			
12	*A. terreus*	Dumping sites, mangrove rhizosphere	PE	60 days	-	58.51 ± 8.14	-	SEM, FTIR	Sangale et al., 2019
	A. sydowii				94.44 ± 2.40				
13	*A. niger*	Cooking oil, grease and petroleum products	PE: black and white polythene	70 days	-	B: 38, W: 26	-	SEM	Padmanabhan et al., 2019
	A. flavus					B: 27, W: 16			
	Unidentified sp.					B: 64, W: 45			
14	*Aspergillus sp.*	Marine waters	Plastic bottles	6 weeks	-	22	-	FTIR, SEM, XRD	Sarkhel et al., 2020
15	*A. niger*	Soil of the plastic waste environment	PE	4 weeks	-	L: 40 ± 3.3 S: 12±3	-	FTIR, SEM	Saeed et al., 2022
	A. glaucus					L: 25 ± 3.3 S: 15±3			
16	*A. alternata*	Marine sediment	Commercial PE bags	120 days	-	-	-	FTIR, XRD, GPC, GC-MS, SEM	Gao et al., 2022

17	*A. terreus (F4)*	Soil	PE powder of PE bags and bottles	13 days	-	-	-	Clear zone formation	Nakei et al., 2022
	A. terreus (F5)								
	T. islandicus(F6)								
	A. terreus (F8)								
	Aspergillus sp. (F7)								
	Phoma sp. (F2)								
	E. rubidurum (F1)								
	N. fischeri (F3)								
18	*A. flavus*	Gut of *Galleria mellonella*	PE	40 days	-	-	-	AFM, SEM	Riabi et al., 2023
19	*T. harzianum*	Soil contaminated with plastic	PE film (60 µm thick)	30 days	-	3.39 ± 0.3	-	SEM, FTIR, GC–MS	Ruan et al., 2023
			PE particles (355 µm and 160 µm in diameter)			-			
20	*F. solani*	Municipal waste disposal site	PE	90 days	-	-	-	SEM, FTIR	Wróbel et al., 2023
	F. oxysporum								
	L. araneicola								
	T. lixii								

Table No.2: Biodegradation studies on LDPE using fungi

Sr. No.	Name of Fungal species	Collection Site	Type of plastic	Incubation Time	TS (%)	WL (%)	CO_2 (g/L)	OtherPlastic degradation test	Reference
				LDPE					
1	*A. niger*	Biochemistry	Untreated LDPE	6 months	-	<15	-	Variation in Viscosity,	Pandey & Singh, 2001

		Division, National Chemical Laboratory, Pune, India	100 hours UV irradiated LDPE			22		Chain Scission, FTIR, SEM	
2	*P. pinophilum, A. niger*	Culture	Thermally oxidized LDPE	31 months	-	-	-	DSC, XRD, SEM, FTIR	Volke-Seplveda et al., 2002
3	*A. niger, G.virens, P. pinophilum, P. chrysosporium*	Culture	LDPE	9 months	-	-	-	DSC, WAXS, FTIR, GC, SEM	Manzur et al., 2004
4	*A. niger* *P. funiculosum*	Waste	LDPE film modified with 60% (wt/wt) Bionolle	90 days	17.9 ± 0.6 MPa	7.53 100	-	SEM, FTIR	Łabuzek et al., 2004
5	*A. fumigatus* *A. terreus* *F. solani*	Solid waste	LDPE film (15 µm)	100 days	-	-	-	FTIR, SEM, HT-GPC	Zahra et al., 2010
6	*P. chrysosporium* *T. wortmannii*	culture collection at the Federal University, Brazil soil of the Muribeca Landfill	LDPE/modified starch	90 days	-	-	-	XRD, SEM, FTIR	Ferreira et al., 2010
7	*A. oryzae*	HDPE film (buried in soil for 3 months)	Untreated LDPE	3 months	26	5	-	Elongation percentage, SEM, F TIR	Konduri et al., 2011
			MnS LDPE		51	47.2			
			TiS LDPE		45	41.6			
			FeS LDPE		40	36.1			
			CoS LDPE		39	34			
			UV LDPE		21	18			
8	*A. awamori* *M. subtilissima* *G. viride*	Waste coal	F0: LDPE F1: Modified with Bionolle (70:30)	225 days	F0: 13.7 F1: 6.7	F0: 0.26 F1: 0.25	-	FTIR, SEM	Nowak et al., 2011
		Forest			F0: 13.7 F1: 6.9	F0: 0.13 F1: 0.52			

		Extinct volcano crater			F0: 13.2 F1: 7.3	F0: 0.28 F1: 0.26			
9	*A. niger, Aspergillus sp. (5), Fusariumsp. (2)*	Municipal solid waste	LDPE	7 days	-	-	-	Growth	Kumar et al., 2013
10	*T.harzianum*	Soil sample of dumpsite	UV- treated PE	15 days	-	40	-	SEM, FTIR, NMR	Sowmya et al., 2014
			autoclaved			23			
			surface-sterilized PE			13			
11	*Aspergillus sp.,Lysinibacillus sp.*	Soil from municipal landfill	(25 days UV pre-treated) LDPE films (20 µm)	56 days	-	-	-	SEM, FTIR, XRD	Esmaeili et al., 2014
12	*Saccharomyc*	PE dumped garbage	LDPE	30 days	-	43	-	-	Muthumani & Anbuselvi, 2014
	A. niger					72	4.2		
	A. flavus					11	-		
	Streptomyces					40	-		
13	FSM-3*Aspergillus*	Municipal solid waste	LDPE	60 days	-	8	20.26	Change in pH, SEM, FTIR	Das & Kumar, 2014
	FSM-5					5	18.4		
	FSM-6					7	17.9		
	FSM-8					7	17.8		
	FSM-10					9	19.3		
14	*A. niger*	Culture	LDPE	30 days	-	0.09	-	SEM	Beg et al., 2015
			sago starch filled LDPE (70/30)			6.52			
15	*L. theobromae*	*Psychotriaflavida*	LDPE (20 µm)	90 days	-	-	-	FTIR, DSC, SEM, changes in viscosity	Sheik et al., 2015
	Aspergillus sp., P. lilacinus	*Humboldtiabrunonis*							
16	*P. ostreatus*	collection of the Department of Microbiology of the Federal University of Viçosa	LDPE with 50% green polymers	100 days	-	-	-	Tensile strength, CO_2 evolution, SEM, FTIR	Da Luz et al., 2015

17	*A. nomius*, *Streptomyces* sp.	Waste dumping site	LDPE	90 days	-	4.9 5.2	2.85 4.27	AFM, FTIR, GC-MS	Gajendiran et al., 2016a
18	*A. clavatus*	Landfill soil	LDPE	90 days	-	35	2.32	SEM, AFM, FTIR	Gajendiran et al, 2016b
19	*C. viridis*	Dumping site soil	LDPE	90 days	-	14.8	4.46	SEM, AFM, FTIR	Gajendiran et al., 2016c
20	*R. oryzae*	Culture	LDPE	1 month	60	8.4 ± 3	-	SEM, FTIR, AFM	Awasthi et al., 2017
21	*P. oxalicum* *P. chrysogenum*	Plastic dumping ground	LDPE	90 days	-	36.60 34.35	-	FESEM, AFM, FTIR	Ojha et al., 2017
22	*A. oryzae*	Dumpsite	LDPE sheets	16 weeks	-	36.4±5.53	-	FTIR, GC-MS	Muhonja et al., 2018
23	*A. oryzae*	PE bags buried in the soil for six months	Surface sterilized green LDPE 1% Palmitic acid	90 days	-	PDB: 25 CDB: 32.5 PDB: 30 CDB:40	-	FTIR, SEM	Jayaprakash &Palempalli, 2018
24	*P. ostreatus*	Culture	LDPE	150 days	-	-	-	colonization percentage, AFM, SEM, FTIR	Gómez-Méndez et al., 2018
25	*A.flavus* *A. versicolor* *F. solani*	Municipal dump yard	LDPE	60 days	-	17 19 13	20.8 20.9 19.2	FESEM, FTIR	Das et al., 2018
26	*M. circinelloids*	Culture	LDPE (19μ)(untreated) (thermally treated)	45 days	-	1.328± 0.27 0.77	-	FTIR	Sharma et al., 2019
27	*Aspergillus sp.* *Candida sp.*	Landfill soil	polythene bag (40 polythene bag (20	2 months	-	0.6 2.33	-	FTIR	Sáenz et al., 2019a
28	*A. flavus* *A.s terreus*	Soil	LDPE	4 months in media, 9 months in soil	-	M: 14.3, S: 30.6 M: 13.1, S: 11.4	-	SEM, FTIR	Verma & Gupta, 2019
29	*A. terreus*	Ecuadoria	LDPE	77 days	-	35.3	-	SEM	Sáenz et al.,

	A. niger	n mangrove				22.14			2019b
30	*T. hamatum*	Plastics from Soil	LDPE (40 µm)	7 days	-	0.5 ± 0.4	-	FTIR, TGA, GPC, SEM	Malachová, 2020
			UV/ T60:			1.3 ± 0.4			
			γT150			0.9 ± 0.1			
31	*A. fumigatus*	Landfills	Black LDPE	16 weeks	-	3.8	-	SEM, FTIR, XRD, GC–MS	El-Sayed et al., 2021
	A. carbonarius					2.267			
	Consortium		Untreated			5.01			
			T-LDPE			39.1			
			C-LDPE			17.76			
			γ-LDPE			5.79			
32	*D. italiana*	Culture collection of the Institute of Excellence in Fungal Research	LDPE (0.12 mm)	90 days	1.56,	43.90	0.45 -1.45	SEM, FTIR, GC-MS	Khruengsai et al., 2021
	T. jaczewskii				1.78,	46.34	0.36 -1.22		
	C. fructicola				0.43,	48.78	0.45 -1.45		
	S. citrulli				1.86,	45.12	0.33 -1.26		
	A. niger				3.34	28.78	0.37 -1.27		
33	*Pencilliumsps*	Soil from disposal site	LDPE	40 days	-	19.17± 0.02	-	SEM-EDAX and FTIR	Lakshmi & Selvi, 2021
	Fusarium sps					7.08±0.05			
	A.fumigatus					21.88 ±0.03			
34	*T. viride*	Culture collection	LDPE	5 days	-	-	-	Enzymatic degradation	Johnnie et al., 2021
35	*T. lanuginosus*	NCIM, NCL	LDPE (8 µm)	30 days	-	9.21 ± 0.84	-	SEM, FTIR	Chaudhary et al., 2021
36	*P. chrysogenum F. oxysporum T. brevicompactum P. lilacinum F. falciforme*	Abandoned dumpsite in northern Italy	LDPE (400 µm)	30 days	-	-	-	SEM, ATR-FTIR	Spina et al., 2021
37	*P. simplicissimum strains F1 and F2*	Municipality garbage plastic	Untreated LDPE	40 days	-	-	F1: 20 ± 3.45 F2: 05 ± 1.67	SEM, FTIR	Ghosh & Pal, 2021

				150 days		F1: 58.0±4.04 F2: 24.78 ± 3.94	-		
			Ethanol treated			F1: 60.1 ± 3.56 F2: 25.58 ± 2.72	-		
38	*Fusarium sp.*	Waste disposal site	LDPE	40 days	-	7.08	-	Plate assay method, Zone method, SEM-EDAX, FT-IR	Lakshmi & Selvi, 2021
	Pencillium sp.					19.17			
	A. fumigatus					21.88			
39	*Cephalosporium sp.*	NCIM, NCL	LDPE	56 days	-	12.22± 0.82	-	FTIR, TGA, SEM, XRD	Chaudhary et al., 2022
40	*R. oryzae*	Plastic dumping site	LDPE	60 days	-	60	-	FTIR, SEM	Seenivasagan et al., 2022
41	*P. chrysogenum*	Polythene debris	LDPE andbiodegradable plastic	30 days	-	P:8 BP: 23	-	SEM	Saxena et al., 2022
	R. nigricans					P: 6 BP: 14			
	C. murorum					P: 2 BP: 5			
	M. echinata					P: 3 BP: 8			
	A. fumigatus					P: 7 BP: 15			
	S. chartarum					P: 2 BP: 7			
	A. niger					P: 9 BP: 28			
	C. globosum					P:5 BP:10			
	A. flavus					P:7 BP:18			
	F. oxysporum					P: 3 BP: 8			

42	*T.harzianum*	IAFB	LDPE microplastics	9 days	-	-	-	Enzymatic activity	Bernat et al., 2023
43	*P. flavidoalba*	Decaying hardwoods of Neem	LDPE	45 days	-	46.79 ± 0.67	0.00307	FTIR, SEM	Perera et al., 2023
44	*Cladosporium sp.*	Soil	untreated LDPE	30 days	-	0.30 ±0.06	-	ESEM, FTIR	Gong et al., 2023
			heat treated			0.70±0.06			
45	*S. halophilus*	Gut of wood-feeding termites	LDPE (25 µm)	45 days	43.6	18.6	-	-	Elsamahy et al., 2023
	M. guilliermondii				19.2	11.1			
	M. caribbica				32.0	13.3			
	consortium				63.4	33.2			
46	*C. cladosporioides*	Agricultural fields	LDPE film (6 µm)	90 days	-	-	-	ATR-FTIR, Raman and SERS spectroscopy, SEM	Puliga et al., 2023
47	*Penicillium citrinum*	Soils of plastic waste dump yard	LDPE (51 µm)	90 days	-	38.82 ± 1.08	-	FE-SEM, FTIR, TGA	Khan et al., 2023
			Nitric acid treated LDPE			47.22 ± 2.04			
48	*Aspergillus sp. 1, Aspergillus sp. 2, Trichoderma sp., Rhizopus sp., Penicillium sp., Alternaria sp., C. parapsilosis*	E1: activated sludge and river sediment,	A: LDPE with 20 % thermoplastic starch (TPS) B: LDPE + TPS C: LDPE + TPS + styrene-ethylene-styrene degradation (SEBS)	56 days	-	A: 3.3184 B: 14.1152 C: 16.0062	-	SEM, FTIR	Kučić Grgić et al., 2023
		E2: compost				A: 3.9625 B: 20.4520 C: 21.9277			
49	*G. candidum*	Soil	LDPE (10 µm)	90 days	-	1.5809	-	SEM, FTIR	Lin et al., 2024
	F. oxysporum					1.7823			
	Trichoderma sp.					1.8398			

Table No. 3 Plastic biodegradation studies on HDPE, PS-PU, PS and PU with fungi

Sr. No.	Name of Fungal species	Collection Site	Type of plastic	Incubation Time	TS (%)	WL (%)	CO_2 (g/L)	Other Plastic degradation test	Reference
HDPE									
1	*Aspergillus, Penicillium*	Compost	HDPE	3 months	-	-	-	DSC, FTIR	Ojeda et al., 2009
2	*A. niger*	Culture	HDPE	6 months	-	-	-	SEM, FTIR, Variation in Viscosity	Alariqi& Singh, 2010
3	*A. niger*	Waste dumpsite	HDPE (20*μ*)	1 month	61	3.44	-	SEM, FTIR	Mathur et al., 2011
4	*A.terreus*	dump yard	HDPE (40 µm)	30 days	-	9.4±0.1	-	FTIR, SEM, GC-MS	Balasubramanian et al., 2014
5	Consortium	Compost	HDPE 80/starch 20	200 days	-	-	-	Synchrotron-FTIR microscope (SFTIR-M), SEM, FTIR, Tensile testing	X. Liu et al., 2013
6	*A. tubingensis*	Plastic waste dump site in Gulf of Mannar, India	HDPE (40 µm)	30 days	-	6.02 ± 0.2	-	FTIR	Sangeetha Devi et al., 2015
	A. flavus					8.51 ± 0.1			
7	*P. oxalicum*	Plastic dumping ground	HDPE	90 days	-	55.34	-	FE-SEM, AFM, FTIR	Ojha et al., 2017
	P. chrysogenum					58.59			
8	*A. oryzae*	PE bags buried in the soil for six months	Surface sterilized black HDPE	90 days	-	PDB: 22.6	-	FTIR, SEM	Jayaprakash & Palempalli, 2018
						CDB: 28			
			1% Palmitic acid			PDB: 24			
						CDB: 33			
9	*B. adusta*	Ohgap Mountains, South Korea	HDPE (0.05 mm thick)	90 days	-	-	-	SEM,Raman Spectroscopy	Kang et al., 2019

10	*M. circinelloides*	Culture	HDPE (10 µ)	45 days	-	1.428 ± 0.51	-	FTIR	Sharma et al., 2019
			thermal pretreated			1.13			
			HDPE (38 µ)			0.709 ±0.14			
			thermal pretreated			0.61			
10	*A. Flavus*	Gut contents of wax	HDPE microplastic	28 days	-	-	-	FTIR	Zhang et al., 2020
11	*A. fumigatus*	Soil dump	HDPE	90 days	-	T:2.12	-	SEM	Rani et al., 2020
						UT: 1.43			
	A. flavus					T: 1.38			
						UT: 1.31			
	F. solani					T: 2.58			
						UT: 1.84			
12	*A. flavus*	Farm sludge (FS), soil, wax and meal worms' excreta	HDPE sample 1	100 days	-	5.5	-	SEM, FTIR	Taghavi et al., 2021
			Sample 2			2.5			
13	*C. parapsilosis*	Deep marine sediment	HDPE	96 hours	-	-	-	SEM, AFM, FTIR and Crystal Violet Assay	M. M. Oliveira et al., 2022
14	*Cephalosporiumstrain*	NCIM, NCL	HDPE films	56 days	-	-	-	Changes in pH, TDS, conductivity of MSM, FTIR, TGA, SEM	Chaudhary et al., 2022
15	*C. halotolerans*	Digestive tract of *G. mellonella* larvae	HDPE microparticles	15 days	-	-	-	SEM, FTIR, enzyme and protein analysis	Napoli et al., 2023
PS-PU									
1	*N. gliocladioide*	Soil	PS-PU	44 days	60	-	-	SEM	Barratt et al., 2003

	P. ochrochloron								
	G. pannorum								
2	*G. pannorum, Phoma sp.*	Soil	PS-PU	5 months	up to 95	-	-	Soil analysis, Fungal community analysis	Cosgrove et al., 2007
3	*F. solani,*	Soil, wall paints, plastic debris	PS-PU sheets	3 weeks	-	L:100 P:72.5	-	Clear zone test	Ibrahim et al., 2011
	A. solani					L:71.8 P:63.6			
	A. terreus					L:26.1 P:58			
	A. fumigatus					L:43.5 P:39.5			
	A. flavus					L:40.5 P:94.8			
	Spicaria sp					L:12.7 P:22.9			
4	*P.microspora*	Woody plants of various families	PS-PU	2 weeks	-	-	-	Zone clearance, enzyme activity, FTIR	Russell et al., 2011
5	*L. theobromae, P. janthinellum, F. verticilloides, P. puntonii*	Forest soil	PS-PU	15 days	-	-	-	Biomass determination, Clear zone formation	Urzo et al., 2017
6	*P. laurentii*	Aircraft	PES	8 days	-	-	1.2 ± 0.2 mol%	IR microscopy	Hung et al., 2019
			PEA				-		
			Thermocet PS-PU				-		
			Irogran				-		
7	*E. clematidis*	Culture collection of the Institute of Excellence in Fungal Research	PS-PU	2 weeks	-	-	0.85	FTIR spectroscopy, GC-MS, Enzymatic Activity Assay	Khruengsai et al., 2022
PS									

1	*P. variabile*	Culture	PS	16 weeks	-	-	-	SEM, FTIR, GPC	Tian et al., 2017
2	*T. hamatum*	Plastics from Soil along highway	PS	7 days	-	0.9 ± 0.4	-	FTIR, TGA, GPC, SEM	Malachová et al., 2020
3	*P. glaucoroseum*	Soil, activated sludge, farm sludge	PS (2 mm)	100 days	-	1.8	-	SEM, FTIR, AFM	Taghavi et al., 2021
4	*Cephalosporiumsp.*	Culture	PS	56 days	-	13.15± 0.44	-	FTIR, SEM, TGA, XRD	Chaudhary et al., 2022
5	*P. chrysosporium*	China Center for Type Culture Collection	PS	35 days	-	19.7	-	FTIR, SEM, GC-MS	F. Wu et al., 2023
PU									
1	*P. chrysosporium*	Culture	PU foam	10 days	-	-	-	Lignin Peroxidase production	Nakamura et al., 1997
2	*C. globosum*	Department of Microbiology of the Biological Research Institute, Romania	PU	130 days	-	-	-	FTIR, SEM, Weight loss	Oprea, 2010
3	At 37°C, *A. flavum, C. rugosa, A. kalrae*At 45°C, *Aspergillussp*., community of*Lichtheimia sp., A. fumigatus, M. cinnamomeaE.*	Compost	PU	28 days	>70	-	-	Loss in tensile strength and percentage elongation at break	Zafar et al., 2014
4	*M. ruber* *M. sanguineus* *Monascussp.*	Dumping site soil	PU	5 days	-	-	-	enzyme production, SEM, Zeta analysis	El-Morsy et al., 2017
5	*Pestalotiopsis sp.*	*Nepenthes ampullari*	PU	3 weeks	-	-	-	Enzyme essay	Bong et al., 2017

6	*C. cladosporioi*	Plastic debris of the shoreline of Lake Zurich	PU	6 days	-	-	-	GC-MS	Brunner et al., 2018
	X.graminea,								
	P. griseofulvum								
	Leptosphaeri asp.								
	A.bisporus	Fungal collection		14 days					
	M. oreades								
7	*A. fumigatus*	Solid waste dumping site soil	PU film (~0.2 mm)	4 weeks	-	15-20	10.05	FTIR, DSC, SEM, Esterase Activity Assay	Osman et al., 2018
8	*Uncultured, Arthrographis, Apiotrichum, Aspergillus, Thermomyce*	Soil	PU cubes	12 weeks		71 % mass loss		SEM, GC-MS, LC-MS	Gunawan et al., 2020a
	Uncultured, Arthrographis, Thermomyces, Apiotrichum, Mortierella	Compost				30 % mass loss			
9	*Cladosporium*	PU rich site in an ocean	PU	15/30 weeks	-	-	-	SEM, FTIR, GC-MS	Gunawan et al., 2022b
	P. chrysogenum								
10	*R. oryzae*	Soil	PU film (0.1 mm)	2 months	-	2.7	-	SEM, Enzymatic analysis	K. Y. Wu et al., 2023
	A. alternata					3.3			
11	*Cladosporium sp.*	Activated sludge	PBA-PU film	28 days		MSM: 32.42 PDB: [illegible]	-	SEM, FTIR	Liu et al., 2023
			PU foam	14 days		MSM: 15.3 PDB: 83.8			
12	*Clonostachy* PB54	Landfill	PU	90 days	-	L: 38 S: 45	-	FTIR, XPS, LC-MS	Bhavsar et al., 2024
	Clonostachy PB62					L: 36			
	Purpureocillium spp. PB57					L: 33 S: 42			

	PB49					S: 39			
13	*L. iraniensis*	PU foam	PU films	4 months	-	MEA: 13.55	-	SEM	Xu et al., 2024
	M. alpina					CMEA: 26.30			

Table No. 4 Investigations on degradation of PVC and PP types of plastic using fungi

Sr. No.	**Name of Fungal species**	**Collection Site**	**Type of Plastic**	**Incubation Time**	**TS (%)**	**WL (%)**	**CO2 (g/L)**	**Other Plastic degradation test**	**Reference**
				PVC					
1	*P. chyrosporium*	soil mixed with municipal sewage sludge	PVC films and cellulose (1:1)	3 months	-	-	-	FTIR	M. I. Ali et al., 2009
2	*P.chrysosporium*	Soil	PVC film	10 months	-	-	7.31 (after 4 weeks)	SEM, GPC, NMR, FTIR	M. I. Ali et al., 2014
	L. tigrinus						-		
	A. niger						6.02 (after 4 weeks)		
	A.s sydowii						-		
3	*Cochliobolus sp.*	Soil from plastic industry	PVC	7 days	-	-	-	FTIR, GC-MS, SEM	Sumathi et al., 2016
4	*C. globosum*	Culture collection	PVC films (40–50 µm)	28 days	-	75	-	SEM	Vivi et al., 2019
5	*P. chrysosporium*	waste plastic and wood	PVC films	2 months	-	31	-	FTIR, SEM	Khatoon et al., 2019
6	*T.hamatum*	Plastics from Soil	PVC	2 months	-	20.0± 0.5	-	FTIR, TGA, GPC, SEM	Malachová et al., 2020
	T. abietinum					17.5± 0.7			

	B. nivea FK1					18.4± 0.7			
	B. nivea JM5					15.5± 0.9			
7	*A. niger*	Soil of the plastic waste	PVC	28 days	-	10±3.3	-	FTIR, SEM	Saeed et al., 2022
	A. glaucus					32±3.3			
8	*P. glandicola*	Dumping site	PVC	6 weeks	-	6	-	-	Emmanuel-Akerele and Akinyemi, 2022
	A. flavus					12			
	A. fumigatus					6			
	P. chrysogenum					2			
	A. niger					10			
	Fusarium sp.					6			
	T. viridae					10			
9	*A. fumigatus-3*	Landfill	PVC Strips	30 days	-	2.15 ± 0.42	-	SEM, Enzymatic activity	El-Dash et al., 2023
	A. fumigatus-2					1.92±0 .51			
	Malassezia sp.					1.46±0 .7			
	A. fumigatus-1					0.718± 0.1			
PP									
1	*P. chrysosporium*	Culture	PP with lignin	30 days	-	-	-	elongation at break, UV-Spectrometry of enzyme	Mikulášová &Košíková, 1999
2	*A. niger*	Biochemistry Division,	PP	6 months	-	22	-	SEM, FTIR	Pandey & Singh, 2001
3	*A. niger*	Culture	i-PP	6 months	-	-	-	SEM, FTIR, Variation in Viscosity	Alariqi& Singh, 2010
4	*Trichoderma*	culture	PP/TPSwith 6 wt% of EVA	3 weeks	-	90/10: 1.0	-	SAXS, TEM, TGA, SEM, FTIR	Hanifi et al., 2014
						70/30: 10.9			
						50/50: 28.8			
5	*L. theobromae*	*Psychotriaflavida*	PP (20 µm)	90 days	-	-	-	FTIR, DSC, SEM, changes in viscosity	Sheik et al., 2015
	Aspergillus sp., P. lilacinus	*Humboldtiabrunonis*							

6	*T. villosa, T. versicolor, P. sanguineus*	Soil/ culture	PP and EVA copolymer, wood flour of *Eucalyptus grandis* and *Pinus elliottii*	12 weeks	-	-	-	SEM, CO_2 production	Catto et al., 2016
	F. ferrea								
7	*B. adusta*	RECOSOL	Polypropylene (PP) PP/*Eucalyptus globulus* (PP/EG), PP/ Pinecones (PP/PC), PP/ *Brassica rapa* (PP/BR)	49 days	-	-	-	SEM, FTIR, AFM, static contact angles (SCA)	Butnaru et al., 2016
8	*Aspergillus sp.* and *Penicillium sp.*	Culture	PP 1 cycle	30 days	-	−0.262 ±	-	SEM, FTIR	T. A. De Oliveira et al., 2020
			PP 7 cycle			−0.620 ± 0.053			
9	*A. fumigatus*	Solid waste dumping site	PP cups	6 months	-	-	-	SEM, FTIR	Oliya et al., 2020
10	*C. hoffmannii P. richardsiae*	Hydrocarbon-contaminated environment	PP	2 months	-	-	-	SEM, Raman spectroscopy, FTIR—ATR, Enzymatic Activity	Porter et al., 2023
11	*C. halotolerans*	Soil of solid waste dumping site	sunlight-exposed PP	8 months	-	8.6	-	FTIR	Parit et al., 2023
			UV-exposed			6.1			
			un-treated			4.2			
12	*A. flavus*	Municipal waste landfill site	PP	90 days	-	-	-	SEM, FTIR	Wróbel et al., 2023
	A. fumigatus								
	F. oxysporum								
	P. granulatum								

Table No. 5 Investigations on degradation of PET, PCL and PHB types of plastics with fungi

Sr. No.	Name of Fungal species	Collection Site	Type of Plastic	Incubation Time	TS (%)	WL (%)	CO_2 (g/L)	Other Plastic degradation test	Reference
PET									
1	*P. fluorescens*	Culture	PET (225-275 µm)	3 months	-	-	-	SEC, SEM	Marqués-Calvo et al., 2006a
	A. niger								
	P. pinophilum								
2	*A. niger*	Coleccio´ nEspan˜ola de Cultivos Tipo	PET	3 months	-	-	-	optical imaging profiler (OIP)	Marqués-Calvo et al., 2006b
	P. pinophilum								
3	*P. funiculosum*	Landfill	PET 0/100	84 days	-	0.08	-	SEM, FTIR, XSP	F, PająK, et al., 2011
			90/10			0.07			
			75/25			0.21			
			50/50			0.19			
			100/0			90.28			
4	*A. awamori, M. subtilissima, G. viride*	Waste	PET (pbsa)	225 days	98	5.76	-	SEM, FTIR	Nowak et al., 2011
		Forest				2.02			
		Extinct volcano crater				17.03			
5	*T. terrestris*	Soil	PET	24 hrs	-	-	-	Cutinase production	Yang et al., 2013
6	*Aspergillus sp., Penicillium sp., Fusarium sp.*	Sewage	PET flakes	70 days	-	-	-	SEM	Umamaheswari et al., 2014
7	*A. oryzae*	Culture	PET nanoparticles	15 days	-	1.0 ± 0.1	-	SEM	Chaves et al., 2018
	Trichoderma sp. C65					1.7 ± 0.3			
	Trichoderma sp. C68					1.1 ± 0.2			
	Trichoderma sp. L1239					7.1 ± 0.2			
	*M. arundinis*L43					2.4 ± 0.4			
	*M. arundinis*L84					4.1 ± 0.5			

	Fusarium sp.					1.4 ± 0.2			
	R. miehei					0.3 ± 0.1			
	P. brevicompactum					0.2 ± 0.1			
	Aspergillus sp. C362					0.1 ± 0.0			
	Aspergillus sp. C363					0.4 ± 0.1			
	Trichoderma sp. C64					0.4 ± 0.1			
	Trichoderma sp. C70					0.2 ± 0.0			
	Neopestalotiopsis sp.					0.4 ± 0.1			
	E. sorghinum					0.5 ± 0.1			
8	*Microsphaeropsis, Mucor, Trichoderma, Westerdykella, Pycnidiophorasp, Microsphaeropsisarundin*	Fresh water	PET	15 days	-	-	-	HPLC-UV, FTIR, SEM, Fluorescence analysis	Malafatti-picca et al., 2019
9	*Clitocybe sp.*	Culture collection	PET	6 months	-	-	-	SEM, EDX	Janczak et al., 2020
	L. laccata								
10	*Pseudomonas sp.*	AS, FS and soil	PET film	100 days	-	0.6	-	SEM, FTIR, AFM	Taghavi et al., 2021
11	*Moniliophthoraroreri*	Cacao pods	PET	21 days	-	31	-	Dry weight measurement, Titration assay, SEM	Vázquez-Alcántara et al., 2021
12	*A. tamarii, Penicillium crustosum*	Soil from college premises	PET	30 days	-	-	-	terephthalic acid release (TPA) release, FTIR and SEM	Anbalagan et al., 2022
13	*L. aphanocladii*	IBPPM Collection of Rhizospheric Microorganisms	PET	30 days	-	11.6 ± 2.9	-	Enzyme production	Pozdnyakova et al., 2023
	F. oxysporum					22.0 ± 2.2			

	T. harzianum	Institute of Ecology and Evolution, Russian Academy of Sciences				17.2 ± 3.8			
	T. sayulitensis	Rhizosphere of *Miscanthus* grown in Zn-polluted soil				10.0 ± 3.3			
14	*P. ostreatus* *P. pulmonarius*	University of Ibadan, Nigeria, ZERI, Namibia	PET flakes	60 days	-	-	-	FTIR GC-MS	Odigbo et al., 2023
				PCL					
1	*P. lilacinus*	soil and activated sludge	PCL	10 days	-	10	-	HPLC	Oda et al., 1995
2	*A. fumigatus*	Culture	PCL	14 days	-	-	-	DSC, weight reduction and reduction in tensile strength	Albertsson et al., 1998
3	*A. fumigatus, P. simplicissimum*	Culture	PCL	45 days	-	50-55	-	SEC, DSC, FTIR, SEM, ESCA (Electron Spectroscopy for Chemical Analysis)	Renstad et al., 1998
4	*Paecilomyces ssp.,Thermomycessp.*	Soil	PCL	30 days	-	-	-	Weight measurement, Soil analysis	Nishide et al., 1999

5	*Penicillium sp.*	Soil	PCL	50 days	-	56	-	SEM	Kamiya et al., 2007
6	*P. jejuensis*	Orange leaves	PCL	12 days	-	-	-	Cutinase activity, TOC	Seo et al., 2007
7	*A. fumigatus, A. niger, A. versicolor, Aspergillus sp., P. simplicissimum, Penicillium spp.* and *C. cladosporioides*	Soil	PCL	9 months	80/20: 38 60/40: 25 40/60: 13	-	-	SEM	Rosa et al., 2009
8	*P. oxalicum* strain DSYD05-1	Soil	PCL	6 days	-	-	-	Enzymatic assay, weight loss	Li et al., 2012
9	*T. terrestris* CAU709	Soil	PCL	24 hrs	-	-	-	Cutinase production	Yang et al., 2013
10	*P. antarctica* JCM 10317	Culture collection, Japan	PCL	7 days	-	-	-	SEM, Enzymatic degradation	Shinozaki et al., 2013
	Ustilago maydis MAFF 236374, 236375, 236376, 236377, 236378	NIAS Gene Bank, Japan							
	S. cerevisiae BY4741	EUROSCARF, Germany							
11	*P. japonica*	*Hyoscyamus muticus* plant	PCL film	15 days	-	93.33	-	-	Abdel-Motaal et al., 2014
			PCL foam	30 days		43.2			
12	*Amycolatopsis sp.*	Agricultural soils	PCL	30 days	-	-	-	protease, esterase and lipase production	Penkhrue et al., 2015
13	*Trichoderma sp.* (16H)	Soil of western and central parts of Spitsbergen,	PCL	1 month	-	21.54	-	SEM	Urbanek et al., 2017
	C. rosea (16G)					52.91 34.50 (liq. $20^{O}C$)			

		Svalbard Archipelago							
14	*A. fumigatus*	Compost 37°C	PCL	91 days	-	100	-	Tensile strength	Al Hosni et al., 2019
		Soil 37°C							
	T. lanuginosus	Compost 50°C							
	N.ramose, *F. solani*, *A. fumigatus*	Compost 25°C							
	F. solani	Soil 25°C							
15	*C. globosum*	Culture collection	PCL	28 days	-	75	-	SEM	Vivi et al., 2019
16	*A. porosum*, *P. samsonianum*, *T. pinophilus*, *P. lilacinum*, *F. acetilerea*	KACC	PCL	45 days	-	-	-	Clear zone formation	Lee et al., 2021
16	*Geomycessp*, *Sclerotinia*, *Fusarium sp*, *Mortierella*, *H. anomala*	Soil	PCL	1 month				Clear zone formation	Urbanek et al., 2021
17	*M. roreri*	Cacao pods	PCL	21 days	-	43	-	Dry weight measurement, Titration assay, SEM	Vázquez-Alcántara et al., 2021
				PHB					
1	*P. simplicissimum*, *V. leptobactrum*, *A. fitmigatus*	Compost	PHB, PHBHV	98 days	-	-	-	weight loss and loss of mechanical properties	Mergaert et al., 1994
2	*P.lilacinus*	soil and activated sludge	PHB	10 days	-	100	-	HPLC	Oda et al., 1995
3	*Mucor sp.*	Soil	PHB/ HV	23 days				Weight measurement, Soil analysis	Nishide et al., 1999

4	*Penicillium, Cephalosporium, Paecilomyces,*	garden soil	PHB	30 days	-	-	-	Mass loss, mechanical test	Savenkova et al., 2000
5	*Trichoderma sp.*	Soil	PHB	50 days	-	-	-	FTIR	Râpă et al., 2014
6	*A. fumigatus, P. farinosus, F. solani*	Buried in an activated sludge	PHB	25 days	-	98.9±4.0 at 37°C	-	SEM, Sturm test	Kim et al., 2000
	A. fumigatus, C. protuberata, P. simplicissimum		Sky-Green1 (SG)	55 days		77.5±2.4 at 28°C			
	A. fumigatus, A. parasiticus		Mater-Bi1 (MB)			72.1±2.2 at 60°C			
7	*A. fumigatus*	Soil (37°C)	PHB	300 days	-	-	-	-	Al Hosni et al., 2019
	A. fumigatus	Compost (37°C)							
	F. solani	Compost (25°C)							
	T. lanuginosus, Sordariales sp., S. thermophilum, C. thermophilum	Compost (50°C)							
8	*A. niger*	Department of Biotechnology /Ministry of Science, a local isolate from soil contaminated with oil wastes	PHB in solid medium	12 days	-	100	-	-	Iman et al., 2019
			PHB in liquid medium	14 days					

9	*P. oxalicum*	Soil of dumping site	PHB	emulsion and films form within 36–48 h at 30 °C in lab-built soil environment within 1 week	-	-	-	SEM, NMR, DSC, FTIR, Gel Filtration Chromatography, Molecular Weight Determination	Satti et al., 2020

Table No. 6Biodegradation of PLA, PBS, DEHP, LLDPE and PBSA types of plastics by fungi

Sr. No.	Name of Fungus species	Collection Site	Type of plastic	Incubation Time	TS (%)	WL (%)	CO_2 (g/L)	Other Plastic degradation test	Reference
PLA									
1	*P. antarctica*	Culture collection, Japan	PLA	7 days	-	-	-	SEM, Enzymatic degradation	Shinozaki et al., 2013
	U. maydis MAFF 236374, 236375, 236376, 236377, 236378	NIAS Gene Bank, Japan							
	S. cerevisiae	EUROSCARF, Germany							
2	*Amycolatopsi ssp.*	Northern Thailand	PLA film	7 days	-	36.7	-	Enzyme production	Penkhrue et al., 2015

3	Two strains of *T. lanuginosus* and *Sordariales sp.*	Compost (50˚C)	PLA	300 days	-	-	-	-	Al Hosni et al., 2019
4	*A. porosum, P. samsonianum, T. pinophilus, P. lilacinum, F. acetilerea*	Korean Agricultural Culture Collection (KACC)	PLA	45 days	-	-	-	Clear zone formation	Lee et al., 2021
5	*P. chrysosporium*	China Center for Type Culture Collection, China	PLA	35 days	-	19.7	-	FTIR, SEM	F. Wu et al., 2023
PBS									
1	*Penicillium sp.*	Soil	PBS	34 days	-	46	-	SEM	Kamiya et al., 2007
2	*F. solani*	Farmland soil	PBS	14 days				CO_2 evolution	Abe et al., 2010
3	*P. chrysanthemicola*	Healthy leaves of wheat, barley, rice, grown in fields	PBS film (Bionolle 1001G) (20 µm)	10 days	-	-	-	Enzymatic activity, SEM	Koitabashi et al., 2012
4	*T. terrestris* CAU709	Soil	PBS	24 hrs	-	-	-	Cutinase production	Yang et al., 2013
5	*P. antarctica*	Culture collection, Japan	PBS film	7 days	-	-	-	SEM, Enzymatic degradation	Shinozaki et al., 2013
	U. maydis MAFF 236374, 236375, 236376, 236377, 236378	NIAS Gene Bank, Japan							
	S. cerevisiae	EUROSCARF, Germany							

6	*C. magnus*	larval midgut of a stag beetle, *Aeguslaevicollis*	PBS	4 days	-	-	-	Enzyme production	Suzuki et al., 2013
	C. magnus, F. floriforme, P. antarctica	Japan Collection of Microorganisms of the Riken Bio-resource Center, Japan							
7	*A. thailandensis*	Soil	PBS	14 days	-	-	-	Enzyme production, SEM	Penkhrue et al., 2015
8	*Paraphoma sp.*	Culture, isolated from barley	PBS film	7 days	-	-	-	Enzymatic degradation	Koitabashi et al., 2016
9	*P. Antarctica, Paraphoma sp.*	culture	PBS (Bionolle #1020)	1- 4 hrs	-	-	-	LCMS, SEC	Sato et al., 2017
10	*T. pinophilus, A. cellulolyticus ,P. pinophilum*	Compost (50˚C)	PBS	300 days	-	< 50	-	-	Al Hosni et al., 2019
	A. fumigatus	Soil (37˚C)				< 75			
11	*Geomyces sp., Sclerotinia, Fusarium sp., Mortierella, Hansenulaanomala*	Soil	PBS	1 month	-	-	-	Clear zone formation	Urbanek et al., 2021
DEHP									
1	*F. oxysporum,*	Soil in central	DEHP	7 days	-	-	-	Biomass production	Suárez-Segundo et al.,

	M. alpina	Manchester UK							2013
	P. pulmonarius	Chinese University of Hong Kong Collection							
	two strains of *P. ostreatus*	American Type Culture Collection							
	P. florida	Universidad Autonoma de Tlaxcala collection							
2	*F. culmorum*	CICB at Universidad Autónoma de Tlaxcala, Mexico	DEHP (1000 mg/L)	144 h	-	99	-	GC–MS	Ahuactzin-Pérez et al., 2016
			DEHP (500 mg/L)	84 h		93			
				144 h		98			
3	*P. ostreatus*	Local market	DEHP	20 days	-	-	-	Enzyme production	Hock et al., 2020
	P. seryngii								
	L. edodes								
	A. bisporus								
4	*A. niger*	Dumping ground soil	DEHP (urine bag, blood bag)	20 days	-	-	-	SEM	E. A. M. Ali et al., 2023
	A. nidulans								
	R. nigricans								
5	*F. culmorum*	Research Centre for Biological Sciences at Universidad Autónoma de Tlaxcala, Mexico	DEHP	312 hours	-	-	-	96.9 % biodegradation, Enzyme production	Hernández-Sánchez et al., 2024
LLDPE									

1	*A. niger, P. funiculosum, C. globosum, G. virens, P. pullulans*	Culture	LLDPE	28 days	-	0.37	-	SEM, DSC, TGA, FTIR	Chandra &Rustgi, 1997
			MA-g-LLDPE			0.2			
2	*Aspergillus, Penicillium*	Compost	LLDPE	3 months	-	-	-	DSC, FTIR	Ojeda et al., 2009
3	*P. chrysosporium*	DSMZ	LLDPE (12 micron)	180 days	-	-	-	FTIR, DSC, TGA, GPC	Corti et al., 2012
4	*A. terreus, A. wentii, E. nidulans*	Waste material soil	LLDPE, LLDPE + High Molecular weight (HmHDPE)	3 months	-	-	-	Enzymatic activity	Poonam et al., 2013
5	*T. hamatum*	Plastic waste soil	LLDPE- γ irradiation	7 days	-	2.2±1.2	-	FTIR, TGA, GPC, SEM	Malachová et al., 2020
			90°C			3.9±0.5			
6	*D. hansenii*	Agricultural soil	LLDPE MPs	30 days	-	2.5-5.5	-	FESEM	Salinas et al., 2023
PBSA									
1	*Aspergillus sp.,Cunninghamellasp., Thermomyce ssp.*	Soil	PBSA	25 days	-	-	-	Weight measurement, Soil analysis	Nishide et al., 1999
2	*Penicillium sp.*	Soil	PBSA	20 days at 25°C	-	60	-	LC-MS/MS, Enzyme production	Kamiya et al., 2007
				50 days on university soil		50			
3	*P. chrysanthemicola*	Healthy leaves of wheat, barley,	PBSA film (Bionolle	10 days	-	-	-	Enzymatic activity, SEM	Koitabashi et al., 2012

		rice, grown in fields	3001 G)						
4	*P. antarctica*	Culture collection, Japan	PBSA	7 days	-	-	-	SEM, Enzymatic degradation	Shinozaki et al., 2013
	U. maydis MAFF 236374, 236375, 236376, 236377, 236378	NIAS Gene Bank, Japan							
	S. cerevisiae	EUROSCARF, Germany							
5	*C. magnus*	larval midgut of a stag beetle	PBSA	4 days	-	-	-	Enzyme production	Suzuki et al., 2013
	C. magnus, F. floriforme, P. antarctica	Japan Collection of Microorganisms of the Riken Bio-resource Center							
6	*Paraphoma sp.*	Culture, isolated from barley	PBSA	7 days	-	-	-	Enzymatic degradation	Koitabashi et al., 2016
7	*Paraphoma*-like Fungus	Culture	PBSA 20µm	8 hours	-	-	-	Gel electrophoresis	Sameshima-Yamashita et al., 2016
8	*P. antarctica, Paraphoma sp.*	culture	PBSA (Bionolle #3020)	1- 4 hrs	-	-	-	LCMS	Sato et al., 2017
9	*P. antarctica*	culture collection (JCM)	PBSA film (20 mm)	3 days	-	-	-	SEM	Kitamoto et al., 2018
10	*Geomyces sp., Sclerotinia, Fusarium sp.,Mortierella, H. anomala*	Soil	PBSA	1 month	-	-	-	Clear zone formation	Urbanek et al., 2021
11	*A. fumigatus*	Farmland soil	PBSA Films	28 days	-	-	-	SEM, NMR, Enzymatic	Chien et al., 2022
	A. terreus								

			(soil burial experiment)					activity	
12	*Fusarium sp.*	In situ soil	PBSA	55 days	-	-	-	CO_2 production, enzymatic activity	Tsuboi et al., 2024

Table No. 7 Investigations on biodegradation of different types plastics by fungi

Other types of plastic									
Sr. No.	**Name of Fungus species**	**Collection Site**	**Type of plastic**	**Incubation Time**	**TS (%)**	**WL (%)**	**CO_2 (g/L)**	**Other Plastic degradation test**	**Reference**
1	*P. ostreatus, P. chrysosporium, T. versicolor, G. trabeum, P. radiata*	Culture collection of the Institute of Forstbotanic of The Universitat	Lignin/styrene products 10.3 (LPSl 0), 32.2 (LPS3	68 days	-	LPS 50 and LPS 32 by 50.41 and 32.17	-	SEM, UV-spectrometry, Synthesis of Polymerizates, Mass Reduction	Milstein et al., 1996
	P. ostreatus, T. versicolor, P. radiata	Collection of Bundesanstalt fur Material for schung und - prufung, Berlin	lignin/ methyl methacrylate (1 1 to 18 wt% lignin)						
2	*P. chrysosporium*	Culture	PVA	15 days	-	-	-	gel permeation chromatography (GPC), FTIR, HPLC	Betty Lucy López et al., 1999
3	*Fusarium*	Culture	PLGA 43/57	12 weeks	-	91.1	-	DSC, SEM, Change in viscosity	Cai et al., 2001
4	*A. niger*	NCL, India	EPF 30R (~100 µm) in compost	6 months	-	Unirradiated: 10 100 hr UV irradiated: > 75	-	Variation in Viscosity, Chain Scission, FTIR, SEM	Pandey &Singh, 2001

			EPQ 30R (~100 µm) in compost			Unirradiated: <15 100 hr UV irradia			
5	*P. chrysosporium*	Fungal Culture Collection of the National	Polyamide-6	5 months	-	50	-	SEM	Klun et al., 2003
6	*I. hispidus*	Culture Collection of	poly(ester-amide)	32 to 90 days	-	-	-	GPC, SEM	Šašek et al., 2006
7	*A. clavatus* *P. funiculosum*	Dry and wet soil Culture	poly(ethylene succinate) (PESu)	20 to several days	-	-	-	SEM, Enzyme production	Ishii et al., 2007
8	*A. niger*	Culture	PS: PLA (30%) PS: PLA: OMMT (5%)	28 days	4.9 6	-	-	TGA, SEM, FTIR, XRD	Barkoula et al., 2008
9	*A. niger*	Culture	copolymers of lactic acid, terephthalic acid and ethylene glycol	60 days	-	W:65 Y:70	-	FTIR, SEM	Soni et al., 2009
	A.versicolor					59 62			
	A clavatus					55 60			
	A.fumigatus					53 65			
	A.alternata,					68 81			
	Mucor sp.					48 64			
	Penicillium sp.					45 68			
	Rhizopus sp.					51 55			
10	*A. niger*	Culture	EP	6 months	-	-	-	SEM, FTIR, Variation in Viscosity	Alariqi& Singh, 2010
11	*A. niger, P.*	Guangzho	POE-	28 days	-	-	-	SEM, tensile	Z. Yang et

	*pinophilum*A *C. globsum, G. virens, A. pullulans*	u Institute of Microbiology	g-MAH					strength	al., 2010
12	*Aspergillus niger*	Culture	TPGS, TPS	45 days	-	-	-	TGA, SEM	Canché-Escamilla et al., 2011
13	*Fusarium sp.,Trichosporon sp.*	Mangrove Sediments	Dimethyl phthalate (DMP), dimethyl isophthalate	24 days	-	-	-	Enzymatic assay	Luo et al., 2012
14	*Fusarium sp.*	garden soil and waste leachate	Polycarbonate (PC)	15 days	-	-	-	Clear zone, AFM	Arefian et al., 2013
15	*Chaetomium sp.*	Agricultural soil	Biodegradable mulch (BDM) films	10 weeks	-	-	-	Clear zone formation, SEM	Bailes et al., 2013
16	*P. pulmonarius*	ATCC Chinese University of Hong Kong Collection	DBP & DEP	7 days	-	-	-	Radial growth rate and biomass Differentiation zone of grown	Suarez-Segundo et al., 2013
	P. ostreatus(Po 37 and Po	American Type Culture							
	P. florida	Universidad Autonom a ´de							
	F.oxysporum	Soil of the suburbs, park							
	M. alpina								
17	*T. versicolor*	American Type Culture Collection	PAH	60 days	-	-	-	Enzyme activity	Lladó et al., 2013

	L. tigrinus	Central bureau voorSchimmelcultures							
18	*Fusarium* *Ulocladium* *Chrysoporium* *Penicillium*	PC contaminated garden and waste leachate	PC	7 days	-	-	-	clear zone of amylase and lipase, and AFM	Arefian et al., 2013
19	*C. guilliermondii, A. fumigatus*	Culture Collection of Basidiomycetes, Czech Republic	Polyesteramides (PEA)	6 weeks	-	-	-	Enzyme production (lipase and esterase)	Novotný et al., 2015
20	*M. elongata*	Compost	70 TPF	125 days	-	45.23	-	tensile strength	Vieyra et al., 2015
21	*Trametes versicolor*	National Collection of Biology Laboratory, University of Tehran, Iran	TPS, CNFs	2 months	-	-	-	SEM, DMA	Babaee et al., 2015
22	*P. antarctica, Paraphoma sp.*	Culture	PBSA (Bionolle #3020), PBS (Bionolle #1020) PBA	1- 4 hrs	-	-	-	LCMS	Sato et al., 2017
23	*C. byrsina*	Wonorejo Mangrove soil, Indonesia	Plastic	6 weeks	-	22.7	-	enzymatic degradation	Kuswytasari et al., 2019

24	*A. flavus*	Municipal waste	Hexadecane	14 days	-	52.92± 8.81	-	GCMS, SEM	M. Perera et al., 2019
25	*Clitocybe sp.* *L. laccata*	Culture	polylactide	6 months	-	-	-	SEM-EDX	Janczak et al, 2020
26	*Aspergillus* sp. and *Penicillium* sp.	Culture	PBAT - thermoplasti	30 days	-	1.04 ± 0.080	-	SEM, FTIR	T. A. De Oliveira et al., 2020
27	*M. roreri*	Cacao pods	polyethylene succinate (PES)	21 days	-	59	-	Dry weight measurement, Titration assay, SEM	Vázquez-Alcántara et al., 2021
28	*P. sordida*	Culture	Bisphenol F (BPF)	14 days	-	-	-	Enzymatic degradation	Wang et al., 2021
29	*Fusarium culmorum and F. oxysporum*	Culture collection	DBP	7 days	-	-	-	Esterase Activity	González-Márquez et al., 2021
30	*M.roridum*	Culture	BPA	72 hrs	-	-	-	LC-MS/MS, Enzyme production	Jasińska et al., 2021
31	*A. flavus*	Field soil	compostable film microplastics (CFMPs)	12 months	-	-	-	ATR-FTIR	Pedrini, 2022
32	*Acremonium sp.*	Inside plastic fuel bottles	PAHs	30 days	-	-	-	UHPLC	Héctor et al, 2022
33	*A. flavus*	Sanitary landfill soil	DBP	15 days	-	-	-	GC-MS	Puranik et al., 2023
34	*P. lilacinum*	Farmland soil	biodegradable	30 days	-	15	-	SEM, FTIR, LCMS	Tseng et al., 2023
35	*Phanerochaete sp.*	Leaves of *Handroanthusimpetiginosus*	BPA	7 days	-	-	-	SEM	Conceição et al., 2023