

## ORIGINAL RESEARCH ARTICLE

# LDPE Biodegradation Potential of Landfill-Derived *Myrothecium* sp. Strain Gavilo–Nemenzo (FS3) from Davao Oriental, Philippines

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## ABSTRACT

Plastic pollution remains a major environmental concern because of its persistence and resistance to natural degradation. This study aimed to isolate and characterize microorganisms associated with degraded LDPE plastic litter collected from the sanitary landfill in Davao Oriental, Philippines, and evaluate their potential for LDPE biodegradation. Microbial isolation from degraded LDPE samples yielded ten isolates, comprising five bacterial (BS1–BS5) and five fungal (FS1–FS5) strains. Morphological characterization was performed through observation of colony morphology and microscopic features of the recovered isolates. Screening assays identified fungal isolate FS3 as the most efficient LDPE degrader, causing surface roughening, thinning, deformation, fragmentation, and extensive fungal colonization of the plastic substrate. Stereomicroscopic and SEM analyses revealed dense fungal colonization and penetration of the LDPE surface, accompanied by extensive deterioration compared with uninoculated controls. Molecular characterization through Internal Transcribed Spacer (ITS) sequencing identified isolate FS3 as *Myrothecium* sp., exhibiting 100% sequence identity with *Myrothecium* sp. strain Wt303, and the isolate was consequently designated *Myrothecium* sp. strain Gavilo–Nemenzo (FS3). Future multilocus phylogenetic and morphological investigations will evaluate its taxonomic status and may support the proposal of the reserved species name *Myrothecium gavilonemenzorum* sp. nov. if warranted by the evidence. The isolate demonstrated LDPE biodegradation activity and polymer surface deterioration, highlighting its potential as a biological agent for plastic waste remediation. These findings demonstrate that sanitary landfill environments harbor microorganisms with plastic-degrading capabilities and support the potential application of *Myrothecium* sp. strain Gavilo–Nemenzo (FS3) in sustainable waste management, environmental biotechnology, and taxonomic investigations.

**Keywords:** Biodegradation, *Myrothecium* sp., Low-density polyethylene (LDPE), plastic pollution, sanitary landfill

Submitted: 18 May 2026  
Revised: 20 May 2026  
Accepted: 10 Jun 2026  
Published: 24 Jun 2026



**How to cite:** Gavilo, E. M., and Nemenzo-Calica, P. (2026). LDPE Biodegradation Potential of Landfill-Derived *Myrothecium* sp. Strain Gavilo–Nemenzo (FS3) from Davao Oriental, Philippines. *Davao Research Journal*, 17(2), 97–108. <https://doi.org/10.59120/drij.v17i2.587>

## INTRODUCTION

Plastic pollution has become a major global environmental challenge due to the accumulation of non-biodegradable synthetic polymers in terrestrial and aquatic ecosystems (Verzosa et al., 2024; Lahoy and Antonio, 2025). Since their introduction in the 1850s, plastics have become indispensable because of their durability, versatility, low cost, and resistance to degradation (Tournier et al., 2023). Among the various plastic types, low-density polyethylene (LDPE) is one of the most widely used materials in plastic bags, food packaging, wrappers, sachets, and other single-use products because of its flexibility, light weight, and moisture resistance (Andrady, 2017; Gong et al., 2023). However, its extensive use and improper disposal have significantly contributed to the global plastic waste crisis.

Approximately 430 million tons of plastic are produced annually worldwide, much of which eventually becomes waste (Vasquez, 2024). Due to its highly recalcitrant polymer structure, LDPE persists in the environment for decades and degrades very slowly under natural conditions (Gajendiran et al., 2016).

Conventional waste management approaches, including landfilling, recycling, and incineration, have not been sufficient to address the growing volume of plastic waste. Landfills accumulate large quantities of plastics, while incineration may release harmful gases and toxic compounds (Wojnowska-Baryła et al., 2022). In addition, plastic fragmentation generates microplastics that contaminate soils, freshwater systems, oceans, and food chains, posing risks to ecosystems and human health (Eze et al., 2024; Pislán et al., 2026).

The problem is particularly significant in the Philippines, which has been identified as a major contributor to marine plastic pollution due to inadequate waste management systems and improper disposal practices (Jambeck et al., 2015; Meijer et al., 2021). More than 2.7 million tons of plastic waste are generated annually, with a considerable proportion entering marine environments (Climate Change Commission, 2024). These concerns highlight the need for sustainable and environmentally friendly approaches to plastic waste management.

Microbial biodegradation has emerged as a promising alternative because microorganisms can colonize plastic surfaces

and utilize enzymatic processes to break down polymer chains (Qin et al., 2021; Ullah et al., 2025). During biodegradation, microorganisms form biofilms, secrete extracellular enzymes, fragment polymers, and ultimately convert degradation products into simpler compounds, including carbon dioxide, water, methane, and biomass (Zeenat et al., 2021). Numerous bacterial and fungal species have demonstrated the ability to degrade polyethylene and other synthetic polymers under laboratory conditions (Shankar et al., 2019; Gorish et al., 2024).

Among these microorganisms, filamentous fungi are considered particularly promising because of their extensive hyphal networks, adaptability to harsh environments, and production of oxidative and hydrolytic enzymes, including laccases, lipases, esterases, and peroxidases (Ekanayaka et al., 2022; Chigwada et al., 2025). Furthermore, recent studies have highlighted the central role of oxidative enzymes, including laccases, manganese peroxidases, lignin peroxidases, and cutinases, in initiating the breakdown of chemically stable polymer chains and facilitating subsequent polymer fragmentation (Ameen et al., 2025; Qin et al., 2021; Bautista-Zamudio et al., 2023; Chigwada et al., 2025). Previous studies have documented polyethylene degradation by several fungal genera, including *Alternaria*, *Penicillium*, *Aspergillus*, and *Fusarium* (Spina et al., 2021; Srikanth et al., 2022). In particular, *Fusarium* species, unlike *Myrothecium* species, have been shown to colonize and deteriorate low-density polyethylene (LDPE) through enzymatic depolymerization and biofragmentation processes (Zahra et al., 2010; Omidoyin et al., 2025), thereby enabling the utilization of complex synthetic polymers as alternative carbon sources under nutrient-limited conditions (Kamil et al., 2025). Notably, to the best of our knowledge, there are currently no published reports demonstrating plastic-degradation potential in *Myrothecium* species, making the present study the first to provide evidence of such activity within this genus.

Landfill ecosystems are considered valuable reservoirs of potentially plastic-degrading microorganisms because they harbor diverse microbial communities that are continuously exposed to plastic-rich environments (Munir et al., 2024). Such exposure may promote adaptation to synthetic polymers and enhance biodegradation capabilities (Awasthi et al., 2023). Several studies have successfully isolated plastic-degrading

bacteria and fungi from landfill environments, demonstrating their potential for bioremediation applications (Lamela et al., 2023; Gong et al., 2023). Accurate identification of these microorganisms is essential, and Internal Transcribed Spacer (ITS) sequencing is widely recognized as the universal DNA barcode for fungal identification due to its high taxonomic resolution and reliability (Schoch et al., 2012). Combining morphological and molecular approaches has therefore become the preferred strategy for characterizing fungal biodegraders (Chigwada et al., 2025; Ameen et al., 2025).

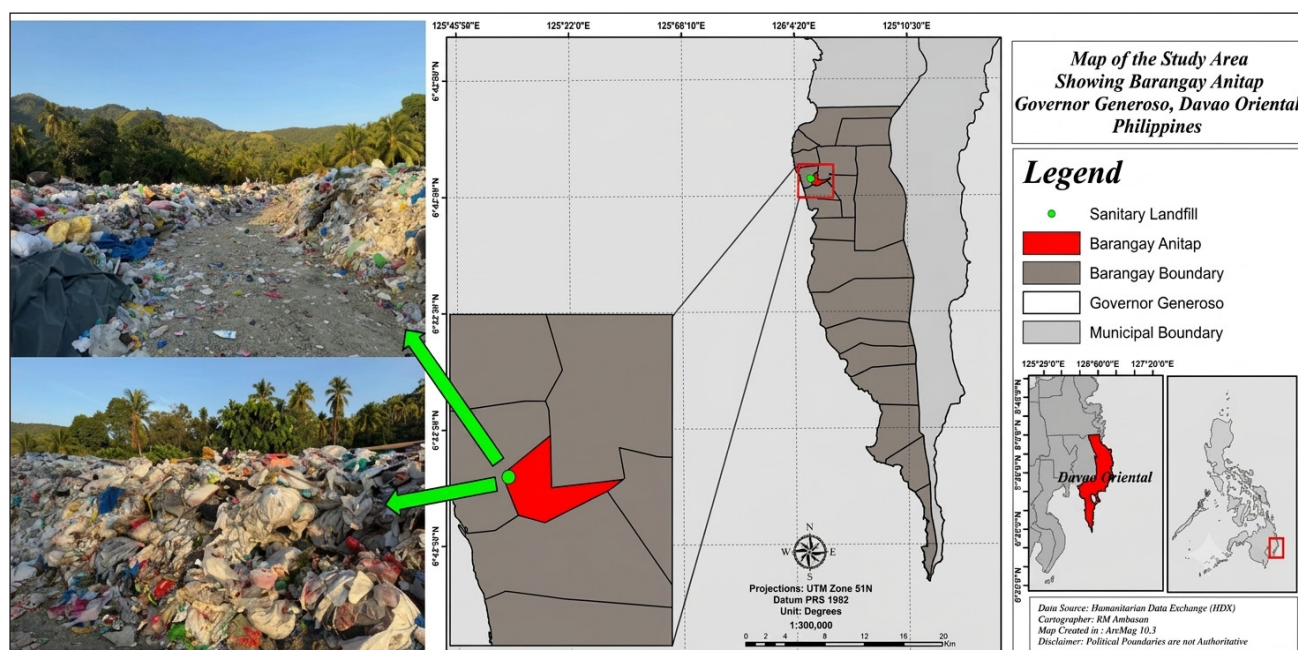
Despite growing international interest in microbial plastic biodegradation, studies on indigenous fungal degraders in the Philippines remain limited, particularly those derived from sanitary landfill environments. Existing local research has focused primarily on plastic-associated bacteria (Lamela et al., 2023), while information on landfill-derived fungi capable of degrading LDPE is scarce. Furthermore, little is known about plastic-degrading fungal communities in Mindanao, especially in Davao Oriental. Addressing this knowledge gap is important for developing locally adapted bioremediation strategies that utilize indigenous microorganisms already acclimatized to plastic-contaminated environments.

Therefore, this study investigated microorganisms associated with highly degraded LDPE plastic litter collected from the sanitary landfill of Barangay Anitap, Governor Generoso, Davao Oriental, Philippines. Specifically, the study aimed to isolate and characterize microbial communities associated with degraded LDPE, evaluate their biodegradation potential, and identify the isolate exhibiting the greatest LDPE biodegradation activity through morphological and microscopic characterization. The findings provide localized evidence of native microbial resources with potential applications in LDPE biodegradation and contribute to the development of sustainable biological approaches for plastic waste management in the Philippines.

## MATERIALS AND METHODS

### Description of the study area

The study was conducted using plastic waste samples collected from the sanitary landfill in Barangay Anitap, Governor



**Figure 1.** Location map of the study area in Barangay Anitap, Governor Generoso, and actual view of the sanitary landfill showing the sampling site for highly degraded low-density polyethylene (LDPE) plastic litter collection.

Generoso, Davao Oriental, Philippines, located at 6°37'55.36"N and 126°06'49.08E (Figure 1). Barangay Anitap is one of the coastal, rural barangays in the municipality, characterized by agricultural lands, residential areas, and patches of secondary vegetation. The barangay is influenced by a tropical climate with relatively high humidity, warm temperatures, and considerable year-round rainfall, creating environmental conditions conducive to microbial survival and growth. Topographically, Barangay Anitap consists of gently rolling to moderately sloping terrain, with low-lying areas extending toward the coastal portions of the municipality. The area comprises mixed soil types commonly associated with agricultural and landfill environments, which can support diverse microbial communities. The surrounding environment is continuously exposed to sunlight, fluctuating moisture levels, and organic waste accumulation, all of which contribute to the physical weathering and degradation of plastic materials.

The sanitary landfill in the barangay serves as a disposal site for mixed municipal solid wastes, including domestic, commercial, and agricultural refuse. The landfill was selected as the sampling site because of the visible accumulation of highly degraded plastic wastes and the prolonged environmental exposure of the materials to heat, ultraviolet radiation, rainfall, and soil microorganisms. These environmental and topographical characteristics provide favorable conditions for microbial colonization and adaptation, thereby increasing the potential to isolate indigenous microorganisms capable of degrading low-density polyethylene (LDPE).

### Sample collection

Five highly degraded low-density polyethylene (LDPE) plastic litter samples were randomly collected from different areas within the landfill using sterile gloves and forceps. Only plastic materials exhibiting advanced stages of environmental degradation were selected for sampling. These samples were characterized by visible physical deterioration, including discoloration, brittleness, surface cracks, fragmentation, thinning, a roughened texture, and the presence of adhering soil particles or biofilm-like microbial growth. The selection of severely weathered plastic litter was based on the assumption that prolonged environmental exposure increases the likelihood of microbial colonization and adaptation to plastic substrates. The collected samples were individually placed in sterile zip-lock bags, properly labeled, and transported to the Microbiology Laboratory at the Davao Oriental State University in Mati City, Davao Oriental, for microbial isolation and characterization. Care was taken to minimize contamination during collection and handling to preserve the naturally occurring microorganisms associated with the degraded LDPE surfaces.

A limitation of this preliminary study is the relatively small number of LDPE samples collected ( $n = 5$ ), which may not fully represent the microbial diversity associated with degraded plastics across the entire landfill. Nevertheless, the selected samples provided an initial basis for isolating and screening microorganisms with potential to degrade LDPE. Future studies involving a larger number of samples and multiple sampling periods are recommended to capture greater microbial diversity and strengthen the ecological representativeness of the findings.

### Isolation and characterization of microorganisms from degraded LDPE plastics

Microbial isolation was conducted in accordance with standard microbiological procedures. Each of the five degraded LDPE plastic litter samples was rinsed with sterile distilled water to remove loosely attached debris. The individual plastic litter

sample was then immersed in sterile saline solution and vortexed to detach surface-associated microorganisms. For bacterial isolation, a loopful of each diluted suspension was streaked onto Nutrient Agar (NA; HiMedia Laboratories Pvt. Ltd., Maharashtra, India), while fungal isolates were cultured on Potato Dextrose Agar (PDA; HiMedia Laboratories Pvt. Ltd., Maharashtra, India). The inoculated plates were incubated at room temperature for 24–48 hours for bacterial growth and 5–7 days for fungal growth. Distinct microbial colonies that developed on the culture media were repeatedly sub-cultured until pure isolates were obtained. Each colony exhibiting distinct morphological characteristics was considered a separate isolate. The purified bacterial isolates were coded as BS1–BS5, where “B” represented bacteria and “S” represented sample, while fungal isolates were coded as FS1–FS5, where “F” represented fungi and “S” represented sample. The purified isolates were subsequently maintained on Nutrient Agar (NA) slants for bacteria and Potato Dextrose Agar (PDA) slants for fungi for further characterization and biodegradation screening.

Morphological characterization of the bacterial and fungal isolates was performed based on colony appearance and cultural characteristics. Bacterial isolates grown on Nutrient Agar plates were examined for colony color, shape, margin, elevation, opacity, and surface texture. Fungal isolates cultured on Potato Dextrose Agar plates were characterized according to colony color, texture, sporulation pattern, pigmentation, and hyphal appearance.

### Screening of LDPE biodegradation activity

The biodegradation potential of the microbial isolates was evaluated using sterile blue LDPE plastic substrates. Commercial LDPE plastics were cut into uniform 1 cm<sup>2</sup> pieces, surface-sterilized with 70% ethanol, and then rinsed with sterile distilled water. For bacterial isolates, a loopful of a 48-hour pure culture was uniformly streaked over the entire surface of Nutrient Agar (NA) plates to establish confluent growth. For fungal isolates, a uniform mycelial plug (approximately 5 mm in diameter) obtained from the actively growing margin of a pure culture was aseptically transferred onto Potato Dextrose Agar (PDA) plates. The bacterial cultures were incubated for 48 hours, whereas the fungal cultures were incubated for 5 days at room temperature to ensure sufficient microbial growth before LDPE exposure. Subsequently, one sterile LDPE plastic strip (1 cm<sup>2</sup>) was individually placed on top of each established bacterial or fungal culture.

The inoculated setups were then incubated at room temperature for 18 days and regularly monitored for visible signs of biodegradation. Changes observed on the LDPE surfaces included discoloration, thinning, surface roughening, fragmentation, fungal colonization, and deformation. Uninoculated LDPE substrates served as the control treatment for comparison.

After the incubation period, all LDPE samples were examined under a stereomicroscope at 40× magnification to assess microbial attachment and surface alterations. The plastic surfaces were observed under a stereomicroscope to detect bacterial interaction, fungal hyphae penetration, biofilm formation, surface erosion, and structural deterioration. Photographic documentation of the observed changes was conducted for comparative analysis between inoculated and uninoculated LDPE samples.

### Scanning Electron Microscopy (SEM) analysis

Scanning Electron Microscopy (SEM) analysis was performed to confirm further the biodegradation effects of the most active isolate on LDPE surfaces. The LDPE samples were carefully removed from the culture setups and gently rinsed with sterile distilled water to eliminate loosely attached microbial biomass. The samples were air-dried before SEM preparation.

The prepared LDPE samples were subjected to SEM examination at different magnifications (500x, 1000x, and 2000x) at Ateneo de Davao University, Davao City, Philippines, to observe microstructural changes on the plastic surfaces. Surface characteristics such as cracks, pits, grooves, erosion patterns, and fungal penetration were analyzed and compared with those of uninoculated control samples. The SEM analysis provided detailed evidence of physical deterioration associated with microbial biodegradation activity.

### Identification of the potential LDPE-degrading isolate

The isolate that demonstrated the highest biodegradation activity was identified through both morphological and molecular characterization. Morphological identification was based on colony and microscopic characteristics. Colony features, including growth pattern, texture, pigmentation, and other cultural characteristics, were observed on the growth medium. Microscopic examination was also performed to evaluate hyphal structures, conidiophores, and spore morphology. These observations provided preliminary taxonomic information regarding the fungal isolate.

For molecular identification, genomic DNA was extracted and the Internal Transcribed Spacer (ITS) region of ribosomal DNA, a widely accepted DNA barcode for fungal identification (Schoch et al., 2012), was amplified and sequenced using the universal fungal primers ITS1 and ITS4. Molecular characterization was conducted at the Philippine Genome Center Mindanao (PGC Mindanao), University of the Philippines Mindanao.

The resulting sequence chromatograms were subjected to quality assessment and trimming using FinchTV. High-quality forward and reverse sequences were assembled into a consensus sequence using BioEdit and MEGA11. The consensus ITS sequence was subsequently compared against reference sequences in the NCBI GenBank database using the BLASTn algorithm to determine the closest taxonomic match. Molecular identification was evaluated based on query coverage, E-value,

percent identity, and the most significant database hit.

Sequence analysis revealed that isolate FS3 showed a 100% query cover, 100% percent identity, and an E-value of 0.00E+00 with *Myrothecium* sp. strain Wt303 (GenBank Accession No. PQ787664.1), indicating a highly reliable match. Based on these results, the isolate was identified as belonging to the genus *Myrothecium*. However, species-level identification could not be assigned with confidence because the closest matching reference sequence available in the GenBank database was identified only to the genus level. Additional molecular analyses and comparison with more comprehensive reference sequences would be required for definitive species-level identification.

The confirmed *Myrothecium* isolate was maintained as a pure culture under laboratory conditions for preservation and future studies. Deposition of the isolate in an appropriate microbial culture collection repository will be pursued to ensure long-term preservation, accessibility, and reproducibility of the research findings.

## RESULTS

### Isolation of potential plastic-degrading microorganisms from the sanitary landfill

Five highly degraded LDPE plastic litter samples collected from the sanitary landfill of Barangay Anitap, Governor Generoso, Davao Oriental served as sources of microbial isolation. The samples consisted primarily of weathered plastic bags, sachet wrappers, and thin plastic films that exhibited discoloration, brittleness, fragmentation, thinning, and surface roughness (Figure 2). These materials were partially buried within landfill soil and continuously exposed to moisture, heat, organic wastes, and microbial activity. Figure 2 shows the actual degraded LDPE plastic litter samples collected from the sanitary landfill and utilized for the isolation of bacterial and fungal strains in this study.



**Figure 2.** Highly degraded LDPE plastic litter samples collected from the sanitary landfill of Barangay Anitap, Governor Generoso, Davao Oriental used for microbial isolation.

Microbial isolation from the sanitary landfill yielded 10 isolates: 5 bacterial and 5 fungal. The bacterial isolates were coded as BS1, BS2, BS3, BS4, and BS5, while the fungal isolates were designated as FS1, FS2, FS3, FS4, and FS5. The coding system represented the microorganism type, wherein “B” denoted

bacteria, “F” denoted fungi, “S” denoted the sampling site, and the numerical value corresponded to the isolate number. As summarized in Table 1, the bacterial isolates cultured on nutrient agar exhibited generally consistent colony characteristics across replicates.

**Table 1.** Description of the five bacterial isolates cultured on Nutrient Agar (NA).

Isolate	Colony color	Form/Shape	Elevation	Margin	Surface/Texture	Opacity	General observation
BS1	Cream to pale yellow	Irregular streak growth	Slightly raised	Entire to slightly undulate	Smooth, moist	Opaque	Moderate bacterial growth observed along streak lines
BS2	Creamy to pale yellow	Irregular to filiform streaks	Slightly raised to convex	Entire to undulate	Smooth, glistening, slightly mucoid	Opaque	Dense streak development with some mucoid portions
BS3	Yellowish cream	Irregular streak growth	Slightly raised	Entire to slightly undulate	Smooth, moist	Opaque	Moderate to dense bacterial growth across the agar surface
BS4	Pale cream to yellowish	Irregular to circular	Slightly raised to convex	Entire	Smooth, shiny, slightly mucoid	Opaque	Moderate colony growth with isolated mucoid colonies
BS5	Creamy yellow	Irregular	Raised	Slightly lobate to undulate	Smooth, moist	Opaque	Moderate to dense colony formation observed on nutrient agar

Aside from the bacterial isolates obtained from the degraded LDPE plastic litter samples, five distinct fungal isolates were also successfully isolated from the sanitary landfill environment. These isolates were designated as FS1, FS2, FS3, FS4, and FS5, where “F” represented fungi, “S” referred to the sampling site, and the numerical value corresponded to the isolate designation. The fungal isolates were cultured on Potato

Dextrose Agar (PDA) to evaluate their colony morphology, mycelial texture, pigmentation, sporulation, and growth characteristics. Table 2 presents the summary of the morphological characteristics of the fungal isolates, highlighting variations in colony appearance and growth behavior that may reflect differences in fungal diversity, physiological adaptation, and biodegradation potential.

**Table 2.** Description of the five fungal isolates cultured on Potato Dextrose Agar (PDA).

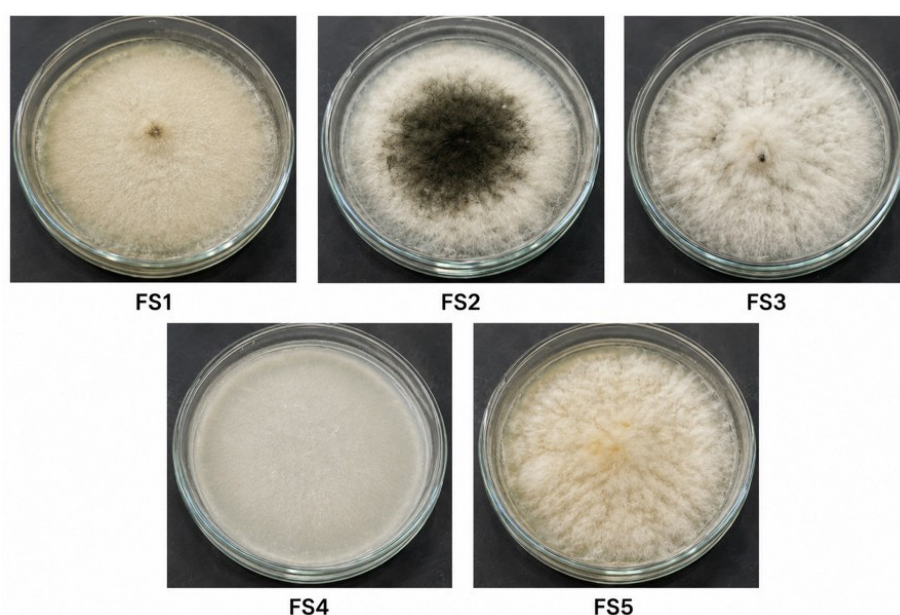
Fungal isolate	Colony color	Mycelial texture and appearance	Growth characteristics	Sporulation/Pigmentation Observed	Overall Observation
FS1	Whitish to pale cream	Smooth to slightly cottony; sparse and circular colonies	Limited radial expansion; moderate fungal development	Small dark-centered sporulating portions observed in some replicates	Early fungal sporulation with moderately established colonies
FS2	White to grayish with dark centers	Dense, cottony, and opaque mycelia	Rapidly spreading colonies with moderate to dense mycelial growth	Dark green to black pigmentation indicating active sporulation	Mature fungal growth with extensive colony development
FS3	White to creamy	Cottony and filamentous texture; thick and opaque colonies	Moderate radial spreading with active proliferation	Isolated pigmented portions observed in some replicates	Well-established fungal colonies with vigorous growth
FS4	Pale white to translucent	Thin, smooth, and slightly cottony mycelia	Moderate radial expansion with relatively uniform surfaces	Minimal pigmentation observed	Less dense fungal growth compared to other isolates
FS5	Creamy white	Filamentous and cottony; moist and opaque colonies	Moderately spreading colonies with consistent fungal development	Yellowish portions observed in some replicates	Moderate fungal growth with stable colony morphology

### Morphological characteristics of the isolated microorganisms

The bacterial isolates (BS1–BS5) exhibited generally uniform colony morphology on Nutrient Agar, characterized by cream-to-yellowish pigmentation, smooth, moist surfaces, an opaque appearance, and slight elevation. Differences among isolates were limited to colony form, margin configuration, and the extent of mucoid growth (Table 1). The colony morphology characteristics presented in Table 1 were recorded from direct observations of pure bacterial cultures during the isolation and characterization phase of the study. Although photographic

documentation of isolated colonies is unavailable, the reported morphological descriptions were documented contemporaneously during laboratory observations.

The fungal isolates (FS1–FS5) displayed greater morphological variability than the bacterial isolates, with differences in pigmentation, mycelial texture, sporulation, and radial expansion on PDA (Figure 3). Among the isolates, FS2 and FS3 showed dense cottony mycelia and pronounced sporulation, whereas FS4 exhibited relatively sparse growth. A detailed summary of fungal characteristics is provided in Table 2.

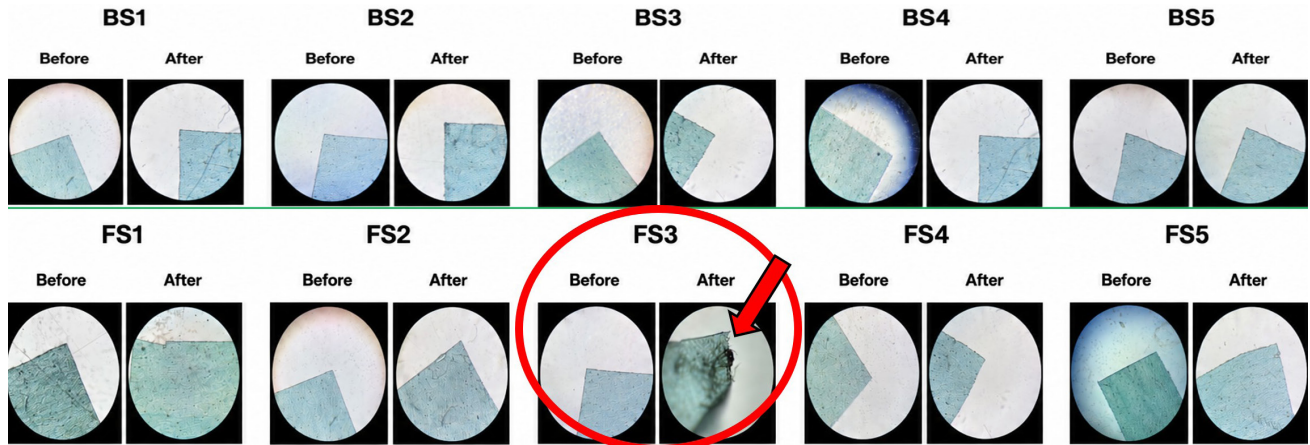


**Figure 3.** Colony morphological characteristics of fungal isolates cultured on Potato Dextrose Agar (PDA).

### Screening of microbial isolates for LDPE biodegradation

As shown in Figure 4, the blue low-density polyethylene (LDPE) plastic substrates, each measuring approximately 1 cm<sup>2</sup>, initially exhibited a smooth, intact, uniformly square morphology with no observable tears, cracks, perforations, or surface deformations before incubation. Following 18 days of incubation with the different microbial isolates, most LDPE substrates

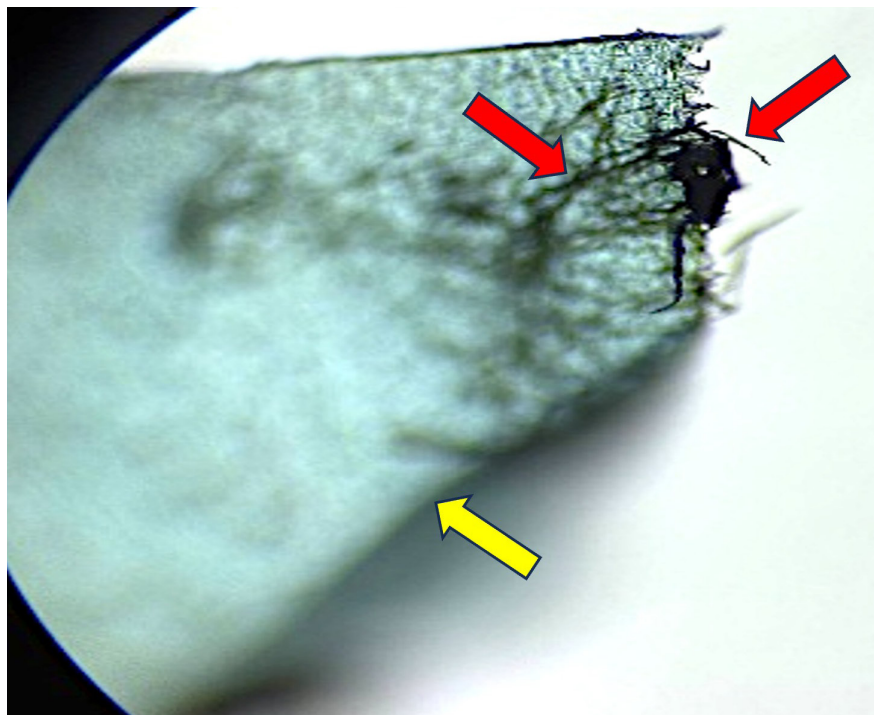
remained morphologically unchanged, indicating minimal or no visible biodegradative activity on the polymer surface. However, the LDPE substrate inoculated with isolate FS3 exhibited pronounced physical deterioration characterized by severe surface deformation, irregular edges, loss of the original square structure, and visible fungal colonization. Dense fungal hyphae were observed attached to and penetrating the LDPE surface, suggesting active colonization and biodegradation of the polymer.



**Figure 4.** Morphological appearance of blue low-density polyethylene (LDPE) plastic substrates ( $\approx 1 \text{ cm}^2$ ) before and after the 18-day biodegradation assay following inoculation with bacterial and fungal isolates under the stereomicroscope (40x).

A closer look at FS3 under the stereomicroscope, as shown in Figure 5, reveals that FS3 exhibited the most visible LDPE

deterioration among all isolates tested, providing qualitative evidence of potential polyethylene biodegradation activity.

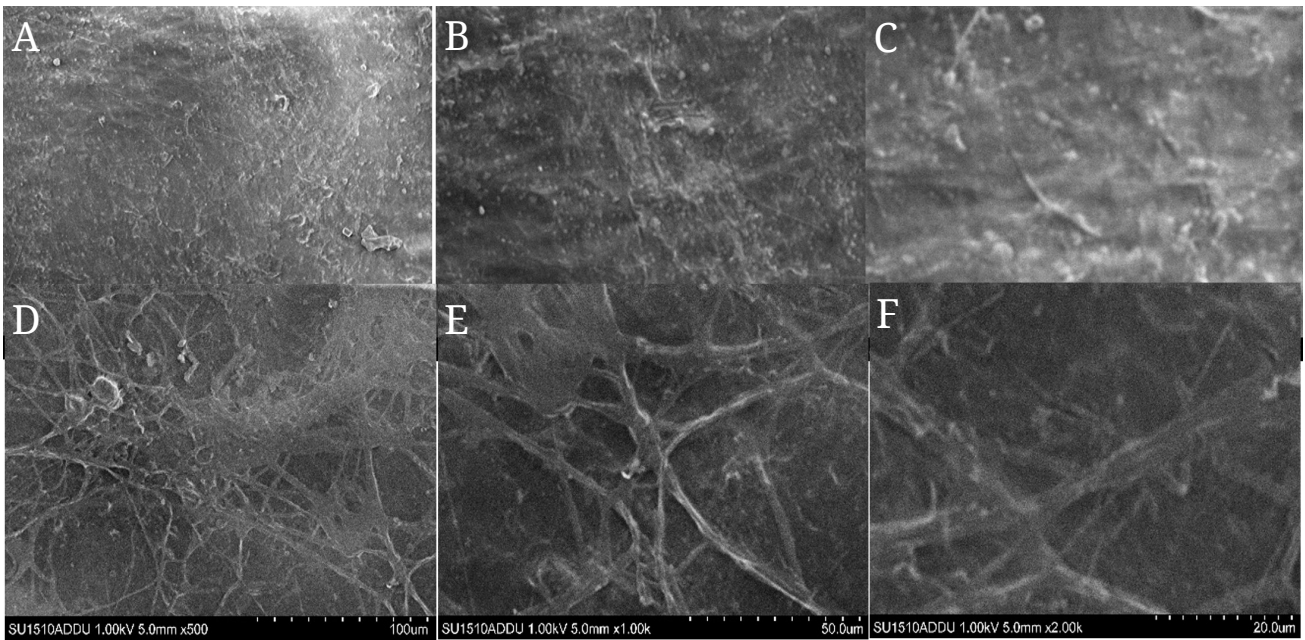


**Figure 5.** Zoomed stereomicroscopic image (40 $\times$  magnification) of the blue low-density polyethylene (LDPE) plastic substrate inoculated with fungal isolate FS3 after the 18-day biodegradation assay, showing visible fungal hyphae attached to the plastic surface (red arrows) and the blue LDPE plastic substrate (yellow arrow).

### Scanning Electron Microscopy (SEM) analysis of LDPE-degradation

Scanning Electron Microscopy (SEM) analysis was conducted to confirm the biodegradation activity of FS3 on LDPE surfaces

compared with the uninoculated control. SEM examination revealed substantial deterioration of LDPE surfaces exposed to FS3, including pits, cracks, grooves, erosion patterns, and fungal attachment. In contrast, uninoculated controls retained smooth and intact surfaces, indicating minimal structural alteration (Figure 6).



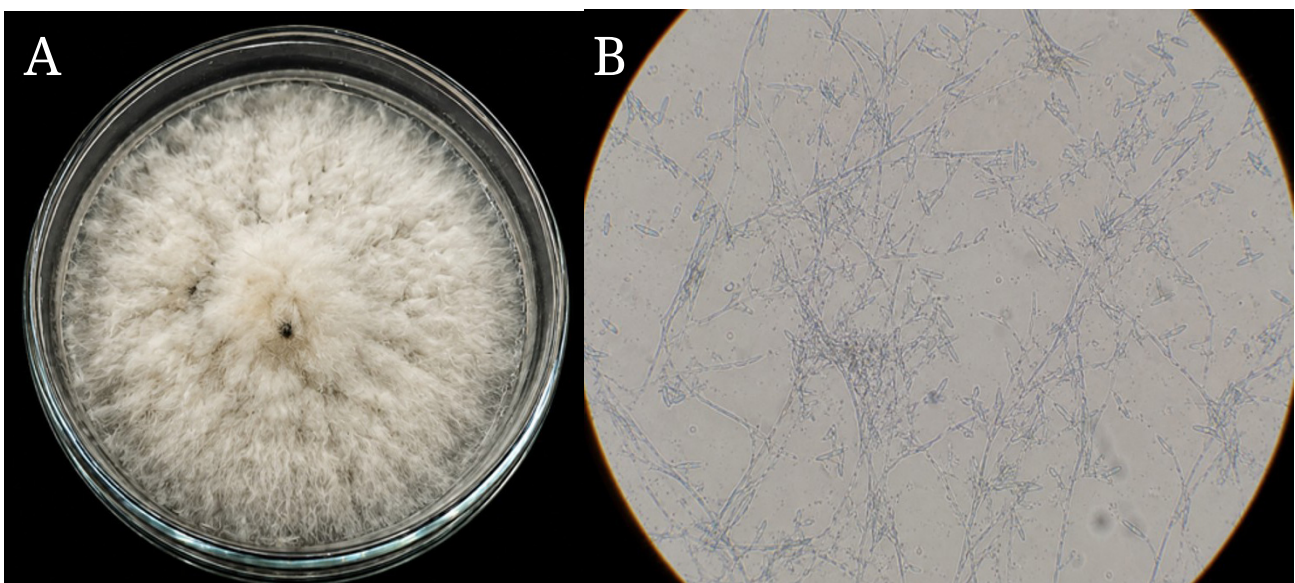
**Figure 6.** Scanning Electron Microscopy (SEM) images showing the surface morphology and degradation of low-density polyethylene (LDPE) plastics inoculated with fungal isolate FS3 after 18 days of incubation, compared with the uninoculated control. Panels A–C show the morphology of the uninoculated control LDPE plastic at (A) 500 $\times$ , (B) 1,000 $\times$ , and (C) 2,000 $\times$  magnifications, respectively, exhibiting a relatively smooth and intact surface. Panels D–F show the morphology of LDPE plastic inoculated with isolate FS3 at (D) 500 $\times$ , (E) 1,000 $\times$ , and (F) 2,000 $\times$  magnifications, respectively, revealing visible surface deterioration, erosion, cracks, pits, hyphal penetration, and fungal colonization, indicating the biodegradation or “plastic-eating” effect on the LDPE plastic surface.

#### Identity of the best plastic-degrading fungus (Isolate FS3)

Among all the microbial isolates evaluated in this study, fungal isolate FS3 exhibited the greatest biodegradation potential against low-density polyethylene (LDPE). This was evidenced by extensive fungal colonization of the plastic surface, visible deterioration and deformation of the LDPE substrate, and pronounced structural damage observed through stereomicroscopy and Scanning Electron Microscopy (SEM) analyses.

As shown in Figure 7, isolate FS3 was characterized based on its cultural and microscopic characteristics. On Potato

Dextrose Agar (PDA), FS3 produced white to creamy colonies with a dense, cottony, and filamentous mycelial texture. The isolate exhibited moderate to rapid radial expansion accompanied by vigorous mycelial proliferation, resulting in thick and well-established colonies. Microscopic examination under low-power magnification revealed an extensive network of hyaline, septate, and branched hyphae distributed throughout the field of view. Numerous elongated to cylindrical conidia were observed either singly or in small clusters along the hyphae. Several regions exhibited aggregations of conidia associated with branched hyphal structures, indicating active sporulation.



**Figure 7.** Cultural and microscopic characteristics of fungal isolate FS3. (A) Colony morphology of FS3 grown on Potato Dextrose Agar (PDA) after 14 days of incubation, showing dense, cottony, white-to-creamy mycelial growth. (B) Low-power (100 $\times$ ) photomicrograph of FS3 showing hyaline, septate, branched hyphae and abundant elongated to cylindrical conidia.

To confirm the identity of the isolate, molecular characterization was conducted at the Philippine Genome Center Mindanao (PGC Mindanao), University of the Philippines Mindanao. The Internal Transcribed Spacer (ITS) region of ribosomal DNA was amplified and sequenced using the universal fungal primers ITS1 and ITS4. Sequence chromatograms were quality-checked and trimmed using FinchTV, assembled into a consensus sequence using BioEdit and MEGA11, and compared against reference sequences in the NCBI GenBank database using the BLASTn algorithm.

Molecular analysis revealed that isolate FS3 showed a 100% query cover, 100% sequence identity, and an E-value of 0.00E+00 with *Myrothecium* sp. strain Wt303 (GenBank Accession No. PQ787664.1), indicating a highly reliable match. The sequence was therefore assigned to the genus *Myrothecium*. However, species-level identification could not be determined because the closest matching reference sequence in the database was identified only to the genus level. According to the molecular identification report, additional analyses and comparison with more comprehensive reference sequences would be necessary to resolve the isolate to the species level.

The combined morphological and molecular evidence confirms that FS3 belongs to the genus *Myrothecium*. Given its superior LDPE-degrading capability and strong colonization of plastic surfaces, *Myrothecium* sp. FS3 represents a promising fungal candidate for the biodegradation of polyethylene and warrants further investigation for potential applications in plastic waste bioremediation.

## DISCUSSION

### Environmental origin and microbial diversity of LDPE-associated isolates

The discovery of a potential “plastic-eating” fungus from a sanitary landfill in Governor Generoso, Davao Oriental, Philippines highlights the ecological importance of landfill environments as reservoirs of microorganisms adapted to synthetic polymer contamination. The successful recovery of bacterial and fungal isolates from degraded LDPE supports the role of landfill environments as reservoirs of microorganisms adapted to plastic-rich conditions. These observations indicate prolonged environmental exposure and partial degradation of the polymers. Environmental weathering promotes oxidation and fragmentation of plastics, increasing their susceptibility to microbial colonization and biodegradation (Andrady, 2017). Similarly, Pilapitiya and Ratnayake (2024) reported that weathered plastics become more vulnerable to biological attack because surface oxidation and structural irregularities enhance microbial attachment and enzymatic interaction.

The successful isolation of five bacterial and five fungal isolates from degraded LDPE samples demonstrates the adaptive capacity of microorganisms inhabiting landfill ecosystems. Landfills contain complex mixtures of organic waste, leachate, moisture, heat, and synthetic polymers that create selective pressures favoring metabolically versatile microorganisms (Remmas et al., 2023). The observed microbial diversity therefore suggests the presence of organisms capable of utilizing recalcitrant substrates as alternative carbon sources. Similar findings were reported by Bitalac et al. (2023), who observed that microorganisms colonizing plastic surfaces may develop physiological adaptations enabling survival and growth on polymer-associated substrates. The recovery of both bacterial and fungal isolates from degraded LDPE further supports the concept that plastic surfaces can serve as specialized microbial habitats or “plasticspheres,” where prolonged exposure to synthetic polymers selects for microorganisms capable of attachment, colonization, and potential

polymer utilization (Bitalac et al., 2023; Zeenat et al., 2021). Such adaptation may enhance the capacity of landfill-associated microorganisms to participate in plastic biodegradation processes. The consistency in colony morphology across replicate cultures further indicated phenotypic stability and culture purity, supporting the reliability of the isolation and characterization procedures.

The coexistence of bacterial and fungal isolates in degraded LDPE samples suggests the potential for synergistic biodegradation mechanisms in landfill ecosystems. Plastic degradation commonly involves microbial consortia rather than single microorganisms alone (Amobonye et al., 2020). Bacteria may initiate polymer oxidation and surface fragmentation, whereas fungi contribute through extracellular enzymatic degradation and hyphal penetration. Zhou and Haq (2025) similarly demonstrated synergistic degradation of polyethylene terephthalate (PET) by bacterial consortia containing *Bacillus* and *Pseudomonas* species. Such microbial interactions may accelerate polymer deterioration and enhance biodegradation efficiency in natural environments.

### Morphological and structural characterization of LDPE-degrading microorganisms

Morphological characterization revealed variation in colony and mycelial features among the isolates, suggesting the presence of metabolically diverse microbial groups capable of colonizing plastic-associated environments. Such diversity may influence microbial attachment, biofilm formation, and subsequent biodegradation activity. Biofilm formation is recognized as an important initial stage in plastic degradation because attached microorganisms can directly secrete degradative enzymes onto polymer surfaces (Zeenat et al., 2021). Similar observations have been reported for plastic-associated microorganisms isolated from contaminated environments (Ali et al., 2023; Lamela et al., 2023).

The fungal isolates exhibited distinct differences in mycelial density, pigmentation, sporulation, and radial growth. Notably, FS2 and FS3 developed dense, cottony mycelia and exhibited extensive colony expansion, characteristics commonly associated with active fungal colonisation. Filamentous fungi are considered promising plastic degraders because their hyphal networks can penetrate polymer surfaces and secrete extracellular oxidative enzymes that catalyze depolymerization (Ekanayaka et al., 2022). Comparable growth characteristics have been reported in landfill-derived fungi capable of polyethylene degradation (Gong et al., 2023; Peria et al., 2026).

The aggressive colonization exhibited by fungal isolate FS3 is consistent with previously reported biodegradation mechanisms of filamentous fungi. Fungal hyphae facilitate plastic deterioration through attachment, biofilm formation, and secretion of extracellular oxidative enzymes such as laccases, peroxidases, esterases, and cutinases capable of cleaving long hydrocarbon chains (Ameen et al., 2025; Bautista-Zamudio et al., 2023; Ekanayaka et al., 2022). Similar biodegradation patterns, including cracking, pitting, erosion, and fragmentation of polyethylene films, have been documented in fungi such as *Aspergillus clavatus*, *Penicillium simplicissimum*, *Alternaria alternata*, and *Cladosporium* species (Gajendiran et al., 2016; Gong et al., 2023; Peria et al., 2026).

### Biodegradation performance and identification of *Myrothecium* sp. Strain Gavilo-Nemenzo (FS3)

Among all isolates evaluated, fungal isolate FS3 demonstrated the highest biodegradation activity against LDPE. The pronounced deterioration observed in FS3-treated LDPE indicates active fungal interaction with the polymer and supports its potential role in polyethylene biodegradation. Dense fungal hyphae were visibly attached to and penetrating

the polymer surface, suggesting active interaction with the LDPE matrix and possible utilization of polymer-associated carbon compounds. Scanning Electron Microscopy (SEM) further confirmed these observations, revealing pits, grooves, cracks, erosion patterns, cavities, and irregular surface roughness in inoculated LDPE films, whereas control films remained smooth and compact. Fungal hyphae were strongly attached to the polymer surface, indicating active colonization and enzymatic interaction. Similar SEM findings were reported by Gao et al. (2022) and Gong et al. (2023), who observed severe cracking and surface erosion in polyethylene films exposed to fungal degraders. According to Ameen et al. (2025), such deterioration patterns are hallmarks of fungal-mediated biodegradation involving oxidative depolymerization and mechanical penetration of polymers by fungal hyphae. The observed cracking, pitting, grooves, and surface erosion are consistent with the early stages of polyethylene biodegradation reported in previous studies involving both landfill-derived and environmental fungal isolates. These structural alterations increase the surface area available for microbial attachment and enzymatic activity, thereby enhancing the polymer's susceptibility to further degradation (Gajendiran et al., 2016; Gao et al., 2022; Gong et al., 2023).

The exceptional biodegradation performance of FS3 may be associated with its cultural and microscopic characteristics. As shown in Figure 7, FS3 produced dense white-to-creamy colonies with a cottony, filamentous mycelial texture and vigorous radial growth on Potato Dextrose Agar (PDA). Such extensive mycelial development likely enhanced fungal attachment, biofilm formation, and sustained contact with the LDPE surface, thereby facilitating biodegradation. Microscopic examination under low-power magnification revealed an extensive network of hyaline, septate, and branched hyphae accompanied by numerous elongated, slightly curved to cylindrical conidia. Several areas exhibited clusters of conidia associated with branched hyphal structures, indicating active sporulation and robust fungal growth. These characteristics are typical of filamentous fungi that efficiently colonize solid substrates and may contribute to their capacity to establish persistent interactions with polymer surfaces.

To accurately determine the identity of the isolate, molecular characterization was conducted at the Philippine Genome Center Mindanao (PGC Mindanao), University of the Philippines Mindanao. The Internal Transcribed Spacer (ITS) region of ribosomal DNA was amplified and sequenced using universal fungal primers. Sequence chromatograms were quality-checked and trimmed using FinchTV, assembled into a consensus sequence using BioEdit and MEGA11, and compared against reference sequences in the NCBI GenBank database using the BLASTn algorithm. Molecular analysis revealed that isolate FS3 exhibited 100% query cover, 100% sequence identity, and an E-value of 0.00E+00 with *Myrothecium* sp. strain Wt303 (GenBank Accession No. PQ787664.1), indicating a highly reliable match. The isolate was therefore assigned to the genus *Myrothecium*. Because the closest reference sequence was identified only to the genus level, species-level identification could not be established with confidence and would require additional molecular analyses and comparison with a broader set of reference sequences.

The molecular identification of FS3 as *Myrothecium* sp. is particularly significant because members of this genus are known for their ability to colonize diverse organic substrates and produce a wide range of extracellular enzymes and secondary metabolites. These enzymatic capabilities enable fungi to degrade complex natural polymers and may also facilitate the transformation of synthetic polymeric materials. Although studies specifically examining polyethylene degradation by

*Myrothecium* species remain limited, the extensive colonization and deterioration of LDPE observed in the present study suggest that this isolate possesses metabolic and enzymatic attributes that contribute to polymer degradation. The strong attachment of fungal hyphae to the LDPE surface and the pronounced surface damage observed through SEM indicate that FS3 is capable of establishing intimate contact with the polymer and initiating structural modification.

The degradation observed in FS3 may be associated with biochemical pathways commonly reported among filamentous fungi capable of utilizing synthetic polymers. Fungal biodegradation generally begins with attachment and biofilm formation on the polymer surface, followed by the secretion of extracellular oxidative and hydrolytic enzymes that generate reactive intermediates capable of cleaving long-chain hydrocarbons (Qin et al., 2021; Ameen et al., 2025). Subsequent depolymerization produces lower-molecular-weight compounds that can be assimilated into fungal metabolic pathways and ultimately mineralized. Although enzymatic activities were not directly measured in the present study, the extensive surface deterioration and fungal colonization observed in FS3 are consistent with these established biodegradation mechanisms.

More specifically, oxidative enzymes such as laccases, lignin peroxidases, manganese peroxidases, esterases, and cutinases have been reported to initiate the breakdown of chemically stable polymer chains by introducing oxygen-containing functional groups into the polymer structure (Ameen et al., 2025; Bautista-Zamudio et al., 2023; Ekanayaka et al., 2022). This oxidative modification increases polymer hydrophilicity and susceptibility to further enzymatic attack, resulting in chain scission, surface erosion, and the formation of lower-molecular-weight degradation products. These products may subsequently enter fungal metabolic pathways where they can be utilized as supplementary carbon sources and eventually converted into carbon dioxide, water, and fungal biomass through mineralization processes (Qin et al., 2021; Ameen et al., 2025). The extensive cracking, pitting, erosion, and hyphal penetration observed in the present study are consistent with these previously reported fungal biodegradation mechanisms.

Accurate taxonomic identification is a critical component of contemporary biodegradation research. While colony morphology and microscopic characteristics provide valuable preliminary information, these traits can vary depending on environmental conditions, growth media, and developmental stage. Consequently, molecular approaches such as ITS sequencing have become the standard method for fungal identification and taxonomic confirmation (Schoch et al., 2012). Recent reviews on fungal plastic biodegradation have emphasized that molecular characterization enhances the reliability, reproducibility, and comparative value of biodegradation studies by ensuring accurate taxonomic placement of candidate degraders (Ameen et al., 2025; Chigwada et al., 2025; Kamil et al., 2025). The integration of morphological observations with ITS-based molecular identification in the present study therefore provides a robust framework for characterizing FS3 and supports its recognition as a promising LDPE-degrading fungal isolate.

Although FS3 produced substantial visible deterioration of the LDPE substrate, the present study primarily generated qualitative evidence of biodegradation through stereomicroscopy and SEM observations. The observed deformation, fragmentation, surface roughening, and fungal colonization strongly suggest polymer deterioration; however, the extent of degradation could not be quantitatively determined because measurements such as percentage weight loss, changes in polymer chemistry, tensile strength reduction, carbon mineralization, or enzyme activity

were beyond the scope of the study. Consequently, the results should be interpreted as preliminary evidence of biodegradation potential rather than a direct quantification of degradation efficiency. Similar studies have emphasized that SEM observations are most powerful when complemented by analytical techniques such as Fourier Transform Infrared Spectroscopy (FTIR), carbon mineralization assays, and weight-loss analyses to verify polymer modification and degradation rates (Qin et al., 2021; Gorish et al., 2024; Ameen et al., 2025).

The biodegradation performance of FS3 may also be attributed to its environmental origin. The isolate was obtained from highly degraded plastic litter continuously exposed to synthetic polymers, organic wastes, and environmental stressors within the landfill ecosystem. Such conditions likely promote adaptive evolution and enzymatic specialization among microorganisms inhabiting plastic-rich environments (Chigwada et al., 2025). Likewise, Awasthi et al. (2023) highlighted that landfill-derived microorganisms are valuable candidates for biodegradation research because prolonged exposure to plastics may select for organisms capable of utilizing recalcitrant polymers. The isolation of a potential LDPE-degrading *Myrothecium* sp. from a sanitary landfill in Davao Oriental is particularly significant because studies on indigenous fungal degraders in the Philippines remain limited. The use of locally adapted microorganisms may offer advantages for future bioremediation applications because these organisms have already evolved under environmental conditions characterized by continuous plastic exposure and waste accumulation (Lamela et al., 2023; Awasthi et al., 2023).

The findings of this study have important implications for sustainable plastic pollution management in the Philippines. LDPE plastics such as sachets, wrappers, and plastic bags are among the most persistent environmental pollutants due to their hydrophobicity, high molecular weight, and chemically stable carbon-carbon backbone (Andrady, 2017; Dey et al., 2024). Improper disposal and accumulation of these plastics contribute significantly to terrestrial and marine pollution in the country (Climate Change Commission, 2024). Conventional disposal methods including landfilling and incineration remain inadequate and may generate secondary environmental impacts such as toxic emissions and long-term contamination (Qin et al., 2021). In contrast, microbial biodegradation offers a more sustainable alternative because microorganisms naturally convert polymers into simpler and less harmful compounds (Amobonye et al., 2020).

The ability of FS3 to visibly colonize and deteriorate LDPE supports the growing recognition of fungal-assisted biodegradation as a promising strategy for plastic remediation. Filamentous fungi possess extensive hyphal systems and robust extracellular enzymatic mechanisms that make them particularly effective in attacking recalcitrant polymer surfaces (Ekanayaka et al., 2022; Bautista-Zamudio et al., 2023). The discovery of an indigenous landfill-derived *Myrothecium* sp. with biodegradation potential therefore provides valuable preliminary evidence supporting the development of locally sourced microbial technologies for plastic waste management and environmental biotechnology applications in the Philippines. Furthermore, the findings contribute to the growing body of evidence that landfill ecosystems should not only be viewed as repositories of waste but also as reservoirs of potentially beneficial microorganisms with environmental biotechnology applications. Continued exploration of these microbial resources may support the development of sustainable, locally relevant strategies for mitigating plastic pollution and complement existing waste management practices in the Philippines.

This study has several limitations that should be considered when interpreting the results. First, only five highly

degraded LDPE samples were collected from a single sanitary landfill. The sampling strategy was designed for exploratory microbial screening and isolation of potential LDPE degraders rather than statistical representation of the entire landfill microbial community. Consequently, the samples may not capture the full diversity of plastic-associated microorganisms present at the site, and future studies involving larger sample sizes and multiple sampling locations are recommended. Second, although isolate FS3 was successfully identified as *Myrothecium* sp. through ITS sequencing, species-level identification could not be established because the closest matching sequence in the GenBank database was identified only to the genus level. Additional molecular analyses may therefore be necessary to achieve species-level resolution. Finally, the biodegradation findings are based primarily on qualitative observations of fungal colonization and surface deterioration. Future investigations incorporating FTIR analysis, weight-loss measurements, carbon mineralization assays, enzymatic activity profiling, and other quantitative approaches are recommended to verify the extent of LDPE degradation and further elucidate the mechanisms involved.

## CONCLUSION

Molecular characterization conducted at the Philippine Genome Center Mindanao identified isolate FS3 as *Myrothecium* sp. strain Gavilo-Nemenzo based on Internal Transcribed Spacer (ITS) sequencing, which showed 100% query cover and 100% sequence identity with *Myrothecium* sp. strain Wt303 (GenBank Accession No. PQ787664.1). Although species-level identification could not be established because the closest reference sequence in the database was identified only to the genus level, the molecular results confidently confirmed the placement of the isolate within the genus *Myrothecium*. The identification of *Myrothecium* sp. strain Gavilo-Nemenzo (FS3), coupled with its demonstrated ability to colonize and visibly deteriorate LDPE, highlights the potential of indigenous landfill-derived fungi as biological agents for plastic waste remediation. These findings contribute to the growing body of knowledge on fungal-assisted plastic biodegradation, underscore the value of sanitary landfills as reservoirs of microorganisms with environmental biotechnology applications, and provide a foundation for developing locally sourced and sustainable approaches to plastic waste management in the Philippines. Furthermore, the study supports future investigations involving quantitative biodegradation assays, enzymatic characterization, and pilot-scale bioremediation studies to further evaluate the biodegradation capabilities of *Myrothecium* sp. strain Gavilo-Nemenzo (FS3).

The study provides important preliminary evidence that indigenous landfill-derived fungi in Davao Oriental possess potential applications in plastic biodegradation and environmental biotechnology. The discovery of *Myrothecium* sp. strain Gavilo-Nemenzo highlights the value of landfill ecosystems as reservoirs of beneficial microorganisms that may contribute to future biological approaches for plastic waste remediation. Nevertheless, the findings remain preliminary because quantitative analyses such as FTIR, weight-loss measurements, carbon mineralization assays, and enzyme activity profiling were not performed. Future studies should incorporate these methods to verify degradation efficiency and further elucidate the mechanisms involved in LDPE biodegradation.

## RECOMMENDATIONS

- Future studies should conduct quantitative analyses, including Fourier Transform Infrared Spectroscopy (FTIR), weight-loss measurements, and enzymatic activity assays, to verify the extent

and mechanisms of LDPE degradation by *Myrothecium* sp. strain Gavilo-Nemenzo.

- Additional molecular studies are recommended to achieve species-level identification of *Myrothecium* sp. strain Gavilo-Nemenzo and further characterize its biodegradation-related traits.
- Local Government Units (LGUs) in Governor Generoso and neighboring municipalities should support collaborative research on indigenous plastic-degrading microorganisms as part of sustainable solid waste management and environmental conservation initiatives.
- Academic institutions and waste management authorities are encouraged to evaluate the biodegradation potential of *Myrothecium* sp. strain Gavilo-Nemenzo under landfill-simulated conditions to assess its suitability for local bioremediation applications.
- Similar studies should be conducted in other sanitary landfills and waste disposal sites in Davao Oriental and Mindanao to identify additional indigenous microorganisms with potential applications in plastic waste remediation and environmental biotechnology.

## ACKNOWLEDGMENT

The authors sincerely acknowledge Mr. Marlene Barrete of the Science Laboratory, Faculty of Agriculture and Life Sciences, for his valuable laboratory support and guidance throughout the experimental work. His expertise significantly contributed to the completion of this study. Gratitude is also extended to Ateneo de Davao University for facilitating the Scanning Electron Microscopy (SEM) analysis, which was essential in confirming LDPE surface degradation.

## FUNDING SOURCE

The study was self-funded.

## AUTHOR CONTRIBUTIONS

E. M. G: Conducted the field sampling and laboratory experiments, analyzed the data, and prepared the initial draft of the manuscript. P. N. C: Conceptualized the study, supervised the overall research process, contributed to the study design and data interpretation, and critically reviewed and approved the final manuscript for publication.

## DECLARATIONS

### Informed consent statement

This study involved the collection and analysis of low-density polyethylene (LDPE) plastic waste and the isolation of associated microorganisms from a sanitary landfill site in Barangay Anitap, Governor Generoso, Davao Oriental, Philippines. All sampling activities were conducted with proper authorization from relevant local authorities and in accordance with environmental safety and waste management guidelines to ensure minimal disturbance to the site. No human participants or vertebrate animals were involved in this research. All microbial handling, cultivation, and experimental procedures were performed under appropriate laboratory safety conditions to prevent environmental release and ensure researcher safety. Standard aseptic techniques and biosafety protocols were strictly followed throughout the study. The researchers also ensured responsible management and disposal of all biological and plastic materials used during experimentation to avoid secondary environmental contamination. This study upholds the principles of environmental responsibility, biosafety, and scientific integrity. It aims to contribute to sustainable, eco-friendly solutions for managing plastic pollution without harming ecosystems or public health.

## Conflict of interest

The authors have no conflicts of interest regarding the results of the study.


## AI Declaration

The authors declare that no Artificial Intelligence (AI) or AI-assisted technologies were used in the preparation of this manuscript.

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Print-ISSN 2244-4432 Online-ISSN 2984-7125