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Research Article

Biodegradation of Low-Density Polyethylene Film by UV Irradiated and Non-Irradiated *Pseudomonas aeruginosa* D5

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Abstract: Low-density polyethylene (LDPE) constitutes 60% of total plastic production, and non-degradable polyethylene carry bags are the most common type of solid waste found. Their recalcitrance in the environment is thus a major concern for environmentalists. This study investigated the potential of Ultraviolet (UV) induced mutation in enhancing biodegradation of LDPE films by two diesel degrading bacteria, *Alcaligenes faecalis* D4 and *Pseudomonas aeruginosa* D5. The two strains were screened for LDPE utilisation, and the best strain was subjected to UV irradiation. The successful mutant was then used for LDPE biodegradation studies *in vitro* for 28 days and compared with the wild-type strain. The rate of LDPE film utilisation was estimated using cell density measurement, weight loss and FTIR spectroscopy. Only *P. aeruginosa* D5 was able to survive UV irradiation at different exposure times. The mutant strain was able to utilise LDPE, resulting in cell density across the incubation time and corresponding weight loss of the films after 28 days, resulting in a 9% better weight reduction than the wild type strain after incubation. The mutant strains also demonstrated significant chemical alterations, including the introduction of carboxylic acids, amines, and alkenes. The detection of multiple carbonyl peaks (2399.05 cm^{-1}, 1100.56 cm^{-1}) in untreated LDPE and their shifts in mutant-treated samples (2498.63 cm^{-1}, 1700.65 cm^{-1}) indicate oxidative degradation, leading to the formation of aldehydes, ketones, and carboxylic acids. These findings reveal the LDPE utilisation potentials of mutant *P. aeruginosa* as well as the application of mutation to enhance pollutant bioremediation.

Keywords: UV Irradiation, *Pseudomonas*, LDPE, Wild Type, Biodegradation, FTIR

Introduction

The widespread use of synthetic polymers began in the 1940s, marking the start of a new age in materials and manufacturing technologies. Plastics are an integral part of modern life, found in nearly all consumer and industrial sectors, with production on the rise (Geyer *et al.*, 2017). For over 50 years, plastics have influenced various aspects of daily living, including household items, construction, packaging, healthcare, and automotive applications (Kibria *et al.*, 2023). The global population growth and economic expansion have driven increased demand for plastic goods (Lambert *et al.*, 2014). While vital for innovation and reducing greenhouse gas emissions (Plastics Europe, 2021), pure plastics require additives like plasticisers and stabilisers to enhance their thermal, mechanical, and physical properties (Kibria *et al.*, 2023). Plastics become waste due to irrational production, inappropriate disposal at landfills, and inadequate recycling management. The leakage of plastic waste into the environment, including terrestrial and aquatic ecosystems, is occurring at an unprecedented rate and poses significant challenges to waste management for growing populations, mainly in developing countries (Kershaw, 2015; Godfrey, 2019). According to a report by the World Bank, plastics make up almost 12% of the world's total waste generation (20–30% by weight) (Awasthi *et al.*, 2017; Kaza *et al.*, 2018). Of particular concern is the fact that an estimated 60% of these plastics ultimately enter the environment as Plastic Waste (PW) (Zhang *et al.*, 2021). Presently, the issue of marine pollution resulting from PW has emerged as a serious threat to biodiversity, with estimates indicating that between 60 and 80% of marine debris is comprised of plastic materials (Paletta *et al.*, 2019; Peng *et al.*, 2020). It is estimated that only 6-26% of plastic

fragments are recycled, while the remainder becomes microplastics (MPs, <5 mm) through physical wear, UV irradiation, thermal oxidation, and microbial treatment (Zhou *et al.*, 2021).

From 2007 to 2011, municipal waste generation rose globally by 37.3%, an equivalent of roughly an 8% increase per year (Idowu *et al.*, 2019). A prominent component of plastic waste is low-density polyethylene (LDPE). It accounts for 60% of the total plastic production (Gajendiran *et al.*, 2016). The global production of LDPE is the second dominant among plastic production, which was 64 million tons, while the waste generation of LDPE became the first dominant, which was 57 million tons, in 2015 (Geyer *et al.*, 2017). Unfortunately, LDPE plastics are usually nondegradable, and the accumulation of low-density polyethylene films used in consumer packaging in the environment has generated a lot of problems due to their recalcitrance (Oluwole *et al.*, 2024). Recently, microorganisms have become the focus of interest for the environmentally friendly disposal of plastic and polymer-based waste (Mohanan *et al.*, 2020).

The initial stages of plastic biodegradation are characterised by the adhesion of microbial communities to plastic surfaces, followed by the formation of biofilms. This process serves as a crucial precursor to the degradation of plastics and underscores the potential for microbial intervention in addressing plastic pollution (Perera and Hemamali, 2022). *Pseudomonas aeruginosa Aspergillus niger, Brevibacillus borstelensis, Bacillus subtilis, Kocuria palustris, Bacillus pumilus, Pseudomonas sp., Bacillus amyloliquefaciens, and Serratia marcescens* (Abed *et al.*, 2018) *Fusarium lini, Bradyrhizobium japonicum, Pseudomonas sp. AKS2*, amongst others, has demonstrated a remarkable capacity for adhering to plastic surfaces and has been recognised as potent for plastic biodegradation (Łabużek , *et al.*, 2004; Perera and Hemamali, 2022). Although many studies have reported microbial degradation of PE, significant degradation of PE wastes has not yet been achieved at real scales (Montazer *et al.*, 2020); it has been reported that mutations in O-antigen, which plays a fundamental role in the attachment of gram-negative bacteria on hydrophilic surfaces can enhance the affinity towards hydrophobic surfaces (Bogino *et al.*, 2013; Sandhu, 2024).

Mutagenesis is a crucial technique in industrial biotechnology aimed at enhancing the production of specific metabolites through genetic modifications in microorganisms. This process facilitates the development of novel strains with improved capabilities essential for bioremediation, enabling them to effectively degrade environmental pollutants. Random mutation has emerged as a viable molecular approach for the creation of SPS that efficiently degrade microbial strains. To generate mutations, UV irradiation, ethyl methyl sulfate, and ethidium bromide (EtBr) are used as mutagens (Rafeeq *et al.*, 2023). Bacteria with the necessary degrading capacity may be produced as effective remediation systems by properly employing information about the biochemistry, physiology, and genetics of an organism (Shaharoona *et al.*, 2006). Numerous bacteria gain new genetic features via means of conjugation, transformation, and transduction, among others. In the laboratory, these techniques of genetic material exchange are often used to introduce a desired gene into a bacterial cell, hence conferring certain benefits to the strain (Rafeeq *et al.*, 2023).

Random mutagenesis and subsequent screening and selection are an effective strategy used to improve the activity of specific strains and enzymes. By exposing plastic-degrading microbial strains to mutagens, such as UV, a high mutation frequency can be obtained, and mutants with higher enzyme activity can be selected. If required, cycles of mutagenesis and selection can be repeated until a significantly higher efficiency is reached. A modified strain of Pseudomonas putida, developed through DNA restructuring, was found to enhance the degradation of low-density polyethylene (Anantharam and Talkad, 2018). Furthermore, Li *et al.* (2020) noted that following the induced mutation of Pseudomonas putida strain KT2440, there was an overexpression of the glyoxylate carbo ligase and glycolate oxidase operons, thereby conferring on the strain the ability to utilise ethylene glycol as its sole carbon source. Given the potential of mutation in enhancing biodegradation efficiency (Xiong *et al.*, 2025), this study aims to investigate the potential of UV-induced mutation to improve the biodegradation of Low-Density Polyethylene (LDPE) film by two diesel-degrading bacteria.

Materials and Methods

Source of Isolates

The isolates used for this investigation, *Alcaligenes faecalis* D4 and *Pseudomonas aeruginosa* D5, were diesel-degrading bacteria from previous research and were obtained from the Department of Microbiology, Ekiti State University, Ado Ekiti.

Nutrient Basal Media Contents

The basal mineral media used for testing the biodegradability of LDPE consisted of the following elements (prepared in 1L distilled water): 1g/L K_2HPO_4, 0.2 g/L KH_2PO_4, 1 g/L $(NH_4)_2SO_4$, 0.5 g/L $MgSO_4.7H_2O$, 1 g/L NaCl, 0.01 g/L $FeSO_4.7H_2O$, 0.002 g/L $CaCl_2.2H_2O$, 0.001 g/L $MnSO_4.7H_2O$, 0.001 g/L $CuSO_4.5H_2O$, 0.001 g/L $ZnSO_4.7H_2O$.

Collection of LDPE Sheets

LDPE used for sachet water packaging was obtained from a water processing and packaging factory located within Ekiti State University (EKSU), Ado-Ekiti campus and was used for the degradation studies.

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Preparation of Bacterial Stock Solution

Five colonies were picked from an overnight culture of *Pseudomonas aeruginosa* D5 and *Alcaligenes faecalis* D4 and transferred to 10 mL of nutrient broth. The culture broth was incubated for 3 hours and centrifuged at 6000 rpm for 10 minutes to obtain culture-free cell pellets. The procedure was repeated twice, and the cell pellets were resuspended in 10mL Mineral Salt Medium (Yao *et al.*, 2022).

Screening For LDPE Utilisation

LDPE films were cut into 3 cm × 3 cm strips, surface sterilised by soaking in 70% ethanol overnight, rinsed with distilled water, and subsequently dried in an incubator at 50 °C. Two millilitres of bacterial culture were added to 98 mL of mineral salt medium, along with 2 g (approximately 7 strips) of the prepared LDPE films, in a 250 mL conical flask. The setup was incubated at 35°C for 14 days. The control set-up consisted of mineral salt medium without inoculated bacteria strain and untreated LDPE films, which were also maintained under similar conditions (Kyaw *et al.*, 2012; Dey *et al.*, 2020).

Measurement of Cell Density

The cell density was measured by taking aliquots from both inoculated and uninoculated broths supplemented with LDPE films. The samples were analysed using serial dilution, after which pour plating on nutrient agar was done so as to estimate the total viable colony counts at 7-day intervals. (Dey *et al.*, 2020).

Mutation Studies

Induction of Mutation

Pseudomonas aeruginosa D5 and *Alcaligenes faecalis* D4 were subcultured on Petri dishes in triplicate from overnight cultures and exposed to a UV-C germicidal lamp in a laminar flow hood (Wuxi Kwang Purification Co., Ltd., Wuxi, China) for 10, 20, and 30 minutes. After exposure, the cultures were incubated in the dark for 24 hours (Talkad *et al.*, 2014). Strains that survived UV exposure were selected as mutants and used for biodegradation studies.

Biodegradation of LDPE by Selected Mutant Bacteria

Mutant *Pseudomonas aeruginosa* D5 obtained from UV exposure was used to prepare a bacterial stock solution. Four millilitres of the stock solution were inoculated into 196 mL of mineral salt medium containing 2 g (approximately 7 strips) of prepared LDPE films in a 250 mL conical flask. The setup was incubated at 35°C for 28 days. A non-inoculated mineral salt medium with untreated LDPE films was maintained as the negative control, while the mineral salt medium inoculated with the wild-type *Pseudomonas aeruginosa* D5 and LDPE films served as the positive control under the same conditions.

Measurement of Biodegradation

Cell density was determined using serial dilution and plating for viable colony counts at 7-day intervals, as described above. This process was carried out over a period of 28 days period.

The percentage of weight loss was determined after 28 days of incubation at 35 °C using the method described by (Nademo *et al.*, 2023). To measure weight loss, residual LDPE films from the four bacterial suspensions were collected, thoroughly washed with 2% (w/v) aqueous sodium dodecyl sulfate, and rinsed with distilled water to remove microbial films and residual medium. The residual LDPE samples were collected and dried overnight at 60 °C before being weighed. The weight loss was calculated and compared using the following formula:

Weight loss (%) = (initial weight) - (final weight)/ initial weight ×100.

The structural changes in the LDPE films after incubation with the wild-type bacteria, mutant bacteria strain, and without inoculation were analysed using a Fourier Transform Infrared Spectrometer (Varian 600 Mid LR Dual MCT/DTGS Bundle with ATR). Spectra were recorded in the frequency range of 4,000 cm^{-1} to 500 cm^{-1} at 25°C, with a helium-neon laser lamp as the IR radiation source. To prepare the pressed pellets, the extracted samples were ground with potassium bromide in a 1:100 ratio and analysed at a resolution of 4 cm^{-1} (Oluwole *et al.*, 2024).

Results

Screening of Bacterial Isolates for LDPE Utilisation

The screening of the selected bacteria for LDPE utilization revealed that *Pseudomonas aeruginosa* D5 exhibited a steady increase in cell density, rising from 5.69 log_{10} CFU/mL on the first day of incubation to 6.0 log_{10} CFU/mL on the 7th day, with a slight further increase to 6.04 log_{10} CFU/mL on the 14th day. In contrast, *Alcaligenes faecalis* D4 showed a decline in growth, with its cell density decreasing from 5.95 log_{10} CFU/mL on the first day to 5.60 log_{10} CFU/mL on the 7th day, and further dropping to 5.48 log_{10} CFU/mL on the 14th day. This suggests that *Pseudomonas aeruginosa* D5 has more ability to utilise LDPE film as a sole carbon source (Table 1).

Table 1: Cell Density (Log_{10}CFU/ml) of *Pseudomonas aeruginosa* D5 and *Alcaligenes faecalis* D4 during 14 Day Degradation of LDPE

Isolates	Day 1	Day 7	Day 14
P. aeruginosa D5	5.699	6.000	6.041
A. faecalis D4	5.945	5.602	5.477
Control	0.000	0.000	0.000

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Cell Density Measurement of Mutant and Wild Strains

Following an exposure to the Ultraviolet radiation, there was observable growth in culture plates of *P. aeruginosa* D5 after 10 minutes and 20 minutes of exposure, respectively. However, *Alcaligenes faecalis* D4 was not able to grow after exposure to UV irradiation. The observations of the LDPE degradation experiment using the mutant strain of *P. aeruginosa* D5 are presented in Figure 1. There was an increase in the cell density when the UV-irradiated strain recovered from 20 minutes of irradiation exposure was incubated with LDPE films for 28 days, monitored at 7-day intervals.

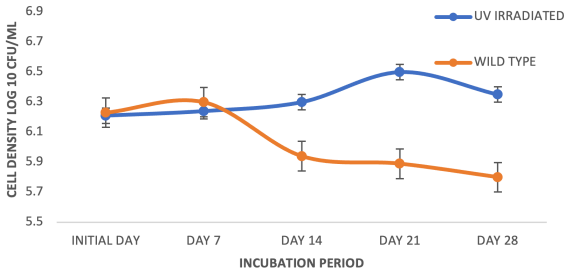

Fig. 1: Cell Density of UV-irradiated and Wild-type Strain of *P. aeruginosa* D5 during a 28-day LDPE Degradation

The increase was from an initial cell density of 6.28 to 6.5 log10 CFU/ml after 21 days of incubation.

A slight decline in cell density was however observed on the 28th day of incubation (6.3 $\log_{10}$ CFU/ml). The cell density of the wild type culture although increasing sharply from the initial day of incubation started declining from the 14th day whereas the wildtype was increasing.

Weight Loss Measurement

After 28 days of incubation, the percentage weight loss was estimated and it was observed that the percentage weight loss of LDPE films treated with the selected UV irradiated *Pseudomonas aeruginosa* D5 was 9% as compared with the unexposed strain which was able to achieve about 1.5% weight loss in LDPE films (Figure 2).

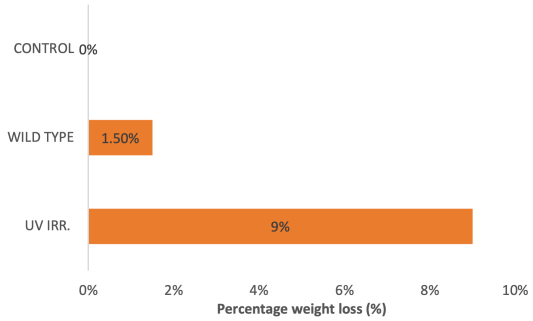

Fig. 2: Weight Loss (%) of LDPE Films incubated with UV-irradiated and wild-type strains of *P. aeruginosa* D5

Table 2: Summary of the FT-IR results of the degraded LDPE samples by the UV-irradiated and wild-type strains of *Pseudomonas aeruginosa* D5 in comparison with the untreated samples and the negative control samples after 28 days

Vibrational Frequency (Vfh) (cm^{-1})	Untreated Sample (cm^{-1})	UV Irradiated *P. aeruginosa* D5 (cm^{-1})	Wild Type *P. aeruginosa* D5 (cm^{-1})	Negative Control (cm^{-1})	Functional Groups
3500-3200	3204.62	3500.46	3411.23	3104.25	Hydroxyl
2700-2500	2500.39	2998.95	2916.46	2400.73	Amines
2500-2300	2399.05	1700.65	2897.10	1246.25	Carbonyl
1700-1100	1100.56	-	1421.65	1012.71	Carbonyl
	1310.78	1901.74	2250.19	1150.38	Alkanes
	-	1248.95	-	-	Alkanes
1300-900	928.64	-	1386.41	928.64	Phenol
1000-700	729.01	-	1050.28	-	Ester
800-650	684.28	-	986.14	800.96	Amide I
	-	-	991.24	631.45	Alcohol
580-520	518.23	-	550.32	518.53	Bromo-alkanes
1700-1600	-	1582.90	-	-	1^0 amines
1530-900	-	1521.67	-	-	Carboxylic
		1350.17			
		1127.34			
		800.62			
1500-1447	Nil	1446.38	Nil	Nil	Alkenes
950-993	Nil	992.49	Nil	Nil	Amide II

FTIR Analysis of Residual LDPE Strips After Microbial Degradation

The Fourier Transform Infrared Spectroscopic (FTIR) analysis carried out on the experimentally biodegraded and control LDPE samples shows that isolates were able to induce some changes in some wave numbers, which were signs of degradation of the polymer in the IR spectrum. The FTIR analysis shows that the untreated LDPE exhibits typical functional groups with minimal oxidation, UV irradiated *P. aeruginosa* D5 shows increased hydroxyl and carbonyl groups, indicating

enhanced oxidation and hydroxylation compared to untreated LDPE and also demonstrates significant chemical changes with the introduction of carboxylic acids, amines, and alkenes. There was a shift in hydroxyl groups (3204.62 cm^{-1} to 3500.46 cm^{-1}) from the untreated sample to UV-irradiated strains. Multiple carbonyl peaks were detected in untreated LDPE (2399.05 cm^{-1}, 1100.56 cm^{-1}), and a shift was found in UV-irradiated treated samples (2498.63 cm^{-1}, 1700.65 cm^{-1}). While the wild type strain shows functional group changes indicative of controlled degradation, and negative control displays minimal changes, confirming the specificity of the microbial degradation observed in UV-irradiated treated sample (Table 2).

Discussion

The consumption of synthetic petroleum-based plastics in developing countries has been reported to be greater than that of the world average because of the higher rate of urbanisation and economic development (Emadian *et al.*, 2017). The potential of a microorganism to utilize a given substrate is contingent upon its growth and adherence to that substrate. In the present study, we observed that the bacterial isolates were capable of utilising untreated Low-Density Polyethylene (LDPE) as their sole carbon source.

The growth profile for screening for LDPE utilisation by selected bacteria strains revealed that *Pseudomonas aeruginosa* D5 steadily increased in cell growth throughout the 14-day incubation compared to *Alcaligenes faecali*s D4, which indicates that *Pseudomonas aeruginosa* D5 has a greater ability to degrade and utilise LDPE film as a sole carbon source. Similar findings have been reported in previous studies, and these findings not only indicate high affinity of *Pseudomonas aeruginosa* cells for the polyethylene but also raise the possibility that the low carbon availability in *Pseudomonas aeruginosa* cultures may enhance hydrophobic interactions, leading to biofilm development. Devi (2019) reported in their study that *P. aeruginosa* was able to attain a stable, almost 10^9 CFU/ml in Bushnell Hass broth and 8.0×10^8 CFU/ml in minimal salt medium after 20 days of incubation. Kyaw *et al.* (2012) also found that biofilm development was rapid in the case of *Pseudomonas aeruginosa* PAO1 (B1) during the comparative analysis on biodegradation of LDPE films by different species of *Pseudomonas* (Gumbi *et al.*, 2019) However, Devi *et al.* (2023) revealed that *Alcaligenes faecalis* strain ISJ128 demonstrated a removal rate of 0.0018 day−1 along with a half-life of 462 days. Tribedi and Sil (2013) reported 5 ± 1% LDPE degradation with *Pseudomonas* sp. AKS2 and enhanced LDPE biodegradation were achieved with biofilm formation.

Many strain improvement techniques have been employed to increase the degradation yields of bacterial strains. UV light has been reported to possess lethal and mutagenic properties in a variety of organisms, including bacteria (Witkin, 1976), and in this study, it exhibited its lethal effect on *Alcaligenes faecalis.*

The long exposure time, compared to mostly 1 to 8 minutes in literature (Joshi *et al.*, 2013; Tian *et al.*, 2016), was used to observe the possibility of the bacteria isolates surviving higher UV radiation doses. It was observed in the study that while there was some growth on the plates that were exposed to 30 minutes of UV radiation, this was also observed at 10 and 20 minutes. Ghosh and Oman (2024) in their investigation of the effect of exposure time on lethality and mutagenesis in *Escherichia coli* found out that UV exposure durations of 4 and 8 min resulted in a 10-fold decrease in CFU levels, while 16 min of exposure resulted in a 100-fold decrease compared to the untreated control. They further noted that prolonging the exposure time to 24 and 32 min led to a striking 10^5-fold reduction in CFU levels. The degradation studies *in vitro* showed that the initial period of growth of cells was rapid for UV-irradiated *P. aeruginosa* D5 and for the wild-type strain. This can be attributed to the acclimatisation of bacteria in the basal medium with the degraded carbon source from the plastics.

UV-irradiated strains showed a steady increase from the 1st day of incubation to the 21st day of incubation, but with a decline in density after 28 days. In contrast, the wild-type strain showed a gradual decline in cell density from the 14th day to the 28th day of incubation. The decline in cell density after 28 days could result from depletion of degradable components of the LDPE films as well as accumulation of toxic intermediate compounds. This result indicates that the UV irradiated strains showed better potential to degrade and utilize LDPE film as sole carbon source and this observation suggests that random mutagenesis of *Pseudomonas aeruginosa* D5 can accelerate the biodegradation of LDPE film and the exposure time of *Pseudomonas aeruginosa* D5 to UV has a profound effect on the biodegradability of the bacteria. This result aligned with a similar study as reported by Nourollahi *et al.* (2019), where it was observed that maximum growth of the LDPE degrading bacteria was found to be within 6 to 16 days in the *Pseudomonas* isolates they used. Rafeeq *et al.* (2023) also reported in a review journal that to generate mutations, UV radiation, ethyl methyl sulphate and ethidium bromide are used as mutagens. Similarly, studies by Anantharam and Talkad (2018) and Kumar and Raut (2015) found enhancements in the activity of their investigated isolates following UV radiation exposure. Mao *et al.* (2015) observed that exposing the bacterium *Pseudochrobactrum* sp. to UV irradiation for 120 seconds resulted in improved phenol degradation.

The weight loss data analysis for the polyethylene degradation revealed that the UV-irradiated *Pseudomonas aeruginosa* D5 with 20 minutes exposure time exhibited higher degradation than the wild type

strain, resulting in a 9% reduction in the weight of the films after 28 days of incubation. The weight loss of the LDPE films can be attributed to the breakdown of the carbon backbone due to enzymatic degradation by these bacteria, which was also reported in a similar study by Midhun *et al.* (2015). The maximum loss in weight was seen for LDPE films incubated with UV-irradiated strain. The weight loss could correspond to the consumption of LDPE by UV-irradiated *P. aeruginosa,* utilising LDPE as its source of carbon and energy (Pathak and Navneet, 2017).

In many LDPE biodegradation studies, the weight loss method was used to determine microbial consumption of polymers (Das and Kumar, 2015; Jamil *et al.*, 2017). The results indicate the LDPE degradation potential of UV-irradiated *Pseudomonas* species. Similar findings were reported in a series of studies. Dong *et al.* (2011) observed appreciable copper tailings degradation rates (17%) by the bacteria *Thiobacillus ferrooxidans* after exposure to 30 minutes of UV irradiation compared to the original bacteria, thus validating the role of mutation in enhanced bioactivity of bacteria. Joshi *et al.* (2013) also found that UV-irradiated *Pseudomonas* sp. LBC1 was able to reduce the time required for complete degradation of sulfonated azo dye by 25% compared to the wild type. Xiong *et al.* (2025) also confirmed the potential of mutation in improving biodegradation of microplastics by bacteria, noting the increase in enzyme laccase production as well as 53.65% degradation achieved after 50 days of incubation with the mutant bacteria. Talkad *et al.* (2014) found that mutant P. putida was able to improve the degradation of low-density (low crystallinity) polyethylene following UV and EMS treatment.

FTIR analysis serves as a crucial method for identifying the creation or loss of functional groups within polymer molecules following microbial treatment. It is employed to examine the broken-down products, various groups, and chemical moieties that are integrated into the polymer during biodegradation research (Kavitha and Bhuvaneswari, 2021; Peixoto *et al.*, 2017; Montazer *et al.*, 2018). In this study, FTIR analysis of the treated LDPE samples using UV irradiated and wild-type *Pseudomonas aeruginosa* D5 revealed changes in the functional groups of LDPE samples. The oxidation or hydrolysis of LDPE by bacterial enzymes creates functional groups that improve the polymer's hydrophilicity and degradability by microorganisms. There was the formation of new peaks and also a loss of new peaks when comparing the untreated samples with the wild type and mutant strain of *P. aeruginosa* D5. Peak ranges 520 -1300 cm^{-1} were found to disappear in the LDPE films incubated with the irradiated strain, although the peaks were retained in the wild-type strain. The mutant was also found to create a new range of functional groups at peaks in the range of 1530 – 900 and 950- 993 cm^{-1}, which were not observed in the control and the wild-type strain treatment.

The UV-irradiated strain also demonstrated significant chemical alterations, including the introduction of carboxylic acids, amines, and alkenes. The detection of multiple carbonyl peaks (2399.05 cm^{-1}, 1100.56 cm^{-1}) in untreated LDPE and their shifts in UV irradiated-treated samples (2498.63 cm^{-1}, 1700.65 cm^{-1}) indicate oxidative degradation, leading to the formation of aldehydes, ketones, and carboxylic acids which is indicative of possible hydroxylation and oxidation during the LDPE degradation process. The increase in the carbonyl group and double bond indices in LDPE films compared to those in the control group. The formation of alkenes and amides indicates polymer chain scission and the introduction of nitrogen-containing functional groups, which is consistent with microbial degradation pathways. Rong *et al.* (2024) highlight that the increase in C=C bond formation is principal during LDPE biodegradation.

Muhonja *et al.* (2018) also analysed the biodegradability of untreated LDPE using FT-IR and observed similar formation of new peaks at 1700–1650 cm^{-1} and 1000–1100 cm-1. Zhang *et al.* (2021) and Liu *et al.* (2019) also reported that photodegradation of plastic by UV radiation is considered the most important weathering process for the MPs generation, which induces the splitting of chemical bonds, branching, and formation of oxygen-containing groups such as carboxylic, aldehyde, ketone, and hydroxyl.

These results align with the findings of previous studies that highlight the role of microbial oxidation and the formation of intermediate degradation products such as carboxylic acids, aldehydes, and amines (Pinto *et al.*, 2018). Dey *et al.* (2020) reported that these esters, alcohol, etc., could be subsequently converted to smaller fatty acids through an intermediate step of aldehyde production by dehydrogenase enzymes. Polymer degradation (mineralisation) forms new products during or at the end of processes, e.g., CO_2, H_2O or CH_4 (Pathak and Navneet, 2017). The shifting, addition, and deletion of peaks indicate structural changes made by microbial activity (Bhatia *et al.* , 2014). Harshvardhan and Jha (2013) observed that the increase in the keto carbonyl bond index, ester carbonyl bond index, and vinyl bond index in FTIR spectra provides strong evidence for the biodegradation of polyethylene. This valuable finding highlights the potential for monitoring biodegradation processes through these indicators.

Conclusion

Random UV-induced mutagenesis has been widely reported to positively impact the biodegradation ability of bacterial strains compared to their wild-type counterparts in the remediation of organic pollutants. This study evaluated the effects of UV exposure on isolates used for the biodegradation of low-density polyethylene (LDPE). It was observed that only *Pseudomonas aeruginosa* D5 survived exposure times of

10 and 20 minutes. The results demonstrated that the biodegradation abilities of these isolates increased following UV exposure, leading to enhanced degradation of LDPE film. From this study, the weight loss and FT-IR analysis helped reveal the potential of UV irradiation as a method of strain improvement, which can effectively enhance the ability of the *Pseudomonas aeruginosa* strain to degrade LDPE. Further studies on the impact of the UV mutagenesis on the enzyme activity of the test strain and genomic profiling of the mutant strain will help better understand the effectiveness of induced mutation on bioremediation of recalcitrant pollutants in the environment.

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Conflict of Interest

The authors declare that they have no known conflicts of interest associated with this publication.

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Author's Contributions

Olusola Adeoye Oluwole: Conceptualised and designed the study; supervised the experimentation; proofread and corrected the final draft.

Temitayo Omotunde Olowomofe: Supervised the experimentation; proofread and corrected the final draft.

Ikeoluwa Gloria Olaniyan: Carried out the experimentation; wrote the first draft of the manuscript.

Ethics

There are no ethical issues to report.

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