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The biodegradation of low-density polyethylene by *Bacillus* species

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Abstract
Polyethylene (PE) products have short-term applications, resulting in the daily release of enormous quantities of plastic wastes into the environment with their attendant public and environmental health threats of global concern. Developing an eco-friendly management method to abate the menace prompted this research work. Four *Bacillus* species were isolated from different dumpsites in Owerri Metropolis, and identified using 16S rDNA sequencing, as *B.pumilus, B.siamensis, B.coagulans* and *B. subtilis*. The ability of the microbial isolates to degrade polyethylene (table water sachets) was determined using microbial growth measurement in liquid medium (Optical Density (OD600)), disappearance and introduction of functional groups (Fourier Transform Infrared spectroscopy (FTIR) and weight loss analysis measured after sixty (60) days of incubation in mineral salt vitamin media. Microbial density showed a gradual and progressive increase from 0 day to 60 days : *B. siamensis* (0.12 - 0.84), *B.pumilus* (0.11-.67), *B.coagulans* (0.12 - 0.61) and *B.subtilis* (0.11 – 0.60), as against the control medium which remained unchanged (0.11). Similarly, FTIR spectra showed additional functional groups (carboxylic acids, ethers, esters, amines, methylene, alcohols, and alkenes in the polyethylene materials exposed to the test isolates: *B.siamensis* (17 peaks), *B.pumilus* (12 peaks), *B.coagulans and B.subtilis* (13 peaks each), but control (8 peaks). There were subatantial reduction in the residual weights of the PE materials: *B.siamensis* (52%), *B.pumilus* (26%), *B.coagulans* and *B.subtilis* (18% each). The observations showed that these *Bacillus* spp. indigenous to Owerri Metropolis have the ability to degrade PE and utilize it as a carbon source, and it was concluded that biodegradation was achieved, and that PE which was regarded to be inert can be biodegraded when exposed to the right microorganisms.

Keywords: *polyethylene, biodegradation, Bacillus spp., eco-friendly, dumpsite*

Introduction

Increased production and wide range applications of plastic materials in various aspects of modern life, including packaging, fibres and textiles, plastic pipes and fittings, medical devices, electronics and automotive parts have made them staple products and indispen-sable to man. Their versatility arises from their advantageous characteristics such as clarity, light weight, hardness, durability, flexibility, easy processsibility, resistance to chemicals and moisture and low cost (Longo et al.,2011; Yoon et al., 2012). However, synthetic plastics exhibit other qualities such as high molecular weights, 3-dimensional structure, hydrophobicity and biochemically inert nature which make them recalcitrant to microbial actions (Esmaeili et al., 2013; Celina et al., 2019; Chamas et al., 2020). Polyethylene (low-density polyethylene (LDPE), me-

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dium-density polyethylene (MDPE), high- density polyethylene (HDPE) and linear low-density polyethylene (LLDPE, polyethylene terephthalate (PET)) is the most widely used plastics, and is mainly employed in packaging. Various institutions, commercial centres, pharmacy and supermarkets have customized and designed polyethylene bags with attractive colours for packaging of their goods, and these innovations have consequently enhanced polyethylene production and usage as well as plastic waste generation (Uwakwe et al., 2023). In most developing countries , Nigeria inclusive, the waste are indiscriminately disposed along the roads, streets, dumpsites and landfills, and at least 80% of these plastics and other wastes end up in rivers, oceans, drainages and waterways, causing serious ecological and human problems (Hajramurni, 2018; Brando et al., 2018). Management of plastic wastes is among the greatest global ecological challenges, especially in developing countries of the world. Conventional management methods such as incineration, land filling, open and ocean dumping and recycling have been employed in handling plastic wastes, but most of these methods were found to be inefficient, and are associated with serious environmental and health problems (Ren et al., 2019; Chen et al., 2020; Ni et al., 2022). Similarly, production of biodegradable plastics has been advocated as an alternate method of handling plastic wastes, however the process has not gained enough ground especially in developing countries including Nigeria due to lack of public awareness, limited availability of industrial composting facilities, economic and technical challenges (Kubowicz and Booth, 2017). Furthermore, in the past few decades, there has been an increased interest in the use of diverse microorganisms, including *Brevibacillus borstelensis* (Hadad et al., 2005), *Pseudomonas* spp.(Nanda and Sahu,2010), *Bacillus mycoides* and *B. subtilis* (Ibiene et al., 2013), *Lysinibacillus xylanilyticus* and *Aspergillus niger* (Azeko et al., 2015), *Pseudomonas auriginosa* (Mukherjee et al., 2018), *Paenibacillus* sp. (Bardaji et al., 2019)), *Eubacterium* sp. D1 (Ren et al., 2019), *Microbacterium oxydans* (Najafi and Levin, 2020), *Proteus, Serratia and Lactobacillus* spp. (Uwakwe et al., 2023) and a host of other microorganisms to degrade polyethylene and other plastic wastes, with substantial achievements recorded by different researchers in different countries of the world. The process involves attachment of microorganisms to the polymer surfaces, enzymatic breakdown of the complex structure into short units of low molecular weights (oligomers and monomers) and their utilization as carbon and energy sources which result to the growth and multiplication of the microbes (Arutchelvi et al., 2008; Bhardwaj et al., 2012; Kopecka et al., 2022). Utilization of the low-molecular weight compounds results in mineralization with carbon dioxide ($C0_2$), water (H_2O) and biomass as the ultimate end products, making the process eco-friendly (Ren et al., 2019, Uwakwe et al., 2023). However, not much of such work is seen in Imo State and Nigeria generally, hence this study which was an attempt to degrade low-density polyethylene with indigenous bacteria isolated from waste dumpsites in Imo state, Nigeria as way of contributing towards solving this global plastic waste management challenge.

Materials and Methods

Isolation of low-density polyethylene degrading bacteria

Bacterial isolates used in low-density polyethylene degradation were isolated from soil samples collected from solid waste dumpsites in Owerri Metropolis, using mineral salt medium (1.0g NH_4NO_3, 0.2g $MgSO_4.7H_2O$, 1.0g K_2HPO_4, 0.1g $CaCl_2.2H_2O$, 0.15g KCl, 0.1g yeast extract and 1.0mg of each of the following microelements: $FeSO_4.6H_2O$, $ZnSO_4.7H_2O$ and $MnSO_4$) with polyethylene powder as the sole source of carbon, according to the methods of Gilan et al., (2004), Azeko et al., (2015) and Bardaji et al., (2019). Incubation was in a rotary shaker at 37° C for 4 weeks. Microbial growth was assessed using optical density (OD600) in UV-visible spectrophotometer. Thereafter, suspensions from each set up were serially diluted, cultured on Nutrient agar with sodium azide which is selective for the growth of *Bacillus* species and incubated for 24 hours. Only the colonies with higher exponential growth were selected, subcultured on nutrient agar and pure cultures were obtained for identification and biodegradation studies.

Identification of isolated *Bacillus* species

The isolated *Bacillus* spp. were identified using biochemical and molecular characteristics. Biochemical parameters considered included Gram-staining, oxidase, catalase, motility, citrate utilization, Methyl Red and sugar fermentation tests as described by Bargey's Manual of Determinative Bacteriology (Krieg & Holt, 1984); Cheesbrough, (2006) and American Society for Microbiology (ASM), (2020). Similarly, molecular identification was achieved through geno-

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mic DNA extraction of each isolate, according the manufacturer's protocol, using genomic DNA isolation kit (numbers 24700, 24750 and 24770), obtained from Norgen Biotek Corporation, Canada. The 16S rDNA of the isolates were amplified using universal primers, and the resulting nucleotide sequences were compared to sequences obtained from GenBank (http://www.lahey.org/studies/webt.html) using the Basic Local Alignment Search Tool, as proposed by Sambrook and Russel, (2001), Janda and Abbott, (2007), and the modified method of Ogbulie and Nwakamma, (2015).

Biodegradation Assays

Low-density polyethylene (table (pure) water sachets) which was shredded, ground and sterilized was used in assessing the ability of the test isolates to degrade low-density polyethylene. Mineral salt vitamin (MSV) medium (1.0g $(NH_4)_2SO_4$, 1.0g KH_2PO_4, 8.0g K_2HPO_4, 0.2g $MgSO_4$.7H2O, 0.1g NaCl, 0.02g $CaCl_2.2H_2O$, 0.01g $FeSO_4$, 0.5mg $Na_2MoO_4.2H_2O$, 0.5mg $MnSO_4$, 0.2ml inositol, 0.2mg p-amino benzoid acid, 0.4mg pyridoxine, 2.0 µg thiamine, 2.0µg biotine and 120.5µg vitamin B12), dissolved in 1 litre of distilled water and autoclaved at 121°C for 20 minutes) was used for incubation as proposed by Patil and Bagde (2015).

Microbial growth measurement in liquid medium

Microbial broth culture of each test isolate was prepared, and 1ml of 10^{-1} dilution was seeded into different conical flasks containing 100 ml of mineral salt vitamin media and 0.5g of the polyethylene material. Incubation was in a rotary shaker at 37°C and 150 rpm for 60 days. Growth of the isolates was monitored by measuring the absorbance using visible spectrophotometer at 600nm (OD600) of each medium at the interval of 10 days. The polyethylene served as the sole source of carbon in the medium.

Assessment of changes in the functional groups in the polyethylene structure

Changes in the chemical structure in the polyethylene materials following exposure to the test isolates were investigated using Fourier Transform Infra-Red Spectroscopy (FTIR). At the end of of the 60 days incubation period, the residual polyethylene materials were recovered, dried at room temperature and chemical changes investigated. (Azeko et al., 2015; Ren et al., 2019). The absorbance (wavelength) ranged from 4000 cm^{-1} to 650 cm^{-1}. Control sample was without microbial inoculation.

Weight loss analysis

Incubation of 0.5g of the polyethylene materials in mineral salt vitamin medium with the test isolates was also for 60 days. At the end of the incubation, the residual polyethylene materials were recovered and washed thoroughly with 2% aqueous dodecyl sulphate solution to remove the nutrient medium and microbial biofilms. They were further washed with 70% alcohol, rinsed with distilled water, dried and reweighed to determine the average weight loses (Nanda et al., 2010; Skariyachan et al., 2018). Percentage weight loss was calculated.

Results and Discussion

Isolation and identification of low-density polyethylene degrading bacteria

Following the cultivation of the soil samples in mineral salt medium and sub-culturing in nutrient agar with sodium azide, four *Bacillus species* with the potential of degrading low-density polyethylene were isolated. The colonies appeared white or creamy or light grey with either smooth or rough surfaces. Analysis of the bio-chemical characteristics of the isolates indicated that they are gram-positive, motile, oxidase and catalase positive, but citrate, indole and methyl red negative. Similarly all the species are glucose, sucrose, maltose, galactose and mannitol fermenters, with acid production, while none of the isolates fermented lactose and sorbitol. Howerer, only one of the isolates could ferment inositol. The similarities found in the morphological and biochemical characteristics of the isolates are strong indications of their being closely related, and these findings corroborated the American Society of Microbiology (2020) methods of identifying bacteria. Furthermore, based on the 16S rDNA sequencing, identities of the species were confirmed with their percentage similarities to similar *Bacillus* species at GenBank (http://www.lahey.org/studies/webt.html) as: *Bacillus siamensis* (with sequence nucleotide: GATGTTAGCGGCGGACGGGTGA, 100% simimila-rity and GenBank accession number OR763561); *Bacillus subtilis* (sequence nucleotide: TGGTAGTGTT AGGGGGTTTCCGC, 99.7% si- milarity and GenBank accession number KU740250); *Bacillus coagulans* (sequence nucleotide: GAATGCATTTATG CAACATGGGC, 100% similarity and MA820466 GenBank accession number and *Bacillus pumilus* with sequence nucleotide: GCAGTCGAGCGGACAGAA

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GGGA, 99.86% similarity and OR243874 GenBank accession number). The mole-cular identification results gave credence to the morphological and biochemical results, and therefore confirmed that the isolates belong to the same genus.

Growth dynamics of the *Bacillus* spp. in low-density polyethylene suspensions

Results obtained from the incubation of the *Bacillus* spp. in MSV media with the sachet water materials as the sole source of carbon for 60 days showed gradual and steady increase in microbial density as indicated by the increase in absorbance values at OD600. As the period of incubation progressed, gas bubbles were observed in the culture media, while the turbidity increased. However, the control media remained clear without gas bubbles. These results corroborate the the findings of Azeko et al., (2013) and Ren et al., (2019). The highest absorbance (microbial density) was recorded in the medium with *Bacillus siamensis* (0.12 - 0.84), followed by *B.pumilus* (0.11 - 0.67), *B.coagulans* (0.12 - 0.61) and *B.subtilis* (0.11 -0.60) (Table 1). The observed air bubbles, turbidity and increase in microbial densities in the media inoculated with the test isolates were indications of microbial activities, and their ability to adapt to the nutrient conditions of the media, degrade and utilize the polyethylene materials as their sole source of carbon. It could therefore be inferred that the isolates adapted to, and switched over to the nutrient contents of the culture media, hence adaptability is one of the key factors for biodegradation. These re-sults corroborateed the findings of Azeko et al., (2013); Ren et al., (2019); Emmanuel-Akereleet et al., (2022) and Esamahy et al., (2023) who employed different microorganisms in polyethylene degradation. However the varying absorbance rates showed that the different *Bacillus* spp. possess different capabilities of degrading polyethylene, and this could be attributed to the sources of isolation, environmental factors and the genetic make-up of the species. The organisms were isolated from different dumpsites with differences in their coordinates and components: *B.siamensis* and *B.subtilis* (Nekede Mechanic village), *B.pumilus* (Orji) and *B.coagulans* (Obinze) in Owerri Metropolis. Similar observations and assertions were made by Skariyachan et al., (2017); Biki et al., (2021) and Kopecka et al., (2022) in their separate works on microbial degradation of polymers.

Table 1. *Mean growth of Bacillus spp. (Absorbance atOD600) following exposure to low-density polyethylene for 0 - 60 days*

Isolates	Time in days						
	0	10	20	30	40	50	60
B. pumilus	0.11± 0.00	0.12± 0.09	0.18± 0.37	0.32± 0.23	0.56± 0.07	0.62± 0.28	0.67± 0.0
B.subtilis	0.11± 0.00	0.11± 0.07	0.27±0.11	0.34± 0.90	0.50± 0.09	0.57± 0.00	0.60± 0.3
B. siamensis	0.12± 0.00	0.12± 0.00	0.27±1.05	0.45± 0.33	0.70± 0.33	0.77± 0.08	0.84± 0.0
B. coagulans	0.12± 0.00	0.12± 0.06	0.23±0.16	0.38± 0.11	0.51± 0.29	0.53± 0.09	0.61± 0.2
Control	0.11± 0.00	0.11± 0.01	0.12±0.11	0.11± 0.05	0.11± 0.21	0.11±0.00	0.11± 0.0

/Structural changes in the low-density polyethylene due to exposure to the *Bacillus* spp

At the end of the sixty (60) days of exposure of the low-density polyethylene, to the test isolates, analysis of the chemical structure of the polyethylene with FTIR spectroscopy revealed that in the control sample which was not exposed to microbial inoculation, there were 8 peaks (function groups) comprising ethane (1362.166 cm^{-1}), amine (1636.613 cm^{-1}), carboxylic acid (2024.583cm^{-1}), methylene (2623.294cm^{-1} and 2899.527cm^{-1}) and alcohols (3240.487cm^{-1} and 3801.152 cm^{-1}), as shown in Figure 1. However, in the polyethylene materials exposed to the different *Bacillus* species, increased number of peaks were recorded, suggesting introduction of new functional groups or increase in the number of existing groups due to microbial actions. The FTIR spectrum of the polyethylene surface inoculated with *Bacillus siamensis* recorded 17 peaks (functional groups), *B. subtilis* and *B. coagulans*, 13 each and *B. pumilus* 12. There were additional carbonyl groups which included esters, ethers, carboxylic acids and amines (1600cm^{-1}-2199cm^{-1}), nitriles (2467cm^{-1} - 2597cm^{-1}), alcohols comprising primary, secondary and tertiary alcohols (3000cm^{-1} -

EQA 67 (2025): 26-35

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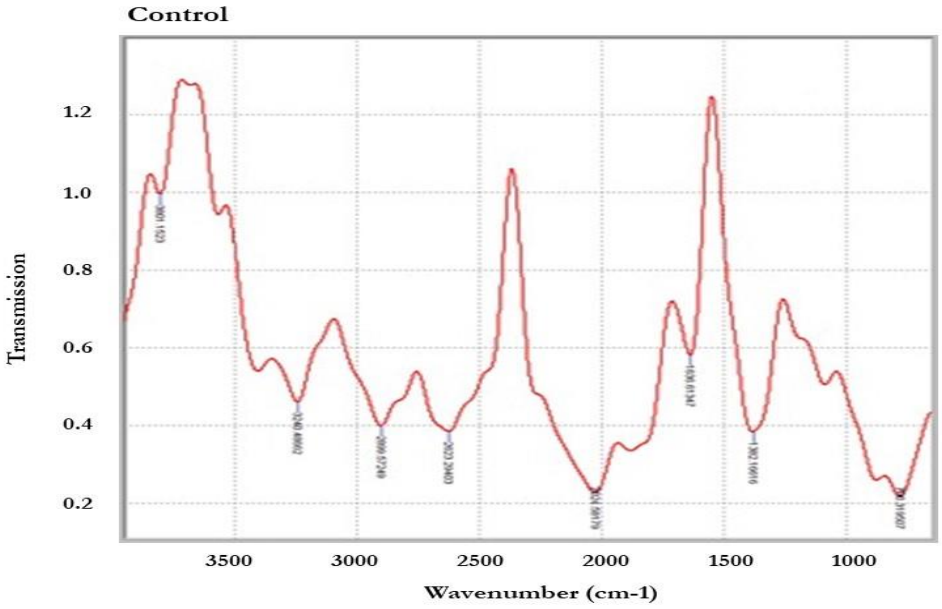
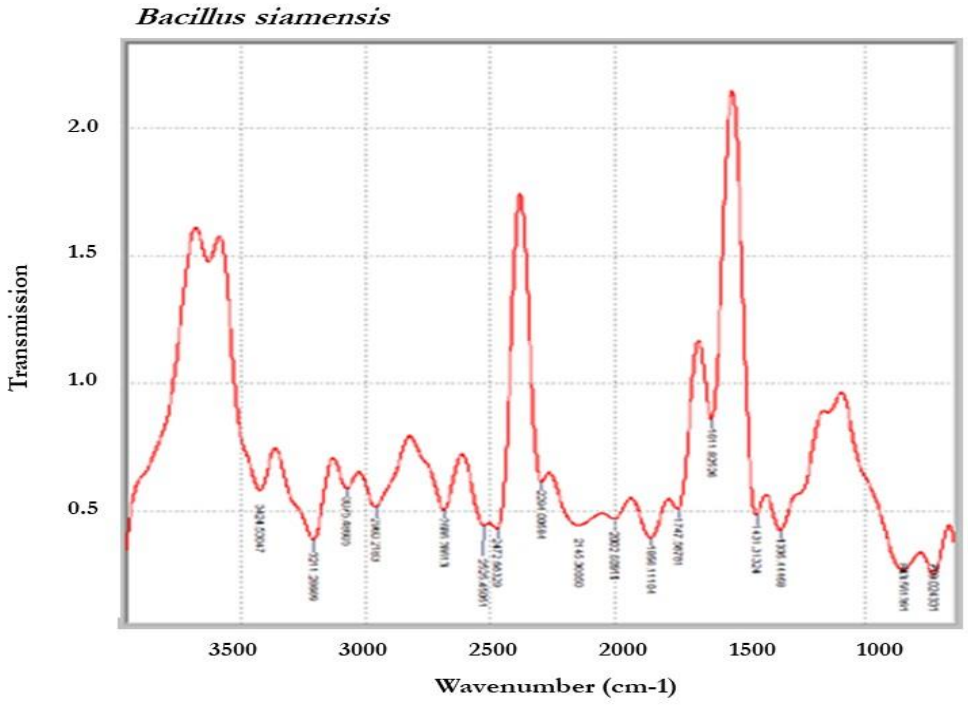


Center X	Peak Area
780.3195	99.95564
1382.166	101.3395
1636.613	76.11111
2024.582	516.8696
2623.294	286.884
2899.572	261.6992
3240.487	323.8647
3801.152	23.32518

Figure 1
FTIR spectrum of low-density polyethylene without microbial inoculation (control)indicating 8 functional groups (peaks)

3500cm^{-1}), alkene (1200cm^{-1}-1599cm^{-1}) and methylene (2600cm^{-1}-2999cm^{-1}) as presented in Figures. 2 – 5. The additional functional groups are byproducts of oxidative degradation of the low-density polyethylene materials by the *Bacillus* species, with the carbonyl compounds being points of cleavage in PE degradation. Similarly the increased numbers of ethenes and methylene were an indication of the breaking down of the complex structure of the polyethylene to smaller units, resulting in the formation of smaller molecules of short-chained oligomers, dimmers and monomers of low molecular weights, which can pass through the semi-permeable outer membrane of microbial cells, and then be utilized as energy and carbon sources. These results agreed with the findings of Hadad et al., (2015) and Ren et al., (2019); Srikant et al., (2022) and Ugueri et al., (2022) who recorded the formation of new



Center X	Peak Area
719.0243	22.5602
843.5614	82.41958
1335.445	2111.2549
1431.313	125.7181
1611.825	111.4555
1747.588	15.98983
1856.111	390.3767
2002.609	179.7694
2145.381	401.8579
2294.006	25.23037
2472.683	128.5582
2525.451	149.1887
2686.286	7251.924
2960.218	239.238
3075.486	118.3603
3211.287	270.6248
3424.538	189.3183

Figure 2
FTIR spectrum of LDPE incubated with Bacillus siamensis showing 17 peaks (functional groups)

EQA 67 (2025): 26-35

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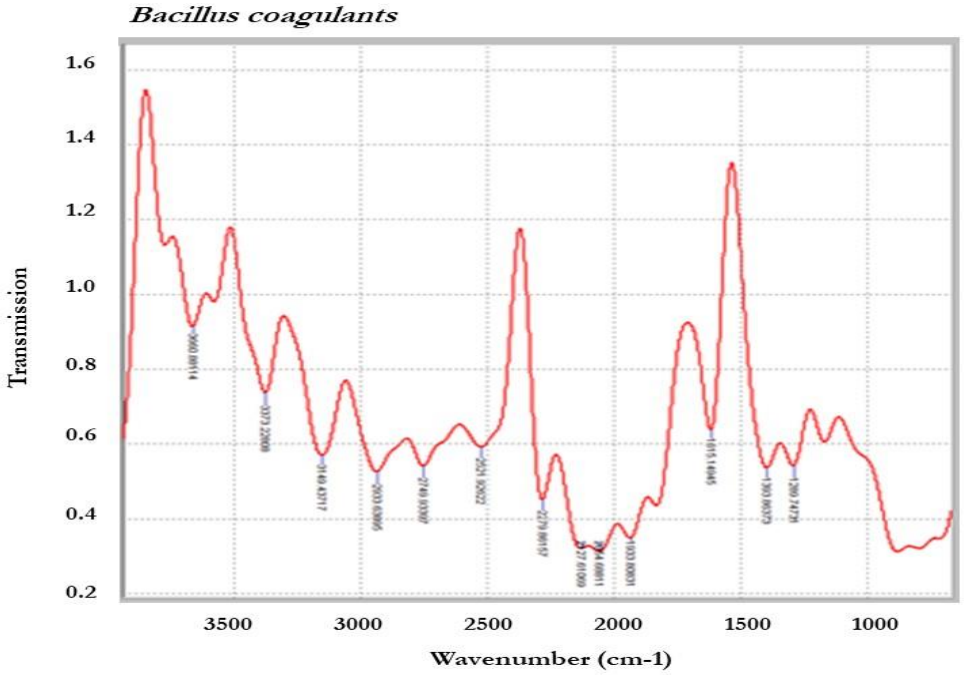
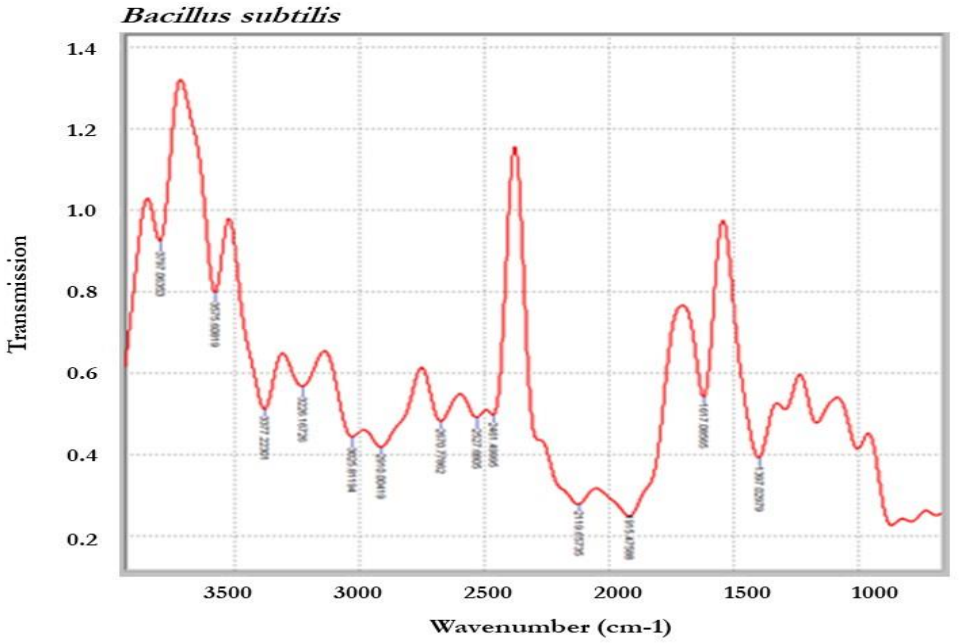


Center X	Peak Area
1289.747	25.91511
1393.864	70.16718
1615.149	81.07222
1933.608	225.8559
2054.688	122.1303
2127.611	127.1059
2279.862	104.0252
2521.926	172.4828
2749.934	177.2707
2933.639	209.0282
3149.437	187.0556
3373.228	129.4428
3660.881	139.4439

Figure 3
FTIR spectrum of LDPE exposed to Bacillius coagulans with 13 peaks (functional groups)



Center X	Peak Area
1397.03	65.02322
1617.086	45.36264
1915.476	226.662
2119.657	226.8666
2461.500	51.12382
2527.681	69.03948
2670.779	102.45
2910.004	170.3024
3025.812	113.6746
3226.167	109.9265
3377.223	132.315
3575.608	51.89232
3797.064	14.02707

Figure 4
FTIR spectrum of LDPE inoculated with Bacillus substilis indicating 13 peaks (functional groups)

functional group in polymer structures after exposure to different microbial isolates for varying periods of time. The degradation processes are enzymatic, involving extracellular enzymes which depolymerize synthetic polymers (cleavage) to give rise to the formation of additional functional groups, and intracellular enzymes (depolymerases) which breakdown the smaller units into absorbable forms which are utilized by the microorganisms for energy release. This assertion corroborates the findings of Novotny et al., (2018); Nag et al., (2021); Prajapati et al., (2021)., Zhang et al., (2022) and Devi et al., (2023) who identified such enzymes as lipases, hydrolases, carboxylmethyl cellulase (CMCase), xylanases, proteases, oxidases and peroxidases in their separate works on biodegradation of plastics. Further evidences of PE degradation by the isolates were the presence of more stretching and asymmetrical vibrations observed in carboxylic acid, ether, nitrle, amines, ethane and ester bands, as well as weak methylene bands in all the PE samples inoculated with the *Bacillus* spp. Similar observations were also recorded by Ibiene et al., (2013); Khandare et al., (2021) and Lin et al., (2022). The vibrations and bending could be attributed to

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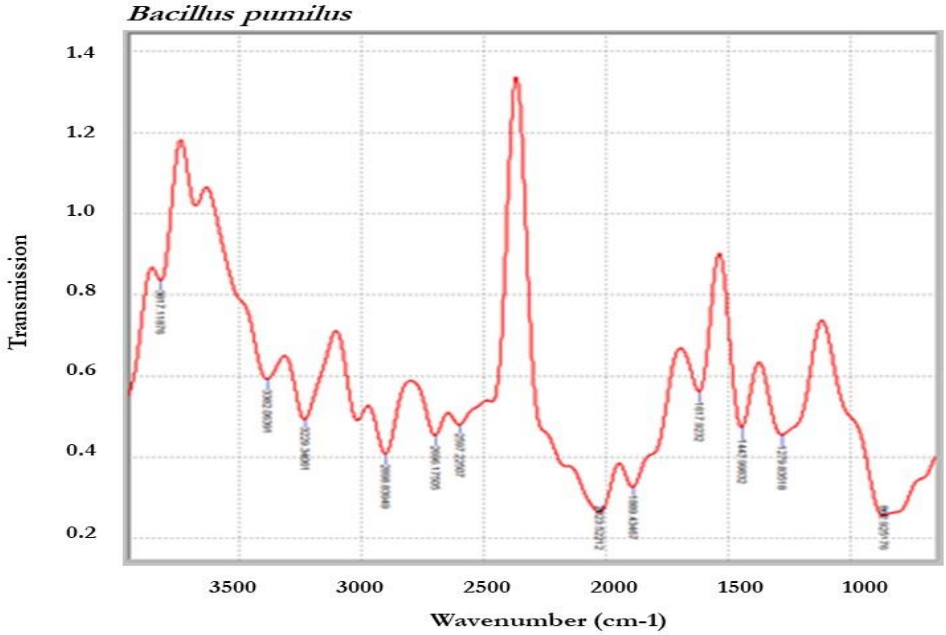
the weakening of the chemical structure of the PE due to microbial activities, suggesting their ability to degrade and utilize the PE as their sole source of carbon and energy. Furthermore, exposure of polyethylene to the test isolates resulted in the release of various chemical compounds including alcohols, carboxyl compounds, esters, benzene, methylene, paraffins, xylene, ethane, toluene and various others of medical, pharmaceutical, agricultural and industrial uses, as also recorded by Prajapati et al, (2021); Lin et al., (2022); Ni et al., (2022).



Center X	Peak Area
862.9252	76.03855
1279.835	61.9371
1443.998	40.0118
1617.923	19.11066
1889.425	175.75
2023.522	364.6644
2597.225	174.6521
2696.175	119.3712
2898.839	226.6266
3229.341	136.791
8382.064	151.4937
3817.119	25.52436

Figure 5
FTIR spectrum of LDPE exposed to Bacillus pumilus showing 12 peaks (functional groups)

Percentage weight loss in LDPE due to microbial actions

After the 60 days incubation of LDPE with the *Bacillus* species, results obtained showed reduction in net weight of the polyethylene materials, with *Bacillus siamensis* recording highest value (52%), followed by *B.pumilus* (26%) and *B.coagulans* and *B.subtilis* (18%) respectively, while no change was observed in the control sample not exposed to microbial attack, as shown in table 3. The decrease in the net weight of the residual polyethylene materials confirmed the results obtained from microbial growth and FTIR analyses, and the ability of the *Bacillus* species to utilize the polyethylene as their sole source of carbon and energy. The organisms exhibited different degrees .in their ability to degrade polyethylene. . Similar results were recorded by Nanda et al., (2010) who used 3 strains of *Pseudomonas* P1 (31.4% and 16.3%), P2 (39.7% and 19.6%) and P3 (46.2% and 29.1%) to degrade natural and synthetic polyethylene, Ibiene et al., (2013) using *Bacillius subtilis* (17.72% and 23.155) and *Bacillius mycoides* (10.50% and 11.35%) to degrade HDPE and LDPE, Jaina et al., (2023) who degraded polyethylene with different bacterial species coded P1 (50%), P2 (-) and P3 (33.3%)and Aziza et al., (2024) who recorded varying degrees of net weight reduction in residual plastic material after exposure to various microorganisms which include *Vibrio alginolyticus* (0.4%), *Pseudoalteromonas* (4.9%), *Microbulbifer pacificus* (4.2%), *Pseudomonas marincola* (6.3%), and *Bacillus*

Isolates	Initial weight before incubation	Final weight after 60 days of incubation	
		Mean Value (n = 3)	% wt Loss
B. pumilus	0.5	0.37±0.05	26%
B. subtilis	0.5	0.41±1.08	18%
B. siamensis.	0.5	0.24±0.09	52%
B. coagulans	0.5	0.41±0.00	18%
Control	0.5	0.50±0.00	

Table 2
Mean and Percentage Weight Loss in LDPE after 60 Days of Incubation with Bacillus Spp

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subtilis (5.5%) The differences recorded in the polyethylene-degradation capabilities of the microbial isolates could be attributed to the variations in enzyme and biofilm syntheses, species-specific characteristics, environmental factors prevalent in their sources of isolation, biosulfactants and reactive oxygen species production, period of incubation and genetic constitution and adaptability (Prajapaty et al., 2021; Lin et al., 2022; Ni et al., 2022., Uwakwe et al., 2023; Aziza et al., 2024). In this present study, *Bacillus siamensis* was found to possess higher level of competence in polyethylene degradation, and this is a pointer to its greater rate of adaptation, through genetic mutation, to the changes in its environment and nutrition from the dumpsite to mineral salt vitamin medium used for incubation

Conclusions

Bacillus species indigenous to Owerri Metropolis and isolated from dumpsites were able to degrade low-density polyethylene, hence their ability to utilize it as a sole source of carbon, as depicted by the increased microbial densities, functional groups and decrease in the net weight of the residual LDPE materials after the 60 days of incubation. Based on these findings, It was concluded that biodegradation of low-density polyethylene was achieved, disabusing the generally accepted impression in Imo State that polyethylene and other plastic products were non-biodegradable. *Bacillus* species exhibited varying degrees of biodegradative competence, with *Bacillus siamensis* being identified as the most effective for degrading low-density polyethylene. The organisms exhibited the same pattern of growth with minimal increase in bacterial densities within the first 20 days of incubation, and significant increase subsequently, indicating their adaptation to changes in their environment and nutrition. It was further concluded that biodegradation of polyethylene resulted in the release of chemical compounds such as alcohols, acids, amines, esters, ethane, methylene, nitriles, ethers, benzene and various other chemical compounds which could be utilized in the medical, pharmaceutical and various industrial establishments for variable uses, making the process a waste-to-wealth scheme that could be embarked upon for economic growth and development. It was therefore recommended that indigenous microbial species be exploited and employed in polymer waste manage-. ment, and the strategies be optimized for maximal outcome and to minimize environmental pollution and health hazards associated with polymer disposal and improper management.

References

ALI S.S., ELSAMAHY T., AL-TOHAMY R., ZHU D., MAHMOUD Y.A., KOUTRA E., METWALY M.A. (2021). Plastic Waste Biodegradation: Mechanism, Challenge and Future Prospects. Science of the Total Environment,780. http://doi.org/10.1016/j.scitotenv.2021.149712

ARUTCHELVI J., SUDHAKAR M. ARKATKAR A., DOBLE M., BHADURI S., UPPARA P.V. (2008) Biodegradation of polyethylene and polypropylene. Indian Journal of Biotechnology, 7:9-20.

ASM - American Society of Mrcrobiology (2020) Identifying bacteria through look, growth, stain and strain. retrieved: http://www.asm.org/article

AZEKO S.T., ETU-UDO G.A., ODUSANYA O.S. MALATESTA K., ANUKU N., SOBOYEJO W.O. (2015) Biodegradation of Linear Low Density Polyethylene by SerratiaMarcescens subsp. marcescens and its Cell Free Extracts. Waste Biomas Valor, 6:1047-1057. https://doi.org/10.1007/S12649-015-9421-0.

AZIZA A., FAIRUS S., SAARI (2024) Isolation and characterization of polyethylene and polyethylene teraphthalate -degrading bacteria from Jakarta, Indonesia. The Open Biotechnology Journal,18:e187400787280343 http://dx.doi.org/10.2174/0118740707280343231208102253

BARDAJI D.K.R., FURLAN J.P.R., SHEHLING E.G (2019) Isolation of a Polyethylene Degrading Paenibacillius sp. from a landfill in Brazil. Archives of Microbiology, 201: 699-704. https://doi.org/10.1007/S00203-019-01637-3.

BHARDWAJ H., GUPTA R., TIWARI A. (2012) Microbial Population Associated with Plastic Degradation. Open Access Scientific Reports, 1(5):272-274. http://dx.doi.org/10.4172/scientificreport.272

BIKI S.P., MAHMUD S., AKHTER S., RAHMAN M.J., RIX J.J., AL BACHCHU M.A., AHMED N. (2021) Polyethylene degradation by Ralstonia sp. strain SKM2 and Bacilliussp strain SMI isolated from landfill soil site. Environmental Technology and Innovation, 22. http://doi.10.1016/j.eti.2021.101851.

BRANDSON A.M., GARCIA A.M., KHLYSTOV N.A., WU W.M., CRIDDLE C.S. (2021) Enhanced bioavailability and degradation of polystyrene in an enrichment derived from the gut microbiome of Tenebrio molitor(meal worm larva). Environmental Science and Technology, 53 (3):2027–2036. https://doi.org/10.1021/ace.est.0c04952

DOI: 10.6092/issn.2281-4485/20474

CHAMAS A., MOON H., ZENG J.J., QUI Y., TABASSUM T., JANG J.H., ABU-OMAR M., SCOTT S.L., SUH S. (2020) Degradation rates of plastic in the environment. ACS Sustainable Chemistry and Engineering, 8:3494 -3511. https://doi.org/10.1021/acssuschememg.9b06635

CHEESBROUGH M. (2006) Biochemical tests to identify bacteria. In: Cheesbrough M. (ed). District laboratory practice in tropical countries, part 2, 2nd Edition. Cambridge University Press, UK, pp 62-70.

CHEN M., LIU Z., JIANA S., HOU H. (2020) A feasible route for reutilization of plastic wastes. Science of Total Environment, 710. http://doi.org/10.1016/j.scitotenv.2020.136256

DEVI D., GUPTA K.K., CHANDRA H., SHARMA K.K., SAGA K., MORI E., MALA DE FARIA (2023) Biodegradation of low-density polyethylene (LDPE) through application of indigenous strain *Alicalinenes faecalis* ISJ128.Environmental Geochemistry and Health. 45(12): 9391-9401 https://doi.org/10.1007/s10652-023-01590-z

EMMANUEL-AKERELE H.A., AKINYEMI P.O., IGBOGBO-EKPUNOBI O.E. (2022) Isolation and identification of plastic degrading bacteria from Dumpsites – Lagos. Advances in Environmental Technology, 1:59–71. https://doi.org/10.22104/AET.2020.5268.1428

ESMAEILI A., POURBABAEE A.A., ALIKHANI H.A., SHABANI F.,ESMAEILI E. (2013) Biodegradation of low densitypolyethylene (LDPE) by mixed culture of Lynsinibacillusxylanilyticus and Aspergillus nigerin soil. PLOS ONE, 8(9):1-10. https://doi.org/10.1371/journal.pone.0071720

GILAN I., HADAR Y., SIVAN A. (2004) Colonization, biofilm formation and biodegradation of polyethylene by a https:/strain of Rhodococcusrubber. Applied Microbiology and Biotechnology, 65:97-104. https://doi.org/:10.1007/500253-004-1584-8 04

HADAD D., GERESH S., SWAN A. (2005) Biodegradation of polyethyelene by the thermophilic bacteriumBrevibacillusborstelensis. Journal of Applied Microbiology, 98:1093 -1100. https://doi.org/10.1111/j.1365-2672-2005.02553.x

HAJRAMURNI A. (2018) Indonesia aims to tackle plastic waste. www.thejakartapost.com

IBIENE A.A., STANLEY H.O., IMMANUEL O.M. (2013) Biodegradation of polyethylene by Bacillus sp. Indigenous to the Niger Delta Magrove Swamp. Nigerian Journal of Biotechnology, 26: 68-79. ISSN: 0189 17131

JAINA A., PANIGRAHY S.S., DONGRE N., JAIN P. (2023) Isolation and Characterization of Plastic-Degrading Bacteria from the Soil. Scope, 13(4): 838-842. https://7d17c-838-842.202317754

JANDA J.M., ABBOTT S.L. (2007) 16S rRNA Gene sequencing for bacterial identification in the diagnostic laboratory. Journal of Clinical Microbiology, 45(9):2761-2764.

KHANDARE S.D., CHAUDHARY D.R., JHA B. (2021) Marine bacterial biodegradation of low-density polyethylene (LDPE) plastic. Biodegradation, 32(2):127-143. https://doi.org/10.1007/51032-021-09927-0

KOPECKA R., KUBINOVA I., SOVOVA K., MRAVCOVA L., VITEZ T., VITEZOVA M. (2022) Microbial degradation of virgin polyethylene by bacteria isolated from a landfill site. SN Applied Sciences, 4:302-312. https://doi.org/10.1007/s42452-022-05182-x

KUBOWICZ S., BOOTH A.M. (2017) Biodegradability of plastics: Challenges and Misconception. Environmental Science and Technology, 51(21):12056 -12060. https://doi.org/10.1021/ace.est.7b04051

LIN Z., JIN T., ZOU T., XU L., XI B., XU D., HE J. (2022). Current Process on Plastic/Microplastic Degradation: Fact influences and mechanism. Environmental Pollution, 304:119-159. doi:10.1016/j.envpol.2022.119159

LONGO C.,SAVARIS M., ZENI M., NICHELE R.B., COULON GRISA A.M. (2011) Degradation study of polypropylene (pp) and bioriented polypropylene (BOPP) in the environment. Materials Research, 14(4). http://dx.doi.org/10.1590/51516-14392011005000080

MUKHERJEE S., ROYCHAUDHURU U., KUNDU P.P (2018) Biodegradation of polyethylene via complete solubilization by the action of Pseudomonas fluorescence, biosurfactant produced by Bacillius licheniformis and anionic surfactant. J. Chem. Technology Biotechnology, 93: 1300-1311. http://doi.org/10.1002/jctb.5489

NAG M., LAHIRI D., DUTTA B., JADAV G., RAY R.R. (2021) Biodegradation of used polyethylene bags by a new marine strain of Alcaligenes faecalis LNDR-1. Environmental Science Pollution Researc International, 28(30):41365-41379. DOI:10.1007/S11356-021-13704-0

NANDA S. SAHU S.S., ABBRAHAM J. (2010) Studies on the biodegradation of natural and synthetic polyethylene by Pseudomonas spp. Journal of Applied Science and Environmental Management, 14(2):57-60. ISSN:1119-8362.

NI Z., MINGZHU D., YINGJIN Y. (2022) Current Advances in Biodegradation of polyolefins. Micro organisms, 10(8):1537. https://doi.org/10.3390/microorganisms.100081537

NOVOTNY C., MALACHOVA K., ADAMUS G., KWIEDIEN M., LOTTI N., SOCCIO M., VERNEY V., FAVA F. (2018) Deteriotation of irradiation/high-temperature pretreated Linear Low- Density PE (LLDPE) by

DOI: 10.6092/issn.2281-4485/20474

Bacilliusamyloliquefaciens. International Journal of Biodegradation 132:259-267. https://doi.org/:10.1016/j.ibiod.2018.04.014

OGBULIE T.E., NWAKANMA C. (2015) Essential Analytical Methods in Biotechnology. Unique Books Publisher, Nigeria. pp. 63-89.

PATIL R., BAGDE U.S. (2015) Enrichment and isolation of microbial strains degrading bioplastic polyvinyl alcohol and time course study of their degradation potential. African Journal of Biotechnology. 14(27):2216-2226. https://doi.org/10.5897/AJB2011.3980.

PRAJAPATI R., KHOLI K., MAITY S., SHARMA B.K (2021) Potential chemicals from plastics waste. Molecules, 26(11):3175. https://doi.org/10.3390/molecules26113175

REN L., MEN L., ZHANG Z., GUAN F., TIAN J., WANG B., WANG J., ZHANG Y., ZANG W. (2019) Biodegradation of Polyethylene by Enterobacter sp. D1 from the Gut of Wax Moth Galleria mellonella. International Journal of Environmental Research and Public Health,16:1941. https://doi.org/10.3390/ijerph16111941

SAMBROOK J., RUSSELL D.W (2001) Molecular cloning: A laboratory Manual. 3rd Edition. Cold Spring Harbor Laboratory Press, NY, USA.

SKARIYACHAN S., SETTUR A.S., NAIK S.Y., NARK A.A, USHARAN M.,VASIST K.S. (2017) Enhanced biodegradation of low and high-density PE by novel bacterial consortium formulated from plastic contaminated cow dung under thermophiolic conditions. Envionmental Science and Pollution Research 24:8443-8457. https://doi.org/10.1007/s11356-017-85370

SKARIYACHAN S., PATIL A.A, SHANKAR A., MANJUANTH M., BACHAPPANAVAR N., KIRAN S. (2018) Enhanced polymer degradation of polyethylene and polypropylene by novel thermophilic consortia of Brevibacilliussps. and Aeurinibacillius sp. screened from waste management landfills and sewage treatment plants. Polymer Degradation stability 149:52-68. https://doi.org/10.1016/j.polymdegradstab.2018.018

SRIKANTH M., SANDEEP T.S.R.S., SUCHANTHA K.K., GODI S. (2022) Biodegradation of plastic polymers by fungi: A brief review. Bioresources and Bioprocessing, 9(42). https://doi.org/10.1186/540643-022-00532-4

UGUERI U., ATUNANYA E.I., USMAN Z. (2022) Biodegradation of polystyrene plastics by bacterial isolation from plastic composted waste oil and molecular charactyerization of plastic degrading bacterial isolates. African Journal of Microbiology Research, 16(6).247-257. https:/doi.org/10-5897/AJMR2022.9341

UWAKWE F.E., EZEJIOFOR T.I.N., OGBULIE T.E., ANYALOGBU E.A.A., OKAFOR S.A. (2023) Investigating the Biodegradation of Low-Density Polyethylene by *Proteus and Serratia* Spp. Engineering and Technology Journal, 8(3):2052-2055. doi:104719/etj/v8i3.08

UWAKWE F.E., EZEJIOFOR T.I.N., OGBULIE T.E., ANYALOGBU E.A.A. (2023) A Comparative Study of Biodegradation of Low-Density Polyethylene by Proteus and Lactobacillus Spp. International Journal of Advanced Research in Biological Sciences, 10(7): 93 – 102. https://doi.org/10.1007/s42770-024-01487-8

YOON M.G., JEON H.J., KIM M.N. (2012) Biodegradation of polyethylene by a soil bacterium and alkb cloned recombinant cell. Journal of Bioremediation and Biodegradation 3(145). https://doi.org/10.4172/2155-6199-.1000145

ZHANG Y., PENDERSON J.N., ESER B.E., GUO, Z.(2022) Biodegradation of polyethylene and polystyrene: From microbialdeteroriation to enzyme discovery. Journal of Biotechnology Advances, 60:107991. https:/doi.org/10.1016/j.biotechadv.2022.107991