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RESEARCH PAPER

Bio-transformation of untreated polyethylene sheet by *Serratia marcescens* with polyethylene-polymerase activity

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Key Message: The study shows that *Serratia marcescens* has the ability to produce laccase, manganese peroxidase, and esterase, which are enzymes essential for the degradation of polyethylene. It reveals that the synergetic activities of these enzymes produced by *Serratia marcescens* significantly enhance the biodegradation of polyethylene and emphasizes bioremediation as an effective approach for managing plastic pollution to achieve a green environment.

Abstract

Polyethylene (PE) wastes is a threat to the ecosystem and microbes with variant enzymatic activities have been revealed as excellent degraders of PE wastes, however, knowledge of their physicochemical properties are essential to suggest an effective condition for the bio-degradation process. This study reveals the optimum working conditions for manganese peroxidase (MnP), laccase (Lac), and esterase produced by *Serratia marcescens* in polyethylene-based medium (PBM) incubated at pH 7.0, 37 ^{o}C, and 180 rpm for a month, and shows the biodegradation efficiency of *Serratia marcescens* on unmodified PE sheet. The activities of the enzymes, and their physicochemical properties were evaluated by spectrophotometric method, and the degradation activity of *S. marcescens* on unmodified polyethylene sheet was analyzed via scanning electron microscope (SEM) and fourier transform infrared spectrophotometer (FTIR). The result revealed maximum activities of MnP (6.88 U/mg) and esterase (5.62 U/mg) on day ten, while Lac activity (7.53 U/mg) was optimum on the eighth day of cultivation. The physicochemical study showed the enzymes were active and stable over a broad range of pH and temperature with optimum MnP activity at pH 7.0 and 60 °C, Lac activity at pH 5.0 and 50 ^{o}C, and esterase activity at pH 9.0 and 50 °C. Activities of MnP, Lac, and esterase were enhanced in the presence of Ca^{2+} and Mg^{2+} and chelated by EDTA. Pits and holes were displayed on the SEM profile of the *S. marcescens*-degraded PE sheet, while aromatic OH and carboxylic functional groups were seen on the FTIR spectra of the degraded PE sheet. In conclusion, this study shows *S. marcescens* has PE biodegradation potentials and produces thermostable activities of MnP, Lac, and esterase which can be adopted for industrial processes, and plastic biodegradation to achieve a green environment.

Keywords: Esterase, Laccase, Manganese peroxidase, Polyethylene (PE), *Serratia marcescens*

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Introduction

The demand for plastic polymers in homes and industries for packaging of manufactured goods has ranked plastic polymers as the most enormously used commodity of the 21st century (Koshti et al., 2018; Mohan et al., 2025). Among the various types of plastics, polyethylene (PE) is the most prevalent due to its wide usage in homes and packaging industries as elucidated by its chemical composition (Hiraga et al., 2019). Polyethylene is a polymer with ethene subunit (Hiraga et al., 2019). Polyethylene is used to produce plastic bags, films, containers and bottles (Maurya et al., 2020). According to Taniguchi et al. (2019), polyethylene (PE) polymer used in homes and packaging industries accounts for about 19 million tons out of an estimate of 260 million tons of the annually produced plastic polymers. Although the use of PE has supported daily human activities, the indiscriminate use of PE and its numerous derivatives, coupled with improper disposal mechanisms, has led to the widespread accumulation of PE waste in the environment (Kamala et al., 2025).

The conventional methods used for managing PE wastes includes; recycling, incinerating and landfilling. However, only about 20% of PE wastes are recycled into films, fiber, sheets, and bottles while others are either incinerated or dumped on landfill sites in the environment (Taniguchi et al., 2019). Similarly, these methods are not effective because they are exorbitant and environmentally unfriendly and PE wastes discarded in the environment threaten various terrestrial and aquatic forms of life (Ogunjemite et al., 2023). Amidst the

remediation methods that have been previously deployed to manage PE wastes, biological remediation (which involves the use of microbes and enzymes) has been identified as the most efficient strategy for PE waste management (Yanbing et al., 2020). These remediation techniques do not only sustainably manage PE wastes but also produce environmentally friendly end products (Danso et al., 2019).

During PE biodegradation ultra-violet (UV) radiation or heat act as bio-deteriorating agents altering the properties of PE, afterwards enzymatic activities are produced by the microbes to break PE polymer into monomers or subunits. These PE-subunits are ingested into the cells of the microbes, and metabolized to generate adenosine triphosphate for cellular activities (Ogunjemite et al., 2023) while nitrogen gas, water, and carbondioxide are released as wastes (Pathak et al., 2017; Ogunjemite et al., 2023). Different studies have unveiled bacterial and fungal species as bio-degraders of PE (Zuriash et al., 2023), hence, *Serratia marcescens* was used for this study. *Serratia marcescens* is a bacillar, Gram-negative bacterium in the *Enterobacteriaceae* family (Kahrarian et al., 2019). *Serratia marcescens* is a facultative anaerobe found in water, soil, insects, and plant surfaces. Extracellular enzymes such as manganese, cellulase, amylase, chitinase, and protease have been produced from *Serratia marcescens* (Cahyani et al., 2017). However studies on polyethylene polymerase such as MnP, lignin peroxidase, laccase, and esterase from *Serratia marcescens* are limited. Esterase is a hydrolytic enzyme that catalyzes the cleavage of ester bond found in intermediate product of PE degradation (Koshti et al., 2018).

Ligninolytic enzymes such as manganese peroxidase (MnP), lignin peroxidase (LiP), and laccase (Lac) are oxidative enzymes that break PE polymer into monomers (Bai et al., 2025). During PE biodegradation, microbes produce laccase to form carbonyl group to weaken the surface of PE while manganese peroxidase is produced to hydrolytically cleave PE monomers and esterase's is synthesized to break ester bonds in the monomers until H_2O and CO_2 is released (Sunil et al., 2020). These enzymes work synergistically to enhance the process of PE biodegradation (Yan et al., 2022). In addition, understanding the enzymatic mechanisms involved in PE biodegradation is crucial for optimizing microbial-based strategies for plastic waste mitigation. The identification of efficient PE-degrading enzymes from bacteria such as *Serratia marcescens* could contribute to the development of eco-friendly and cost-effective alternatives to conventional plastic waste management methods (Nedi et al., 2024). Studies on the biodegradation of unmodified polyethylene sheets by bacteria and fungi with their enzymatic activities are limited. Hence, in this study, *S. marcescens* was screened for the production of manganese peroxidase, laccase, and esterase under PE exposure (PBM) and the physicochemical properties of the enzymes were determined. In addition, the degradation potentials of *S. marcescens* on unmodified PE sheets was also elucidated and assessed through scanning electron microscopy (SEM) and fourier transform infrared spectrophotometry (FTIR).

Materials and Methods

Preparation of polyethylene (PE) sheet

Trashed water sachet nylons (100 pieces) were taken from waste bins at different cafeteria in Elizade University. The water sachet nylons were confirmed as polyethylene by the Chemistry Unit, Physical and Chemical Sciences Department, Elizade University, Nigeria. The polyethylene nylons were manually minced and sieved through a 0.4 mm sieve for uniformity. The polyethylene particles were later washed in running water, and decontaminated by soaking in a solution of sterile and 90% ethanol for 1 h (Azeko et al., 2015).

Preparation of *Serratia marcescens* culture and enzymes production

Serratia marcescens isolated in our laboratory was used for this study (Ogunjemite et al., 2024). The *Serratia marcescens* was maintained on nutrient agar slant stored at 4 °C. *Serratia marcescens* culture was prepared in 100 mL sterile nutrient broth containing 0.5 g peptone, 0.5 g NaCl, 0.15 g beef extract, and 0.15 g yeast extract incubated at 37 ^{o}C, pH 7.0, and 180 rpm for 24 h. Similarly, 350 mL polyethylene-based medium (PBM) was prepared in a sterile Erlenmeyer flask. PBM contained 0.01 g PE sheet, 0.7 g NH_4NO_3, 0.7 g KH_2PO_4, 0.07 g $KH_2PO_4{\cdot}12H_2O$, 0.28 g NaCl, 0.28 g KCl, 0.035 g $CaCl_2{\cdot}2H_2O$, 0.07 g $MgSO_4$, and 0.007 g $FeSO_4{\cdot}7H_2O$. Ten percent (10%) of *Serratia marcescens* culture was then added into the PBM and incubated at 37 ^{o}C, pH 7.0, and 180 rpm, for 30 days to screen for esterase, MnP, and laccase activities produced by *Serratia marcescens.* Erlenmeyer flask containing PMB without *Serratia marcescens* culture was used as the control. The experiment was replicated thrice. Every 48 h, 7 mL was aseptically pipetted from the PBM and centrifuged at 10,000 rpm for 20 min at 4 °C. The activity of cutinase, lipase, and esterase were then assayed from the supernatant. Total protein concentration in the filtrate was also evaluated by bovine serum albumin (BSA) as described by (Olajuyigbe et al., 2016) to determine the specific activities of the enzymes. PBM was freshly prepared, and each enzyme was produced on the day of its optimum activity. The cultivation period was terminated by centrifuging the culture at 10,000 rpm, and 4 °C for 20 minutes, and the supernatant was used for the characterization studies.

Manganese peroxidase assay

Manganese peroxidase (MnP) activity was determined by studying the oxidation of phenol red in the presence of MnP, and H_2O_2. The reaction mixture contained 0.5 mL of the supernatant, 0.05 mM manganese sulfate (0.4 mL), 0.05 mM phenol red (0.7 mL), 25 mM sodium succinate buffer (1 mL), gelatine 1mg/mL, and 25 mM sodium lactate (1 mL). 1 mL of

the reaction mixture was then introduced into 5 N NaOH (0.2 mL) and H_2O_2 (0.5 mL) was added to initiate the reaction at 30 °C and the absorbance was read at 600 nm in a visible spectrophotometer (ε600 = 22 mM^{-1} cm^{-1}) (Kheti et al., 2023).

Laccase assay

Laccase activity was determined by measuring the oxidation of 1mM ABTS (2, 2'azino-di-[3-ethylbenzothiazoline-6-sulphonic acid) in phosphate buffer of 50 mM concentration at pH 4.5. The reaction mixture includes 1.5 mL ABTS and 1.5 mL of the supernatant. The ABTS cation formed was assessed by taking the absorbance of the reaction mixture at 420 nm in a visible spectrophotometer for 5 min (ε420 = 36 mM^{-1} cm^{-1}) (Elsayed et al., 2023).

Esterase assay

Esterase activity was assayed by evaluating the release of p-NP butyrate. The substrate mixture contained 0.5 mM p-NP butyrate (C_4) in methanol, 50 mM tris-HCl buffer (pH 8) and 0.1% Triton X-100. The reaction mixture contained 400 µl of substrate mixture and 40 µl of the supernatants incubated at 37 °C for 1 h. Enzyme activity was determined by measuring the release of p-NP at an absorbance of 405 nm (ε405 ¼ 18 mM^{-1} cm^{-1}) (Ramnatha et al., 2017).

Characterization of enzymes produced by *Serratia marcescens*

The activities of MnP, laccase, and esterase were measured at different temperatures (30 °C–80 °C) to determine the optimum temperature for enzyme activity. The enzymes were incubated for 3 h at each of the temperatures, and their activities were assayed to determine the effect of temperature on the stabilities of the enzymes (Ogunjemite et al., 2024). Likewise, the activity of MnP, laccase, and esterase in different buffer solutions was investigated to determine the optimum pH of the enzymes. Glycine-HCl buffer (pH 3); sodium acetate buffer (pH 5); Tris-HCl buffer (pH 7), and glycine-NaOH buffer (pH 9 and pH 11) were used for the study. The enzymes were incubated at 37 ^oC for 3 h in the buffers to obtain the stability of the enzymes at different pH (Ogunjemite et al., 2024). Furthermore, 1mM, 5mM, and 10 mM Ca^{2+}, Cu^{2+}, Ba^{2+}, Mg^{2+}, Mn^{2+}, and Hg^{2+} buffers were used to investigate the effect of metal ions on the enzymes activities. Metal chelating effect of ethylene diamine tetraacetic acid (EDTA) on the activities of the enzymes was also analyzed (Ogunjemite et al., 2024).

Biodegradation studies of polyethylene sheet

Unmodified PE sheets (2 cm × 2 cm) manually cut from water sachet nylon was used for this study. Polyethylene (PE) sheets of 0.1 g was measured and disinfected in a sterile solution of 70% (v/v) ethanol, and sterile water. The PE sheet was then added into aseptic Erlenmeyer flask containing freshly prepared 300 mL *S. marcescens* culture pH 7.0 and incubated at 50 ^oC in a shaking incubator at 180 rpm for 30 days. Erlenmeyer flask containing only PE sheets in sterile nutrient medium was used as the control. The experimental setup was in triplicate. At the end of the experiment, PE sheets were retrieved from the in vitro biodegradation setup and washed with several milliliters of aseptic distilled water. The PE sheets were air-dried overnight until a constant weight was obtained, and the degree of degradation was assessed by Zeiss Evo MA variable pressure scanning electron microscope (SEM) (Carl Zeiss STM AG, Germany) (Ibrahim et al., 2009). Fourier transform infrared (FTIR) spectrophotometer (Shimadzu FTIR spectrophotometer) was also used to investigate alterations in bonds and functional groups in the degraded PE sheet compared to the control (control) (Mohanan et al., 2020).

Statistical analysis

Results are recorded as mean ± standard deviation. The data were analyzed using the one-way analysis of variance. The mean values were correlated with the Duncan test and statistical package for social sciences (SPSS) by IBM version 16 was used.

Results

Enzyme production in polyethylene-based media (PBM)

Manganese peroxidase (MnP), Lac and esterase production by *S. marcescens* in the submerged culture of PBM are shown in Fig. 1. On the tenth day, MnP and esterase were optimally produced and 6.88 U/mg, and 5.62 U/mg specific activities were recorded, while on the eighth day Lac activity (7.53 U/mg) was maximally produced.

Effect of pH on MnP, Lac, and esterase activity and stability

The activity of MnP produced by *S. marcescens* at different pH is shown in Fig. 2a. Optimum MnP activity was obtained at pH 7 (Fig. 2a). The enzyme showed relative activities of 60 % and 71.2% at pH 3 and pH 5 however, there was a reduction in activity to 68% at pH 9, and 30% activity was retained at pH 11. Similarly, MnP exhibited residual activities of 41.7% and 63.6% at pH 3 and pH 5 when incubated for 3 h at room temperature (Fig. 2b). At pH 7 optimum MnP stability was attained and a residual activity of 82% was recorded. Also, there was a decrease in MnP activity at pH 9, and pH 11 (69.5% and 42%).

Laccase (Lac) activity was maximally produced at pH 5 (Fig. 2c). Interesting, the enzyme showed activity over all the studied pH and more than 45% relative activity was observed at pH 11. Likewise, optimum residual activity was obtained at pH 5 while laccase residual activity reduced with an increase

in pH above pH 5 after incubation for 3 h at room temperature (Fig. 2d). Esterase showed increasing relative activity from pH 3 to pH 9 where the optimum activity was attained (Fig. 2e). Esterase retained 81% activity at pH 7 and exhibited optimum residual activity of 83.5% at pH 9 (Fig. 2f).

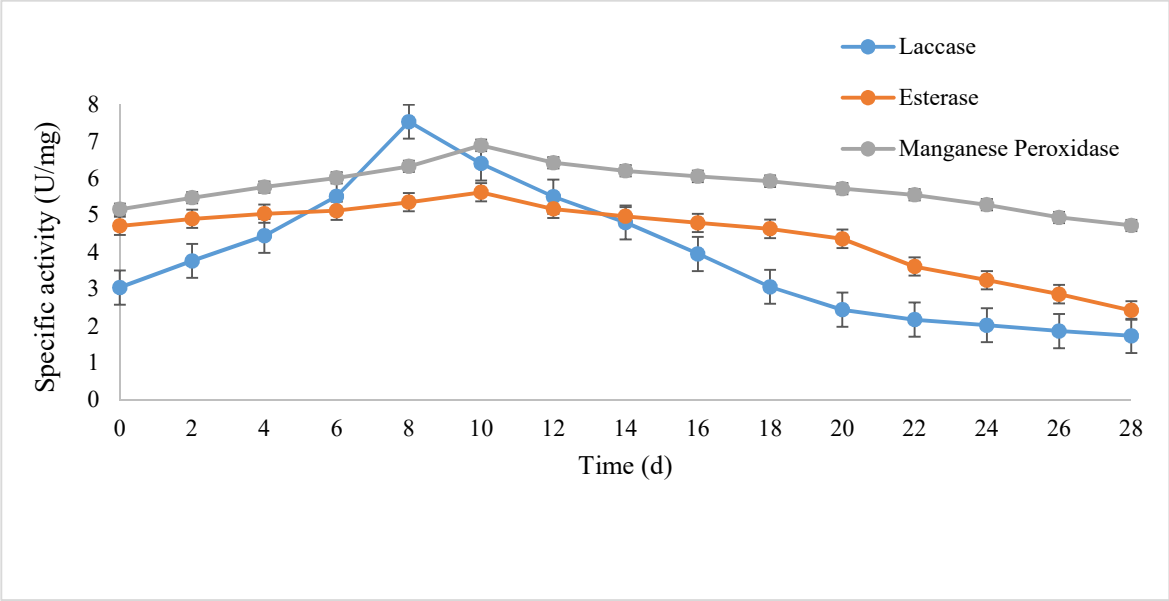
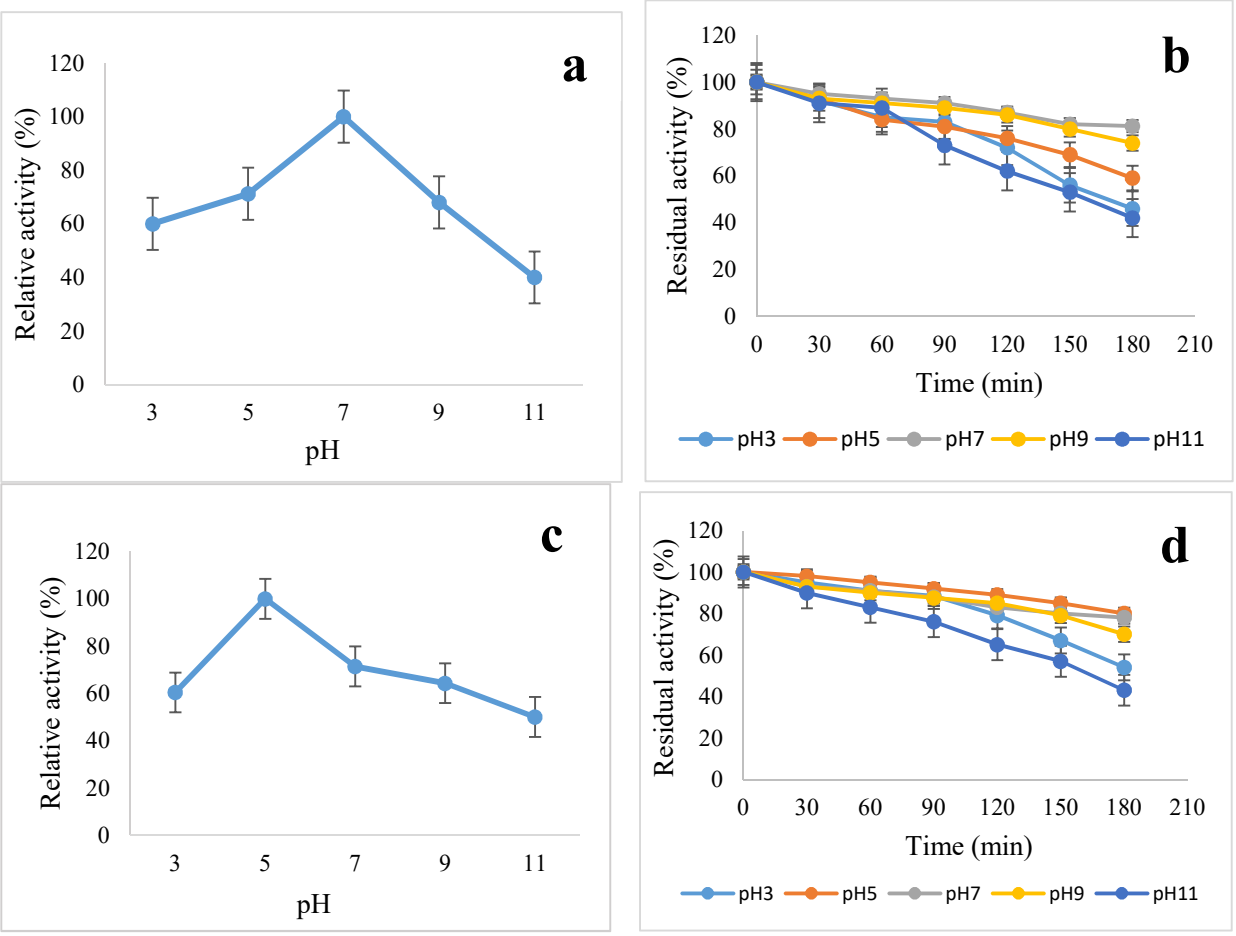


Fig. 1 Production of MnP, Lac, and esterase by *S. marcescens* in PBM. (Error bars represent mean ± standard deviation)



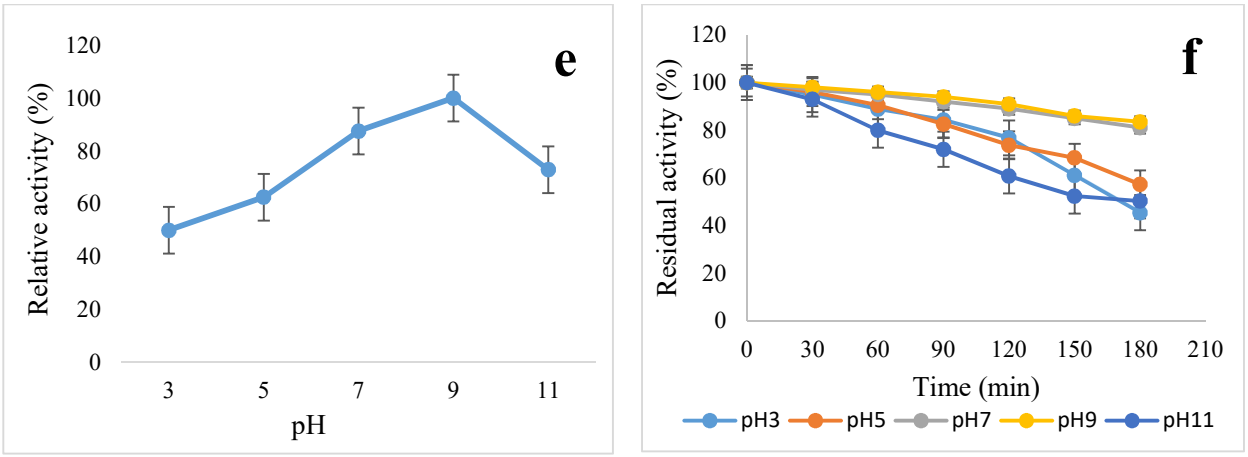
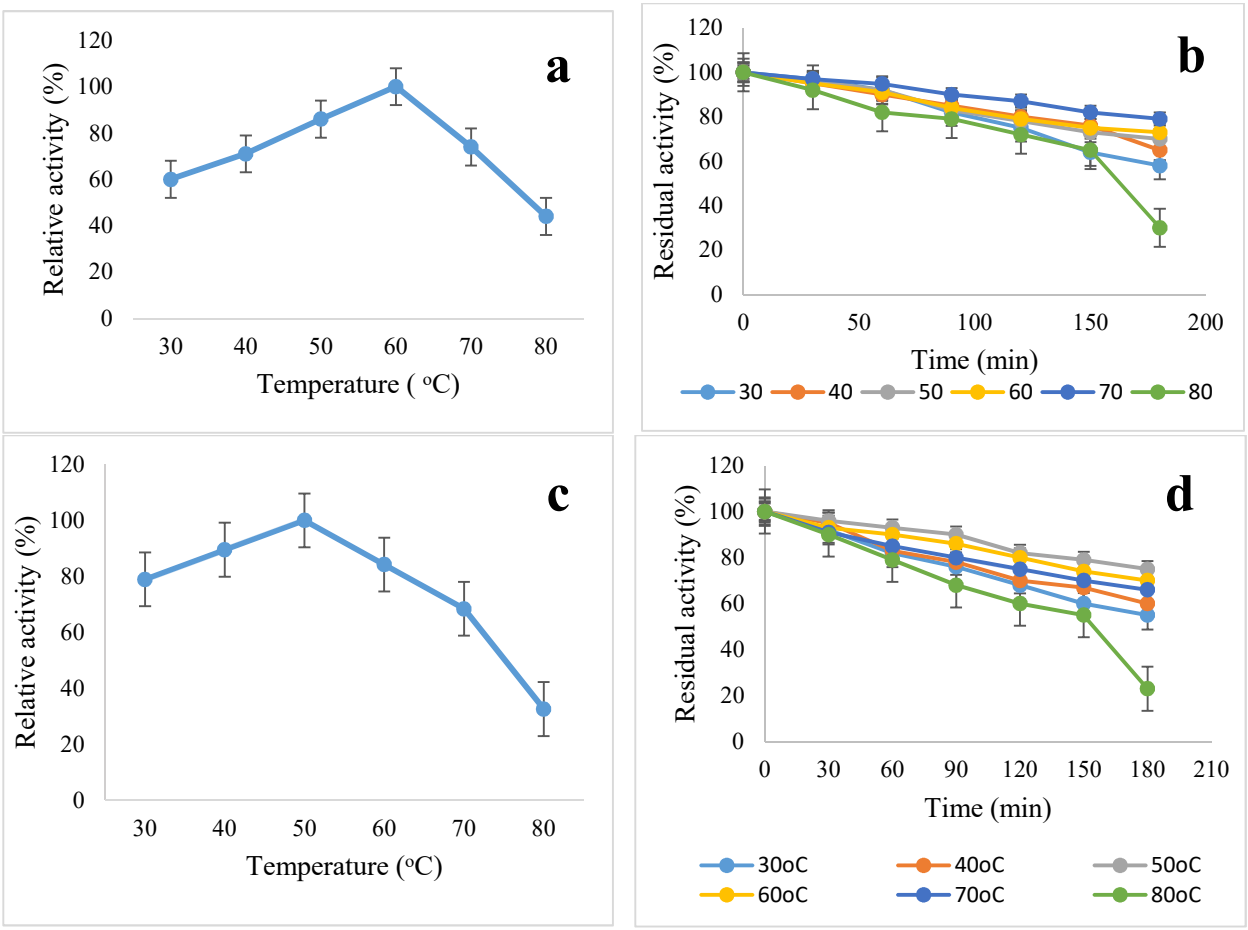


Fig. 2 Effect of different pH on (a) MnP activity, (b) MnP stability, (c) Lac activity, (d) Lac stability (e) Esterase activity, and (f) Esterase stability from *Serratia marcescens.* (Error bars represent mean ± standard deviation)



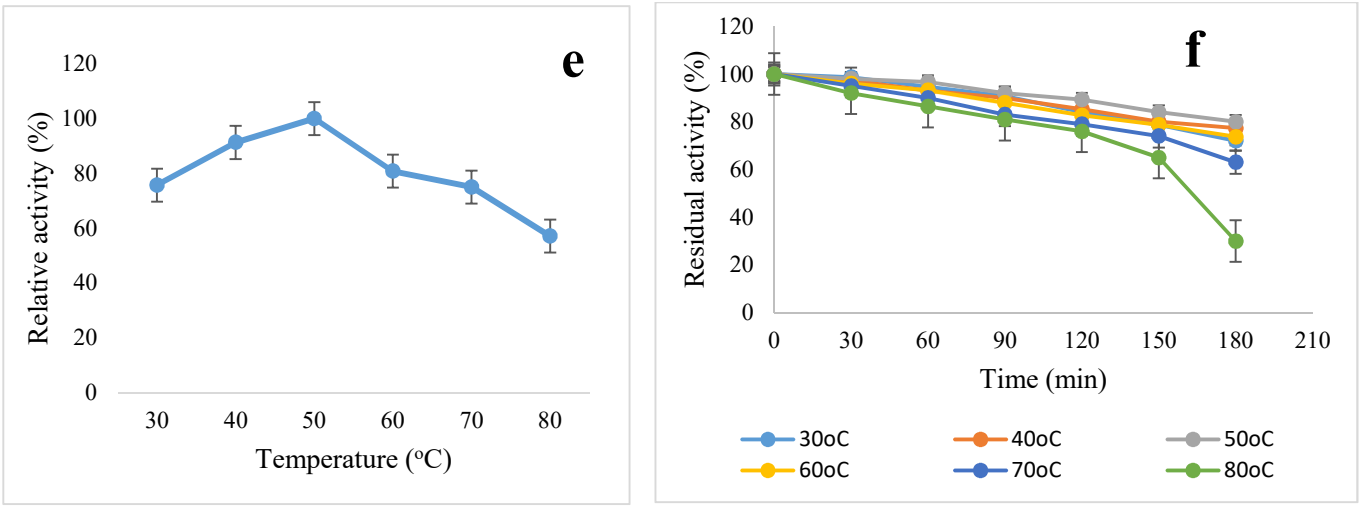


Fig. 3 Effect of temperature on (a) MnP activity, (b) MnP stability, (c) Lac activity, (d) Lac stability (e) Esterase activity, and (f) Esterase stability from *Serratia marcescens.* (*Error bars* represent Mean ± standard deviation)

Effect of temperature on MnP, Lac, and esterase activity and stability

The activity of MnP at different temperature is shown in Fig. 3a. Sixty percent (60%), 71%, and 86%, relative activities were recorded at 30 ºC, 40 ºC, and 50 ºC and optimum MnP activity was obtained at 60 ºC (Fig. 3a). Also, MnP activity was optimally stable at 60 °C after 3 h of incubation (Fig. 3b). The activity of laccase was optimum at 50 °C (Fig. 3c). Relative activity of 71% was recorded at 30°C, while the activity started reducing after 50 °C till 32% relative activity was recorded at 80 °C. Likewise 65% optimum laccase residual activity was obtained at 50 °C which reduced to 23% at 80 °C after incubation at room temperature for 3 h (Fig. 3d). Similarly, esterase was optimally active at 50 °C and the relative activities are presented in Fig. 3e. In ditto, esterase activity was optimally stable at 50 °C with 30% residual activity displayed at 80 °C.

Effect of metal ions and EDTA on MnP, Lac and esterase activity

Manganese peroxidase from *S. marcescens* exhibited 124.3±0.33 %, 166.9±0.02 % and 114.6±0.03 % increase in activity when Ca^{2+}, Mn^{2+} and Ba^{2+} (respectively) was added (Fig. 4a) except for Hg^{2+}, Cu^{2+} and EDTA. Similarly, laccase activity was elevated significantly by Cu^{2+} (125±0.02 %), Ca^{2+} (119±0.02 %), and Mg^{2+} (108±0.03 %) (Fig. 4b). Esterase activity was enhanced by Mg^{2+} (118 ±0.02 %), Ba^{2+} (110±0.01 %), and Ca^{2+} (125±0.03 %). Esterase activity was significantly reduced by Hg^{2+} (33 ±0.03 %), Cu^{2+} (50 ±0.02 %), and Mn^{2+} (68 ±0.02 %). Twenty-eight percent (28 ±0.02 %) relative activity was obtained when EDTA was added to the solution.

Biodegradation study

The SEM surface morphology of the unmodified PE sheets before and after biodegradation with *s. marcescens* is presented in Fig. 5. The SEM profile of the PE sheet after biodegradation showed presence of holes, scrapings and cracks (Fig. 5b). The FTIR spectra of the degraded unmodified polyethylene sheet was compared with the control polyethylene sheet. The result revealed change in peaks at 400 nm wavelength to 700 nm in the degraded unmodified polyethylene sheet (Fig. 6b). Also there were alterations in peaks at 870 nm wavelength (C-C vibrations); 1060 nm (substituted ether group); 1300 nm (O-H plane bend) and 1540 nm (amide (NH) bend when compared with the control PE sheet.

Discussion

The ability of *S. marcescens* to grow in polyethylene base media shows its adaptation and utilization of polyethylene as a source of carbon for growth (Akash et al., 2025). *S. marcescens* have also been reported to be isolated during biodegradation studies of different plastic polymers by previous researchers such as Uwakwe et al. (2023); Ogunjemite et al. (2024). The production of optimum manganese peroxidase, esterase on the tenth day and production of laccase on the eighth day of *S. marcescens* growth shows the potentials of *S. marcescens* to produce PE-polymerase enzymes essential for the biodegradation process of PE (Bai et al., 2025). Similar observation was recorded by Sunil et al. (2020) who showed MnP, laccase and esterase production by bacterial isolates used for PE degradation. This result also corroborates earlier findings of Pathak et al. (2017); Gong et al. (2018); Elif et al. (2020); Maurya et al. (2020) who revealed that MnP, laccase and esterase activities are produced by bacterial and fungal isolates during PE biodegradation.

The physicochemical studies of the enzymes showed MnP activity produced by *S. marcescens* was optimum at pH 7.0. The highest MnP activity was attained at the neutral pH because according to Veronica et al. (2021) neutral pH aids MnP protonation and deprotonation states, which is essential for effective substrate binding and catalysis. MnP was likewise optimally stable at pH 7.0 because it supports the synthesis of hydrogen bonds and salt bridges needed to balance the heme-pocket in MnP structure (Veronica et al., 2021). The optimum temperature for MnP activity and stability was attained at 60 ^{o}C. This thermal activity and stability displayed by the enzyme shows the molecular structure possess thermal strength that can withstand the heat needed to degrade synthetic polymer such as PE (Muthusamy et al., 2017; Placido et al., 2020).This result also corroborates the previous study by Niyedita et al. (2024) who showed that high temperatures enhances the solubility of PE making it accessible for enzymatic reactions. Ca^{2+}, Mn^{2+} and Ba $^{2+}$ increased MnP activity because they stabilized the structure, and facilitated the interaction with the plastic polymer (PE). Also, Mn^{2+}enhanced MnP activity by aiding the conversion of Mn (II) to Mn (III) (Ogunjemite et al., 2023). EDTA inhibited MnP activity by binding to the active site, and reducing interaction of MnP with PE the substrate (Ogunjemite et al., 2023). This corroborates the findings of Olajuyigbe et al. (2015) who reported the chelating effect of EDTA on MnP.

Serratia marcescens also produced laccase with maximum activity and stability at pH 5.0. According to Elsayed et al. (2023), acidic pH increases laccase ability to oxidize both phenolic and non-phenolic substrates such as PE. Similar observation was reported by Yue et al. (2021) who showed optimum laccase activity during polyethylene bio-degradation in an acidic culture. The activity of laccase was highest at 50 ^{o}C. This agrees with Mahuri et al. (2023) who revealed 50 ^{o}C as the temperature for optimum activity of laccase from fungi isolates during polyethylene degradation. According to Vignesh et al. (2022); Cahyani et al. (2017), thermostable laccase are effective in the degradation of plastics as they help to reduce the molecular weight of the plastic polymer by increasing the carbonyl index. The result also showed that laccase activity was elevated by Cu^{2+}, Mg^{2+} and Ca^{2+}. Cu^{2+} enhanced the activity of laccase by stabilizing the copper center of the enzyme for catalytic activity leading to the production of water (Arregui et al., 2019). This result also supports the findings of Ivan et al. (2021) who reported that laccase activity produced by *Bacillus spp* was increased by $Mg^{2+}$and Cu^{2+}. However, laccase activity was lower in Ba $^{2+}$ and Hg $^{2+}$ solution as well as in EDTA (10±0.03 %). Similar observation was made by Agrawal et al. (2018); Krishnaswamy et al. (2022) who showed that laccase activity produced by *Pseudomonas spp* during plastic degradation was reduced by Mn^{2+}, Ca^{2+} and EDTA because their presence altered the structural conformation of the enzyme and inhibited its activities. In addition, the result showed *Serratia marcescens* produced esterase with highest activity and stability at pH 9. According to Rodriguez et al. (2024), alkaline condition improves substrate ionization of esterase, and breaking of ester bonds in the polyethylene. The alkaline (pH 9.0) also maintained esterase activity over a longer period, making efficiently stable at the pH (Yi et al., 2021). Esterase was active and stable at 50 ^{o}C because it has thermo-stability that maintains the 3 dimensional structure without being denatured (Niyedita et al., 2024). The metal ions (Ca^{2+}, Mg^{2+} and Ba^{2+}) enhanced esterase. According to Yi et al. (2021), Ca^{2+}, Mg^{2+} and Ba^{2+} increases esterase activity by maintaining the structural conformation of esterase for effective catalytic activity.

A visual analysis is an important technique for elucidating the rate of PE biodegradation, because alterations in the physical morphology of PE usually occur before the complete degradation process (Raddadi et al., 2019). The result showed that the SEM profile of the PE sheet after biodegradation displayed holes, scrapings and pits which are types of surface alteration (Arshad et al., 2025; Trad et al., 2025). Alterations in physical morphology such as cracks and holes were also revealed on the surface of PE treated by *Microbulbifer hydrolyticus IRE-31* and *Bacillus pacificus* (Raddadi et al., 2019; Peng et al., 2020). The FTIR spectra of the degraded unmodified polyethylene sheet is presented in Fig. 6. Notably, C-C aromatic stretch, and carboxylic acid O-H stretch were displayed at 2900 nm and 3440 nm wavelengths showing *S. marcescens* degradative activity on the unmodified PE sheet. The observed C-H stretch shows reduction of di-acid and di-alcohol groups in the PE polymer, and indicates the effective hydrolysis of polyethylene (Li et al., 2020). This result corroborate the previous study by Spinal et al. (2021); Arshad et al. (2025) who detected O-H, and carboxylic group (-OH, -COOH) as degradation products in the FTIR spectra of biodegraded polyethylene.

Conclusion

In this study, *Serattia marcescens* produced thermostable MnP, Lac, and esterase with optimum activities at 60 ^{o}C, 50 ^{o}C, and 50 ^{o}C in polyethylene based media respectively. The enzymes also showed activities over a broad range of pH, and optimum activities and stabilities were recorded at pH 7, pH 5, and pH 9 respectively. MnP activity was increased in the presence of Ca^{2+}, Mn^{2+} and Ba^{2+}. Lac activity was enhanced by Ca^{2+}, Cu^{2+} and Mg^{2+}, while esterase activity was elevated by Ca^{2+}, and Ba^{2+}. Grooves, scrapings, and cracks were seen on the SEM micrograph of the PE sheet after 30 days biodegradation period, while the spectra of the degraded polyethylene sheet revealed O-H group, and carboxylic group (-OH, -COOH) which are products of PE hydrolysis. In conclusion, this research shows the distinct physicochemical properties of MnP, Lac, and esterase synthesized by *S. marcescen*s and the biodegradation potentials of *S. marcescens* on unmodified PE. Hence, we recommend exploring *S. marcescens* for industrial applications, particularly its potential use in polyethylene degradation, to promote a greener environment.

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Authors' Contributions: F.O. designed the research study. O.O. performed the experiments. D.S. did statistical analysis and wrote the protocols. J.A. wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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Data availability: The data that support the findings of this study are available with the corresponding author upon reasonable request.

Declarations

i. Ethics approval and consent to participate: Ethical approval and informed consent were not required for this study as it did not involve human participants, human data, or animals.

ii. Conflict of Interest: The authors declare that there are no conflicts of interest.

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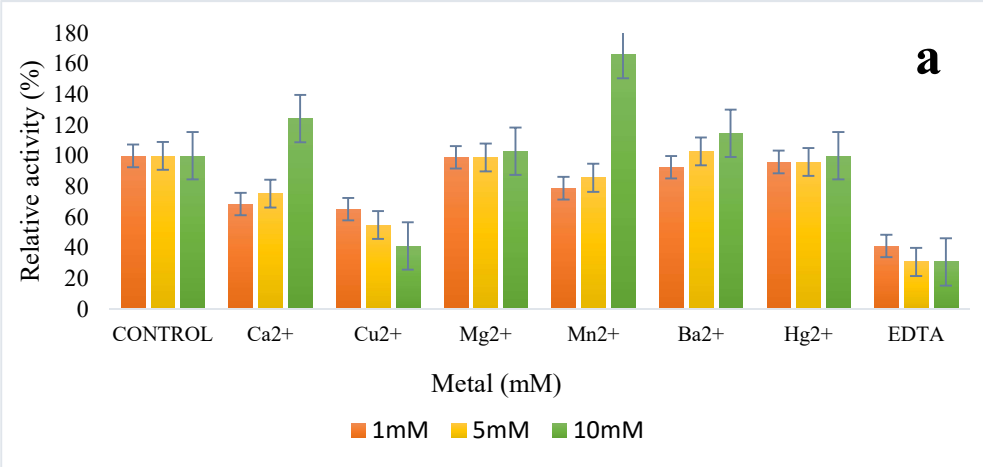

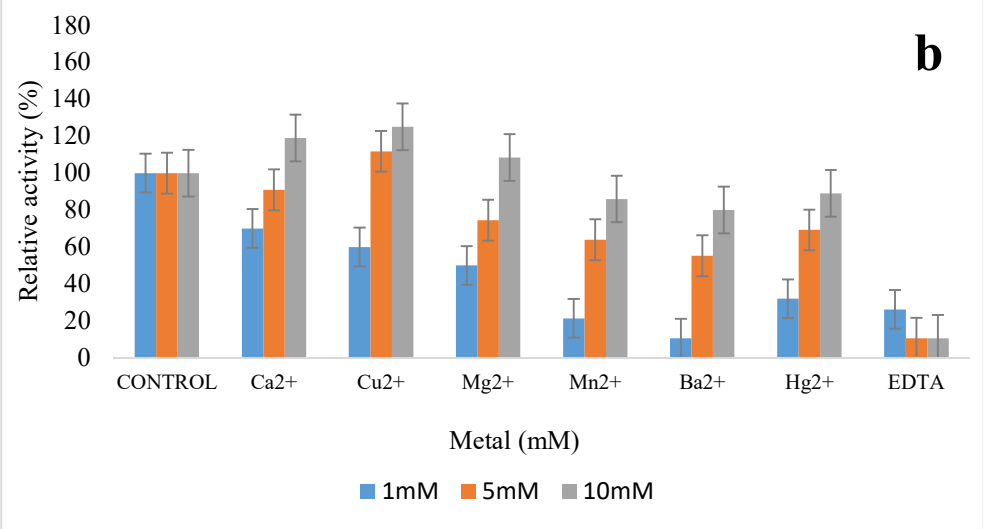

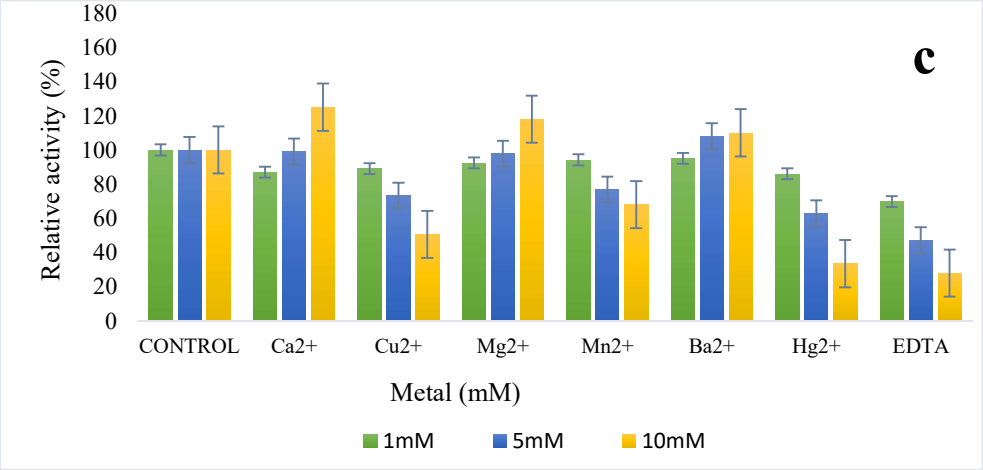

Fig. 4 Effect of metal ions on (a) MnP activity (b) Lac activity and (c) Esterase activity from *Serratia marcescens* (Error bars represent mean ± standard deviation)

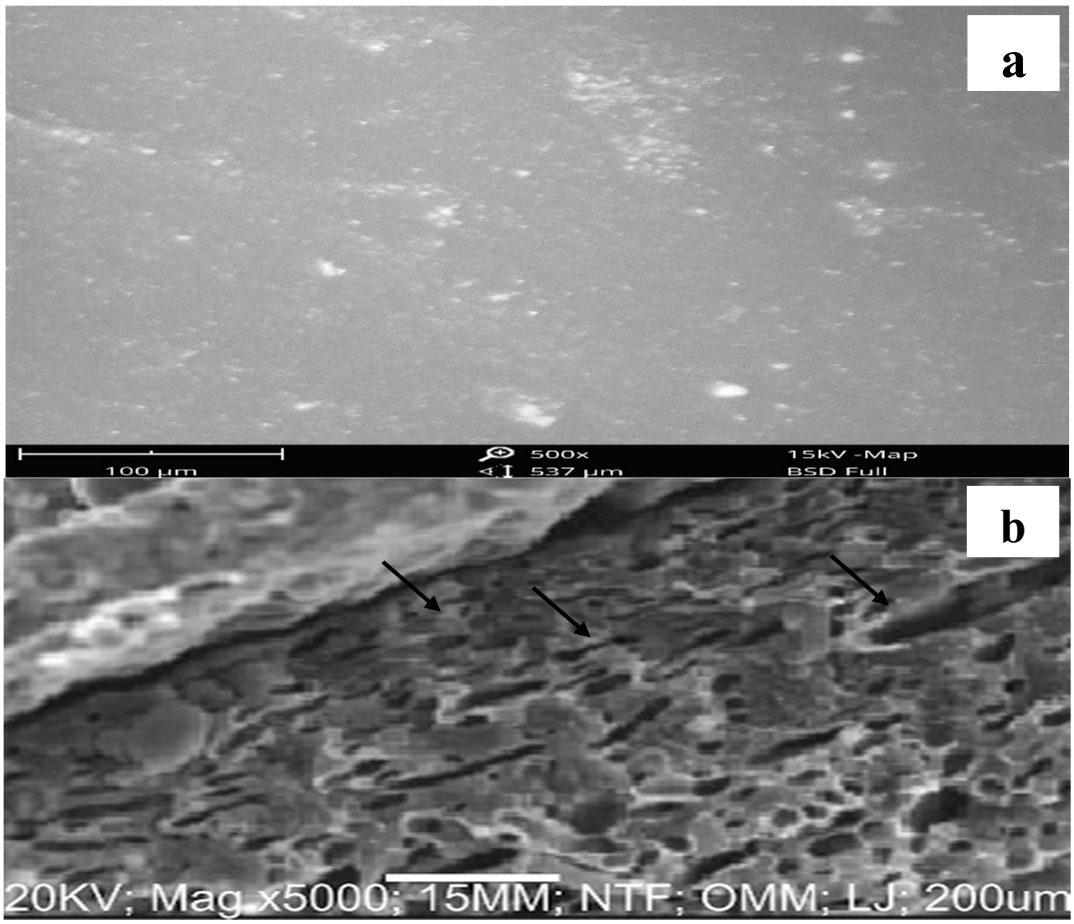

Fig. 5 Showing SEM micrograph of (a) control PE Sheet (b) *Serratia marcescens* degraded PE sheet

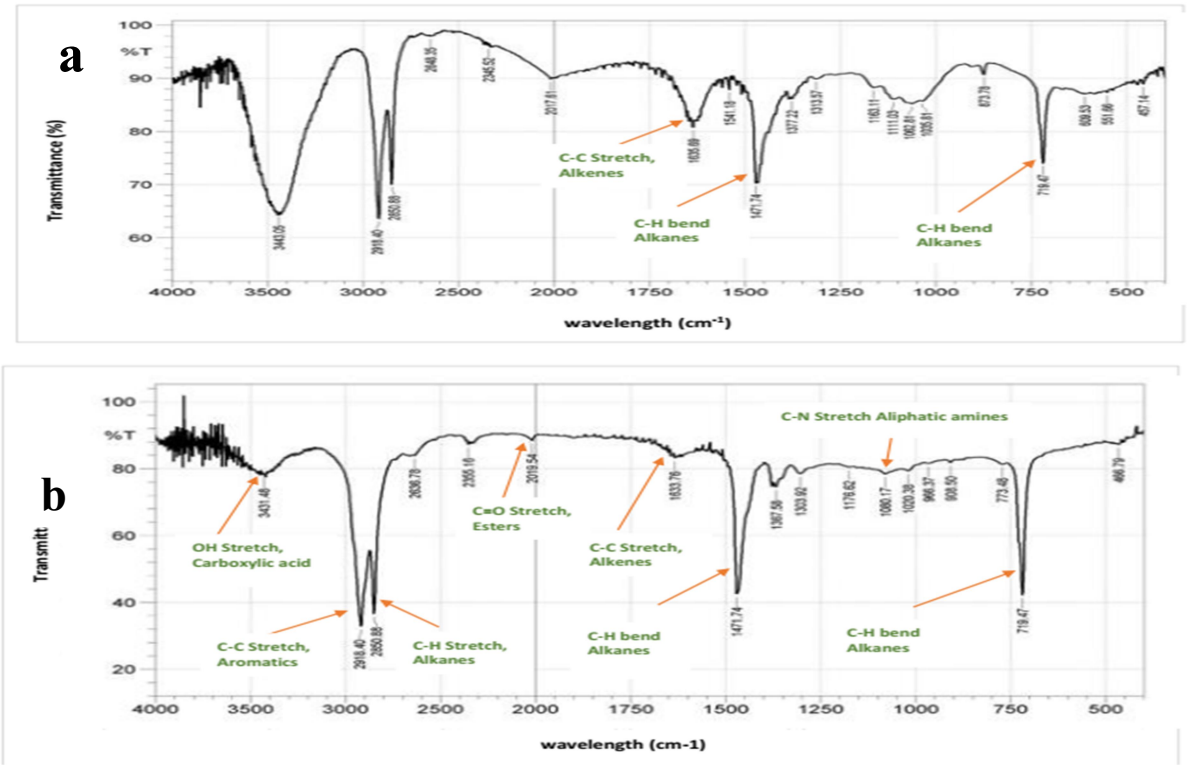

Fig. 6 Showing the FTIR spectra of (a) control PE sheet, and (b) *Serratia marcescens* degraded PE sheet

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