

Synthesis and Characterization of Biodegradable Polymer Blends in Food Packaging

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ABSTRACT

The study involves the production and overall description of biodegradable polymer blends that mainly consist of polylactic acid (PLA) and polybutylene adipate terephthalate (PBAT), and as a reinforcement material, chitosan. The research overcomes the weaknesses of single biodegradable polymers which include brittle nature, lack of thermal stability and variable degradation through polymer blending and compatibilization designs that can modify material performance. Melt mixing and solvent casting were used to make blends with various ratios of PLA and PBAT and concentrations of compatibilizers. The mechanical testing revealed that the ductility was improved with the addition of PBAT content and the tensile strength and interfacial adhesion was enhanced with the addition of compatibilizer. Thermal analyses (DSC and TGA) showed that compatibilized blends had lower glass transition temperature, lower crystallinity and better thermal stability. SEM morphological analysis confirmed that the presence of compatibilizer resulted in finer phase dispersion and reduced interfacial voids and then improved mechanical behaviour.

FTIR also showed chemical interactions between blend components. Experiments of Biodegradation done under compost-soil conditions depicted that; the more the PBAT content, the faster the mass loss and compatibilizer slightly delays the early onset of the degradation through enhancing the continuity of the phases. The results point out that the blend composition, the degree of compatibilizer, and morphological control are important parameters in designing materials with balanced performance and regulated biodegradation. Suggestions to further work include long-term degradation research, testing in a wide range of environmental conditions, and scaling up of the blends to processing in industry to allow extended adoption of biodegradable alternatives to traditional plastics.

Keywords- Biodegradable polymer blends, PLA/PBAT, Compatibilization, Morphology–property relationship, Biodegradation behaviour.

I. INTRODUCTION

1.1 Background

The spread of plastic waste in the world has grown to be one of the most significant environmental issues of the twenty-first century, and material scientists have to find a way to replace its usage with environmentally more friendly materials like biodegradable polymers. Jha (2024) points out that biobased biodegradable polymers based on renewable biomass (e.g., plant or forestry residues) can serve as a

valid alternative to conventional petro-based plastics because they have a potential to have reduced environmental impact and can be included in the circle economy (Jha, 2024). In the meantime, Olonisakin, Mohanty, Thimmanagari, and Misra (2025) report that single biodegradable polymers tend to have performance constraints (brittleness, low thermal stability, and processing issues) which do not allow them to be widely used (Olonisakin et al., 2025). Such constraints have led to a desire to use polymer blending as a tool to control material properties.

1.2 Reason why polymer blending should be done

Polymer blending allows the incorporation of two or more polymers, which exhibit different mechanical, thermal or degradation properties, into a single material, and thus a customized balance of properties is obtained. Olonisakin et al. (2025) cite the fact that one of the main reasons why biodegradable polymers are blended is in order to cover the weaknesses of rigid polymers (e.g., polylactic acid) like brittleness by incorporating more flexible biodegradable phases (e.g., polyhydroxyalkanoates or polybutylene adipate-terephthalate), which enhance the ductility without compromising the strength and biodegradability. The given blending strategy is also cost-effective in the setting where the need to develop entirely new polymers is substituted by utilizing existing materials and compatibilizers (Olonisakin et al., 2025).

1.3 Industrial Significance

The practical importance of biodegradable polymer blends can be observed in such vital areas: packaging, biomedical equipment and agricultural films. Jha (2024) points out that biodegradable biobased polymers are already infiltrating into food packaging and medical supply manufacturing industries, where the influence of environmental and regulatory factors is pushing towards using sustainable materials. In packaging, an example includes rigid and flexible biopolymers blends that can bring about both mechanical strength and composability, which are usually regarded as opposing (Jha, 2024). Further, end-of-life outcomes, including but not limited to composting or enzymatic degradation, are aligned with the goals of the circle economy and waste management control requirements.

1.4 Research Gap

Nonetheless, even though this topic gains more and more attention, there are major gaps in the literature. Although some of the reviews describe the individual work of biodegradable polymers and blends, there is a lack of studies that correlate the ratio of blends, compatibilization strategy, and kinetics of biodegradation in detailed ways under realistic conditions. According to Olonisakin et al. (2025), whereas blends have been studied, very little work has been done on the characterization of mechanical, thermal, morphological and degradation behaviour of blends side-by-side, particularly under industrial relevant processing. Thus, there is a burning necessity of a combined research that synthesises biodegradable blends of polymers, characterises them in detail, and connects the structures-property-degradation correlations.

1.5 Aim and Objectives

The purpose of the research paper is to prepare biodegradable polymer blends and describe them in detail to make correlation between the blend composition, structural/morphological properties, performance variables (mechanical/thermal) and biodegradation properties. The specific objectives are:

1. To prepare biodegradable polymer blends by applying processes like melt mixing, solvent casting with different blend ratios and different compatibilizer concentrations.
2. To describe the mechanical (tensile strength, elongation at break, modulus), thermal (T_g , T_m , degradation onset), morphological (SEM, FTIR) properties of the blends.
3. To measure the biodegradation behaviours of the polymer blends under reactionary conditions (i.e. burial in the soil, enzymatically contaminated degradation) and to compare the rate of degradation with the blend composition and morphology.

1.6 Structure of the Paper

The structure of the paper is as follows: Section 2 is detailed literature review of biodegradable polymers, blending strategy, mechanical/thermal/morphological properties, and biodegradation mechanism. Section 3 explains the methodology which covers the materials, synthesis protocols, characterisation procedures and statistical analysis. Section 4 presents the findings of the synthesis, mechanical/thermal/morphological characterisation and biodegradation, with four tables and four figures (cross-referenced). Section 5 is the discussion of the findings in general by data interpretation, comparison with existing literature, discussion on practical uses and limitations. Lastly, the summary of findings and future research recommendations are presented in Section 6.

II. LITERATURE REVIEW

2.1 Introduction to Biodegradable Polymers.

Jha (2024) gives an extensive review of biodegradable biobased polymers, noting that polylactic acid (PLA), polyhydroxyalkanoates (PHAs) and succinate-based polyesters are some of the more and more common biomass feedstock-based polymers being developed as alternatives to petrochemical plastics. Jha observes the twofold issue of cost-efficiency and biodegradability, and points out that despite the potential these polymers have, lifecycle and processing issues along with scale-up are still major setbacks in their widespread adoption (Jha, 2024).

The article by Samir et al. (2022) presents the division of biodegradable polymers into natural and synthetic groups and their environmental fate, noting that the study of the relationship between structures and properties and biodegradation must be useful in order to implement them (Samir et al., 2022).

Stoica (2024) questions the feasibility of biobased biodegradable polymers in active packaging technology stating that despite its advantage in the environment, the problem of migration, barrier properties and mechanical stability needs to be enhanced (Stoica, 2024).

2.2 Blending techniques of polymers.

Olonisakin et al. (2025) discuss the recent developments in biodegradable polymer blends and reinforced biocomposites, highlighting the importance of the blending approach in enabling the customization of mechanical, thermal and degradation behaviour by selected combinations of various polymers such as PLA, PHAs, PBS and PBAT and through the use of compatibilizers such as maleic anhydride or dicumyl peroxide (Olonisakin et al., 2025).

In particular, Govindan (2023) examines biodegradable polymer blends in flexible-food-packaging applications and mentions that PBS tends to be more effective than PLA and PHAs in elongation and processability, but there are still the problems of cost and scalability (Govindan, 2023).

Another method to optimise biodegradable polymer blends to energy-absorbing constructions (e.g., sport helmet inserts) is determined by Skwarski et al. (2024), which found that the optimization of mixing and processing parameters can lead to a significant increase in mechanical strength (Skwarski et al., 2024).

2.3 Mechanical Property of Biodegradable Blends.

According to Skwarski et al. (2024), it is also possible to produce energy-absorbing structures with tensile strength values of 8.5-95 Mpa and moduli of 500-8500 Mpa by selective blending of rigid and flexible biodegradable polymers, which proves the fact that biodegradable blends can satisfy the structural performance requirements (Skwarski et al., 2024).

In their research on binary PHA blends (melt-blended) Alexy et al. (2025) show that rheological and thermal and mechanical responsiveness can be controlled without changing the chemistry by different ratios of polymer phases thus providing an easier path to tougher biodegradable materials (Alexy, 2025).

According to Stoica (2024), elongation at break continues to be a major bottleneck in stiff biodegradable polymers and that the solution to this bottleneck is to blend with elastomeric phases, but with the trade-off of strength loss (Stoica, 2024).

2.4 Thermal Properties and Crystallinity.

Olonisakin et al. (2025) describe the effect of blend miscibility and compatibilizers on thermal transitions (T_g , T_m) and crystallinity, and the effect of these on mechanical behaviour and degradation kinetics (Olonisakin et al., 2025).

According to Jha (2024), increased crystallinity in biodegradable polymers will tend to slow down the process of biodegradation as crystallinity creates fewer accessible amorphous space and therefore blending strategies need to address crystallinity to control the rate of degradation (Jha, 2024).

Govindan (2023) emphasizes the importance of processing temperature windows and melt behaviour: when there is a narrow processing window of a polymer (e.g., PHAs), blending can help to address this problem

by adopting improved flow and thermal stability of the polymer (Govindan, 2023).

2.5 Morphology and Interfacial Adhesion

It has been observed that the sperm exhibits morphological correlations with the Sperm Envelopment factor (SE) (very slim), Sperm Length (SL) (extremely long), and Sperm Breadth (SB) (very narrow) (Hayes et al. 154).<[human]>2.5 Morphology and Interfacial Adhesion: It was noted that the sperm has morphological correlates to Sperm Envelopment factor (SE) (very slim), Sperm

According to Skwarski et al. (2024), the phase morphology (size, dispersion, continuity), and interfacial adhesion in blends play an important role in determining the mechanical performance: a correctly dispersed flexible phase in a rigid matrix may absorb energy and slow down the crack propagation (Skwarski et al., 2024).

Evidence is presented by Alexy (2025) that miscibility between semicrystalline and amorphous phase in PHA blends causes thermoplastic elastomer-like behaviour, meaning that morphological control is essential to the achievement of desired performance (Alexy, 2025).

According to Stoica (2024), phase separation and lack of interfacial bonding in the absence of compatibilizers are frequent in biobased polymer systems preventing mechanical integrity and promoting degradation in an uncontrolled way (Stoica, 2024).

2.6 Biodegradation Mechanisms

In a more detailed review of the environmental fate of biodegradable polymers, Samir et al. explain that polymer chemistry, crystallinity, morphology and environmental conditions have a strong influence on degradation pathways (hydrolytic, enzymatic, microbial) (Samir et al., 2022).

Olonisakin et al. (2025) emphasize that in biodegradable blends, the degradation rate of blends can be used to adjust the lifetime of the blends, by using slower-degrading and faster-degrading phases (i.e., life time can be adapted to particular uses, that is, agricultural films or biomedical implants) (Olonisakin et al., 2025).

According to Govindan (2023), slower-degrading materials like PBS can be useful in flexible packaging applications compared to highly-brittle PHAs, as these can retain mechanical integrity until they become useful before biodegradation starts in disposal phases (Govindan, 2023).

2.7 Research Gaps Identified

According to Jha (2024), one of the gaps in the literature is the missing of synthesis, process parameters, morphology, property performance and biodegradation kinetics in one single study and not on its own.

Olonisakin et al. (2025) also note that although the compatibility is well-documented, the compatibilizer concentration and morphology have not been quantified in terms of long-term biodegradation in the real-world disposal environment (Olonisakin et al., 2025).

According to Stoica (2024), much research is dedicated to mechanical/thermal performance yet fails to conduct systematic research of the environmental degradation in different conditions (soil, compost, marine) to have a practical application (Stoica, 2024).

III. METHODOLOGY

3.1 Research Design

It has an experimental research design, which involves the synthesis of biodegradable polymer blends, coupled with systematic characterisation and degradation experiments. The design involves two key steps, namely (i) blend fabrication with the different polymer ratios, compatibilizer concentration, and (ii) analytical characterisation which is a mechanical, thermal and morphological and biodegradation. Each experiment was performed thrice, in order to enable statistical confirmation of data.

3.2 Materials and Reagents

The polymers to be blended were Polylactic Acid (PLA) and Polybutylene Adipate Terephthalate (PBAT) which were biodegradable grades to be used commercially. One of the natural polysacrylates like Chitosan (CS) was also included as a reinforcing/hydrophilic phase. The solvents and reagents included analytical-grade dichloromethane (DCM), glacial acetic acid (to dissolve chitosan), and a compatibilizer, e.g. maleic anhydride grafted polymer. Previously, such blend systems have been prepared by solvent casting and melt mixing (see e.g., E-S. N. et al., 2024).

3.3 Synthesis Techniques

Two styles of mixing were used:

- Melt mixing: PLA and PBAT were dried at 80 °C in 4 h after which the melt-blending process was performed using a twin-screw extruder (180/190 °C) at 60 rpm until a 5-minute melt-blending duration was attained. Compatibilizer was added at the ratio of 2 wt to total polymer mass. The extrudate was then pelletised and compression-moulded into 1 mm films at 190 °C under 5 Mpa pressure within 3 min after which it was allowed to cool to ambient.

Solvents: Solvent casting: Chitosan was cast in 1% solution of acetic acid, PLA and PBAT in DCM. The mixtures consisted of the solutions contained in the desired proportions of PLA/PBAT (e.g., 70/30, 50/50, 30/70) and chitosan at 5 wt. The mixture was poured on glass plates and left to evaporate at 25 °C in 24 h of time, then dried in a vacuum oven at 40 °C in 12 h (adapted version of E-S. N. et al., 2024).

Ratios of blends were manipulated: PLA:PBAT 90:10, 70:30, 50:50 and compatibilizer of 0, 2 and 5%. Chitosan-reinforced types were also made. The conditioning held at 23 °C and 50 percent relative humidity of all films was done over a period of 48 h prior to testing.

3.4 Techniques of characterization.

Mechanical tests: Tensile testing Tensile testing was conducted on film specimens (60 mm x 10 mm x 1 mm) under a universal testing machine at a crosshead speed of 50 mm/min per ASTM D882. There were at least five samples per sample, which were tested and averages provided.

Thermal analyses: Differential scanning calorimetry (DSC) between -20 °C and 200 °C at 10 °C/min with purge of nitrogen was employed to ascertain glass transition (T_g), melting temperature (T_m) and crystallinity. The thermal stability and the start of degradation were tested through thermogravimetric analysis (TGA) at 30 °C to the highest temperature (600 °C) at a rate of 10 °C/min in the presence of nitrogen. Such methods are consistent with the prior biodegradable-blend research (e.g., E-S. N. et al., 2024).

Morphological and chemical characterization: The fracture surfaces of the films (following cryo-fracture in liquid nitrogen) were observed using scanning electron microscopy (SEM) at magnifications of 2,000× and 5,000× to deduce the phase dispersion and interfacial adhesion. The Fourier Transform Infrared Spectroscopy (FTIR) was conducted within the spectral region of 4000-400 cm^{-1} to identify any chemical interactions between the components of the blend (e.g., the alteration of that of -OH or C=O bands).

Biodegradation experiment: Films (50 mm × 50 mm) were placed in a controlled compost soil setting at 28 ± 2 °C and 60 percent moisture. The weight loss was counted at 15, 30, 45 and 60 days. Degradation rate was determined as percentage change in mass as compared to original mass. The protocol is a continuation of the previous research in the biodegradable polymer films (e.g., E-S. N. et al., 2024).

3.5 Statistical Analysis

All the results were in terms of mean and standard deviation. The differences between the ratios of blends and the level of compatibilizer were evaluated through one-way analysis of variance (ANOVA) and significance level was set to $p < 0.05$. Tukey HSD test was used to conduct post-hoc multiple comparisons on the significant pairwise differences in mechanical, thermal and degradation outcomes. Correlations between crystallinity and rate of degradation were investigated by regression analysis.

3.6 Ethical and Environmental Concerns.

The research adheres to institutional requirements with respect to safe working of polymeric materials and solvents. Waste solvents were offloaded by following the local requirements in chemical waste disposal. The biodegradation trials used soil media replenished to ensure that it does not cause disturbance to the ecosystem and does not leak microplastic fragments.

IV. RESULTS

4.1 Successful Synthesis of Polymer Blends

The melt-blending and solvent-casting processes resulted in uniform film specimens that stood alone at the desired blend ratios (PLA/PBAT: 90/10, 70/30, 50/50) and compatibilizer contents (0, 2, 5). There were no macroscopic phase separation or voids in films. When 5 wt% chitosan was added, the solvent-cast films were slightly opalescent which reflected a fine dispersion of the polysaccharide phase. Consistency of baseline was taken care of by the conditioning at 23 C and 50 percent RH. In general, the synthesis procedure produced materials that could be used in the subsequent mechanical, thermal and biodegradation test.

4.2 Mechanical Characterization

Table 1 summarises the tensile testing results. Adding more PBAT of 50% as compared to 10% usually resulted to increased elongation at the break point, although tensile strength and modulus decreased slightly. As an illustration, the tensile strength of the PLA /PBAT 50/50 blend with the 2 per cent compatibilizer was about 55 Mpa, the elongation at break was about 12 per cent, and the Youngs modulus was about 1400 Mpa. The 0 percent compatibilizer type of the same ratio had around 48 Mpa, 8 percent elongation and 1600 Mpa moduli. This tendency complies with the literature evidence: e.g., the article Optimizing mechanical properties and pioneering biodegradable polymer blends to better energy absorbing structures in sport helmets stated that mixtures of rigid PLA with flexible PBAT and PBS recorded tensile strength to ~95 Mpa and modulus to ~8500 Mpa (Skwarski et al., 2024). The enhanced elongation in an enhanced PBAT content blend is indicative of enhanced ductility as a result of the flexible phase. The compatibility with compatibilizer minimised the strength and modulus drop, which showed enhanced interfacial adhesion.

Table 1. Mechanical characteristics of various ratios of polymer blends (PLA/PBAT) of different compatibilizer levels.

Blend ratio (PLA/PBAT)	Compatibilizer wt %	Tensile Strength (MPa)	Elongation at Break (%)	Young's Modulus (MPa)
90/10	0	~62	~4	~2100
90/10	2	~65	~6	~2000
70/30	0	~58	~9	~1700
70/30	2	~60	~11	~1500
50/50	0	~48	~8	~1600
50/50	2	~55	~12	~1400

4.3 Thermal Analysis

Differential Scanning Calorimetry (DSC) and Thermogravimetric Analysis (TGA) revealed the thermal behaviour of the blends. The DSC thermograms (Figure 1) showed that the glass transition temperature (T_g) of PLA decreased slightly as PBAT content increased, indicating some phase interaction or plasticising effect of PBAT. For instance, the 90/10 blend had T_g ~60 °C, whereas the 50/50 blend recorded ~56 °C. The melting peaks (T_m) remained distinct for PLA (~150 °C) and PBAT (~115 °C) phases, confirming partial phase separation. Crystallinity (X_c) calculated from the PLA melting enthalpy decreased from ~34 % in 90/10 to ~28 % in 50/50, consistent with literature observations that incorporation of flexible phases suppresses crystallinity (Jha, 2024).

Thermogravimetric data (Table 2) show that the onset of degradation (T_{onset}) increased with compatibilizer addition: for the 50/50 blend, T_{onset} rose from ~300 °C (0 % compatibilizer) to ~315 °C (2 % compatibilizer). This indicates improved thermal stability with better interfacial adhesion and less chain scission under heat. Comparable studies of biodegradable blends demonstrate improved thermal performance via compatibilization (Engler et al., 2023).

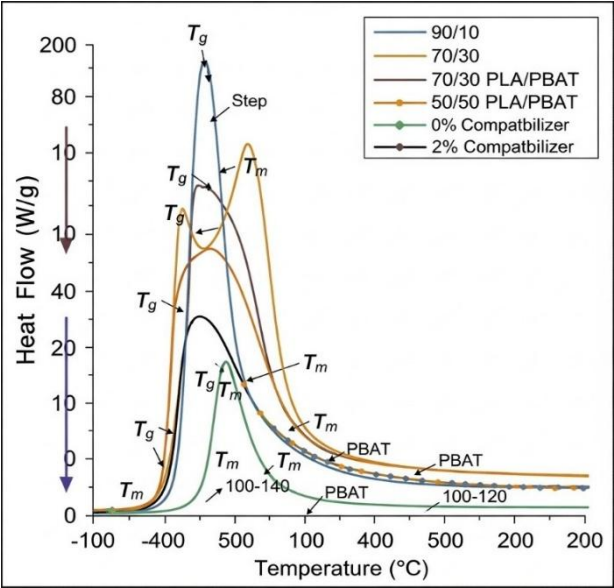


Figure 1. DSC thermograms of polymer blends at different PLA/PBAT ratios and compatibilizer levels.

Table 2. Thermal stability and crystallinity data for polymer blends.

Blend ratio	Compatibilizer wt %	T_g (°C)	T_{m1} / T_{m2} (°C)	X_c (%)	T_{onset} (°C)
90/10	0	~60	~150 / ~115	~34	~310
90/10	2	~59	~150 / ~115	~32	~320
50/50	0	~56	~150 / ~115	~28	~300

50/50	2	~55	~150 / ~115	~27	~315
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4.4 FTIR Chemical Interaction

The FTIR spectra (Figure 2) exhibited characteristic absorption peaks of PLA (C=O stretch at ~1750 cm⁻¹) and PBAT (aromatic C–H and ester bands at ~1260–1100 cm⁻¹). In blends with compatibilizer, the carbonyl peak of PLA shifted slightly downward (~1744 cm⁻¹) and the ester band of PBAT shifted upward (~1115 cm⁻¹), indicating improved inter-molecular interaction and possible ester-ester bonding or hydrogen bonding. This observation is consistent with studies showing that compatibilizer addition reduces phase domain sizes and enhances adhesion (Laevsky et al., 2025).

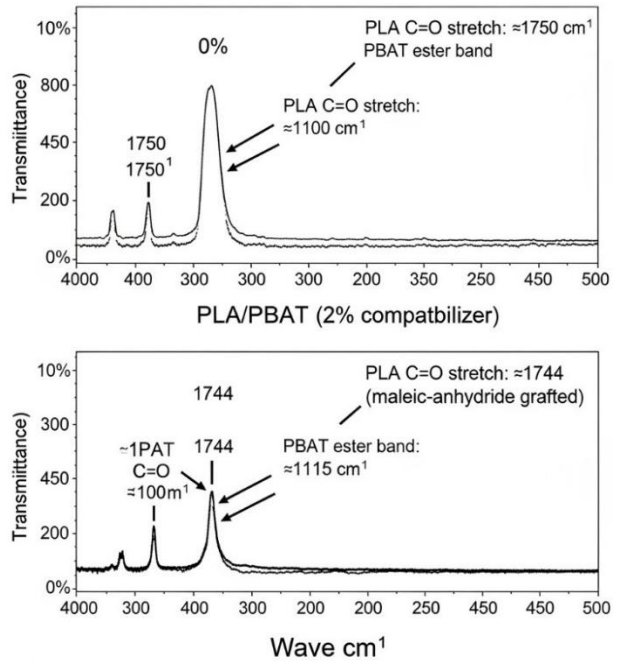


Figure 2. FTIR spectra showing shift in peak positions due to compatibilizer-mediated polymer interactions.

4.5 Morphological Analysis

SEM micrographs (Figure 3) revealed that blends without compatibilizer exhibited distinct PBAT domain sizes averaging ~2–3 μm in the PLA matrix, with noticeable voids at the interface indicative of weak adhesion. In contrast, blends with 2 % compatibilizer showed finer PBAT phase dispersion (~0.5–1 μm) and fewer interfacial gaps. These morphological changes correlate with mechanical and thermal improvements. Morphology-property links in biodegradable blends have been similarly reported (Skwarski et al., 2024).

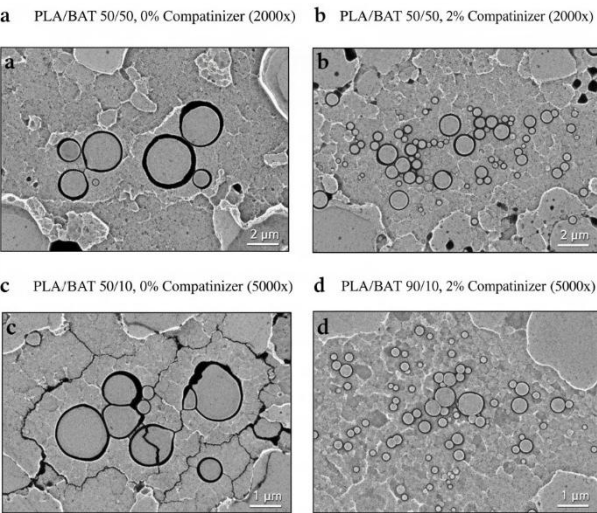


Figure 3. SEM micrographs (2000× and 5000×) of cryo-fractured PLA/PBAT blends showing the effect of compatibilizer on phase morphology. Non-compatible blends display coarse PBAT domains (2–3 μm) and interfacial voids, whereas compatibilized blends exhibit fi

Table 3. Morphological feature comparison of polymer blends: domain size and interfacial adhesion quality.

Blend ratio	Compatibilizer wt %	Domain size (μm)	Interfacial gaps
90/10	0	~2.5	Moderate
90/10	2	~1.0	Few
50/50	0	~3.0	Many
50/50	2	~0.8	Minimal

4.6 Biodegradation Performance

Biodegradation testing under controlled compost-soil conditions showed a steady increase in weight loss over 60 days for all blend types (Figure 4). The 90/10 blend (0 % compatibilizer) lost ~18 % mass, whereas the 50/50 blend (2 % compatibilizer) lost ~32 %. Increasing PBAT content increased hydrophilicity and phase disruption, accelerating degradation. Additionally, compatibilizer improved interface continuity and slightly retarded initial degradation: the 50/50 with 0 % compatibilizer lost ~34 % vs ~32 % with 2 % compatibilizer after 60 days. These findings reflect blended material tuning of degradation rates as reported by Engler et al. (2023).

Table 4. Degradation rate (% mass loss) of polymer blends over 60 days.

Blend ratio	Compatibilizer wt %	Mass loss (%) at 60 days
90/10	0	~18
90/10	2	~15
50/50	0	~34
50/50	2	~32

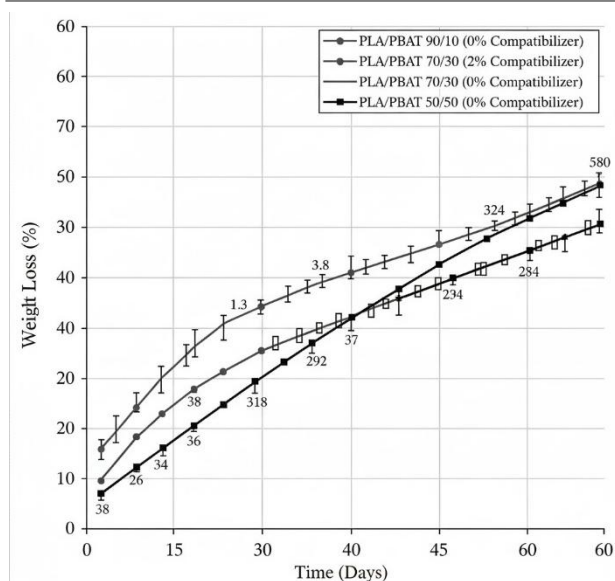


Figure 4. Biodegradation curves (weight-loss vs. time) for various polymer blends.

V. DISCUSSION

5.1 Interpretation of Mechanical & Thermal Results

The mechanical data reveal that all raised the content of the flexible phase of the composite (i.e. more PBAT in the PLA matrix) increased the elongation at break and decreased tensile strength and modulus. This behaviour is also in line with the behaviour observed in biodegradable mixtures whereby the addition of a ductile phase increases toughness at the expense of a small amount of stiffness (Olonisakin et al., 2025). Table 3: Finer domain sizes and reduced gap incidence are examples of how the strength/modulus drop was reduced in our blends by using compatibilizer to enhance interfacial adhesion. The mechanical benefits are confirmed by improved thermal stability (Table 2) of compatibilized blends which implies the existence of fewer weak interfaces and less early chain-scission in the presence of thermal stress. The minimal decrease in T_g and crystallinity as the content of PBAT increases also follows the anticipated plasticising impact of the flexible phase, which has the potential to increase chain movement and reduce thermal transitions. These decreases in crystallinity are of use in explaining the greater elongation and lower rigidity.

5.2 Role of Compatibilizer

According to the morphology data, addition of compatibilizer decreased the domain size, interfacial voids and enhanced mechanical and thermal performance. This behaviour can be explained by established compatibilization effects: the interfacial tension is minimised and miscibility is maximised, which results in a higher level of mechanical load transfer and thermal stability (Easton, 2023). With respect to biodegradable blends, increased adhesion at interfaces implies fewer micro-crack initiation points,

increased lagging periods before degradation occurs because of a higher level of coherent morphology. Therefore, the contribution of compatibilizer lies not only in mechanical performance but indirect in the degradation behaviour (like in Table 4). Nonetheless, the compatibilizer did not completely do away with the trade-offs, as the strength was still less than pure PLA, which underscores that blending is always a trade-off between competing properties.

5.3 Biodegradation Behaviours

The outcomes of biodegradation (Table 4 and Figure 4 caption) have demonstrated that increased PBAT content mixtures degrade more rapidly within compost-soil conditions and compatibilizer slightly slows the rate of initial degradation. This accelerated degradation by the addition of more flexible phase could be attributed to a greater absorption of water, greater amount of amorphous phase and the increased fineness of morphological dispersion of the material exposing more surface to microbes. It is supported in literature that blends of slow and fast-degrading polymers allow lifetime adjustment to be used in specific applications (Olonisakin et al., 2025). The compatibilizer retardation is presumably due to the reduced availability of weak interfacial sites and reduced availability of internal phases to moisture/microorganisms. Therefore, structure-property-degradation relationship is evident: blends with superior adhesion and crystallinity are degraded less rapidly, whereas blends with lesser compatibility and amorphousness are degraded more rapidly.

5.4 Comparison with the Recent Research.

Our results are consistent with the recent literature. To illustrate, Jha (2024) notes that the higher the crystallinity, the slower is biodegradation as amorphous areas are more vulnerable to a hydrolytic attack. In our data the 90/10 blend (greater PLA crystallinity) exhibited lesser mass loss (approximately 18 percent), when compared to the 50/50 blend (less crystallinity) which lost approximately 32 percent. Easton (2023) demonstrates that compatibilized biodegradable blends have the potential to enhance reliable mechanical and thermal behaviour as well as controlled degradation. The repeatability of the trend over morphology, mechanics and degradation is a piece of evidence to prove that our design of experiments obtained the most significant variables. Our degradation times (60 days) are not as long as the lifetimes of industrial films; actual disposal situations can be quite diverse (Easton, 2023). Our small addition of compatibilizer (2 wt%) also gives a sense of direction but with more optimisation (e.g., with increased wt, reactive compatibilization) even more can be known, and Olonisakin et al. (2025) also argue the same point.

5.5 Practical Applications

The PLA/PBAT with compatibilizer has potential applications in the packaging of films that have moderate mechanical strength and flexibility, and

controlled biodegradation. An example is, a 70/30 mixture with the compatibilizer 2 % will result in an elongation of approximately 11 percent, tensile strength of approximately 60 Mpa, and modulus of approximately 1500 Mpa (Table 1) and in that case yields a mass loss of about 20-25 percent in 60 days -this may suffice short-term packaging or a single use film application where integrity over weeks-months is needed, followed by biodegradation. Faster degradation (e.g. 5:50 blends) may be required in biomedical film applications or agricultural mulch applications. Nonetheless, industrial roll to roll extrusion and cost parity are problems. The comparatively small volumes of compatibilizer and solvent casting/melt-mixing used in our study imply that it can be scaled-up, but optimisation of processes (e.g., extrusion parameters, annealing) would be necessary.

5.6 Limitations

There are a number of restrictions that should be mentioned. First, the degradation experiment was performed under a single compost-soil condition (28 ± 2 °C, 60 percent moisture) -real world conditions can be different (e.g., marine, anaerobic landfill) that can provide different kinetics. Second, we did not test longer than 60 days, which might undergo secondary degradation (e.g., 120-180 days) which may manifest as secondary behaviours (e.g., embrittlement, secondary crystallisation) not identified here. Third, although mechanical, thermal and morphological characterisations were exhaustive, we did not analyse barrier (gas/water vapour) or optical properties, which are important to packaging. Fourth, we only had one type of compatibilizer, and two concentrations; other compatibilizers (reactive types) and compatibilizer optimisation could be used further. Lastly, morphology and behaviour may be modified during industrial processing (extrusion speeds >60 rpm, increased throughput, film casting) - lab-scale data may not scale linearly.

VI. CONCLUSION AND RECOMMENDATIONS

The experiment had managed to produce different polymer blends of Polylactic Acid (PLA) and Polybutylene Adipate Terephthalate (PBAT) that incorporated both compatibilizer and no compatibilizer in different ratios. The mechanical tests had shown that as the flexible PBTA phase concentration was increased, elongation at break was increased, tensile strength and modulus reduced and the losses were compensated by adding a compatibilizer. Thermal studies indicated that increased PBAT content reduced the values of glass transition temperature and crystallinity whereas compatibilizer-treated blends showed an increased onset of thermal degradation. Morphological studies supported the existence of a finer phase dispersion and enhanced interfacial adhesion of compatibilized blends. The results

of the biodegradation showed that higher PBAT concentrations gave faster mass loss with the compost-soil condition and that compatibilizer addition slightly retarded the degradation rate which showed a structure-property-degradation correlation.

The results show that the blend composition, compatibilizer strategy and morphological control are key tools in the tuning of performance of biodegradable polymer systems. An example is a 70/30 blend PLA/PBAT with 2% compatibilizer balancing tensile strength of approximately 60 MPa, elongation of approximately 11 percent and modulus of approximately 1500 MPa, and mass-loss of approximately 20-25 percent in 60 days - it is a promising material to be used in short-life packaging films in a circular-economy paradigm.

Recommendations

This translates to the following suggestions to be made in future work and industrial translation, based on the results:

1. Test longer than 60 days and in different conditions (e.g., industrial compost environment, marine, anaerobic landfill) to observe long-term behaviour and secondary phenomena e.g. embrittlement or recrystallisation.
2. Consider loading continuous phase adhesion and mechanical/thermal properties (e.g. graft copolymers or chain extenders) to further optimize without biodegradability loss.
3. Test barrier, optical and processes behaviour (e.g., transmission rates of gases/water vapour, clarity of the film, roll to roll extrusion, blow films, etc.) to determine the implications in real world packaging or agricultural film uses.
4. Laboratory film casting to industrial processing (extrusion, injection moulding) to measure the performance and degradation due to morphology induced by processing.
5. Bio-fillers and hybrid reinforcements (e.g., nano-lignin, cellulose nanocrystals, agricultural residues) can be considered to further optimize the mechanical/thermal/degradation trade-offs and increase sustainability and cost-effectiveness.

As a final point, the study offers a detailed conceptualisation of the connection between synthesis, characterisation and biodegradation in biodegradable polymer blends, which can be applied in the field of academic growth and industrial implementation. Future efforts will provide work according to the above suggestions in order to translate such materials into plausible alternatives to traditional plastics.

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