ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Original Research Article

Effects of UV Irradiation and Soil Burial Treatment on Mechanical Properties and Surface Morphology of Starch-Based Plastic

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Abstract: Starch-based plastics are gaining attention as eco-friendly alternatives to their petroleum-based counterparts due to their biodegradable and renewable characteristics. However, a comprehensive evaluation of their mechanical performance and durability under varying environmental conditions is lacking. Thus, this study investigates the impact of UV irradiation and soil burial on the mechanical properties and surface morphology of starch-based plastics. The weight loss and important mechanical parameters, including tensile strength and elongation at break, were analysed using standard testing procedures on starch-based plastic samples that were subjected to varying durations of UV irradiation and soil burial. Furthermore, the surface morphology of these samples was examined using scanning electron microscopy (SEM) and Fourier-transform infrared spectroscopy (FTIR) analysis to analyse composite degradation. There was a 64.7% reduction in elongation at break for the soil burial treatment and a 92.1% reduction for the UV irradiation treatment, indicating significant deterioration in the mechanical properties of the plastic. Weight loss was used as an indicator of degradation, showing a 55.1% weight loss in the soil burial treatment and a 9.1% weight loss in the UV irradiation treatment after 100 days. FTIR analysis revealed structural changes during degradation, with both treatments showing the formation of new peaks. This suggests that degradation occurred over the treatment period, likely due to chain scission of the polymer. SEM analysis of the surface morphology of the samples showed more pronounced changes with the soil burial treatment, where numerous small holes were observed. These findings contribute to a comprehensive understanding of the behaviour of starch-based plastics under UV irradiation and soil burial treatment conditions, offering valuable insights into their potential applications and limitations across industries, including packaging and agriculture.

Keywords: Starch-based plastics, UV irradiation, soil burial, mechanical properties, biodegradability, photodegradation

Received: 1st June 2024

Accepted: 13th May 2025

Available Online: 1st July 2025

Published: 9th September 2025

Citation: Basha, R. K., Qi, S. H., Hasnan, N. Z. N., *et al.* Effects of UV irradiation and soil burial treatment on mechanical properties and surface morphology of starch-based plastic. *Adv Agri Food Res J* 2025; 6(2): a0000573. https://doi.org/10.36877/aafrj.a0000573

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1. Introduction

The widespread adoption of plastic is attributed to its favourable mechanical and thermal properties, stability, and durability. However, the widespread use of plastics has led to severe environmental consequences, including pollution and ecological disruption, due to their slow degradation after disposal (Gewert *et al*., 2015; Othman *et al*., 2019a; Othman *et al*., 2019b; Risyon *et al*., 2016; Webb *et al*., 2013). Recognising the urgency to address these issues, bio-based plastics emerge as a sustainable solution. Research and commercialisation efforts focusing on the integration of bio-based plastics into various products such as garbage bags, composting yard waste bags, grocery bags, and agricultural mulches are currently ongoing (Ali *et al*., 2013; Bajpai, 2019; Ismail *et al*., 2011; Puls *et al*., 2011; Qi *et al*., 2017; Vroman & Tighzert. L., 2009).

At present, approximately 85% to 90% of total bio-based plastics are primarily derived from starch (Bastioli, 2000; Rosenboom *et al*., 2022). Starch is chosen as a preferred material for bio-based plastics due to its lower cost, abundance, and renewable nature (Azmi *et al*., 2019; Siqueira *et al*., 2021; Vilpoux & Averous, 2002). Additionally, starch can be obtained from a variety of agricultural crops such as tapioca, corn, and potatoes (Basha *et al*., 2020; Nordin *et al*., 2020; Othman *et al*., 2020; Shapi'i *et al*., 2022). Most importantly, starch-based plastics exhibit complete degradability, presenting a fundamental solution to the ongoing issue of plastic pollution. The degradation of plastic can be understood because of chemical, physical, or biological reactions that lead to changes or loss in its properties, including bond scissions and subsequent chemical transformations. The American Society for Testing and Materials (ASTM) and the International Organisation for Standardisation (ISO472) define degradable plastic as a type of plastic that undergoes an irreversible process resulting in significant changes in its structure, loss of properties such as integrity, molecular weight, mechanical strength, or structure, or fragmentation under specific environmental conditions over time. Degradation can be classified into several categories, including photodegradation, thermal degradation, ozone-induced degradation, mechanochemical degradation, catalytic degradation, and biodegradation. Each of these methods triggers the degradation of starch-based plastic through different mechanisms and under different conditions (Singh *et al*., 2007; Tyagi *et al*., 2022). Starch-based plastics are inherently linked to polymer degradability due to their unique composition and characteristics. Starch, a polysaccharide made up of glucose units, serves as a renewable and biodegradable raw material for producing these plastics. Given that most polymers consist of covalently bonded organic components, they are generally susceptible to UV damage. The primary and widespread UV-induced damage mechanism in polymers is known as chain scission through photolysis. This process involves the direct action of high-energy photons on the polymer's "backbone," causing long chains to break into shorter segments (Kaing *et al*., 2004).

Moreover, starch-based plastics exhibit a high degree of susceptibility to microbial activity and environmental factors, facilitating their breakdown into simpler, natural components. Starch-based plastics tend to undergo biodegradation, meaning that microorganisms can enzymatically break down the complex starch molecules within the plastic structure. This process transforms the starch-based plastic into smaller, environmentally benign components, such as water, carbon dioxide, and organic compounds. The biodegradation of starch-based plastics is a key attribute that distinguishes them from traditional, non-biodegradable plastics and positions them as a more environmentally friendly alternative in addressing plastic pollution concerns. To comprehensively grasp polymer biodegradation within soil environments, the variable nature of soil composition must be acknowledged. The biodegradability of polymers in soil is closely influenced by uncontrollable variables, including humidity, temperature, chemical composition, and pH (Tyagi *et al*., 2022). These factors, susceptible to geographical variations, introduce a dynamic element, potentially leading to variations in microbial biodegradation processes across different locations and seasons. Within the soil itself, aerobic degradation predominates for the most part. An increase in water content reduces the levels of O_2 and CO_2 in soil, consequently enhancing anaerobic biodegradation. More importantly, soil humidity plays a crucial role, as water facilitates hydrolytic bond cleavage and reduces molecular weight, making polymers more susceptible to microbial degradation. Furthermore, water contributes to the leaching of additives such as plasticisers and pigments in polymers, often leading to brittleness. A soil humidity of 50−60% is optimal for facilitating aerobic biological processes (Liang *et al*., 2003). Additionally, water aids in maintaining soil pH, a critical factor for fostering microbial growth (Rousk *et al*., 2009).

Based on the understanding of the predominant roles of photodegradation and biodegradation in starch-based plastics, the aim of this study was to assess the changes in mechanical and thermal properties during both degradation processes. The study utilises laboratory-scale test methods designed to simulate real-world disposal conditions. This approach is also environmentally friendly and cost-effective.

2. Materials and Methods

2.1. Material

The plastic samples utilised in this study were obtained from Maribumi Starchtech Sdn Bhd located in Malaysia. To ensure experimental accuracy, all specimens were sourced from the same production batch. The plastic samples were then stored in a dry and cool environment to prevent exposure to light and minimise moisture loss. This controlled storage condition aimed to maintain the integrity and properties of the plastic samples throughout the duration of the study.

The plastic sheet was precisely cut into dimensions of 100 mm x 15 mm for the tensile test, and 30 mm x 30 mm for weight loss determination, Fourier Transform Infrared (FTIR) analysis, and Scanning Electron Microscopy (SEM) examination were carried out for both the soil burial treatment (biodegradation) and UV irradiation treatment (photodegradation).

2.2. Preparation of Soil Burial Treatment for Biodegradation Study

Soil burial treatment was conducted to assess the impact of environmental conditions on starch-based plastic. Rectangular pots measuring 67 cm x 23.5 cm x 19 cm were used for this purpose. The pots were filled with soil, and the moisture content of the soil was regulated by daily water sprinkling and monitored to maintain a humidity range of 40-45% (Thakore *et al*., 2001). Any excess water was drained through the hole located at the bottom of the pot.

The soil burial treatment was conducted in an open environment, allowing for normal exposure to sunlight. Prior to the burial, the plastic samples were cut to the desired dimensions and positioned approximately 8 cm below the soil surface. At specific intervals, plastic samples were extracted from the pots for various analyses, including tensile testing, weight loss determination, FTIR analysis, and SEM examination. To prepare the samples for analysis, they were gently removed from the soil and rinsed with distilled water to eliminate any soil or foreign particles. Subsequently, the samples were air-dried to a constant weight before further experimental procedures were carried out (Thakore *et al*., 2001). The moisture content of the soil was maintained within the range of 40-45% to ensure optimal microbial activity and prevent the soil from becoming excessively wet or dry (Chandra & Renu, 1997).

2.3. Preparation of Ultra Violet (UV) Irradiation Glass Box for Photodegradation Study

UV irradiation treatment was performed to assess the effects of UVA exposure on starch-based plastic. For this purpose, a glass lamp-housing box measuring 60.5 cm x 31 cm x 30 cm was constructed. The box was equipped with a UVA lamp. To ensure proper UV protection, the glass box was laminated with UV-blocking film and covered with a woody material.

The UVA lamp used in the experiment was a type F15T8BLB (SANKYO DENKI) obtained from KVC Industrial Supplies Sdn, Malaysia. This lamp emits UV rays within the range of 315 nm to 400 nm and has a power output of 15 W, as suggested by Sadi *et al*. (2010). The UVA lamp was positioned at the upper part of the glass box. In the UV irradiation treatment, film pieces were prepared and positioned inside the lamp-housing box, maintaining a consistent distance of 7 cm from the UVA lamp. According to Saad *et al*. (2009), this distance was chosen to ensure detectable changes in the degradation process. The experiment was conducted under ambient air conditions, with a temperature range of 30-35°C. The relative humidity was monitored and maintained between 40-50% using a humidity meter.

Samples were periodically collected from the UV irradiation setup for tensile testing, weight loss determination, Fourier Transform Infrared (FTIR) analysis, and Scanning Electron Microscopy (SEM). These intervals were chosen to monitor the effects of UV irradiation on the starch-based plastic samples for 100 days.

2.4. Weigt Loss Determination

Weight loss determination was conducted to quantify the degradation process that occurred during the UV irradiation and soil burial test, as described by Guohua *et al*. (2006). The weight loss of the samples was measured using a weighing balance (SARTORIUS), and the results were recorded. This analysis allows for the assessment of the extent of degradation experienced by the starch-based plastic samples during the treatment. By tracking the weight loss over time, it becomes possible to evaluate the degradation rate and overall degradation performance of the plastic samples. The percentage weight loss of sample over time can be evaluated by using Equation 1 (Azahari *et al*., 2011; Guohua *et al*., 2006):

$$W_l = \frac{W_o - W_t}{W_o} \; x \; 100\% \qquad (1)$$

where,

W_l = Weight loss (%)

W_o = Initial weight before biodegradation (g)
W_t = Weight at time t during the biodegradation (g)

2.5. Mechanical Test

Tensile measurements, including tensile strength and elongation at break, were conducted using a universal testing machine (model 3365) equipped with a 5 N load cell. The tests were performed at room temperature. The cross-head speed was set to 50 mm/min, and the initial grip distance was set at 50 mm. For each test, five specimens were replicated, and a minimum of three specimens were tested to ensure accuracy and reliability. The average results from the three specimens were recorded and used for analysis. The parameters obtained from the tensile test included the percentage of elongation at break (%), and tensile strength (MPa) at the point of fracture. The elongation at break measurement indicates the degree of brittleness or flexibility of the plastic.

2.6. FTIR Measurement

For the FTIR test, the specimens were prepared with dimensions of 30 mm x 30 mm. Two specimens were analysed: the unexposed specimens and those exposed to UV irradiation and soil burial treatments. The FTIR test was conducted to examine structural changes in the specimens, indicating the occurrence of degradation (Wu & Fan 2008).

The FTIR analysis was performed using a PerkinElmer Spectrum 100 FTIR Spectrometer. The test covered a wavelength range of 400-4000 cm^{-1}.

2.7. SEM Measurement

For the SEM test, the specimens were prepared in dimensions of 30 mm x 30 mm. Two specimens were analysed: the unexposed specimens and the specimens exposed to UV irradiation and soil burial treatment. The SEM test was performed to examine changes in the surface morphology of the specimens, which serve as an indicator of polymer degradation. This analysis is based on the studies conducted by Guohua, *et al.*, (2006) and Kiatkamjornwong *et al*. (1999)

The SEM analysis was conducted using an S-3400N Scanning Electron Microscope. The electron acceleration voltage was set to 5 kV.

3. Results and Discussions

3.1. Weight Loss

This section discusses the findings for weight loss of the starch-based plastic that occurs due to the soil burial treatment and UV irradiation.

3.1.1. Weight loss of starch-based plastic during soil burial treatment

During the soil burial test, the weight loss of the starch-based plastic sample was measured throughout the experiment. Percentage weight loss served as a measure of degradation, with elevated values suggesting a higher degradation rate (Nordin *et al.* 2024; Muthukumar *et al*., 2010; Thakore *et al*., 2001).

Figure 1 demonstrates the trends in percentage weight loss of the samples. From day 0 to day 13, there was a significant increase in percentage weight loss, rising steeply from 15.6% to 46.3%. However, from day 13 to day 100, there was no significant increase in percentage weight loss, with the values remaining in the range of 46.3% to 55.1%. This suggests that the degradation rate of the plastic sample was higher in the first 13 days, but it slowed down from day 13 to day 100, indicating a continued but slower degradation process. Ultimately, after 100 days of soil burial treatment, the percentage weight loss of the samples reached 55.1%.

According to Azahari *et al*. (2011), the rapid degradation observed during the first 13 days can be attributed to the composting process in the soil. Composting in soil can be divided into two stages: the active composting stage and the curing period. During the active composting stage, the temperature of the soil increases and remains elevated as long as there is oxygen present, leading to enhanced microbial activity and a dramatic increase in percentage weight loss. In the curing period, the soil temperature decreases, but the composting process of the film continues at a slower rate, resulting in a slight increase in the percentage of weight loss during this period (day 13 to day 100). It is important to note that the weight loss of the specimen is accompanied by a reduction in thickness, which can be attributed to surface erosion (Shah *et al*., 2010).

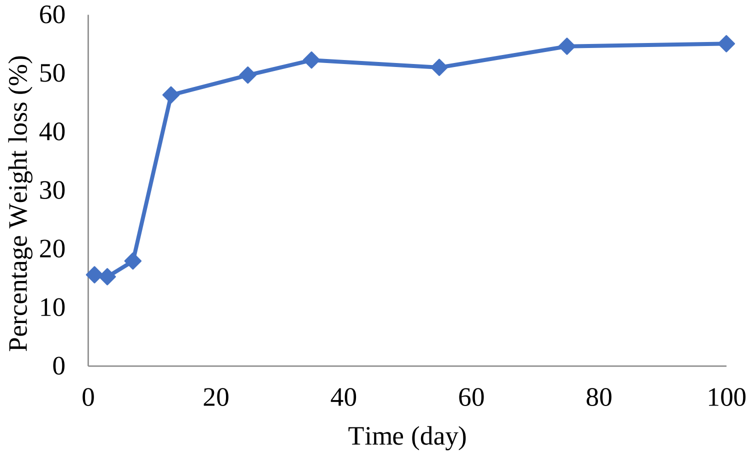

Figure 1. Percentage weight loss of plastic over time in soil.

3.1.2. Weight loss of starch-based plastic under UV irradiation

The graph showing the percentage weight loss of the starch-based plastic film under UV light exposure is presented in Figure 2. It is evident that the percentage of weight loss increases steadily over the exposure period. The impact of UV irradiation on the percentage weight loss of the starch-based plastic was relatively less significant. After 100 days of UV irradiation, there was only a 9.1% decrease in weight. This suggests that the starch-based plastic did not experience substantial weight loss when exposed to sunlight for an extended period. Pandey *et al*. (2005) assert that percentage weight loss serves as an indication of percentage degradation. The weight loss percentage of the starch-based plastic was more significant in the soil burial treatment, indicating a greater degree of degradation in this environment.

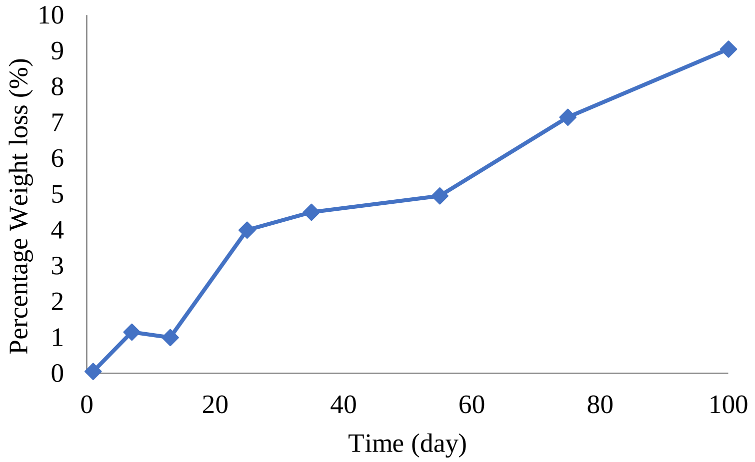

Figure 2. Percentage weight loss of plastic over time under UV Irradiation

3.2. Mechanical Behaviour of Starch-Based Plastic

Figure 3.3 shows the stress-strain curve of untreated starch-based plastic, which served as the control in this study, illustrating its mechanical behaviour. The curve demonstrates that starch-based plastic exhibits viscoelastic properties. In region (a) of Figure 3, the curve exhibits a rapid increase where the stress is directly proportional to the strain. This region is known as the elastic reversible strain area or elastic deformation. The material behaves elastically, meaning that the strain is reversible, and the material can return to its original shape after the applied stress is removed.

As the curve progresses, it enters region (b) where the stress-strain relationship continues to increase until reaching the yield point. At this point, the plastic strain area begins, and the strain of the plastic becomes irreversible. This is evident in Figure 3.3 in the form of a distinct bend in the curve away from the stress coordinate. The rate of plastic flow increases as stress is applied, leading to eventual rupture or failure of the film.

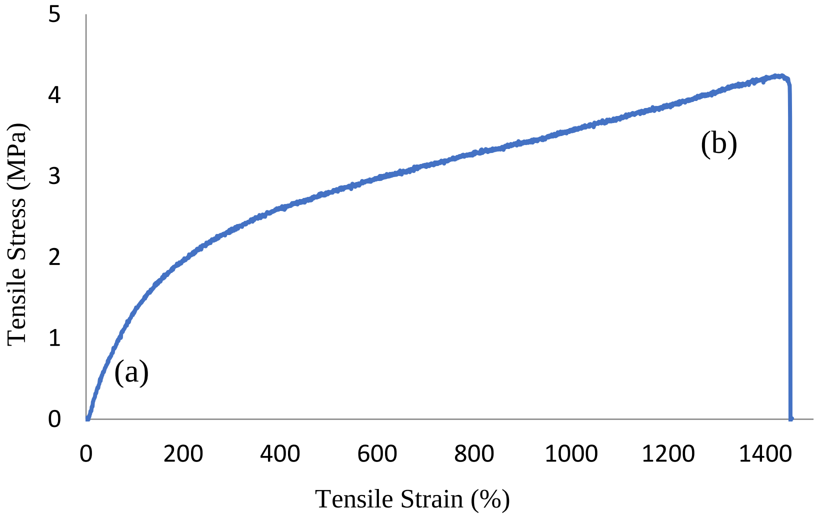

Figure 3. Tensile stress-strain curve of starch-based plastic

3.2.1. The effect of soil burial treatment on mechanical properties

Figure 4 shows the elongation at the break of the starch-based plastic sample throughout the soil burial treatment. The elongation at break initially decreases significantly within the first 25 days and then remains relatively constant thereafter. On day 0, the elongation at break is recorded at 157 mm, decreasing to 55 mm by day 100, resulting in a 64.7% reduction.

Figure 5 illustrates the tensile strength of the starch-based plastic as a function of burial time. Tensile strength represents the force required to pull the plastic film to the point of fracture. The graph shows an initial increase in tensile strength within the first 7 days, followed by a consistent range of 9-16 MPa. The increase in tensile strength may be due to the increased cross-linking within the polymer.

These results demonstrate that the soil burial treatment influences the mechanical properties of the samples. According to Dintcheya and La Mantia (2007), elongation at break serves as an indication of degradation. The increase in the weight loss percentage of the soil-buried samples, accompanied by a decrease in elongation at break, suggests that degradation occurs throughout the soil burial treatment. Soil burial treatment leads to the deterioration of mechanical properties, particularly the elongation at break (Guohua *et al.*, 2006). The changes in mechanical properties observed during the soil burial test are attributed to the consumption of starch by microorganisms in the soil (Artham & Doble, 2008; Muthukumar *et al.*, 2010).

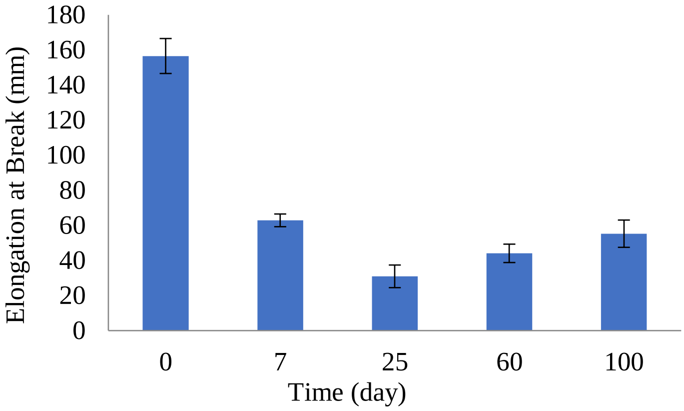

Figure 4. The effect of soil burial treatment on elongation at the break of the samples.

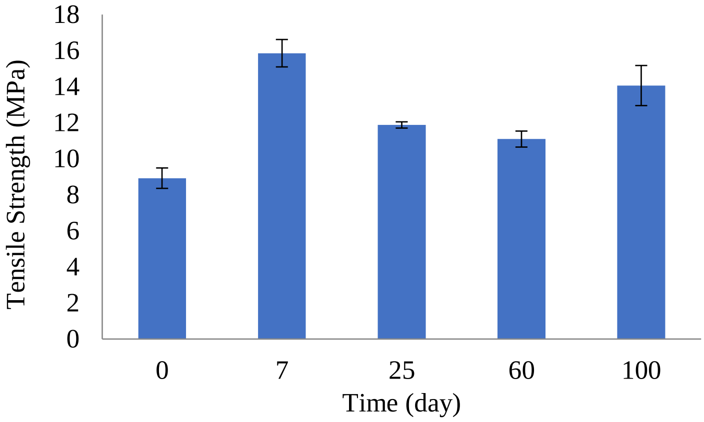

Figure 5. The effect of soil burial treatment on the tensile strength of the samples.

3.2.2. The effect of UV irradiation on mechanical properties

Plastics can be subjected to stress during use, making it essential to determine their mechanical properties, which involves not only scientific but also technological and practical considerations (Azahari *et al.*, 2011). When exposed to UV light, plastic materials undergo significant changes and experience a loss in mechanical properties, which can shorten their shelf life (Rehim *et al.*, 2004). The graphs of elongation at break and tensile strength as a function of the duration of plastic sample exposure to UV light are presented in Figures 6 and 7, respectively.

Referring to Figure 6, the elongation at the break of the sample decreases as the duration of UV irradiation increases. The percentage decrease in elongation at break for the UV-irradiated samples is 92.1%. The elongation at break of the sample exhibits a dramatic decrease in the first 20 days, followed by relatively slight differences in elongation at break from day 40 to day 100. The reduction in elongation at break with exposure time can be attributed to a decrease in molecular weight and an increase in cross-linking (Dintcheva & La Mantia, 2007). Cross-linking involves the bonding of polymer chains with adjacent chains through the creation of covalent bonds. However, the decrease in elongation at break is more significant in the UV irradiation, which is consistent with the findings reported by (Muthukumar *et al.*, 2010).

Figure 7 presents the graph of tensile strength as a function of the duration of plastic treatment under UV irradiation. The tensile strength of the UV-irradiated samples initially increases with the days of UV exposure, reaching a maximum value of 15.9 MPa, which then further decreases to 13.7 MPa. However, the tensile strength of the sample does not exhibit significant changes and remains within a range of 10 MPa to 16 MPa. Based on the research of Dintcheva & La Mantia (2007), this slight increase in tensile strength can be attributed to the cross-linking of the polymer. Initially, UV irradiation leads to a decrease in molecular weight, causing chain scission and subsequently resulting in lower tensile strength.

Overall, these results indicate that UV radiation induces changes in the mechanical properties of the starch-based plastic. Elongation at break, as an indicator of degradation, agrees with the findings of Rehim *et al*. (2004), where elongation at break decreases with increasing UV exposure time, while tensile strength is less affected It is important to highlight that the weight loss of the UV-irradiated sample increases, accompanied by a decrease in elongation at break, indicating degradation throughout the UV irradiation exposure. During the exposure period, oxygen uptake increases, and the rate of formation of intermediate products increases, leading to an increase in carbonyl group concentration. At this stage, the effect of UV irradiation on starch-based plastic is primarily due to slight chain scission. Chain scission causes the reorientation of shorter polymer chains, making them more readily crystallisable and resulting in a polymer with a higher degree of crystallinity (Miltz & Narkis, 1976; Ratanakamnuan & Aht-Ong, 2006; Rehim *et al*., 2004).

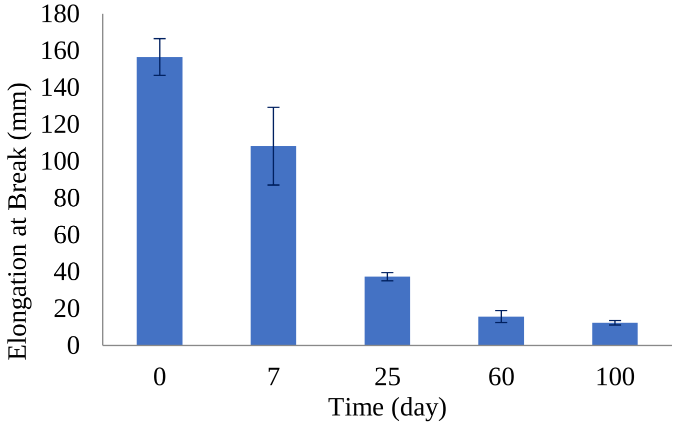

Figure 6. The effect of UV light on elongation at the break of the samples.

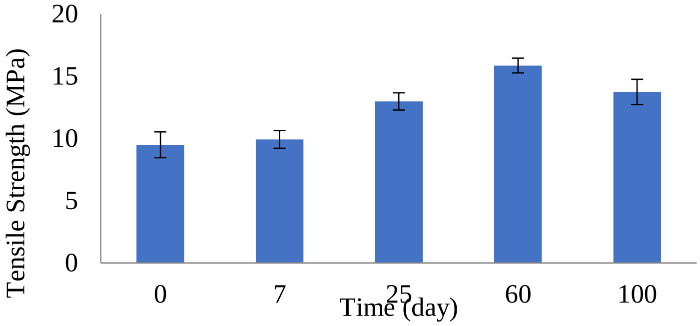

Figure 7. Effect of UV light on the tensile strength of the samples.

3.3. FTIR Analysis of Sample after Soil Buried and UV Radiation Treatment

FTIR analysis was used to detect structural changes in the starch-based plastic resulting from the effects of UV irradiation and soil burial treatment (Rehim *et al*., 2004). Based on the work of (Xu *et al*., 2005), the broadband at 3336 cm^{-1} corresponds to OH stretching, while the peaks at 2943 cm^{-1} and 2907 cm^{-1} represent CH stretching.

Figure 8 shows the infrared spectra of the untreated sample compared to the sample subjected to soil burial treatment. Figure 9 presents the infrared spectra of the untreated sample, and the sample exposed to UV irradiation. In both the soil-buried and UV-treated samples, the OH stretching peak at 3360 cm^{-1} broadens. A new peak also emerges at 2820 cm^{-1}, which represents the CH stretching bond. Additionally, a new peak at 1490 cm^{-1} is observed in the sample after UV irradiation. The CO bond stretching in the range of 976-1200 cm^{-1} shows slight changes in the peak. The appearance of new peaks indicates the formation of new bonds during the soil burial treatment and UV irradiation.

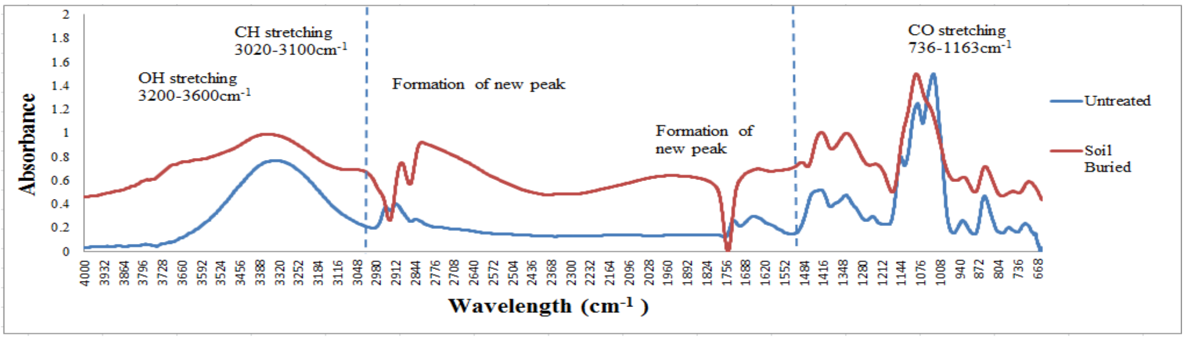

Figure 8. FTIR spectra for starch-based plastic before and after soil buried treatment.

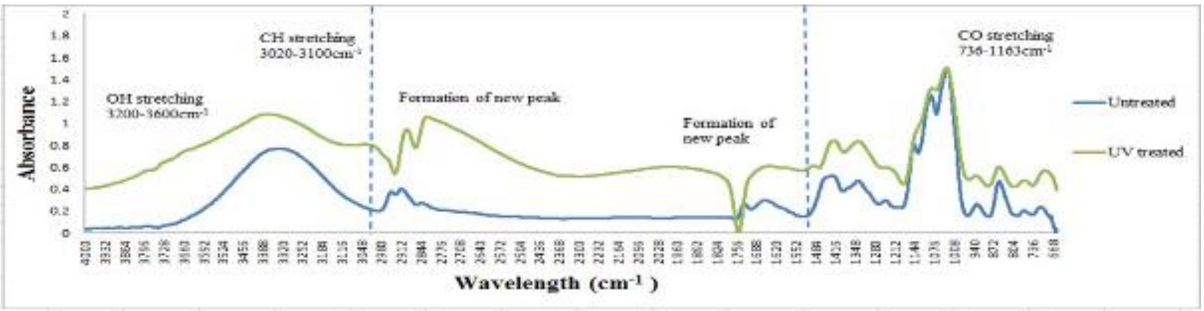

Figure 9. FTIR spectra for starch-based plastic before and after UV treatment

3.4. SEM Analysis of Sample after Soil Buried and UV Radiation Treatment.

SEM was used to examine the surface morphology of the sample before and after UV irradiation and soil burial treatment. Figures 10 (a), (b), and (c) show the morphologies of the untreated sample, soil-buried sample, and UV-treated sample, respectively. The visual inspection showed white spots, which are attributed to starch particles in the plastic film. After exposure to UV irradiation, the white spots persisted, and some pits were observed. However, the surface morphology showed no significant differences compared to the untreated sample. In contrast, the soil-buried sample exhibited a less dense surface morphology than the untreated sample, with a reduction in the number of small white spots. Additionally, small bubbles and tiny holes appeared on the surface morphology. The presence of tiny holes and pits are evidence of starch removal (Ratanakamnuan & Aht-Ong, 2006). Comparing the surface morphology shows that soil burial treatment had a more significant impact on the morphology of starch-based plastic.

Muthukumar *et al*. (2010) compared the surface morphology of catalyst-blended polymer with starch-blended polymer and found that the surface deterioration in starch-blended polymer was more uniform. Additionally, Rehim *et al*. (2004) concluded that the degradation rate of plastic blends with higher starch content was faster compared to blends with lower starch content. The study also demonstrated that the degradation rate increased when the plastic blend was exposed to UV sunlight before soil burial treatment, as evidenced by the SEM test revealing more holes and cavities on the blend's surface.

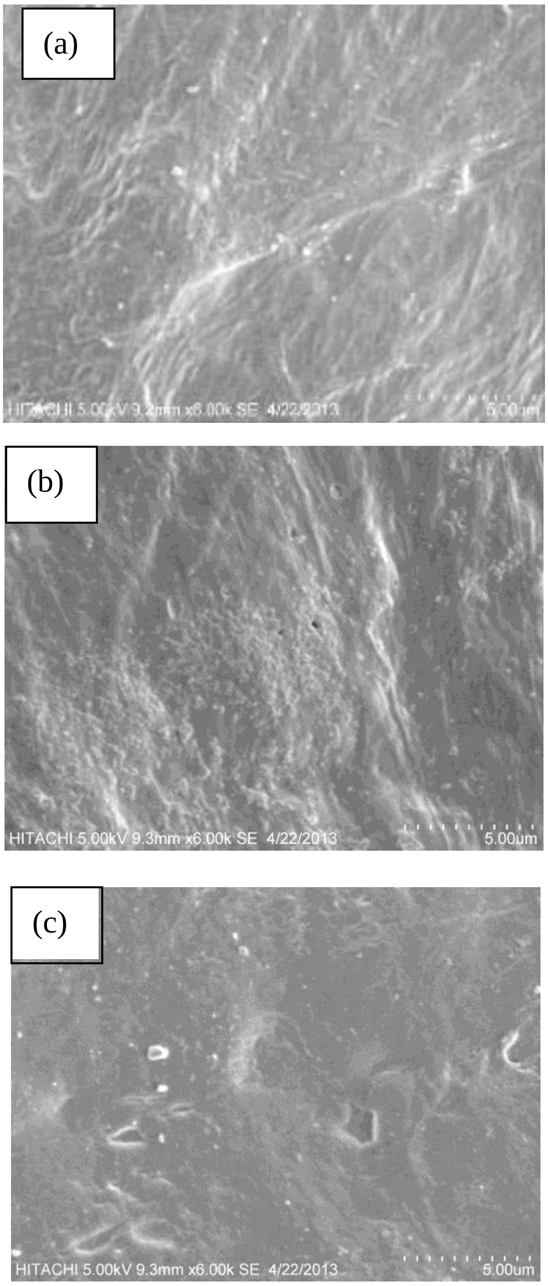

Figure 10. SEM micrographs of (a) original plastic film, (b) after exposure to soilburial treatment, (c) after exposure to UV treatment

4. Conclusions

The study emphasised the significance of starch-based polymers' degradability, especially in addressing environmental issues related to the continuous production of plastic waste derived from petroleum. In this study, starch-based films were exposed to UV irradiation and soil burial treatment to observe their effects on the mechanical and morphological properties that indicate degradability. The percentage of weight loss in the soil burial test was higher than in the UV irradiation test, indicating a substantial involvement of microbial activity in the active degradation process, according to the weight loss determination. Both treatments resulted in changes to the mechanical properties, showing a decrease in elongation at break, particularly for the samples exposed to UV irradiation. Although starch-based plastic can be used in the food industry, it is better suited for indoor use or as a primary application, as UV radiation weakens the material's mechanical properties. FTIR analysis revealed structural changes in the plastic during degradation, with both treatments showing the formation of new peaks. SEM analysis showed the surface morphology changes in the treated samples. The soil burial test resulted in more noticeable effects, with the presence of bubbles and holes indicating degradation. In conclusion, the study demonstrated the degradation of starch-based plastic under soil burial treatments and UV irradiation, occurring at different rates and magnitudes. Weight loss, deterioration of mechanical properties, the formation of new bonds detected by FTIR analysis, and surface changes observed in SEM analysis all provided evidence of degradation. The findings demonstrate the significant potential for starch-based plastics to be utilised in industries such as packaging and agriculture, where there is a growing demand for biodegradable materials.

Author Contributions: Conceptualization, Roseliza Kadir Basha, Writing review and editing, Roseliza Kadir Basha Nor Amaiza Mohd Amin, Noor Zafira Noor Hasnan, Siti Hajar Othman and Farah Saleena Taip; conducting experiments and data analysis, Sim Hui Qi and Nazatul Shima Azmi.

Funding: GP/2017/9547500

Acknowledgements: The authors acknowledge Universiti Putra Malaysia for providing financial support for the research project (GP/2017/9547500).

Conflicts of Interest: The authors declare no conflict of interest.

References

Ali, R. R., Rahman, W. A. W. A., Ibrahim, N. B., *et al.* (2013). Starch-based biofilms for green packaging. In R. Pogaku, A. Bono, & C. Chu (Eds.), *Developments in Sustainable Chemical and Bioprocess Technology*. Springer.

Artham, T., Doble, M. (2008). Biodegradation of aliphatic and aromatic polycarbonates. *Macromolecular Bioscience*, *8*(1), 14–24.

Azahari, N. A., Othman, N., Ismail H. (2011). Biodegradation studies of polyvinyl alcohol / corn starch blend films in solid and solution media. *Journal of Physical Science*, *22*(2), 15–31.

Azmi, N. S., Kadir Basha, R., Othman, S. H., *et al*. (2019). Characterization of antioxidant tapioca starch/polyaniline composites film prepared using solution casting method. *Food Research*, *3*(4), 317–324. https://doi.org/10.26656/fr.2017.3(4).144

Bajpai, P. (2019). *Biobased Polymers: Properties and Applications in Packaging*. Elservier.

Basha, R. K., Othman, S. H., Noor Hasnan, N. Z., *et al*. (2020). Mechanical properties and antioxidant activity of sweet potato starch film incorporated with lemongrass oil. *Advances in Agricultural and Food Research Journal*, *1*(2).

Bastioli, C. (2000). Global status of the production of biobased packaging materials. *Conference Proceedings: The Food Biopack Conference*, 2–7.

Chandra, R., Renu, R. (1997). Biodegradation of maleated linear low-density polyethylene and starch blends. *Polymer Degradation and Stability*, *56*, 185–202.

Dintcheva, N. T., La Mantia, F. P. (2007). Durability of a starch-based biodegradable polymer. *Polymer Degradation and Stability*, *92*(4), 630–634.

Gewert, B., Plassmann, M. M., Macleod, M. (2015). Pathways for degradation of plastic polymers floating in the marine environment. *Environmental Science Process*, *17*(9), 1513–1521.

Guohua, Z., Ya, L., Cuilan, F., *et al*. (2006a). Resistance, mechanical properties and biodegradability of methylated- cornstarch/poly(vinyl alcohol) blend film. *Polymer Degradation and Stability*, *91*(4), 703–711.

Ismail, H., Majid, R. A., Taib, R. M. (2011). Effects of soil burial on properties of linear density polyethylene (LDPE)/thermoplastic sago starch (TPSS) blends. *Pertanika Journal of Science and Technology*, *19*(1).

Kaing, V., Guo, Z., Sok, T., *et al*. (2004). Photodegradation of biodegradable plastics in aquatic environments: Current understanding and challenges. *Science of The Total Environment*, *911*, 168539.

Kiatkamjornwong, S., Sonsuk, S., Wittayapichet, S., *et al*. (1999). Degradation of styrene-g-cassava starch filled polystyrene plastics. *Polymer Degradation and Stability*, *66*(3), 323–335.

Liang, C., Das, K. C., McClendron, R. W. (2003). The influence of temperature and moisture contents regimes on the aerobic microbial activity of a biosolids composting blend. *Bioresources Technology*, *86*(2), 131–137.

Miltz, J., Narkis, M. (1976). The effect of ultraviolet radiation on chemically crosslinked low-density polyethylene. *Journal of Applied Polymer Science*, *20*, 1627–1633.

Muthukumar, T., Aravinthan, A., Mukesh, D. (2010). Effect of environment on the degradation of starch and pro-oxidant blended polyolefins. *Polymer Degradation and Stability*, *95*(10), 1988–1993.

Nordin, N., Fisal M. F., Othman, *et al*. (2024). Biodegradability of corn starch films containing nanocellulose fiber and thymol. *Nanotechnology Reviews, 13*(1), 20240110

Nordin, N., Othman, S. H., Rashid, S. A., *et al*. (2020). Effects of glycerol and thymol on physical, mechanical, and thermal properties of corn starch films. *Food Hydrocolloids*, *106*(March), 105884. https://doi.org/10.1016/j.foodhyd.2020.105884

Othman, S. H., Kechik, N. R. A., Shapi'i, R. A., *et al*. (2019a). Water sorption and mechanical properties of starch/chitosan nanoparticle films. *Journal of Nanomaterials*, *2019*. https://doi.org/10.1155/2019/3843949

Othman, S. H., Majid, N. A., Tawakkal, I. S. M. A., *et al*. (2019b). Tapioca starch films reinforced with microcrystalline cellulose for potential food packaging application. *Food Science and Technology*, *2061*, 1–8.

Othman, S. H., Tarmiti, N. A. N., Shapi'i, R. A., *et al*. (2020). Starch/banana pseudostem biocomposite films for potential food packaging applications. *BioResources, 15*, 3984–3998.

Pandey, J. K., Reddy, K. R., Kumar, A. P., *et al*. (2005). An overview on the degradability of polymer nanocomposites. *Polymer Degradation and Stability*, *88*(2), 234–250.

Puls, J., Wilson, S. A., Hölter, D. (2011). Degradation of cellulose acetate-based materials: A review. *Journal of Polymer and the Environment*, *19*(1), 152–165.

Qi, X., Ren, Y., Wang, X. (2017). New advances in the biodegradation of poly(lactic) acid. *International Biodeterioration and Biodegradation*, *117*, 215–223.

Ratanakamnuan, U., Aht-Ong, D. (2006). Photobiodegradation of low-density polyethylene/banana starch films. *Journal of Applied Polymer Science*, *100*(4), 2725–2736.

Rehim, A. E., Hegazy, E. S. A., Ali, A. M., *et al*. (2004). Synergistic effect of combining UV-sunlight–soil burial treatment on the biodegradation rate of LDPE/starch blends. *Journal of Photochemistry and Photobiology A: Chemistry*, *163*(3), 547–556.

Risyon, N. P., Othman, S. H., Basha, R. K., *et al*. (2016). Effect of halloysite nanoclay concentration and addition of glycerol on mechanical properties of bionanocomposite films. *Polymer & Polymer Composites*, *24*(9), 793–800.

Rosenboom, J. G., Langer, R., Traverso, G. (2022). Bioplastics for a circular economy. *Nature Reviews*, *7*, 117–137.

Rousk, J., Brookes, P. C., Bååth, E. (2009). Contrasting soil pH effects on fungal and bacterial growth suggest functional redundancy in carbon mineralization. *Applied and Environmental Microbiology*, *75*(6), 1589–1596.

Saad, G. R., Khalil, T. M., Sabaa M W. (2009). Photo- and Bio-degradation of poly(ester-urethane)s Films Based on Poly[(R)-3-Hydroxybutyrate] and Poly(ε- Caprolactone) blocks. *Journal of Polymer Research*, *91*(4), 703–711.

Sadi, R. K., Fechnie, G. J. M., Demarquette, N. R. (2010). Photodegradation of Poly(3-hydroxybutyrate). *Polymer Degradation and Stability*, *95*(12), 2318–2327.

Shah, A. A., Hasan, F., Hameed, A., *et al*. (2010). Biological degradation of plastics: A comprehensive review. *Polymer Degradation and Stability*, *95*(10), 1988–1933.

Shapi'i, R. A., Othman, S. H., Basha, R. K., *et al*. (2022). Mechanical, thermal, and barrier properties of starch films incorporated with chitosan nanoparticles. *Journal Nanotechnology Reviews*, *11*, 1464–1477.

Singh, B., Sharma, D. K., Gupta, A. (2007). Controlled release of thiram fungicide from starch-based hydrogels. *Journal of Environmental Science and Health*, *42*, 677–695.

Siqueira, L. V., Maniglia, B. C., Tadini, C. C. (2021). Starch-based biodegradable plastics: methods of production, challenges and future perspectives. *Current Opinion in Food Science*, *38*, 122–130.

Thakore, I. M., Desai, S., Sarawade, B. D., *et al*. (2001). Studies on biodegradability, morphology and thermo-mechanical properties of LDPE / modified starch blends. *European Polymer Journal*, *37*, 151160.

Tyagi, P., Agate, S., Velev, O. D., *et al*. (2022). A critical review of the performance and soil biodegradability profiles of biobased natural and chemically synthesized polymers in industrial applications. *Environmental Science and Technology*, *56*(4), 2071–2095.

Vilpoux, X., Averous, L. (2002). Chapter 18 Starch-based plastics. *Technology, Use and Potentialities of Latin American Starchy Tubers*, 521–553.

Vroman, I., Tighzert. L. (2009). Biodegradable polymers. *MDPI: Material*, *2*(2), 307–344.

Webb, H. K., Arnott, J., Crawford, R. J., *et al*. (2013). Plastic degradation and its environmental implications with special reference to Poly(Ethylene Terephthalate). *MDPI Polymers*, *5*(1), 1–18.

Wu, H., Fan, J. (2008). Measurement of radiative thermal properties of thin polymer films by FTIR. *Polymer Testing*, *27*(1), 122–128.

Xu, Y. X., Kim, K. M., Hanna, M. A., *et al*. (2005). Chitosan-starch composite film: Preparation and characterization. *Industrial Crops and Products*, *21*(2), 185–192. https://doi.org/10.1016/j.indcrop.2004.03.002