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Abstract

Low-density polyethylene, the material used to make most plastic shopping bags, has a considerable negative impact on the environment. It is enough intriguing for a substance to decay, develop for whatever reason (hydrolysis, Pseudomonas aeruginosa, etc.), and be exposed to the elements. Sodium trimetaphosphate was used in this experiment to treat sago starch. Using additives (glycerol/urea, 1% benzophenone, and epolene wax) in the same amount of starch, sago starch was blended with low-density polythene in various ratios of 0, 10, 20, and 30% weight percent. The mixture was then compounded via melt mixing technique and injection molded to form sheets. The results demonstrated that as the starch content grew, the untreated composite's tensile characteristics gradually lost their strength. In comparison to virgin low-density polythene, the loss of tensile strength and elongation at break was roughly 23.3% and 87.5%, respectively, with 30 weight percent of starch loading. In contrast to virgin low-density polythene, the treatment

composite at 30 weight percent starch loading lost 17.3% of its tensile strength and 98.8% of its elongation at break. The low-density polythene in the treated composite had a lower percentage of tensile strength, but it was more elongated at break than the untreated composite due to the superior distribution and consistency of sago starch. Weight, morphological, and tensile characteristics were evaluated in relation to hydrolysis, Pseudomonas aeruginosa, and natural weather in order to assess the biodegradability of this composite.

Keywords: Low-density polythene, sago starch, morphology, mechanical features, biodegradability

Introduction

Since a large portion of the municipality's damaged areas are composed of polymeric materials, contamination by ruined polymeric ingredients is a serious issue. Fighting the contamination brought on by the breakdown of these wastes into hazardous and beneficial compounds is a difficult undertaking. Solid waste derived from synthetic polymer materials is identified as a major cause of ecological contamination, which can take up to a thousand years to land [1]. To cut down on pollution, it's critical to produce certain biodegradable components. These materials not only improve everyday living but also lessen their post-use environmental impact. Natural renewable polymers like chitosan, fiber, and sago starch were evaluated separately and in conjunction with possible improvements in plastic characteristics and product biodegradation. Over the past thirty years, plastic components have been utilized more and more in the manufacturing of food, textiles, housing, transportation, building, pharmaceuticals, and entertainment. Due to its strength, light weight, and durability, thermoplastic polyethylene, such as low-density polyethylene materials, is currently utilized in plastic films for garbage bags, distribution bottles, assembly, farm bags, compost bags, and a variety of molded laboratory components. The polymer polyethylene is hydrophobic. Microbes are unable to readily land on this carbon-carbon bond. Biodegradability of plastic is offered as a remedy for the issue of abuse. Plastics made of starch have lessened the greenhouse effect and have not damaged the environment [2]. The emphasis on environmentally friendly plastics for use in agriculture, medicine, fishing, and food packaging has increased recently [3].

In agriculturally resource-rich nations like Malaysia, starch is an inexpensive, renewable, entirely biodegradable natural element [4]. It is also widely available. It is a naturally occurring polymer consisting of 1-4-α-D glucopyranosyl units that repeats itself. Typically, it is made up of a mix of linear (amylose, secondary) and branching (amylopectin, primary) components. Scheme 1 displays the structures of amylose and amylopectin.
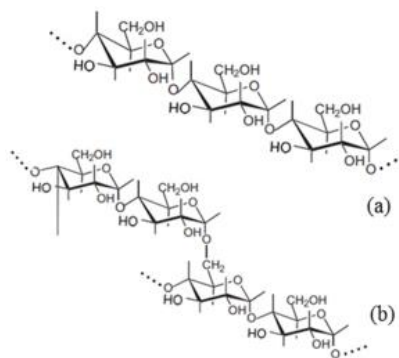
Scheme 1. The chemical structure of (a) amylose and (b) amylopectin.

Sago starch is the most common starch in Malaysia and is obtained from the pith of several tropical palm stems, including sago palms. Another potential application for sago is as biodegradable filler in thermoplastics, as indicated by this starch. Because of the possible use of this technique in the elimination of plastic waste, blending sago starch with low-density polyethylene has drawn a lot of attention. Impurities in starch-filled polythene composites have led to poor mechanical characteristics. The hydrophilicity of starch causes its interactions with other materials to occur both during and after the process [5]. The compatibility of low-density polyethylene/thermoplastic starch-based mixing methods will be improved by glycerin and starch cross-linked sodium trimethophosphate (STMP) with plasticizing agents. The most significant food additives, STMP, have a low hazardous concentration. Despite a great deal of research on the biodegradation of polythene [6-8], the results were based on polyethylene combined with starch. Microorganisms (bacteria and fungi) are the main invaders of biodegradation, spreading through soil and water. Using FTIR spectroscopy, Goheen et al.[9] monitored the degradation of the polyethylene (PE)/starch film in the soil to assess the release of starch and chemical alterations in the PE. None of this study, however, depends on assessing the relationship between morphology, tensile property, and microbial biodegradability. Here, the impacts of starch concentration and additive addition to modified sago starch (SS)/low-density polyethylene (LDPE) composites are examined,

along with the effectiveness of these modifications both before and after the mechanical qualities and biodegradability of the materials are taken into account.

Experimental

Ingredients

The matrix used in this study was made of LDPE pellets that were obtained from the Petlin PE (Malaysia) Sdn Bhd division. The density and melt flow indexes of the LDPE were 0.928 g/cm^3 and 3.2 g/10 min, respectively. The percent moisture was 1113%, and its starch value was above 85%. The biodegradable agents used in this study were a mixture of glycerol, SS, and urea. The benzophenone was supplied by H.L. Blanchford Limited (Ontario, Canada). The reagent grades glycerol (glycerin, $C_3H_8O_3$) as plasticizing agents, the urea and epolene wax were bought from Sigma Aldrich Chemical Company Inc. in Malaysia.

Procedures

Improved Sago Starch

The Shin et al. approach [10, 11] was used to modify SS because it was not compatible with LDPE and did not process well. For two hours, at 45°C, cross-linked STMP (5.40 g) was added to 50 g of SS. The composite was further prepared and dried using grounded cross-linked stainless steel for two hours at 50°C.

Preparing Samples

Prior to usage, all components were dehumidified by 20 hours at 80°C in a vacuum oven. Granular SS and LDPE were combined in varying weight percentages between 0 and 30%. The treated SS was first combined with LDPE in a Mini Blender (Most Machine Builder, Fairfield, New Jersey, USA) with 2% dissolved mediator (Epolene wax E-43p, White Group, USA) and the same amount of starch additives (glycerol/urea and 1% benzophenone). In Table 1, chemical compositions are displayed. A co-rotating twin-screw extruder (model: TSE 20, GmbH & Co. KG, Germany) was used to create the aforementioned mixer via melt blending, and injection molding was then used to manufacture a composite sheet. The rotor speed used for the compounding process was 90 rpm, and the temperature die (150°C/150°C) was used to measure the temperature from the feeder (160°C/160°C). A pelletizer was then used to palletize the extruded components. These platelets were used to create dumbbell-shaped specimens using an injection-molded machine (Toyo, model:

Si180iii-E200, Japan). Figure 1 shows a schematic representation of the biodegradable film preparation process.

Table 1. Prepared composition sample.

Sample code	LDPE (wt%)	Starch (wt%)	A	B	C
Virgin LDPE	100	0	–	–	–
$L_{90}S_{10}$ (LUS_{10})	90	10	–	–	–
$L_{80}S_{20}$ (LUS_{20})	80	20	–	–	–
$L_{70}S_{30}$ (LUS_{30})	70	30	–	–	–
$L_{90}S_{10}GU_{15}$ (LMS_{10} A)	90	10	15	1	2
$L_{80}S_{20}GU_{15}$ (LMS_{20} A)	80	20	15	1	2
$L_{70}S_{30}GU_{15}$ ($LMS_{30}A$)	70	30	15	1	2

L: LDPE; U: unmodified sago starch; M: SS treated with STMP; The number after the letter S indicates the percentage of starch; A; additives; glycerol:urea=2:1 (wt%); B: benzophenone; C: Epolene wax (wt%).
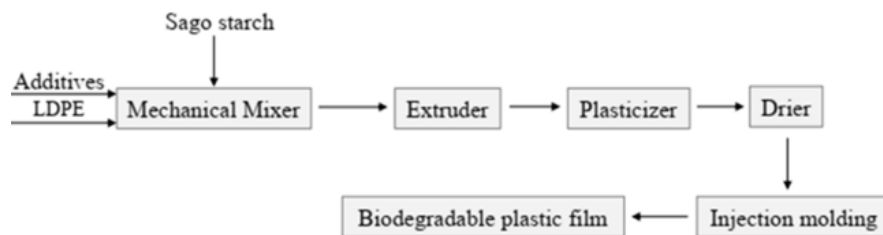

Figure 1. Schematic illustration for the production of biodegradable films.

Test Mechanically

The tensile characteristics of composites have been measured using specimens in the shape of dumbbells (125 × 3 mm^2). The ASTM-D 638-14 standard was used to assess the composite's tensile characteristics using a Shimadzu UTM (Model AG-1, Japan) [12]. At a gauge length of 50

mm and a crosshead speed of 10 mm/min, the tensile test was completed. Every experiment was conducted at $25 \pm 2°C$ and $55 \pm 4\%$ relative humidity. Every result was analyzed as the average of five samples.

A **Morphological Observation**

The tensile fractured surfaces of the treated and untreated SS plastic composites were examined using a Zeiss Evo 50 SEM operating at a voltage of 20 kV, both before to and following biodegradation. To spread the electric charge during the test, the samples were broken in liquid nitrogen, and their fracture edges were covered with a thin layer of gold and inserted in aluminum sputum.

Tests of Degradation

The percentage of weight loss during hydrolysis, tensile characteristics (TS and Eb), morphology, exposure to *Pseudomonas aeruginosa*, natural weather, and burial in the ground all provided information about the composite's biodegradation behavior in virgin LDPE, LUS_{30}, and $LMS_{30}A$.

Studies on Hydrolysis

Simple Hydrolysis

Arvanitoyannis et al. [13] proposed the technique of utilization. Dumbbell-shaped specimens were submerged in 30 ml of distilled water at 80°C for general hydrolysis. To track weight loss during the course of the study, weight fluctuations were computed every three hours.

Hydrolysis of Alkali

Arvanitoyannis et al. recommended the method of use [13]. The specimens, the size of dumbbells, were submerged in 30 milliliters of 0.1N NaOH solution at 80°C. To track weight loss during the course of the study, weight fluctuations were computed every three hours. The molded samples were accurately weighed prior to testing. Additionally, the mold samples were accurately weighed following an 18-hour exposure to a deteriorated environment. Equation (1) was used to calculate the weight loss percentage.

$$\text{Weight loss } (\%) = \frac{W_b - W_a}{W_b} \times 100 \qquad (1)$$

W_a stands for mold weight following degradation, whereas W_b stands for mold weight before to degradation.

Bacterial Growth Preparedness

The material was divided into flat pieces of 5 by 5 cm^2 and placed on top of the nutrient-rich agar in the Petri plate. In an infertile environment, *P. aeruginosa* was refined using a nourishing agar medium. After being prepared in saline, the bacterial suspension was applied to the sample. A 4 × 4 cm^2 piece of parafilm was placed inside and covered for 90 days at 30°C with a humidity level above 90%.

Experiment on Natural Weather

The dumbbell-shaped specimens were subjected to naturally occurring actinic radiation at UMP Gambang, Pahang, Malaysia, for 180 days while being planted in racks. The rack is 45 degrees tilted toward the equator and is not obstructed by any open area where it is obscured by other things. To gauge deterioration, specimens were taken one, three, and six months after being exposed to rain, sunshine, wind, and other environmental factors [14]. The average temperature was 28.5±0.35°C, and 58% of the air was relative humidity. In order to compare the shelf life of similarly prepared samples exposed to external conditions, an interior control test was carried out. The percentage of lost features after one, three, and six months was calculated.

FTIR (Perkin Elmer System 2000) was used to measure the development of the carbonyl group. The frequency range in which specimens were scanned was 4000-400cm^{-1}. 52 successive scans with a resolution of 4 cm^{-1} were acquired for each spectra. The level of photo-oxidation of PE was determined using the Carbonyl Index (CI). Its definition is the proportion of an internal thickness band at 1465 cm^{-1} to the absorbance of carbonyl at about 1715 cm^{-1}. Equation (2) was used to measure the carbonyl index (CI):

$$CI = A_{1715}/A_{1465} \qquad (2)$$

Results and Discussion

Evaluation of Morphological Observations and Mechanical Features

The effects of treated and untreated starch content on the percentage loss of TS and Eb for SS plastic composites are depicted in Figures 2(a) and (b). As compared to virgin LDPE, we observed a steady increase in the percentage loss for the untreated composites of TS (LUS$_{10}$, LUS$_{20}$, and

LUS$_{30}$) (Figure 2a). Virgin LDPE had a TS of roughly 9.86 MPa. The loss of TS has risen with an increase in starch concentration. The weakening of the starch-LDPE interfacial bond could be the cause of TS loss. Spherical starch has a smaller effective cross-sectional area of LDPE as the starch percentage rises. The starch-induced hydroxyl group on the surface demonstrates hydrophilic characteristics and a robust hydrogen bonding between molecules. This observation is consistent with the findings that the researchers have provided [15]. Though it is less than that of the untreated SS plastic composites (LUS$_{10}$, LUS$_{20}$, and LUS$_{30}$), the percentage drop in TS of treated SS plastic composites (LMS$_{10}$A, LMS$_{20}$A, and LMS$_{30}$A) relative to virgin LDPE has been gradually rising. Better interfacial bonding following the addition of the LDPE matrix and additives (glycerol: urea = 15%, ferric stearate 0.1%, and epolene wax 2%), is most likely the cause of this. As the amount of cross-linked starch declined, the functional -OH group's reaction with STMP decreased as well. The phosphate group in STMP and the –OH group of cross-linked starch reacted substantially. Consequently, the desired starch/LDPE interaction between LDPE or starch molecules instead of intermolecular and intramolecular can be supported by strong hydrogen bonds between LDPE/starch and plasticizer molecules. This lowers the loss of compatibility between LDPE and starch, which in turn results in a lower loss of TS.
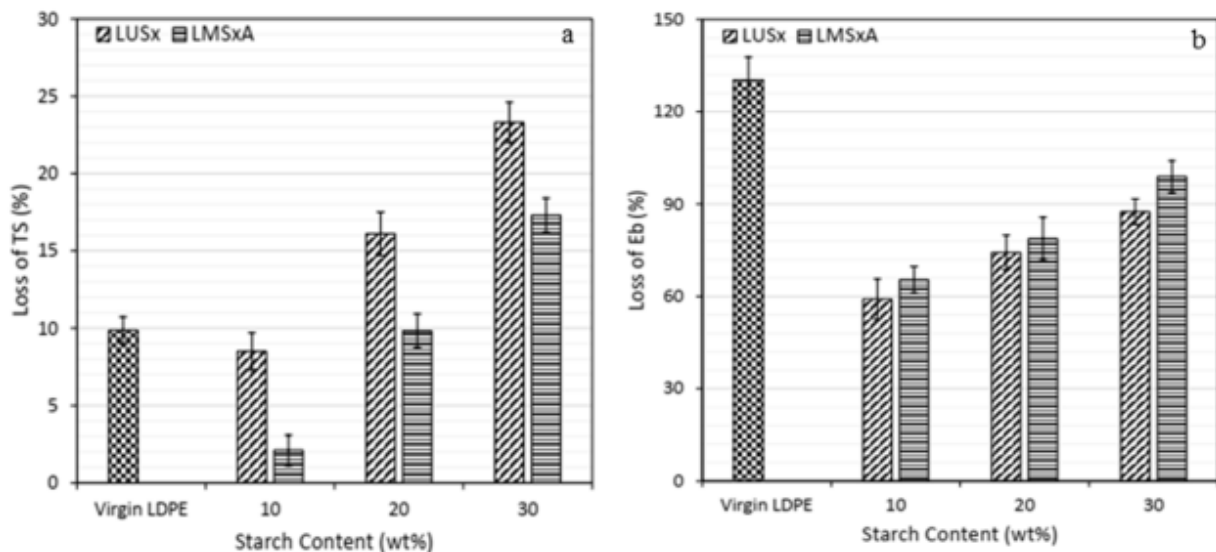

Figure 2. Impact of starch concentration on the percentage loss in (a) tensile strength (TS) and (b) elongation at break (Eb) of LUS$_x$ and LMS$_x$A composites. . LUS: LDPE/untreated SS; LMSA: LDPE/treated SS with additives. The percentage of starch is indicated by the subscript x following the letter S.

The filler load effect of Eb percent loss of treated and untreated SS plastic composites is displayed in Figure 2(b). It was discovered that virgin LDPE had an Eb of 130.23%. We found that as filler loading rises, the percentage loss in Eb for composites also rises. Through its ability to absorb moisture and lessen the impact of physical bonding between the LDPE/SS contact, this starch may impose its hydrophilic character and interfere with the absorption effect [16]. Agglomeration may occur at higher points of stress concentration in the presence of higher filler components, as was previously mentioned. This might cause cracks to propagate in the mixtures. As the amount of starch in the combination increases, this causes a percentage loss of Eb. A similar trend was noted by Wang et al. [17] in LDPE mixes filled with natural filler.

Figure 3 shows the morphology of virgin LDPE, SS, treated SS plastic composite (LMS$_{30}$A), and untreated SS plastic composite (LUS$_{30}$). The granular sizes of SS range from 10 to 40 μm, as shown in Figure 3(a). Figures 3(b)–3(d) depict the morphologies of the virgin LDPE, LUS$_{30}$, and LMS$_{30}$A composites, respectively. The addition of SS to LDPE results in a weaker spread between SS and LDPE, as Figure 3(c) illustrates. The degradation of the mixture's mechanical properties with the starch content was identified by this micrograph. There are locations of very modest stress concentration where the starch and LDPE can establish an interfacial interaction. The SEM micrograph of the LMS$_{30}$A composite with a mixture of benzophenone, dispersion agent, and glycerol/urea plasticizers is shown in Figure 3(d). Compared to the LUS$_{30}$ composite, we observed that the size or aggregation of SS decreased when the treated starch was added to the mixtures. The morphology of the sample in LMS$_{30}$A of Figure 3(d) demonstrated the inability to detect phase separation between the SS and matrix. As opposed to Figure 3(c), it is evident that greater interfacial adherence has resulted in a significant improvement in interfacial morphology. Since glycerol/urea lowers the intramolecular and intermolecular hydrogen interactions between LDPE and starch, the combination of plasticizers, STMPs, and dispersion agents can form additional hydrogen bonds with SS. This explains why the LMS$_{30}$A composite was inspected for its mechanical properties and not the LUS30 composite.
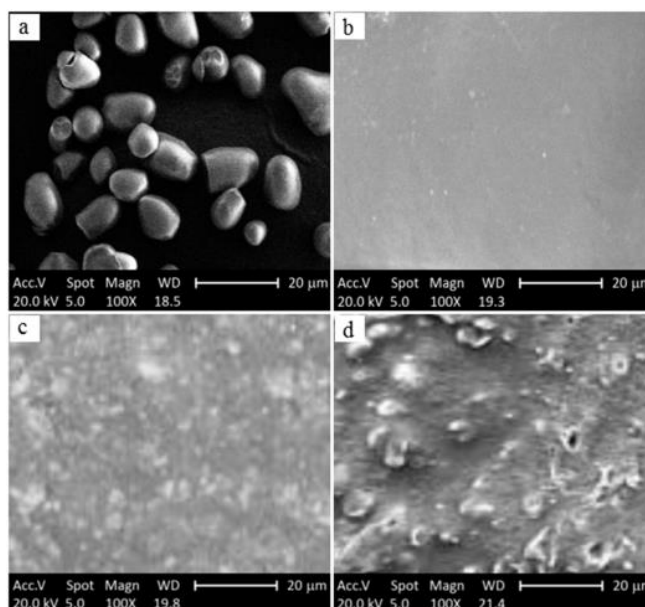
Figure 3. SEM photographs of the (a) SS granules, (b) virgin LDPE, (c) LUS_{30} and (d) $LMS_{30}A$ composites.

Tests of Degradation

Simple and Alkali-Induced Hydrolysis

The weight loss LDPE composite, $LMS_{20}A$, and $LMS_{30}A$, and alkali-accelerated summarized in Table 2. composites, weight LDPE has been LDPE has significant weight loss exposure duration are of SS dissolved in cause of this. Alkali in greater weight loss as Table 2 illustrates. technique for composite's

Samples	Weight loss (%)		
	6 h	12 h	18 h
Simple hydrolysis			
Virgin LDPE	0.000	0.003	0.012
LUS_{20}	0.541	1.324	2.352
LUS_{30}	0.826	1.834	2.741
$LMS_{20}A$	0.264	0.553	0.923
$LMS_{30}A$	0.392	0.934	1.832
Alkali hydrolysis			
Virgin LDPE	0.006	0.011	0.017
LUS_{20}	1.325	2.321	4.576
LUS_{30}	1.556	2.475	5.231
$LMS_{20}A$	0.621	1.023	2.586
$LMS_{30}A$	0.758	1.127	3.285

percentage of the virgin LUS_{20}, LUS_{30}, after simple hydrolysis hydrolysis is Compared to LDPE/SS reduction from virgin considerably slower. demonstrated when starch levels and high. The deterioration water could be the hydrolysis may result than simple hydrolysis, The aim of this ascertaining a biodegradability is to

demonstrate that artificial composites can exhibit varying pH levels when submerged in water. Starch-based mold degradation can be accelerated by high pH levels.

Table 2 Weight changes of virgin LDPE, LUS_{20}, LUS_{30}, $LMS_{20}A$, and $LMS_{30}A$ blends after 18 h of hydrolysis.

The SEM micrographs of the LMS30A composite exposed to simple and alkali-accelerated hydrolysis for eighteen hours are shown in Figures 4(a) and 4(b). The SEM image verified the starch particle decay that was seen in the LDPE matrix. As can be observed in Figure 4(a), simple hydrolysis collapses the large voids on the flat surface of LDPE, exposing imbedded starch granules. Comparing alkaline hydrolysis to simple hydrolysis, Figure 4(b) demonstrates significantly more holes and voids. These pores validated the removal of SS by hydrolysis and disclosed the rate of biodegradation. Hydrolysis-induced SS absorption causes LDPE to become holey, which leads to LDPE deterioration.
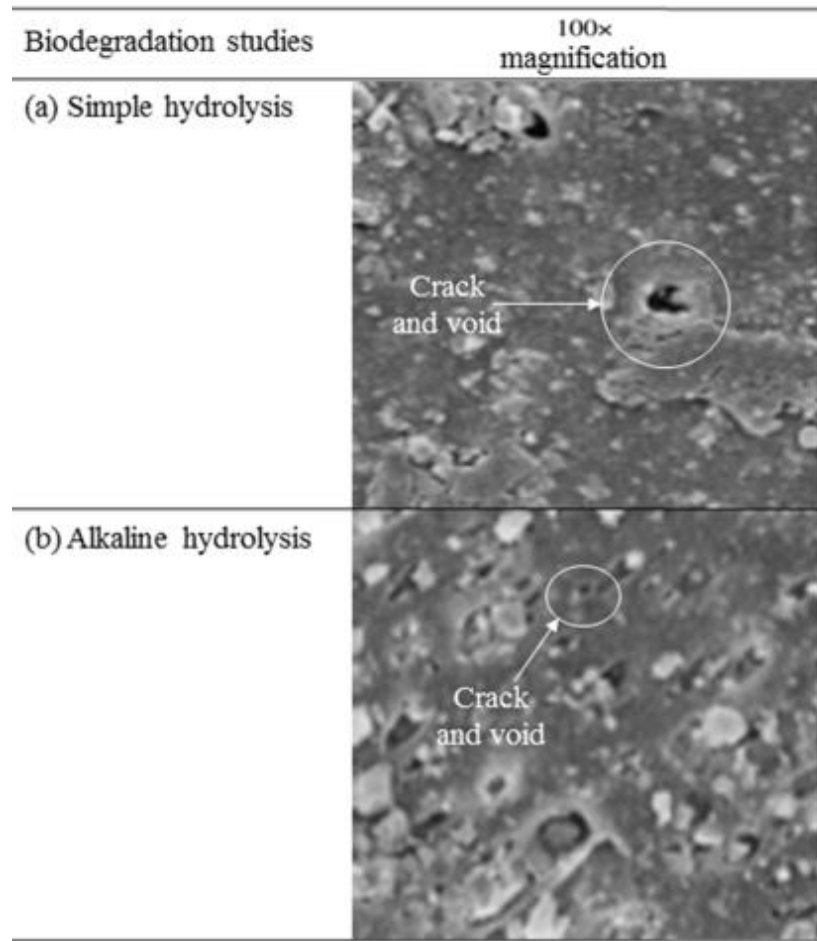
Figure 4. SEM photomicrographs of LMS$_{30}$A blends were taken after 18 hours of (a) simple hydrolysis and (b) alkaline hydrolysis.

Pseudomonas Aeruginosa Exposure

Biodegradation is monitored using the most effective weight loss strategy as a function of time [18]. After 90 days of exposure to *Pseudomonas aeruginosa*, virgin LDPE, LUS$_{30}$, and LMS$_{30}$A show a reduction percentage of composite characteristics (weight loss, TS, and Eb). As a result, virgin LDPE lost a little weight. Because carbon-free media can diminish LDPE, *P. Aeroginosa* can be held accountable for biodegradation, which is the cause of the weight loss. [19]. The weight loss in our investigations, which include the biodegradation of LMS$_{30}$A and LUS$_{30}$ composites, shows a linear growth. Virgin LDPE (Figure 5A) did not exhibit any discernible enhancement, but

black specks from portions B and C of Figure 5 performed on the sample's surface, indicating bacterial enhancement. The idea that sago starch in LDPE composites attracted bacteria to attack the composite was further confirmed by the composites' increased weight loss over a 90-day period. The LUS_{30} and $LMS_{30}A$ composites had the greatest rates of biodegradation, at 5.26% and 5.15%, respectively. However, after being exposed to *Pseudomonas aeruginosa* for 90 days, virgin LDPE only shown 0.35% biodegradation.

Table 3. After 90 days of exposure to *Pseudomonas aeruginosa*, virgin LDPE, LUS_{30}, and $LMS_{30}A$ composites showed weight loss and a decrease in tensile characteristics (TS, and Eb).

Loss in properties	Time (days)	Samples		
		LDPE	LUS_{30}	$LMS_{30}A$
Weight loss (%)	30	0.12	3.36	2.86
	60	0.28	5.45	3.65
	90	0.35	7.26	5.15
Loss of TS (%)	30	8.5±0.9	20.2±0.5	13.3±0.7
	60	17.2±0.4	29.4±0.7	18.8±0.5
	90	23.4±0.7	38.6±0.9	26.7±0.8
Loss of Eb (%)	30	15.3±0.5	23.7±0.8	18.4±0.5
	60	26.6±0.7	31.2±0.6	28.2±0.7
	90	37.5±0.8	49.3±1.1	43.4±0.5

Before testing, the LUS_{30}, and yields TS and Eb 0.8, 7.56 ± 0.4, 8.15 130.23 ± 15.3%, 0.04%, Ninety days after pseudomonas virgin LDPE, $LMS_{30}A$ composite values of 9.86 ± ± 0.6 MPa and 16.2 ± 0.9%, 1.47 ± respectively. contracting aeruginosa, we observed an increase in the percentage loss of TS and Eb in all samples, with Eb showing the

greatest effect. Compared to TS, Eb provides a more sensory assessment of the level of deterioration [20]. For this reason, when LDPE has more crystallinity, its Eb becomes less flexible [21]. Because it gets denser, more material becomes opaque, and the degree of this varies on the concentration. With an increase in exposure time, losses in the TS of the LUS_{30} and $LMS_{30}A$ composites rose gradually. The pattern was exactly the same as Eb's. The latter phase saw a sharp decline in the Eb %. Although there was no interfacial adhesion between the LUS_{30} composite and the LDPE for the $LMS_{30}A$ composites, there were greater gaps between the two. Light and oxygen can enter the LDPE's interior at this time. Therefore, compared to the $LMS_{30}A$ composite, the LUS_{30} composite lost more TS as the exposure period rose. For composite in $LMS_{30}A$, the greatest loss of TS and Eb was 26.7% and 43.4%, respectively, ninety days after *Pseudomonas aeruginosa* infection.

Figure 5. Sample degradation following Pseudomonas aeruginosa exposure: (A) virgin LDPE, (B) $LMS_{30}A$, and (C) LUS_{30} composites.

SEM testing has been done to verify bacterial deterioration. Figure 6 shows a SEM micrograph of the composite in $LMS_{30}A$ following a 90-day *Pseudomonas aeruginosa* incubation period. The composite in $LMS_{30}A$ (Figure 6(a)) has a consistent and smooth surface morphology prior to testing. A few voids and bores in $LMS_{30}A$ are executed on the composite surface, as seen in Figure 6(b). These gaps demonstrate that *Pseudomonas aeruginosa* removed the SS and specify the pace of damage. Regions of bores infested with microbes are displayed. Bacteria that consume SS leave gaps in LDPE, which eventually leads to LDPE degradation. The breakdown mechanism involves

the ingestion of SS by microorganisms, which results in the molecular weight loss of LDPE chains and their subsequent disintegration. Subsequently, microorganisms grew more appealing and smaller LDPE chains more hydrophilic.
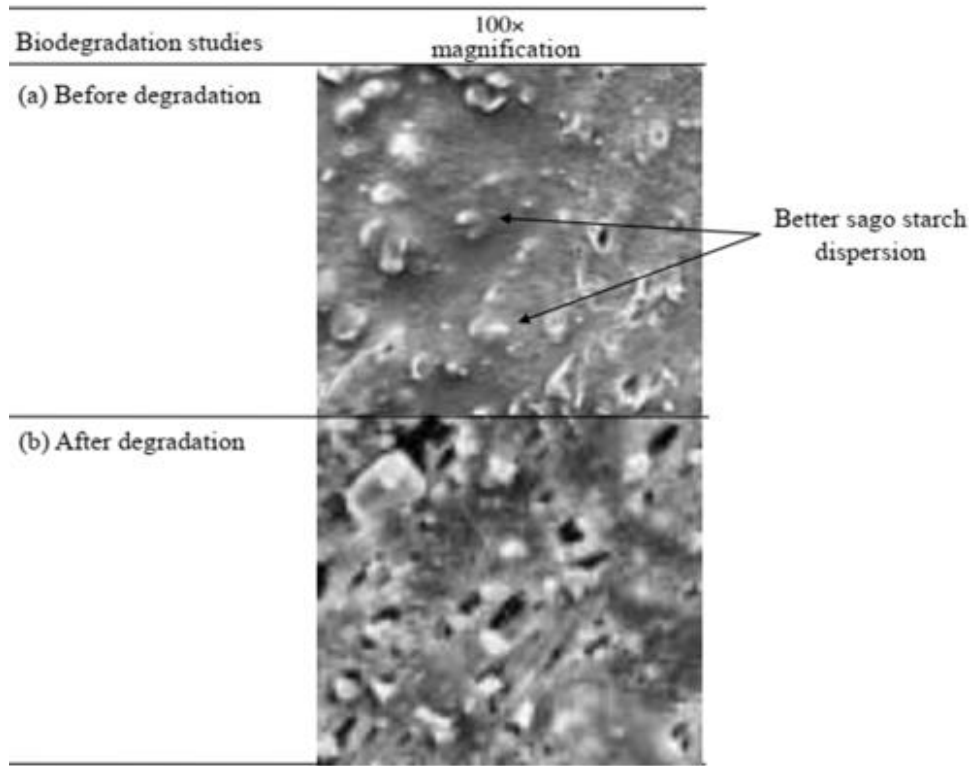

Figure 6. SEM micrographs (100 times magnification) of $LMS_{30}A$ blend composites, taken (a) prior to and (b) following a 90-day exposure to *Pseudomonas aeruginosa*.

Studies on Natural Weather

The weight loss (%) and composite carbonyl indices in virgin LDPE, LUS_{30}, and $LMS_{30}A$ following six months of exposure to ambient weather are displayed in Figure 7. Figure 7(a) shows that for both the LUS_{30} and $LMS_{30}A$ composites, CI rose as their effectiveness time decreased. The results indicates that as the exposure period rose, the CI climbed even more. It causes the SS's microstructure to become embedded in LDPE. Thus, the higher the SS content of the LDPE, the easier it is for light and oxygen to pass through its internal components, leading to higher CI and more porosity.
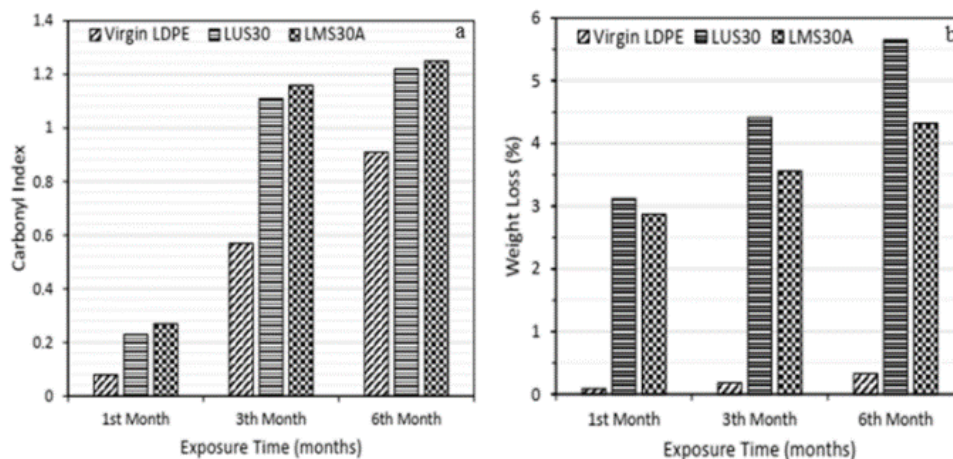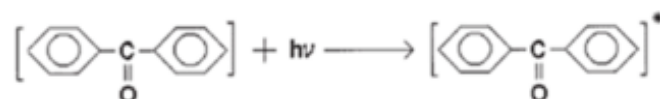
Figure 7. Following six months of natural weather, (a) the carbonyl index and (b) the weight loss of virgin LDPE, LUS$_{30}$, and LMS$_{30}$A blends.

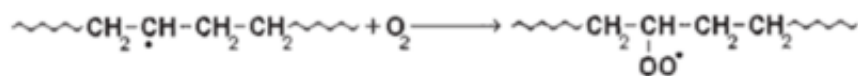Adding benzophenone may increase CI due to the following method:

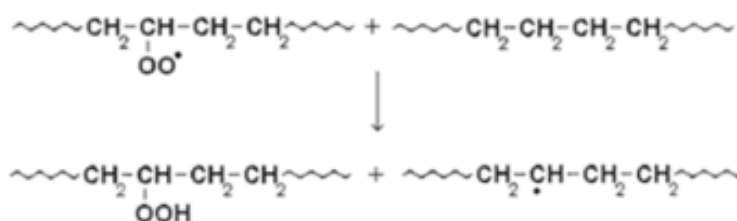1. UV rays are absorbed by benzophenone, which also increases the excited state:

2. In its excited state, benzophenone separates the H atom from LDPE to create an LDPE free radical:
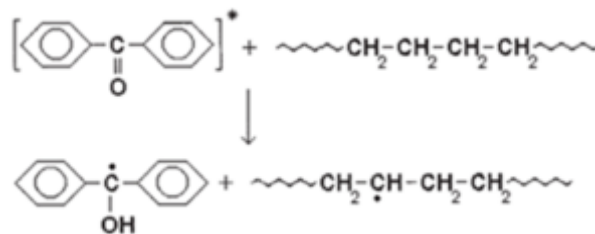
3. When this free radical interacts with O$_2$, a peroxide radical $(ROO\cdot)$ is created:
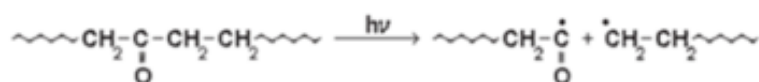

4. ROO. releases a H atom from another polymer molecule to make hydroperoxide (ROOH):
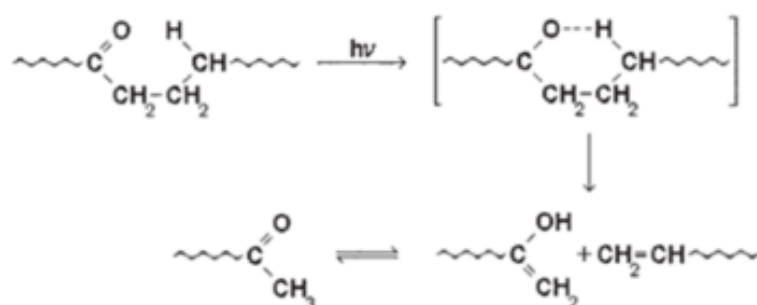

16

5. LDPE molecules containing a carbonyl group (CG) rot when exposed to ROOH:

6. A Norrish type I or type II procedure subsequently causes the CG-containing LDPE molecule
   to decay.

Norrish type II

As a result, in the procedure described above, a rise in the CG-containing LDPE chain fragment causes an increase in the CI inside the LDPE chain. This mechanism results in a reduction of the molecular weight and tensile properties of the polymer while also shortening the polymer chains. According to Figure 7(b), the virgin LDPE has a reversal phase in the first month, which is followed by a minor weight loss (0.33%), whereas the blends containing starch show additional weight loss. Weight loss exposure to the LUS$_{30}$ composite can reach as high as 5.65% after six months, as Figure 7(b) demonstrates. But benzophenone added to the LMS$_{30}$A compound lessened its weight loss by as much as 4.32%.

Table 4 illustrates how exposure duration increased the percentage loss in TS and Eb of virgin LDPE, LUS$_{30}$, and LMS$_{30}$A composite. Because these starch granules are prone to collecting moisture, they have a high concentration of hydroxyl groups due to their water-absorbing properties. Rainfall on a regular basis is connected to natural weather tests. The theory is that water molecules will first seep into the inner layers of exposed SS plastic composites, where they will then be absorbed by the starch particles that were on the exterior. But under the outside exposure test, the benzophenone addition aids in lessening the composites' tensile characteristics. The chain reaction that results in scission exposure is what causes the increase in exposure time and the % reduction in TS with the addition of benzophenone. Benzophenone has the ability to split long

polymer chains into shorter ones and generate free radicals. So, the composite containing 1% benzophenone had the largest percentage drop in TS. Table 4 shows that after six months of exposure, the TS of the 1% $C_{13}H_{10O}$ composite dropped by roughly 38.2%. This indicates that a specific quantity of photosensitizer starts to weaken and break after a given amount of exposure. Table 4 shows that Eb and TS are on the same trend. The SEM analysis revealed that the blend's SS lacked an interfacial bond with the LDPE, which explained why the percentage loss in Eb was so high in the sixth month. This space allows light and oxygen to enter the LDPE more easily.

Table 4. Percentage loss in tensile features (TS and Eb) of virgin LDPE, LUS_{30}, and $LMS_{30}A$ composites during outdoor exposure.

Loss in properties	Time (months)	Samples		
		LDPE	LUS_{30}	$LMS_{30}A$
Loss of TS (%)	1	11.4±0.6	26.1±0.5	18.2±0.7
	3	20.3±0.5	39.4±0.8	30.3±0.6
	6	29.8±0.8	53.2±0.7	38.2±0.8
Loss of Eb (%)	1	19.2±0.8	31.3±0.8	23.6±0.6
	3	31.6±0.7	45.8±0.9	35.7±0.9
	6	42.4±0.5	71.2±1.2	48.2±1.3

The surface morphology of the LUS_{30} and $LMS_{30}A$ composites is shown in Figure 8 both before and after they were exposed to the elements. The LUS_{30} composite showed reduced LDPE-starch compatibility in Figure 8(a). Six months of weathering the LUS_{30} composite resulted in a rough surface with big fractures, elongated voids, and droplets, as Figure 8(b) illustrates. Long-lasting cavities could result from the starch particles being removed as a result of moisture absorption, which pushes the grains out of the cavity by swelling and growing in size. The $LMS_{30}A$ composite is displayed in Figures 8(c) and 8(d) before and after six months of exposure to the elements. Following the observation of naturally occurring weather, the composite's fracture surface in $LMS_{30}A$ was severely damaged. Natural weather testing in the cavities verifies the removal of SS and specifies the pace of ruin. A biodegradation rate is influenced by the number and size of cavities created in the LDPE.
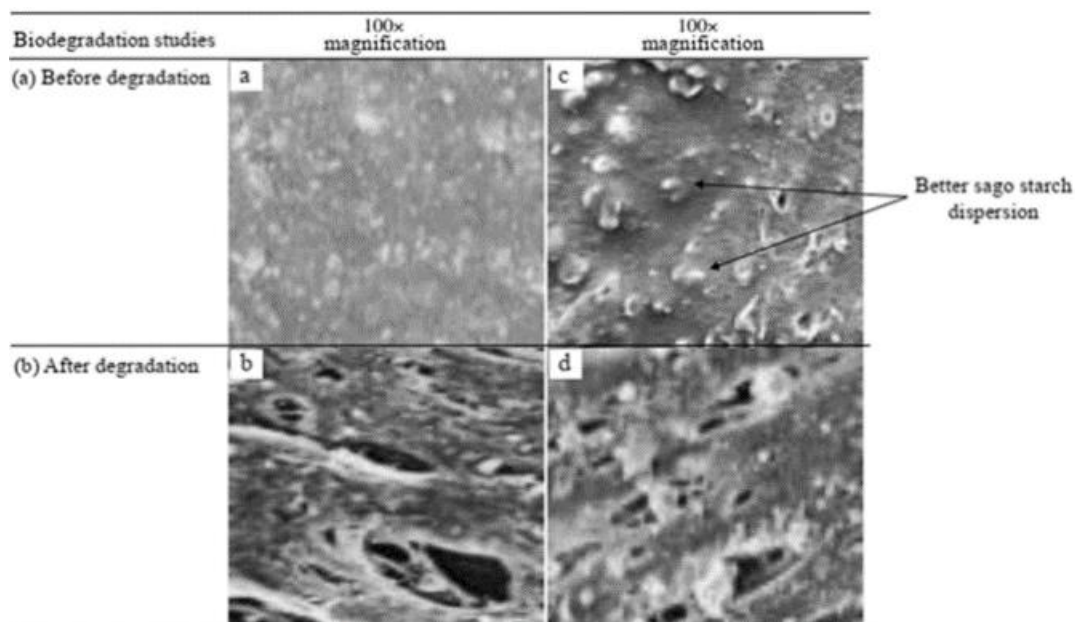
Figure 8. SEM photographs (magnification 100×) of the following mixes of LDPE/SS: (a) LUS_{30} and (c) $LMS_{30}A$ composites prior to exposure to weather; (b) LUS_{30} and (d) $LMS_{30}A$ composites subsequent to weather exposure.

Conclusions

When exposed to natural weather, the results of the tensile test show that the treatment SS plastic composites showed a lower loss in tensile features compared to the untreated SS plastic composites because of a better interfacial bond between LDPE and starch. Treatment SS had better compatibility and interaction with LDPE than untreated SS, so the percentage loss in TS of the treatment SS plastic composite was greater than the elongation at break. Alkaline hydrolysis causes highly dramatic changes and manages rapid degradation after 18 hours compared to simple hydrolysis. Composites have biodegraded more quickly as their degradation times have grown. Probably the most significant alteration in composites among all the degradation tests carried out was brought about by the weather. Based on data, these novel polymer blends can be used as agricultural plastics in packaging, horticulture, film, flower boxes and bags, and other related industries where quick deterioration is recommended.

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