

Bio-Based Plastics and Their Degradation by Soil Microbes

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Abstract

Bio-based plastics, which are degradable polymer-blends from renewable agricultural products had been investigated as good substitute for non-degradable petroleum-based plastics. The attempt is to modify the non-biodegradability, strong carbon-carbon bonds, hydrophobicity, and durability properties of conventional thermoplastics, to ensure their natural decomposition by soil microorganisms. The surface topography of the corn-starch/plastic blended-sheets were taken using a scanning electronic microscope (PPSK)SEM, model, before subjecting them to soil burial biodegradation process. The major bacteria species identified from the soil after culturing, incubation, and biochemical identifications were Staphylococcus aureus, E. Coli, Samonella Sp., Bacillus Sp., Pseudomanas Sp., Lactobacillus Sp. etc. The mechanical properties, percentage weight-loss, reduction in tensile properties, water absorption properties, appearance of remarkable voids, and cracks on the plastic surfaces, as compared to the pure plastic samples, confirmed the extend of biodegradation.

Keywords: *Bio-plastics, Microorganisms, Weight-loss, Tensile properties,*

I. Introduction

Bio-based or bio-plastics are synthetic polymers, prepared from renewable agricultural products or biomass, in order to achieve biodegradation and other desirable properties. These type of plastics can decompose without generating carbon dioxide or other greenhouse gases during the process of degradation their waste products.

Petroleum-based plastics, which are generally hydrophobic, non-biodegradable, and constitute the greatest municipal wastes, when no longer in use, had been investigated for their eco-friendly method of decomposition. However, the use of plastic in all field of life, increase in demand and non-degradability of plastics are the reasons for their menace in human environment. Plastic waste had been a global epidemic and the impact on the eco-sysytem can not be over-emphasied, because, they can be used for just a few minutes, discarded or dumped to stay for many years without degradation. The problems of plastic wastes had been a great environmental pollutant, blocking drainages and cluttering seas, rivers, streams or other surface waters. They can choke birds, fishes, or other animals, when mistaekely taken for food. Plastic waste can prevent penetration of oxygen, nitrogen, etc, into farm lands when depossited on them, therefore reduces the soil fertility which can poorly affect crop yields. Litters from plastic wastes are very unsightly, environmentally unfriendly, can be bleeding sights for disease causing insects like mosquitoes, flies, or rodents, etc. The transformation of plastic material into environmentally friendly material had been a challenge facing chemists, engineers, environmentalists, health workers etc, especially at this corona virus pandemic.

The global interest on subjecting petroleum-based synthetic non-biodegradable polymers to microbiological degradation had attracted a lot of public, media, and scientific attentions. The chemical structure responsible for functional group stability, reactivity, hydrophilicity and swelling behavior of polymer materials is the most important factor affecting their biodegradability, Anderson and Shive, (1999). Biodegradation generally, is the microbial transformation of macro-substances through bacterial or enzymatic metabolic processes. However, studies had been going on, to naturally decompose plastics materials by blending or modifying them, to attract moisture or microorganisms, which could attack their molecules and initiate biodegradation.

Lucas et al (2008), reported that biodegradation involves three stages, such as, bio-deterioration, which is a super-facial activities of microorganisms or other decomposers on the physical or chemical microstructure of the plastic matrix; bio-fragmentation is the catalytic breaking of plastic chains into oligomers, dimers or monomers, by ecto-enzymes or free-radicals secreted by microorganisms(depolymerases); assimilation is the integration of molecules transported in the cytoplasm during the microbial metabolism, as shown in Figure 1.1 below. The final stage according to Singh and Sharma (2008); Bonhomme, et al (2003) is

the mineralization process, which is the complete conversion of the degraded monomers into molecules like, CO₂, N₂, CH₄, and H₂O, due to the excretion of oxidized metabolites. The pathway for polymer microbial-degradation by de-polymerases could be outlined as:

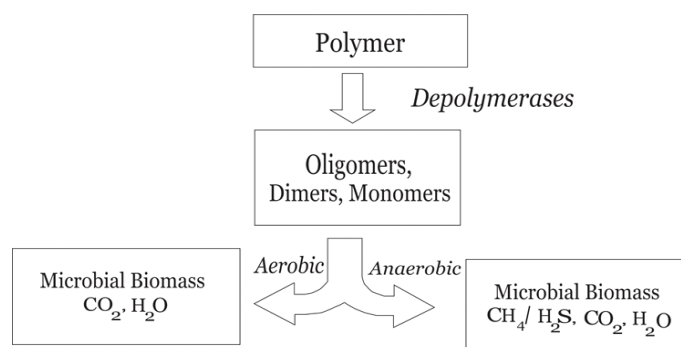


Fig. 1.1: Microbial-degradation Pathway of Plastics

Vasile, (1993) and Matsumra, (2005) demonstrated the conversion pathway of polymer degradation via aerobic and anaerobic microbial activities as:

Aerobic biodegradation: $\text{Polymer(s)} + \text{O}_2 \text{ (g)} \longrightarrow \text{CO}_2 \text{ (g)} + \text{H}_2\text{O(l)} + \text{biomass} + \text{residue}$

Anaerobic biodegradation: $\text{Polymer} \longrightarrow \text{CO}_2\text{(g)} + \text{CH}_4 \text{ (g)} + \text{H}_2\text{O(l)} + \text{biomass} + \text{residue}$.

During aerobic biodegradation, oxygen is utilized as electron acceptor by microorganisms to break down polymeric molecules into smaller compounds, such as, carbon, hydrogen, biomass, etc. In anaerobic biodegradation, microorganisms decompose polymers chains under anoxic conditions. Gnanavel, et al, (2012) concluded that microorganisms could act directly or indirectly on the exposed part of plastic composites, which could serve as source of carbon or nitrogen for their growth. The chemical equations above shows that both aerobic and anaerobic conditions are suitable for decomposition of polymer chains. Premraj and Mukesh, (2005) also suggested that plastics may undergo degradation by the process of oxidation reaction, under the influence of intracellular and extracellular enzymes (endo-and exo-enzymes). They confirmed that the byproducts formed after such decomposition were non-toxic for living organisms. Pramila, etal(2012) considered this as the safest method of degradation of plastics, with anticipated less toxic by-products and potential bio-geo-chemical cycles of the substrate. They observed that, microbial cells found it very difficult to penetrate the polymeric materials to initiate attack, instead they attached on the surface and create erosion, by feeding on the additives incorporated into the polymer matrix.

It was therefore anticipated that, introduction of some functional groups like hydroxyl groups into synthetic polymer matrix, could facilitate absorption of water, which can weaken the polymer bonds, resulting into disintegration of the polymer molecules.

Starch as a natural polymer of comparable industrial applications, judging from its tonnage production, has not been traditionally regarded as a raw material for plastic industries. The presence of hydroxyl groups in starch molecule had been considered for blending with plastics, to initiate water absorption and attraction of starch loving organisms to act on plastic blends. Cornstarch had been found suitable for this research because, it is very rich in amylopectin, high flexibility, lower elongation at breaking point, and tensile strength (Walenta et al, 2001). These properties could make corn-starch molecules absorb water, swell and break up in fragments, that can further be digested by microorganisms, and hence resulting to biodegradation of the plastic. However, the demand, generation and disposal of single-used daily plastics had tremendously increased during the global pandemic. There is an urgent need to providing plastics with low energy from renewable sources which, could be degraded by microorganism, to enhance plastic waste management, especially, during this period of corona virus pandemic.

II. Materials And Methods

2.1 Equipment/apparatus used includes

Injection moulding machine, Instron testing machine, electric drying oven, auto clave, desiccator, refrigerator, thermometer (0 to 300 °C), pH meter, digital weighing balance, Scanning Electronic Microscope(PPSK)SEM model), etc.

2.2 The Plastic Materials

The polymer materials used to prepare the bio-plastic blend films were high-, and low density polyethylene pellets, obtained from, Ceeplast Industries, Aba, Abia State, Nigeria. The densities of the polymers were 0.97, and 0.952 g/cm³ respectively. Their melt flow index were 9.0 g/10 mins, at 230 °C and 2.0 g/10 minutes at 190 °C respectively.

2.3 Compatibilizer

A Sigma Aldrich grade compatibilizer (Maleic-anhydride-graft-polyethylene (MA-g-PE) with viscosity of 1,900.00 at 140 °C, density of 0.92 g/ml at 25 °C, insoluble in water, but soluble in organic solvents was gotten from FINLAB Chemicals, Owerri, Nigeria.

2.4 The Corn Starch

The corn starch was prepared from corn seeds collected from Department of Crop Science, College of Agriculture, Mgbakwu, Anambra State, Nigeria. This was extracted by steeping method and characterized before blending with the plastics.

2.5 Preparation of bio-plastic blends

Corn-starch/high-, and low density polyethylene blend films were prepared by thoroughly mixing 2 % of plastic pellets against 0.5 % of corresponding corn starch granules. The mixtures were blended using an injection moulding machine maintained at 250 °C, and extruded as sheets. 0.05 % of Maleic anhydride-graft-polyethylene was added to another set of plastic sheets in order to improve their mechanical properties. The plastic sheets were allowed to cool after moulding, before subsequent tests.

The surface topography of the polyethylene sheets were later taken using a laboratory scanning electronic microscope (PPSK)SEM, model, before subjecting them to soil burial biodegradation process.

2.6 Microbiological analysis of the soil samples

The microbial inhabitants of the soil sample were investigated, isolated and characterized according to standard.

i. Sterilization of materials

The conical flasks, test tubes, petri-dishes, metal rods, glass slides, iron loop, etc, used were sterilized by washing with clean water, and detergent. These materials were kept in the square section of Astell Scientific auto-clave at a high pressure and saturated steam of 121 °C for 20 minutes before use.

ii. Preparation of normal saline

The normal saline was prepared by dissolving 0.9 g of sodium chloride in 100 cm³ of distilled water, and transferred into different test-tubes. 10 g of the soil sample, was mixed with 5 cm³ of distilled water, and kept for 10 minutes to soak well. The soil sample homogenate was prepared by transferring 1 cm³ of the soil mixture into each of the test-tubes containing 10 ml of the normal saline, and labelled as 10⁻¹, 10⁻², 10⁻³, 10⁻⁴, 10⁻⁵ and 10⁻⁶. 1 cm³ of the soil homogenate was pipetted from the test tubes labelled 10⁻¹ into 10⁻², while 10⁻² was transferred into 10⁻³, till 10⁻⁶ in order to distribute the soil microorganisms.

iii. Identification of soil Microorganisms

1 g of nutrient agar (Master Biology Brand) was dissolved in 100 cm³ of distilled water, and boiled to dissolve the media completely. This was used to get the total count and pure culture of the microorganisms present in the soil sample. The media was sterilized by autoclaving at 121 °C, allowed to cool to 80 °C before addition to the soil sample.

1 cm³ of the media was transferred into the sample homogenate using spread plate technique. The samples were incubated for 48 hours at the temperature of 37 °C to allow for the growth of the microorganisms.

The sub-culturing method involved the identification of different colonies of the organisms present in the soil after the incubation period. The growth colonies on the agar were counted using iron loop which had been heated to red hot. Different colonies were picked and sub-cultured on agar plates containing 15 cm³ of the media and were kept for 24 hrs incubation period.

2.7 Biodegradation Tests

The micro-graphs of the plastic materials were taken before the soil burial, using a scanning electronic microscope. 10 plastic buckets of volume 2000 cm³ were perforated underneath, filled with 500 gram of the moist soil sample. The buckets were kept at the open place, and covered with plastic films to avoid water evaporating from the soil surface. Weighed samples of polyethylene/corn starch blend films were buried at a depth of 10 cm from the soil surface for a period of 180 days. The control samples (pure high-, and low density polyethylene) were also buried in the soil under the same conditions. The extend of biodegradation of the plastic samples were determined at regular time intervals (30 days) by removing the samples from the soil, and washing gently with distilled water to remove soil adhering on the film surface.

The soil burial test was studied by evaluating the weight loss of the films over time. The weight loss was determined every 30 days from the starting days, and was calculated by

$$\text{Weight loss} = \frac{W_i - W_f}{W_i} \times 100$$

where : W_i is the initial dry weight of the film before soil burial and W_f is weight of plastic films after soil burial.

III. Result And Discussion

The physico-chemical analytical results of the corn starch used for the plastic blending are represented on Table 1.0. The moisture content of 12.60 % and pH level (6.7) of corn starch slurry are good for growth of microorganisms under exposed environment. The values for the percentage yield and ash content are good parameters for commercial applications. Other values as listed on Table 1.0 are good qualities for formation of biodegradable plastics.

Plastics are highly hydrophobic and are chemically inert, therefore, cannot be digested by soil microorganisms to initiate their decomposition. Introduction of polar compounds like starch, having carbonyl and hydroxyl groups, to plastic chains, can increase their hydrophilicity and facilitate microbial metabolic activities on the plastic matrix. The degradation of synthetic polymers by soil microbes can only be possible due to the presence of hydroxyl groups introduce to their chain via starch molecules.

Table 1.0: Results on the Physico-chemical tests on corn starch

| Physico- chemical Tests | Values |
|-------------------------------------|-----------|
| Moisture Contents (%) of Corn Seeds | 10 % |
| Moisture Content of Corn Starch (%) | 12.60 % |
| % Yield of Corn Starch (%) | 38.96 % |
| pH of Soil sample | 6.70 |
| Ash Content (%) | 9.40 % |
| Solubility in Water and Alcohol | Insoluble |

3.1 Growth of soil microorganisms before and after incubation period



Fig. 3.0: Pure culture of the soil media before 24 hours Fig.3.1:Showing growth of microbes after 24 hours of incubation. incubation .

Figures 3.0 and 3.1 represent the microbial growth in the soil culture before and after 24 hours of incubation period, using spread plate technique. Different colonies of the micro-organisms were observed as in Fig. 3.1, separated after sub-culturing, and further biochemical identification of the organisms.

The activities of the isolated strains are shown in Table 2.0. It was observed that the dominant isolate exhibited gram-negative rod-shaped, spherical gram-positive and coma-shaped gram-negative characteristics. We observed also that, *Staphylococcus aureus*, *E. Coli*, *Samonella Sp.*, *Bacillus Sp.*, *Pseudomanas Sp.*, and *Lactobacillus Sp.* were the major bacteria species identified in the soil sample. Our findings were in conformity to that of Kathiresan(2003). He studied the degradation of polyethylene blends buried in mangrove soil and concluded that the major microorganisms involved in the degradation were *Pseudomanas Sp.* and *Staphylococcus aures*. He therefore suggested that, these organisms were responsible for the polyethylene degradation. The catalase activity was observed to be higher in all the organisms except in *Lactobacillus species*. The catalase enzymes can convert substrates to hydrogen and water Hansberg et al, (2012). It can decompose the plastic under a suitable condition to elemental hydrogen and oxygen. The motility rate, which is the ability of organisms to transport metabolic energy within their cells was observed to be higher in *Pseudomanas sp.*, *E- coli*, and *Lactobacillus sp.*, than in other species. Oxidase activities were observed more in the *Lactobacillus sp.* which shows that the organism can metabolize in aerobic condition. The bacterium can produce cytochrome by utilizing oxygen as electron transfer chain of cells, and consequently convert the substrate to water, Eric, (2006).

| Biochemical-characteristics | Different Soil Microorganisms | | | | | |
|-----------------------------|-------------------------------|--------|------|-----|-----|-----|
| | St | E-coli | Sa | Ba | Ps | La |
| Gram reaction | + | - | - | + | + | - |
| Shape | Spherical | Rod | Coma | Rod | Rod | Rod |
| Size (mm) | 1.0 | 2.2 | 1.4 | 1.8 | 2.5 | 4.2 |

| | | | | | | |
|--------------------------|---------------|-------|----------------|-------------|-------------|--------|
| Spore test | — | + | — | — | + | — |
| Motility | — | + | — | — | + | + |
| Indole test | + | — | — | — | — | — |
| H ₂ S | — | — | — | — | — | + |
| Coagulase | + | — | — | — | — | — |
| Citralase | — | — | — | + | + | — |
| Catalase | + | + | + | + | + | — |
| Oxidase | — | — | — | — | — | + |
| Appearance on agar plate | Golden Yellow | White | White & spread | Bluish grey | Bluish grey | Bluish |

Table 2.o: Biochemical characteristics of different isolates from the soil sample.

Keys: St—*Staphylococcus aureus*; Ps—*Pseudomas sp.*; E-coli, La—*Lactobacillus sp.*; Ba—*Bacillus sp.*; Sa—*Samonella sp.*

3.2 Results on the Soil Burial Test

The topography of the plastic materials as were taken before soil burial tests using scanning electronic microscope and the micro-graph of the polymer matrix are represented in Figures 2.0, 2.1, 2.2, and 2.3. The cross section of the films were observed with some corn starch granules spread across the surfaces, while the control or (pure)sample of low density polyethylene sheet without any additive is represented in Figure 2.0 and 2.1., respectively. However, the neutral and starch blended high density polyethylene films are also shown respectively in Figures 2.2 and 2.3.



It was observed that, voids, cracks, and erosion appeared on the surfaces of the plastic/ starch blended samples, but, the neutral(neat) plastic sheets remained unchanged after 180 days of soil burial. The blended sheets exhibited some wearing-out properties when rubbed with bare hands, after the soil burial period. These are remarkable evidence of biodegradation of the blended plastics as against the unblended (neat) samples, which were used as control. These developments are in conformity to the findings of Jakubowicz(2003), who studied the mechanical behaviour of biodegradable polyolefins exposed to soil burial tests and observed that there was significant change in the mechanical properties of the blends after the periods of soil burial process. The Scanning electron microscopic analysis of samples buried in the compost, also revealed the formation of pores, cavities, chain discontinuities and cracks. Also the fourier transform and infra red spectroscopic of his studies, recorded significant biodegradability of polyethylene-starch blends. Pure (neat) polyethylene was reported to remain practically unchanged after 125-days period of compost burial tests.

Shogren et al, (2003), (Arutchelvi et al, 2007) and Akiyama, et al(2003) discovered drastic decrease in mechanical properties of polyolefins/starch blends using soil microorganisms. They reported that soil microorganisms easily degraded the starch in the blend leaving behind, the plastic molecules. Removal of starch molecules by the soil micro-organisms reduced the mechanical properties of the void-containing matrix, resulting into super-facial deterioration of the plastic matrix. Further microbial attack on the polymer matrix promoted subsequent biodegradation due to the increased surface area available for interaction with the microorganism and moisture. Extra cellular enzymes secreted by these micro-organisms also contributed to the degradation.

The degraded low molecular weight compounds are further utilized by microbes as carbon and energy sources. Small oligomers may also diffuse into the organism and get assimilated.

3.3 Tensile-strength Properties of the Corn-starch/Plastic Blends

The data on the tensile strength (TS) and elongation at break(EB) properties of corn-starch/plastic blends before soil burial test are illustrated graphically as shown in Figure 3.3. There is significant decrease in the tensile strength from 21.77 to 6.73 N/mm² for uncompatibilized HDPE blends as corn-starch content increased from 2.50 wt. % to 15.00 wt. %. The decrease in TS of the blends, presumably is due to lack of strong bonds and incompatibility between the plastics chains and the corn starch molecule. It is probable that the inclusion of corn-starch molecules into the polyolefin molecules caused a very significant stress concentration. In effect, fracture could be initiated from the weak interface of the blends, due to their envisaged poor interfacial forces of attraction, thus, resulting in reduced bonding energy and low tensile properties. *Thakore et al (1999)* who studied on low density polyethylene/potato starch blends found that, the mechanical properties of the blend samples decreased with increased starch or starch acetate content. The TS of uncompatibilized low density polyethylene/corn starch blends as shown in Figure 3.3, also decreased with increased starch content from 11.61 to 8.95 N/mm².

The higher TS of HDPE as compared to that of LDPE obtained in this study is attributed to the former's higher density, lack of branching, and stronger intermolecular force of attraction that exist in its chains.

Incorporation of maleic Anhydride-graft-Polyethylene(MA-g-PE) to the plastic chains helped to improve the mechanical properties. It was assumed, that there is an interaction between the hydroxyl groups of starch and that of MA-g-PE, because, a polar interaction between the two(Starch and Plastic) would not improve their mechanical properties to any significant extent (*Boryniec et al, 2004*). In contrast to our results, *Matzinos et al (2001)* who characterized LDPE/starch blends reported an increase in the strength of the blends with starch contents of up to 50 wt. % after which the tensile strength of the blends decreased with any further increased in starch content.

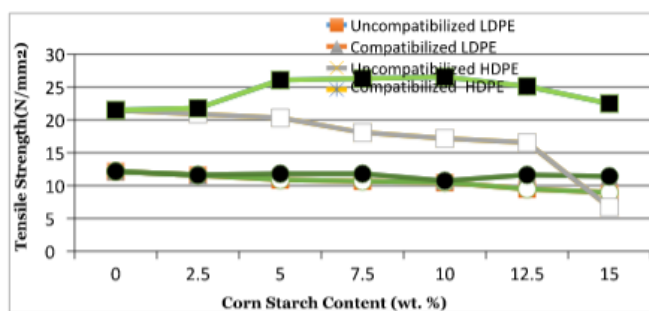


Figure 3.3 : Plot of Tensile Strength of HDPE, and LDPE/ Corn Starch Blends against compatibilized samples.

3.3.1 Tensile Properties of Corn-Starch/Plastics Blends after Soil Burial Tensile Strength.

The tensile strength(TS) of the uncompatibilized HDPE, and LDPE/Corn-Starch blends exposed to soil burial test after 180 days as shown in Figure 3.4, demonstrated remarkable reduction from 21.48 N/mm² to 3.08 N/mm² and 11.61 to 8.95 N/mm² for HDPE and LDPE/starch blends respectively. The figures show that the TS of the blends decreased with increase in corn starch content and soil burial time. The decrease in the tensile strength of the plastic/corn starch blends could be attributed to the formation of pits and voids in the blends which took place after the assimilation of starch granules on the surface of blended plastics by microorganisms. The blends invariably lost their structural characteristics or bonding force, because, the soil microorganisms had consumed surrounding starch granules on the surface of the blends. Thus, the degradation of the blends occurred as a result of the vacation of starch site, which were earlier occupied by water or microbes, leading to extensive degradation of the blends(*Hanafi et al, 2011*). The water inside the soil during the soil burial test definitely diffused into the blend samples, causing swelling, and thereby accelerating biodegradation process within the starch/plastic blends.

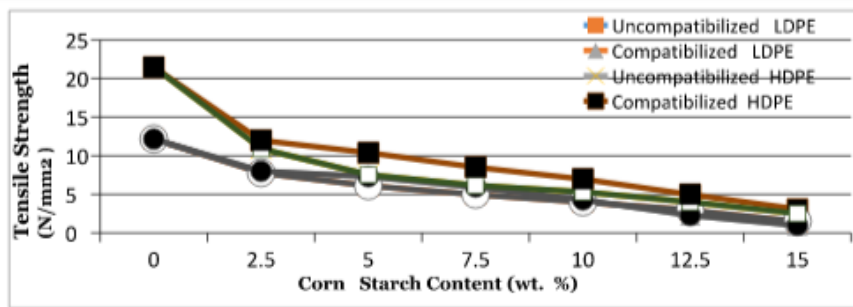


Figure 3.4: Plots of Tensile Strength for both Compatibilized and Uncompatibilized Plastics/ Corn-starch Blends after Soil Burial.

3.4.1 Elongation at Break (EB) Before Soil Burial Testes

The elongation at break for HDPE/corn starch blends as shown in Figure 3.5, was observed to increase from 136.65 to 170 % with increase in starch content up to 7.50 wt. % and thereafter, decreased to 100 %, with further increase in corn starch content. It is observed that all LDPE/corn starch blends (compatibilized or uncompatibilized) exhibited higher elongation at break than HDPE/corn starch blends. This is attributed to the outstanding higher flexibility, ductility, stretch strain properties of LDPE over HDPE (Stephen, 2013).

The decrease in EB for LDPE/corn starch blends could be attributed to the heterogeneous dispersion of starch in the plastic matrices, and thus, the incompatibility of plastic and starch. The more the starch contained in the blend, the more the reduction in elongation at break, and vice versa, as was observed in the research works carried by Martins et al(2001), Kang et al and Obasi (2013).

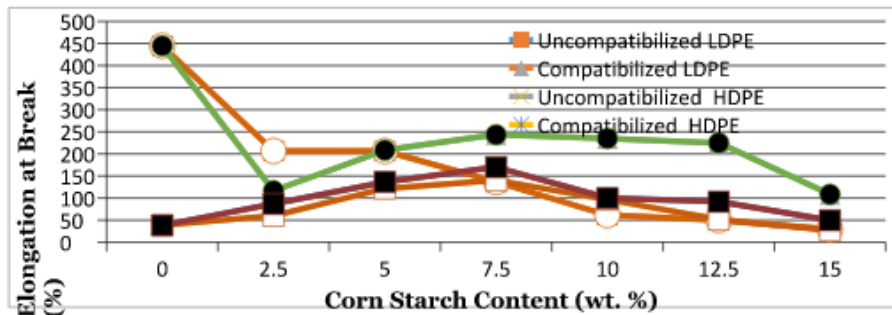


Figure 3.5: Elongation at Break (%) before Soil burial for both Compatibilized and Uncompatibilized Plastics/Corn Starch Blends.

3.4.2 Results on the Elongation at break after Soil Burial

The plots of EB after soil burial tests as shown in Figures 3.6 displayed that, the longer the soil burial period, the more the reduction in the value for the blends, and vice versa.

The drop in elongation at break from 17.50 to 2.11 % for the uncompatibilized HDPE, and from 19.34 to 7.23 % for uncompatibilized LDPE between 2.5 to 15 wt. % corn starch content after of soil burial test as shown in Figure 3.6 illustrated that the reduction in EB for the polyolefin/corn starch blends was more prominent at higher starch content. This decrease is attributed to the presence of hydroxyl groups in starch molecule making them highly hydrophilic.

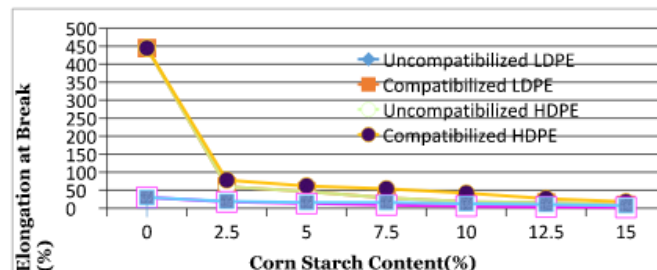


Figure 3.6 : Plot of Elongation at Break (%) for Uncompatibilized and Compatibilized Plastics/Corn-starch Blends after Soil Burial.

However, the elongation at break before and after soil burial tests as represented in Figures 3. 5 and 3.6 above confirmed that increase in corn starch and soil burial periods resulted into decrease in the elongation at break, although the compatibilized blends showed some improved properties.

3.5 Weight-loss after Biodegradation

The plots in Figures 3.7 (a & b) and 3.8 (a & b) demonstrate the weight-loss of starch blended plastic sheets after soil burial. The extent of biodegradation of the plastic/corn-starch blended samples were revealed by the continuous reduction in weight with the extension of soil burial periods. The weight of pure (neat) samples of LDPE and HDPE remained the same at 0.00 % respectively, through-out the biodegradation period, for both compatibilized and uncompatibilized plastic sheets. This was attributed to the inertness (or resistance) of plastics to air, moisture, and microbial attack.

However, the reduction in weight of low density polyethylene blend sheets as shown in Figure 3.7(a) ranges from 6.12 % to 6.10 % (0.02 % wt. loss) for starch content of 2.5 g; 6.12 to 6.04 % (0.24 % wt. loss) at 10 wt. g starch and 6.12 to 5.45 % (9.68 % wt. loss) at 15 wt. g starch, after 30, 90, and 180 days of soil burial respectively.

High density polyethylene also exhibited remarkable weight loss as shown in Figure 3.8(a & b) throughout the biodegradation periods. The compatibilized LDPE, and HDPE blends showed reduced weight losses when compared to the uncompatibilized blends throughout the soil burial periods. This could be attributed to the increased adhesion, and bonding effect of MA-g-PE to the polyolefin matrix/corn starch bonding sites. The weigh-loss for compatibilized LDPE, and HDPE blended with 2.5 g wt. , and 5.0 g wt. of corn starch after 30 to 90 days of soil burial tests, were low when compared to the uncompatibilized blends. This could be attributed to (i) the short time for biodegradation, and (ii), low content of corn starch to render biodegradation.

It was assumed that, the hydrophilic nature of starch allowed for moisture absorption, and retention that contributed to microbial consumption of the starch granules. Borghei et al (2010), and Danjaji et al (2002) had also reported the biodegradation of polyolefin incorporated with starch and, suggested that the, reduction in the weight of corn starch blended plastic samples is attributed to the removal of the corn starch granules by soil microorganisms. This could result into the increase in their weight with increased starch content and extension of biodegradation period.

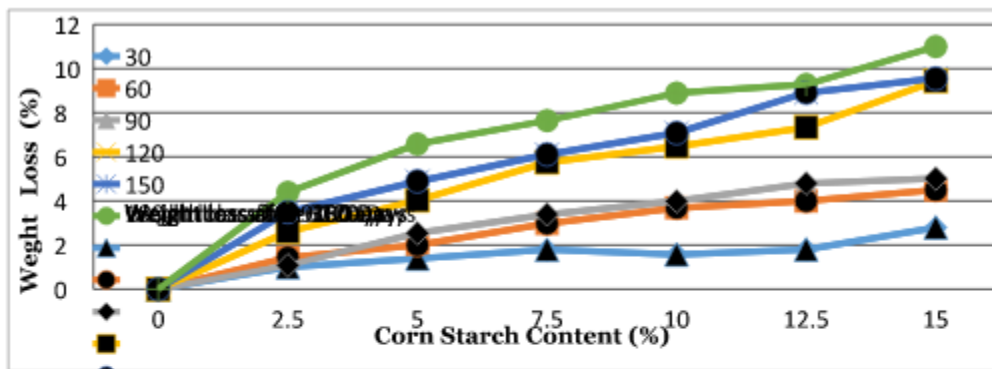


Figure 3.7(a): Weight loss of Compatibilized Low Density Polyethylene/ Corn Starch Blends.

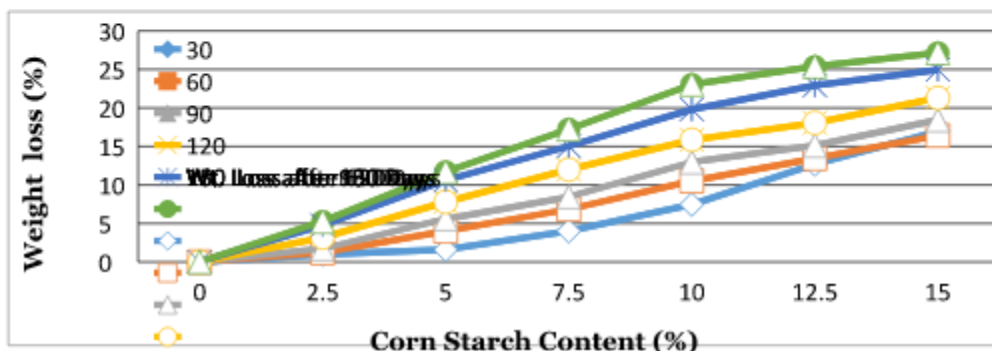


Figure 3.7(b): Plot of Weight loss of Uncompatibilized Low Density Polyethylene /Corn Starch Blends

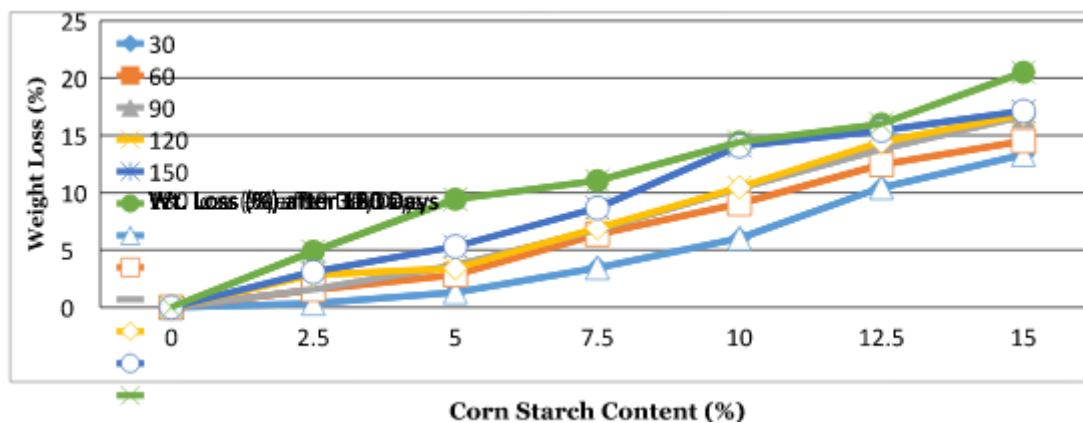


Figure 3.8a: Plot of Weight loss of High Density Polyethylene and corn Starch Blends

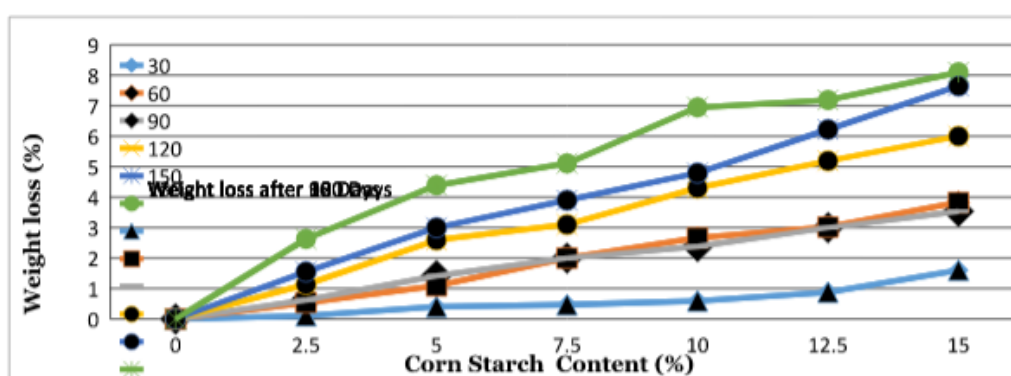


Figure 3.8 b: Plot of Weight loss of Compatibilized High Density Polyethylene and Corn Blends

The biodegradation of polyethylene films containing 40 wt. % gelatinized corn starch, and 15 wt.% poly (ethylene-co-acrylic acid) (EAA) was studied in a variety of aqueous environment by Gould et al (1990). They studied the biodegradation of starch grafted polyethylene by soil burial test, and reported continuous loss in weight of the polymers with increased number of test periods.

It is therefore, expected, that extension of the degradation period could result into complete degradation of the plastic fragments, since the weight loss increased with increase in the number of soil burial days (from 30 to 180 days)..

IV. Conclusion

Plastic materials, which had been an inevitable objects to industrial, agricultural, domestics or social, packaging, and had constituted the greatest municipal waste pollution, were able to undergo some significant degradation. The remarkable reduction in the mechanical properties of both HDPE, and LDPE/Corn-Starch blends had proved that plastics could naturally decompose when no longer in use. Our findings has suggested also that starch loving microorganisms could be isolated from compost soil to initiate biodegradation process in plastics' molecular chains. The hydrophilicity property of starch or its water absorbency attracted microorganisms, to feed on the plastic/starch blends and later decompose them. Compatibilizing agent was incorporated to plastic and starch, in order to bind them and improve their mechanical properties, especially, those that could be used for engineering purposes. Natural degradation of plastics by microorganisms is cheaper, because, no energy transmission is not required.

Production and utilization of bio-plastics will positively decrease the plastic wastes and contaminations from our environment.

Biodegradation of plastics materials is necessary, especially, at this COVID- 2019 pandemic, when careless people ignorantly use waste plastic containers or bottles, picked from waste-bins, which may be contaminated, for storage of water, milk, honey, peas, etc. This, however could increase the possibility of spreading of this deadly disease and impose other health challenges. Scientific attentions should be channeled towards formulating this type of plastics that could decompose naturally after use.

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