

● **Test on the Elongation at Break(%) for both Compatibilized/Uncompatibilized HDPE blends**

The elongation at break (EB) for the pure, compatibilized and uncompatibilized corn-starch blended HDPE were recorded along the meter rule pointer on the tensile testing machine and the average values calculated.

● **Weight-loss Determination**

HDPE/Corn starch blend films were weighed and buried at a depth of 10 cm in plastic buckets containing humus soil. Pure HDPE samples were buried under the same condition and were left at the open for 180 days. The percentage weight-loss was determined according to ASTM D6003- 96 standard test.

3.0 RESULTS AND DISCUSSION

3.1 Tensile Strength

The tensile strength of the uncompatibilized and compatibilized HDPE/Corn-Starch blends before the biodegradation tests are graphically represented in figure 1. The systematic increase in corn starch contents from 2.50 wt.% to 15.00 wt.%, tremendously decreased the tensile strength from 20.90 N/mm² to 9.73 N/mm² for the corn starch blended polyethylene. The reduction in the tensile strength could be attributed to the poor interfacial adhesion between the bio-filler/polyolefin bonds. The results were in conformation to the findings of Thakore et al (1999). The pure HDPE exhibited highly stable tensile strength value of 21.48 N mm² through- out the periods of soil burial as against the blended sheets. Pure high density polyethylene is known for it's high strength to density ratio due to it's lack of chain branching which is the reason for their high strength (Boryniec et al 2004).

The tensile strength of the high density polyethylene /corn starch blends were greatly increased at maleic anhydride-graft-polyethylene contents of 4.0 wt % based on 10 wt. % corn starch content, and decreased thereafter. The decrease in the tensile strength of compatibilized high density polyethylene, after the addition of 4.0 wt. % maleic anhydride-graft-polyethylene is probably due to the molecular morphology of HDPE near the surface or in the bulk of the plastic phase *Sanadi et al (2001)*. Transcrystallization and changes in the apparent strength of the bulk matrix can result to changes in the contribution of the matrix to the composites strength. It is believed that MA-g-PE increased the adhesion between the polyolefin matrices and corn starch. The improved interfacial adhesion between the

polyolefins and corn starch has a positive impact on stress transfer, thus reducing the chance of interfacial debonding, and leading to improved tensile strength properties (Ramkumar and Bhattacharya, 1997). The results obtained above support the assumption that the interaction between starch and MA-g-PE was a chemical one between the hydroxyl groups in corn starch and anhydride groups in MA-g-PE, because, a polar interaction between them would not improve their properties to any significant extent (Boryniec et al, 2004).

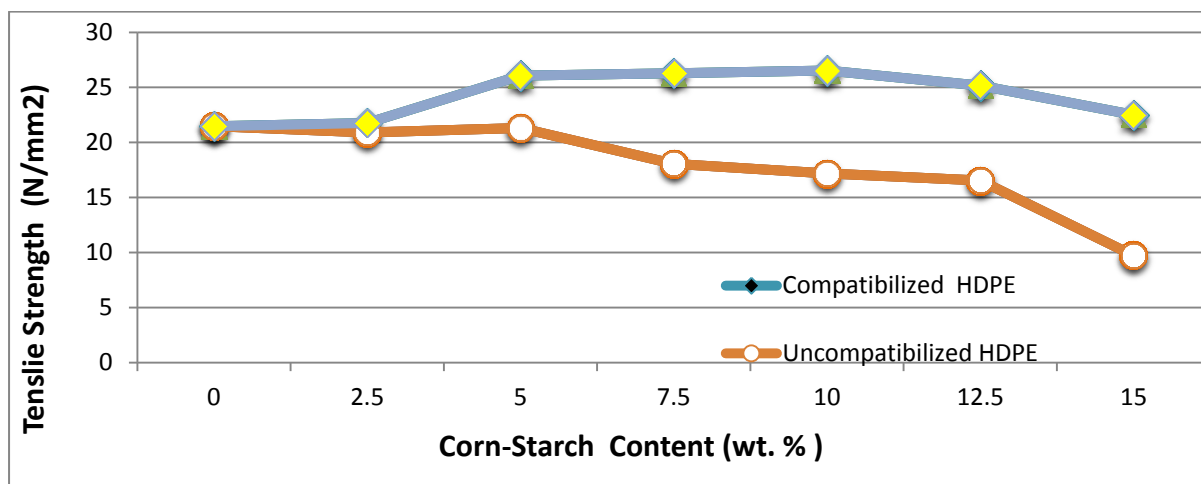


Figure 1: Plots of Tensile Strength of Uncompatibilized and Compatibilized Corn-starch Blended Polyethylene Before Biodegradation Tests

3.2 Elongation at Break (%)

It was observed that increase in the corn starch content alternatively decreased the elongation at break of the blends. This could be due to the heterogeneous dispersion of starch granules within the polyethylene matrix. Starch molecules cannot stretch-out, therefore, cracks occurred reducing the elongation of the polyolefin/starch blends. This was in conformity to the findings of Martins, et al(2001); Obasi, (2013) and Kang, et al(1998), who reported that slight increase in starch content decreased the elongation at break of sweet potato starch blended polypropylene. The elongation at break was observed to increase with increase in starch content up to 7.50 wt % and thereafter, decreased with further increase in corn starch content. This can be attributed to the findings of Enamul (2013) who reported that, at higher starch content, filler-filler interaction becomes more pronounced than filler-matrix interaction. This can reduce the effective cross-sectional area of the polyethylene due to the presence of the starch particles. Addition of MA-g-PE into the polyethylene /corn starch mixture increased the EB of blends as compared to uncompatibilized blend films. The results showed that the modification of the polyethylene/corn-starch blends with MA-g-PE

improved the elongation at break of the blends. It is assumed that the copolymer increased the interfacial attraction between the starch and polyethylene particles. The sharp reduction after the starch content of 7.50 wt % could be due to the heterogeneous molecular imbalance within the starch/filler intermolecular attractions. This according to Chandra (1998) tends to lower the elongation at break property of the blends.

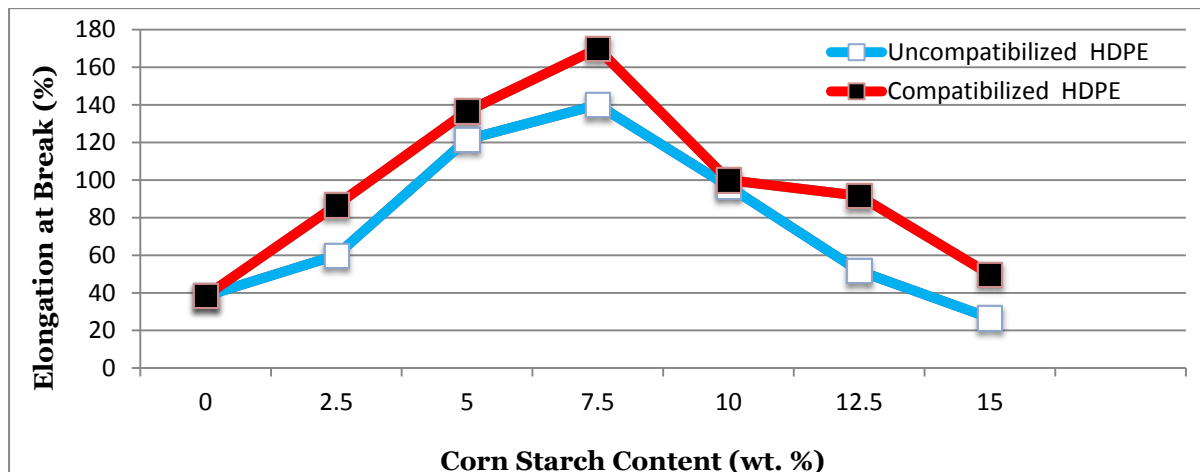


Figure 2 : Plots of Elongation at Break(%) of Uncompatibilized and Compatibilized High Density Polyethylene/ Corn-Starch Blends

3.3 Percentage Weight-loss

There was no apparent weight-loss for the Pure HDPE throughout the entire soil burial testing period, showing that pure polyethylene is inert to air, moisture and microbial attack and therefore are non-biodegradable. The plots show continuous increase in the weight-loss of HDPE/corn starch blended sheets with increased starch content. The reduction in the weight of the blended samples could be due to the removal of starch granules by soil microorganisms. It is expected that extension of the biodegradation period could result into complete bio-fragmentation, assimilation and mineralisation of the blended polyethylene. Albertsson (1998) had reported that the penetration of small amount of solar radiation reaching the film under soil surface might initiate oxidation process which can result into weight-loss. The plots also revealed the evidence of biodegradation by the gradual increase in the weight-loss of the blends.

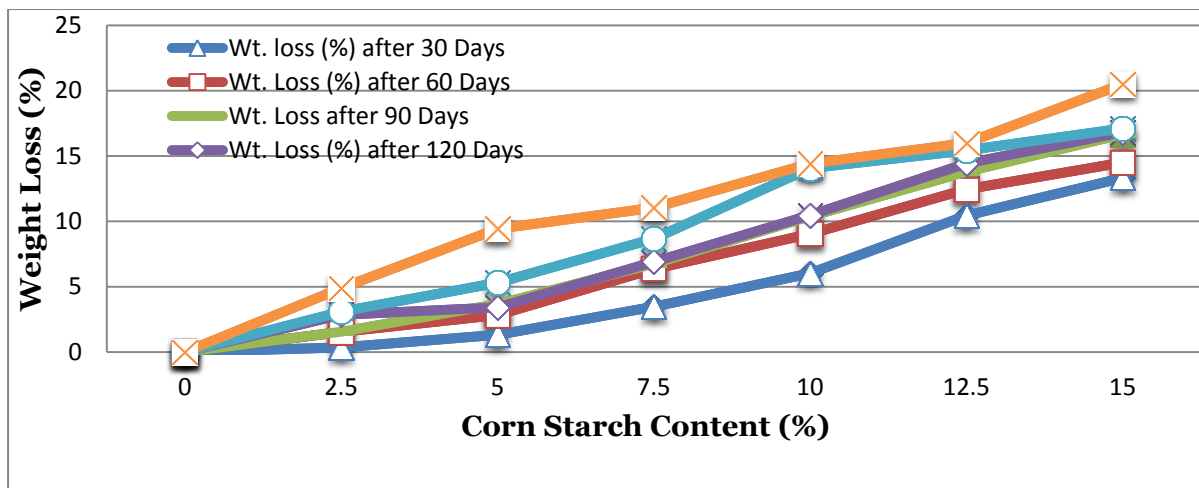


Figure 3: Plot of Weight loss of High Density Polyethylene /Corn- Starch Blends.

It is to be expected that the extension of the degradation period could result into complete degradation of the polyolefin fragments, since the weight loss increased with increase in the periods of soil burial days (ie from 30 to 180 days). The compatibilized 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 blends. The weight-loss for compatibilized HDPE blended with 2.5 wt. %, and 5.0 wt.% corn starch after 30 to 90 days of soil burial tests were low when compared to the uncompatibilized blends. This could be due to (i) the short time for biodegradation, and (ii), low content of corn starch to render biodegradation process. The plots revealed the biodegradation of the blends as evidenced in increased weight losses.

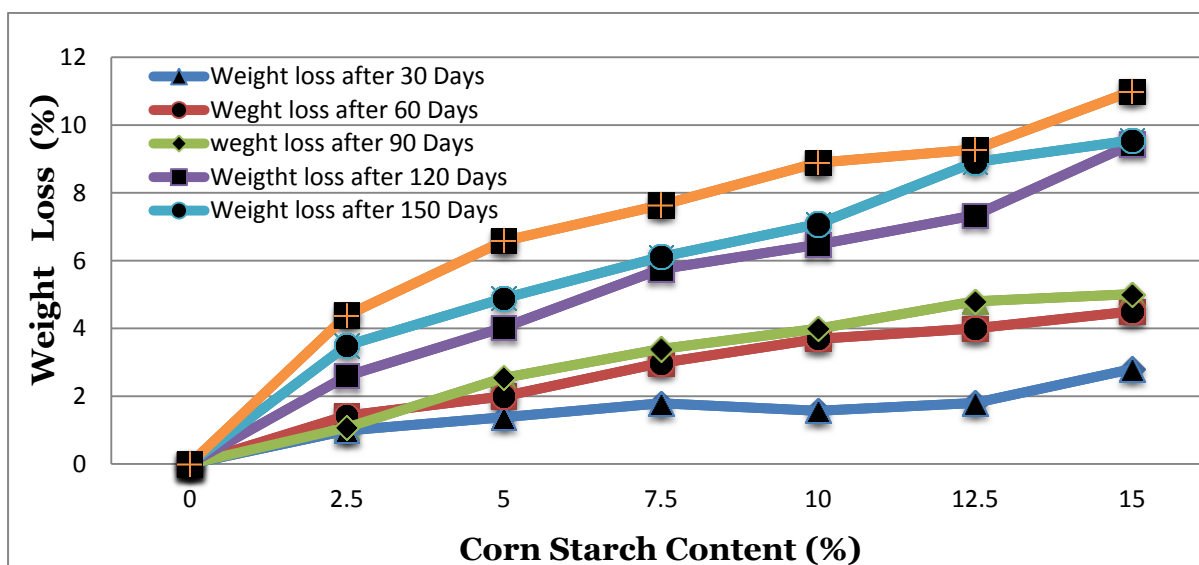


Figure 4: Plot of Weight loss of Compatibilized High Density Polyethylene and Corn - Starch Blends.

(4) CONCLUSION

The tensile strength and elongation at break for the uncompatibilized HDPE /Corn-starch blends decreased with increase in starch contents. The pure HDPE exhibited higher tensile strength value, when compared to both uncompatibilized and compatilized blends. We can therefore conclude that, the decrease in the mechanical properties of the starch blended polyethylene is a good evidence of degradation.

Addition of coupling agent (MA-g-PE) was observed to improve the mechanical properties of the blended polyethylene. MA-g-PE modified HDPE/Corn-starch blends also exhibited reduced weight-loss properties than uncompatibilized HDPE and can be recommended for packaging or other engineering purposes. Significant biodegradation process was recorded within the short period of this study, therefore, complete biodegradation and mineralization is expected to occur on extension of the biodegradation period.

The use of con- starch in this research is due to its availability, non-toxicity, and ease of processability. There is an urgency to promote the use of starch blends in plastic applications, because starch represents a material with low energy demands from renewable sources. It can initiate biodegradation of HDPE by attracting starch-loving organisms to feed on the polymer chains. Biodegradation of plastics through incorporation of starch had been investigated and is seen as an option in the waste management. If polyethylene is made self-decomposing, it will reduce the resources invented on waste management, reduce the danger of death to animals who mistaken the wastes for prey, and reduce the problem of emission of dangerous gasses during recycling or incineration process.

5. REFERENCES

- Albertson, A.C. Biodegradation of Synthetic Polymers. II. A limited Microbial Conversion of 14 C in Polyethylene to 14 CO₂ By Some Soil Fungi, *Applied Polymer Science* 2, 3419 (1998).
- Boryniec, S., Slusarczyk, C., Zakowska, Z., and Stobinska, H. , Biodegradation of the films of polyethylene modified with Starch. Studies on Changes of their Supermolecular Structures. *Academic Journal*. 49(6), 424 (2004).
- Chandra, R. and Rustgi, R. Biodegradable Polymers, *Progress. Polymer Science*. 23, 1273-1335 (1998).

- Enamul H., Tan Jie Ye, Leng, C.Y., and KhairulZaman, M. D., Sago Starch-Mixed Low-Density Polyethylene Biodegradable Polymers: Synthesis and Characterization, *Materials*, 7 (2013).
- Kang, B.G., Yoon,S.H., Yie ,J.E., Yoo, B.S. and Suh, M. (1999). Studies on the Physical Properties of Modified Starch Filled High Density Polyethylene . *Journal of Applied Polymer Science*, 60, 177-184, (1999).
- Sanadi, A.R., Caufield, D.F., Jacobson, R.E. and Rowell, R.M., Renewable Agricultural Fibres as Reinforcing Fillers in Plastics: Mechanical Properties of Kenaf Fibre-Polypropylene Composites. *Industrial and Engineering Chemistry Research*, 34(5), 1889-1896 (2001).
- Shrogren, R.L., Doane, W.M., Garlotta, D., Lawtan, J.W. and Willet, J.L. Biodegradation of Starch / Polylactic Acid/Poly(hydroester- ether) Composite Bars, *Polymer Degradation and Stability*, 79, 405-411, (2003).
- Thakore, C.M., Lyer, S., Desai, A., Lele, A. and Devi, S., Morphology, Thermomechanical Properties, and Biodegradability of Low Density Polyethylene/Starch Blends, *Journal of Applied Polymer Science*, 74(12), 2791-2801, (1999).
- Tokiwa, Y., Calabia Buenaventurada, P. Ugwu, Charles U., Aisa, Seilchi Biodegradation of Plastics , *International Journal of Molecular Science* , 9, 3722-3742, (2009).
- Watanabe,T., Ohtake,Y., Asabe,H. Murakami,N., Furukawa, M. Biodegradability and Degrading Microbes of Low Density Polyethylene. *Journal of Applied Polymer Science* 111, 555 - 559(2009).
- Yamada-Oodera, K., Mukumoto, H., Katsuyaya, Y., Saiganji, A., and Tani, Y. Degradation of Polyethylene by a Fungus, *Penicillium Simplicissimum*, *Polymer Degradation and Stability*. 72, 323-327, (2001).