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Studies on the Mechanical Properties of *Dioscorea Dumetorum* Starch Filled Linear Low Density Polyethylene Composites

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Abstract

Mechanical and end-use properties of linear low density polyethylene filled *with dioscorea dumetorum* (bitter yam) starch of particle size 100 µm at varying percentages as the function of filler contents were investigated. The polymer composite was fabricated by mixing LLDPE with 0 to 10% of *dioscorea dumetorum* (bitter yam) starch using injection moulding machine to obtain a material with enhanced and desired properties. The experimental test on mechanical properties such as tensile strength, elongation at break, hardness flexural and compressive strength carried out on the polymer composite produced showed an increase in the tensile strength, hardness, flexural and compressive strengths with reduction in elongation at break. The results showed that the filler had positive impacts on the mechanical properties as the filler volume increased. The optical microscopy seemed to show an improvement on the dispersion of the filler in the composite matrix as the filler volume fraction increases.

Keywords

Dioscorea Dumetorum Starch, LLDPE, Mechanical Properties, Optical Microscopy

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1. Introduction

Nowadays, polymeric composite materials are being used in variety of applications such as automotive, sporting goods, marine, electrical, industrial, construction and household applications. Polymeric composites have high strength and stiffness, light weight and high corrosion resistance [1]. However, these plastics are made of petroleum-based materials that are not readily biodegradable [2]. The most important disadvantage of such composite materials is the problem of disposal after end use. These raised the attention of people for the use of natural, sustainable, biodegradable and renewable resources. Recently, the sources of fillers for polymeric materials has been shifted to agricultural materials [3] or natural products (as an alternative to expensive and toxic inorganic fillers) due to their availability, low cost, eco-friendly and biodegradability. There has been an increased interest in enhancing the biodegradability of synthetic plastics by blending them with low cost natural biopolymers. It is clear that the starch powder can change the properties of polymer matrix because of its nature size, shape and distribution. Thus, the development of biodegradable polymers that are derived from renewable natural resources has gained increasing interest [4]. The development and production of biodegradable thermoplastics, Tps is considered important in reducing the total amount of synthetic plastic waste [5].

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2. Experimental Investigation

2.1. Materials

- *Dioscorea dumetorum*, (bitter yam) Starch.
- Linear Low Density Polyethylene (LLDPE).

2.2. Sample Preparation

The linear low density polyethylene used in this study was obtained from Ceeplasts Company Limited, Osisioma road, Abia State, Nigeria. It has a melt flow index of 2.5 g/min and density 0.926 g/cm^3. The bitter yam from which *dioscorea dumetorum*, bitter yam, starch was produced was obtained locally from Edda, Ebonyi state, Nigeria. The *dioscorea dumetorum* was properly treated to remove impurities before it was peeled, grind, dried, crushed and sieved to particle size of 100 µm.

2.3. Polymer Composites Preparation

The linear low density polyethylene filled with *dioscorea dumetorum*, starch of particle size of 100µm samples were prepared by thorough mixing of 200g of linear low density polyethylene matrix with appropriate filler quantities at varying percentages of 2, 4, 6, 8 and 10 wt%. Then, the resulting constituent of each composite sample was melt-blended and homogenized in an injection moulding machine and the composite samples were produced and obtained as sheets. Then dumb-bell shaped samples were cut out for tensile and flexural tests.

2.4. Mechanical Testing

Test for tensile properties were carried out as described in American Standard testing and measurement, method D638, using the Instron universal testing machine at crosshead speed of 10 mm/min using dumbbell test piece. Flexural properties were carried out as described in American Standard testing and measurement, method D-790, using the Instron universal testing machine at crosshead motion of 5 mm/min. Compression test was carried out as prescribe in described in American Standard testing and measurement, method D-695, using the universal Instron tester. Hardness properties test was carried out as prescribe in in American Standard testing and measurement, method D-2240.

2.5. Optical Microstructure

The optical microstructure analysis was performed using Nikon Eclipse ME600 optical microscope.

3. Discussion of Results

3.1. Mechanical Properties

The results of mechanical properties of starch reinforced Linear Low Density Polyethylene (LLDPE) composites are show in Tables 1-4 below.

Table 1. Result of Tensile Proprieties of starch reinforced LLDPE composites.

Sample	Tensile Strength (Mpa)	Modulus (Mpa)	Elongation (%)
0%	12.26891	78.68272	877.1929825
2%	9.84548	70.458525	749.9960351
4%	8.11744	63.418225	663.222193
6%	8.90261	59.842965	681.7354123
8%	10.770955	67.089445	786.9481754
10%	11.64943	68.74568	877.1929825

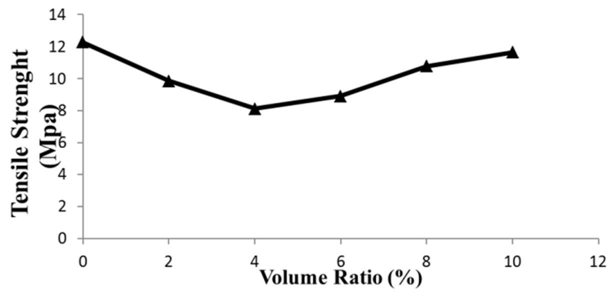

Fig. 1. Effect of tensile strength on volume ratio of starch reinforced LLDPE composite.

From Fig. 1. above, the ultimate tensile strength of Starch reinforced Linear Low Density Polyethylene (LLDPE) composites, showed decrease in properties as filler volume ratio increases, this might be due to uneven dispersion of the fillers in the polymer matrix due to the low filler volume, which resulted in the applied force not evenly distributed inside the polymer matrix and also the possibility of the formation of voids in the polymer layer next to surface, thereby causing tension concentration at the voids vicinity, generating fractures, thus a reduction in the tensile strength. However as filler volume fraction increases above 4% there was a gradual increase in tensile strength, tensile modulus and elongation at break.

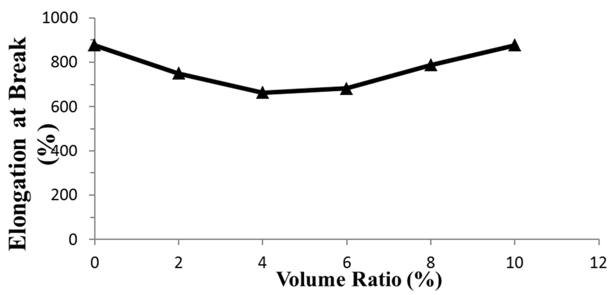

Fig. 2. Effect of elongation on volume ratio of starch reinforced LLDPE composites.

The Percentage Elongation at Break of the composites also decreases on addition of filler as shown in Fig. 2. and Table 1 above; this is due to the interference of filler in the mobility of the matrix. This is also in agreement with other previous works [6, 7]. This interference is created through the physical interaction and immobilization of the polymer matrix by the presence of mechanical restraints, thereby reducing the elongation at break [8]. At higher filler load of 6% and above there was a gradual improvement in this property.

Table 2. Result of Flexural strength of starch reinforced LLDPE composite.

Sample	Flexural Strength (Mpa)	Flexural Modulus (Mpa)
0%	7.4394	120.4973
2%	7.74323	116.96374
4%	7.84743	99.96375
6%	7.74741	97.8291
8%	7.74108	96.6946
10%	12.2124	116.9026

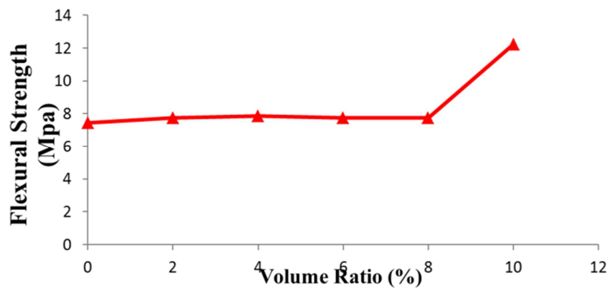

Fig. 3. Effect of flexural strength on volume ratio of starch reinforced LLDPE composite.

Flexural strength of Starch filler reinforced Linear Low Density Polyethylene (LLDPE) composites as shown in Fig. 3 above, indicated a decrease as the filler volume ratio increases, this might be due to uneven dispersion of the fillers in the polymer matrix due to the low filler volume, which resulted in the applied force not evenly distributed inside the polymer matrix [9]. The properties however show improvement as filler volume fraction increases above 6%.

Table 3. Result of compression strength of starch reinforced LLDPE composite.

Sample	CompressiveStrength (Mpa)	Compressive Load at Break (N)
0%	5.248765	199.97805
2%	4.142445	157.82708
4%	3.747445	108.48774
6%	3.527415	141.841475
8%	2.894445	110.278425
10%	3.695865	140.812485

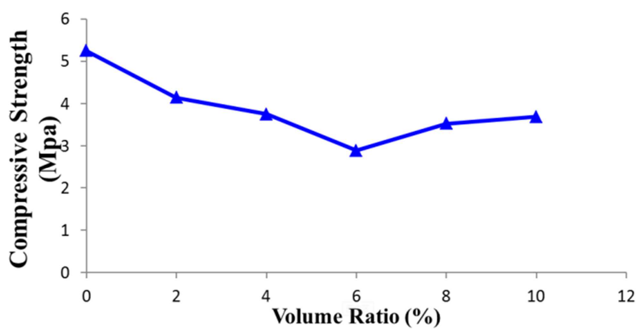

Fig. 4. Effect of compressive strength on volume ratio of starch reinforced LLDPE Composite.

Compression test results as shown in Fig. 4 indicated decrease in both compressive strength compared to the pristine composite. This might be due to the interruption of the structural arrangement of the atoms in the Linear Low Density Polyethylene by the fillers, coupled with worsening interfacial bonding between filler (hydrophilic) and matrix polymer (hydrophobic), [10]. Another reason, might be that the chemical reaction at the interface between the filler particles and the matrix may be too weak to transfer the compressive stress.

Table 4. Result of Surface hardness of starch reinforced LLDPE Composite.

Sample	Hardness (Shore D)
0%	63
2%	68
4%	74
6%	83
8%	87
10%	94

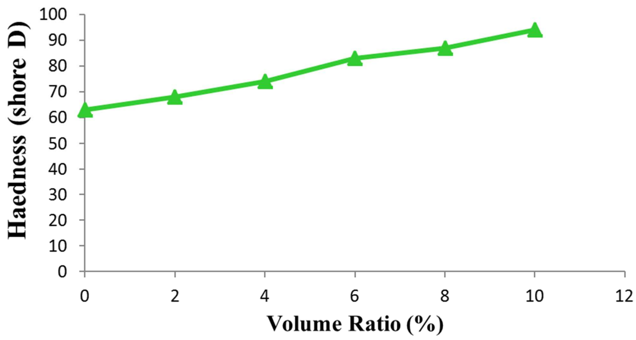

Fig. 5. Effect of hardness on volume ratio of starch reinforced LLDPE composite.

Hardness test result shown in Fig. 5, indicate an increase in hardness value as filler volume fraction increases, thus indicating that the presence of these fillers in the polymer matrix improves the surface stiffness of the composites.

3.2. Optical Microstructure

The optical microstructures of the samples (Mag X100) are shown in plates 1-4.

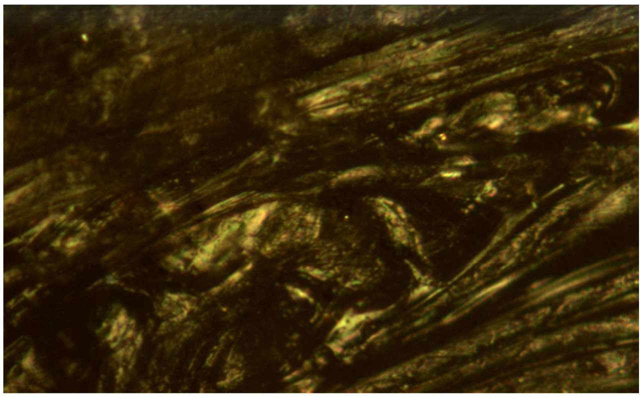

Fig. 6. Optical microstructure of 4% Starch Reinforced LLDPE Composite.

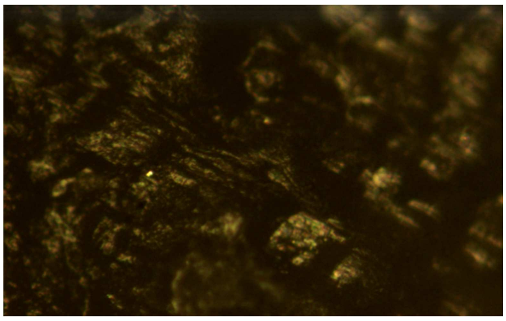

Fig. 7. Optical microstructure of 6% Starch Reinforced LLDPE Composite.

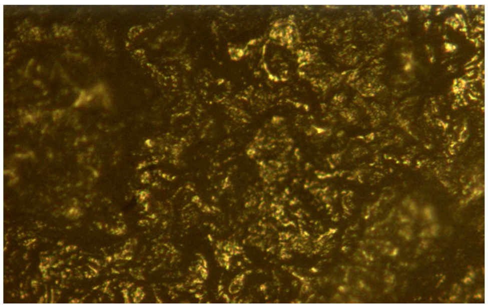

Fig. 8. Optical microstructure of 8% Starch Reinforced LLDPE Composite

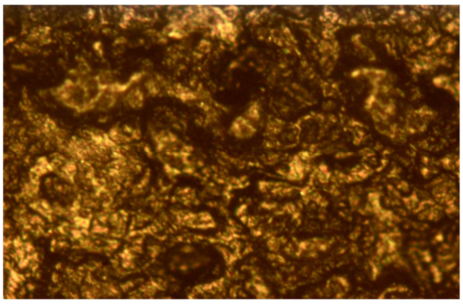

Fig. 9. Optical microstructure of 10% Starch Reinforced LLDPE.

From the above plates it was observed in that there were uneven dispersion and agglomeration of filler particles in the polymer matrix; however, there seem to be an improvement on the dispersion of the filler in the composite matrix as the filler volume fraction increases. This also confirms the poor mechanical properties of the composite obtain at lower filler volume fraction, which indicates, that as the filler volume fraction increases there were improvement in the mechanical properties of the composite.

3.3. Summary and Conclusion

The fabrication of starch reinforced Linear Low Density Polyethylene (LLDPE) composites, has shown the increase in mechanical properties of these composites. Thus, the mechanical properties of the composites were found to depend on the polymer matrix-filler interaction, particle size and distribution of the filler particles within the matrix. However, the extent of reinforcement was perhaps due to the interaction between the organic phase of the filler and organic polymer. *Dioscorea dumetorum, (*bitter yam) starch; a degradable and decomposable natural organic material, can be used as a biodegradable filler incorporated into polymers. Since, the starch filler at higher filler loading and even dispersion in the polymer matrix can improve the mechanical properties of these composites.

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