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Experimental Evaluation of LDPE Composites Using Hardwood Sawdust WRT the Physical and Mechanical Properties.

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ABSTRACT

This study evaluated the effects of different percentages of hardwood sawdust on the mechanical properties of sawdust-low density polyethylene (LDPE) composites. The mechanical properties of the composites were evaluated in terms of their tensile, flexural, impact strength, hardness, and elongation. The melt blending technique was used to prepare the composites and was the mechanical properties was characterized. The property tests showed that the optimum tensile strength (30.33MPa) and elongation property (12.60%) were obtained at 0% weight of filler, while that of tensile modulus (590.30MPa) was obtained at 35% weight. The optimum flexural strength (56.10MPa) and modulus (2.67MPa) were obtained at 35% weight of the filler, while that of the impact strength (213j/m) was obtained at 10% weight of filler, after which it experienced a decline till it reached 35%weight. In contrast to the impact, the hardness test (4.5MPa) experienced a continuous increase proportional to increase in filler weight, and arrived its optimum point at 35% weight. The results indicate that the addition of hardwood sawdust has a significant impact on the mechanical properties of the composites. The observed changes in mechanical properties are attributed to the interaction between the sawdust particles and the LDPE matrix. The findings suggest that incorporating hardwood sawdust in LDPE composites can lead to alterations in their mechanical properties, making them suitable for applications in construction materials, furniture, and packaging. Further optimization and characterization of the composites are recommended to explore their full potential in practical applications.

Key words: Hardwood Sawdust, Low Density Polyethylene (LDPE), Composites, Mechanical Properties, Melt Blending Technique.

INTRODUCTION

Natural fibers in this context refer to wood fiber and various agro-based fibers such as bast, leaf, seed, and stem fibers [1]. There are several factors driving the increased interest in natural fiber composites, including environmental concerns and the need for sustainable materials that have led to the exploration of renewable resources as alternatives to petroleum-based plastics [1-2]. The field of natural fiber-reinforced thermoplastic composite materials has been rapidly growing in recent years, both in terms of industrial applications and fundamental research.

Lignocellulosic fibers, which are derived from plant sources and consist of cellulose, hemicellulose, and lignin, are commonly used as fillers or reinforcements in thermoplastic composites. They can be incorporated into thermoplastics such as polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), and polystyrene (PS). These materials offer potential cost savings due to the use of low-cost agro-fibers and the ability to achieve high filling levels, up to 75%. They are also non-abrasive to processing equipment and can contribute to rural job generation and the development of non-food agricultural-based economies [2].

However, there are practical limitations to the use of lignocellulosic fibers in composites. One major limitation is the requirement for low processing temperatures, typically below 200°C, to avoid fiber degradation and volatile emissions that could affect the properties of the composite. This restricts the choice of thermoplastics that can be used. Another limitation is the high hygroscopicity of agro-fibers, leading to moisture absorption and potential dimensional instability of the composite [1]. Techniques such as acetylation and good fiber-matrix bonding can help reduce moisture absorption. The choice of processing technique also affects fiber dispersion, with larger fibers generally providing greater properties but potentially leading to clumping in the composite. [2-3].

A particular kind of natural fiber composite that combines thermoplastic polymers with wood is called a wood-plastic composite (WPC). Since the early 1980s, WPCs have been used in a variety of industries, such as decking, windows, door profiles, and vehicle interiors. When compared to unreinforced polymers, the combination of wood and thermoplastics gives benefits such enhanced toughness, fatigue resistance, and creep resistance (Conference, 1997).

The impact of hardwood sawdust on the characteristics of low density polyethylene composites has been studied by numerous other researchers [4–13], and the results showed a notable improvement in these characteristics.

This research therefore aimed at evaluating the effects of hardwood sawdust on the mechanical properties of sawdust-low density polyethylene (LDPE) composites.

MATERIALS AND METHOD

The polyethylene used in the study was waste Low Density Polyethylene (LDPE) obtained from the industrial wastes of the IBETO Group of Companies in Nnewi, Nigeria. The wood fiber used was hardwood sawdust obtained from the local timber market in Awka, Nigeria. The study involved preparing composites with different percentages of sawdust mixed with LDPE. The composite processing was done manually by physically mixing the components in a bowl. The mixture was then injected into a mold using an injection molding machine.

A. Raw Materials Preparation:

The LDPE from consumed table water sachets was crushed and pelletized. The hardwood sawdust was sun-dried for 36 hours and sieved using an 18-mesh size.

B. Processing:

Up to 35% by weight of sawdust was mixed with LDPE. The manual mixing was followed by injecting the mixture into a mold using an injection molding machine. The processing parameters included an injection pressure of 150 MPa and a temperature of 160°C.

RESULTS AND DISCUSSION

Various tests were conducted on the wood sawdust-filled LDPE composites, including tensile, flexural, hardness (Brinell), and unnotched impact tests. The test results are presented in the tables below, showing the performance of the composites at different filler weights.

Table 1 provides the tensile test results, including breaking load, extension, strain, tensile strength, tensile modulus, and elongation for different filler percentages. Table 2 presents the flexural test results, including load, deflection, flexural strength, and flexural modulus. Table 3 displays the results of hardness and unnotched impact tests, showing the unnotched Izod impact values and Brinell hardness numbers for each filler weight.

Furthermore, Table 4 compiles the composite performance properties, including elongation at break, tensile strength, tensile modulus, flexural strength, flexural modulus, unnotched impact, and Brinell hardness number for different filler percentages.

The analysis section discussed the effects of hardwood sawdust on the mechanical properties of the composites. It highlights factors such as poor adhesion, non-uniform fiber distribution, and the nature of the LDPE used, which contribute to the decrease in tensile strength. However, it notes that the modulus is not significantly affected by non-uniformity and shows an improvement due to the presence of fibers.

The graphs presented in Figures 1 and 2 demonstrate the relationship between filler content and tensile strength as well as the flexural properties. The flexural properties of the LDPE composites exhibit improvement with the addition of sawdust, as observed by the increase in flexural strength.

Overall, the test results and analysis provide insights into the mechanical performance of the wood sawdust-filled LDPE composites and the influence of different filler percentages on their properties.

Table 1: Tensile and Elongation Properties Results.

Filler Weight (%)	**Breaking Load (N)**	**Extension (mm)**	**Strain**	**Tensile Strength (MPa)**	**Tensile Modulus (MPa)**	**Elongation (%)**
0	4549.50	18.90	0.126	30.33	240.70	12.60
10	4309.50	14.70	0.098	28.73	293.20	9.80
20	3637.50	10.50	0.070	24.25	346.40	7.00
25	3295.50	8.10	0.054	21.97	406.90	5.40
30	2941.50	6.15	0.041	19.61	478.30	4.10
35	2568.00	4.35	0.029	17.12	590.30	2.90

Note: Tensile specimen Dimensions = 150mm x 30mm x 5mm

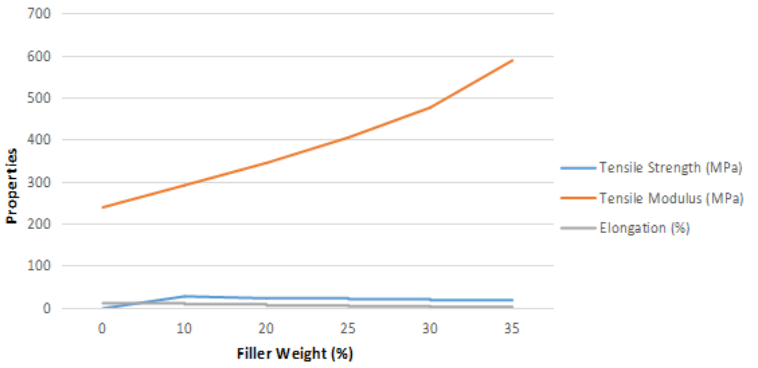

Fig. 1: Graph of Tensile and Elongation Properties.

From table 1 and Fig. 1 above, the optimum tensile strength (30.33MPa) and elongation property (12.60%) were obtained at 0% weight of filler. This showed that as the filler weight decreases, the tensile strength and elongation increases. Also, the optimum strength of tensile modulus (590.30MPa) were obtained at 35% weight, which showed a constant increase in the modulus as the filler weight also increases.

Table 2: Flexural Property Results.

Filler Weight (%)	Load (N)	Deflection (Mm)	Flexural Strength (MPa)	Flexural Modulus (GPa)
0	844.40	1.85	38.00	1.23
10	888.90	1.73	40.00	1.39
20	960.00	1.60	43.20	1.62
25	1008.90	1.40	45.40	1.95
30	1088.90	1.28	49.00	2.30
35	1246.70	1.26	56.10	2.67

Note: Flexural specimen= 60mm × 20mm x 10mm

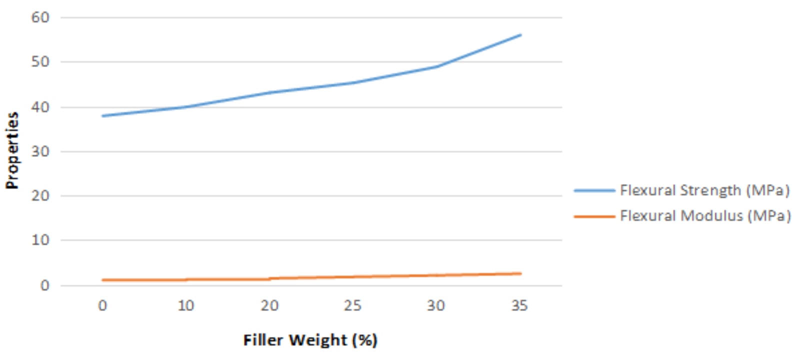

Fig. 2: Graph of Flexural Property

From table 2 and figure 2 above, the optimum flexural strength (56.10MPa) and modulus (2.67MPa) were obtained at 35% weight of the filler. This showed that as the filler weight increases, the flexural properties also increases.

Table 3: Hardness and Impact Test Results

Filler Weight (%)	Unnotched Izod Impact (J/m)	Brinell Hardness Number (MPa)
0	0	2.3
10	440	3.1
20	375	3.8
25	315	4.3
30	287	4.4
35	213	4.5

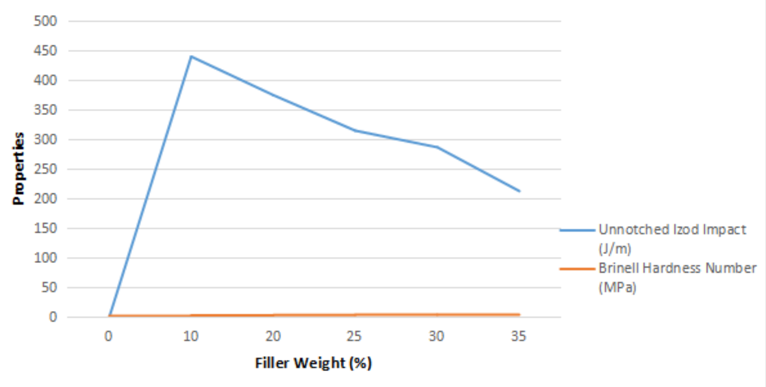

Fig. 3: Graph of Impact and Hardness Properties

Table 3 and Figure 3 above showed that the optimum impact strength (213j/m) was obtained at 10% weight of filler, after which it experienced a decline till it reached 35%weight. In contrast to the impact, the hardness test (4.5MPa) experienced a continuous increase proportional to increase in filler weight, and arrived its optimum point at 35% weight.

Table 4: Compiled composite performance

Filler by Weight (%)	Elongation at break (%)	Tensile strength (MPa)	Tensile modulus (MPa)	Flexural strength (MPa)	Flexural modulus (GPa)	Unnotched impact (J/m)	Brinell hardness No (MPa)
0	12.6	30.33	240.7	38	1.23	0	2.3
10	9.8	28.73	293.2	40	1.39	440	3.1
20	7.0	24.25	346.4	43.2	1.62	375	3.8
25	5.4	21.97	406.9	45.4	1.95	315	4.3
30	4.1	19.61	478.3	49	2.3	287	4.4
35	2.9	17.12	590.3	56.1	2.67	213	4.5

CONCLUSION

In conclusion, this study investigated the effect of hardwood sawdust on the processing and performance of wood flour LDPE composites. The results obtained provide valuable insights into the physico-mechanical characteristics of these composites and their potential applications. It showed that the optimum tensile strength (30.33MPa) and elongation property (12.60%) were obtained at 0% weight of filler, while that of tensile modulus (590.30MPa) was obtained at 35% weight. The optimum flexural strength (56.10MPa) and modulus (2.67MPa) were obtained at 35% weight of the filler, while that of the impact strength (213j/m) was obtained at 10% weight of filler, after which it experienced a decline till it reached 35%weight. The hardness test (4.5MPa) experienced a continuous increase proportional to increase in filler weight, and arrived its optimum point at 35% weight. This showed that the inclusion of hardwood sawdust in the LDPE matrix had a significant impact on the composite properties. It was observed that the addition of sawdust resulted in an increase in LDPE modulus, indicating the presence of adhesion between the hardwood sawdust and LDPE. This suggests that there was some level of interaction between the wood fiber and the polymer matrix. However, it was also found that the filler-matrix bond strength in the sawdust LDPE system was not satisfactory, leading to a decrease in LDPE strength with increasing wood fiber content. This could be attributed to poor adhesion between the sawdust and LDPE, as well as non-uniform fiber distribution due to inadequate mixing. These factors contributed to a reduction in the tensile strength of the composites.

In summary, the use of hardwood sawdust in wood flour LDPE composites presents both opportunities and challenges. While the inclusion of sawdust can enhance the LDPE modulus, the overall strength of the composite may be compromised due to insufficient filler-matrix adhesion. However, the application of appropriate coupling agents and compatibilizers can address these limitations and unlock the full potential of these composites. The findings of this study have implications for various applications where wood flour LDPE composites are used, such as in construction materials, furniture manufacturing, and automotive components. By optimizing the formulation and processing parameters, it is possible to develop wood flour LDPE composites with improved mechanical properties and enhanced performance, thereby expanding their range of applications.

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