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# FABRICATION AND CHARACTERIZATION OF COMPOSITES FROM HIGH DENSITY POLYETHYLENE AND FLAMBOYANT SEEDS SOLID WASTES

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## ABSTRACT

This research work studied the potentials of utilizing plant and plastic wastes in the production of high quality composites. Composites of different percent filler loading (0-60%) were fabricated from high density polyethylene and flamboyant seeds wastes using compounding and compressing moulding machine. The fabricated composites were characterized via mechanical and morphological properties using ASTM (American Society for Testing and Materials) standards. The results obtained from the various parameters ranges from the lowest to the highest filler loading composite materials are: Tensile strength 32.6 - 18.9 MPa; tensile modulus 12.75 - 30.62MPa; elongation at break 68.9-61.84%, flexural strength 50.30 - 14.88 MPa; flexural modulus 12.75 - 30.62 MPa; and impact strength 0.55 - 0.07 J/m$^2$. The SEM micrographs have shown better distribution of filler particles in the lowest filler loading composite.

**Keywords:** Composites, High density polyethylene, Flamboyant seeds, Solid wastes

## Introduction

The problems of environmental pollution are enormous and diverse which are mainly caused by human activities. These activities generate various forms of pollutants, which includes solid wastes. Plastic wastes are among the worst environmental solid wastes due to non-biodegradability (ability to stay longer in the environment) which many ends up in the oceans [1].

It may be converted into microplastics by some environmental factors such as sun, wind, etc. which are detrimental to sea creatures. Plastic wastes account for almost 25% by volume of the total solid waste in Nigeria and this situation may continue to degenerate because of indiscriminate production of plastic materials and poor disposal methods [1].

The increase demands of special materials by our developing industries to meet certain

specifications require fabrication of new composite materials. Fabricating composite materials from plant and plastic wastes, can be of dual advantages in addressing the challenging environmental solid waste pollution and providing more economic opportunities in the society [2].

Natural fibers are materials that are produced by geological processes, or from bodies of plants or animals. These fibers possess important qualities such as being strong, light, abundant, non-abrasive, and non-hazardous; as such could therefore be used as fillers in fabricating composite materials with certain required qualities. For example, natural fibre polymer composite has high specific strength and stiffness among other qualities [3]. Flamboyant plant is a common ornamental tropical flowering plant. Its seeds are very hard under a tight covering. This quality make the flamboyant plant seeds to be a suitable material as filler in fabricating composite materials [4]. Natural fibre (filler) can be treated with various reagents at different concentrations to achieve certain required qualities in the composite products such as water resistance, fire resistance, etc. [3].

Due to the current challenges of environmental pollutants, scientist have been trying to solve these problems by converting these wastes into products of high specific qualities and also eco-friendly, among which is production of composite materials from plastic and plant solid wastes. The fabricating of these composites has always come with challenges due to differences in the properties of the individual materials. As a result researchers are trying to curb the menaces concerning the fabrication of these composites by improving their properties through different treatment to achieve a certain required qualities for specific applications. With no compromise this work will also consider fabricating composite materials from available solid wastes (HDPE and flamboyant seeds) with certain treatments to achieve desired qualities for better applications.

## EXPERIMENTAL PROCEDURE

### Preparation of samples

Flamboyant Pods were sampled randomly from various points within Kaduna Metropolis directly from flamboyant plant. After removing the seeds out of its pods, was washed with distilled water and dried by placing in an oven at 150 ºC for 1h and weighed. The drying and weighing was repeated until constant weighed was obtained. The dried seeds were grinded using Jaw crusher (PE900X1200) and sieved

using standard sieve (100 µm). The resultant seed particles of 100 µm size was then weighed and stored in an air tight container before the next stage of the fabrication processes.

**Sampling of the waste HDPE (matrix)**

Empty bottles identified with appropriate code '2' (ASTM resin code) were used for this study. The bottles were sampled from various 'Fura and Nono' centers within Kaduna Metropolis using random sampling method. The samples were washed properly, dried and cut into flakes form of about 30x30 mm length and width respectively. The flakes were then stored in a nylon bags and kept for next stage of the fabrication processes.

**Treatment of the pretreated flamboyant seeds (filler) with NaOH**

The pretreated flamboyant seed samples of particle size 100 µm obtained was chemically modified by 3% NaOH. This was achieved by immersing 300 g of the pretreated sample into 3 litres of 3% NaOH for an hour, and then washed with 3 litres of distilled water and 1% acetic acid to neutralized Na ions. The washing process was monitored with pocket-size pH meter until neutral pH was achieved. The treated sample was dried using vacuum oven (BTL 230) at 60 ˚C for 48 hours and stored in an air tight containers to avoid moisture absorption before next fabrication processes [5].

**Fabrication of Composites**

Six different composites materials and a control G, were fabricated and labeled A-G according to the ratio of the matrix, filler and the amount of boric acid used. The composite materials fabricated were shown in the table below.

Table 1: Composite Materials and Percent Compositions of Materials

| CODE | % MATRIX | % FILLER | % BORIC ACID |
|---|---|---|---|
| A | 90 | 10 | 0 |
| B | 90 | 8 | 2 |
| C | 80 | 16 | 4 |
| D | 70 | 24 | 6 |
| E | 60 | 32 | 8 |
| F | 50 | 40 | 10 |
| G | 100% (CONTROL) | | |

**Compounding Molding**

Composite B was prepared by weighing 90 g of the matrix and transferred to the heater roller of the 'two roll milling machine' at

130 ˚C and allowed to melt, then 8 g of the treated filler and 2 g of the boric acid were added to the melted matrix and allowed to mix for 5min. The melted composite was transferred into a metal mould of the dimension 200mm x 200mm x 5mm

Same processes were followed to produce composite C, D, E and F with appropriate amounts of matrix, filler and boric acid as shown in the above table. Composite A was prepared in the same manner only that boric acid was not added.

The control material G was prepared by weighing 100g of the matrix and transferred to the heater roller of the 'two roll milling machine' at 130˚C and allowed to melt, then transferred to a metal mould of same dimensions as described above [6].

**Compression Moulding**

A resultant molten liquid in the metal mould was subjected to press on compression moulding machine at 160 ºC for 5 minutes. The temperature was then adjusted to 25 ºC and 4 Pa pressure for 3 min for the composite to solidify. The composite was ejected from the machine and cut into different dimensions according to ASTM standard for various characterization processes. Each of the composites was treated in the same manner as above [6].

**Characterization**

The following mechanical and morphological analyses were carried out on the composites according to ASTM standards.

**Mechanical Properties**

**Tensile test (ASTM D638)**

The tensile test was carried out using tensile properties tenser (YG026D multifunctional Electronic Fabric Strength Machine) according to ASTM D638 with maximum force of 10 kN. The samples dimensions were 100x15x5 (mm) length, width and thickness respectively. A cross-head speed of 2 mm/min was used. The test specimens were hold in the grips of the testing machine and tightened evenly and firmly to prevent any slippage as the test commenced. The resistance and elongation of the specimens were measured and recorded using load cell until a failure or rupture occurred. From the tensile machine, tensile parameters (tensile strength, tensile modulus and elongation at break) were determined and recorded [5].

**Flexural test (ASTM D790)**

The flexural or 3-point bending test was carried out on Enerpac universal material testing machine with a maximum load of 100 kN and cross head speed of 5 mm/min. the test was carried out according to ASTM D790. The dimensions of the sample were 100x30x5 mm length, width and thickness respectively. Each specimen was positioned horizontally on sample compartment of the machine and then pressed to start. The flexural strength and modulus were determined and recorded [5].

**Impact strength test (ASTM E23)**

The impact strength of the composite samples was carried out using the charpy impact tester according to ASTM E23 (Notched) standard. Samples were tested at room temperature by a single swing of the pendulum hammer using Norwood. The specimen size was 100x11x5 (mm). Each sample was placed on the vice and clamped firmly. The pendulum hammer was raised to the required height and then released and strike the sample at once. Then impact energy absorbed by the specimen was recorded. The impact strength of the samples in joules per square metre was recorded [5].

**3.5.3 Morphological Analysis (SEM)**

The morphology of the control (100% matrix), lowest filler loading (10%) highest filler loading (60%) composite materials were studied using scanning electron microscope (SEM) at an accelerating voltage of 5.0Kv and magnification of 500 x. Test samples were initially sputter-coated with gold (using cressington sputtecoater 108 auto) in order to prevent any electrical discharge during examination with the microscope [4].

## RESULTS AND DISCUSSION

### Results

The results for the physical, chemical, mechanical and morphological parameters of the composite materials fabricated are presented as follows:

### Mechanical Properties

The results for the mechanical properties of the fabricated composites viz: tensile strength, elongation at break, tensile modulus, flexural strength, flexural modulus, impact strength and hardness are presented in figure 1- 6.

#### Morphological Analysis

The results for the morphological analysis obtained from the Scanning Electron

Microscope (SEM) were depicted in plate 1-3.

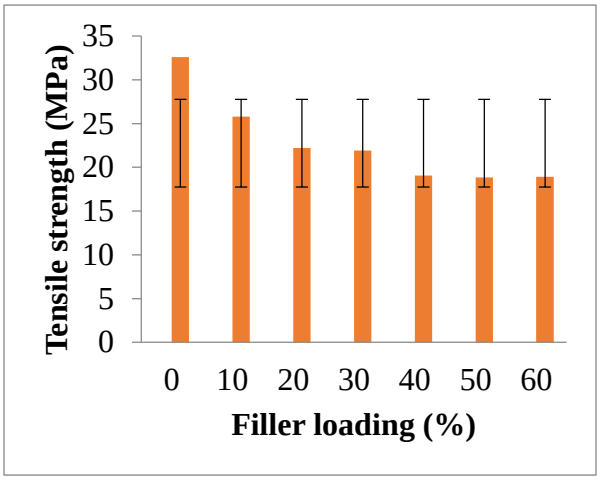


Figure 1: Tensile strength versus % filler loading of the fabricated composites

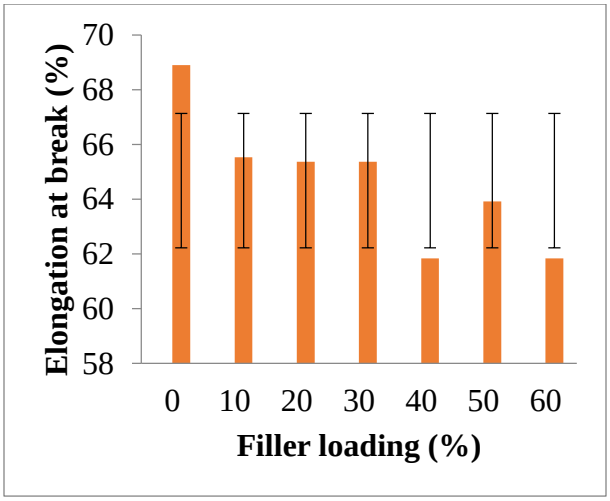


Figure 2: Elongation at break versus % filler loading of the fabricated composites

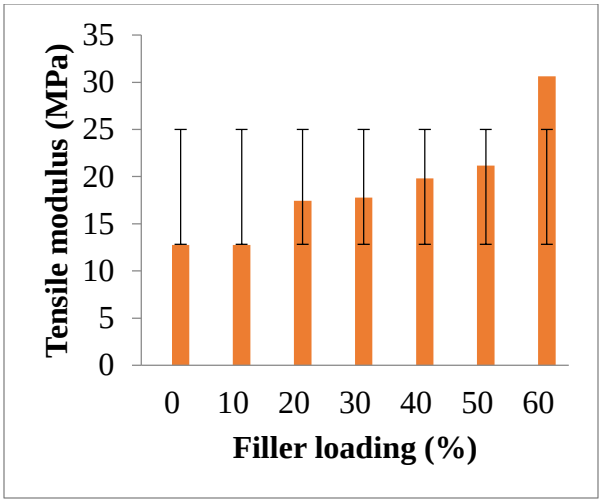


Figure 3: Tensile modulus versus % filler loading of the fabricated composites

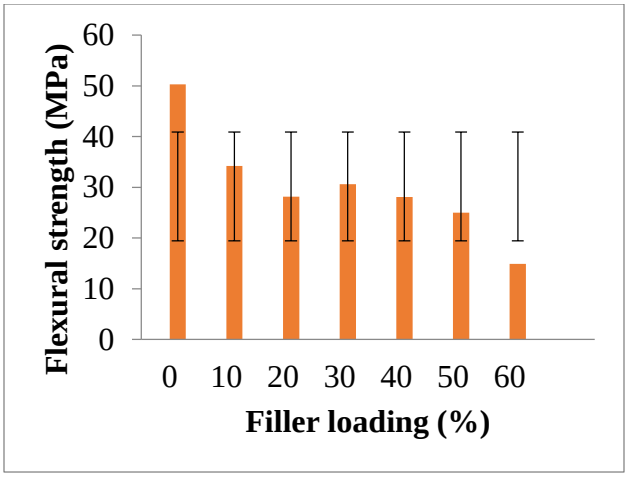


Figure 4: Flexural strength versus % filler loading of the fabricated composites

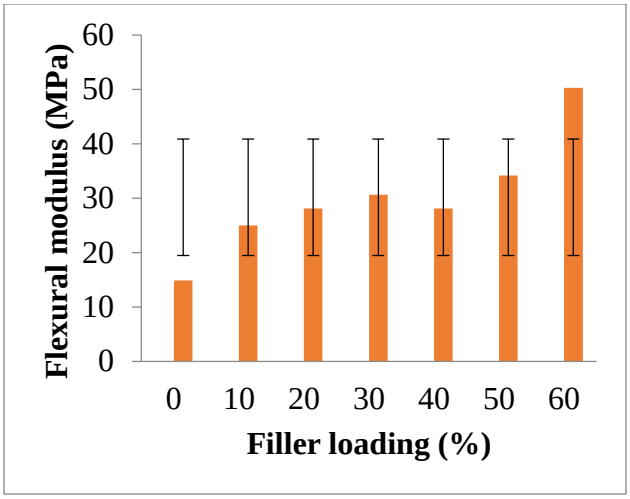


Figure 5: Flexural modulus versus % filler loading of the fabricated composite

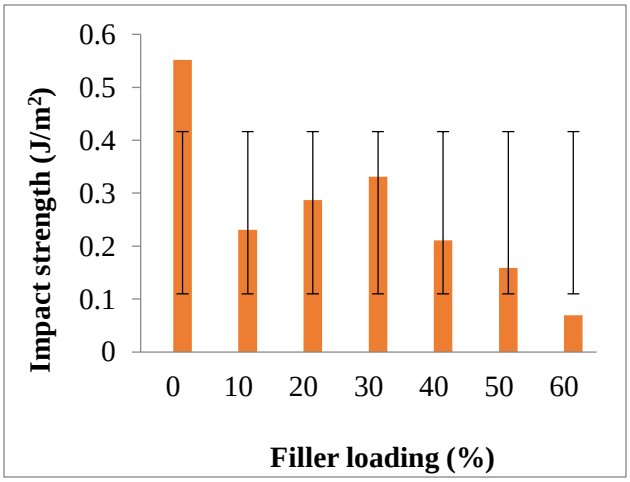


Figure 5: Impact strength versus % filler loading of the fabricated composites

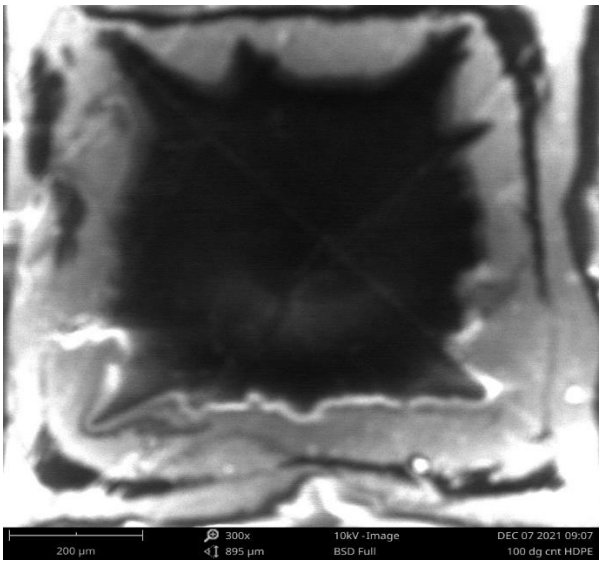


Plate 1: SEM micrograph of fracture surface from tensile measurement of 0 % filler loading composite

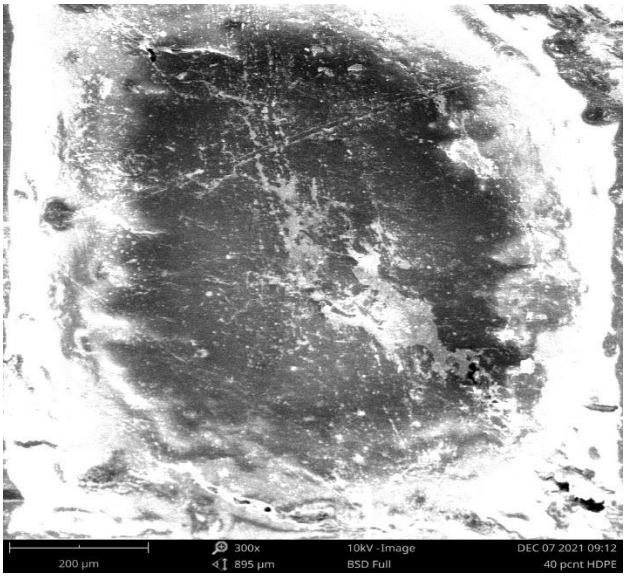


Plate 2: SEM micrograph of fracture surface from tensile measurement of 60 % filler loading Composite

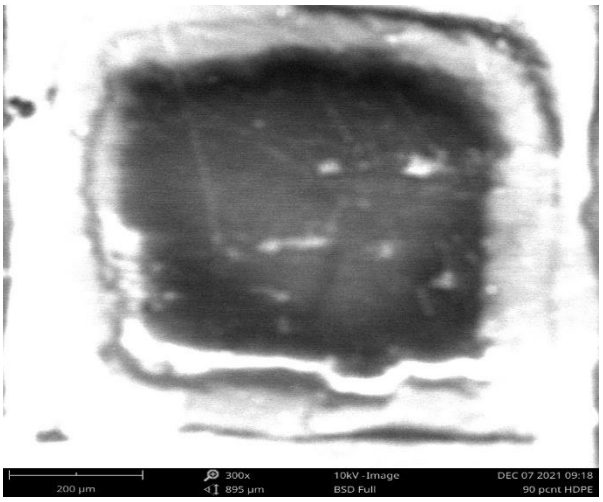


Plate 3: SEM micrograph of fracture surface from tensile measurement of 10 % filler loading composite.

## DISCUSSION

### Mechanical Properties

### Tensile Strength

The effects of filler loading on tensile strength of the composites were presented in Figure 1. It was observed that the tensile strength decreased with increase in filler loadings, except in 50% filler loading which may be due to formation of voids or agglomeration during the fabrication processes. This decrease is attributed to weak interfacial adhesion between the matrix and the fillers as a result of poor wettability. This wettability increases with the increase in the filler loadings, hence, the matrix begin to lose its binding ability which in turn reduced filler / matrix interfacial adhesion therefore caused the tensile strength to decrease. This adversely affects the stress transfer from the matrix to the filler. Similar findings were reported by [7, 8, 9].

### Elongation at break

The effect of filler loading on elongation at break of the composites is presented in Figure 2. The elongation at break of the composites decreases with increase in filler loading but the neat polymer showed highest elongation at break compared to the rest of the composites. This observation highlights the fact that the incorporation of high percent filler into polymer matrix improves the stiffness of the composites thus reducing toughness, that is to say the addition of the rigid filler decreased the ductility of the polymer matrix. This is because of the reduction in the bond strength at the filler / matrix interface. From the Figure 2 it can be seen that 40% filler loading is lower than 50% filler loading this is attributed to the voids formed during processing. Similar trend has been reported by [10].

### Tensile Modulus

The results of tensile modulus of the fabricated composites are presented in Figure 3. From the results, it was observed that the tensile modulus increases with

increase in filler loading. This increase is attributed to the reduction in ductility of the matrix. This observation indicates the fact that the addition of much filler into polymer matrix improves the stiffness of the composites thus reducing toughness, that is to say the addition of the rigid filler decreased the ductility of the polymer matrix thus causing the tensile modulus to increase. Similar result reported that tensile modulus increased with increase in filler loading of areca fibre / high-density polyethylene (HDPE) composites from 20 to 60% filler loading [11].

**Flexural Strength**

The results of flexural strength of the fabricated composites are presented in Figure 4. From the results, it is observed that an increase in filler loading of the Flamboyant Seed Particles from 10 to 60% caused a significant decrease in flexural strength of the composites. This is as due to poor wettability of the filler as the amount of filler increases leading to a weak interfacial adhesion between the Flamboyant Seed particles and the HDPE. This can also be attributed to the difficulties in achieving homogeneous dispersion associated with higher filler loading causing poor filler / matrix interaction thus affecting stress transfer from the polymer matrix to the filler. It was also reported that flexural strength dropped steadily as the filler loading increases with untreated cow hair from 10 wt% to 50 wt% [10].

**Flexural Modulus**

The results of flexural modulus of the fabricated composites are presented in Figure 4.5. From the results, it was observed that the flexural modulus progressively improved with increase in filler loading. The improvement begins at 10% steadily increasing to 60% filler loading except at 40% filler loading, which may be due to formation of voids or agglomeration in the fabricating processes. The increase in flexural modulus with increase in filler loading is because of the reduction in the molecular chain mobility of the HDPE matrix leading to an increase in stiffness of the HDPE matrix.

**Impact Strength**

The effects of filler loading on the impact strength of the composites are presented in Figures 6. It was observed that the impact strengths of the composites increases from 10% to 30% and then decreases steadily from 30% to 60% with increase in filler loading. The initial improvement in impact strength from 10% to 30% is due to the

presence of enough filler particles in the composites to absorb and share the stress with the matrix. The final drop in impact strength from 30% to 60% is as a result of weak bonding between the flamboyant seed particles and the HDPE matrix. There is an observed trend of increase in impact strength of HDPE / leather composites from 10% to 30% there after a decrease from 40% to 60% was observed [7].

**Morphological Properties**

The effect of filler loading of the fabricated composites was investigated in relation to tensile strength using scanning electron microscopy (SEM) PHENOM PRO X (Phenomworld, Eindhoven, Netherlands) at fractural point. Plate 1, 2 and 3 depict micrographs of 0%, 10% and 60% filler loading composites respectively. Plate 1 was observed to have a better distribution, being it purely matrix (0% filler loading). This even distribution explains better tensile strength compared to plate 2 and 3. The distribution of plate 2 which is 10% filler loading is better compared to plate 3. This explains better filler/matrix interaction than plate 3. This could be the reason for lower mechanical properties showed by 60% filler loading compared with 10% filler loading. Similar trend was reported [12].

## CONCLUSION

This research work revealed that HDPE and flamboyant seed wastes can be converted to eco-friendly composite materials. The six different composites were fabricated from compounding and compressing moulding machine. All these composites has shown good mechanical properties. Composite with 30% filler loadings has shown a consistent improvement in all the parameters analyzed. There was some variation of trend in some composites, which may be due to formation of voids or agglomeration during the fabrication processes. The SEM analysis has revealed the effect of filler loading of the composites materials interfacial bonding, having shown better distribution in the micrograph (plate) of the lowest filler loading composite. These may lead to the conclusion that, the fabricated composites can be used for various purposes in composite industries, which may also serve as remedy for environmental control.

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