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A Study on the Mechanical Properties of Low Density Polyethylene Composite Reinforced with Baobab Pod Fibre (BPF).

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Abstract

This study focused on the use of Baobab pod fibres as a potential reinforcement material for Low density polyethylene (LDPE) polymer. The fibre reinforced composites were produced using compression moulding at a temperature of 150 ^{0}C for 30 min and a formulation of Baobab pod fibre (BPF) to Low density polyethylene (LDPE) ratios of 10-90 wt%, 20-80 wt%, 30-70 wt% and 40-60 wt% were used respectively. The mechanical properties namely; tensile strength, impact strength, flexural strength and hardness of the composites produced were then investigated. The composite with 10-90 wt% BPF/LDPE ratios was found to have the best mechanical properties with tensile property of 75.72 MPa, Impact strength of 4.46 J/mm^2, flexural strength of 17.24 MPa and hardness of 26.7 HV. Based on the results obtained, it shows that Baobab pod fibres have excellent properties for use as polymer reinforcement that can be used for various applications.

Keywords : Baobab pod, Fibre, Polymer Composite.

Introduction

Natural fibres are extensively available in nature and are found all over the world. Natural fibre-based composites are becoming popular day-by-day and replacing synthetic fibre-oriented composites due to their outstanding biodegradability, renewability, decomposability, stiffness, higher length to weight ratio, and low cost [10] , [2]. Natural fibre reinforced polymer composites represent an opportunity to partially minimize environmental impacts by integrating biodegradable fibre such as baobab in place

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of synthetic fibres in composite materials production. Hazards of synthetic fibre, recycling issues, and toxic by-products are the main driving factors in the research and development of bio-composites [14]. However natural fibre itself has some limitation when related to manmade fibre due to hydrophilic nature of the natural fibre caused weak interfacial interaction between the polymer matrix and the fibre. In order to improve the fibre surface morphology different chemical treatment techniques to be used to improve surface morphological of the fibre in order to avoid unwanted materials from the surface of fibre [1].

The combination of organic natural fibres and inorganic or organic polymers has a high potential for improving mechanical performances, and thus expanding the areas of application [6]. Although composites reinforced with synthetic fibres possess superior mechanical properties, they have some severe drawbacks that include high cost, poor recyclability and non-biodegradability [13]. Reinforced polymeric composites are also generating dramatic revolutions in this sector for sophisticated applications, especially to water repellence, corrosion, and antibacterial properties. Natural fibres could be applied as filler materials, along with bio-fibres and matrix polymer, in composites for acquiring better performances [4].

Numerous Studies have been carried out using different natural fibre reinforcement agent for polymers like hemp, sugarcane bagasse, jute, sisal, coir, cotton and bamboo. But little attention had been given to the potential use of baobab fibre as reinforcement for polymer matrix. *Adansonia Digitata* called the Baobab tree in both English and French is very characteristic of the Sahelian region and belongs to the Malvaceae family. Popularly called Kuka among the pre-dominant Hausa speaking populace of northern Nigeria is widely distributed and is found in all parts of the region [5].

The plant is predominantly found in the hot and drier regions of tropical Africa. It has multi-purpose uses and every part of the plant is reported to be useful. Fibre from the inner bark is strong and widely used for making rope, basket nets, snares, fishing lines and it’s even used for weaving. The fibres are also available from disintegrated wood and have been used for packing. Other fibres used for rope are obtained from root bark [12]. The Tree has seeds (pods) which contains natural fibres and pulp. The pulp is either sucked or made into a drink while the bark is used in making ropes [9], but fibres from the pod have been ignored and its potential use has not been properly explored.

Natural fibre`s availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to man-made fibres, they are more environmentally friendly, and are used in transportation, military applications, building and construction industries, packaging, consumer products [8]. There are a lot of studies carried on chemical composition; mechanical, thermal, and morphological characteristics have been carried out on natural fibres [3] , [15]. Natural fibres are categorized into four main classes: seed fibres; baobab, cotton, coir, and kapok, leaf fibres; sisal, agave, pineapple, and abaca, bast fibres; kenaf, ramie, hemp, jute, and flax, and stalk fibres; wood, straw, and bamboo. There have been global research by scientist to develop biodegradable polymers as a waste management option to curtail plastic pollution which is amongst the biggest environmental disasters of modern era [16]. This study on baobab fibres is expected to harness the use of a brand new fibre that has never been used, enhance local content development and contribute to cur tailing the problem of non-biodegradability of synthetic plastic [11].

2. Methodology

2.1 Materials

Baobab seeds, Distilled water (100% purity), Low density polyethylene (LDPE) (Hebei Zhongsheng new materials technology company limited, China),Sodium hydroxide (NaOH) pellets (98% purity, analytical grade),Two roll mill machine (Reliable Rubber and Machinery Company North Bergen New Jersey, U.S.A. Model No 12000), Compression moulding machine (Carver Incorporation new Jersey, U.S.A. Model No 12000), Weighing machine (Kern and Solm Company Berlingen Germany Model No D72336), Tensile Strength testing Machine(Instron Machine Model 3369, GBT. Number 3369K1781, Capacity 50 KN, Weight 141kg, Maximum speed 500mm/min, Power requirement 100/120/220/240V, Maximum vertical test space 1193mm.), Charpy Impact testing Machine (Capacity 15J and 25J, Serial No 412-07-15269C, Norwood Instruments Limited Great Britain), Flexural Testing Machine (Universal Materials Testing Machine, Norwood Instruments Limited. Serial No Cat. Nr 261,100KN Capacities) and Hardness Testing Machine (Vickers Hardness Tester. DIN 53505 ISO 868 ASTM D2240, Serial No 07/2012-1329, Model MV1-PC).

2.2 Experiment

The raw baobab pod fibres (BPFs) used in this study was collected from Zaria city market in Northern Nigeria. Low density polyethylene (LDPE) was supplied by Nigeria Institute of Leather and Science Technology (NILEST) Samaru-Zaria, Kaduna state, Nigeria. Sodium hydroxide (NaOH) pellets (98% purity, analytical grade) and distilled water (100% purity) were supplied by a vendor. All chemicals were used as received. Figure .1 shows the images of baobab pods fibres after extraction from the pod.

Figure 1: Baobab fibres after extraction from the pod

Ripe and mature baobab pods were flocked from baobab tree. They were sliced open mechanically using a knife. The fibres were screened out from the pod by hand and then washed in a running tap water to remove the remaining pulp that gummed the fibres together.

Figure 2: **Ground Baobab pod fibres**

Finally, the fibres were allowed to dry for 24 hours. The dried baobab fibres were subjected to size reduction by grinding using local milling machine. The ground fibres were then sieved as shown in Figure 2, in order to ensure equal distribution of the fibres.

2.3 Fabrication of Baobab Reinforced Low Density Polyethylene Composites

Table 1, presents the formulation used for the production of the low density polyethylene baobab reinforced composites:

Table 1: Formulation of Composites

Formulation	Low Density Polyethylene	Baobab fibres
(%)	(g)	(g)
100	100	0
90:10	90	10
80:20	80	20
70:30	70	30
60:40	60	40

2.4 Two roll machine and process of mixture

The two-roll mill machine was heated to a temperature of 150 ^{o}C for 30 min, which is the melting temperature of low density polyethylene. The Baobab pod fibres cwere mixed with low density polyethylene by a way of compounding using two-roll. 90 wt% of LDPE were poured into the preheated two-roll mill to melt the LDPE for 5 min, followed by gradual pouring of 10 wt% Baobab pod fibres into the melted LDPE and a complete mixing of the fibre with the matrix was achieved. Finally, the compounded Baobab/LDPE was scraped from the mill and sheet was formed.

2.5 The compression moulding process

The compression moulding machine was heated for 30 min at the set temperature of 150 ^{o}C. After which the compounded sample was placed inside a rectangular mould. The arrange mould coated with aluminium foil paper and taken into the preheated compression mould machine. The hydraulic press was held under a pressure of 10 KN for a period of 6 min. Thereafter, the sample was removed from the press and allowed to cool before removing the composite sample from the mould.

The procedure was repeated for 20 wt%, 30 wt%, 40 wt% and 0 wt% of Baobab pod fibre with the corresponding 80 wt%, 70 wt% , 60 wt% and 100 wt% matrices of low density polyethylene (LDPE).

3. Results and Discussion

3.1 Tensile Strength of composites

Tensile strength is one of the most important properties of cellulose fibre reinforced composites because it indicates the resistance of material to break under tension. Figure 3 shows the maximum tensile strength for the composites was 86 MPa for 30 wt % which is much higher than that of the virgin (unreinforced) composite which has 61 MPa. The maximum tensile strength obtained at 30 wt% might be due to proper binding between the fibre and matrix of the LDPE all other reinforced composites had tensile strength higher than that of the unreinforced LDPE.

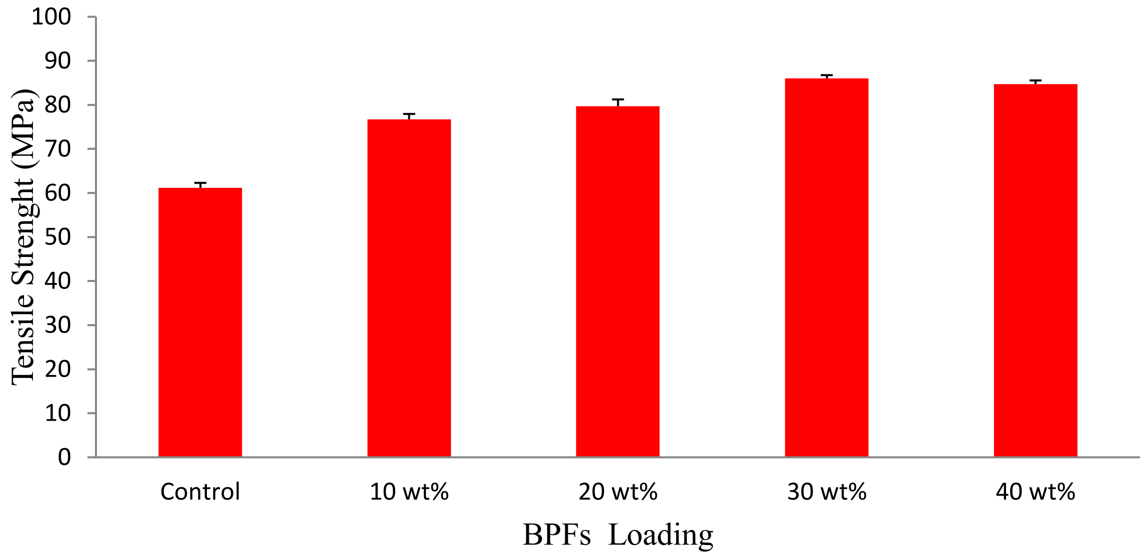

Figure 3: Tensile Strength of composites at varying BPF loading.

3.2 Flexural Strength of composites

The flexural strength of the reinforced LDPE/Baobab fibre composites is higher than that control unreinforced LDPE as shown in Figure 4. This is a clear indication that flexural strength was increased with baobab fibre reinforcement. The highest flexural strength was obtained at 30 w % which is 17.36 MPa. The overlap in error bar between 20 wt %, 30 wt % and 40 wt % does not show much significant difference between the results.

All samples have modulus of rapture above 16.4 MPa while that of the unreinforced sample stood at 16.4 MPa this shows that the unreinforced LDPE has the tendency to rapture faster than that of the baobab reinforced composites.

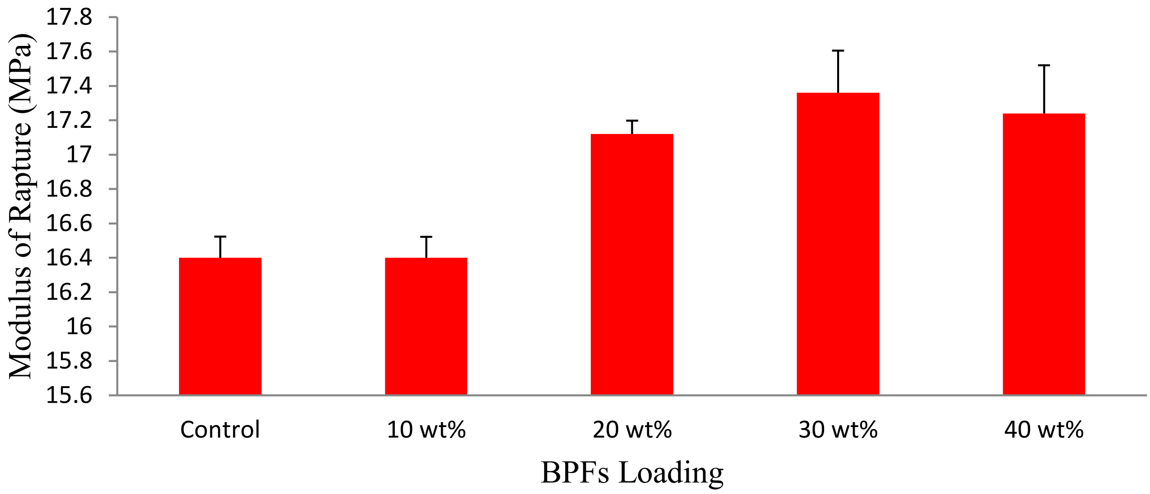

Figure 4: Flexural Strength of Composite at varying BPF loading

3.3 Hardness of Composites

From Figure 5, it was observed that the addition of the baobab fibre to LDPE increases the hardness property, this indicated that hardness of the composite material formed is directly proportional to the increase in BPF addition at the point where there is high proportion of BPF reinforcement loading with respect to the LDPE. The lowest hardness strength of 26.7 HV was obtained at 10 wt% of Baobab fibre loading while the highest was recorded at 45.3 HV for 40 wt %.

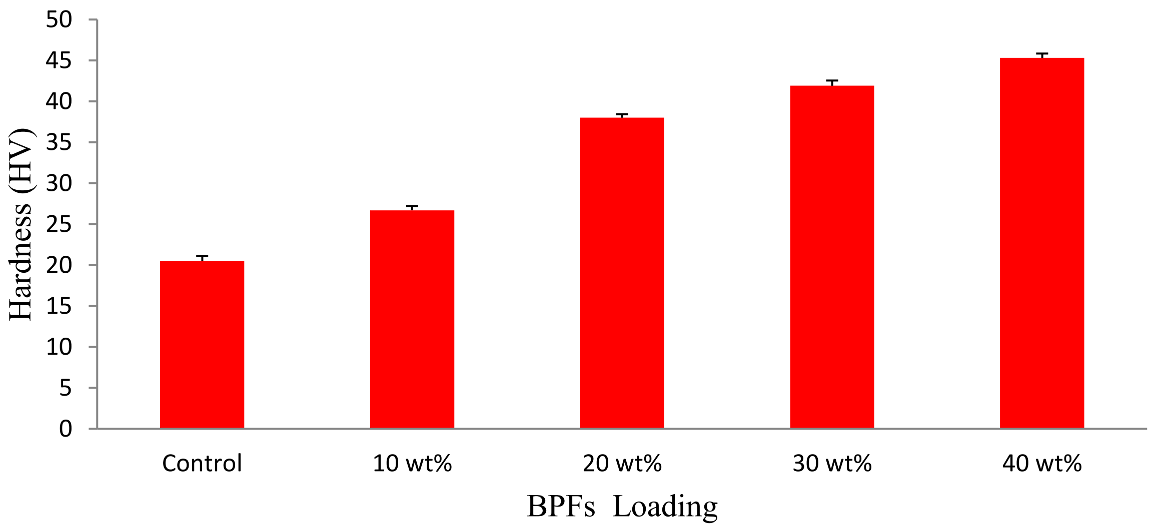

Figure 5: Hardness of Composites at varying BPF loading

3.4 Impact Strength of Composite

The impact strength of the BPF reinforced composites decreased with increased loading as can be seen from Figure 6. The impact properties decrease due to poor interfacial adhesion between the matrix and the fibre. The fibre loading increases the brittleness of the composite.

The error bar overlapped between 10 wt %, 20 wt% and 30 wt% fibre loading shows that there was no significant change in impact strength between the two composites.Tensile strength and water absorption are important properties to be determined when using natural fibre as a reinforcing material. For this study, the composite that exhibits best of those properties is sample 3 (30 wt% Baobab fibre and 70 wt% LDPE). It has very low water absorption of 0.1707 % and the highest tensile strength of 86.05 MPa. The hydrophobic nature of the reinforcing material (LDPE) will not allow water absorption into the matrix and thereby restraining water sensitivity. The tremendous increase in the tensile property of the Baobab fibre may be attributed to proper homogeneous mixing of the fibre and the matrix at the Baobab fibre-LDPE interface after the fibre was chemically treated.

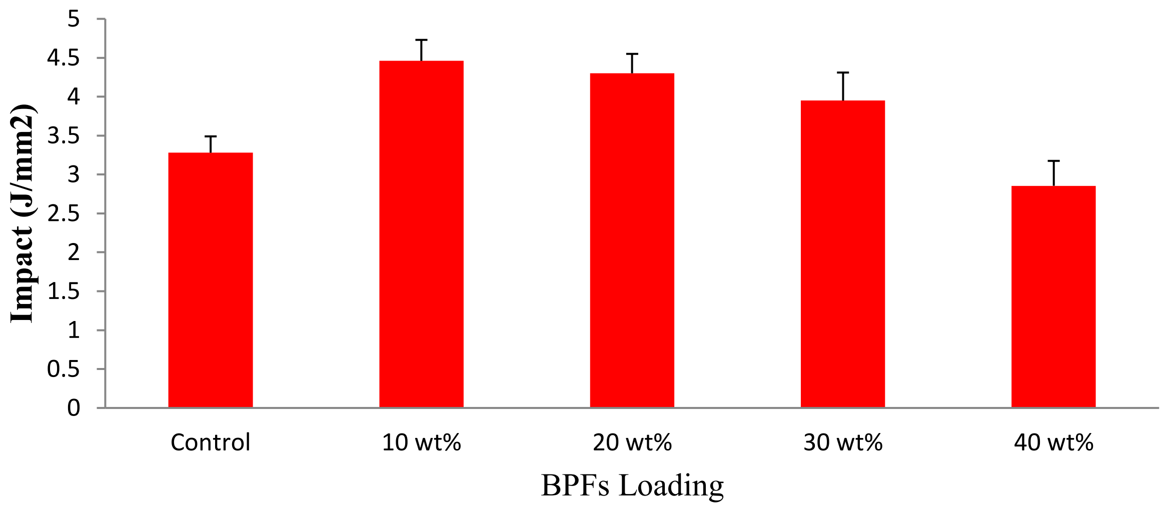

Figure 6: Impact Strength of Composite at BPF loading

4. Conclusions

In this research work, fibre reinforced polymer matrix were developed from fibres extracted from Baobab pods and low-density polyethylene (LDPE) using extrusion and compression moulding techniques. The mechanical properties related to the composites produced were investigated. The following conclusions are made based on the experimental results and analysis of the data: NaOH treatment of baobab pod fibres alters the mechanical properties of the fibres. LDPE/Baobab fibre reinforced composites are suitable materials to meet the emerging demands arising from scientific and technologic advances.

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