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Fabrication and Characterization of Baobab Pod (*Adansoniadigitata)* Fiber Reinforced Polyester Resin Composite

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Abstract

The use of natural fibers as reinforcement in polymer composites is receiving tremendous attention in recent times due to environmental issues, high cost and unsustainable nature associated with conventional synthetic fibers. This work is focus on the characterization of baobab fiber reinforced unsaturated polyester resin. The fibers were obtained from Sabo market in Zaria and sliced longitudinally, screened, washed with water, dried under sun and treated with 5% NaOH solution for fabrication and characterization. Samples were fabricated with different fiber loading of 10-30 wt%. The samples were moulded using Hand Lay-up method followed by pressing and post cured at 60^{o}C for 3 h. The result showed tensile strength decreases as the loading of fiber increased from 20 to 30 wt%. It was also observed that baobab composite has the highest tensile strength of 18.85 MPa at 20 and least (16.45 MPa) at 15 wt%. The result also revealed the elongation at break increased from 20 to 25 wt%. At 25 wt% it has a maximum value (18.4%) elongation at break; at 30 wt%. It was also observed that the density increased with increase in the fiber loading from 15 to 30 wt% (1.23-2 g/cm^3), respectively. At 15 wt% shows a maximum water take-up of 6.53% while from 20 to 30 wt%, Flexural strength increased from 10 to 15 wt% (23.98-46.3 Mpa). However, the bending stress decreases on increasing the fiber loading from 20-30 wt% (30.2-25.2 Mpa). The elastic nature of the composite generally increased with increase in fiber loading. This study, however recommend hybridization of baobab pod fiber with other natural fiber to investigate the mechanical and physical property of the hybrid composite for better result.

Keywords: Baobab, fabrication, polyester, resin, unsaturated

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Introduction

Composite material is a microscopic or macroscopic combination of two or more distinct materials recognizable interface between them, separated on a scale larger than atomic with its distinct properties. It is usually consisting of reinforcing phase such as fibres or particles supported by a binder or matrix. Natural fibres are good in composite making due to their reinforcing properties and biodegradability [1].

The use of natural fibers as reinforcement in polymer composites is receiving tremendous attention in recent times due to environmental issues, high cost and unsustainable nature associated with conventional synthetic fibers [2]. They are of economic with low density and high mechanical resistance and abundant in nature. Therefore, composite is an important aspect of engineering which has led to much concern and investigations towards promoting the development of new technologies for production and use of alternative materials from renewable resources and also reducing environmental pollution. Composites consists reinforcement which are either natural or synthetic. Composite materials are used over conventional materials mostly due to their superior mechanical and chemical properties as well as their ability to be tailored specifically for the object at hand [3].

Baobab pod fibre (Kuka in Hausa) which is the fibrous material is used in this composite making due to its high extension at break and its high density [4]. It is popular and widely cultivated plant in the surrounding region of West Africa and grows in temperate regions of the world; it is obtained from the pod and bark of the tree *Adansoniadigitata*. Aside the fibre, it has nutritional and other useful properties [5]. Baobab tree provides income and employment to rural and urban communities [6]. The different parts of the plant provide food, shelter, clothing and medicine as well as material for hunting and fishing [7]. Polyester resin is the matrix used due to its general purpose in composite making and they are used for the familiar fibre glass boat, automobile reactional vehicle, and all sorts of storage tanks, pultruded piping, portable toilets, and countless commercial and military application. It usually contains inhibitors that allow their storage as liquid for a year or more. The resin becomes rigid in time as short as one minute or as long as several hours when a catalyst is applied which leads to curing during fabrication of polymer composite product.

The reinforcing phase can be either fibrous or non-fibrous (particulate) in nature and if they are derived from plants or living species, they are called Natural fibre [8]. Baobab fiber is a natural fibre used as reinforcement; it has been reported to have been used in composite making with different matrices such as LDPE, epoxy resin etc. This research aimed at the study on the fabrication and characterization of baobab fiber reinforced unsaturated polyester resin composite with the following objectives:

i. To have a full fabrication on baobab pod fiber/unsaturated polyester resin composite using hand-layup method.
ii. To compare the mechanical and physical properties of varying fibre loading.

Materials and Methods

Collection and preparation of baobab pod fibre

The baobab pod fibres were obtained from Sabo market in Zaria and sliced longitudinally. The fibres were screened out from the baobab fruit. It was then washed with water to remove the whitish fruit after which it was sun dried [9].

Treatment of the baobab pod fibre with 5 wt% NaOH

The dried baobab pod fibres were treated with 5 wt% NaOH. Some quantity of the fibres was put into a beaker containing 800 ml (24 wt% NaOH) of solution. The mixture was stirred continuously. After treatment, it was washed thoroughly with distilled water to remove the unwanted material (wax, lignin, etc.) [10].

Fabrication of composite

The cleaned and dried mould was treated with petroleum jelly to avoid sticking of the composite to the mould. The fibers were laid uniformly over the mould before applying the mixed unsaturated polyester. The polyester was first mixed with catalyst (1 g of methylethylketone peroxide) and then accelerator (1 g of naphthalene cobalt) for some minutes in beaker and was applied to the fiber in the mould. After which it was then cured using a pressing machine for 24 h. The composite formed was removed and left at room temperature and then transferred to an oven for post curing at 60^{o}C for 3 h, before cutting and testing at Mechanical and Civil Engineering workshop ABU Zaria [10].

Tensile strength test

The composites were cut into three dumb bell shapes (dog bone shape) according to ASTM D636, each per fiber weight. Each specimen was fixed between the teeth of the tensile testing machine and a force of 1.2kN was applied continuously until the specimen breaks. The machine produced a graph of load versus extension, which was then used to determine the maximum stress and percentage elongation of each sample. [10]

Flexural test

The flexural test was carried out according to ASTM D790 using a universal materials testing machine of 100kN capacity, Tensile testing of the composite specimens was carried out using an Instron Machine Model 3369, System Number 3369K1781, Capacity 50kN, USA. ASTM D638 was adopted [11]. The baobab composites were prepared prior to testing with a sample gauge length of 80 mm; the cut samples were placed each on the teeth of the machine and tested at a gross head speed of 10 mm per minute [10].

Water absorption analysis

This test method determines the relative rate of absorption of water by plastics when immersed. The composite samples were cut into rectangular shapes according to ASTM D570 (50 x 10 x 3 mm) and then weighed and immersed into water for 24 hours then latter removed and weighed. The percentage of water absorbed was then calculated by the formula [10, 12];

$$\text{Water absorption (\%)} = \left(\frac{w - wo}{wo}\right) * 100 \qquad 1$$

where: ***w*** is final weight and ***wo*** is the initial weight

Density analysis

The composites were cut into length of 40 mm breadth the thickness of 3 mm for different fibre loading and weighed differently, the volume was determined by multiplying the length by the breadth by thickness and further the density was determined by the formula used by [13],

$$\text{Density} = \frac{Mass}{Volume}$$

Additionally, the presence of certain organic compounds (such as wax and pectin) found on the surface of these fibers can sometimes act as a barrier to destroy the effective interfacial adhesion between the filler and the polymeric matrix [13].

$$V_f = \frac{W_f/\rho_f}{(W_f/\rho_f) + (W_m/\rho_m)},$$

where *Vf* is the volume fraction of fiber (%), *Wm* and *Wf* are the mass of the matrix and fiber, respectively, and *ρm* and *ρf* refer to the density of the matrix and fiber, respectively.

Results and Discussion

Effect of fiber loading on tensile strength of the composite were presented in Fig. 1 while Fig. 2 shows the effect of fiber loading on elongation at break of baobab-polyester composite. Fig. 3 shows, the effect of fiber loading on density of the composites while Fig. 4 effect of fiber loading on water absorption of the composites and Fig. 5 shows the effect of fiber loading on the flexural strength of the composite, respectively.

From Fig. 1, baobab composite has the highest tensile strength of 18.85 MPa at 20 wt% and least (16.45 MPa) at 15 wt%; this might be due to weak compatibility between the fiber and the polyester mixture.

Generally, tensile strength decreases as the loading of fiber increased from 20 to 30 wt%. This trend might be due to poor dispersion of the fiber-polyester composite [8]. 20 wt% has a tensile strength of 18.85 MPa which is a higher tensile strength when compared to the optimal value (10.4 MPa) for dum palm fiber-polyester composite and also higher than the 9.5 MPa for luffa-polyester fiber reported by Summou *et al.* [14]. Similarly, baobab fiber at 10 wt% reported in this work has more tensile strength (18.76 MPa) than Sisal-polyester composite (12.8 MPa at 10 wt %) [15].

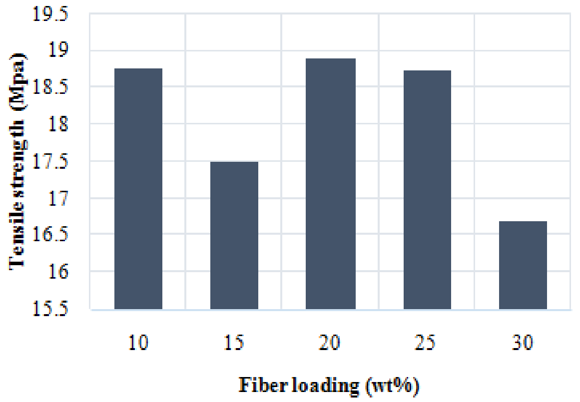

Figure 1: Effect of fiber loading on tensile strength of the treated baobab pod fibre with unsaturated polyester resin composite

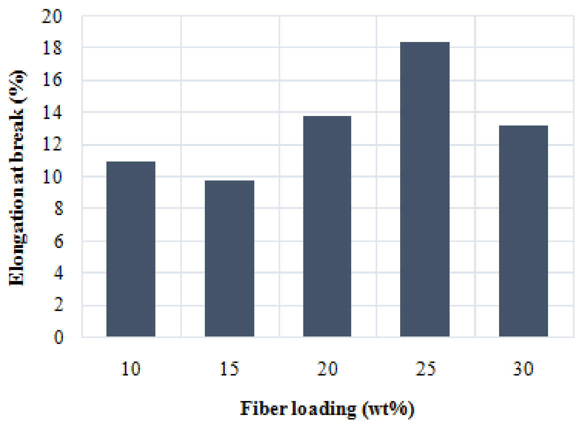

Figure 2: Effect of fiber loading on elongation at break of baobab-polyester composite

From Fig. 2, 10wt% has an elongation at break of 11% which dropped at 15Wt% with 9.8%. The drop may be due to the poor dispersion between the fibre and matrix in the composite. It was also observed from Fig. 2, that the elongation at break increased from 20 wt% to 25 wt% which indicates an increase in the elastic nature of the composite with increase in the fiber loading. The elongation at break dropped at 30 wt% of the sample may be due poor interaction in the constituent of the composite. 25 wt% has the highest elongation at break of 18.4% of the composite which is higher when compared to luffa (2.8%) and dum palm (2.3%) fiber-polyester treated composite [4].

From Fig. 3, it was observed that the 10 wt% has a 1.39 g/cm^3 density and dropped at 15 wt% with 1.23 g/cm^3. The drop might be due to poor dispersion in the composite. It was also observed that the density increased with increase in the fiber loading from 15 to 30 wt% (1.23 – 2 g/cm^3) respectively which indicates good fiber-polyester interaction and adhesion. From Fig. 4, the water absorption increased from 10 to 15 wt% (5.02 - 6.53%) due to increase in fiber loading. 15 wt% has the highest water taken up at 6.53%. It can also be seen from 20 to 30 wt%, there was decrease in water absorption with increase in fiber loading. This may be due to poor dispersion of the fiber-polyester composite.

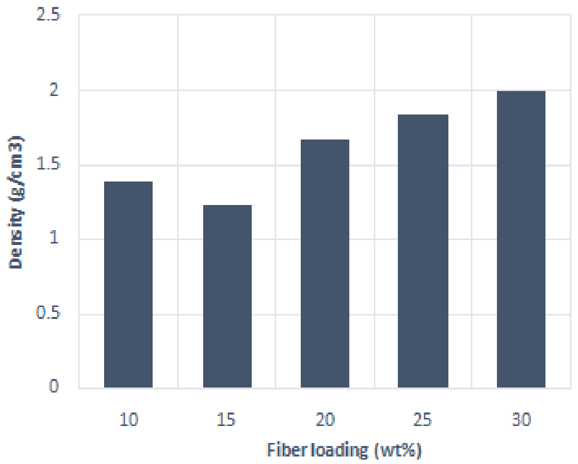

Figure 3: Effect of fiber loading on density of the composites

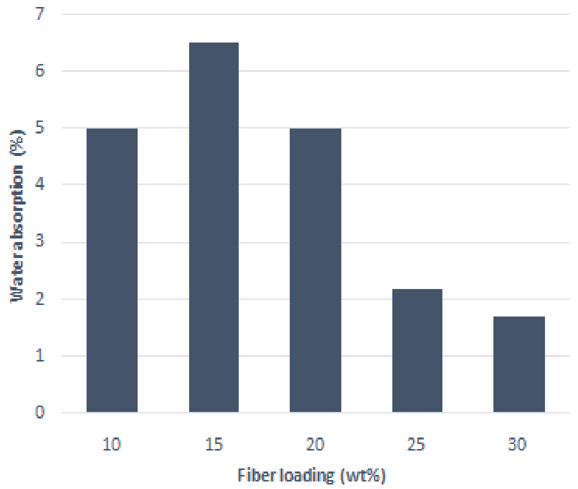

Figure 4: Effect of fiber loading on water absorption of the composites

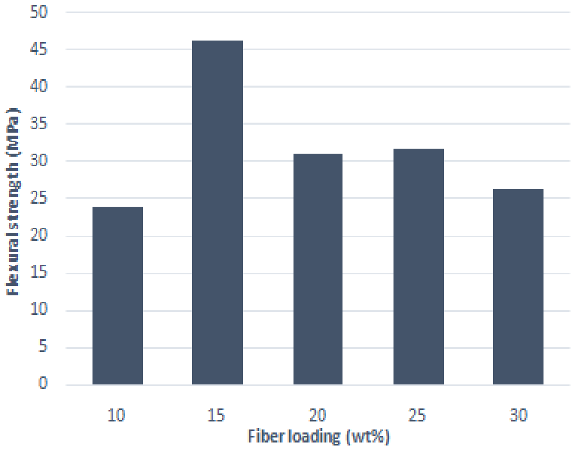

Figure 5: Effect of Fiber Loading on the Flexural Strength of the Composite

From Fig. 5, it can be seen that flexural strength increased from 10 wt% to 15 wt% (23.98 – 46.3 Mpa). However, there was a decrease in the bending stress on increasing the fiber loading from 15 to 20 wt% (46.3–31.0 Mpa). The reason for the drop in the bending stress may be based on the unfavorable week fiber-matrix adhesion with increasing fiber content Siddika *et al.* [8]. The highest value of the flexural strength was at 15 wt% (46.3 Mpa) compared to dum palm polyester treated composite (45.77 Mpa) bending stress [4].

Conclusion

The mechanical and physical properties of boabab pod fiber with polyester composite were investigated by varying the fiber loading from 10 to 30 wt%. The fiber was treated with 5 wt% of NaOH to remove cellulose lignin. It was observed that at 20wt% it has the highest value of tensile strength of the baobab-polyester composite and when compared with luffa and dum palm fiber- polyester composite has more tensile strength. It was also observed that the elastic nature of the composite increased with increase in fiber loading from 15 to 25 wt% (9.8 to 18.4%). From the investigation it was also observed that the density increased with increase in the fiber loading from 15 to 30 wt% (1.23 – 2 g/cm^3) which indicates that there was good fiber-polyester interaction and adhesion [16]. At 5 wt% of fiber was seen to have the highest water intake (6.53%) and decreased from 20 to 30 wt% with increase in fiber loading.

The highest value of the flexural strength of the baobab/polyester composite (Fig. 5) was at 15 wt% (46.3 Mpa) compared to dum palm polyester treated composite (45.77 Mpa) bending stress [4].

Recommendations

1. Hybridization of baobab pod fiber with other natural fiber should be use to also investigate the mechanical and physical property of the hybrid composite.
2. The utilization of the baobab pod fiber which are locally available should be processed and marketed

Competing interest: The authors declared no competing interest.

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