

Physico-Mechanical Properties of *Luffa aegyptiaca* Fiber Reinforced Polymer Matrix Composite

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Abstract

This paper presents the study of moisture content, hardness, bulk density, apparent porosity, tensile and flexural characteristics of composite properties of *Luffa aegyptiaca* fiber. *Luffa aegyptiaca* reinforced epoxy composites have been developed by hand lay-up method with *Luffa* fiber untreated and treated conditions for 12 Hrs and 24 Hrs in different filler loading as in 2:1 ratio (5%, 10%, 15%, 20% and 25%). The effects of filler loading on the moisture content, hardness, bulk density, apparent porosity, tensile and flexural properties were studied. In general, the treated *Luffa* fibre composite for 24 Hrs showed better improvement properties via addition of modified *Luffa* fibre as reinforcement. However, tensile and flexural properties improved continuously with increasing filler loading up to 20% but decreasing at 25% due to weak interfacial bonding for both untreated and treated composite. The favourable results were obtained at 20% for treated composite at 24 Hrs especially at tensile and flexural characteristics and are suitable for mechanical applications.

Keywords

Luffa aegyptiaca, Fiber, Flexural, Filler Loading

1. Introduction

Composite material can be referred to as a combination of two or more materials that results in better properties than the individual component used alone [1] or it can also be described as a structural material that consists of two or more constituents at a macroscopic level and constituents are not soluble in each other [2]. The two con-

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stituents are reinforcement and a matrix [3]. However, in modern materials engineering the term usually refers to a “MATRIX” material that is reinforced with fibers [4]. Most composites used today are at the leading edge of materials technology with performance and costs appropriate to ultra demanding applications such as spacecraft [5].

All of the different fibers used in composites have different properties and so affect the properties of the composite in different ways. This also provides stiffness to the composites. Fillers find application in the polymer industry, almost exclusively to improve mechanical, thermal, electrical properties and dimensional stability [6]. Fillers increase the number of chains, which share the load of a broken polymer chain. Research activities in recent time were towards finding alternatives fillers to replace the inorganic one [7]. The uses of natural fibers (organic fillers) have the following advantages when compare to the inorganic fillers: low density, low-cost, non-abrasive, availability from natural resources, they are renewable natural resources, they are recyclable and biodegradable [8]. Natural fibre reinforced FRPs can solve both the performance and environment related issues.

Luffa is a plant from the cucumber family grown for its multipurpose fruit (**Figure 1**) in many tropical countries. It is an annual climbing or trailing herbaceous species that can be 15 m long. The Luffa genus encompasses seven (7) species among which *Luffa aegyptiaca* and *Luffa acutangula* are primarily grown for its fibre production. The young fruits and leaves can be cooked as vegetable (fruits can be used in India to make curry) or eaten fresh or dried [9]. More so, when the fruit matures it becomes fibrous (**Figure 2**); the fiber is used as sponge for washing and scrubbing utensils as well as the human body. But due to the presence of hydroxyl groups from cellulose and lignin, natural fiber exhibits highly hydrophilic properties [10]. This makes fiber-matrix adhesion very difficult because most structural polymers are hydrophobic in nature which results in an unexpected failure of the composite material in service [11]. Therefore, in order to maximize natural fiber reinforced composite performance, fiber surface modification as well as a chemical additive to polymer matrix is required to improve the performance [12]. Thus, the present investigation seeks to characterize the physic-mechanical and morphological properties of sponge gourd (*Luffa aegyptiaca*) reinforced epoxy composite.



Figure 1. *Luffa aegyptiaca*.



Figure 2. Dried *Luffa aegyptiaca*.

2. Experiment

2.1. Materials

- 1) *Luffa aegyptiaca* (fibrous);
- 2) Epoxy (LY 556) and Hardener (HY 951);
- 3) Sodium Hydroxide;
- 4) Distilled Water;
- 5) 88 Universal Mold Release Wax;
- 6) Acetic Acid.

2.2. Equipment

The equipment used was:

- 1) Digital weighing balance (Pocket Scale, Black AWS-100 g);
- 2) Steel mould (Fabricated 3-piece mould with detachable top and base for dumb-bell and sheet shape);
- 3) 1.0mm sieve, (YS-C-638);
- 4) Beaker and measuring cylinder (200 and 100 mils respectively);

2.3. Material Preparation

Raw *Luffa aegyptiaca* fiber was cut opened lengthwise, the dried seeds shaken out and the dried fibrous sun-dried for six (6) hours. It was later cut into smaller sizes, grounded and then sieved with 1.0 mm sieve to obtain fine fiber particles (**Figure 3**). Composite samples were fabricated with 5%, 10%, 15%, 20% and 25% fillers in the ratio of 2:1 as in volume fraction using dumb-bell mould of 120 mm × 30 mm × 3 mm and rectangular sheet mould of 187 mm × 125 mm × 3 mm by hand laying method and finally left to air-cure for 24 Hrs (**Figure 4**). Thereafter, the laminates are taken carefully without any damage. Specimens are cut for testing as per ASTM standards.



Figure 3. Grinded Luffa fibers of particle size 1.0 .mm.



Figure 4. Preparation of composite testing.

2.4. Fiber Chemical Treatment

The fibers were immersed in NaOH solution with a concentration of 20% for 12 and 24 hours respectively at room temperature. After treatment, the fibers were washed with 2% acetic acid and again washed under running water then finally allowed to dry at room temperature for 2 days.

3. Characterization of Composite Materials

3.1. Determination of Moisture Content

A representative sample of the test fibers was weighed (M_2), dried at 110°C for 1 hour and then weighed (M_1) again. The difference in mass was divided by the initial mass, and then multiplied by 100:

Mathematically, this was calculated using Equation (1).

$$\% M.C = \frac{(M_2 - M_1)}{M_2} \times 100 \quad (1)$$

where $M.C$ = Moisture content;

M_1 = Weight of the sample after drying;

M_2 = Weight of the sample before drying.

3.2. Determination of Hardness Test

Micro-hardness measurement was done using a Leitz Hardnes (OS-2H) tester. This tester had a diamond indenter, in the form of a right pyramid with a square base and an angle 136° between opposite faces under a load of 3 N in accordance with ASTM E384.

3.3. Determination of Bulk Density

The dried samples were weighed accurately on a weighing balance as (W_d) after which the test pieces were soaked in a beaker of water of 1000 ml for about seven (7) hours of soaking, the specimens were weighed wet and the wet weight recorded as (W_w). Each specimen was later suspended in the beaker of water with the aid of a thread and the suspended weight of each specimen was recorded as (W_s).

The bulk density was calculated using Equation (2).

$$Bd = \frac{W_d \times \rho_w}{W_w - W_s} \quad (2)$$

where B_d = Bulk Density;

W_d = Dried Weight;

ρ_w = Density of Water (1 g/cm³);

W_w = Wet Weight;

W_s = Suspended Weight.

3.4. Determination of Apparent Porosity

The specimens were weighed dried (D), immersed in water for seven (7) hours to soak and weighed thereafter as (W). Finally, the specimen was weighed when suspended in water. This was recorded as (S). The apparent porosity (P) was then calculated using Equation (3).

$$P = \frac{W - D}{W - S} \times 100 \quad (3)$$

3.5. Determination of Tensile Strength

The tensile strength test was conducted on a computerized universal testing machine (**Figure 5**). The test was conducted in accordance with ASTM D 3039 method. The sample of 120 mm length was clamped into the two jaws of the machine. Each end of the jaws covered 30 mm of the sample. Reading of the tensile strength test in-



Figure 5. UTS machine sample loaded for tensile.

strument for Newton force and extension were initially set at zero. Tensile stress was applied until the failure of the sample was obtained. Four (4) specimens of each sample have been used for the measurement of the above mechanical properties at ambient laboratory environment and average results are reported.

3.6. Determination of Flexural Strength Test

Flexural Strength of samples was also tested on the computerized universal testing machine (**Figure 6**). The three-point bend flexural test was conducted in accordance with ASTM D 790 method. The σ_{bh} flexural strength, namely the maximum stress at break, was calculated using the formula.

$$\sigma_{bh} = \frac{3FL}{2bh^2} \quad (4)$$

where σ_{bh} = Flexural strength;

F = Breaking force (Newton);

L = Support distance (mm);

b = Width of Specimen (mm);

h = Thickness of Specimen (mm).

4. Results and Discussion

4.1. Moisture Content

The **Figure 7** revealed that the percentage moisture content rate for untreated fiber which is 10.36% was the highest among the treated one due the fact that natural fibers exhibits highly hydrophilic properties with the presence of cellulose and lignin compared to the treated.

4.2. Hardness Test

From the graph of micro-hardness against filler loading in **Figure 8**, the hardness rate increases as the percentage filler loading increase. Exhibiting a maximum hardness rate at 25% filler loading for all polymer composite except for that of control sample with 44.3 Hv. Still at 25% filler loading, the treated polymer composite for 24 Hrs has the highest hardness rate of 100.2 Hv compared to other polymer samples due to the increase in percentage filler content which results in the highest micro-hardness.

4.3. Bulk Density

Figure 9 revealed that the bulk density increased as the filler loading increased except for untreated composite



Figure 6. UTS machine Sample loaded for Flexural testing.

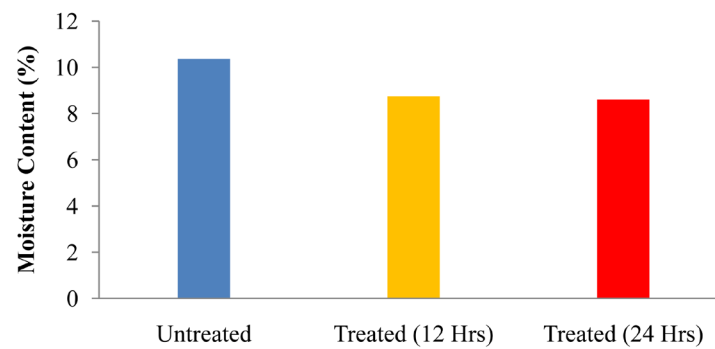


Figure 7. Moisture content variation of Luffa fiber composite.

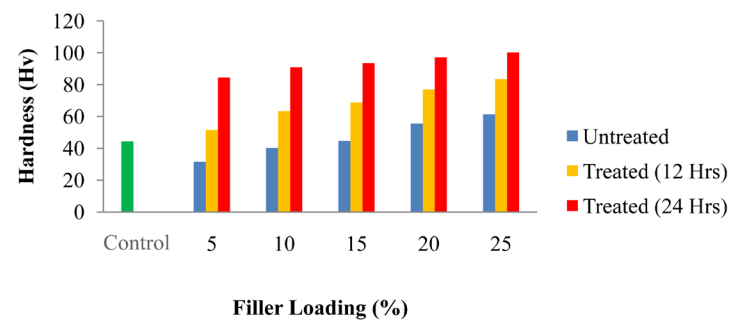


Figure 8. Hardness of Luffa fiber composite against filler loading.

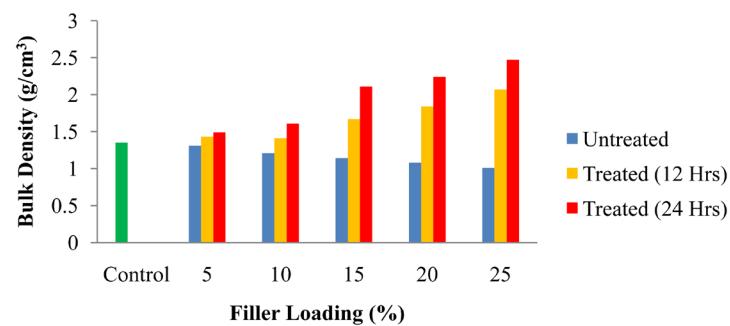


Figure 9. Bulk density of Luffa fiber composite against filler loading.

which decreased. However, a maximum percentage rate of 2.07 g/cm^3 and 2.47 g/cm^3 for treated composites for 12 Hrs and 24 Hrs respectively at 25% filler loading was also exhibited. While that of untreated composite has 1.31 g/cm^3 at 5% filler loading lower than even the control sample which has 1.35 g/cm^3 . The bulk density measures the change in weight of the composite with respect to the total volume of material where the total volume is the sum of both closed and open pores. Thus, as the filler loading increases, this leads to the closure of internal pores.

4.4. Apparent Porosity

In **Figure 10**, the apparent porosity equally decreases as the filler loading increases except for untreated composite which increases. The favourable percentage rate of apparent porosity exhibited by Luffa fiber composite are that of treated composite (12 Hrs and 24 Hrs) having 0.94% and 0.72% respectively at 25% filler loading higher than the control sample with 0.44%. While that of untreated composite for the same filler loading at 25% had 1.67% due to micro-cracks and non-uniform interfacial interaction of fiber-matrix.

4.5. Strength Properties

Fiber content and fiber strength are influencing parameters for the strength related properties of the composite [13]. **Figure 11** and **Figure 12** showed differently the strength variation with different percentage filler loading in tensile and flexural strength respectively. Thus, both figures indicate a gradual increase in both tensile and flexural strength up to 20% fiber content with 15% and 20% exhibiting the highest strength for treated polymer composite improved by the Luffa fiber than that of the control. However, at 25% filler loading there was a decrease in strength in both tensile and flexural strength for treated and untreated polymer composite due to maximum strength had been attained and further addition of fiber content weakened/disrupted the fiber-matrix bond. Similar observations were reported by Imoisili *et al.* 2012 [14]. They experimented on coconut shell ash on the tensile properties of epoxy composite.

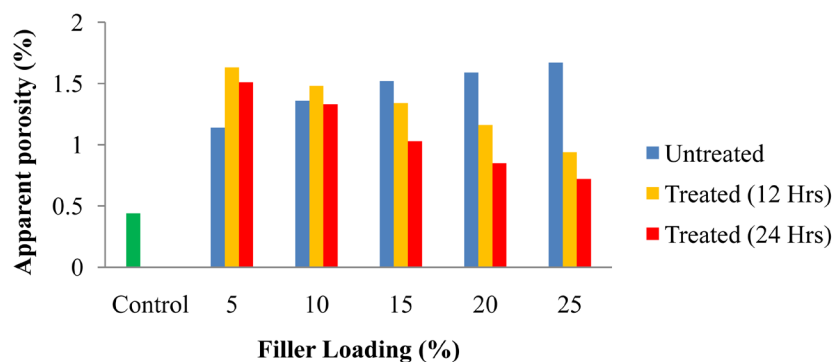


Figure 10. Apparent porosity of Luffa fiber composite against filler loading.

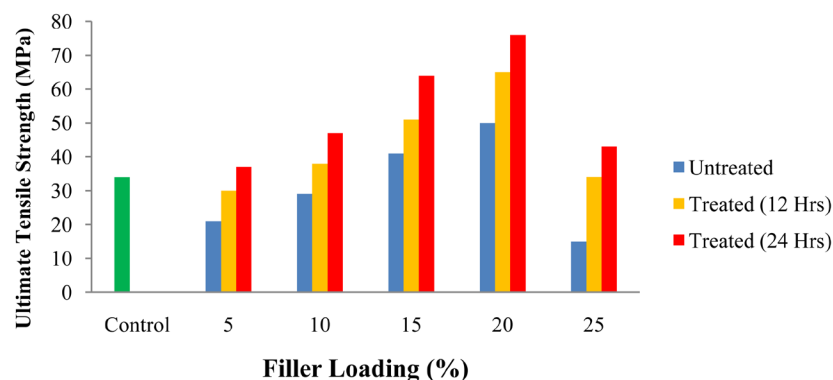


Figure 11. Ultimate tensile strength of Luffa fiber composite against filler loading.

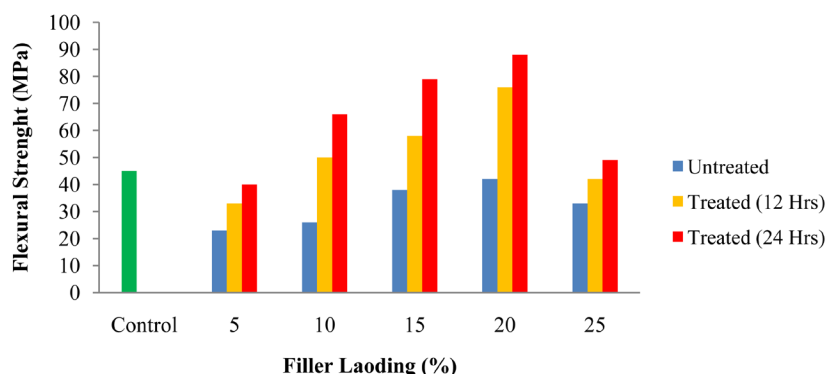


Figure 12. Flexural strength of Luffa fiber composite against filler loading.

5. Conclusion

The physico-mechanical properties of *Luffa aegyptiaca* fiber composite were investigated. In general, the treated composite for 24 Hrs showed an improvement by adding modified Luffa fiber as reinforcement. The results of moisture content of the Luffa fiber was reported and it revealed that the untreated fiber showed a higher content of moisture compared to the treated fibers due to the presence of hydroxyl group from cellulose and lignin fiber. However, tensile and flexural properties improved continuously with increasing filler loading up to 20% but decrease at 25% due to weak interfacial bonding for both untreated and treated composite with 20% having the favourable tensile and flexural strength.

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