

On the difficulties in manufacturing of luffa fibers reinforced bio-composites and variations in their dynamic properties

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ABSTRACT

Defects and structural differences in raw bio materials such as luffa plant result in large scattering mechanical properties such as density, damping and elasticity modulus. There are difficulties during the manufacturing process of the composites reinforced by bio materials inherent to the nature of bio materials. The major problems and restrictions encountered with the use of green luffa materials for composite manufacturing and the variations in the dynamic properties of luffa composites are studied in this study. First, the structural differences in the raw luffa plants are presented and the difficulties in manufacturing the luffa fibers based composites are discussed. After that, the variations in the measured modal parameters of luffa composites such as natural frequencies and loss factors are presented. The results showed that the luffa composites can be manufactured with similar properties without any special selection of luffa *cylandrica* samples for controlling the structural differences. However, a preliminary selection of bio raw samples is required if small variations in the dynamic hence mechanical properties of luffa composites are desired.

Keywords: Luffa bio composite, Composite manufacturing, Dynamic properties: 72.7

1. INTRODUCTION

The increasing demand for environmentally friendly materials and the need to reduce the cost of reinforcement materials in composites has resulted in the development of new bio materials based composites (1, 2). Luffa fibers (3-6) are a kind of new alternative material to the mineral fibers (7). Their low cost as well as their low density, high specific stiffness and recyclability make them very attractive as a reinforcement in composites (8). However, the mechanical properties such as density and stiffness of the composites of these green fibers to be used in practical applications may have large variations due to the defects and structural differences of the raw green fibers inherent to their nature. The variations in their structures and their size also limit the manufacturing of the composites of these green materials for different applications. As underlined in the literature (9, 10), many factors can influence the structure and the composition of the natural fibers including the variety of the luffa plant, the growth conditions (e.g., ground and treatments), the maturity and the retting degree.

There have been some studies in the literature for evaluating the mechanical properties of luffa composites (3, 4, 11-14). Boynard and D'Almeida (13) investigated the morphology of the fibrous vascular system of luffa and mechanical properties and they underlined that, without any surface treatment, luffa already has a high potential use as a core material in hybrid composites. In another study about the dynamic properties of luffa fibers, Genç (3) showed that the damping characteristics of luffa *cylandrica* composite is high compared to the glass fiber composite. The elastic properties, sound absorption and transmission loss levels of luffa fibers based composites were investigated in some other studies (4, 11, 12) and the results showed that the luffa composite structures may have considerably high stiffness, sound absorption and transmission loss levels and their mechanical properties are promising for noise and vibration control engineering applications. Paglicawan et al. (14) studied the flexural properties of loofah fiber reinforced plastic using polyester resin as a matrix and they showed that the concentration of fibers in the loofah itself has a significant effect on the mechanical properties in the transverse and longitudinal direction. The tensile and flexural modulus varied depending on the sample preparation of the composite and the direction of loading.

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The main difficulties and restrictions with the use of luffa green materials as a reinforcement in composites and the variations in the dynamic properties of luffa composites were discussed in this study. First, the structural differences in the raw luffa cylindrical samples were presented and the difficulties in their manufacturing were discussed. After that, the variations in the measured modal parameters of luffa composites such as natural frequencies and loss factors were presented. The results show that the luffa composites can be produced with similar properties without any special selection of luffa cylindrical specimens in order to homogenize the batch of fibers for controlling the structural differences. However, a preliminary selection of raw samples is required if the mechanical or dynamic properties of the luffa composites are desired to have small variations.

2. THE STRUCTURAL DIFFERENCES OF LUFFA FIBERS AND MANUFACTURING CONSTRAINTS

A luffa plant is covered with green peel and hanging on the plant at the beginning. When the ripening period of fibers inside the plant is completed, the outer green layer starts to dry. After the dry layer is removed, the fibrous structure (luffa cylindrica) is emerging (3). The structure used as fiber material has a cylindrical shape and a non-uniform fiber distribution as shown in Figure 1. The fibers are interlocked. The cross section contains some holes and the rib structure as shown in Figure 1c. The ribs provide structural strength. The luffa cylindrica may have four or three holes even for the same harvest.

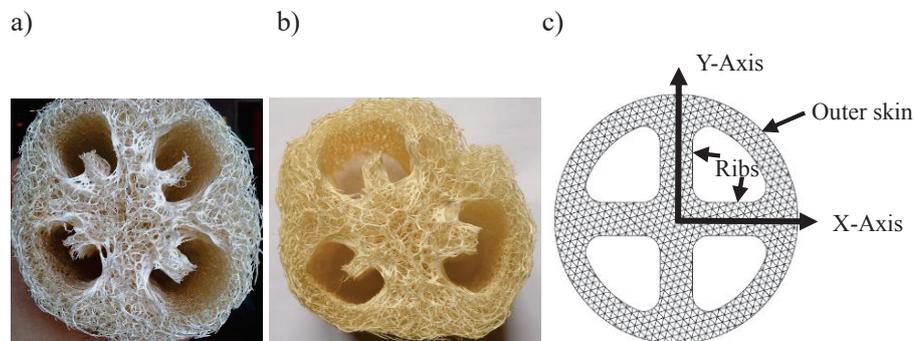


Figure 1 – The structure of luffa cylindrica samples: the luffa fiber with four (a) and three (b) holes and the schematic showing the cross section of a luffa cylindrica sample (c)

It is clear that there will be structural differences in the ribs of the three- and four-hole luffa fiber samples. The press direction during the manufacturing process will also affect the properties of the luffa composites. The structure of luffa cylindrica consists of many short fibers making an interlocked mesh. Because of this kind of fiber structure layout, the individual fibers could not separate from the body unlike other natural fibers such as flax, sisal and hemp. However, the fibers need to be cut in order to manufacture bigger specimens and the properties of the specimens produced from a complete luffa cylindrica samples and the pieces of luffa cylindrica samples will be different.

Some fibers have dislocations (deformed zones) or defects on the surface of the luffa cylindrica as shown in Figure 2. These defects are formed during the growth of the plant. The region of dislocations will have different mechanical properties than the other regions. Therefore, the defective fibers should be identified and excluded.

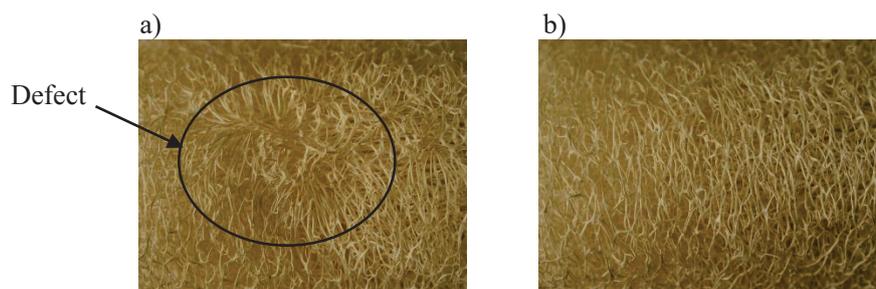


Figure 2 – The luffa fibers with (a) and without (b) a defect

The measured masses of the twenty dry luffa cylindrica specimens with the approximately the same dimensions were plotted in Figure 3. It is seen that the mass of the luffa samples varies from 40.4 to 137.4 gr; the average being 75.4 gr for the given specimens with a standard deviation of 31.7 gr.

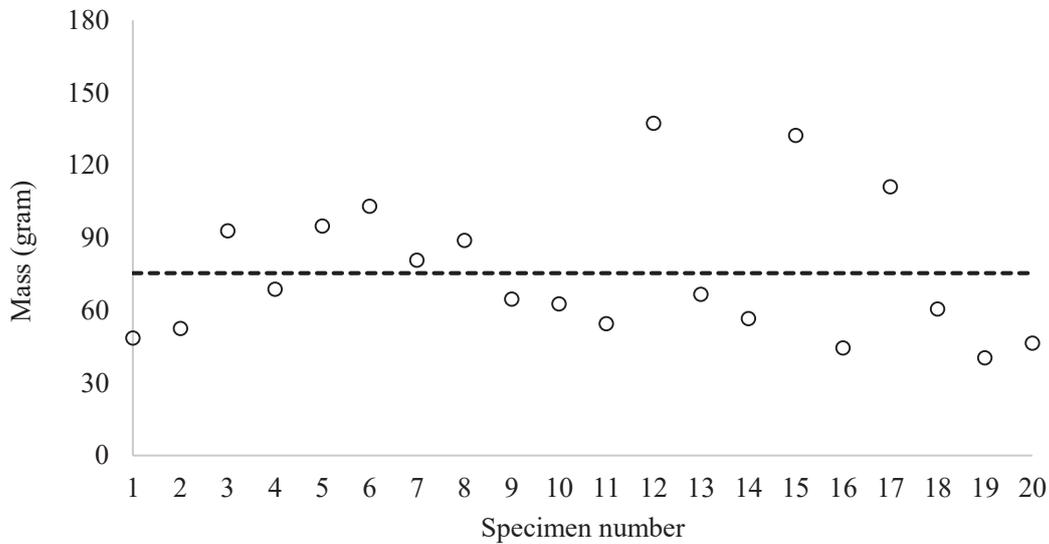


Figure 3 – Mass distribution of the twenty dry luffa cylindrica specimens

The interlocked fibers mesh of the luffa plant provides extra strength to the luffa composite structures as long as small samples are needed so that there is no need to cut the luffa cylindrica samples. However, the luffa plant needs to be cut in order to manufacture bigger specimens hence the continuity of the specimen is destroyed and a strength loss is inevitable in this case. It should be noted that the manufacturing process takes about 100-400 minutes for curing depending on the matrix type and and hardener ratio. Shortening this time by increasing the hardening rate is possible. However, the matrix will not be diffused homogeneously in this case.

3. THE VARIATIONS IN DYNAMIC PROPERTIES OF LUFFA COMPOSITES

Five luffa composite plates were manufactured using five different luffa cylindrica samples. The epoxy/luffa volume fraction of the composite plates is 0.65. The length and width of the plates are 200 and 100 mm, respectively. Their thickness and density are 5.3 ± 0.7 mm and 800 ± 60 kg/m³ as different luffa fiber plants were used to manufacture the luffa composite samples. Frequency response functions (FRFs) in the simulated free-free boundary conditions (i.e., hanging the test sample using a fishing line) are conducted by exciting the test samples by a modal hammer (Endevco 2302-10) and measuring the response to the excitation by an accelerometer (B&K 4507B). The measured FRFs were then analyzed and the modal parameters were identified by using the circle fit method (15, 16).

The natural frequencies of the first three modes of the luffa composite samples are plotted in Figure 4. The average natural frequencies and standard deviations are 229.3 ∓ 31.0 , 280.5 ∓ 38.3 and 619.5 ∓ 80.6 Hz for the first three modes of the five different luffa composite plates. The loss factors of the first three modes are plotted in Figure 5. The average loss factors and standard deviations are 3.6 ∓ 0.6 , 2.8 ∓ 0.6 and 2.6 ∓ 0.7 % for the first three modes of the five different luffa composite plates. It should be noted that the elasticity moduli of the samples are proportional to square of the modal frequencies (11). Therefore, the variations in the stiffness values of the luffa composites are much higher than the variations in the measured natural frequencies.

The results in Figures 4-5 show that the dynamic properties of Sample 1, 2 and 4 are quite close to each other while both the natural frequencies and damping levels of Sample 3 are quite different from the values of the other four samples. If the mechanical or dynamic properties of the luffa composites are desired to have small variations, it will be better here to exclude Sample 3 and 5 from the batch. The average natural frequencies and standard deviations are 205.5 ∓ 3.4 , 250.4 ∓ 7.0 and 557.4 ∓ 9.0 Hz for the first three modes of the luffa composite plates when Sample 3 and 5 are excluded. Similarly, the average loss factors and standard deviations are 3.2 ∓ 0.1 , 2.6 ∓ 0.1 and 2.2 ∓ 0.1 % for the first three modes of the luffa composite plates when Sample 3 and 5 are excluded.

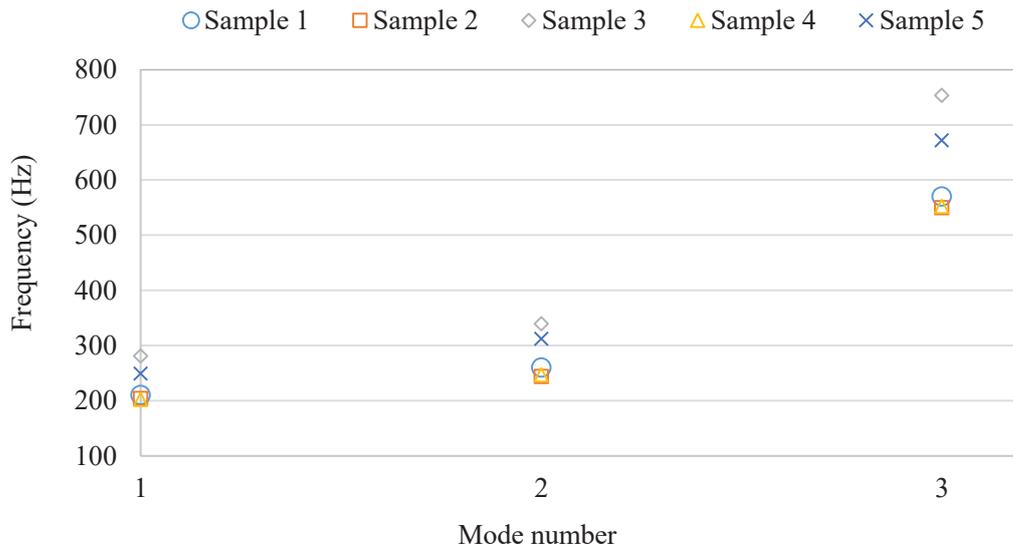


Figure 4 – Measured natural frequencies of the first three modes of the five different luffa composite plates

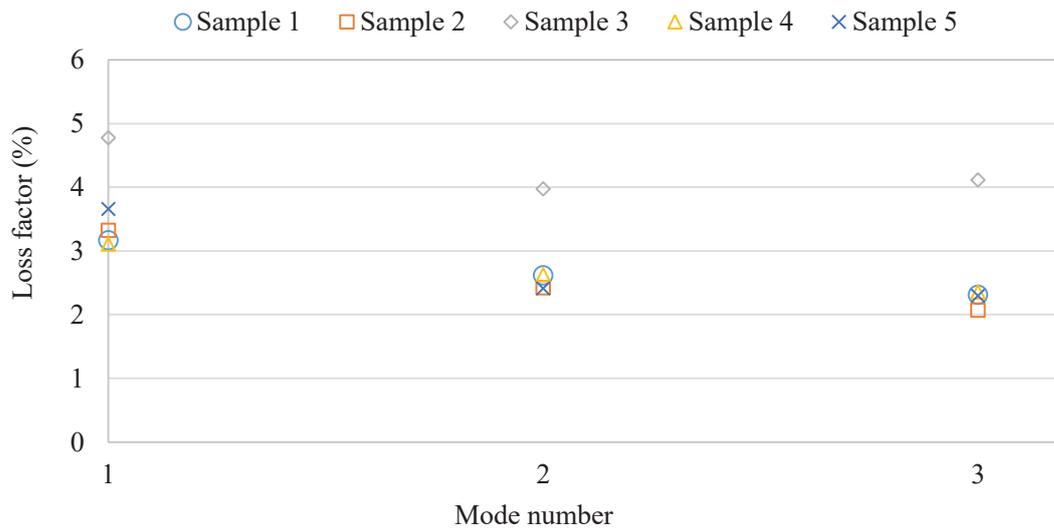


Figure 5 – Measured loss factors of the first three modes of the five different luffa composite plates

4. CONCLUSION

The major problems and restrictions in manufacturing process of the luffa reinforced composites and variations in the dynamic properties of luffa composite structures were explored and discussed in this study. First, the problems inherent to the nature of green fibers such as structural differences and defects in the luffa cylindrica samples were revealed. Then, modal frequencies and loss factors of some luffa composite plates and variations in these modal parameters were identified. It was seen that the deviations of the masses of randomly selected twenty luffa plants with approximately the same dimensions in a batch can be more than thirty-five percent. The deviations of the first three modal frequencies and loss factors of randomly selected the five luffa plants in a batch were identified to be less than fifteen and thirty percent, respectively. The results showed that the luffa composites can be produced with similar properties without any special selection of luffa cylindrica samples in order to homogenize the batch of fibers. However, a preliminary selection of raw samples is required if the mechanical properties of the luffa composites are desired to have small variations (e.g., less than five percent). It should be emphasized that, despite the difficulties in homogenizing the batch of luffa cylindrica samples for mass production and manufacturing the luffa composite structures, increasing the use of these green materials so as to minimize the use of chemical based composites is vital for environment.

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