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EVALUATION OF BUTIRI FIBERS ELASTICITY MODULUS WITH DIFFERENT DIAMETERS BY WEIBULL ANALYSIS[1]

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Abstract

Since environmental issues are becoming more and more important worldwide, Nowadays Natural fibers are been used to substitute the synthetic ones. Although Buriti fiber is an important natural fiber and its mechanical properties surpass in various aspects some other lignocelluloses fibers, such few studies have been conducted with the fiber obtained from buriti palm tree. In order to better evaluate the mechanical properties and possible applications, this paper aims to improve the elastic modulus of the buriti fiber by Weibull statistics, by evaluating their mechanicals properties and possible applications. The fibers were divided in diameter intervals and the tensile strength and elastic modulus were measured in each range. The fractured surface was examined using scanning electron microscopy. The results, interpreted by the Weibull statistical method, showed a correlation between the fiber elastic modulus and its diameter. An analysis by scanning electron microscopy indicated the possible reasons for this correlation.

Key words: Fiber buriti; Tensile test; Analysis of Weibull modulus of elasticity; SEM.

AVALIAÇÃO DO MÓDULO DE ELASTICIDADE DE FIBRAS DE BURITI COM DIFERENTES DIÂMETROS POR ANÁLISE DE WEIBULL

Resumo

Uma vez que questões ambientais são cada vez mais importantes em todo o mundo, as fibras naturais são atualmente usadas para substituir materiais sintéticos. Ainda não foram realizados muitos estudos sobre as propriedades das fibras retiradas do pecíolo da planta conhecida no Brasil como buriti. A fim de melhor avaliar as propriedades mecânicas e possíveis aplicações, este trabalho visa avaliar o módulo de elasticidade da fibra de buriti pelo método estatístico de Weibull, através da avaliação destas propriedades mecânicas será possível indicar melhores aplicações para esse tipo de fibra. O lote de avaliação das fibras foi dividido em intervalos de diâmetro para a obtenção da resistência à tração e módulo de elasticidade para cada intervalo. A superfície fraturada foi analisada por microscopia eletrônica de varredura. Os resultados, interpretados pelo método estatístico de Weibull, mostrou uma correlação entre o módulo de elasticidade das fibras e seu diâmetro. Uma análise por microscopia eletrônica de varredura indicou os possíveis motivos para essa correlação.

Palavras-chave: Fibra de buriti; Teste de tração; Analise de Weibull; MEV.

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1 INTRODUCTION

The use of natural fibers as reinforcement for polymeric materials as a substitute for synthetic fibers has increased over the last decade, especially glass fibers in composites, for different industrial sectors such as packaging, automobiles and even in the construction industry.[(1)] This is mainly due to its unique characteristics such as abundance, biodegradability, low density, non-toxic, less abrasiveness to processing equipment and useful mechanical properties, and yet it is worth emphasizing its low cost.

There is an attempt to use of natural fiber composites in place of glass fiber, mainly in nonstructural applications. Even a number of vehicle components (previously made from fiber glass composites) are now made of natural fiber composites.[(1-3)]

Composite materials such as carbon, Kevlar and glass fiber came to dominate the aerospace, construction, automotive and sports industries. Glass fibers are commonly used to reinforce plastics because of their low cost (as compared to Kevlar and carbon) and reasonably good mechanical properties. However, such fibers have serious drawbacks (Table 1), compared with natural fibers.

Table 1. Comparison between natural fibers and glass fibers[(1)]

Comparison of natural fibers and glass fibers		
	Natural Fibers	Glass fibers
Density	Baixo	Double of natural fibers
Cost	Low	Low, but higher than natural fibers
Renewable	Sim	No
Recyclabe	Yes	No
Energy Consumption	Low	High
CO2 neutral	Yes	No

The deficiencies have been heavily exploited by the defenders of natural fiber composites. Table 1 shows the advantages of natural fibers in comparison to glass fibers.[(1,4,5)] The none carbon dioxide production in natural fibers is particularly attractive. The burning of fossil derivatives releases large quantities of carbon dioxide to the atmosphere. This phenomenon is the main inductor greenhouse effect and world climate exchange.[(1,6,7)]

Thus the purpose of this paper is to analyze the elasticity modulus which is an important feature of the mechanical properties for the buriti fiber, after this study the fiber can be applied to composite materials. In these work will be used Weibull statistics methodology.

2 MATERIALS AND METHODS

Buriti fibers were extracted directly from the buriti palm tree stem. The stem were initially cut in the approximately dimension of 3 mm x 40 cm x 2 cm, these strips were dried at 60°C in oven for 24 hours.

After dried the stem was defibrillated into separated fibers, the fibers had an average diameter of approximately 0.5 mm in length. When the fibers were ready 100 were randomly taken from the lot for a statistical evaluation of its diameter.

These fibers were measured using a projector profile and a histogram obtained with the variation of diameter for these fibers (Figure 1). From these histograms obtained a mean diameter of 0.47 mm, it is noteworthy that the seven intervals in which the fibers were separated need to be studied separately in the evaluation of elasticity for the fiber buriti by Weibull statistics method.

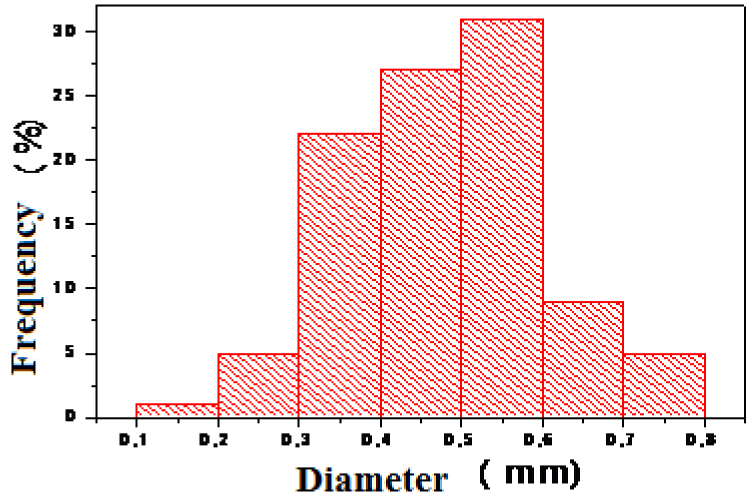

Figure 1. Diameter distribution of buriti fibers.

In the present work were carried out tensile tests on fiber buriti, and these results were obtained the elasticity modulus of buriti fibers, this parameter is very important for the feasibility of engineering projects.
Based on the seven intervals for the equivalent diameter showed in Figure 1, 140 fibers were analyzed, such that each interval contribute with 20 fibers for the corresponded analysis of equivalent diameter. All the buriti fibers were measured on profile projector, Nikon model 6C, to ensure the correct equivalent diameter, 10 repetition were made for each measurements fiber in different points of the fiber and then rotated 90°. The fibers were then tested individually in tension at a temperature of 25°C in a EMIC machine model DL10000.
In tensile tests were used to avoid sliding and damage in the fibers a special grid. The strain rate used was 4.2 x 10^{-4}m/s. With the values of tensile strength for the buriti fibers, the elasticity modulus were calculated and interpreted by Weibull method, using the computer program Weibull Analysis.
Some buriti fibers after break in tension, were analyzed by scanning electron microscopy in a Jeol microscope model JSM 6460 operating at 15 kV.

3 RESULTS AND DISCUSSION

Through the analysis of data obtained from tensile tests on Instron machine were built strength vs. strain curves for each interval of diameter on the buriti fiber.
Based on the results provided by tensile tests was calculated the elastic modulus for each fiber tested, using Equations 1 and 2 where, subsequently, these values were analyzed using Weibull statistics for the entire diameter range. By this method, there was obtained data shown in Table 2 for each range of equivalent diameter, as well as the parameters β, θ, R^2, modulus of elasticity and standard deviation.

$$\sigma = E\varepsilon \quad (1)$$

$$\sigma / \varepsilon = E \quad (2)$$

Where: σ is the Stress (MPa), the ε is the elastic deformation and the E ins the modulus of elasticity (MPa).

Table 2 shows the size effect of the buriti fiber diameter on the elasticity modulus. It is evident that all results in each diameter interval are unimodal with the same mechanical properties. As for the smallest fibers there is a large increase in value of the elasticity modulus, so we can assume that the lower the diameter the higher the elasticity modulus.

Table 2. Elasticity modulus of buriti fibers

Equivalent diameter interval (mm)	β	θ (GPa)	R^2	Averange Elasticity Modulus (GPa)	Standart Deviation (GPa)
0,10 – 0,20	3,98	26,78	0,888	24,27	6,83
0,20 – 0,30	5,79	26,83	0,951	24,84	4,98
0,30 – 0,40	6,43	23,49	0,843	21,88	3,97
0,40 – 0,50	7,54	19,76	0,906	18,55	2,91
0,50 – 0,60	6,06	15,91	0,881	14,44	2,83
0,60 – 0,70	6,45	14,79	0,936	13,77	2,51
0,70 – 0,80	7,77	15,25	0,893	14,34	2,19

With the values of the elasticity modulus shown in Table 2, we plot the graph with a linear correlation between the diameter intervals, Figure 2 and it average value in the Figure 3, this ratio shows an inverse relation between diameter and elastic modulus as observed in previous work with density.
The elasticity modulus value calculated for diameters between $0.1 < d < 0.2$ mm do not show a good statistical reliability, the possible causes for these kind of problem is the possible damage to the specimens caused by the fiber grip during the test, that show a impossibility to obtain values for the elasticity modulus in fibers thinners than 0.1 mm.
A hyperbolic equation fits the points to have an estimate of the elasticity modulus (E) for different diameters of the fibers buriti.

$$E = 4,864 / de + 7,674 \quad (3)$$

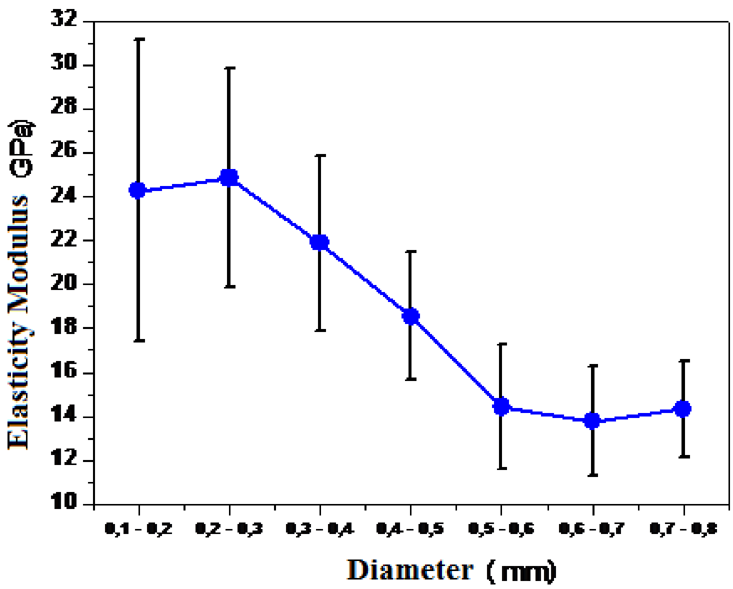

Figure 2. Elasticity modulus.

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In Table 2 it can be seen that values obtained for β are relatively high, which shows a good approximation to the parameter θ in relation to the average elastic modulus, and moreover, it show a low variance in its real value. Therefore, in order to make a better assessment of the possibility of a more favorable correlation, we compared the average elastic modulus and standard deviation with the elasticity modulus characteristic for each diameter interval.

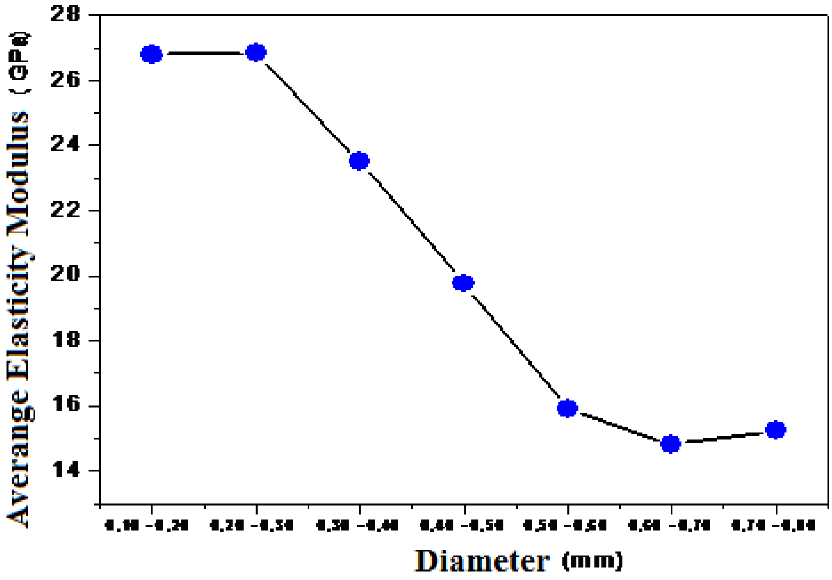

Figure 3. Average elasticity modulus.

Through this analysis it was observed that the stiffness of the buriti fiber is higher for a smaller diameters. By means of a hyperbolic equation[4] is obtained we conclusion that using the thinner buriti fibers is possible to create a more rigid material that could be applied in engineering applications.

$$\theta = 4.8626/de + 8.1792 \qquad (4)$$

According to literature the tensile modulus for lignocellulosic fibers varies from 10 Gpa to 80 Gpa. In this work the value of elasticity modulus calculated is (17.97 ± 3.23) GPa.[2]
Micrographs were made of the fracture surface of the fibers by SEM, in order to analyze the microstructural aspects of fracture (Figure 4).

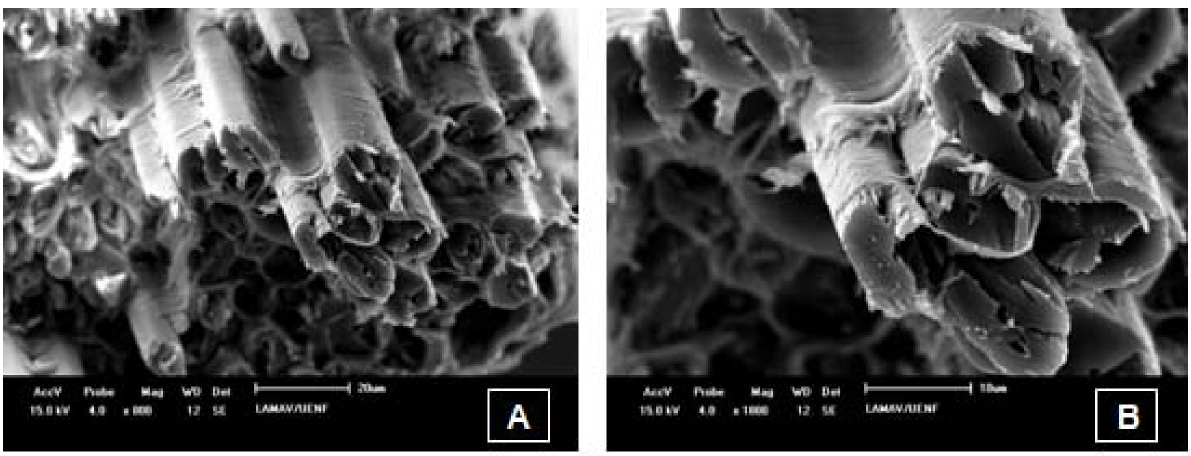

Figure 4. Fracture aspects of buriti fibers.

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Observing the fiber as a set of fibrils. The fibrils have different diameters, so resist differently to the same effort applied to the fiber, it is enough to know that each fibril breaks in different time of the test, depending on the stress applied to the fiber, and stretching that caused tension in the fibril. It can be concluded that the fiber does not break in a totally fragile way, so it can hold an amount of plastic deformation, this aspect is very important, since this may enable the use of composite materials for a wide range of applications.

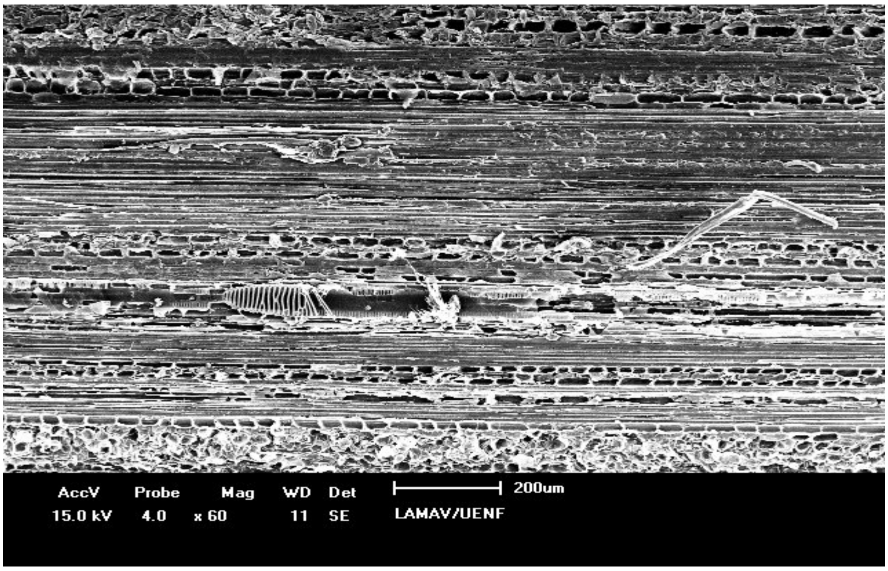

Figure 5. The side of the fiber micrograph.

In Figure 5, note that the amount of the fibers have pores, those pores are responsible for the decrease in the fibers stiffness. These pores are not only the side of the fiber, Figure 6 shows a micrograph of the top of the fiber and can be seen that each fibril is like a tube, surrounding a larger tube. This may be one reason for both the tensile strength and elasticity modulus grown with decreasing diameter.

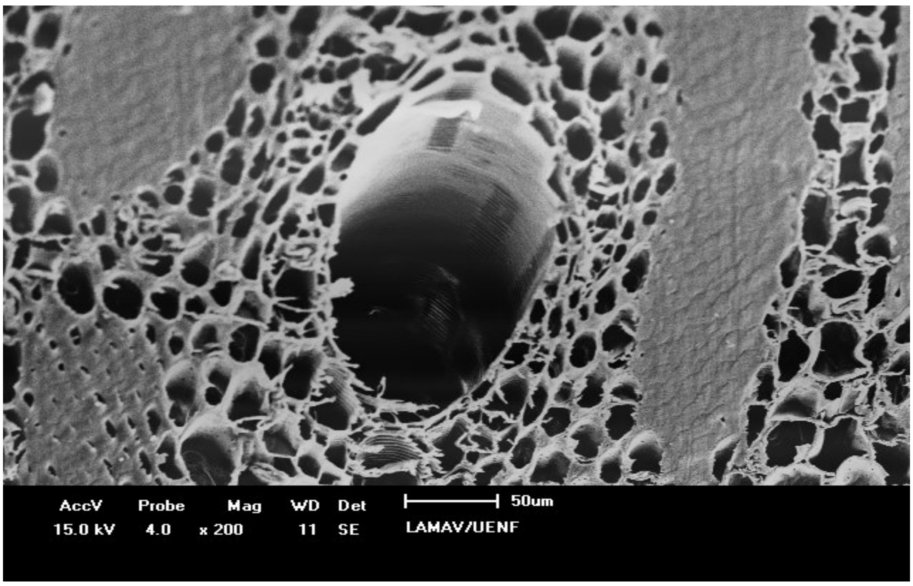

Figura 6. Top of the fiber micrograph.

4 CONCLUSIONS

- Analyzing the distribution of the buriti fiber diameter, found the average diameter of 0.47 mm, from 0.1 mm to 0.8 mm;
- using the Weibull statistical analysis method the elastic modulus obtained with tensile test fibers showed an inverse correlation with the diameter of the fibers;
- the characteristic correlation is adjusted to a hyperbolic equation for both Elasticity modulus and average elasticity modulus. The parameters β and R^2 and the standard deviations support this correlation;
- the results support the idea of selecting the smallest possible diameter of the buriti fibers will increase the performance of polymer composites reinforced with these fibers;
- through the micrograph it can be said that the smaller the diameter of the fiber the lower the volume of defects, and fewer voids exist between the fibrils, which also shows that the mechanical properties of the fiber tends to increase with decreasing diameter.

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