Analysis of the properties of piassava fiber and castor oil polyurethane for application in polymeric composite materials

Análise das propriedades da fibra de piassava e resina poliuretana de óleo de mamona para aplicação em materiais compósitos poliméricos

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ABSTRACT
This work aims to characterize the waste from a broom factory located in the city of Campos dos Goytacazes-RJ, Brazil. The company uses the natural fiber popularly known as "Piaçava Nova", from the south of Bahia, of the species *Attalea Funifera*

Martius. Fibers are used to make brooms that are sold in the city. A large amount of waste generated daily and rendered unusable when discarded irregularly in landfills. Approximately 10m³ of waste per month is created from this small factory. Therefore, this underutilized material can prove to be a quality raw material when used combined with natural resins for development of a polymeric composite floor be used in construction. In addition to the objective, this project sustains the responsibility of the academic society towards the environment, in order to minimize the use of synthetic fibers when there is possibility of using the natural ones.

Keywords: Piassava fiber, natural polyurethane resin, castor oil.

RESUMO
Este trabalho tem como objetivo caracterizar o resíduos de uma fábrica de vassouras localizada no município de Campos dos Goytacazes-RJ, Brasil. A empresa utiliza a fibra natural conhecida popularmente como "Piaçava Nova", do sul da Bahia, da espécie *Attalea Funifera Martius*. As fibras são usadas para fazer produtos que são vendidas na cidade. Grande quantidade de resíduos é gerada diariamente e inutilizaquando descartados irregularmente em aterros sanitários. Aproximadamente 10m³ de resíduos por mês são gerados nesta pequena fábrica. Portanto, esse material subutilizado pode se mostrar uma matéria-prima de qualidade quando utilizado em combinação com resinas naturais para o desenvolvimento de um pavimento de compósito polimérico a ser utilizado na construção. Além deste objetivo, este projeto sustenta a responsabilidade da sociedade acadêmica com o meio ambiente, de forma a minimizar o uso de fibras sintéticas quando houver possibilidade de utilização das naturais.

Palavras-chave: Fibra de piaçava, resina natural de poliuretano, óleo de mamona.

1 INTRODUCTION

Due to the growing concern with the environmental impacts caused by society, new environmentally friendly materials have been researched and developed. There are many works that report the difficulties of reusing waste or that demonstrate environmental concern with the use of materials of synthetic origin (DIAS; RAMOS; FLORENCIO, 2021; JUNIOR et al., 2021; LEITE et al., 2021; NASA, 2020).

In this context the Natural Lignocellulosic Fibers (NFLs), natural fibers extracted from cellulose-containing, appears like an option to substitute the more expensive, non-recyclable and energy-intense synthetic fibers in polymer composites. And also natural resin, are been developed using as base one of the component an oil from plant, for example: epoxy, polyester and polyurethane (AHMAD; FAN, 2018; KANEHASHI et al., 2014; NGUYEN; DELÉGLISE-LAGARDÈRE; PARK, 2015; ROSU et al., 2019; SAJEEB; BABU; ARIF, 2018; TSANAKTSIDIS et al., 2013).

The NFLs are abundant in our planet, biodegradable, recyclable and neutral with respect to carbon dioxide emission, associated with global warming and greenhouse effect (MOHANTY; MISRA; HINRICHSEN, 2000; NABI SAHEB; JOG, 1999). In fact, composites reinforced with traditional natural fibers such as piassava, coconut, sisal, jute, hemp, etc…are already on the market in substitution for common glass fiber automobile components (HILL, 1997; MARSH, 2003; WAMBUA; IVENS; VERPOEST, 2003). Technical aspects could also be in favor of the natural fibers that are softer and, consequently, less abrasive to processing equipment. Furthermore, for some NFLs, the mechanical properties can be superior to the corresponding one of glass fiber composites (MOHANTY; MISRA; HINRICHSEN, 2000; WAMBUA; IVENS; VERPOEST, 2003).

Therefore, the objective of this work was to investigate the properties and characteristics of raw materials that can be used for a new eco-friendly composites using both components as natural, the raw materials are: piassava fiber and natural polyurethane resin. The piassava fiber was analyzed her morphological and physical aspects, since they are a waste from a broom factory and the resin was investigated the ratio between the components to reach the best properties.

2 METHODOLOGY

For this work, the fiber density was determined by the pycnometry method comparing to the distilled water, which was carried out using a pycnometer and a digital scale with an accuracy of ± 0.001 g. The process images are shown in Figure 1.

Figure 1 – Density by pycnometery method.

To determine the piassava fiber density, the pycnometry technique was used by distilled water, using a digital scale with an accuracy of ± 0.001 g and a 50 ml pycnometer. The process consisted in initially weighing the empty pycnometer, then the mass of the pycnometer with water. Subsequently, the mass of the pycnometer / solid / distilled water was measured, thus obtaining the apparent density of the fiber in relation to the water. Before determination of the mass of the assembly, vacuum was applied for 2h in order to remove the existing bubbles.

The equations to calculate the piassava density (ds) as a function of the water density was given by Equations 1 and 2, where m1 is the mass of the empty pycnometer; m2 is the mass of the pycnometer with the fiber; m3 is mass of the pycnometer with fiber + water; m4 is mass of the pycnometer with water.

$$ds = \frac{\rho s}{\rho \text{ water}} = \frac{m2 - m1}{(m4 - m1) - (m3 - m2)} \qquad 1$$

$$\rho s = ds \,.\, \rho \text{ water} \qquad 2$$

The dimensional analysis for fiber characterization was performed by randomly removing 100 fibers and the diameter measurements were performed on a profile projector, Figure 2.

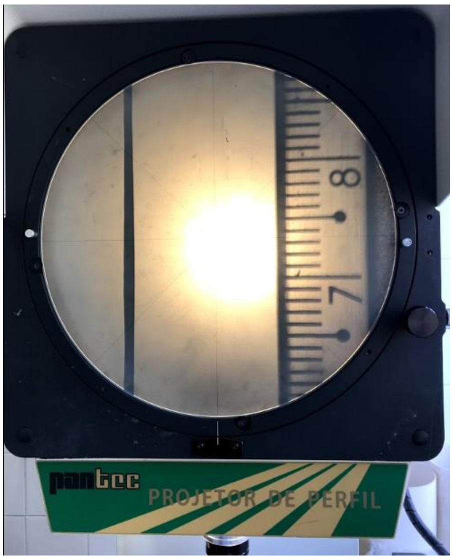

Figure 2 – Projector profile measuring a piassava fiber.

The piassava fibers were also analyzed the microstructural morphology by the Scanning Electron Microscopy (SEM) was used the Super Scan SSX model microscope, Shimadzu, available in LAMAV/UENF.

The natural polyurethane resin made from castor oil used it is a bicomponent (Component A + Component B) were kindly provided by Imperveg company and underwent a stoichiometric analysis in order to achieve an optimum ratio between the components.

3 RESULTS AND DISCUSSIONS

From the lot of piassava fiber was measured using the projector profile, their dimensions, such as: length, diameter and with these results was calculated the density and compared this density with the density made by pycnometery method that was found 1,42g/cm³.

First analyzing the length, Figure 3a, was identify that average length is a large peak varying from 21-27 cm, with this average is good to fabricate some composites pieces to be used at civil construction, for example.

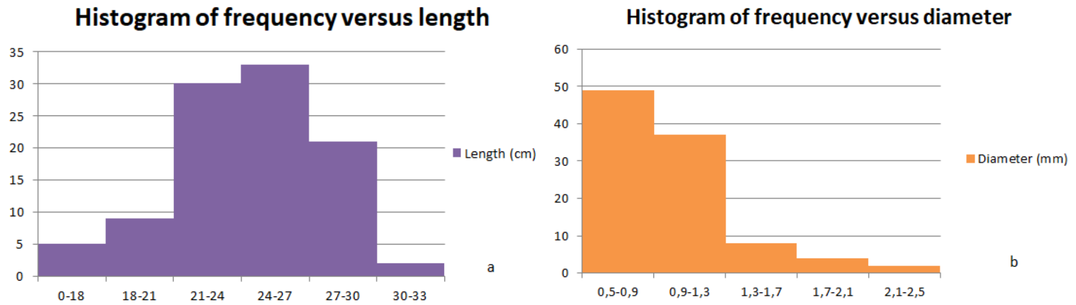

Figure 3 – (a) Histogram of frequency versus length; (b) Histogram of frequency versus diameter.

Now look into the dispersion of diameter frequency, Figure 3b, it is possible to identify that most of piassava fibers starts from 0,5 mm to 1,3 mm, after this range only few fibers were found. Comparing to others NFLs the piassava fiber is quite coarse, and as consequence the flexibility is limited, but still a good reinforcement for eco-friendly composites.

So, after these measurements by projector profile were calculated the density for each fiber from these lot of 100 piassava fibers. At Figure 4 looking the results is clear to identify the peak at range of 0,22 to 0,29 g/cm^3, totally different that was found using the pycnometery technique, 1,42 g/cm³, regarding both techniques they are not 100%

reliable; probably the pycnometery method shall be use inert gas and not distilled water because of porous fiber and the lumen existent in all NFLs. This test will be do as a next step to compare the results from this work.

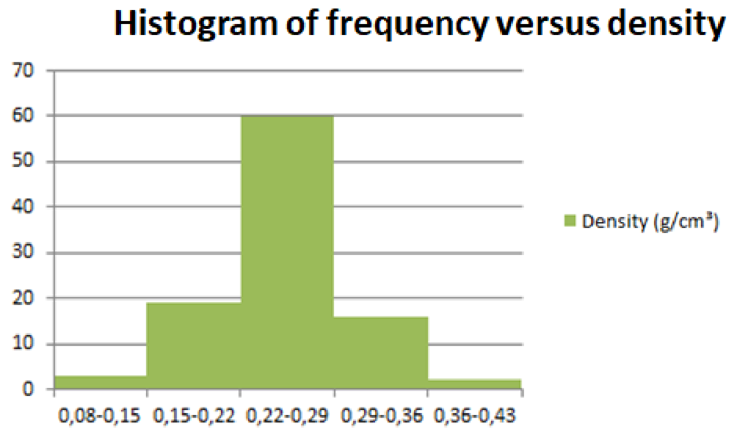

Figure 4 – Histogram of frequency versus density.

Figure 5 shows the topography of the piassava fiber by SEM. It is possible to observe that the piassava fiber has a characteristic with some spots with spiny balls attached at a concave hole, probable attached by a lignin or just hydrogen bridge. These spiny balls are pure silica, and these spiny balls are very good for polymeric composite, because these can be anchorage for the polymeric resins, especially polyurethane. Another observation of this specific piassava fiber, they already loose a lot of spiny balls from her structure, that means during the broom manufacture process the fiber suffer some damages in your microstructure, reinforcing that the spiny ball are attached by a weak hydrogen bridge.

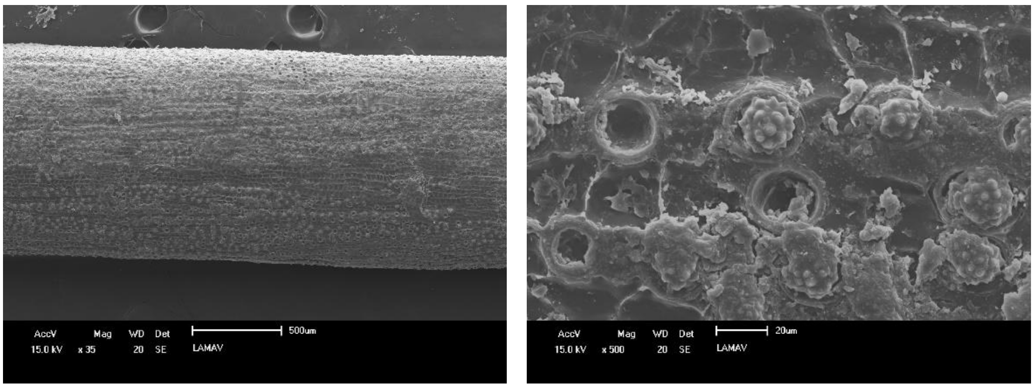

Figure 5 – Microstructure from piassava fiber.

At SEM was possible to measure these spiny ball and concave ball diameters; 22,1 and 23,1 μm respectively. These measurement is very good for the next step of this research that will be analyze the wettability of the natural polyurethane resin and identify the best attach point for the resin.

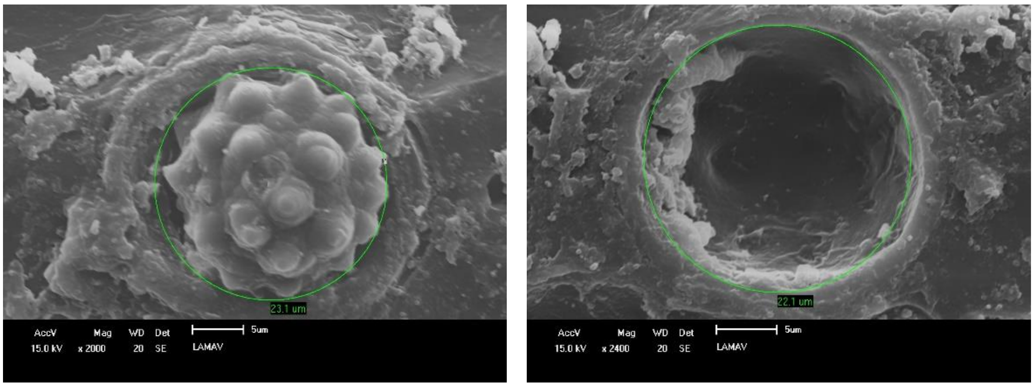

Figure 6 – Spiny ball and concave hole.

Regarding the natural polyurethane resin, since that manufacture Imperveg is not confident with ratio of the components of this new resin with a castor oil base, so, in theory as more poliol is used more "green" will be the resin, since that natural component is the poliol. So based on this were tested the ratios in weight, from 1:1,5 (manufacture indication) to 1:5,0; Figure 7.

Figure 7 – Polyurethane resins with different ratios after curing time.

From 1:1,5 to 1:1,75 it is possible to see that the gases generated during the curing process create some internal delamination at resins. The ratios from 1:1,8 to 1:2,5 were the best results, because of the absence of defects and the efficiency of the cure, since they are rigid. And from 1:2,5 to 1:5,0 the cure is not completed, so the crosslinking among the polymeric chains are impaired, because of the amount of poliol.

For next step is test the best range by mechanical testing and identified the best ratio to be used at new eco-friendly composite.

4 CONCLUSIONS

The average density of the fibers determined by the profile projector was 0,257 ± 0,05 g/cm³.

The density found done by picnometery technique using distilled water was 1,42 g/cm³.

The mean length of the residue was 24.38 ± 3.57 cm and its diameters were irregular, suggesting an oval shape.

Ideal range of stoichiometric ratio are 1:1.8 to 1:2,5 (A: B) with better stiffness and absence of crystals.

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