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Tensile mechanical properties, morphological aspects and chemical characterization of piassava (*Attalea funifera*) fibers

J.R.M. d'Almeida [a,*], R.C.M.P. Aquino [b], S.N. Monteiro [b]

[a] *Materials Science and Metallurgy Department, Pontifícia Universidade Católica do Rio de Janeiro, Rua Marquês de São Vicente, 225, Gávea – 22453-900, Rio de Janeiro, RJ, Brazil*

[b] *Science and Technology Center, Universidade Estadual do Norte Fluminense, Av. Alberto Lamego, 2000, Horto – 28015-820, Campos, RJ, Brazil*

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Abstract

The tensile mechanical properties of piassava fibers, as well as their chemical composition and morphological aspects, are reported. The values obtained showed that piassava has a mechanical behavior and chemical composition comparable to that of coir fibers. The difficulties related with a reliable way of measuring the true elastic modulus of these slender fibers are discussed and a simple correction of the experimental data is presented. As main characteristic surface features piassava fibers present a well arranged pattern of silicon rich star-like protrusions. Its chemical composition reveals that piassava are lignin rich fibers, 48.4 wt%. X-ray diffraction showed that cellulose I is their main crystalline constituent. Their thermal degradation begins at 225 °C, and the whole thermal degradation behavior of piassava fibers has many aspects, like the initial water loss and the content of residues, close to that shown by pure lignin.

Keywords: A. Piassava fibers; B. Mechanical properties; C. Elastic properties; D. Scanning electron microscopy

1. Introduction

Natural fiber reinforced composites have yet many challenges to overcome in order to become largely used as reliable engineering materials for structural elements. However, their use is steadily increasing and many large industrial corporations are planning to use, or have yet commencing to use, these materials in their products [1]. One of the great advantages of these composites is the large quantity of natural fibers available worldwide. Furthermore, as highlighted on many texts, e.g. [2], natural fibers are a biodegradable and renewable resource. Their softness is also an advantage in relationship to the common synthetic fibers, like glass fiber. Natural fibers are much less abrasive and, therefore, the manufacture of natural fiber composites has the benefit of less wear and deterioration of machine member parts.

Flax and hemp are the natural cellulosic fibers that attract the most attention in Europe [3]. On the other hand, jute, sisal, and to a lesser extent coir, are more extensively reported in the literature; see for example [4–9]. There are, however, many other less studied cellulosic fibers that are attractive, whether by their morphology, by their intrinsic properties or by their cost. *Luffa cylindrica* is one fine example of such fibers. Its fibers' natural mat like spatial arrangement provides a detouring path for cracks, and produces tougher composites [10]. Another of such less studied fibers is piassava (*Attalea funifera*).

An earlier study from our group has shown that it is a promising candidate as fiber reinforcement for resin matrix composites [11]. Therefore, in this work, the chemical composition, structural characteristics and tensile mechanical properties of piassava fibers are presented and its main features are highlighted and discussed. One has to point here, that although piassava has some characteristics common to

* Corresponding author. Tel.: +55 021 31141234; fax: +55 021 3114 1236.
E-mail address: dalmeida@dcmm.puc-rio.br (J.R.M. d'Almeida).

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other lignocellulosic fibers, their properties have not yet been fully described. And, in order to enable their reliable use in composites, the basic aspects of their structure and morphology, such as the lignin content and surface topographic features, and aspects related to their thermal behavior, such as the onset of thermal degradation, must be analyzed. This work aims to fulfill this gap of information about these traditional fibers.

2. Piassava (A. funifera)

Piassava is a stiff fiber extracted from the leaves of a palm tree of natural occurrence at the Brazilian Atlantic rain forest. The natural incidence range of the piassava palm tree is close to the coastal zone (up to 60 km inland) and it is mainly concentrated between 13°S and 17°S latitudes. Its grow is favored at regions with hot average temperature (24 °C) and high relative humidity (>80%). The fibers, up to 4 m long with an average width of 1.1 mm, are harvested once by year. The palm leaf is cut, and the fibers are mechanically separated from the petiole. Each palm tree can yield 8–10 kg of fibers. Fig. 1 shows typical cross-sections of piassava fibers, where one can see the usual variability of form and size common to all naturally occurring cellulosic fibers.

The production of piassava fibers is steadily increasing over the past years and, nowadays, it amounts to about 100,000 metric tons per year, as shown in Fig. 2 [12]. The main use of these fibers is for industrial and domestic brooms, industrial brushes, ropes and baskets, carpets and roofs. It is estimated that around 20% of the fiber production is disregarded by the transformation industries. These leftover fibers, that do not meet the requisites for the uses cited above, are, however, undamaged and long enough to be used as reinforcement in fiber composites [11].

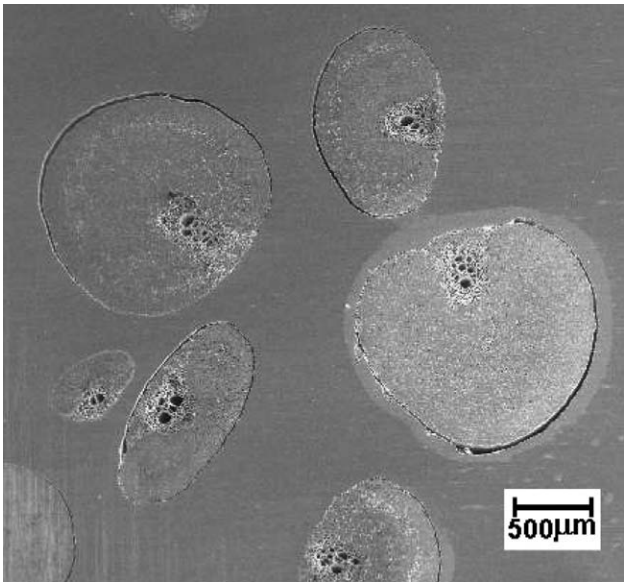

Fig. 1. Transversal cross-section of piassava fibers. Observe the variability of shape and size.

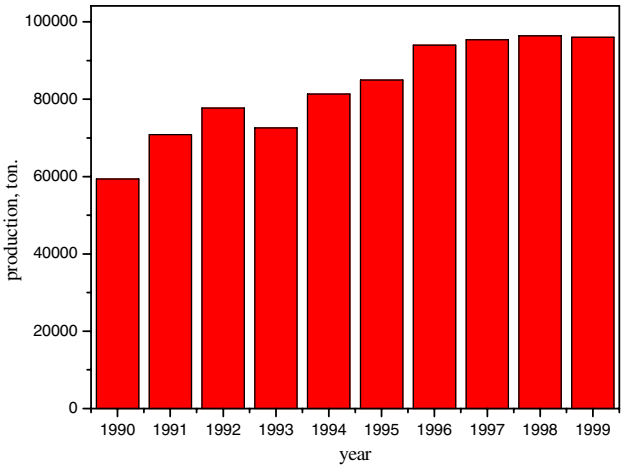

Fig. 2. Annual production of piassava fibers.

3. Experimental methods and materials

Piassava fibers disregarded by a broom industry were used in this work. Their tensile properties were evaluated following the procedures recommended by the ASTM standard D-2101. Since it is not possible to attach mechanically gripped extensometers to the single fibers under test, several gage lengths were used in order to measure the elastic compliance of the test apparatus and to correct for the true modulus of elasticity. The correction procedure used is outlined in Appendix A. The gage lengths used were: 150, 120, 80, 50, 25 and 15 mm. The tests were performed on a mechanically driven machine with 10 kN of capacity and equipped with pneumatic action grips. An optimum hold pressure of 0.3 MPa was experimentally found to give reliable test data. With this clamping pressure neither fiber slippage during tests nor fiber crushing at the grips were found to occur. The test speed used was 1 mm/min and 15 specimens were tested per gage length.

The morphological characterization of the fibers was done by scanning electron microscopy (SEM). The analysis was performed on gold sputtered samples using secondary electrons, and with a beam voltage of 15–20 kV. The composition of topographic features identified at the surface of the fibers was determined by energy dispersive X-rays spectrometry (EDS).

The thermal stability of the fibers was evaluated by thermogravimetric analysis (TGA). This experiment was conducted under nitrogen atmosphere, from ambient temperature (25 °C) to 400 °C at a heating rate of 10 °C/min.

The crystalline character and the chemical composition of the fibers were determined by X-rays diffraction and by the van Soest method, respectively. To perform the X-rays analysis a sample was calcinated at 400 °C by 2 h. This sample was then scanned from $2\theta = 5°$ to $2\theta = 125°$, with