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Characterization of physico-mechanical properties of natural Guaruma fiber (*Ischnosiphon arouma*) for reinforcement in biocomposites.

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Abstract

Materials science and engineering keeps its environmental trend with the constant development of new friendly or green composites. In this sense, the guaruma fiber (*Ischnosiphon arouma*) was evaluated, determining its mechanical, thermal and morphological properties. These results allow to validate its possible use as reinforcement in composite materials. The fibers tensile strength was tested with the help of adaptable clamps, showing a maximum value of 144MPa and an elasticity modulus of 2.43GPa. Thermogravimetric analysis (TGA) showed humidity percentages of 8.4% and a thermal stability limit of 208 ° C. Scanning electron microscopy (SEM) revealed variability in the lumen size and cell wall with a representative influence on mechanical resistance. The results allow to validate the elaboration of composites for applications in non-structural parts.

Keywords: Natural fibers, tensile strength, TGA, SEM.

I. INTRODUCTION

Natural fibers have gained strength as reinforcement in composite materials, thanks to their low density, abundance and mechanical properties [1]. The structural support of the fibers is provided by cellulose, lignin and hemicellulose microfibers, which is why they are known as lignocellulosic fibers [2] and they are responsible for their mechanical properties [3]. Their thermal, mechanical and structural properties have allowed them to venture into industries such as the automotive where they have displaced some conventional synthetic materials [4] in interior and semi-structural parts using thermoplastic or thermosetting materials as matrix [5].

Tensile strength and Young's modulus show large discrepancies in fibers, but due to their nature, their cross sections are variable and irregular. This generates distant values in the same fiber tested by two researchers, due to the conditions on which the tests were carried out where grip, speed, cell, and precision have an important role. [6].

The reinforcement mixture made with natural fibers and polymeric matrices is known as Natural Fibers-Reinforced Polymers (NFRP) [7] and its main impulse has been the preservation of the environment because they allow the creation of biodegradable structural components from renewable resources [8].

The automotive industry has increasingly used hemp, jute, flax and sisal fibers in the production of various components [9]. Other fibers evaluated for industrial purposes in the elaboration of compounds are kenaf, abaca, pineapple leaf, ramie, caraua [10]; sugar palm fiber (Arenga pinnata) [11], cissus [12], *Spartium junceum* [13], among others.

The country's biodiversity allows a great variety of natural fibers, most of which are currently used for handicrafts they were first used as raw material for the making of utensils to cover the basic needs of clothing, storage, packaging and shelter, appropriate for each culture in the region. [14]. Fibers such as fique, cotton, cañaflecha (*gynerium sagittatum*), esparto (*Spartium junceum)*, palma estera (*astrocaryum malybo*), iraca (*Carludovica palmata*), guerregue (*astrocaryum standleyanum*), guaruma (*ischnosiphon arouma*) among others are used to make a variety of decorative objects, backpacks, hats, hammocks, and rugs [15].

This paper seeks to determine the mechanical, thermal and morphological properties of the native fiber extracted from the guaruma plant. (*ischnosiphon arouma*). For the characterization, the thermal stability and moisture content were evaluated from the TG (weight loss / temperature) and DTG (speed of weight lost) / temperature) curves, its tensile strength and elastic modulus were determined under ASTM standards and using images acquired with scanning electron microscopy, its morphology was also observed. The properties obtained make it possible to determine its different fields of application after analyzing their viability for the elaboration of composites reinforced with this fiber.

II. EXPERIMENTAL PART

II.I Materials.

Guaruma fiber is also known by the name of huarumá and chocolatillo, the indigenous communities have names like*: jingurú nodtkai*, *Gá-hec-o*, *Bag-u*, *Baje*, *Bagiibe*, *po-pó-pana y bo-rru juatanoofua* [16]. It is found in the departments of Chocó, Cauca, Guaviare and Vaupés. Its main uses are the making of containers and rugs [15,17]. The fiber and a fabric can be seen in figure 1.

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Fig.1 FIBRES AND FABRIC OF GUARUMA [16]

II.II Methods

The tensile tests are carried out under the ASTM D3822/D3822M standard (Standard Test Method for Tensile Properties of Single Textile Fibers) on the Shimatzu universal machine with a 600 kNI capacity, using accessories for tensile tests on fibers at room temperature with a speed of 1mm/min.

Samples crushed between 5 and 10 mg are used for thermogravimetric analysis (TGA), they are then heated from room temperature to 600 ° C, with an increase of 10°C/min in an inert nitrogen atmosphere using a SDT Q600 model equipment from TA Instruments.

For Scanning Electron Microscopy (SEM) the samples were covered with a thin layer of gold improving conductivity. A JEOL brand microscope model JSM 6490-LV was used with a voltage of 30 kV and high vacuum insulation.

III RESULTS AND DISCUSSION

The maximum tensile strength, elasticity modulus, and deformation were determined using 20 replicas according to the ASTM standard. These properties influence the selection and application of parts made from fiber-reinforced composite materials. The results are shown in Table 1.

Table 1. Guaruma fiber mechanical properties.

Cross Section (mm^2)	Elastic modulus(GPa)	Tensile strength (MPa)	Strain (%)
0,5 x 1,5	2,43 ± 1,2	144,78 ± 52,3	37,24 ± 13,00

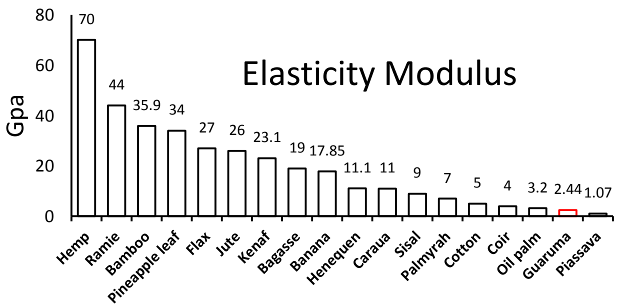

Fig.2 ELASTICITY MODULUS. GUARUMA VS SOME NATURAL FIBRES [17]

In figure 2, it is observed that the guaruma fiber's elasticity modulus is low, its behavior is similar to that of the piassava and oil palm fibers, while other fibers such as hemp, ramie, pineapple leaf and bamboo present much higher modules. That generate great rigidity in these fibers, on the contrary, guaruma fiber presents good flexibility.

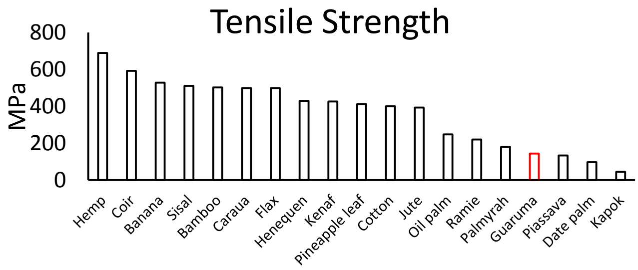

Fig.3 TENSILE STRENGTH. GUARUMA VS SOME NATURAL FIBRES [17]

The strength values obtained in the fiber place it between the palmyrah and piassava fiber as shown in figure 3. The maximum values obtained belong to the hemp, coir, banana, and bamboo fibers, this property is used in the elaboration of industrial composites with mainly jute, kenaf, sisal, flax and cotton fibers that widely surpass the studied fiber.

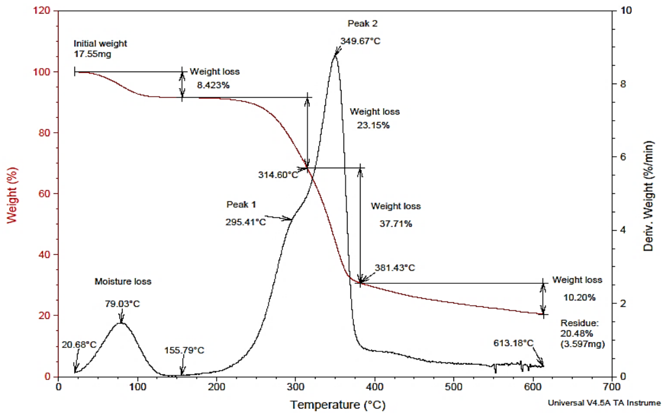

Fig.4 TGA/DTG GUARUMA NATURAL FIBER.

Figure 4 shows the TG and DTG curves for the guaruma fiber. The first mass loss of 8.4% corresponds to the evaporation of the retained humidity [18] with a velocity peak at 79 ° C. The DTG curve also shows two velocity peaks where the greatest loss occurs. These peaks at 295°C and 349°C are related to the initial phase of lignin pyrolysis [12], the depolymerization of hemicellulose, pectins, and glucoside, [19] as well as the decomposition of α-cellulose [20]. At 381°C, the final degradation of lignin and the oxidation of carbonized residues of the fiber occurs [21]. The limit of thermal stability is close to 208°C, a behavior similar to that of the majority of fibers whose degradation is above 200°C, as has been observed in bamboo (214°C), artichoke (230°C), bagasse (222°C) [22], okra (220°C), hemp (250°C), curauá (230°C), kenaf (219°C) and jute (205°C [23].

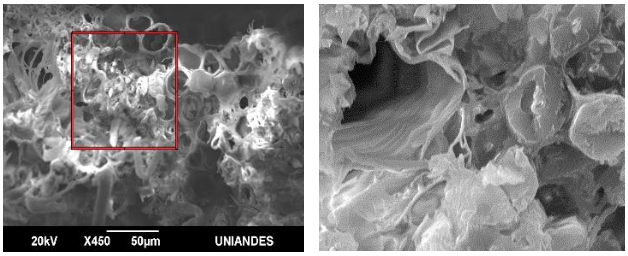

Fig.5 GUARUMA FIBER MORPHOLOGY (X450 AND X3000).

In Figure 5, cells with a wide lumen between 10 and 20 µm and others randomly distributed with a smaller size are observed with a cell wall between 3 and 5 µm and others around 1 to 2 µm. This distribution considerably affects its resistance, despite being a stem fiber with multiple continuous fibers. Similar morphologies with lumen and cell wall distribution variability were found in jute, sisal, curaua, coconut and piassava fibers [21], okra (*Abelmoschus esculentus*) [23], marshmallow (*Althaea officinalis L*) [24], betel nut shell (*Areca catechu*) [25], black-headed fiber (*manicaria saccifera*) [26], artichoke (*Cynara cardunculus L.*) [22] and sugar cane fiber [27], the most uniform distributions generally show the better mechanical resistance.

Although the mechanical properties of guaruma fiber are low compared to others, it has good thermal stability, which allows it to be used as reinforcement in matrices that do not exceed 200°C in its curing process. Therefore, it is feasible to manufacture composite materials reinforced with this type of fiber for use in ornamental-type components that are subjected to very low loads as a replacement alternative to conventional materials.

IV. CONCLUSION

The values obtained in the mechanical behavior are related to the resistance of cell walls and the union between them, the lack of uniformity in the cross section does not adequately distribute the force, leading to a rupture in the areas with lower strength.

The TGA corroborates the hydrophilic character of natural fibers which together with the limit of thermal stability allows to define which surface treatments can improve the interface with the polymeric matrix, which range of temperatures can be used to make the composite material, and the types of polymeric matrices.

SEM allowed visualizing the cross-sectional area of the fiber and evaluating the load distribution, its lack of uniformity considerably affects its mechanical properties these being lower than in other fibers with similar characteristics.

These properties make it possible to direct the industrial application of future composite materials reinforced with guaruma fibers to the elaboration of non-structural elements that are subjected to low loads.

REFERENCES

[1] Saba N., Jawaid M. Alothman O. y Paridah M. «A review on dynamic mechanical properties of natural fibre reinforced polymer composites.,» *Construction and Building Materials*, pp. 149-159, 2016. DOI:10.1016/j.conbuildmat.2015.12.075.

[2] Monteiro, Calado, Rodriguez y Margem., «Thermogravimetric behavior of natural fibers reinforced polymer composites—An overview,» *Materials Science & Engineering* A557, p. 17–28, 2012. DOI:10.1016/J.MSEA.2012.05.109

[3] Saravanakumara et al., «Characterization of a novel natural cellulosic fiber from Prosopis juliflora bark.,» *Carbohydrate polymers*, vol. 92, p. 1928–1933, 2013. DOI:10.1016/j.carbpol.2012.11.064.

[4] Ramesh M., Palanikumar K. y Hemachandra Reddy K. «Plant fibre based bio-composites: Sustainable and renewable green.,» *Renewable and Sustainable Energy Reviews*, vol. 79, pp. 558-584,, 2017.DOI: 10.1016/j.rser.2017.05.094.

[5] Barari B., Omrani E., Moghadam A., Menezes P., Pillai K. & Rohatgi P. «Mechanical, physical and tribological characterization of nano-cellulose fibers reinforced bio-epoxy composites: An attempt to fabricate and scale the 'Green' composite.,» *Carbohydrate Polymer*, vol. 147, pp. 282-293, 2016. DOI:10.1016/j.carbpol.2016.03.097.

[6] Fidelis,Castro, Gomez, Silva. «The effect of fiber morphology on the tensile strength of natural fibers.,» *Journal of Materials Research and Technology*, p. 149–157, 2013. DOI:10.1016/j.jmrt.2013.02.003.

[7] El-Shekeil Y. S. S. & Algrafi M., «Effect of Fiber Loading on Tensile Properties of Cocoa Pod Husk Fibers Reinforced Thermoplastic Polyurethane Composites,» *Applied Mechanics and Materials*, vol. 64, pp. 330-333., 2014. DOI 10.1016/j.matdes.2014.07.034.

[8] Dittenber D. B. & GangaRao H. V., «Critical review of recent publications on use of natural composites in infrastructure.,» *Composites: Part A*,43(8), pp. 1419-1429, 2012.DOI:10.1016/j.compositesa.2011.11.019.

[9] Faruk O., Bledzki K., Fink P. & Sain M., «Biocomposites reinforced with natural fibers: 2000–2010.,» *Progress in Polymer Science*, vol. 37, p. 1552–1596, 2012.DOI: 10.1016/j.progpolymsci.2012.04.003.

[10] Sanjay M., Madhu P., Jawaid M., Senthamaraikannan P. & Senthil S., «Characterization and properties of natural fiber polymer composites:A comprehensive review.,» *Journal of Cleaner Production*, pp. 566-581., 2018.DOI: 10.1016/j.jclepro.2017.10.101.

[11] Ishak M., Sapuan S., Leman Z., Rahman M., Anwar U. & Siregar J., «Sugar palm (Arenga pinnata): Its fibres, polymers and composites.,» Carbohydrate Polymers 91, p. 699– 710, 2013.DOI: 10.1016/j.carbpol.2012.07.073.

[12] Indran, Raj & Sreenivasan, «Characterization of new natural cellulosic fiber from Cissus quadrangularis root,» *Carbohydrate Polymers* 110, p. 423–429, 2014.DOI: 10.1016/j.carbpol.2014.04.051.

[13] Kovacevic, Bischof y Fan., «The influence of Spartium junceum L. fibres modified with montmorrilonite

nanoclay on the thermal properties of PLA biocomposites,» *Composites Part B* 78, pp. 122-130, 2015.DOI: 10.1016/j.compositesb.2015.02.034.

[14] Artesanias de Colombia, «Artesanias de Colombia/portal AC.,» 5 abril 2011. [En línea]. Available:http://www.artesaniasdecolombia.com.co/PortalAC/C_noticias/artesanias-de-colombia-realiza-capacitacion-a-indigenas-wounaan_1212.

[15] Quiñonez Aguilar C. «El tejido de las tribus indígenas de Colombia.» Instituto Colombiano de cultura Hispanica. Biblioteca Luis Angel Arango, Bogotá. Colombia, 2000.

[16] Torres Avendaño E. A. «Cartilla de elaboración de artesanías en chocolatillo (Ischnosiphon arouma) y tetera (Stromanthe jacquinii) por la comunidad Eperara Siapidara, resguardo indígena Joaquincito, río Naya, Valle del Cauca.,» Corporación Autónoma Regional del Valle del Cauca – CVC, Fundación Zoológica de Cali y Resguardo Indígena de Joaquincito., Cali. Valle del Cauca, 2009.

[17] Artesanias de Colombia S.A. CENDAR, «El chocolatillo.,» Artesanias de Colombia S.A. CENDAR, junio 2010. [En línea]. Available: http://www.artesaniasdecolombia.com.co/PortalAC/C_sector/chocolatillo_185.

[18] Miranda, Bica, Nachtigall, Rehman & Rosa, «Kinetical thermal degradation study of maize straw and soybean hull celluloses by simultaneous DSC–TGA and MDSC techniques,» *Thermochimica Acta* 565, p. 65– 71, 2013. DOI:10.1016/j.tca.2013.04.012.

[19] Moriana, Vilaplanaa, Karlssona y Ribes, «Correlation of chemical, structural and thermal properties of natural fibres for their sustainable exploitation.,» *Carbohydrate Polymers* 112, p. 422–431, 2014. DOI:10.1016/j.carbpol.2014.06.009.

[20] Fiore A., Scalici, V. y Valenza, T. «Characterization of a new natural fiber from Arundo donax L. as potential reinforcement of polymer composites.,» C*arbohydrate polymers*, pp. 77-83, 2014. DOI:10.1016/j.carbpol.2014.02.016

[21] Das S., Saha A., Choudhury P., Basak R., Mitra B., T. Todd T., Lang S. y Rowell R. «Effect of steam pretreatment of jute fiber on dimensional stability of jute composite.,» *Journal of Applied Polymer Science* 76, p. 1652–1661, 2000. DOI:10.1002/(SICI)1097-4628(20000613)76:11<1652::AID-APP6>3.0.CO;2-X.

[22] Fiore, A., Valenza, V. & Di Bella G., «Artichoke (Cynara cardunculus L.) fibres as potential reinforcement of composite structures,» *Composites Science and Technology* 71, p. 1138–1144, 2011.

[23] DeRosa, Kenny, Puglia, Santulli y Sarasini, «Effect of chemical treatments on the mechanical and thermal behaviour of okra (Abelmoschus esculentus) fibres,» *Composites Science and Technology* 71, p. 246–254, 2011. DOI:10.1016/j.compscitech.2011.04.003.

[24] Sarikanat Mehmet, Seki Yoldas,Sever Kutlay & Durmuskahya Cenk, «Determination of properties of Althaea officinalis L. (Marshmallow) fibres as a potential plant fibre in polymeric composite materials.,» *Composites: Part B* 57, p. 180–186, 2014.DOI: 10.1016/j.compositesb.2013.09.041.

[25] Yusriah L. Sapuan S.M. Zainudin E.S & M. Mariatti, «Characterization of physical, mechanical, thermal and morphological properties of agro-waste betel nut (Areca catechu) husk fibre,» *Journal of Cleaner Production* 72, pp. 174-180, 2014. DOI:10.1016/j.jclepro.2014.02.025.

[26] Porras A. Maranon A. & Ashcroft I.A, «Thermo-mechanical characterization of Manicaria Saccifera natural fabric reinforced poly-lactic acid composite lamina,» *Composites: Part A* 81, p. 105–110, 2016.DOI: 10.1016/j.compositesa.2015.11.008.

[27] Mohammad K., Hossain; Mohammad R., Karim; Mahmudur R., Chowdhury; Muhammad A., Imam; Mahesh, Hosur; Shaik, Jeelani; Ramsis, Farag;, «Comparative mechanical and thermal study of chemically treated and untreated single sugarcane fiber bundle,» *Industrial Crops and* Products 58, p. 78–90, 2014.DOI: 10.1016/j.indcrop.2014.04.002.