RGSA – Revista de Gestão Social e Ambiental
ISSN: 1981-982X
Submission date: 04/15/2024
Acceptance date: 06/14/2024
DOI: https://doi.org/10.24857/rgsa.v18n5-182
Organization: Interinstitutional Scientific Committee
Chief Editor: Éverton Hillig
Assessment: Double Blind Review pelo SEER/OJS

POLYESTER AND *HYMENAEA COURBARIL* RESIDUE FOR SUSTAINABLE COMPOSITE MANUFACTURING

Pedro Victor de Mendonça Maia [1]
Roberto Yuri Costa Dias [2]
Rafael Vilhena Soares [3]
Alian Gomes da Silva de Mendonça [4]
Samuel de Castro Silva [5]
Roberto Tetsuo Fujiyama [6]

ABSTRACT

Objective: To evaluate the mechanical behavior of polymer composites reinforced by wood residue known as Játobá (*Hymenaea Courbaril*), in powder form. It aims to reduce impacts to the environment through the use of waste.

Theoretical Framework: Composites are generated from the union of materials, aiming to obtain specific properties arising from their components. Usually these are divided into two phases, matrix. The possibility of using materials less harmful to the environment in composite has gained prominence in research in the area.

Method: To obtain the properties of the composites, standardized specimens were manufactured according to ASTM D638. The matrix selected was terephthalic polyester resin and the reinforcement was Játobá wood residue, in the form of powder. The results were obtained by tensile strength tests.

Results and Discussion: The average value of tensile strength obtained was 11.76 (±1.70) MPa. The comparison of the results of this study with other literature revealed the superiority of the tensile strength of the composite of the present work in relation to others with different reinforcements of wood residues.

Research Implications: The use of wood waste in composites is beneficial for reducing the irregular disposal of matter in the environment. Also, it aims to generate added value to a useless material.

Originality/Value: The use of natural and renewable materials as reinforcement in composites is of great relevance, aiming to reduce the use of synthetic raw material. In addition, there is the manufacture of composites of low cost and weight and feasibility of manufacture.

Keywords: Composites, Wood Waste, Jatobá, Mechanical Behavior.

POLIÉSTER E RESÍDUO DE *HYMENAEA COURBARIL* PARA FABRICAÇÃO COMPÓSITO SUSTENTÁVEL

[1] Universidade Federal do Pará, Belém, Pará, Brasil. E-mail: eng.pedromendonca@hotmail.com
Orcid: https://orcid.org/0009-0004-7723-4312
[2] Universidade Federal do Pará, Belém, Pará, Brasil. E-mail: yuricostad@gmail.com
Orcid: https://orcid.org/0009-0008-6386-2667
[3] Universidade Federal do Pará, Belém, Pará, Brasil. E-mail: vilhenarafael007@gmail.com
Orcid: https://orcid.org/0009-0003-8321-2665
[4] Universidade Federal do Pará, Belém, Pará, Brasil. E-mail: alian_silva@hotmail.com
Orcid: https://orcid.org/0009-0005-6324-1631
[5] Universidade Federal do Pará, Belém, Pará, Brasil. E-mail: samuelcastro.ufpa@gmail.com
Orcid: https://orcid.org/0009-0000-0158-8553
[6] Universidade Federal do Pará, Belém, Pará, Brasil. E-mail: fujiyama.ufpa@gmail.com
Orcid: https://orcid.org/0000-0002-2738-6666

RESUMO

Objetivo: Avaliar o comportamento mecânico de compósitos polimérico reforçado por resíduo de madeira conhecida como Játobá (*Hymenaea Courbaril*), na forma de pó. Visa-se redução de impactos ao meio ambiente por meio do aproveitamento do resíduo.

Referencial Teórico: Compósitos são gerados a partir da união de materiais, visando obter propriedades específicas advindas de seus componentes. Geralmente estes são divididos em duas fases, matriz. A possibilidade de utilização de materiais menos danosos ao meio ambiente em compósito tem ganhado destaque em pesquisas na área.

Método: Para a obtenção das propriedades dos compósitos foram fabricados corpos de prova padronizados de acordo com a norma ASTM D638. A matriz selecionada foi resina poliéster tereftálica e o reforço foi de resíduo de madeira Játobá, na forma de pó. Os resultados foram obtidos por meio de testes de resistência à tração.

Resultados e Discussão: O valor médio de resistência à tração obtido foi de 11,76 (± 1,70) MPa. A comparação dos resultados deste estudo com outras literaturas revelou a superioridade da resistência a tração do compósito do presente trabalho em relação a outros com diferentes reforços de resíduos de madeira.

Implicações da Pesquisa: O aproveitamento de resíduos de madeira em compósitos é benéfico visando a redução do descarte irregular da matéria no meio ambiente. Também, almeja-se gerar valor agregado a um material sem utilidade.

Originalidade/Valor: A utilização de materiais naturais e renováveis como reforço em compósitos é de grande relevância, visando reduzir a utilização de matéria-prima sintética. Além disso, tem-se a confecção de compósitos de baixos custo e peso e viabilidade de fabricação.

Palavras-chave: Compósitos, Resíduo de Madeira, Jatobá, Comportamento Mecânico.

POLIÉSTER Y RESIDUOS DE *HYMENAEA COURBARIL* PARA FABRICACIÓN COMPUESTA SOSTENIBLE

RESUMEN

Objetivo: Evaluar el comportamiento mecánico de compuestos poliméricos reforzados con residuos de madera conocida como Játobá (*Hymenaea Courbaril*), en forma de polvo. Se pretende reducir los impactos al medio ambiente mediante el aprovechamiento del residuo.

Marco Teórico: Los compuestos son generados a partir de la unión de materiales, buscando obtener propiedades específicas advindas de sus componentes. Por lo general, estos se dividen en dos fases, matriz. La posibilidad de utilizar materiales menos dañinos para el medio ambiente en composite ha ganado destaque en investigaciones en el área.

Método: Para la obtención de las propiedades de los compuestos se fabricaron cuerpos de prueba estandarizados de acuerdo con la norma ASTM D638. La matriz seleccionada fue resina poliéster tereftálica y el refuerzo fue de residuo de madera Játobá, en forma de polvo. Los resultados se obtuvieron mediante pruebas de resistencia a la tracción.

Resultados y Discusión: El valor promedio de resistencia a la tracción obtenido fue de 11,76 (± 1,70) MPa. La comparación de los resultados de este estudio con otras literaturas reveló la superioridad de la resistencia a tracción del compuesto del presente trabajo en relación a otros con diferentes refuerzos de residuos de madera.

Implicaciones de la investigación: El aprovechamiento de residuos de madera en compuestos es beneficioso visando la reducción del descarte irregular de la materia en el medio ambiente. También, se pretende generar valor agregado a un material sin utilidad.

Originalidad/Valor: El uso de materiales naturales y renovables como refuerzo en compuestos es de gran importancia, con el fin de reducir el uso de materia prima sintética. Además, se tiene la confección de compuestos de bajo costo y peso y viabilidad de fabricación.

Palabras clave: Compuestos, Residuo de Madera, Jatoba, Comportamiento Mecánico.

RGSA adota a Licença de Atribuição CC BY do Creative Commons (https://creativecommons.org/licenses/by/4.0/).

1 INTRODUCTION

Currently, it appears that the great demand for new technologies related to the exacerbated consumption of natural resources has caused some environmental problems that are perceived throughout the world, such as the accumulation of various types of waste in the environment. This circumstance culminated in the intensification of ecological and preservationist debates, including environmental conferences being held in several countries. Therefore, the ideal of sustainability has acted as the basis for countless works and research, including in the area of engineering.

Based on this idea, the development of numerous studies on composites can be observed. These materials can be defined as multiphase materials, generally arranged in two phases, one called matrix and the other reinforcement, the properties of the resulting material are derived from the phases that it consists of. In this sense, efficient composites present good adhesion between the matrix and reinforcement interfaces (Callister & Rethwisch , 2018).

Returning to the ecological principle, there is an area of research focused on natural composites, that is, those that are manufactured using renewable raw materials, among the most used, natural fibers stand out, widely used as reinforcement in composite materials. In the automotive sector, work has been developed with the aim of using renewable raw materials in the manufacture of vehicle components, due to the abundance of such materials and the lower manufacturing costs, such an initiative is viable (Lima *et al.*, 2013; Rodrigues & Fujiyama, 2010; da Costa *et al.*, 2012).

Given this, natural fibers have great potential due to factors such as: biodegradability, abundance and high performance associated with low cost (Kotik , 2019; Branco *et al* ., 2016). In addition to the use of natural fibers, another renewable raw material is used, wood waste from wood industry processes, seeking an alternative reuse for materials that, in principle, would be discarded (da Costa *et al.*, 2024) .

Wood is one of the most important resources today, some factors that make it so valuable

are the fact that it is a renewable resource and presents a certain versatility, it has numerous applications, such as structural material in the construction industry, furniture industry, or raw material for the chemical industry. It is found that the decomposition of wood residues in the open can result in the spread of methane, a gas that promotes the intensification of the greenhouse effect (Pereira *et al* ., 2011).

Therefore, wood is extremely important when it comes to the use of these resources in the field of engineering, especially in the manufacture of composites. The matrix phase also has great importance in the constitution of the composite, in protection against chemical agents and in the distribution of stresses arising from mechanical stress. In this sense, these materials can be developed with wood particles and polymer matrix. When it comes to the matrix, polymers can be thermoset or thermoplastic and biodegradable or non-biodegradable (Khan, 2020). Polymeric matrices are commonly used in composites reinforced by natural fibers, however it is possible to mention the manufacture of cementitious ceramic matrices reinforced by natural fibers (Teixeira *et al* ., 2022; Fujiyama *et al* ., 2014).

There is growing interest among researchers and the wood industry in developing ways to reuse waste. Thus, providing an economic return for the company, which eventually does not use a considerable amount of waste, in addition to resulting in a reduction in the matter deposited in the environment (Zoch , 2013). There are some ways in which discarded wood residue can be found, below Figure 1 illustrates the main ones.

Figure 1

Main types of wood waste found



Source: Adapted from Wildner , MV Reuse of waste from the furniture industry for application in new furniture products. 2015. Course Completion Work (Bachelor of Design), 2015.

There are some works that address and display results on the manufacture of composites using different types of wood waste and different species, some also associated with natural fibers. Lopes *et al* . (2013) promoted research involving polyester matrix composites reinforced with wood residues of different morphologies, the type of wood used was Angelim Pedra, having obtained the best result after tensile testing for a sample sieved above 150 microns and having a mass fraction of 6.86%, the maximum stress value was 24.10 MPa.

Santos *et al* . (2018) obtained property results for the use of waste from Maracatiara , Marupá and Angelim stone, in the form of shavings, from the wood cutting process, from the manufacture of Polyester/Wood Waste composites. The following results were achieved for the types of wood mentioned, respectively: 9.17 MPa, 9.43 MPa and 8.81 MPa.

When it comes to the use of wood waste together with natural fibers, there are results for a hybrid composite of sisal fibers of varying lengths and angelim stone. The best tensile strength value obtained through tests was 19.19 MPa for a proportion of 25% fiber and 75% residue, a value that was higher than that of 50% and 25% residue (Santos *et al* . , 2013).

Jatobá wood waste has also been used to prepare scientific work. Reis *et al* . (2016) produced a hybrid composite analysis, in addition to the aforementioned waste, jute fabrics were added to compose the reinforcement, obtaining an average value of 40.66 MPa.

Therefore, the present study aims to manufacture polymer matrix composite materials reinforced with Jatobá wood residue, (*Hymenaea Courbaril*), in powder form, envisioning the reuse of materials that would initially be discarded, seeking to reduce impacts on the environment. To obtain mechanical properties, with emphasis on the tensile strength limit, standardized test specimens were manufactured, which were subjected to mechanical tests, thus enabling feasibility, mechanical efficiency of the material and effectiveness of the manufacturing method to be assessed.

2 MATERIALS AND METHODS

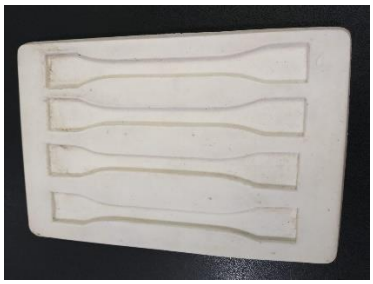
The Jatobá wood residue was obtained by the Composite Materials Laboratory (LABCOM) of the Federal University of Pará (UFPA) in powder form. Once we had the raw material, with the aim of standardizing the composition of the samples produced, a sieving process was carried out using a particle size analysis sieve with mesh 14, equivalent opening of 1.4 mm, as shown in Figure 2 (a). Subsequently, a silicone mold, such as the one identified in Figure 2 (b), with four gaps standardized by the ASTM D638 standard were filled with the objective of quantifying the amount of material needed to fill the mold, totaling 7.9 g, using the

precision balance illustrated by Figure 2 (c).

Figure 2

(a) Granulometric sieve (b) Silicone mold (c) Precision balance with residue







(The) (B) (w)

unsaturated and pre -accelerated terephthalic polyester resin , and to accelerate the process and curing, that is, the solidification of the material, the MEK V388 catalyst was used. The components mentioned are shown in Figure 3 (a), the proportion used was 0.3 g of catalyst for 61.5 g of resin, after which the mold was cast. The specimens were subjected to post-curing in an oven, at a temperature of approximately 60ºC and were then ready to be tested, these are visualized in Figure 3 (b).

Furthermore, in order to avoid slipping in the machine gripper during the process and to facilitate the test, the test specimens had the region known as “ tab ” sanded, shown in Figure 3 (c). For the last stage, the tensile strength test took place, using a universal testing machine in accordance with the ASTM D638 standard, the speed test parameter of 5 mm/min.

Figure 3

(a) Polyester resin and MEK catalyst (b) Cured specimens (c) Tensile test







(The) (B) (w)

3 RESULTS AND DISCUSSIONS

After the tensile strength test, the machine software provides property results, as shown

in Table 1, with emphasis on the maximum tension, obtained by the relationship of Force (N) per Area (mm ^{2}), resulting in the quantity Megapascal (MPa), related to tension. The standard deviation was not high, demonstrating the reproducibility of the process. Figure 4 shows one of the test bodies after the procedure carried out, the sandpaper in the "tab" region was fixed in order to avoid slipping on the machine claw during the process.

Figure 4

Fractured specimen



Table 1

Data obtained from tensile strength test

JATOBÁ	MAX FORCE (N)	MAX VOLTAGE (MPa)	DEFORMATION (mm/mm)	MODULE (MPa)
CP 1	452.33	9.71	0.035	427.74
CP 2	532.05	13.02	0.039	505.35
CP 3	429.94	11.01	0.027	514.11
CP 4	537.56	13.28	0.035	475.8
AVERAGE	487.97 (± 54.89)	11.76 (± 1.70)	0.034 (± 0.005)	480.75 (± 38.96)

CP = Test Body

It is observed that both the average maximum stress value and the individual results for each test specimen were higher than those obtained by Santos *et al* . (2018), using other types of wood waste: Maracatiara, Marupá and Angelim Pedra, with test specimen 4 presenting the highest value among the 4, 13.28 Mpa. All higher than the average values of 9.17 MPa, 9.43 MPa and 8.81 MPa for the respective species.

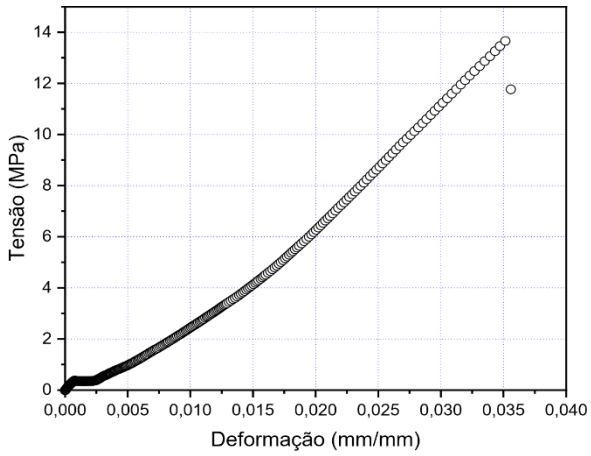
When compared to the hybrids in the studies by Lopes *et al* . (2013) and Santos *et al* . (2013) the values obtained by the test were exceeded, verifying that the presence of other reinforcement elements, that is, natural fibers can provide an increase in mechanical resistance

and, consequently, an increase in the maximum tension value, since the values of 24.10 MPa and 19.19 MPa, verified by the authors, respectively, were higher compared to those exposed in the present work.

Therefore, the result of Reis *et al* . (2016) was considerably higher than those exposed in this article. The presence of a natural blanket, in this case, jute, is understood as a considerable increase in mechanical resistance, as occurred with natural fibers, verifying that these components can act together to promote appreciable properties. Figure 5 shows the graphic behavior of the Stress x Strain curve of the manufactured composite.

Figure 5

Stress x Deformation characteristic curve of the polyester composite reinforced by Jatobá wood waste



The curve shows that in the initial part of the test, a non-fully linear region is observed, which indicates the adjustment characteristic of the polymeric phase and accommodation of the wood residue, after which the composite material begins to resist the loading force. Furthermore, in the manufacturing process, possible problems that could interfere with the results obtained are evaluated. Firstly, because it is an entirely manual process, there is susceptibility to errors, which means superficial flaws can be observed in the test specimens. Known as voids, these can act as stress concentrators and promote early failure of the material in specific regions, that is, reducing its mechanical resistance.

4 CONCLUSION

The present research aimed to evaluate the tensile strength of a polymer composite reinforced with wood waste, as a sustainable alternative for a material that does not have wide applications . In this sense, the objective is to promote the reduction of the use of synthetic materials and the reuse of waste.

Analyzing the values obtained by the test, these are considered to be appreciable, in view of the comparisons made with other authors, this circumstance is optimistic due to the fact that it strengthens the possibility of an alternative destination for wood waste, valuing an ecologically viable and scientifically interesting. Furthermore, the presence of natural fibers and blankets could also be seen working together with the Jatobá wood residue as a way of amplifying the property values obtained, therefore, both come from renewable resources, aiming to maintain the preservationist ideal. .

In general, the study of the use of waste from the wood industry is productive, valuing the ecological ideal that is a global issue, especially with regard to the attitude of companies and industries regarding this circumstance. Therefore, from such research, there is the possibility of obtaining materials that satisfy minimum mechanical requirements and can have applications, such as structural components that withstand low loads.

ACKNOWLEDGEMENTS

We would like to thank the support received by the Faculty of Mechanical Engineering of ITECUFPA and the PIBIC scholarship students from PROPESP-UFPA.

REFERENCES

ASTM D 638 - 10, Standart Test Method for Tensile Properties of Plastic, Annual Book of ASTM Standards, American Society for Testing and Materials.

Branco, C. T. N. M., da Costa, D, S., El Banna, W. R., Fujiyama, R. T., Rodrigues, J. S., Fagury Neto, E. (2016). Mechanical Properties of Polymeric Composite Reinforced by Chopped and Continuous Sisal Fibers. *SAE Technical Paper Series*, 1, 389-392. https://doi.org/10.4271/2016-36-0389

Callister Júnior, W. D & Rethwisch, D. G. (2018). Ciência e Engenharia dos Materiais - uma Introdução. Editora LTC.

da Costa, D. S., Guimarães, M. F., Pereria, L. C. de O., FUJIYAMA, R. T. (2012)

Characterization of Composite with Polyester Matrix and Natural Fiber (Agave Sisalana). *SAE Technical Paper Series*, 36, 0309-0319. https://doi.org/10.4271/2012-36-0309

da Costa, D. S., Banna, W. R. E., & Fujiyama, R. T. (2024). Wood Residue of Jatobá (Hymenaea courbaril) and Short Fiber of Malva in Composites. *Revista De Gestão Social E Ambiental*, 18 (1). https://doi.org/10.24857/rgsa.v18n1-017

Fujiyama, R., Darwish, F. & Perdra, M. V. (2014). Mechanical characterization of sisal reinforced cement mortar. *Theoretical and Applied Mechanics Letters*, 4, 061002-061007. https://doi.org/10.1063/2.1406102

Kotik, H. G. (2019). Fibras naturais e compósitos reforçados com fibras naturais: a motivação para sua pesquisa e desenvolvimento. *Revista Matéria*, 24 (3). https://doi.org/10.1590/S1517-707620190003.0801

Khan, Mohammad ZR; Srivastava, Sunil Kumar; Gupta, M. K. (2020). A state-of-the-art review on particulate wood polymer composites: Processing, properties and applications. *Polymer Testing*, 89, 106721. https://doi.org/10.1016/j.polymertesting.2020.106721

Lima, L. S., Branco, C. T. N. M., Santos, R. M. C., Lima, F. V. M., da Costa, D, S. ; El Banna, W. R., Fujiyama, R. T. (2013). Laminated Composite of Sisal and Curaua Fibers to Different Settings for Use in Bumper Cars. *SAE Technical Paper Series*, 36, 0603. https://doi.org/10.4271/2013-36-0603

Lopes, C.E.P; Pereira, L. C. O.; Costa, D. S. ; Lopes, R. V. P. ; Pinto, V. B. ; Fujiyama, R. T. ; Leite, J. C. (2013). Materiais compósitos de matriz poliéster reforçados com resíduos de madeira de diferentes morfologias (Florianópolis-SC, Brasil). In: Congresso Brasileiro de Polímeros – CBPOL.

Pereiria, L. C. de O., Takahashi, R., Vilhena, R. V., de Oliveira, D. R., Fujiyama, R. T. (2011). CARACTERIZAÇÃO DE RESÍDUOS DE MADEIRA E FIBRAS DE SISAL PARA FABRICAÇÃO DE MATERIAIS COMPÓSITOS DE MATRIZ POLIÉSTER (Blumenal – SC, Brasil). In: XXXIX Congresso Brasileiro de Educação em Engenharia. http://www.abenge.org.br/cobenge/legado/interna.php?ss=8&ctd=86

Reis, M. V. R., Fernandes, E. A., Silva, S. C., Silva, M. L. S., Pereira, G. H. F., Okabe, I. H., Branco, C. T. N. M., Fujiyama, R. T. (2016). Resíduo de madeira jatobá (Hymenaea spp), na forma em pó, em compósitos de poliéster e fibras de juta (Porto Seguro – BA, Brasil). In: 68ª Reunião Anual da SBPC http://www.sbpcnet.org.br/livro/68ra/resumos/listatodos.htm

Santos, J. A., Kuwahara, M., Santos, I. P., SANTOS, C., Pereria, L. C. de O., Lopes, C. E. P., Santos, E. J. S., da Costa, D, S., El Banna, W. R., Fujiyama, R. T. (2013) Materiais compósitos de matriz poliéster reforçado com resíduos de madeira com fibra de sisal de comprimento híbrido com variação de 5 a 15 mm (Belo Horizonte – MG, Brasil). In: 68 Congresso da ABM Internacional. https://abmproceedings.com.br/ptbr/article/materiais-compsitos-dematriz-polister-reforado-com-resduos-de-madeira-e-fibras-de-sisal-de-comprimentohbridocom-variao-de-5-a-15-mm

Santos, R., Ribeiro, M. M., Fujiyama, R. T., Branco, C. T. N. M. (2018) Placas laminadas de

compósito poliéster, tecido de juta e resíduos de madeira. *Estudos tecnológicos (online)*, 12, 68-77. 10.4013/ete.2018.122.04.

Rodrigues, J. S. & Fujiyama, R. T. (2010). Mechanical Behavior of Polyester and Sisal Fibers. *SAE Technical Paper Series*, 1, 0409-0417. https://doi.org/10.4271/2010-36-0409

Teixeira, F. P., Lima, V. N., Moutinho, D. J. C. & Fujiyama, R. T. (2022). Mechanical properties and fractography of cement-based composites reinforced by natural piassava and jute fibers. *CERÂMICA*, 68, 60-66. https://doi.org/10.1590/0366-69132022683853174

Wildner, M. V. Reaproveitamento de resíduos da indústria moveleira para aplicação em novos produtos de mobiliário. 2015. Trabalho de Conclusão de Curso (Bacharelado em Design) – Curso de Design, Centro Universitário Univates, Lajeado, 2015. https://www.univates.br/bdu/items/1982a51e-aad5-48f2-886b-f7e5f463c22b

Zoch, V. P. Produção e propriedades de compósitos madeira-plástico utilizando resíduos minimamente processados. Monografia (Bacharelado em Engenharia Florestal) – Curso de engenhari florstal, Universidade de Brasília, Brasília, 2013. https://bdm.unb.br/handle/10483/4840