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NATURAL FIBERS USED IN COMPOSITE MATERIALS IN THE NORTHERN REGION OF BRAZIL

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Abstract: In recent years, the search for sustainable and low-cost materials has directed scientific research towards the development of alternatives to traditional synthetic materials. Among these alternatives, fibers of plant origin have stood out for their properties and environmental benefits. This article investigates the use of natural fibers in composite materials, focusing on research carried out in the northern region of Brazil, especially at ``*Universidade Federal do Pará*``. The research highlights sisal fiber, known for its mechanical properties and environmental benefits, contextualizing its importance and presenting data on the number of studies produced at universities in the northern region. In addition, the volume of research developed at the Composite Materials Laboratory (LABCOM) of UFPA is detailed, including the classification of works by type, such as Course Conclusion Papers (TCC), dissertations, Institutional Scientific Initiation Scholarship Programs (PIBIC) and others. This article aims to provide a comprehensive overview of academic contributions on the use of natural fibers in the region, promoting sustainable development and innovation in the field of composite materials.
Keywords: Composites, natural fibers, tensile strength.

INTRODUCTION

The Composite Materials Laboratory (LABCOM) of ``*Universidade Federal do Pará*`` (UFPA) has as its main research focus the use of natural fibers of plant origin, which are applied as a reinforcement phase in composites. The objective is to replace synthetic materials such as glass and carbon fibers, promoting a sustainable ideal and increasing the added value of such renewable materials, which have some characteristics such as abundance and low weight, which value such use.

In this sense, there is potential in the use of polymer composites reinforced by natural cellulosic fibers for automotive applications, especially aimed at the performance of automotive bodies, bumpers and gears (Vieira, 2024). Sisal fiber is one of the most widely used and stands out as a promising reinforcement for natural fiber composites due to its specific characteristics, including low cost, lightness, high strength and high modulus. Furthermore, it is safe for health, widely available in some countries, renewable and biodegradable (Li, Mai and Ye, 2000; Sangthong, Pongprayoon and Yanumet, 2009).

Extracted from the leaves of the agave sisalana, a plant native to Mexico, sisal fiber was introduced to Brazil around 1900, especially in the northeast region. Currently, the largest producers are the states of Bahia, Paraíba and ``*Rio Grande do Norte*``. Sisal fiber is widely used in the manufacture of ropes, twine and carpets. In addition, current applications as reinforcement in composite materials (Silva et al., 2009). Figure 1 illustrates the aforementioned plant.

Figure 1: Sisal plantation

Source: Adapted from EMBRAPA, 1997

The growing search for low-cost materials from renewable sources that do not harm the environment has increased interest in sisal fibers as a reinforcement material (Silva, 2003).

According to Angrizani et al., (2006), "the cost of sisal fiber is much lower than that of fiberglass. Furthermore, unlike fiberglass, sisal fiber does not cause abrasion in equipment and molds during manufacturing, which significantly increases the added value in the production of composites."

When industrialized, sisal fiber is transformed into yarn, twine, rope, carpets, bags and handicrafts. In addition, it is used in the manufacture of cellulose pulp for the production of high-strength Kraft paper, cigarettes, diapers, among other products. In the reinforced plastics industry, composites with sisal fibers stand out for their high impact resistance and good tensile and flexural properties (Junior, 2012).

In this context, research on the chemical composition of sisal fiber revealed that it contains 69.4% cellulose, 12.5% hemicellulose, 10.5% lignin and 1.4% pectin. In addition, the average crystallinity index, calculated from two studies, was 72.95% (Martin et al., 2009).

Among natural fibers of plant origin, sisal fiber stands out for its high tensile strength value, compared to other fibers that are also used in rope and sack making, according to studies carried out in this area. Due to this high strength, sisal fiber is an excellent candidate for use as a reinforcing material in polymer matrix composites (Rosario et al, 2019).

Research on the characterization of composite materials with sisal fiber is also frequently carried out at LABCOM (the Composite Materials Laboratory of the School of Mechanical Engineering of ``*Universidade Federal do Pará*``, which is dedicated to the research and development of composite materials, with a focus on materials reinforced with natural fibers. Its activities include the use of various types of natural fibers, aiming at both technological innovation and environmental sustainability, as previously mentioned. In addition, the laboratory stands out for its significant contribution to the production of scientific knowledge in the area, with the frequent publication of articles in specialized journals.

Therefore, this research aims to present a natural fiber that stands out in terms of scientific research in Brazil and was used as a parameter to present some experimental results obtained by LABCOM, namely sisal fiber. A survey of data was also carried out on studies carried out at public universities in the North of Brazil related to this fiber, making it possible to observe important factors such as: technological development in the area of natural materials in the region, innovations in the use of fibers and applications in research in the States.

METHODOLOGY USED

A search was carried out in the "Science Direct" and "Google Scholar" media in order to obtain an article that covered the most commonly used natural fibers and some properties, with limited publication for the last 10 years. The selected keywords were: "natural fibers", "mechanical properties", "tensile properties", "jute" and "sisal". These words provide greater ease in searching for articles due to their relationship with a widely disseminated area of study: the mechanical behavior of natural fibers and composites reinforced by them.

The article was selected based on the following parameters: reliability in the publication medium, consonance with the theme and scope of natural fibers. In addition, works produced by LABCOM were presented, providing data already obtained experimentally by the members of the research group, with some of the fibers presented in the literature. Subsequently, the public universities present in two states in the northern region of Brazil were mapped, then, using the "Google Scholar" platform, a new search was carried

out on the use of sisal fiber, using the name of the public higher education institution in said state and sisal as keywords, the stipulated period was from 2019 to the present. Sisal stands out as one of the most studied natural fibers nationally, especially in the north and northeast regions, hence its choice.

NATURAL FIBERS

Faced with a demand for new technologies, materials that perform specific functions, such as structural ones, are sought, aiming to reduce damage to the environment. Thus, natural fibers have been studied, among many motivations, due to their origin from renewable sources, as well as the possibility of manufacturing biodegradable composites (Kotik, 2019). Table 1 presents the properties of some of the most widespread natural fibers in scientific research in Brazil. The highest tensile strength value is observed for jute.

Fiber	Diameter (µm)	Tensile strength (MPa)	Modulus of elasticity (MPa)
Juta (NORTH)	-—	393-800	10-30
Sisal (NORTHEAST)	50-300	227-400	9-20
Banana (NORTHEAST)	80-250	529-759	8,20
Curauá (NORTH)	170	158-729	-—
Piaçava (NORTH)	-—	134-143	1,07-4,59

Table 1: Properties of natural fibers

Source: Sanjay et al., 2018

PUBLIC HIGHER EDUCATION INSTITUTION IN THE NORTHERN REGION

DISTRIBUTION OF RESEARCH INVOLVING SISAL FIBER IN COMPOSITES

In the graph in figure 2 it is possible to see the relationship between the number of works published state.

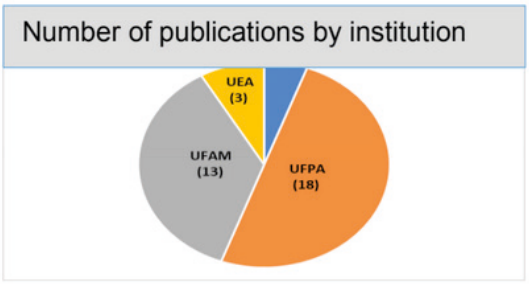

Figure 2: Number of publications using Sisal Fiber by Institution

MAIN STUDIES PRODUCED

In Amazonas, for the UFAM and UEA Universities, among the various works produced, a large portion were articles and TCCs. In addition, their research relates these fibers to the study of construction materials, fiber characterization, use of fibers in composites, manufacture of cement boards, sustainable materials and assessment of the life cycle of materials.

There is a greater focus on the use of sisal fiber for use in structural materials and evaluation of the properties of composite materials. The two Amazonas universities represent 44.44% of the total research produced among the states analyzed, with 36.11% for UFAM and 8.33% for UEA. In the State of Pará, at the UFRA and UFPA Universities, the main research deals with the mechanical properties of composites reinforced with sisal fiber, characterization of the physical properties of fibers, sustainable applications, structural reinforcement in wood, manufacture of blankets for composites and objects. Thus, it can be seen that the works focus on composite materials and their mechanical properties such as resistance. The universities of Pará represent 55.56% of the works produced, 5.56% for UFRA and 50% for UFPA.

WORKS PRODUCED BY LABCOM

Composites reinforced by natural fibers have already been manufactured and tested by LABCOM, using polyester resin as a matrix and having as main result the tensile strength limit, obtained through mechanical tests. For sisal fiber, Kuwahara et al., (2013) produced composites using sisal fibers in a hybrid form, with variable length from 5 to 15 mm, obtaining the following tensile strength values: 16.23 (± 3.64) MPa, 19.64 (± 2.19) MPa and 22.83 (± 0.54) MPa, for increasing mass fractions of 3.9%, 4.87% and 5.41%. Da Costa et al., 2013 worked with jute fiber and manufactured composites using fibers with the following lengths: 5, 10, 15 and 20 mm, the average maximum stress values obtained were: 19.56 (±1.32) MPa; 21.30 (±2.90) MPa; 30.57 (±3.49) MPa; 25.34 (±2.61) MPa, respectively. Hybridizations were also produced using two types of natural fibers. Dias et al, 2023, used jute and sisal fibers as reinforcement, both with a length of 5 mm, and obtained an average maximum stress value of 15.68 MPa. Another fiber that has also been used was piassava, also with a length between 5- and 15-mm.

Tensile strength values of 15.09 (±1.5), 17.49 (±0.98), 19.56 (±1.32) were obtained for 5, 10 and 15 m, respectively. Finally, Carvalho, Silva and Fujiyama, 2019 aimed to evaluate the tensile behavior of composites reinforced by continuous and aligned curauá and banana fibers, obtaining tensile strength values of 228.6 MPa and 272.6 MPa, respectively.

A thorough search was carried out in the data stored by the laboratory researchers to quantify the numerous studies that have been developed over the years at LABCOM. It was found that a total of 67 studies were carried out involving sisal fiber as reinforcement in composites. Of the total research involving this fiber, 2 are related to students involved in the Institutional Scientific Initiation Scholarship Program (PIBIC), 13 refer to course completion work and 7 to master's dissertations, the rest refer to publications in journals, conference proceedings and book chapters. The graph in figure 3 visually presents this proportion.

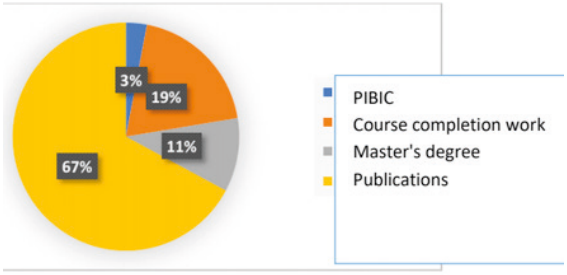

Figure 3: Number of researches using Sisal Fiber by type of work

With a total of 67 research projects, it can be seen that the majority, 67%, are related to other research environments (journals, conference proceedings and book chapters), highlighting the versatility and interest in this fiber beyond formal undergraduate and graduate projects.

The Final Course Papers (TCCs) represent 19% of the research projects, demonstrating the engagement of undergraduate students in the exploration of sustainable materials.

This high participation highlights an academic environment that values research and encourages students to contribute to the advancement of knowledge in the area of composites.

The master's dissertations, which correspond to 11%, reinforce the importance of the topic for more in-depth and advanced studies. This percentage demonstrates that sisal fiber is also a significant topic for graduate studies, contributing to the development of new technologies and applications in composite materials reinforced with natural fibers.

On the other hand, the smallest portion of research, representing 3%, is associated

with the Institutional Scientific Initiation Scholarship Program (PIBIC). This data indicates a potential for growth in the participation of scientific initiation students in studies on sisal fiber.

This illustrates a diversified distribution of research at LABCOM, with a strong presence in various research environments and a significant contribution of TCCs and master's dissertations.

CONCLUSIONS

Analysis of research conducted at public universities in the North region reveals a growing interest in and development of innovative technologies involving sisal fiber. The distribution of research by institution shows that UFPA and UFRA are the universities with the largest number of studies, representing 55.56% of the research in the region, with 50% coming from UFPA and 5.56% from UFRA. In Amazonas, UFAM and UEA also stand out, representing 44.44% of the total, with 36.11% for UFAM and 8.33% for UEA. The breakdown by type of work indicates a significant diversification of research at LABCOM. Of the total of 67 studies involving sisal fiber, 67% are related to publications in journals, conference proceedings and book chapters, evidencing the versatility and academic interest in the topic. Final Course Works (TCCs) represent 19% of the research. Master's dissertations account for 11%, demonstrating the importance of the topic for advanced studies. Works associated with the Institutional Scientific Initiation Scholarship Program (PIBIC) represent 3%, indicating a potential for growth in the participation of scientific initiation students.

This diversified distribution and the significant number of publications reinforce the relevance of sisal fiber in the research and development of sustainable composite materials. Universities in the North region, especially UFPA through LABCOM, play a crucial role in promoting technological innovations and advancing scientific knowledge, contributing to sustainability and technological development.

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