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VEGETABLE POLYURETHANE RESIN BIOCOMPOSITES WITH TITICA VINE FIBER TEXTILE REINFORCEMENT: A REVIEW

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Abstract: Given the growing need for alternative products to synthetic fibers to obtain more sustainable and environmentally friendly products, natural fibers are proving increasingly promising when applied as reinforcement in polymer composites. Taking into account the pollution generated by the exploration of oil and derivatives and the increasingly present threat of their depletion, the academic and industrial sectors are progressively investing in alternative solutions to these non-renewable sources like the use of polymers based on plant resources, such as castor oil-based polyurethane resin. Therefore, this study aimed to analyze, based on a brief literature review, the application of plant resources in composites, both for reinforcement and for the polymeric matrix. This process is proving an increasingly present and urgent trend in the most diverse industrial sectors, adding significant gains to both the environment and society, based on the review study of biocomposites reinforced with titica vine fiber and polyurethane matrix derived from a plant resource.
Keywords: Natural fibers; Titica vine; Biocomposites.

INTRODUCTION

Since ancient times, human beings have been using Natural Fibers (NF) in the most diverse forms of application, such as making ropes, clothing, and utensils for hunting and fishing. With the advancement of technology, Synthetic Fibers (FS) were developed, and due to several factors, such as durability and resistance, they replaced NF [1].

However, due to the environmental problems caused by the abundant use of these synthetic resources, such as inadequate disposal of these materials at the end of their useful life, the emission of polluting gases into the atmosphere arising from their production process, in addition to the worsening of the greenhouse effect, has generated interest in the development of more sustainable and renewable materials [2].

These fibers are increasingly being used in polymer matrices to improve the low mechanical properties of polymers, as the addition of fiber tends to improve their performance, and result in lighter materials. This combination of immiscible materials gives rise to a new material with properties different from the original, called composite [4][8-9].

In addition to using vegetable fibers to replace (SF), vegetable resins can also be used, so that an even more sustainable and environmentally friendly material can be manufactured to produce a biocomposite. An example of this is vegetable-based polyurethanes, which are largely produced from fatty acids or triacylglycerols derived from raw materials such as palm, soybean, or castor bean oil [10-11].

In this context, this article aimed to present a brief review of biocomposites obtained from plant resources, such as natural titica vine fiber and polyurethane bioresin derived from castor oil.

LITERATURE REVIEW

LIGNOCELLULOSIC NATURAL FIBERS (LNF)

LNFs are considered true natural composites, where cellulose microfibers act as reinforcement in a hemicellulose and lignin matrix. The chemical composition of (FNL) varies greatly due to its inhomogeneity. Table 01 lists the chemical composition of some LNFs [12-13].

(FNF_s)	Cellulose %	Hemicellulose %	Lignin %
Titica vine	39	-	-
Bamboo	46–58	16–20	20–22
Jute	64.4	12	11.8
Kenaf	31–39	19	15–19
Hemp	57–77	14–22	3.7-13
Sisal	47–78	10–24	7–11
Ramie	68–91	5-16.7	0.6–0.7
Date palm	32-35.8	24.4–28.1	26.7-28.7
Banana	62–64	19	5
Coconut	37	20	42

Table 01 - Chemical composition of the NF [12][14-16].

Cellulose is the main component responsible for the mechanical strength of NF; increasing the cellulose content and decreasing the spiral angle to the fiber axis provides a gain in fiber resistance [17].

With the growing demand for competitive products in the market that optimize cost versus quality using more sustainable and renewable products, materials based on NF have interesting advantages when compared to SF of glass and carbon, as can be seen in Table 02 [18].

Type of fiber	Costo (US$/ton.)	Energy (GJ/ton.)
Natural fiber	200–1,000	4
Fiberglass	1,200–1,800	30
Carbon fiber	12,500	130

Table 02 - Cost and energy analysis of NF versus SF [18]

Therefore, these and other characteristics, such as high specific mechanical properties, make NF potential candidates to be used as reinforcement in composites, as an alternative to SF for different types of applications [19].

TITICA VINE

In Brazil, the titica vine plant (*Heteropsis flexuosa*) is found predominantly in the Amazon and some fragments of the Atlantic Forest. The titica vine plant can also be found in other South American countries [20-21]. Figure 01 shows the titica vine plant and its fiber.

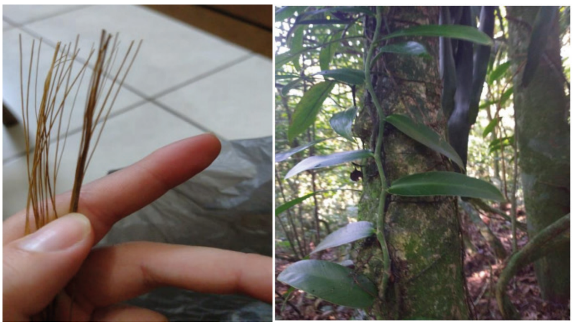

Figure 01 – Titica vine plant and its fiber, respectively.

Titica vine fibers are poorly known, there are few reports in forestry studies and even less in the area of engineering in the production of composites. However, Da Cunha and collaborators [16] carried out a brief comparison of the mechanical properties of this vine with other NF, as shown in Table 03.

Fiber	σmax (MPa)	E (GPa)	ε (%)
Titica vine	25.92 ± 6.7	1.02 ± 0.2	7.36 ± 2.0
Catharanthus roseus	27.02 ± 1.1	1.23 ± 0.04	2.15 ± 0.1
Sugarcane	169.51 ± 18.6	5.18 ± 0.6	6.25 ± 0.01
Tridax procumbens	25.75 ± 2.4	0.94 ± 0.09	2.77 ± 0.6
Kenaf	280 ± 90	22 ± 6	1.29 ± 0.2
Coconut	44 ± 8	2 ± 0.3	4.5 ± 0.8
Agave	68.2 ± 30	2.39 ± 0.7	7.40 ± 4.5

Table 03 – Comparison of the mechanical properties of titica vine with others NF - Adapted from [16]

The use of these NF favors the conscious exploitation of forest resources, in addition to promoting social and economic gains, adding value to the extracted product, favoring the development of the local community, and reducing the predatory exploitation of this resource through sustainable management.

POLYURETHANE DERIVED FROM CASTOR OIL

Polymers are increasingly used as a matrix in composites than other types of matrices, such as metals and ceramics. This is mainly due to their low weight, low cost, simple manufacturing methods, and good chemical resistance that allows them to be used in the most diverse applications [22].

The vast majority of polymer matrices applied in composites are of synthetic origin derived from petroleum. However, the need for sustainable and environmentally friendly products has required the development of bioresins from renewable resources of plant origin, as an alternative to synthetic resins [2].

An example of bioresin is Polyurethane (PU) obtained from the castor bean seed (*Ricinus communis*), from which oil is extracted for the synthesis of resin (PU). This oil has attracted constant interest as a renewable substitute for entirely petrochemical products to obtain polymeric materials, aiming to reduce dependence on oil and maintain a certain environmental balance and economic development with its cultivation [23-24].

POLYMERIC COMPOSITES REINFORCED WITH NATURAL FIBERS (PCRNF)

NF confer certain advantages to polymer composites that make them an attractive alternative to SF. They give the new material lightness, are good thermal and acoustic insulators, and have low cost, in addition to giving the biocomposite good specific mechanical properties and contributing to the reduction of greenhouse gas emissions [25].

These, among other advantages, make these materials good substitutes for conventional materials in the production of composites, meaning they can be applied in the most diverse industrial areas, such as the aerospace and military sectors, among others. The performance of the fiber-reinforced polymer composite, as well as the load capacity of the reinforcement, depends mainly on the type of fiber and its orientation [26].

PCRNF are ecologically viable and more sustainable since the use of fibers as reinforcement reduces the amount of resin to be used, and the fibers are light, contributing to reducing the mass of the final product (resulting in greater savings). They are biodegradable, and if incinerated at the end of their useful life, NF results in recovered energy and carbon credits [27].

STRUCTURAL COMPOSITE

Composites are classified according to the type of reinforcement. They can be characterized according to the length, dimension, and orientation of the NF incorporated into the matrix. This orientation can be classified as continuous and discontinuous, depending on their length/diameter relationship. Continuous and aligned fibers can also be classified as woven and non-woven [28-29]

This reinforcement arrangement in composites, for a known state of tension, has an anisotropic structure, using fabrics as reinforcement. The use of this type of reinforcement generally increases its mechanical properties by approximately three to four times compared to isotropic structures (non-woven format) [29].

In general, textile laminated composites can withstand large flexural strength when subjected to normal tension, as well as being able to resist shear deformation. The use of fabrics in the manufacture of composites is increasingly gaining popularity due to its potential for environmental sustainability, among other factors [30].

CONCLUSION

The use of sustainable, environmentally friendly materials has intensified in academia and industry due to the need for greener products such as NF;

The use of plant resources favors the sustainable management of this resource and reduces predatory exploitation, thus obtaining social and economic gains;

Obtaining lighter products with a low carbon footprint and biodegradable are a possible solution to improper waste disposal and to combat the greenhouse effect;

The development of laminated biocomposites has become popular because they tend to improve mechanical properties due to the reinforcement arrangement applied.

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