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SURFACE TREATMENTS OF LIGNOCELLULOSIC FIBERS IN THE PRODUCTION OF COMPOSITES FROM DIFFERENT MATRIXES

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Abstract: Lignocellulosic natural fibers have been used in the production of composites, whether for reasons of lower production costs, good availability of natural fibers, environmental issues, among others. Improving the characteristics of the new material produced is generally achieved by combining the isolated physical and mechanical characteristics of each material. However, given the importance of ensuring good physical and mechanical properties of composites in industry, there is a need to increase adhesion between fibers and matrices to obtain more resistant and durable composites. Thus, the study aims to explore different surface treatment techniques to reinforce the adhesion between fibers and matrices, and to evaluate the effectiveness of these techniques, by comparing the results obtained with different types of composites with different fibers used as reinforcements. To this end, a bibliographical review was carried out, with the aim of obtaining information about natural lignocellulosic fibers, which are most used as reinforcement in composites, in addition to methods of extraction and processing of lignocellulosic fibers, as well as information about the chemical composition of fibers, physical and mechanical properties, such as density, tensile strength, modulus of elasticity, among others. Furthermore, the research investigates composites reinforced with and without fiber treatments. Surface treatments significantly improve adhesion between fibers and matrices, resulting in composites with better physical and mechanical properties than untreated raw fibers.
Keywords: Surface treatment; Natural fibers; Biocomposites.

INTRODUCTION

Natural or synthetic fibers, thermoplastic or thermoset matrices, fillers, among others, are immiscible materials that can be combined and arranged to form new materials, composites, achieving better mechanical and physicochemical properties. This way, they have many competitive advantages with so-called conventional materials, such as metals and their alloys, [1] and which may be related to reduced costs and environmental impacts and even an increase in mechanical performance, among other factors. According to [2-5], any material, ideally, that presents better performance in all the factors mentioned, or that allows new applications, will acquire real competitive advantages.

Thus, because they are light and have high performance, most of the materials used in the aerospace, automotive and sports equipment sectors are composites reinforced with glass or carbon fibers, as they are highly resistant and have high rigidity [6-8]. However, despite their excellent mechanical properties, they present high manufacturing energy consumption and limitations to recycling at the end of their use. This way, reinforcements with natural fibers are a sustainable and circular alternative, due to their good specific properties, lower cost and low carbon footprint [9]. In addition to being abundant in tropical countries, among other advantages, it is important to mention that natural lignocellulosic fibers are recyclable and biodegradable. And compared to synthetic ones, they have a lower cost and lower energy consumption, around 20% to 40% of their production energy [10].

Amorphous constituents such as lignin and hemicellulose are generally removed with surface treatment of natural fibers, when used as reinforcement, as the fiber's cellulose content, with higher levels of crystallinity, can translate into better mechanical properties of composite materials, whose superior mechanical properties and resistance to thermal degradation may be associated with this condition of the fibers [11].

REVIEW OF LITERATURE

EXTRACTION OF LIGNOCELLULOSIC NATURAL FIBERS

After harvesting the plants, in order for them to be used in composites, some procedures need to be carried out with the lignocellulosic fibers, such as: separation, dissolution of pectin, gums or any other element that can reduce the adhesion of the polymers to the fibers [12].

Figure 1. Main natural fibers used in composites

(Source: https://www.fiberjournal.com/author/mmidanilobna/. Accessed on 12/20/2023).

Depending on the type of fiber category, for the purpose of degrading hemicellulose, lignin, pectin and wax, the duration of the treatment can take from 14 to 28 days, long-lasting processes. Alternatively, chemical treatment and mechanical extraction methods are used. There are several techniques for extracting fibers from plant stems, the main ones being: manual extraction, maceration (most common) and mechanical extraction technique (mechanical decortication) [13-15]. Hornification can also be carried out, in addition, a process that consists of wetting and drying cycles, usually used in the paper and cellulose industry, with the aim of reducing the water absorption capacity of lignocellulosic fibers. cells, resulting in greater dimensional stability of the fiber [16].

MAIN SURFACE TREATMENTS

The mechanical and thermal properties of polymer composites reinforced with natural fibers vary with different parameters, such as: fiber mass fraction, physical, geometric and chemical properties of fibers, moisture absorption behavior of fibers, fiber orientation, fiber hybridization, surface treatment of fibers, type of polymer matrix and manufacturing and curing process [17].

In the production of composites, it is common to use polymer matrices based on polyethylene, polypropylene, polyvinyl chloride, polystyrene, polyolefin and thermosets due to the fact that they can be cured below 200ºC, a temperature above which natural fibers are thermally unstable [18]. However, its efficiency will depend on some factors, among them, the main one, the quality of adhesion between the matrix phase and the surface of the fibers in the interface region, directly impacting its mechanical performance [19]. The transmission of the efforts applied to the composite can be done by the matrix to the reinforcement if the interface presents good efficiency, provided by the greatest possible adhesion between the reinforcement and the matrix [20], thus, some surface treatment may be necessary, as some reinforcements used in composites they do not have adhesion to the matrices [21]. Therefore, the energy required to break the interfacial bonds, propagate cracks and promote the detachment of the reinforcement from the matrix must also be greater [22].

Correctly executed mechanical extraction processes can increase the surface roughness of the fibers, producing conditions for greater interaction and bonding/adhesion between the reinforcing fiber and the matrix, improving the mechanical properties of the composite [23]. Several types of chemical treatments have already been carried out on natural fibers. Among them, alkaline treatment (mercerization), silane treatment, acetic acid treatment, benzoyl peroxide treatment, potassium permanganate treatment, stearic acid treatment, polymer coating, graft copolymerization, isocyanate treatment [12], treatment with acrylic acid, malleated coupling agents, among others; which are compounds used to promote adhesion by chemical coupling. "However, traditional coupling, esterification, grafting and other treatment methods have some disadvantages, such as high cost and environmental pollution" [24].

Polyolefin composites reinforced with untreated or unmodified natural fiber present weak interfaces, due to the different polarities of the phases, hydrophilic natural fibers and hydrophobic polyolefin, limiting the interface to mechanical anchoring between the phases. Furthermore, interfaces of untreated composites tend to have separations in the interfacial region and voids in the interface region. Therefore, the literature shows different strategies to reinforce the interface [25, 26].

Thus, among the chemical treatment methods carried out, the main ones are: mercerization, chemical modification of the fiber through reaction with maleic anhydride, silanization, acetylation and propionylation. Compared to other chemical treatments, alkaline treatment with NaOH is an economical, easy and effective method for large quantities of fiber [27].

Rebelo [28] treated piassava fibers with alkaline concentrations of NaOH of 5% and 10% in the production of PU matrix composites, based on castor oil, in which he observed an increase in the fibrillar surface area and porosity, improving the properties physics and mechanics of composites.

The use of maleic acid polymers avoids the use of other expensive and toxic reagents to obtain similar results, in which the coupling agent interacts by entangling itself with the polymer chains of the matrix, through interdiffusion phenomena and which also creates covalent bonds with hydroxyl groups on the fiber surfaces [29].

CONCLUSION

- The use of natural fibers as reinforcement in composites has increased in recent decades, whether for environmental reasons or lower cost.
- There is great difficulty in transferring efforts from the matrix to reinforcement efficiently in the composites produced.
- Different lignocellulosic fibers used as reinforcement in different matrices produce composites with different physical and mechanical characteristics, depending on the type of fiber and matrix used in these composites.
- The effects produced by surface treatments, by different techniques and processing, in general, significantly improve the adhesion between fibers and matrices, resulting in more resistant and durable composites.

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TREATMENTS AND RESULTS OBTAINED IN RECENT STUDIES

Natural fibers	Chemical treatment	Matrix	Manufacturing technique	Work highlights and reference
Abaca, Manila hemp (30%)	Silane, Maleic Acid (0,2,6,8,10)	High density polyethylene and biopolethylene	injection molding	There was no statistical difference in the tensile properties of both composites. The optimum concentration of coupling agent was 8 wt%. Aiming for better binding or adequate binding with maleic acid, the fibers must have a high cellulose content. (30)
Banana	NaOH, concentrations (10, 15 and 20%)	-	-	Increase in fiber density up to 15% (optimal concentration) and reduction from this concentration, as well as the proportion of cellulose. Increased hydrophobicity, thus doubling the Young's modulus from 20% concentration, by reducing the proportion of cellulose (31)
Hemp	NaOH (5% by weight), Na2SO3 (2% by weight), maleic anhydride, room temperature AT (20.5 and 22 C) and high temperature, HT (120 C)	Polypropylene	-	Treatment with 5% NaOH and 2% NA2SO3 at high temperature (HT) caused an increase in tensile strength and Young's modulus, compared to room temperature (AT). Increase in resistance compared to untreated fiber of 51% at AT and 62% at HT and increase of only 16% at AT and 14% at HT, compared to untreated fibers. (32)
Curauá	TF-AO and TF-S	Epoxy	Manual	Increase in tensile strength is 63% for fiber treatment with aluminum oxide (TF-AO) and 66% for fiber treatment with sand (TF-S) and increase in Young's modulus of 226% and 223% for TF -AO and TF-S, respectively. (33)
Juta	NaOH	Epóxi	-	The treatment was carried out with different contents. Fiber (8, 10, 12%) in which the void volume decreases with the fiber content, mainly treated fibers. The tensile strength of the composite with treated fibers was higher than that of untreated, raw fibers. There was an increase in resistance with the increase in fiber traction. (34)
Sisal	NaOH e NaOH/PVA (alkali/polyvinyl alcohol)	HDPE	Extrusion molding	There was a reduction in the modulus of elasticity and an increase in tensile strength with the treatments. The tensile strength of the fiber treated with NaOH was 563.68 MP and that treated with NaOH/PVA was 594.93 MP, an increase of 5% and 10% compared to untreated fibers. The alkaline treatment reduced the cellulose rotation angle (fibrillation), improving fiber orientation and tensile strength. There was also an improvement in impact resistance with the treatment and the probability of failure was greater. There was also a reduction of 22.67% and 34.38% in moisture absorption, for treatment with NaOH and NaOH/PVA respectively, in relation to untreated fiber.

Table 1. Highlights of different fiber treatments in the production of composites in recent works

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