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## THERMAL ANALYSIS OF NATURAL HYBRID COMPOSITES IN EPOXY AND POLYESTER MATRICES

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**Abstract.** This work aims to study the thermal properties of natural intralaminar hybrid composites with epoxy and polyester matrices. Two different types of natural hybrid composites were produced via the hand layup technique (jute + curauá and jute + sisal) with a twill weaved mat of jute and the other fibers as reinforcement. The composites were thermally characterized by thermogravimetric (TGA) and derivative thermogravimetric (DTG) techniques to investigate the thermal stability of the material, comparing the two types of resin used in the research. A scanning electron microscopy (SEM) analysis was used to investigate the morphology of the natural fibers in the composites. Hybrid composites showed higher thermal stability for epoxy and polyester resin, showing that the hybridization effect was positive for thermal stability.

**Keywords:** Composite Hybrid, Thermal Analysis and Nature Fiber.

### 1. INTRODUCTION

In recent years, the development of Natural Fibre Reinforced Composites (NFRC) has been studied to reduce environmental impacts due to the potential in the substitution of petrochemical derivatives. These materials come from renewable sources and of great exuberance in nature, in addition to being reusable and may be discarded in nature, whereas with artificial fibers this is not possible. Natural fibers applied in the automotive, civil, textile, and aerospace industries, represent an important factor in the development of sustainable products that reduce the energy demand, lower cost, weight and produce a non-toxic product (Martin et al., 2009, Dicker et al., 2014, Gurunathan et al., 2015).

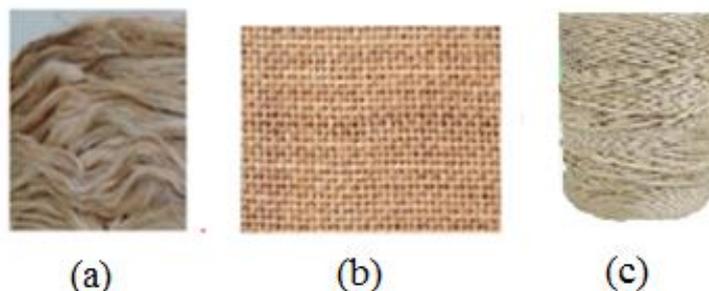
Currently, Brazil has several renewable sources throughout its territory, such as the following plant fibers: jute (*Corchorus capsulari*), sisal (*Agave Sisalana*), curauá (*Ananas erectifolius*), rami (*Boehmeria nivea*), coconut (*Cocos nucifera*) among other fibers (Faruk et al., 2012), and these plants are most used in thermoplastic and thermoset matrices applications and several studies about natural fibers have been applied in the Brazilian industry. Zah et al., (2001), has partnered with the automotive industry in the quest to replace the composites reinforced with synthetic fibers in automobiles with composites reinforced with natural fibers through the Poverty and Environment of the Amazon (POEMA) program. Paluvai et al. (2017), analyzed the mechanical and thermal properties of sisal fiber in the polyester matrix, with two types of chemical treatments: alkaline and mixed (alkaline + silane), the results show that the treated fibers presented higher thermal stability than the untreated fibers. The authors did not find researches about the study of the hybridization effects on the thermal stability and decomposition of natural fiber reinforced composites, highlighting the relevance of this work. Cavalcanti et al. (2019), investigated the mechanical and chemical properties of the hybridization sisal and curauá fibers as reinforcement elements in the jute mat in epoxy matrix, with two types of chemical treatments: alkalized and mixed (alkaline + silane), the results show that the chemical treatments affect the mechanical properties of the jute + sisal composite positively and negatively affect the jute + curauá composite.

The aim of this work was to evaluate the thermal properties of intralaminar hybrid natural composites (jute + curauá and jute + sisal) using two types of resins: epoxy and polyester, through thermogravimetry (TGA) and derivative thermogravimetric (DTG) tests according to ASTM 2550 -17, which analyzed the effect of hybridization in the thermal stability and the decomposition of the constituents of these materials.

## 2. EXPERIMENTAL PROCEDURE

### 2.1 Materials

The materials used in this work were sisal, curauá and jute fibers, as shown in Figure 1 (supplied by Sisalsul), and the polymer matrices used were the epoxy resin - AR260 / AH260 and a polyester orthophthalic resin AZ 14.0/M-50 (supplied by e-composite, Rio de Janeiro). The epoxy resin was in the fraction 100: 26 and for the polyester resin 100 g of hardener for 0.7g - 2% of catalyst was used as per supplier recommendation. For the composite manufacturing process (i.e. jute, jute + sisal and jute + curauá) the hand lay-up technique was used to impregnate the resin in the hybrid composites and jute fabric. Jute fiber was used as a base for the production of the hybrid composites.



**Figure 1. (a) – Curauá fiber, (b) -Jute blanket and (c) – Sisal fiber**

Table 1. Physical and mechanical properties of natural fibres (Jawaid, 2012-Lima, 2019).

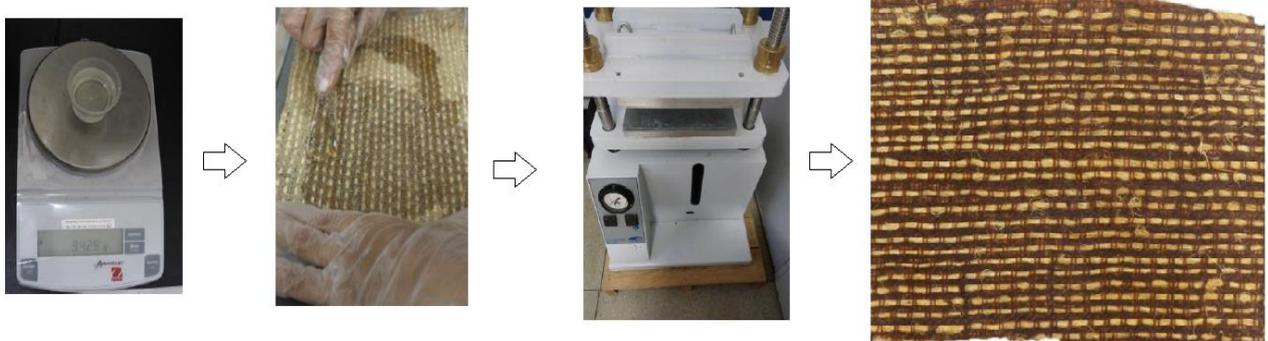
Properties	Jute Fibre	Sisal Fibre	Curauá Fibre
Density (g/cm <sup>3</sup> )	1.3	1.33-1.45	1.4
Tensile Strength (MPa)	393-773	468-700	500-1150
Young's Modulus (GPa)	26.5	9.4-38	11.8
Elongation at break (%)	1.5-1.8	2-7	3.7-4.3
Cellulose (%)	58-63	60.5	58.8
Hemicellulose (%)	12	25.7	23.8
Lignin content (%)	12-14	12.1	14.7

### 2.2 Natural Fibre Reinforced Composites Fabrication (NFRC)

The fabrics were reinforced by natural fibers (curauá and sisal) using a twill braiding model in the longitudinal direction as seen in Figure 1. The hybrid composites have 60% of jute and 40% of the other fibers (curauá and sisal) of percentage in weight. The manufacturing process used was the hand-lay-up as shown in figure 2, and to achieve the curing of the composite, a hydraulic press (Solab SI-20) heated at 80 ° C for 6h was used for the epoxy-based composites, while for the polyester-based composite, a temperature of 25 ° C for 1h and then another heating process at 75 ° C for 3h was used. The volumetric fraction used in the manufacture of the hybrid composites was 70% resin to 30% fiber.



**Figure 1. (a) – Jute nt, (b) -Jute hybrid jute + sisal in the twill model.**



**Figure 2. – Production stage.**

### 2.3 Test methods

The thermogravimetric analysis (TGA) was performed by NETZSCH TG 209 F3 Tarsus as shown in Figure 3, present at the Laboratory of Adhesive and Composite Materials (LADES) – CEFET/RJ, Rio de Janeiro - Brazil. The samples were tested at a heating rate of 10 ° C / min with a range of 30 ° C-600 ° C under a nitrogen atmosphere of 20 ml min<sup>-1</sup>.



**Figure 3. – NETZSCH TG 209 F3 Tarsus.**

### 3. RESULTS

The curves of the components obtained by TGA and DTG are shown in Figure 2 and 3. In the TGA curves three stages of degradation can be observed. In the first stage weight loss starts at 80 °C because of the humidity present in the natural parts, the second stage occurs between 200°C-450°C due to the decomposition of the natural fiber's components, and in the last stage, above 450°C, the production of active carbon residue is observed. DTG curves show the maximum degradation peak (Azwa et al., 2013).

The TGA behavior of the pure epoxy resin is shown in Figure 2 (a), the decomposition process starts around 150°C, while its maximum decomposition occurs at 359.79°C as shown in the DTG as shown in Figure 2 (b), whereas for the pure polyester resin as shown in Figure 3(a), it started at 80°C and the maximum decomposition peak is around 376.4°C, as show in Figure 3 (b). The percentage of mass loss shown in Table 1 indicates that the polyester resin is more volatile than the epoxy resin.

The epoxy composites, the jute untreated composite obtained a more stable  $T_{onset}$  compared to the hybrid composites, and this indicates that the hybridization effect altered the  $T_{onset}$  of material degradation, but DTG results show that the jute + sisal hybrid composite presents a more stable thermal peak, because of the chemical treatment used to clean impurities in the fiber, taken from low thermal constituents.

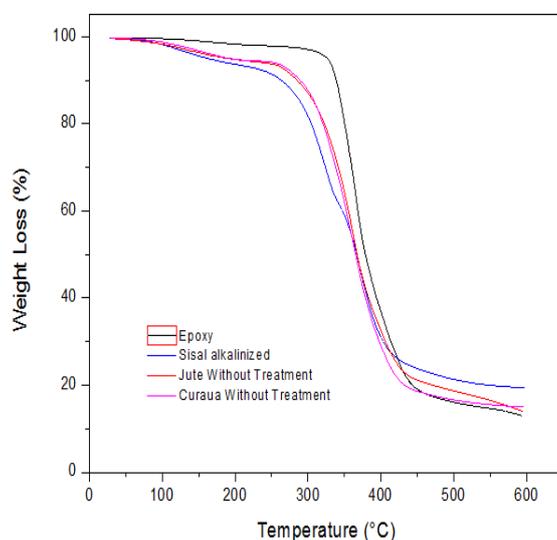


Figure 2. (a)- TG curve for epoxy-based composites.

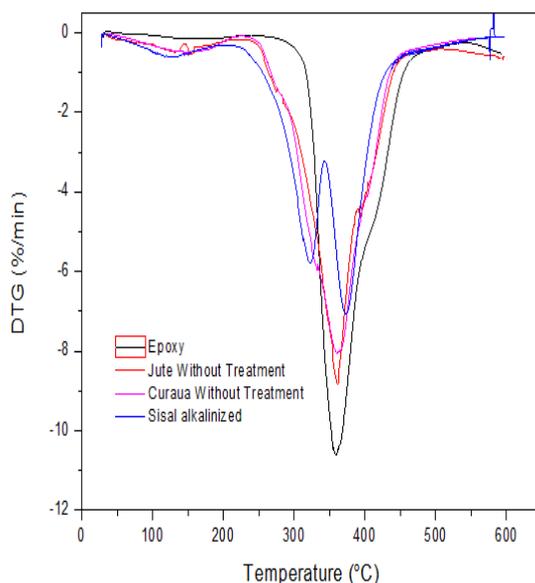
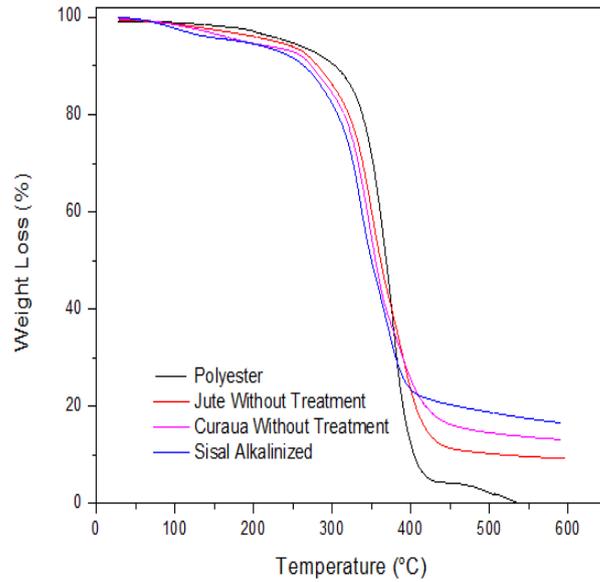
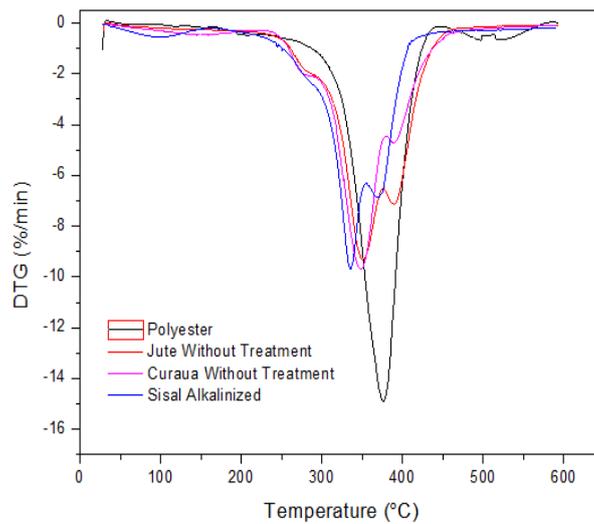


Figure 2. (b)- DTG curve for epoxy-based composites



**Figure 3 (a)- TG curve for polyester-based composites.**



**Figure 3 (b)- DTG curve for polyester-based composites.**

Table 2 shows the thermal properties of the composites studied, the results indicate that the jute + curauá composite presented a higher thermal stability of  $T_{onset}$  for the two types of resins, with a variation of 5.3 °C between the degradation starting temperatures.

The jute + sisal composite presents a small difference in its  $T_{onset}$  between the two resins used, because of the chemical treatment used to increase the interaction between fiber-matrix and the time of exposure of the fiber in the treatments used.

Finally, the jute - epoxy obtained an improved beginning of degradation compared to the jute- polyester and the residual percentage for all the composites were higher in relation in the epoxy than in the polyester.

Table 2- Thermic of Composites Property.

Composite	Temperature Onset (°C)	Temperature Peak Dtg	Residual Mass (%)
Epoxy Resin	330.7	359.7	12.76
Polyester Resin	339.4	376.4	1.0
Jute Without treatment – Epoxy	318.6	357.8	13.80
Jute Without treatment – Polyester	309.9	350.5	9.18
Sisal alkalized - Epoxy	299.4	373.1	19.35
Sisal alkalized - Polyester	301.1	335.7	16.46
Curauá Without treatment - Epoxy	317.2	362.0	14.94
Curauá Without treatment - Polyester	312.5	348.8	13.11

#### 4. CONCLUSION

The results show that the curauá fiber as a reinforcing element contributed to the increase of the thermal stability of the composite for the two types of resin. The jute + sisal composite presented lower values of onset temperature, but the residual mass is higher among all of the composites and may have an application as a retardant material.

However, the pure jute composite presents good thermal stability for the epoxy resin, but its residual loss was high when compared to the hybrid composites.

#### 5. ACKNOWLEDGEMENTS

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