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PINEAPPLE LEAF FIBER AS REINFORCE IN COMPOSITE MATERIALS, AN ALTERNATIVE FOR AUTOMOTIVE INDUSTRY

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ABSTRACT

The composites appear as an extremely favorable alternative for different industries, due to the fact that it combines the best mechanical properties with the best physic-chemical properties of two or more materials. Nowadays, in the evaluation of materials, besides criteria such as economic viability and performance, the environmental criterion was included in this evaluation. Part of the environmental criteria is the use of biodegradable materials and/or recycled materials. In this sense, researches focused on vegetal fibers, as reinforcement in composites are growing considerably and positive results for its performance were achieved. Moreover, the environmental-friendly approach not only is the unique advantage on usage of vegetal fibers, but also it has an economical advantage, because of the low cost and good performance due to low density. The fiber extracted from the pineapple leaf (PALF) is a new alternative for automotive industry as cellulose-based fiber composite. In this sense, the present paper aims to present the characterization of the pineapple leaf fiber for manufacturing the automotive composite materials. Milled pineapple fibers extracted, in two different ways and submitted to mercerization treatments, were characterized by mechanical and thermal properties; density; morphology; FTIR spectroscopy, EDX and X-ray diffraction. It is important to characterize the fibers, in order to obtain appropriate mechanical properties of composite.

1. INTRODUCTION

The advent of the concept of sustainable development, the increasing global and competitive business environment, the strict control imposed by governmental and non-governmental agencies and, moreover, the population's bigger environmental awareness, have forced companies to seek ways to integrate systems that help controlling/minimizing problems related to productivity and the environment. For this reason, it becomes necessary to develop alternatives for the production process.

Not only is it possible to improve the environmental performance, but also the economical and social aspects, considering that recycling can contribute, socially, through job creation. Nevertheless, it contributes, economically, with the reuse of recycled materials and, environmentally, because it reduces waste and environmental pollution. The same survey reveals, in addition, that there is opportunity for all automotive companies surveyed to improve their environmental performances, especially, concerning the recycling of wastes [1].

One factor that favors researches concerning the use of agroindustrial residues is that Brazil is one of the largest producers of natural fibers, which increases, therefore, the expectation of the inclusion of mentioned fibers as reinforcement materials [2].

Due to the growing concern about the scarcity of natural resources, social actors have been forced to find more competent solutions, in order to improve the relationship between the productive sector and the environment. For a consistent evaluation, it is required to introduce such concern to every link of the production chain and extend it to the product's use and after-use stages. Understanding this new reality turns out to be a competitive factor for companies and countries, besides opening numerous business opportunities [3].

In the last decade there was a rapid development in the area of vegetable fiber-reinforced composites. Thanks to the cellulose fibers' low cost, low density, non-abrasiveness, non-toxicity and easiness to be modified by chemical agents, as well as to the fact of being generated from abundant and renewable sources, their use is advantageous [4].

The economical potential of polymer composites containing natural fibers is due to the possibility of trading carbon credits for the production chain, since they present themselves as being a potentially-profitable alternative to carbon fixation in nature, while also reducing CO_2 emissions into the atmosphere during its production cycle, processing and usage [5].

Polymers have, gradually, gained space in the automotive industry, having great improvement after the 80's due to the oil crises and the necessity of building more efficient, economical, safe and comfortable cars. The significant increase in the amount of polymers used in a car, which went up from about 66 pounds in the 70's, to about 396 pounds in the 90's [6].

This paper aims to introduce the pineapple leaf fiber as a technically feasible alternative, due to its favorable features for being used as reinforcement in a polymeric matrix and, also, for being environmentally friendly, since it represents, among other things, a better use of a vegetable residue.

2. MATERIALS AND METODOLOGY

The leaves of the pineapple (Figure 1) were supplied by producers located in the region of Guaraçaí, (in São Paulo State) and Cordeirópolis (in São Paulo State).

Figure 1: Pineapple Leaf Fiber (PALF)

The leaves remained for 48 hours in an oven at 50 °C for drying. Later some leaves were heated for 30 minutes in deionized water and were then taken to the ultrasonic bath during 60 minutes. The fibers were removed with the use of a spatula and the samples were encoded as FAN. Another part of the leaves was heated for 30 minutes in a solution of 10% of acetic acid and was, posteriorly, taken to the ultrasonic bath during 60 minutes. The fibers were removed with the use of a spatula and the samples were encoded as FAA.

After removal of the fibers, each of the two types of fibers (FAN and FAA) were separated into two groups. The fibers of the first group were washed in deionized water, subjected to ultrasonic bath (ultrasound) and dried (80 °C). The fibers of the second group have gone through the mercerization process, i.e., were submerged in a solution of 5 % of sodium hydroxide at room temperature for 1 hour, washed with deionized water until they reached pH 7 and dried (80 °C). The fiber samples were coded, as shown in Table 1.

Table 1: Encoding of the Samples of Pineapple Agricultural Waste Leaf Fiber (PALF)

Code	Description
1 - FAN	fiber obtained through natural defibration
2 - FAA	fiber obtained through defibration with acetic acid
3 - FANM	fiber obtained through natural defibration and mercerization
4 - FAAM	fiber obtained through defibration with acetic acid and mercerization

The characterization of the fiber was performed by evaluating the composition, structure and its mechanical and thermal properties.

3. RESULTS

3.1. X-Ray Fluorescence

As it is a natural fiber, the presence of carbon and oxygen contents is large, the goal of characterization using the technique of X-ray fluorescence was to evaluate possible variations in the chemical composition of the fiber considering the sampling point (Table 2).

Table 2: X-Ray Fluorescence - Pineapple Agricultural Waste Leaf Fiber (PALF)

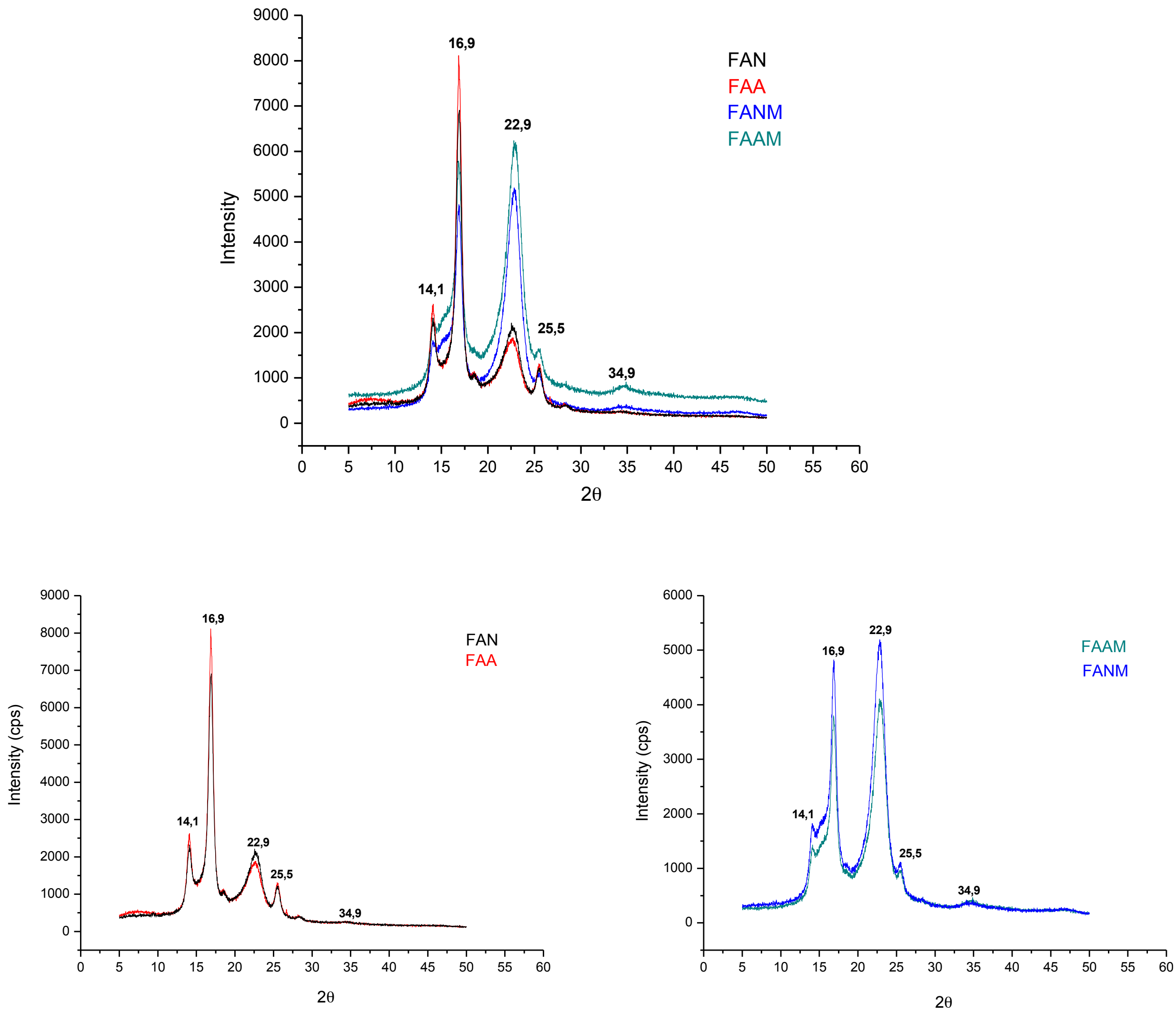
	1- FAN %	3 - FANM %	2 - FAA %	4 – FAAM %
Ca	53,772	55,736	43,876	55,02
K	18,940	16,032	15,297	20,172
Si	13,853	10,021	21,238	8,964
Fe	5,471	8,678	5,089	7,248
S	4,054	4,390	8,918	2,680

Mn	1,780	2,352	1,589	
Ni	0,293		1,539	3,213
Zn	0,810	1,301	1,357	1,211
Cu	0,720	1,124	0,864	1,184
Zr	0,324	0,367	0,235	0,300

Calcium (Ca), potassium (K) and silicon (Si) are the compounds that prevailed in all samples. The compositions presented were obtained with the use of a of Shimadzu EDC 900HS spectrometer.

3.2 X-ray diffraction

The results (Figure 2) indicate that the mercerization increased the peak observed at 22,9 °, which is within the characteristic range for cellulose, confirming that this treatment changes the structure of the material, indeed [7.8].



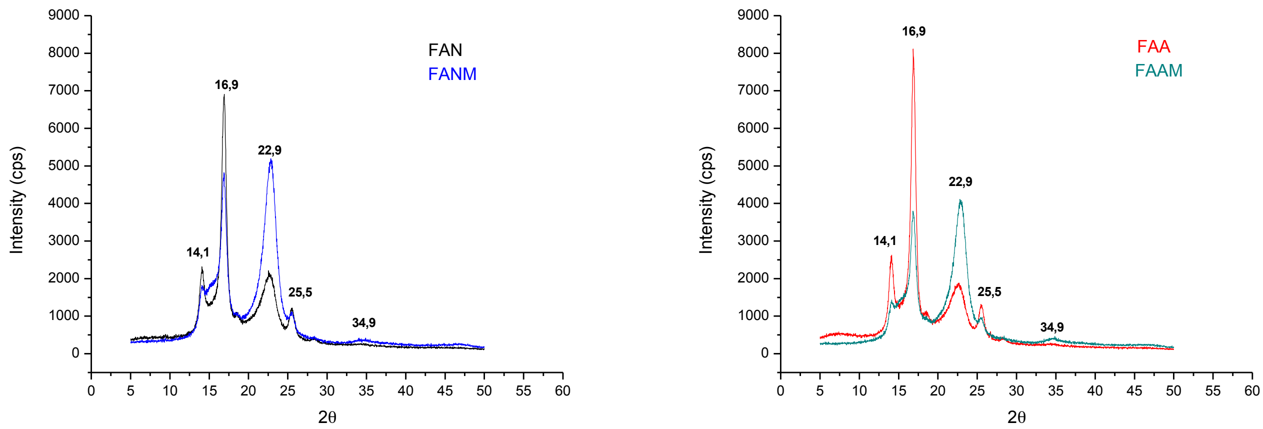
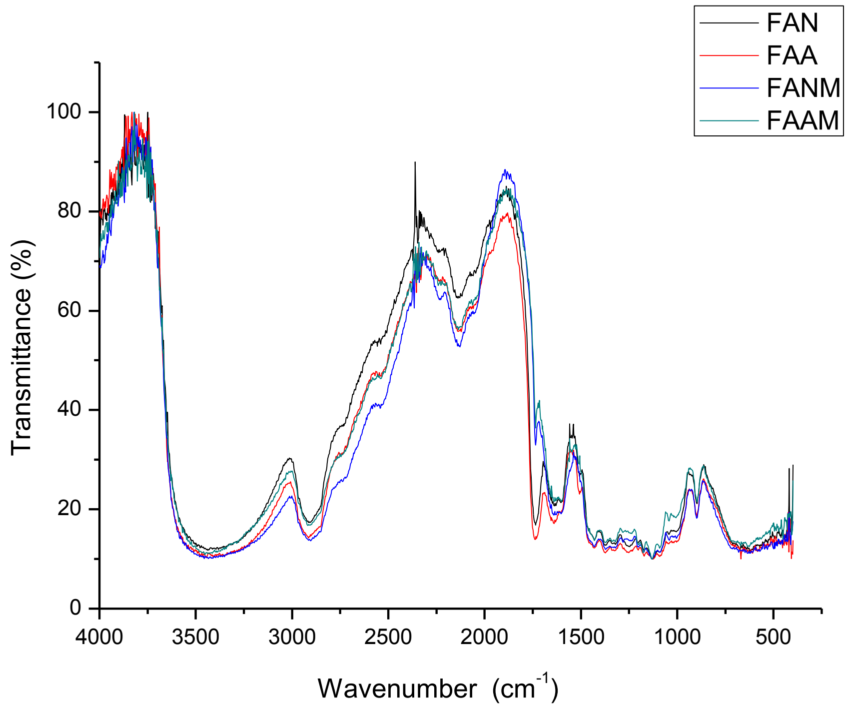


Figure 2: X-ray diffraction - Pineapple Agricultural Waste Leaf Fiber (PALF)

The treatment on the surface helps in the removal of amorphous materials and probable rearrangement of crystalline regions. The increase of crystallinity provides higher adhesion between the fiber and the polymer matrix [7,9].

3.3 Fourier Transform Infrared Spectroscopy (FTIR)

The analysis was performed in the average region, between 400 and 4000 cm^{-1}, which is where fundamental vibrational frequencies are present [10]. The spectra (Figure 3) disclosed characteristic elongations to the components of a natural fiber: cellulose (-OH), hemicellulose (C=O) and lignin (methoxyl-O-CH_3).



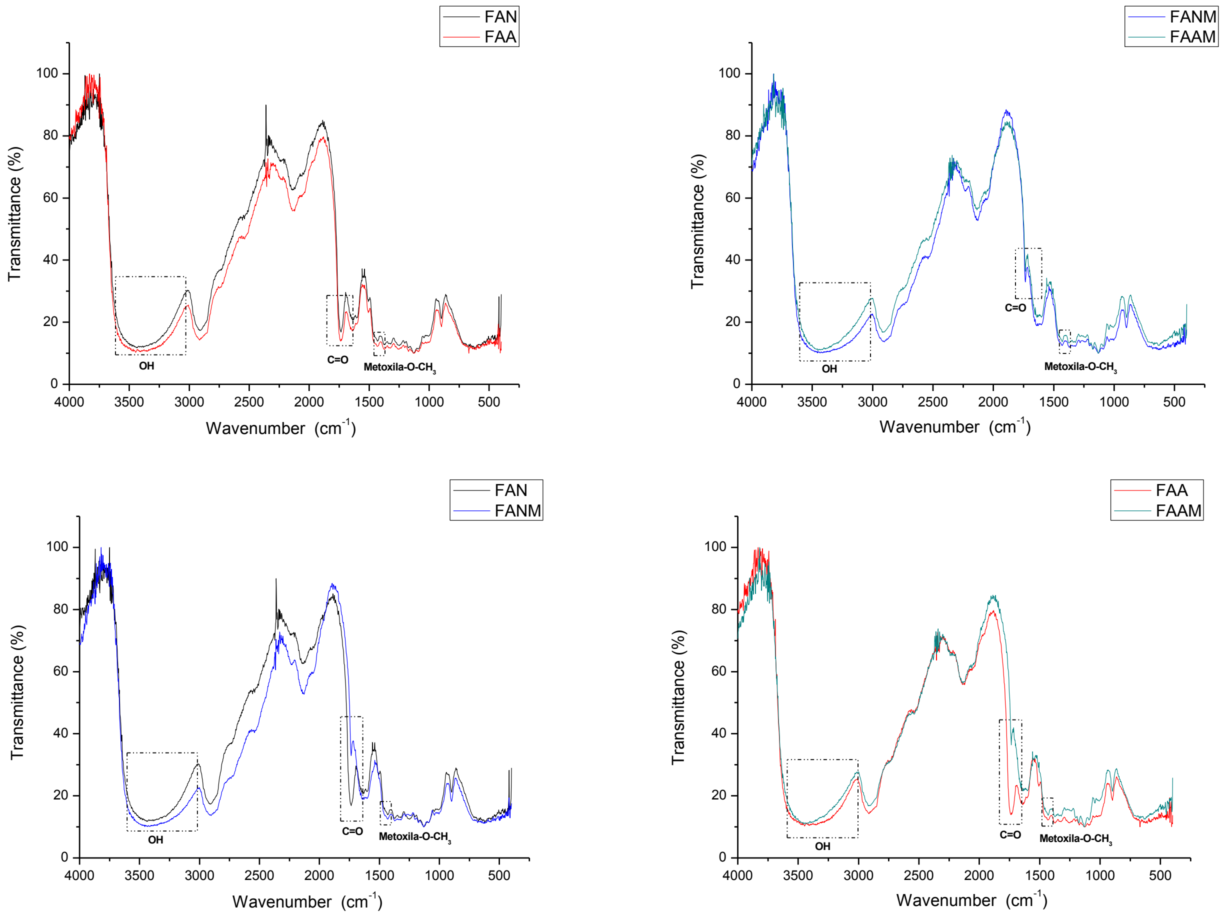


Figure 3: FTIR - Pineapple Agricultural Waste Leaf Fiber (PALF)

The strong, wide and rounded elongation observed between 3300-3500 cm^{-1}, which is a characteristic feature of the hydroxyl group (OH) vibration, is observed in fibers before and after treatment. The elongation observed at 1750 cm^{-1} is characteristic of the carbonyl (C=O) vibration, which was reduced after the mercerizing of the fiber. While the elongation observed, around 1430 cm^{-1}, characteristic for methoxyl, disclosed no significant differences after treatment [11].

3.4 Thermo-gravimetric analysis

The thermogravimetric analyses were performed under the following conditions: temperature ranging from 20 $^{\circ}$C to 700 $^{\circ}$C, nitrogen atmosphere, heating rate of 10 $^{o}C.min^{-1}$, 50 $mL.min^{-1}$ flow. Although the samples have been dried in ovens and kept in desiccators up to the moment of the analysis, due to the hydrophilic character of the vegetable fibers, the process of weight loss occurred up to the temperature of 100 $^{\circ}$C is attributed to the elimination of water from the sample, which evidences that the fibers obtained by defibration with acetic acid have retained more water than the fiber obtained through natural defibration (Figure 4).

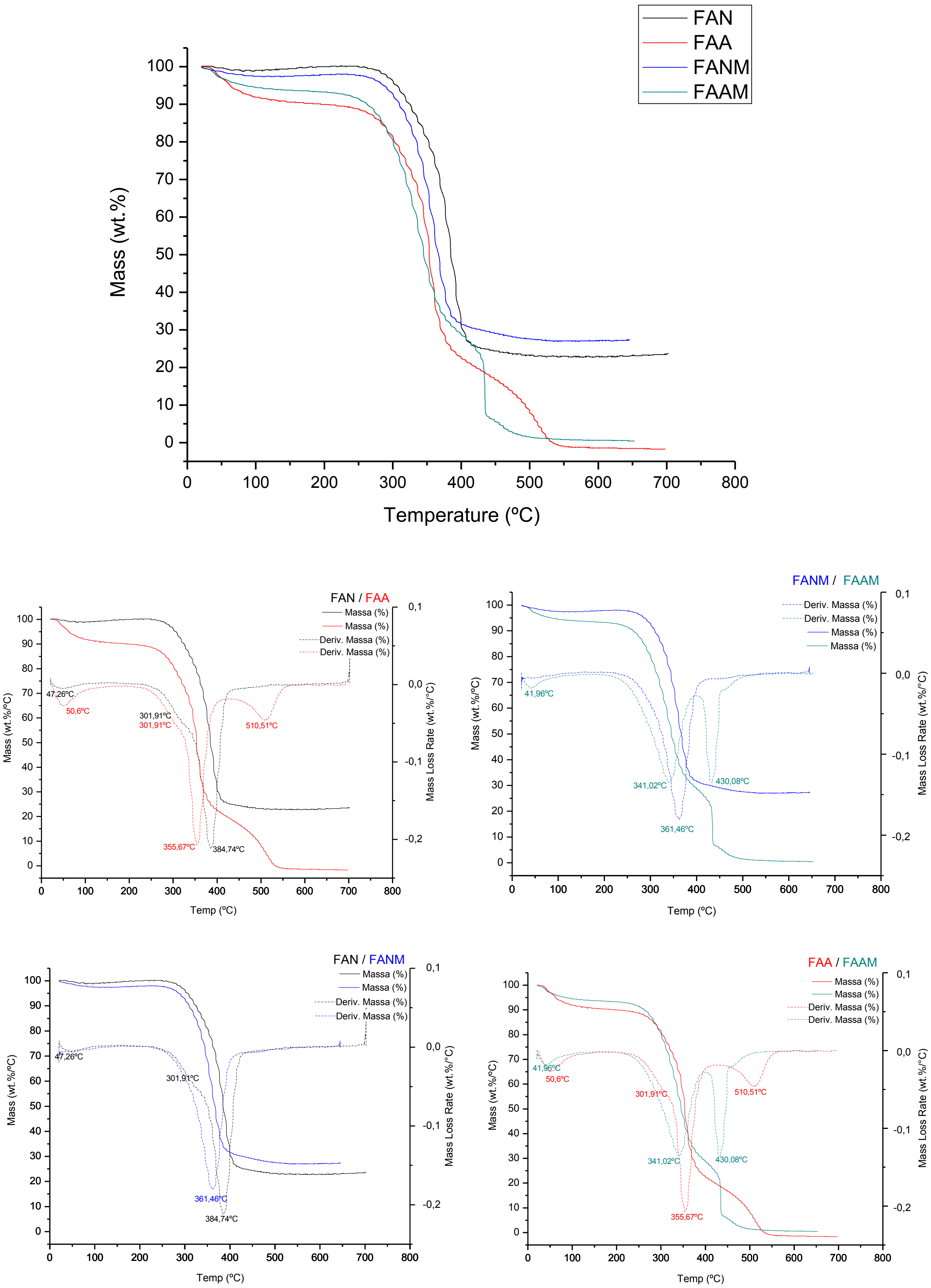


Figure 4: Thermogravimetric - Pineapple Agricultural Waste Leaf Fiber (PALF)

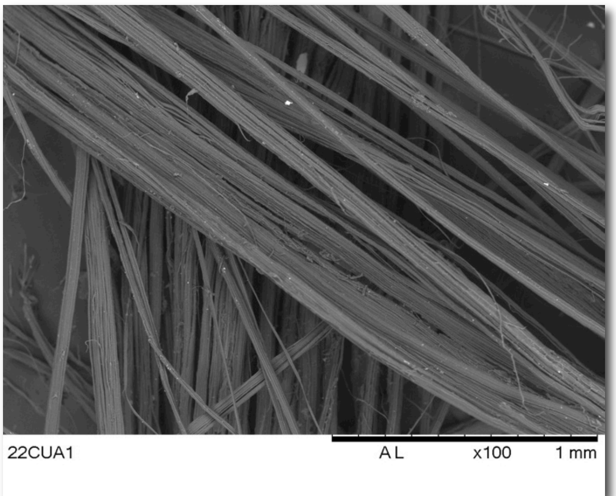
Previous to the mercerization, in both samples (FAA and FAN), the weight loss occurred around 225 and 330 °C with maximum decomposition at 301,91 °C, it is attributed to the process of decomposition of hemicellulose, the process of mass loss occurred around 330 and 435 °C with maximum decomposition at 355,65 °C for FAA and at 384,74 °C for FAN, it is attributed to the degradation of cellulose, the last clearly observed weight loss process in FAA, which occurred around 436 and 575 °C, with maximum decomposition at 510,51 °C, that can be attributed to the degradation of lignin.

After mercerization, in both fibers (FAAM and FANM), the degradation curve was displaced to the left, i.e., the fibers began to degrade at a lower temperature, while the fiber that was extracted without the acetic acid (FANM) revealed only the characteristic peak for cellulose, at 361,46 °C, while the fiber extracted with acetic acid (FAAM) presented two peaks, being the first at 341,02 °C, which is characteristic for cellulose, and the second at 430,08 °C, which can be attributed to the degradation of lignin, indicating that the acetic acid may have had its structure changed, making it more propitious to degradation.

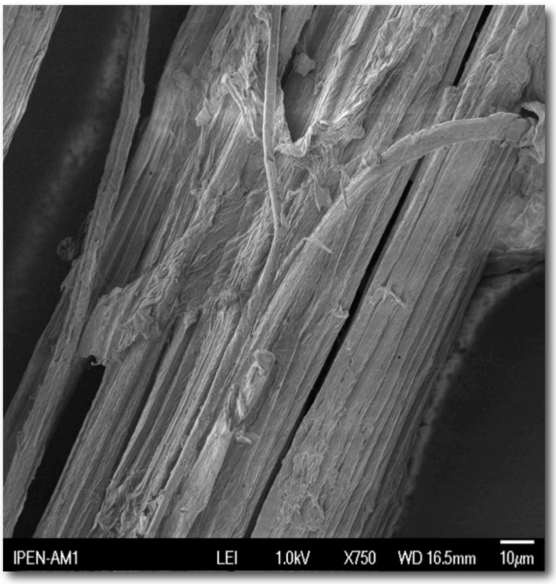
It is evident that the use of acetic acid for removal of the fiber was responsible for anticipating the decomposition and reducing the fiber thermal stability.

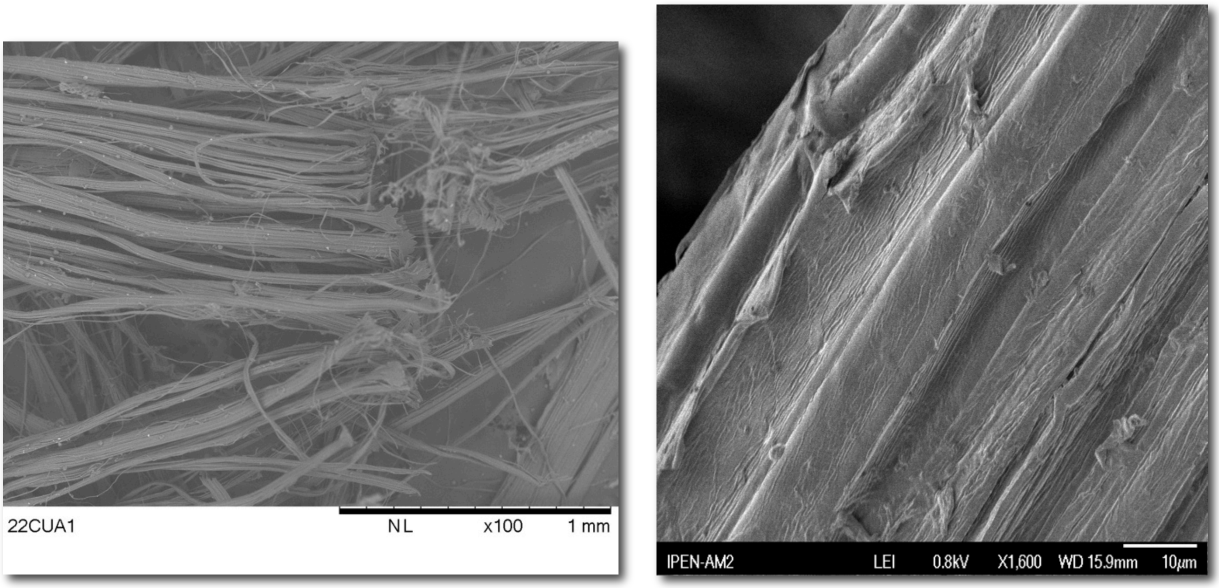
3.5 Scanning Electron Microscopy

The scanning electron microscopy allowed the morphological characterization of the fibers before and after mercerization. Through evaluation of the micrograph, Figure 5, no differences were observed between FAN (a) and FAA (b).



(a)

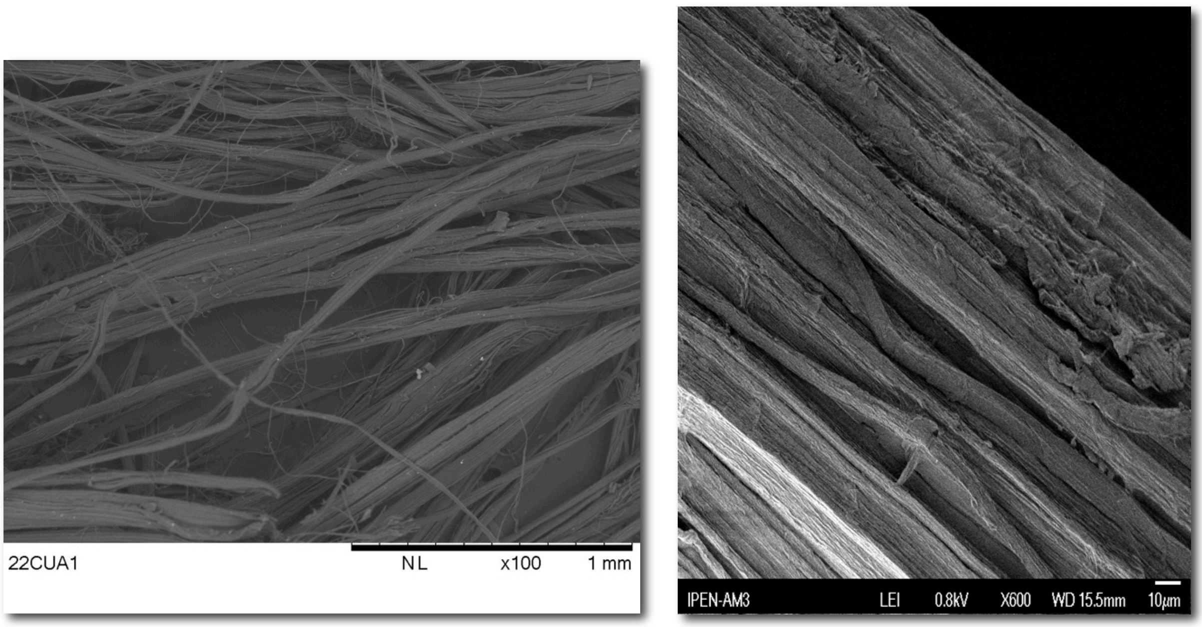




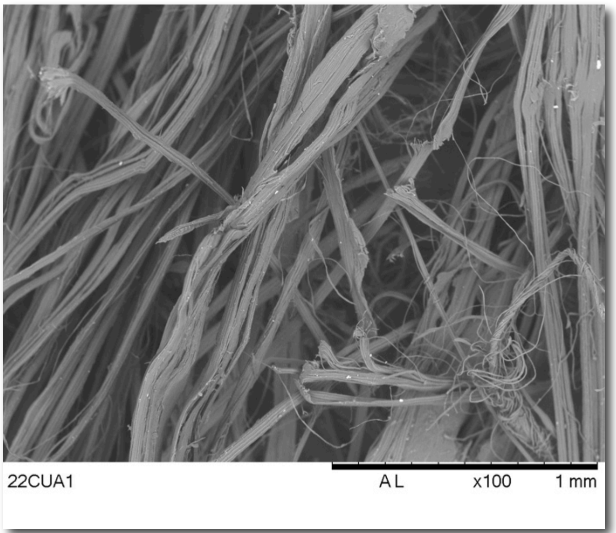
(b)

Figure 5: Scanning Electron Microscopy - Pineapple Agricultural Waste Leaf Fiber (PALF) a)FAN; b)FAA

The mercerization process worked as expected, since it promoted defibration of bundles and removal of surface impurities, as shown in Figure 6.



a)



b)

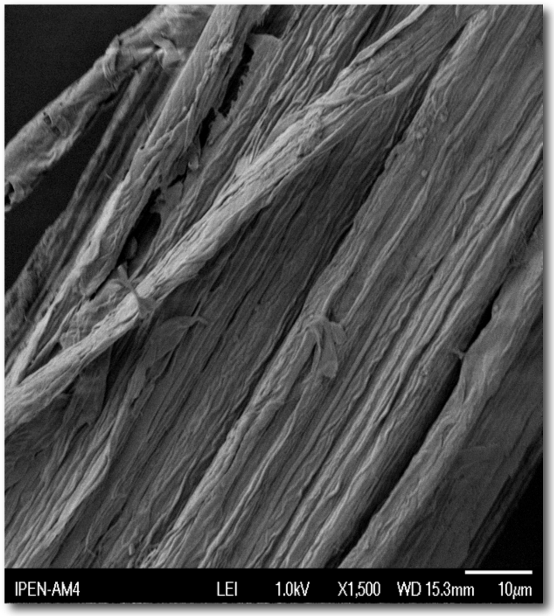


Figure 6: Scanning Electron Microscopy - Pineapple Agricultural Waste Leaf Fiber (PALF) a)FANM; b)FAAM

The micrograph images of the fibers, Figure 6, after mercerization, indicate the presence of more roughness in the fibers, which promotes their interaction with the polymeric matrix.

3.6 Helium Picnometry – Density

Results obtained indicate the fiber density values of the pineapple leaf might vary between 0.8 and 1.6 g/cm^3. In this test, for each fiber (FAN, FAA, FANM and FAAM), thirty (30) samples were tested, and the average result obtained is disclosed in Table 3 [12, 13].

Table 3: Density - Pineapple Agricultural Waste Leaf Fiber (PALF)

1 – FAN	3 – FANM	2 – FAA	4 – FAAM
1,51 g/cm^3	1,55 g/cm^3	1,78 g/cm^3	1,78 g/cm^3

3.7 Tensile Test

The results obtained (Table 4) indicate that the pineapple fiber is resistant and elastic. The average length of the fibers used in the test was 8 cm and 15 specimens were evaluated for each kind of fiber.

Table 4: Tensile Test - Pineapple Agricultural Waste Leaf Fiber (PALF)

		TENSILE STRENGTH (Mpa)	ELONGATION AT BREAK (%)	YOUNG'S MODULUS (GPa)
FAN	min	526,77	1,82	34,11
	max	1.521,78	4,95	69,86
	average	**954,84**	**3,05**	**49,29**
FAA	min	448,73	1,26	43,47
	max	2.185,12	4,43	92,90
	average	**1.025,09**	**3,08**	**59,76**
FANM	min	693,69	1,85	30,77
	max	1.872,96	5,86	94,62
	average	**1.212,68**	**3,36**	**63,45**
FAAM	min	487,75	1,37	54,26
	max	2.009,53	3,71	97,01
	average	**1.083,46**	**2,29**	**75,63**
PALF [16]	min	413,00	-	34,50
	max	1.627,00	-	82,51
	average	**1.020,00**	**1,60**	**58,51**

The mercerization leads to the decrease of the spiral angle and increases the molecular orientation, such changes as shown by the results obtained provide an improvement concerning the material elasticity (Young's modulus's)[14, 15, 16].

4. CONSIDERATIONS

The fibers extracted from the pineapple leaf showed satisfactory results for automotive application in all trials, and the fibers extracted without help from the acetic acid obtained better results in key criteria with higher crystallinity in the trial of x-ray diffraction, better thermal stability in the thermogravimetric test, the result of lower density result and a better performance in tensile test.

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