

# Mechanical Properties of the Palm Fibers Reinforced HDPE Composites

Daniella R. Mulinari, Araujo J. F. Marina, Gabriella S. Lopes

**Abstract**—Natural fibers are used in polymer composites to improve mechanical properties to replace inorganic reinforcing agents produced by non-renewable resources. The present study investigates the tensile and flexural behaviors of palm fibers-high density polyethylene (HDPE) composite as a function of volume fraction. The surface of the fibers was treated by mercerization treatments to improve the wetting behavior of the apolar HDPE. The treatment characterization was obtained by scanning electron microscopy, X-Ray diffraction and infrared spectroscopy. Results evidences that a good adhesion interfacial between fibers-matrix caused an increase strength and modulus flexural as well as tensile strength in the modified fibers/HDPE composites when compared to the pure HDPE and untreated fibers reinforced composites.

**Keywords**—Mechanical properties, palm fibers, polymer composites, surface treatment.

## I. INTRODUCTION

NATURAL fibers like coconut, palm, hemp coir, sugarcane bagasse, and sisal have all been proved to be good reinforcement in thermoset and thermoplastic matrices and being using in automotive applications, construction as well as packaging industries with few drawbacks [1]-[3]. These fibers are mainly made of cellulose, hemicelluloses, lignin and pectin's, with a small quantity of extractives. Compared to glass fiber and carbon fibers, natural fibers provide many advantages, such as, abundance and low cost, biodegradability, flexibility during processing and less resulting machine wear, minimal health hazards, low density, desirable fiber aspect ratio, and relatively high tensile and flexural modulus [4]. However, the natural fibers present some drawbacks, such as the incompatibility between fibers and polymer matrices, the tendency to form aggregates during processing and the poor resistance to moisture, reduce the use of natural fibers as reinforcements in polymers [5]. On the other hand, there are several methods of surface modifications to improve fibers and polymer matrices compatibility, which can be physical or chemical according to modification technique to reduce the hydrophilic character.

Alkali treatment of fibers, also called mercerization, is the common method to improve the adhesive characteristics of the

fiber surface by removing natural and artificial impurities, thereby producing a rough surface topography. Moreover, alkali treatment provides fiber fibrillation, i.e. breaking down of the composite fiber bundle into smaller fibers. In others words, alkali treatment reduces fiber diameter and thereby increases the aspect ratio [6]. In this context, it was evaluated the effect of the surface treatments of the palm fibers by mercerization on the mechanical properties of the composites with high density polyethylene matrix.

## II. METHODOLOGY

### A. Materials

Palm fibers were manufactured by Biosolvit. Fibers were dried at 100°C for an hour, and after being ground in a mill, finally sieved to obtain a sample that passed through a 45 mesh. High density polyethylene (HI-60070) obtained BRASKEN was used as matrix.

Palm fibers (100g) were treated with 1L alkaline solution containing 10 g sodium hydroxide (10% w/v), for an hour under constant stirring at room temperature. Once the time of treatment the solution was filtered in a vacuum filter and fibers were washed with distilled water until neutral pH was attained. Then, fibers were dried in an oven at 50°C for 24 hours.

### B. Characterization of the Fibers

The palm fibers in nature and treated was evaluated by scanning electron microscopy (SEM), X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR).

The fibers morphology was evaluated in a JEOL JSM5310 scanning electron microscope with a tungsten filament operating at 10 kV, employing the low vacuum technique and secondary electron detector. Samples were dispersed on a brass support and fixed with double-sided 3M tape.

X-ray diffractograms were obtained in a Shimadzu diffractometer model XRD6000. Conditions used were: radiation  $\text{CuK}\alpha$ , tension of 30 kV, current of 40 mA and 0.05 (2 $\theta$ / 5 s) scanning from values of 2 $\theta$  it enters 10 to 70° (2 $\theta$ ). CI (degree crystallinity) was calculated as the ratio of the intensity differences in the peak positions at 18° and 22° according with method studied for [7].

Spectra were obtained on an FTIR spectrophotometer (Perkin Elmer). Samples were prepared by mixing the materials and KBr in a proportion 1:200 (w/w). For all spectra, 16 scans were accumulated with a 4  $\text{cm}^{-1}$  resolution.

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### C. Preparation Composites

The treated and in nature palm fibers were mixed with the polymeric matrix (HDPE) in a thermokinetic mixer model MH-50H, with the speed rate kept at 5250 rpm, in which fibers were responsible for 5 and 20 wt% of the composition. After mixing, composites were dried and ground in a mill model RONE. Then, sugarcane palm fibers/HDPE composites were placed in an injector chamber at 200°C and heated at a 2°C/min rate. The melted material was injected in required dimensions in a pre-warm mold in order to obtain tensile and flexural specimens.

### D. Mechanical Properties

Composites were analyzed in an EMIC testing machine (model DL2000), equipped with pneumatic claws. In the tensile tests, five specimens of composites were analyzed, with dimensions in agreement with the ASTM D 638 standard. In the flexural tests, five specimens were analyzed with dimensions in agreement with the ASTM D 790 standard.

## III. RESULT AND DISCUSSION

### A. Fibers Characterization

Figs. 1 and 2 present SEM micrographs of in nature and modified fibers. Examination of the in nature fibers (Fig. 1) shows a large amount of extractives.

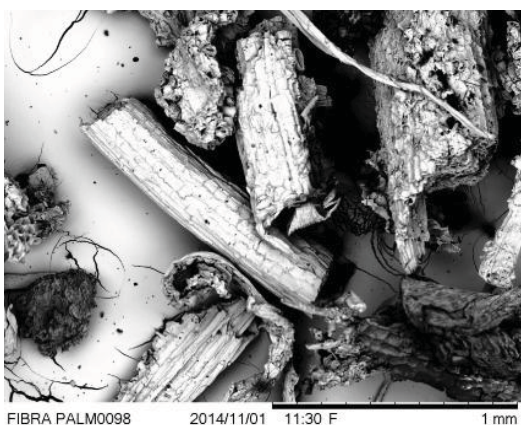


Fig. 1 SEM of the in nature fibers 100X

After the treatment on palm fibers was observed the removal of these extractives on surface fibers (Fig. 2). It was observed an increase in the roughness of fibers, which contributes with the increase of the adhesion between fibers and matrix. Fig. 2 shows the presence of pits arranged along the entire cell wall, which are circular holes about diameter 1  $\mu\text{m}$ . These pits are responsible for transporting water and nutrients throughout various cells to the roots and leaves, and are hidden on the surface fibers, with the treatment occurred the layer removal and pits are revealed.

The presence of pits and globular marks after treatment are important for an increase in the effective surface area and a higher increase of the roughness, with a consequently improving mechanical bonding with the polymeric matrix [6].

These dates can be confirmed by X-ray Diffraction technique. Fig. 3 evidences the X-ray diffractograms of palm fibers treated (a) and untreated (b). It presents two peaks, which are well defined. The presence of these diffraction peaks indicates that the fiber is semicrystalline. These two peaks situated at  $2\theta = 15.4^\circ$  and  $2\theta = 22.5^\circ$  can be attributed to cellulose I and IV. These two peaks are attributed to the (2 0 0) and (1 1 0) crystallographic planes, respectively. According with the method Segal, fibers untreated and treated showed 29% and 35% of crystallinity, respectively.



Fig. 2 SEM of the treated fibers 100X

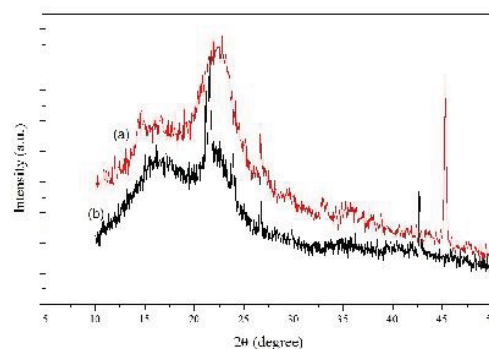


Fig. 3 X-ray diffractograms of the palm fibers treated (a) and untreated (b)

Fig. 4 shows infrared spectra of palm fibers treated (a) and untreated (b). The most visible differences between the spectra of untreated (b) and treated (a) palm fibers are the modifications of the signal at  $2885\text{ cm}^{-1}$  and  $1732\text{ cm}^{-1}$ , characteristics of the stretching of symmetrical CH groups and stretching of unconjugated CO groups present in polysaccharides and xylans. Considering the first region, the ratio between intensity of the C-H stretching band ( $\sim 2900\text{ cm}^{-1}$ ) is lower in the spectrum of the pre-treated palm fibers than observed for the in nature palm fibers. On the other hand, at the second region it may be observed modifications, especially in the ratio between the intensities of the C=O stretching band ( $\sim 1730\text{ cm}^{-1}$ ).

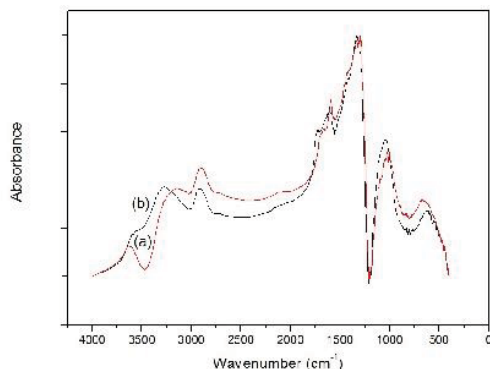


Fig. 4 FTIR spectra of palm fibers treated (a) and untreated (b)

### B. Mechanical Properties

The use of fibers in composites can be considered as the first step for a possible use effective reinforcement. Of this way, it is necessary to evaluate the degree of improvement in fiber quality obtained by chemical treatments, aimed at removing non-structural matter, such as pectin and wax. The composites reinforced with modified fibers exhibited better tensile strength and modulus compared to the composites reinforced with in nature fibers, confirming that modification on palm fibers improves the adhesion between fibers and matrix (Fig. 5).

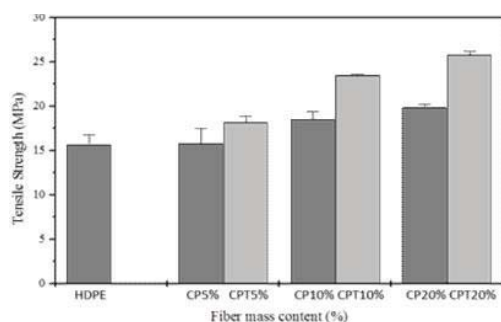


Fig. 5 Tensile strength of in nature (CP) and treated (CPT) palm fibers/HDPE composites

Analyzing the data of the graphics in Fig. 5, it is possible to observe that values of tensile strength increased for composites reinforced with modified fibers, while they decreased for composites with in nature. Values of tensile modulus increases with the addition of modified fibers as can be seen observed in Fig. 6. Composites with 20% (wt/wt) of fibers modified resulted in an increase of approximately 79% in the tensile modulus values, when compared with pure HDPE.

Due to more brittle character of reinforced composites, a decrease in the values of elongation at break was observed, especially for those samples reinforced with modified fiber. The decrease in elongation at break according to the amount of fiber and chemical treatment can also be seen in Fig. 7.

Similar behavior was observed in tests flexural. It is found that the flexural properties are gradually increased with increasing fiber mass content from 5% to 20% (Figs. 8 and 9).

This result may reflect a better fibers-matrix interaction under the compressive stresses developed in part of the transverse section of the specimens during bending for whatever the surface condition of the fibers.

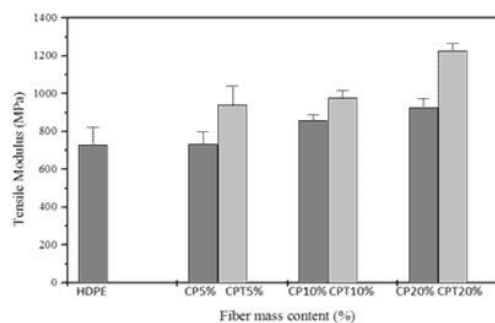


Fig. 6 Tensile modulus of in nature (CP) and treated (CPT) palm fibers/HDPE composites

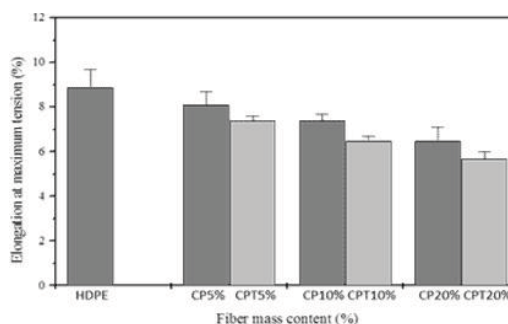


Fig. 7 Elongation at maximum tension of in nature (CP) and treated (CPT) palm fibers/HDPE composites

The modified fiber/HDPE composites yielded higher mean flexural properties compared to pure HDPE and the in nature ones. This demonstrates the contribution of sodium hydroxide in enhancement of fiber-matrix adhesion. Compared to pure HDPE, modified fiber/HDPE composites at 5 to 20% (wt/wt) fiber mass content exhibited 12%, 58% and 74% enhancement in flexural strength and 49%, 67% and 95% in flexural modulus, respectively.

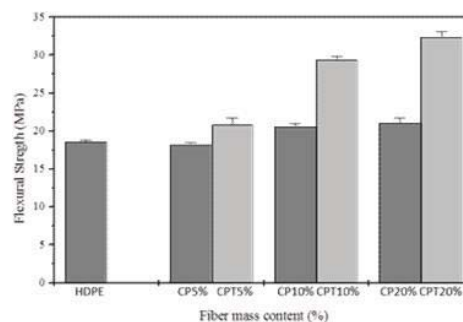


Fig. 8 Flexural strength of in nature (CP) and treated (CPT) palm fibers/HDPE composites

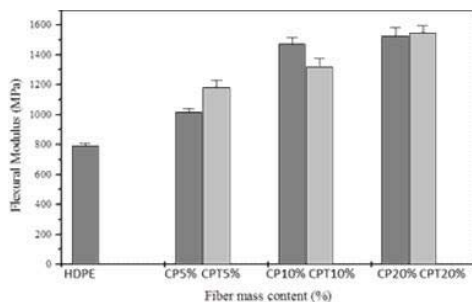


Fig. 9 Flexural modulus of in nature (CP) and treated (CPT) palm fibers/HDPE composites

#### IV. CONCLUSION

Alkali treatment of palm fibers surface was effective for removing extractives and increasing the roughness, crystallinity and functional groups. The effects of modification of the fibers were assessed on the basis of morphology, infrared spectra and X-Ray diffraction. The addition of fibers in HDPE matrix was found to increase strength and modulus flexural as well as tensile strength. The modified fibers reinforced composites exhibited higher flexural modulus and tensile strength if compared to the pure HDPE and in nature fibers reinforced composites.

#### ACKNOWLEDGMENT

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