ISSN: 2415-6620
Vol:9, No:7, 2015

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.

Mulinari, Daniella R. is with the Engineering Department , Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil (phone: +55 24 999651617; e-mail: dmulinari@hotmail.com).

de Araujo, Marina J. F. is with the Centro Universitário de Volta Redonda, Rio de Janeiro, Brazil (phone: +55 24 998572121; e-mail: marina_jfa@hotmail.com).

Lopes, Gabriella S. is with the Centro Universitário de Volta Redonda, Rio de Janeiro, Brazil (phone: +55 24 9981469402; e-mail: gabriella.slopes@gmail.com).

II. Methodology

A. Materials

Palm fibers were manufactured by Biosolvit. Fibers were dried at 100oC for an hour, and after being ground in a mill, finally sieved to obtain a sample that passed thought 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^{o}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 diffractrometer model XRD6000. Conditions used were: radiation CuKα, tension of 30 kV, current of 40 mA and 0.05 (2θ/ 5 s) scanning from values of 2θ it enters 10 to 70º (2θ). CI (degree crystallinity) was calculated as the ratio of the intensity differences in the peak positions at 18º and 22º 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 cm^{-1} resolution.

International Journal of Chemical, Materials and Biomolecular Sciences
ISSN: 2415-6620
Vol:9, No:7, 2015

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.

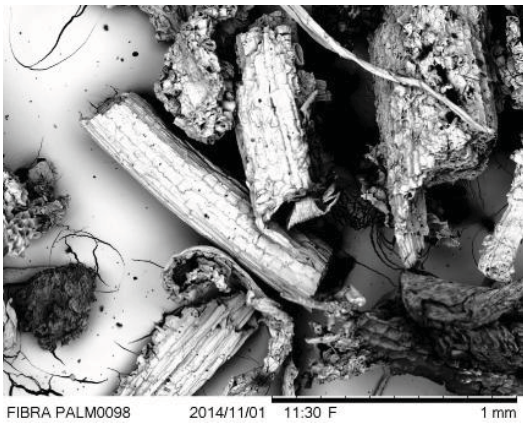

Fig. 1 SEM of the in nature fibers 100X

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 μm. 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 $2\theta = 15.4^o$ and $2\theta = 22.5^o$ 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

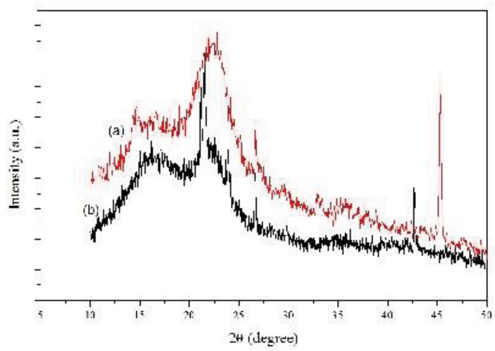

Fig. 3 X-ray diffractograms of the palm fibers treated (a) and untreated (b)

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 cm^{-1} and 1732 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 (~2900 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 (~1730 cm^{-1}).

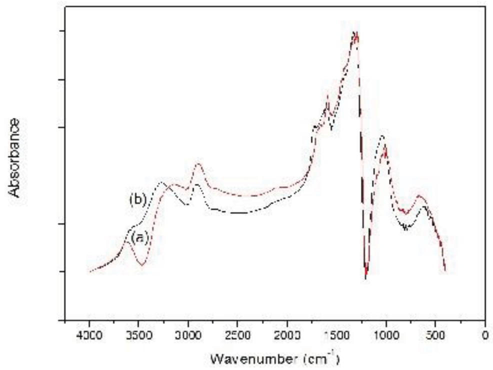

Fig. 4 FTIR spectra of palm fibers treated (a) and untreated (b)

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).

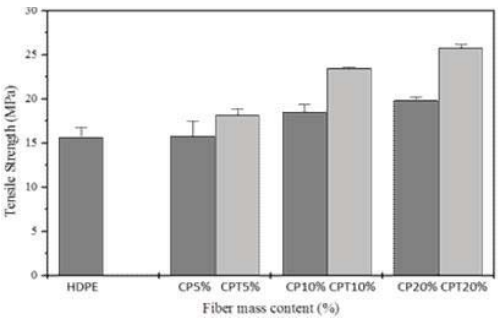

Fig. 5 Tensile strength of in nature (CP) and treated (CPT) palm fibers/HDPE composites

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.

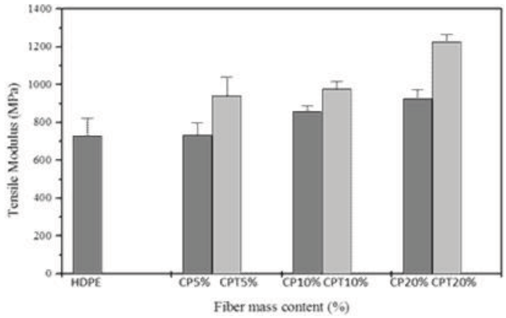

Fig. 6 Tensile modulus of in nature (CP) and treated (CPT) palm fibers/HDPE composites

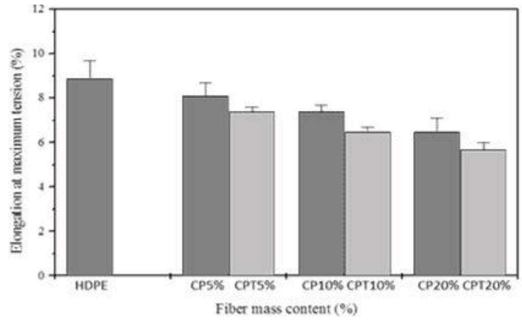

Fig. 7 Elongation at maximum tension of in nature (CP) and treated (CPT) palm fibers/HDPE composites

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.

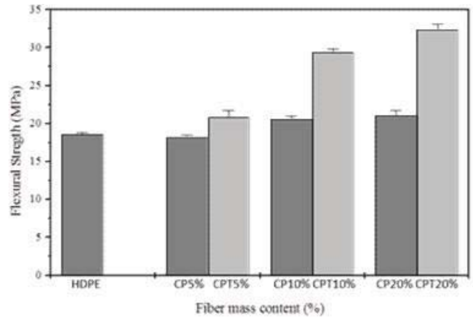

Fig. 8 Flexural strength of in nature (CP) and treated (CPT) palm fibers/HDPE composites

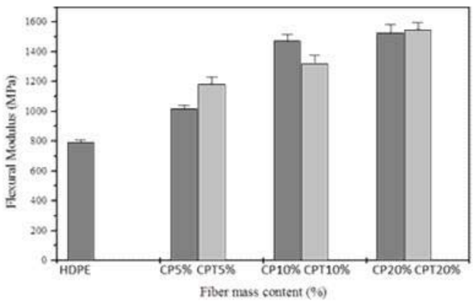

Fig. 9 Flexural modulus of in nature (CP) and treated (CPT) palm fibers/HDPE composites

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

The authors thank FAPERJ (Processes E-26/201-481/2014 and E-26/010-002016/2014) for financial assistance granted.

References

[1] L.Q.N. Tran, "Understanding the interfacial compatibility and adhesion of natural coir fibre thermoplastic composites, "*Compos Sci Technol*, vol.80, May. 2013, pp. 23-30.

[2] D. Dai and M. Fan, "Wood fibres as reinforcements in natural fibre composites: structure, properties, processing and applications". *Natural Fibre Composites*, 2014, pp. 3-65.

[3] A. El-Sabbagh "Effect of coupling agent on natural fibre in natural fibre/polypropylene composites on mechanical and thermal behavior". *Compos Part B*, v.57, Feb. 2014, pp.126-135.

[4] U. Nirmal, "Effect of betelnut fibres treatment and contact conditions on adhesive wear and frictional performance of polyester composites", *Wear*, vol.268, no. 11-12, May. 2010, pp. 1354–1370.

[5] A. K.. Bledzik, P. Franciszczak; Z. Osman and M. Elbadawi. "Polypropylene biocomposites reinforced with softwood, *abaca*, jute, and kenaf fibers". *Industrial Crops and Products*, v.70, Aug. 2015, pp.91-99.

[6] H. Gu, "Tensile behaviours of the coir fiber and related composites after NaOH treatment", *Mater Design*, vol.30, Oct. 2009, pp. 3931-3934.

[7] L. Segal; J. Creely; A. E. Martin Jr. and C. M. Conrad, "An empirical method for estimating the degree of crystallinity of native cellulose using the X-ray diffractometer", *Textile Research Journal*, v.29, Oct. 2009, pp.786–794.

Mulinari, Daniella R. was born in the city of Volta Redonda, Rio de Janeiro, Brazil, on 31st March 1978 having completed Industrial Chemical Engineering at the Engineering School of Lorena/USP in 2003. She has master's degree in Chemical Engineering at the Engineering School of Lorena/USP in 2005 and a PhD in Mechanical Engineering at the Paulista State University Julio de Mesquita Filho. And now a professor at the State University of Rio de Janeiro and the University Center of Volta Redonda, acting on Graduation and Post Graduation.

Has experience in the area of Chemical and Materials Engineering with emphasis in Materials Engineering, mainly in the following topics: Polymeric Composites, Sustainable Energy, Polymer Processing, nanocomposites, adsorption Heavy metals, thermal analysis and mechanical properties. How Interest Research areas are in Composite Materials Development area and in the Materials and Sustainable Technologies Development area. She published the following main articles and books: "Use of the Sugarcane Bagasse in Thermoplastics and Thermosetting Composites" (Sugarcane: Production, Cultivation and Uses, 2012), "Composites of Thermosetting Polymers Reinforced with Natural Fibers" (Composites of Thermosetting Polymers Reinforced with Natural Fibres, 2013), "Lignocellulosic Polymer Composites: Processing, Characterization and Properties" (Lignocellulosic Polymer Composites: Processing, Characterization, and Properties, 2014), "Chemical Modification Effect on the Mechanical Properties of HIPS/Coconut Fiber Composites" (Bioresources, 2010), "Mechanical Properties of Coconut Fibers Reinforced" (Procedia Engineering, 2011). The research areas of interest are in Composite Materials Development area and in the Materials and Sustainable Technology Development area.

Dr. Mulinari is a member of the Structural Teaching Nucleus of Design Course, Production Engineering, Biological Sciences (2011-Present), is also a Member of the Institutional Development Plan (2011-Present). She was honored in 2011 with the Best work of the Accessibility area focusing on Engineering, Information Technology, Architecture and Urbanism, National .

Araujo, Marina J. F. was born in the city of Volta Redonda, Brazil, on 10th April 1996. She completed high school in 2012 in the Anglo-American School in Volta Redonda, Rio de Janeiro, Brazil. She is currently a undergraduate student in Environmental Engineering at the University Center of Volta Redonda, Brazil.

She worked as a Junior Student Researcher in 2012, Scientific and Technological Initiation Student during the years 2013 and 2014.

Currently working on Technological Initiation Student function in the University Center of Volta Redonda, Brazil. She has publications in conference proceedings, such as: XXV Young Scientist Award 'Sustainable Cities' (Brasilia, Federal District: Roberto Marinho Foundation, 2011) and also in Brazilian Science and Engineering Fair (Sao Paulo, Sao Paulo: EPUSP, 2013). Her areas of expertise and interest are waste management, environmental management, composting, natural fibers, polymers and applications. Ms. Araujo was honored in 2013 with the title of "Most Outstanding exihibit in Materials Science", by The ASM Materials Education Foundation, in addition to the 1st place in the category Single Project-Engineering, at the Brazilian Science and Engineering Fair - FEBRACE. In 2011, she was honored with the 3rd position at the XXV Young Scientist Award in the Category 'High School Student', and also at the II Inova VR Award with the 1st place of the category high school student.

Lopes, Gabriella S. has degree in Production Engineering from the University of the State of Rio de Janeiro (2011), Brazil. She has experience in Production Engineering with emphasis in Production Management. It is currently a graduate student in materials at the University Center of Volta Redonda, Brazil.