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ScienceDirect

Procedia Engineering 10 (2011) 2034–2039

Engineering Procedia

ICM11

Mechanical Behaviour of Polypropylene Reinforced Palm Fibers Composites

Goulart, S.A.S.[a]; Oliveira, T.A.[a]; Teixeira, A.[a]; Miléo, P.C.[b]; Mulinari, D.R.[a]

[a]Department of Engineering – UniFOA, Volta Redonda/RJ, Brazil
[b]Biotechnology Department, EEL/USP, University of São Paulo, Lorena/SP, Brazil

Abstract

Nowadays, a great attention has been dedicated to natural fibers as reinforcement for polymers. Natural fibers, compared to glass fibers, exhibit better mechanical properties, such as stiffness, impact strength, flexibility and modulus. However certain 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 these natural fibers as reinforcements in polymers. Several treatments and modifications are being used to improve fibers/matrix compatibility, such as bleaching, acetylation and use coupling agent. In this work, the effect of coupling agent in the palm fibers/ PP composites was evaluated on mechanical behaviour. Palm fibers were mixed with the polymeric matrix (PP) in a thermokinetic mixer, with speed rate maintained at 5250 rpm, in which fibers were responsible for 5 wt% in the composition. When the coupling agent was used, the proportion of PP was 95 wt% and the coupling agent was 5 phr. After the mixture, composites were dried, ground in mill and placed in an injector camera according to ASTM D-790 specification. Results showed that, the addition of coupling agent in the composites improved significantly the flexible strength and modulus when compared to the pure polymer.

Keywords: Polyprolpylene; Palm Fiber; Composites; Natural Fibers; Mechanical Behaviour

1. Introduction

Recently, the composites reinforced with filler have received crescent interest from industries for application in components with individual mechanical properties.

* Corresponding author. Tel.: +55 2433408400 ; fax: +55 24 33408308 .
E-mail address: shane.goulart@foa.org.br

 doi:10.1016/j.proeng.2011.04.337

Reinforcement of polymer matrix using inorganic fillers is widely used, resulting in materials with excellent mechanical and thermal properties [1]. Natural fibers reinforced polymer composites represent one of today's fastest growing industries. Possessing mechanical properties comparable to those of manmade fibers such as carbon, glass or aramid, natural fibers are a potential alternative in reinforced composites because of growing environmental awareness and legislated requirements [2]. These fibers have gained significant importance in technical applications, such as the automotive industry. Additionally, they are obtainable from renewable sources, are biodegradable, low cost, and low specific density [3,4].

Brazil has a large range of natural resources, including natural fibers from several sources, curaua, banana, coconuts, sisal, cotton, sugarcane bagasse [5,6] and palm. Palm diversity is greatest in tropics and subtropics, where palms are of immense ecological and economic importance. The heart-of-palm, also known as palmito, can be extracted from various species of palms. Archontophoenix alexandrae, commonly known as King Palm, produces heart-of-palm of noble type, with higher quality and superior flavor compared to other species of palm. However, a lot of residue is generated from this cultivation [7]. The residue constitutes 80-90% of the total palm weight, with some variation depending on species [8]. The residues from king palm constitute mainly of leaves and leaf sheathes.

Thermoplastic polymers are materials thoroughly used in emergent technologies having low processing cost and density, among other properties such as transparency and possibility of recycling [9]. Polypropylene (PP) was the thermoplastic used in this work, being a semi-crystalline polymer with various industrial applications [10], but it is also a commodity polymer by the low cost, low level of mechanical resistance, processing facility and larger production [11]. Therefore, the combination of lignocellulosic material with thermoplastic matrix can present a considerable problem: incompatibility between the polar and hygroscopic fiber and the non-polar and hydrophobic matrix. Because of this, the chemical modification of natural fibers or the use of coupling agent is beneficial in order to improve interfacial adhesion.

The aim of this study is to investigate the effects of fibers surface treatment (coupling agent) on the mechanical characteristics of PP-composites obtained by injection molding process utilizing the residual fibers obtained after the king palm processing. The fibers were characterized by techniques of X-Ray Diffraction and Scanning electron microscopy (SEM) in order to evaluate the composition of the fibers. The mechanical properties of the King Palm/PP composites were obtained.

2. Experimental

2.1. Materials

Palm fibers residues were collected in a farm, localized in Volta Redonda (Rio de Janeiro, Brazil). These residues were dried and milled. Polypropylene (PP) was provided, as pellets, by BRASKEM (Triunfo, Brazil). Its melting temperature, degree of isotacticity and density at room temperature were 173 0C, 93–98% and 0.905 g.cm^{-3}. Maleic anhydride grafted polypropylene (Polybond® 3200) MAPP was provided by Crompton-Uniroyal Chemical.

2.2. Fibers Characterization

Physical structures of the palm fibers were evaluated by X-ray diffraction technique. 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 to equation 1 [12],

$$CI = I_{22} - I_{18} / I_{22} \quad (1)$$

where I_{22} is the maximum intensity of the 002 lattice reflection of the cellulose I and I_{18} is the maximum intensity of X-ray scattering broad band due to the amorphous part of the sample.

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

2.3. Composites processing

A thermokinetic mixer MH-50H model was used to mix compound palm fibers residues, polypropylene (PP) and maleic anhydride grafted polypropylene (MAPP). Composites were formulated with 5 wt% of palm fibers. When the coupling agent was used, the proportion of PP was 93 wt% and the coupling agent was 2 wt% (Table 1). After mixing, composites were cooled with water and after that, ground to 13 mm. Composites were dried in an oven at 80 °C for 3 h and injected directly in a mold with specific dimensions for impact and flexural specimens.

Table 1. Formulation of the composites in weight percentage.

Samples	PP	Fibers	MAPP
PP	100	----	----
Fiber 5%/PP composite	93	5	2

2.4. Mechanical properties of composites - Flexural tests

Composites were analyzed in an EMIC testing machine (model DL2000), equipped with pneumatic claws. In the flexural tests, a load was applied on the specimen at 1.3 $mm.min^{-1}$ crosshead motion rate. Five specimens were analyzed with dimensions in agreement with the ASTM D 790 standard: 25 mm width, 76 mm length and 3.2 mm thickness. The adopted flexural test was the 3-points method.

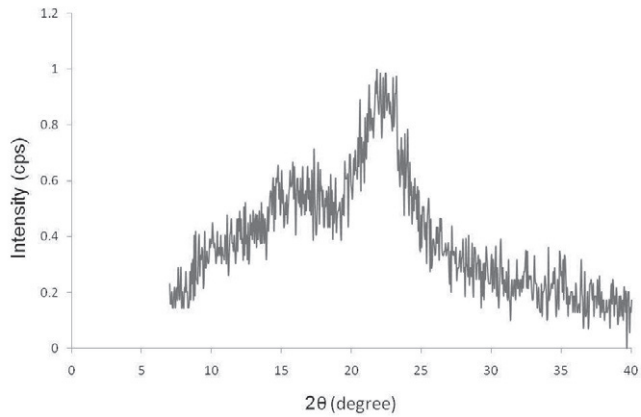

Figure 1. X-Ray diffraction of palm fibers

3. Results and Discussion

3.1. X-Ray diffraction

The crystallographic in nature of fibers was investigated by X-ray Diffraction. Figure 2 show the diffractogram for the king palm fibers, these fibers has characteristics of semicrystalline material. A major diffraction peak was observed for 2θ ranging between 22° and 23°, which corresponds to the cellulose crystallographic planes (0 0 2).

X-ray diffraction peaks for the material can be attributed to crystallinity scattering, whereas the diffuse background can be attributed to disordered regions. According to this method, fibers showed 29% of crystallinity.

3.2. Scanning electron microscopy (SEM)

SEM is an excellent technique for examining the surface morphology of palm fibers. The longitudinal and cross section surface of palm fibers are presented in Figure 2, where it can be observed on the external surface of the cell wall the presence of lignocellulosic material, hydrophobic non-cellulose compounds (such as waxes) and surface impurities. These compounds constitute a protective and smooth layer on the surface of the fibers. It is also possible to observe a superficial layer of parenquima cells. As a consequence, this surface forms weak bonds at the interface between the fibers bundles and the polymeric matrix of the composite.

3.3. Mechanical properties of composites – Flexural tests

The flexural modulus is related to the material rigidity, as can be observed in Table 2, the Young's modulus was higher for the composites when compared to the pure matrix. If the fibers are well distributed and aggregated to the matrix, a higher flexural modulus for the material can be obtained. For the composites obtained in this work, the flexural modulus increased compared to that of the neat polypropylene.

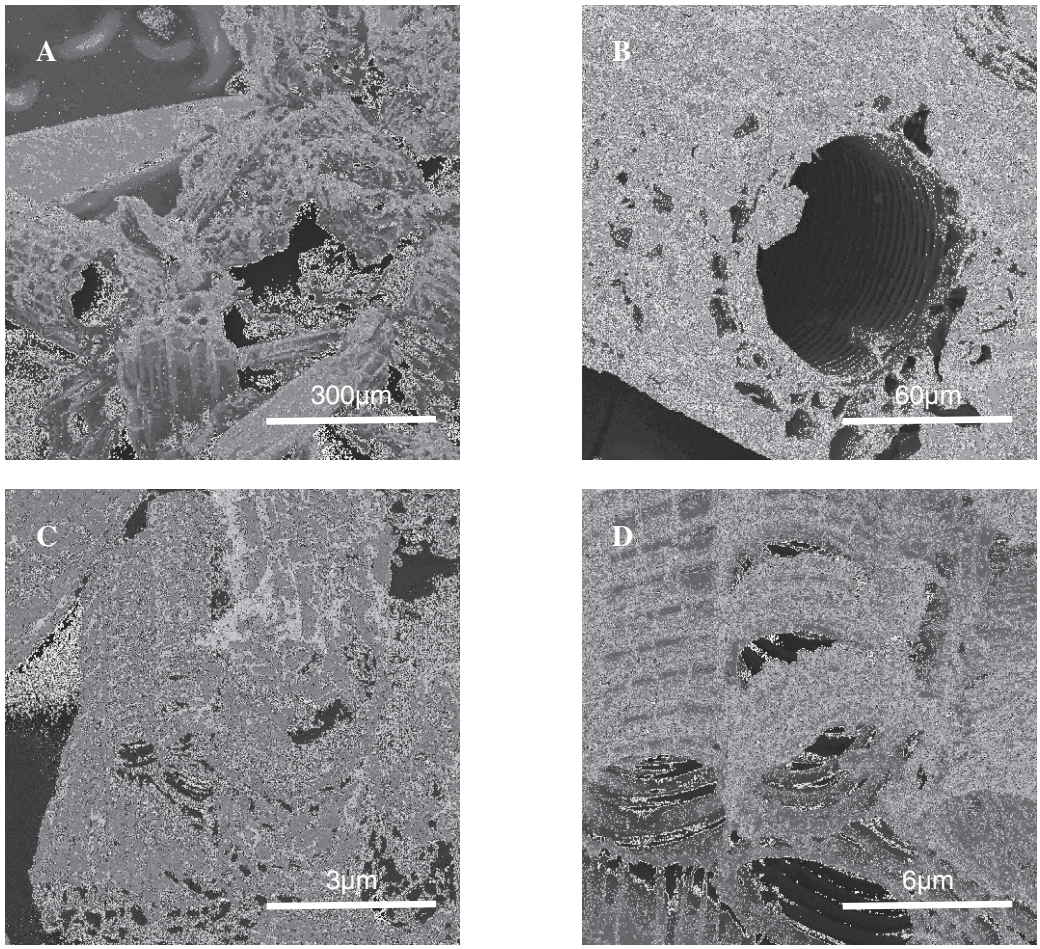

Figure 2. SEM of palm fibers cross section (A) and (B) and longitudinal (C) and (D).

Better performance of composites is attained due to homogeneous distribution of fibers in the matrix, as a result the stress transference between fibers and matrix is more effective, affecting positively the performance.

Table 2. Flexural strength of Palm fibers/Polypropylene Composites

Samples	Flexural strength (MPa)	Flexural modulus (MPa)
Pure Polypropylene	22.6 ± 0.6	641.2 ± 20.9
Fiber 5%/PP composite	24.4 ± 0.9	783.7 ± 83.6

4. Conclusions

Research on biodegradable polymer composites containing lignocellulosic fibers is generating increasing attention due to the dwindling petroleum resources, low costs of lignocellulosic reinforcements with a variety of properties and increasing ecological considerations. In this work, results revealed that the addition of coupling agent in the palm fibers reinforced polypropylene composites is a promising process, as the addition of fibers to the matrix improved the flexural strength and modulus when compared to the pure polypropylene.

Acknowledgements

Authors are grateful for the research support by CAPES and FAPESP.

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