

NATURAL FIBER IN POLYMER COMPOSITES

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Abstract. *The use of natural fibers as reinforcement for thermoplastics has generated much interest due to their low cost, possibility of environmental protection and use locally available renewable resources. In this research the thermal and mechanical properties of composites were evaluated based on natural fiber reinforced in polymers. Natural fibers offer some advantages over synthetic ones, regarding mechanical and thermal properties. The composites were produced by mixing high density polyethylene with cellulose fibers (30%) using an extruder. The tensile specimens were produced by cutting sheets obtained in a hydraulic press. Mechanical properties showed that the composites did not have good adhesion between fiber and matrix. It was observed the presence of blisters and thermal stability of the cellulose fibers in polymeric matrix was also affected. Mechanical properties are in accordance with those of commercial materials. Fracture surface analysis indicate that the composites did not have good adhesion between fiber and matrix.*

Keywords: *sugarcane bagasse, cellulose fibers, composites.*

1. INTRODUCTION

In recent years, natural fiber composites have found an increasing number of applications [Torres and Cubillas, 2005; Stael *et al.*, 2001; Alvarez *et al.*, 2006, Georgopoulos *et al.*, 2005]. These composites have shown special interest in automotives for interior components as such seat frames, side panel and central consoles [Li *et al.*, 2000; Mwaikambo and Ansell, 2002]. The advantages of natural fibers are low-cost, low density and high specific properties. Another important advantage of natural fibers is that they are biodegradable and nonabrasive, unlike other reinforcing fibers. Also, they are readily available and their specific properties are comparable to those of other fibers used for reinforcements. The main disadvantages of natural fibers are low permissible processing temperatures, their tendency to form clumps, and their hydrophilic nature.

Some works were developed using thermoplastic/natural fibers, which showed excellent results in some application areas, especially for interior components in automotives [Dash *et al.*, 2000]. Thermoplastics such as polyethylene (PE) [Bonelli *et al.*, 2005], polypropylene (PP) [Sain *et al.*, 2004] and poly(vinyl chloride) (PVC) [Martins *et al.*, 2004] have been compounded with natural fibers (such as sisal, jute, sugarcane bagasse) to prepare composites.

Among the agro-industrial residue diverse, sugarcane bagasse is detached for be a residue widely generated in high proportions and contains cellulose (46.0%), hemicellulose (24.5%), lignin (19.95%), fat and waxes (3.5%), ash (2.4%), silica (2.0%) and other elements (1.7%) [Sene *et al.*, 2002]. Bagasse is a vegetable fiber mainly constituted by cellulose, that is a glucose-polymer with relatively high modulus, often found as fibrillar component of many naturally occurring composites (wood, sugarcane straw and bagasse) in association with lignin [Pandey *et al.*, 2000].

Fibers and thermoplastic matrix can be placed together in contact in the forms of polymer solution, polymeric films, polymer in powder or granules, using methods as extrusion, compression and injection molding [Curvelo *et al.*, 2001; Chiellini *et al.*, 2001].

High-density Polyethylene (HDPE) was the thermoplastic polymer used in this work, being a semi-crystalline polymer and an important engineering thermoplastic with various industrial applications [Bonelli *et al.*, 2005; Albano *et al.*, 2005; Lei *et al.*, 2007], but it is also a commodity polymer by the low cost, low level of mechanical resistance, processing facility and larger production [Lei *et al.*, 2007]. Therefore, the combination of lignocellulosic material with thermoplastic matrix can present a considerable problem due to incompatibility between the polar and hygroscopic fiber and the non-polar and hydrophobic matrix. The possible solution for this problem has been studied through the chemical modification of fibers due to the presence of hydroxyl groups, very reactive and susceptible to chemical reactions. Non-polar groups can be inserted in the fibers, resulting in hydrophobic characteristics compatibles with thermoplastic matrices [Ma *et al.*, 2005].

Recent studies in respect to mechanical behavior of reinforcement fibers in composites show that these materials can present structural and non-structural applications. The synergetic characteristics of composite materials depend on the initial characteristics of the reinforcement or the matrix [Khalil *et al.*, 2001]. Damage in the composites is associated to matrix crack, failed interfacial bond between fiber and matrix, fiber break and delamination.

In this work, the mechanical and thermal characteristics of HDPE composites obtained by extrusion molding processes and hydraulic press utilizing the bagasse cellulose as reinforcement, will be evaluated.

2. EXPERIMENTAL

The sugarcane bagasse was kindly furnished by DEBIQ/EEL/USP (Brazil); the bagasse was washed, dried and milled at particles < 1 mm. Cellulose from sugarcane bagasse was obtained by pulping with 10% sulfuric acid solution (reactor of 350 L at 120 °C, 10 min), followed by centrifugation with the purpose of separating the rich pentosanes solution. Extracted lignocellulosic fraction was deslignificated with 1% NaOH solution (reactor of 350 L at 100 °C, 1 h) being obtained the crude pulpe and bleached with sodium chloride, as described by Rocha [2000]. The bleached cellulose dry in a store at 50 °C, 12 h.

Afterwards, was carried the mixture of cellulose fibers with the polymeric matrix (HDPE) in an extruder, marks INACOM (Figure 1), in the following composition: 70% HDPE/30% cellulose fibers. The respective temperatures for the four different processing zones from the hopper to horizontal die of the extruder were set as 140/160/180/200 °C and the screw speed rate was maintained at 4 rpm.



Figure 1- Extruder utilized in mixture of the materials (cellulose fibers/HDPE) composites.

High-density Polyethylene (HDPE) material presented in granules (EI-60070), was kindly furnished by Riopol (Brazil).

From the processed material plates in the dimensions 15 cm x 15 cm were obtained using hydraulic press during 2 min to 5.000 Kgf and 150 °C (Figure 2).



Figure 2. Sheet obtained in a hydraulic press.

The cellulose/HDPE composite plates were cut in the necessary dimensions for the mechanical tests (tensile) as shown in Figure 3. Five specimens of composites were analyzed, with dimensions in agreement with the ASTM D 3039 standard.



Figure 3. Cutting sheets obtained of the cellulose fibers cellulose/HDPE composites.

Composites were tested, at room temperature in an Instron universal machine (model 8801), equipped with pneumatic claws at a cross-head speed of 2 mm.min⁻¹.

Materials were also analyzed by thermogravimetry (TG/DTG). Measurements were obtained in a Shimadzu thermogravimetric instrument model TGA-50. Thermal behavior for each one of the preparations was studied by recording the TG/DTG curves between 40-800°C rates under nitrogen atmosphere using weighted samples between 5-10 mg with a heat rate of 20°C min⁻¹ in N₂ atmosphere.

3. RESULTS

The composites obtained by hydraulic press showed a homogeneous distribution of the fibers in the matrix. However, the distribution in the plate was not uniform. The press action is from up to down and the shorter fibers easily penetrated into the melted polymer. Other problem found in the composite was the presence of many blisters also present in the high density polyethylene plate. Tensile strenght results are shown in Table 1.

Table 1. Tensile strenght of the material.

Materials	Tensile strength (MPa)	Tensile modulus (MPa)
High density polyethylene (HDPE)	31.10 ± 1.36	698.2 ± 17.1
Cellulose fibers (30%)/HDPE composites	26.63 ± 0.95	683.6 ± 244.7

It was observed that the cellulose fibers/HDPE composites presented a poor interaction between cellulose fibers from sugarcane and polymeric matrix (HDPE). The amount of added reinforcement did not contribute to the variation of the tensile modulus (Table 1). The fibers insertion can contribute to the modulus increase, because the Young's modulus of the fibers is higher than the thermoplastic modulus. However, to obtain a significant increase, a good interfacial bond between fiber and matrix is necessary [Luz *et al.*, 2007].

The TG analysis confirm these results. TG/DTG curves obtained are presented in Figure 4. Curve A corresponds to pure cellulose, curve B to high density polyethylene (HDPE), and curve C to the cellulose fibers/ HDPE composite. Pure cellulose present two decomposition steps: first at 300°C corresponds to degradation temperature and second one at 380°C corresponds to the completed decomposition temperature. High density polyethylene (HDPE) presents one decomposition peak with maximum at 502°C. Cellulose fibers/HDPE composite shows two different steps: one at 275°C and the other around 389°C. The first peak can be assigned to the degradation of fibers and the second one is related to the decomposition of the HDPE matrix.

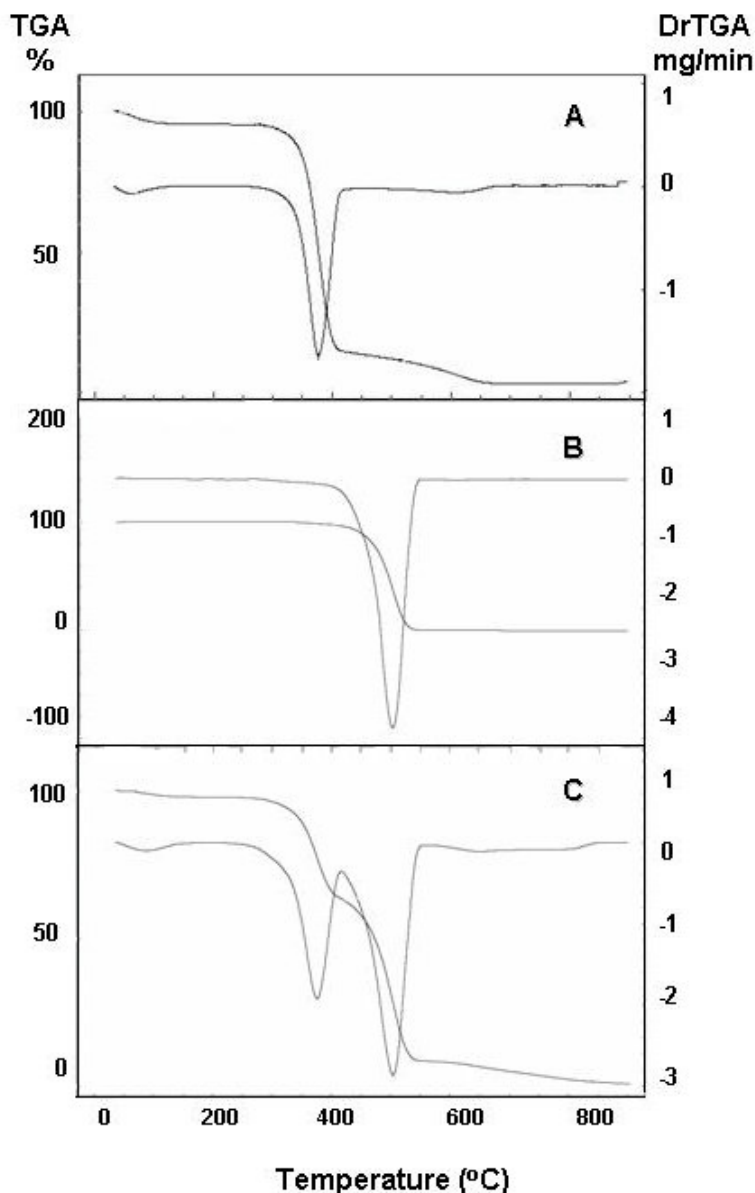


Figure 4. TG/DTG curves obtained for raw material at 20°C min⁻¹.

Table 2 shows the values of the temperatures of maximum mass loss obtained by the differential curve for the cellulose fibers, matrix and cellulose fibers/HDPE composite.

Table 2. TG/DTG curves of materials, in the respective temperatures of maximum mass loss obtained by the differential curve (dm).

Materials	dm (°C)
Cellulose Fibers	62
	378
	613
HDPE	502
Cellulose fibers/HDPE	89
	376
	504.5

Analyzing the table it is possible to observe that the thermal stability of high density polyethylene (HDPE) decrease with the presence of cellulose fibers from sugarcane bagasse, indicating that the degradation process is influenced by the presence of cellulose fibers.

4. CONCLUSIONS

The molding process using extrusion and hydraulic press, was not the appropriate considering that the fibers were not distributed homogeneously and the presence of blisters. The blisters and/or the non-homogeneity of the fibers are defects in the material that directly interfere in the mechanical properties, harming the obtainment of a material with high resistance. The composites did not present, in general, a good interfacial contact between fiber and matrix. Therefore the mechanical and thermal properties of the obtained composites are comparable to the commercial material.

5. ACKNOWLEDGEMENTS

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