

EVALUATION OF THE PROPERTIES OF POLYPROPYLENE / BANANA FIBRE BIOCOMPOSITES.

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ABSTRACT - A new bio-composite was developed by adding banana tree fibres to a polypropylene matrix. Banana fibre was chosen due to its abundance and relative low cost. The physical, chemical, mechanical and thermal properties of the bio-composite were investigated. The material was characterized using the following tests; Izod impact resistance, tensile strength, hardness, specific weight and differential scanning Calorimetry (DSC). The banana fibres (BF) were extracted from pseudostem of banana tree and mixed with a thermoplastic polypropylene (PP) compound in the proportions of 90/10% (PP/BF), 80/20% (PP/BF) e 70/30% (PP/BF) by weight, using an extrusion process to prepare the samples. The properties were compared with PP (100%). The composites made of PP matrix containing banana fibre showed an improvement in impact properties as well as specific weight and thermal conductivity. Chemical and thermal stability also improved.

1. INTRODUCTION

Polypropylene (PP) is a very important semi crystalline thermoplastic for technological applications due to its strength, excellent melt processability, fast crystallization, low density, good mechanical properties and high thermal stability. Polypropylene has a long-term durability against environmental degradation and may experience some biodegradability if mixed with natural fibres (Xiaofei *et al.*, 2008; Howard, 2002). The difficulty of synthetic polymer materials to degrade led to the development of sugar biopolymers. (Howard, 2002). However the mechanical properties of biopolymers are inferior to synthetic polymers for the majority of the commercial applications. Composites are very singular materials as they distribute the properties of all components. The most used materials for reinforcement of polymer composites by the plastic industry are natural fibres and minerals (Park *et al.*, 2008). In the last decade a huge emphasis has been made on the fabrication and use of polymer natural fibre composites instead of synthetic fibres such as glass fibre, carbon fibre, Kevlar amongst others mainly because of costs and the environmental impact these materials cause (Barcellos *et al.*, 2009; Martinelli, 2008).

Biodiversity allows an enormous amount of natural vegetable fibre options that could be used in polymer composites. Furthermore vegetable fibres are renewable resources with a high potential to modify thermoplastic. The most common are; sisal, jute, curaua, coconut, sugar cane bagasse, wood powder and banana tree fibre. Kaemple *et al.* (2002) observed that PP natural fibre composites require special preparation of the fibres prior impregnation into the matrix.

The aim of this work was to develop a new composite with some degree of biodegradability and good mechanical properties. To reach the objective banana fibre pseudo stem was selected due to its high abundance and low cost.

2. EXPERIMENTAL

2.1 Fibre Preparation

The fibre used was from the banana plant pseudostem supplied by Cooperativa Musa Brazil. The extraction of the natural fibre from the plant requires care so as to avoid fibre damage. Sections were cut from the banana plant main stem which were subsequently lightly rolled to remove excess moisture. Excess impurities in the form of pigments, broken fibres and cellulose coating were removed by means of a manual comb. The fibres were then cleaned with hypochlorite, dried, milled and sieved. The fibres were then cut with a pair of scissors to the size of 10cm, grounded by electric mill Retsch ZM 1000 to the range of 200-120 mesh, finally the samples were placed in to an oven at 110°C during 60 min and transferred to a desiccator.

2.2 PP/FB Composites Preparation

The polymer used was polypropylene (PP) and was provided by Sasil Com. Ind. Petroquímica LTDA. The composite material preparation was carried out by dispersing the fibre (BF) previously prepared in to the PP matrix at 160 °C, under agitation during 15 min using manual extruder. PP/BF were blended at different wt/wt ratio as follow; 100/0, 90/10, 80/20 and 70/30. After extrusion the material was transferred to moulds to obtain 7 specimens for each composition for each test according to the ASTM D 638-77 (American Society for Testing and Materials) for tensile strength and ASTM D256-78 (American Society for Testing and Materials) for impact test. For the other experiments the specimens were cut to the size of 128x100x3mm from plates of the composite, following methodology from the literature (Selke, 2007).

3. RESULTS AND DISCUSSION

DSC curves of PP homopolymer and the polymer composites 90/10 (PP/BF), 80/20 (PP/BF) and 70/30 (PP/BF) are shown in Figure 1 and the values of relevant thermodynamic parameters are summarized in Figure 1. The PP sample and composites samples, 90/10 (PP/BF), 80/20 (PP/BF), 70/30 (PP/BF) shown one endothermic peak at 143,9 °C; 148,4 °C; 147,4 °C and 144,8 °C, respectively. The thermal stability was on the range of -85 to 400 °C. The thermal stability is related to the absence of degradation pick in the thermograms. It was not detected characteristic discontinuity on the Tg value.

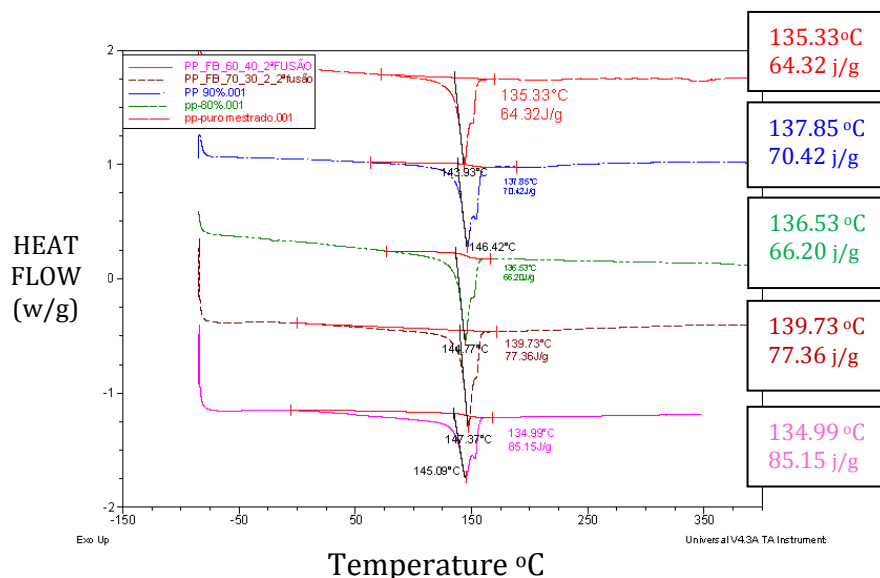


Figure 1 - DSC thermograms of PP, 90/10% (PP/BF), 80/20% (PP/BF) and 70/30% (PP/BF).

The melting temperatures (T_m) shown in table 1 do not change by much with the banana fibre addition. The small change in ΔH values may indicate poor interaction between fibre and the PP matrix. Joseph *et al.* (2003) reported the thermal properties of sisal, polypropylene and their composite. The lignin present in the sisal fibre was degraded in temperatures in the range of 60 to 200 °C and the cellulose decomposed at 350 °C. The PP pure decomposed at superior temperature in relation to the sisal fibre. The composite showed higher thermal stability than that of the sisal fibre or pure PP. In this study the results were different probably because sisal is richer in cellulose fibre than the pseudo stem of banana plant.

Table 1 - Thermal analysis of banana pseudstem fibre and PP composites (PP/BF)

PP/FB (%)	Melting Point (°C)	Enthalpy change (ΔH) J/g
100/0	135.3	64.32
90/10	137.8	70.42
80/20	136.5	66.20
70/30	139.7	77.33

PP decomposed at 398°C, which was higher than the fibre. An interesting finding was the fact that the composites degraded later than the PP pure, indicating that the thermal stability of the composite is higher than pure PP. This increased stability of composite

compared to literature results for sisal fibre may be due to the latter presents improved fibre–matrix interaction as suggested by George *et al.* (1996). The DTG curves obtained in the study further confirmed the superior thermal stability of such composites. In sisal/PP composite two peaks were obtained: a minor peak at 368 °C which corresponds to the degradation of cellulose and a major peak at 476 °C which corresponds to the degradation of cellulose. The initial peak was higher than the individual values of sisal which have the starting peak at 65 °C followed by another at 350 °C. The composite peak had a slightly lower value of individual starting peak of PP at 400 °C, but majority of the degradation for the composite was at 476 °C which was a significant improvement over the constituents. Thus the thermal stability was improved for PP–sisal composite. This indicates that the flammability of the PP–sisal composite would be less than the PP pure.

The figures 2 and 3 show the chemical stability of the samples. The composite 70/30 (PP/BF) presented higher values of mass loss and consequently has lower chemical stability, approximately 10%. For all the other samples the mass loss was smaller than 2% in all medium used, except by the 80/20 (PP/BF) composite in acidic solution that presented mass loss of 3.8%.

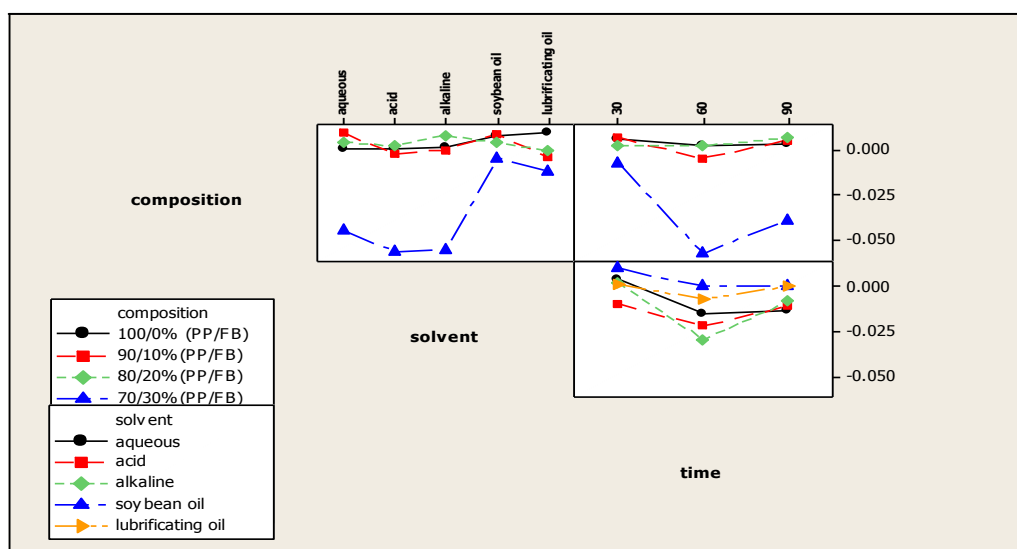


Figure 2 - The main effects of mass loss of the samples studied.

The mass loss values for the samples 100/0, 90/10 e 80/20 (PP/BF) were very close together. The only sample that showed considerable mass loss was 70/30 (PP/BF) in aqueous, acidic and alkaline medium during 60 days and presented low mass loss in edible and lubricating oils during 30 and 80 days of immersion. The fact that the chemical stability. Was good in oils shows important characteristics for application in packaging.

The results of the toughness test for pure PP and all composition of banana fibre are presented in the table 2. It is observed that the addition of banana fibre up to 20% in to the PP matrix increases the toughness of the material in relation to the value of pure PP. When the composition of the fibre riches 30% it was noticed that the toughness decreased. This

behaviour may be explained due to difficulty of homogeneously distribute the banana fibre in to the polymer compromising the toughness test result (Shibata, et al, 2005). The interface between the fibre and the polymer matrix is very important in the mechanical properties of the composite. The interface physical bond on the molecular arrangement and the chemical proprieties of the fibre and matrix (Ichazo *et al.*, 2001). Murkhopadhyay *et al.* (2008) studied the influence of sisal fibre on the toughness resistance of the composite for both sisal as received or sisal chemically treated the resistance results were very similar with the as received fibre being slightly higher. The increase of toughness resistance is related to the plasticizing effect at the interface banana fibre/ PP matrix (Rohlmann *et al.*, 2008; Rahmann *et al.*, 2008). However it is found in the literature similar results to this work it is also related opposite behaviour, but it is understood that the toughness resistance is very sensitive to the type of fibre and matrix (Rohlmann *et al.*, 2008; Rahmann *et al.*, 2008; Liu *et al.*, 2009).

Table 2 - Toughness resistance of the pure PP and fibre and PP composites (PP/FB)

PP/BF composition (%)	Toughness resistance (J/m)
100/0	6.7
90/10	15.5
80/20	20.0
70/30	6.7

Figure 4a presents the results of the tensile strength for the pure PP and for the banana fibre composites 90/10, 80/20, 70/30. It is not observed significant difference in tensile results for the composition up to 20% of banana tree fibre that is very similar to the pure PP. On the other hand the 70/30 PP/BF composite showed tensile strength about 54% smaller than pure PP. This behaviour shows that there is no influence of the banana tree fibre as received on the mechanical propriety of the polymer composite. However, the literature reports opposite behaviour for other fibres such as sisal, roselle, henequem and linen and also it is related to hydration because when the fibre is dehydrated the tensile strength increased (Rohlmann *et al.*, 2008; Park *et al.*, 2008; Pracella *et al.*, 2006; Franco and González., 2003)

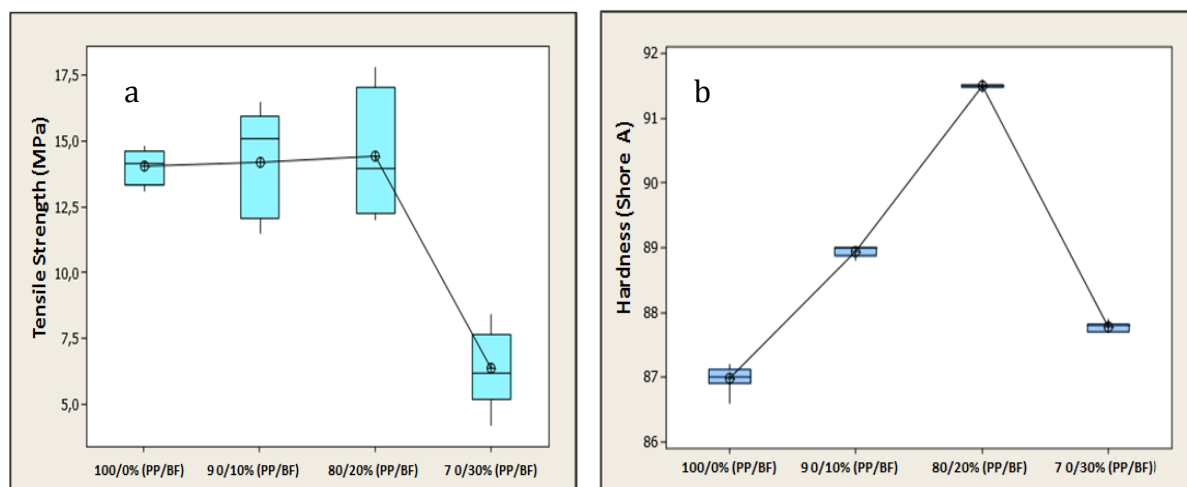


Figure 4 – a)Tensile Strength values for pure PP and 90/10, 80/20, 70/30 banana fibre/ PP composite. b) Hardness values for pure PP and 90/10, 80/20, 70/30 banana fibre/ PP composite.

The hardness measurements are presented in the figure 4b. A very discrete increase on the hardness of the 90/10 and 80/20 composite in relation to the pure PP was observed. However the values of the 70/30 composite hardness are the same as for pure PP. This behaviour shows there is very little influence of the banana tree fibre in the hardness of the material.

4. CONCLUSIONS

This study showed the banana tree fibre composite with fibre addition of 30% is not homogeneous decreasing the mechanical properties of the composite prepared.

Thermal stability slightly increased was observed for the composites studied in relation to the pure PP indicating good processability of the material. The enthalpy increased by 10% for the 90/10 and 80/20 PP/BF composites but for the 70/30 composite the enthalpy increase was around 20% indicating poor interaction between fibre and PP matrix.

In the range of the fibre concentration used in this study was observed changes on the density of the composites. The specific weight increased with concentration of the fibre in relation to the pure PP. The composites with 90/10 and 80/20 PP/BF composition presented good chemical stability in all the medium used in this study, however, it was observed that higher concentrations of banana tree fibre decreases considerably the chemical stability in the studied mediums except in oils.

The mechanical properties were influenced by the composition of the composites. It was observed increase of toughness for the samples with 90/10 and 80/20 PP/BF composite. The hardness increased for the 90/10 and 80/20 PP/TB composite in relation to the pure PP. There was a important reduction in tensile strength for the sample 70/30 PP/BF and for the other two compositions the tensile strength was kept without alteration in relation to the pure PP.

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