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Effect of Fiber Treatment on The Mechanical and Rheological Properties of Polypropylene/Broom Fiber Spartium Junceum Composites

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Abstract: In this study, we investigate the effect of broom fiber incorporation and its surface treatment with stearic acid on the mechanical and rheological (melt flow index) properties of polymeric composites based on Polypropylene/Broom fiber. The results obtained show that in the case of composites with untreated broom fiber, the highest tensile properties and impact strength (Izod) are obtained for a fiber content between (10-20 wt%). For the composites with treated broom fiber, these values are shifted to fiber content of about (30 wt%). The melt flow index (MFI) show certain increase with increasing the content of stearic acid.

Key words: Composites, mechanical properties, natural fiber, polypropylene/broom fiber, surface treatment

INTRODUCTION

Thermoplastic polymers are widely used and have different applications. One of these is the use as structural components. Besides the use of pure polymer for structural purposes, it can be used as a matrix for fiber reinforced composites. These composites are mostly based on the traditional reinforcement fibers, such as glass fibers. However, natural fibers can also be used[1].

The use of natural fibers in polymeric composites have several advantages over the use of traditional fillers; low density, flexibility during the processing with no harm to the equipement, acceptable specific strength properties, low cost and the most important of these properties is that they are biodegradable[2,6].

Conventional fibers such as glass and carbon fibers, can be produced with a definitive range of properties, whereas the properties of natural fibers vary considerably depending on the fiber diameter, structure (proportion of crystalline fibrils and non crystalline regions, spiral angle) supramolecular structure (degree of cristallinity), degree of polymerization, crystal structure (type of cellulose, defects orientation of the chains of non crystalline cellulose and crystalline fibrils), void structure (pore volume, specific interface, size of pores) and finally, wether the fibers are taken from the plant stem, leaf or seed and on the growing conditions[7].

Vegetable fibers are mainly composed of cellulose, it is generally accepted that cellulose is linear condensation polymer consisting of D-anhydroglu-copyranose units of ten abbreviated as anhydroglucose units or even as glucose units convenience joined together by ß-1, 4- glycosidic bonds. It is thus a 1, 4-ß-D-glucan[8].

The main problem in these natural fibers thermoplastic composites is the poor interfacial adhesion between the hydrophobic polymer matrix and the hydrophilic natural fiber [9-11], which often leads to poor mechanical properties of the composite (tensile, impact strength and elongation at break). This is attributed to: poor compatibility between the polar hydrophilic fiber and the non polar hydrophobic polymer (such as polypropylene), with weak interfacial adhesion vegetable fiber and polypropylene matrix and poor dispersion of vegetable fiber in the polypropylene matrix due to strong fiber-fiber interactions resulting from hydrogen bonding[5]. These problems can be solved by physical or chemical modification which involves the use of coupling agents.

The coupling agent used contains chemical groups which can react with the fiber and the polymer. The bonds formed are covalent and hydrogen bonds which improve the interfacial adhesion[7,12].

The aim of this study is to investigate the effect of broom fibers content on the mechanical, rheological properties of broom-fiber reinforced polypropylene. The broom fiber amounts used were 10, 20, 30, 40 and 50 wt%. To improve the matrix/fiber adhesion, the surface of the fibers was chemically modified with stearic acid at different concentrations (0.5, 1, 1.5 and 2 wt%) for the composition PP/Broom fiber (70/30).

MATERIALS AND METHODS

The polymer matrix used in this study was polypropylene "B-UP .123" (Eton Mobil Chemical), with a density of 905 kg m^{-3} and a melt flow index (MFI) of 8.7 g/10 min (at 230°C and 2.16 Kg).

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Polypropylene was selected as the matrix, because it is of the major commodity plastics which may be processed below the decomposition temperature of cellulosic fiber (about 220°C).

Preparation of fiber: Broom fiber was prepared in our laboratory. The broom fiber "Spartium junceum" was obtained from local sources, the shurb can be cultived in lands and the fiber was cleaned and chopped into the desired length ranging from 2 to 4 mm.

Extraction of fiber: As preatreatment, the fibers were dewaxed in (toluene-ethanol) solution (2:1) for 24 h (with stirring) to remove the woving size (potato strach and waxes, flowed by washing of the fibers in distilled water). After filtration, the fibers were dried at 105°C for 15 h.

Fiber treatment: The stearic acid was dissolved in a solution of toluene. The broom fiber was immersed in the solution and kept there for 15 h with stirring at ambiant temperature. The broom fiber was filtered and then kept in the oven at 105°C for 15 h.

Processing: The composite materials were prepared by mixing the polymeric matrix and the broom fiber in a two roll mixer at 180°C. Composites with different amounts of broom fibers (10, 20, 30, 40 and 50 wt%) were obtained. Samples for different tests were prepared by compression molding in hydraulic press at 190°C under a pressure of 250 Kg/cm^2, followed by air cooling.

Characterization equipment

Tensile test: The samples were stored in a dessicator before testing to avoid moisture absorption. The tensile strength properties were measured according to ASTM D 638 using a universal tensile machine "ADAMAL LHOMARGY - DY-22".

The tests were carried out at room temperature (23±2°C) with strain rate of 50 mm/min. From the stress-strain curves the young modulus (E), the stress at break (σ_r) and the elongation at break (ξ_r) were determined.

Impact test: Impact testing was performed using the ASTM D256 Izod impact method using a Ceast pendulum impact instrument. The capacity of the pendulum is 7.5 Joules. Both notched and unnotched impact strengths were determined.

Melt flow index: A controlab extrusion plastometer was used to obtain data for the calculation of the MFI of each material. Procedure was performed according to ASTM D1238 at 230°C under a load of 2.16 Kg.

Microscopy observations: Fractured surfaces of composite specimens were studied by using LEICA STEREOSCA 440 scanning electron microscope (SEM), to investigate the morphology and interface between the fiber and matrix in the composites.

RESULTS AND DISCUSSION

Tensile properties

Stress at break: The effects of fiber and stearic acid content on the tensile properties are represented in the following figures. Fig. 1 represents the effect of fiber content on the stress at break; there is an increase of the stress at break with increasing the fiber content. An optimum is observed for fiber content between 10-20 wt%. This is mainly due to the better dispersion of the fiber at lower content. At higher content there is a decrease of the stress at break because of poor dispersion of the fiber in the polymer.

Figure 2 shows the effect of fiber treatment for the composites (70/30); we can say that the treatment with stearic acid facilitates the fiber dispersion. So, the optimum value of the stress at break is obtained at higher stearic acid concentration. We can also say that the stearic acid in terms of static properties can enhance fiber dispersion and wetting, rather than it can form any interfacial bonding. The increase in tensile strength for the PP/Broom fiber treated with stearic acid can be attributed to several factors; better filler dispersion, creation of some bonds between PP and broom fiber[13] and by greater wettability of broom fiber by the polypropylene matrix, which improves dispersion and orientation of broom fibers in the polymer[5].

Young modulus: Fibers which have higher stiffness than the polymeric matrix increase the modulus of the composites. It was observed in Fig. 3 that for PP/Broom fiber composites, young modulus increases as the proportion of broom fiber rises. This mechanical property depends on the dispersion of broom fibers in PP matrix, since broom fibers are responsible for the decrease of the deformation capacity within the elastic zone[6, 13].

The effect of stearic acid content on the young modulus samples is represented in Fig. 4. In this figure, we observe that there is an increase of the young modulus with the increase of the concentration of stearic acid. This result confirms the better dispersion obtained with stearic acid.

Elongation at break: The incorporation of fillers in polymeric matrix, generally leads to a decrease in the elongation at break due to the rigidity of fibers. Fig. 5

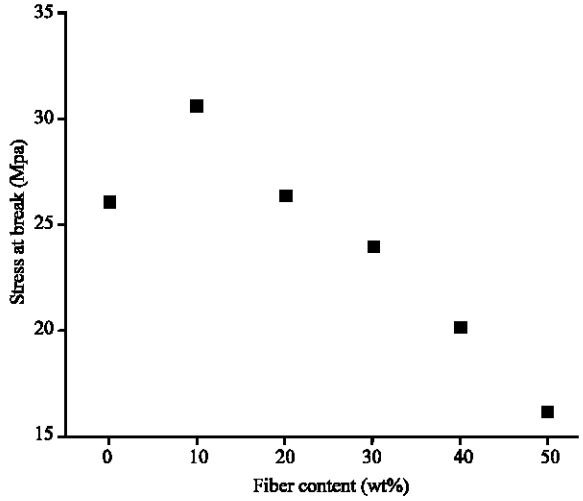

Fig. 1: Effect of Broom fiber content on the stress at break of PP/Broom fiber composites

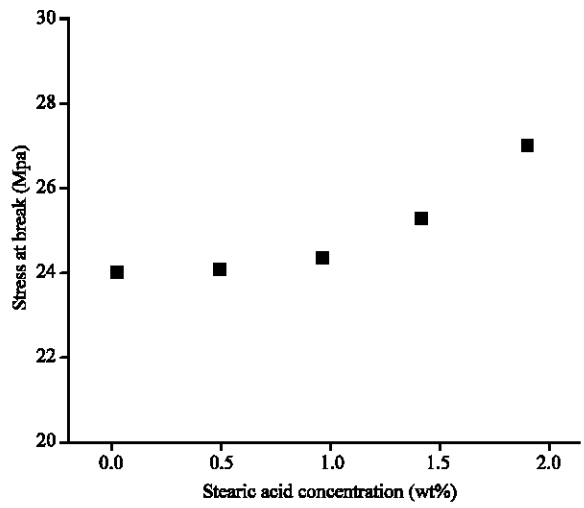

Fig. 2: Effect of treatment with stearic acid on the stress at break of PP/Broom fiber composites at 30% loading

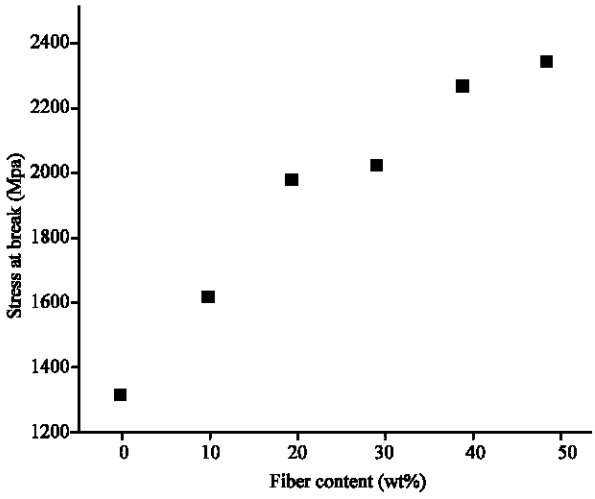

Fig. 3: Young modulus of PP/Broom fiber composites as a function of fiber content

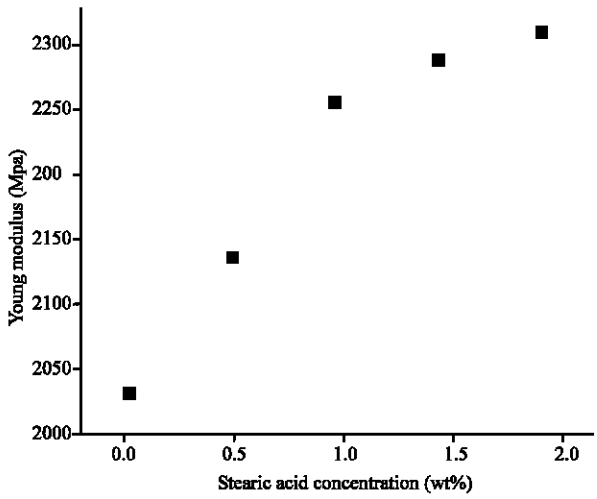

Fig. 4: Effect of treatment with stearic acid, on the young modulus of PP/Broom fiber composites at 30% loading

representing the variation of elongation at break with fiber content confirms that there is a decrease in the elongation at break for the PP/Broom fiber composites compared to that of unfilled PP[14].

The effect of stearic acid on the elongation at break is represented in Fig. 6. For the same fiber content, there is a small variation in the elongation at break of the treated composites. The creation of a certain interface and the rigidity of the fibers are responsible of this decrease.

Impact strength

Impact strength of unnotched samples: Figure 7 shows the variation of impact strength of unnotched samples of PP/Broom fiber composites. At lower fiber content, there is an increase of the energy at break. The incorporation of the fiber in the matrix gives certain rigidity to the composites which increases the energy needed to break the samples. An optimum value of the impact strength is obtained for fiber content between (10-20 wt%). For higher concentrations, there is a decrease of the impact strength due to the poor adhesion between the filler and the polymeric matrix.

The effect of stearic acid on the impact strength of unnotched samples is represented in Fig. 8. An increase of the impact strength values is observed with the stearic acid concentrations, which confirms the creation of an interface between fiber and polymeric matrix. The treatment with stearic acid gives better fiber dispersion.

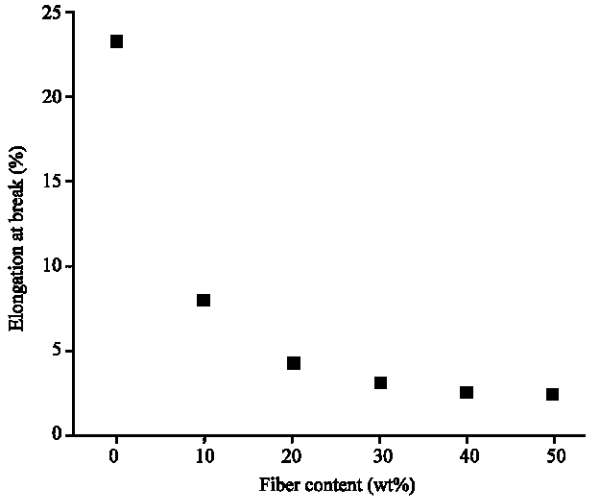

Fig. 5: Elongation at break of PP/Broom fiber composites as a function of fiber content

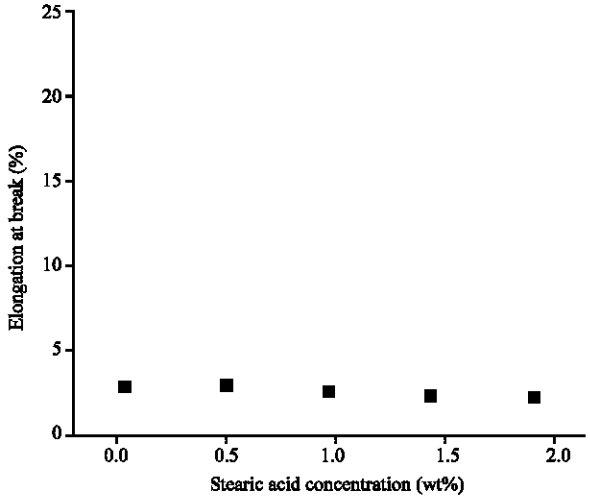

Fig. 6: Effect of treatment with stearic acid on the elongation at break of PP/Broom fiber composites at 30% loading

Impact strength of notched samples: In general notched samples give lower values of impact strength. The creation of a notch in the sample eliminates the energy needed to initiate the break. So, the energy at break is composed only of the propagation energy. The effects of filler concentration and treatment are similar to that for unnotched samples and are represented in Figs. 9 and 10, respectively.

Melt flow index: Figure 11 represents the effect of fiber content on the melt flow index. We observe that there is a decrease in these values as a function of the fiber content. This is due to the fact that the untreated fibers

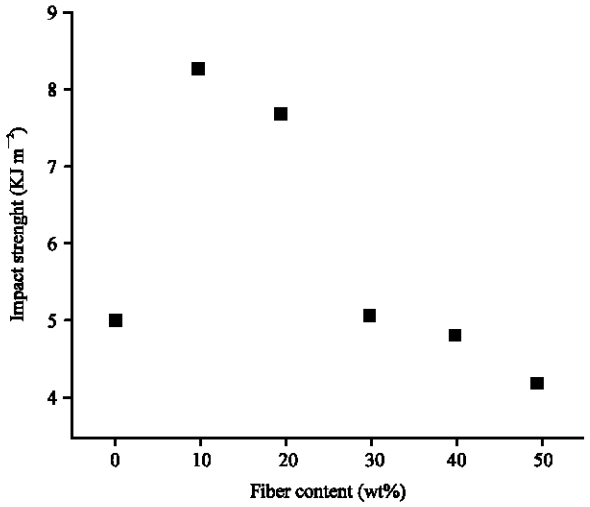

Fig. 7: Impact strength of unnotched specimens of PP/Broom fiber composites as a function of fiber content

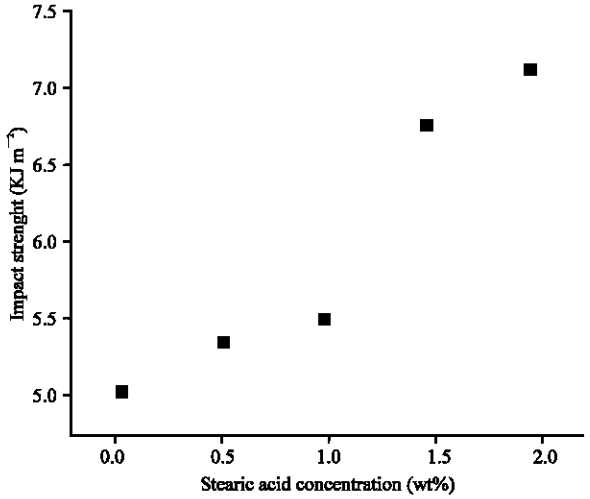

Fig. 8: Effect of treatment with stearic acid concentration, on the impact strength of unnotched specimens of PP/Broom fiber composites at 30% loading

have a tendency to agglomerate instead to be dispersed in the matrix.The agglomerates obtained will restrict the molecular flow.

The effect of stearic acid treatment on the variation of the melt flow index is represented in Fig. 12. We can notice that at constant fiber content, there is certain increase in the melt flow index for stearic acid range between (0.5-1.5 wt%). The treatment enhances the dispersion of the fibers and leads to less agglomerates formation.

Microscopy observations SEM: The micrograph of composite filled with untreated broom fiber (30 wt%)

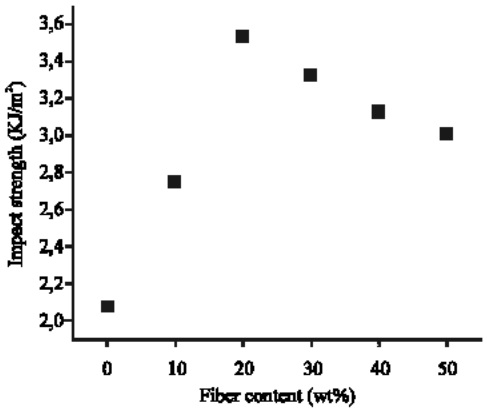

Fig. 9: Varaition of impact strength of notched specimens of PP/Broom fiber composites as a function of fiber content

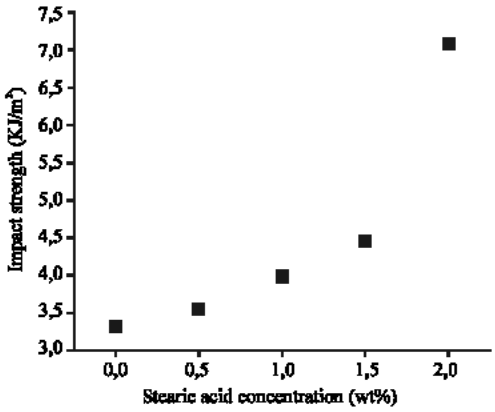

Fig. 10: Variation of impact strength of notched specimens of PP/Broom fiber composites at 30% loading as a function of stearic acid concentration

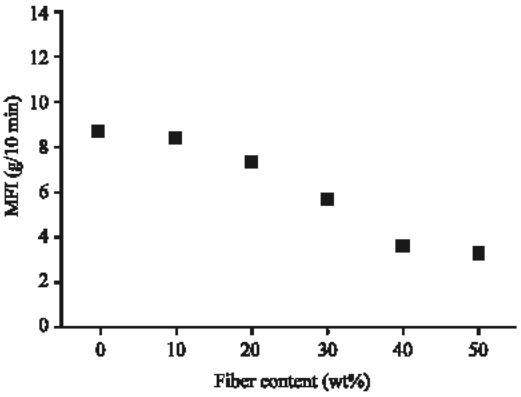

Fig. 11: MFI of PP/Broom fiber composites, as a function of fiber content

represented in Fig. 13, shows clearly a certain phase separation between polymeric matrix and the fiber. Also,

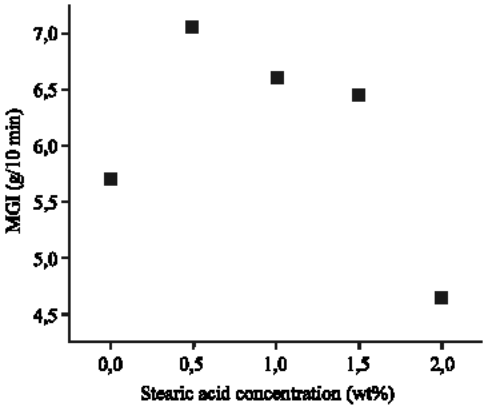

Fig. 12: Effect of treatment with stearic acid on the MFI of PP/Broom fiber composites at 30% loading

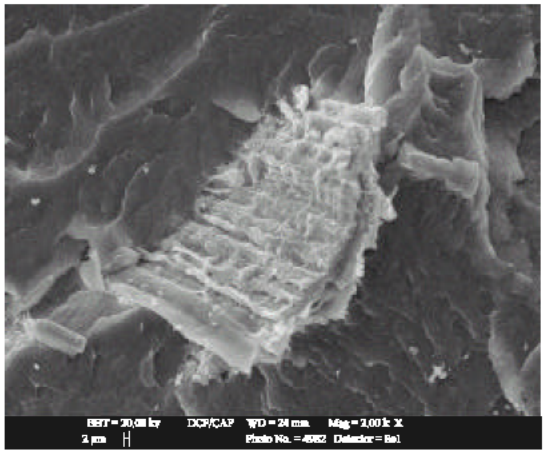

Fig. 13: SEM observation of PP/Broom Fiber (70/30) with untreated broom Fiber

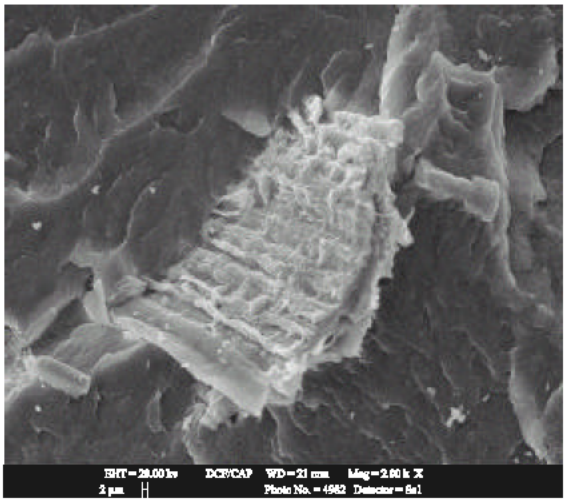

Fig. 14: SEM observation of PP/Broom Fiber/Stearic acid (70/30/1.5)

air bubbles were observed in most samples which are formed due to the residual moisture in the broom fiber[15].

For the treated composites with stearic acid concentration of 1.5 wt%), the SEM observation (Fig. 14) shows a better adhesion between the two phases and a formation of a certain interface.

CONCLUSION

The incorporation of broom fibers in polypropylene matrix, gives the composites good properties in the range of (10-20 wt%) loading, in the case of untreated fibers. The surface treatment of broom fiber improves the tensile properties and impact strength of the composites. These are attributed to the good dispersion of treated broom fibers in the polymeric matrix. The melt flow index (MFI) of the composites with treated broom fiber shows certain increase with increasing the content of stearic acid. The SEM observations confirm the poor fiber dispersion in the polypropylene matrix in the case of untreated broom fiber; however, the surface treatment gives better fiber dispersion.

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