SUBSTITUTION OF SHORT GLASS FIBERS FOR VEGETAL FIBERS IN THERMOPLASTICS REINFORCEMENT

Marco-Aurelio De Paoli, Bárbara Mano, Joyce Rodrigues de Araújo, Márcia Aparecida Silva Spinacé

Instituto de Química, Unicamp, P.O. Box 6154, 13083-970, Campinas, SP, Brazil

Introduction

The development of thermoplastic composites reinforced with short fibers has enlarged the applications of polymeric materials, especially in devices that need high mechanical performance, lower density and good surface appearance. The glass fibers are the most commonly used, imparting resistance, rigidity and dimensional stability to the final material with low cost, compared to other synthetic fibers like aramid and carbon [1]. Recently, the use of vegetal fibers have received attention due to their potential to substitute glass fibers with competitive specific mechanical properties and many advantages that include: lighter weight, biodegradable and less abrasive to the processing equipments [2].

Curaua fibers are vegetal fibers extracted from the leaves of the Curaua plant (*Ananas erectfolius*, gender L. B. Smith), from the Brazilian Amazon region. Studies have shown that this fiber is a promising candidate to substitute glass fiber as reinforcing agent in polymeric composites as they show similar specific mechanical properties [3]. In this work, curaua fibers were used as reinforcement for polypropylene and high density polyethylene, aiming to obtain composites with mechanical properties similar to the commercial composites reinforced with glass fiber. Composites were prepared by extrusion and injection molding. Polypropylene and polyethylene grafted with maleic anhydride were used as coupling agents to provide adhesion between the fibers and the matrices.

Experimental

Curaua fibers, supplied by Embrapa-PA (Belém, Brazil), were milled in a three knives rotary mill to 3-7 mm length. Isotactic polypropylene (PP, H301-Braskem, MFI=10g/10min) or high density polyethylene (HDPE, JV060U-Braskem, MFI=7g/10min) with 5 to 30 wt% of fibres were processed in a co-rotating intermeshing twin-screw extruder (ZSK 26 Mc, Coperion Werner & Pfleiderer, L/D=44) with temperature profile, from feed to die, 160-180 ºC for PP and 120-140 ºC for HDPE and screw rotation of 300 rpm. Fibers were fed through a side-feeder, with screw rotation of 265 rpm for PP and 250 rpm for HDPE. Polypropylene and polyethylene grafted with maleic anhydride, PPMA (37-50 mg KOH g^{-1}) and PEMA (100-130 mg KOH g^{-1}), supplied by Megh. Ind. Com. Ltda, were used as coupling agents for PP and HDPE, respectively, and their content varied from 2 to 10 wt%. The granulated composites were dried at 100 ºC for 1 h and injection molded (Arburg, All-rounder M250) into test specimens according to ASTM D638-02 for tensile tests. The temperature profile used, from hopper to nozzle, was 180-205 ºC for PP and 150-170 °C for HDPE composites. Tensile tests were taken with cross head speed of 5 m min^{-1} using an extensometer. Results correspond to an average of seven measurements.

Results and discussion

Curaua fiber (CF) loading

The results obtained in the tensile tests of composites with different fiber loadings are shown in Table 1 for PP and HDPE matrices. The incorporation of fibers increased the Young modulus of the composites and the maximum rigidity was obtained with 30 wt% of fibers in both cases. The fibers also increased the mechanical resistance of composites of both matrices, but in this case a maximum was reached with 20 wt% of fibers. Compared to the unfilled polymers, composites with 20 wt% of fibers presented increments of 15 % in the resistance for PP matrix and 56 % for HDPE matrix. As can be seen, the effect of the fibers was more pronounced in the properties of HDPE composites than in PP composites.

From these results we concluded that the loading of 20 wt% of fibers optimized the mechanical properties of the composites for both matrices.

Table 1. Tensile properties of composites of PP or HDPE as a function of the curaua fiber content.

	PP matrix		HDPE matrix	
CF (wt%)	σ_{max} (MPa)	E (GPa)	σ_{max} (MPa)	E (GPa)
0	27.2 ±0.5	1.7 ±0.2	17.8 ±0.1	1.0 ±0.1
5	27.2 ±0.2	1.9 ±0.1	19.4 ±0.2	1.3 ±0.1
10	29.0 ±0.5	2.0 ±0.1	22 ±2	1.6 ±0.2
20	31.4 ±0.5	3.4 ±0.2	27.8 ±0.4	2.3 ±0.2
30	31 ±3	3.8 ±0.5	26.4 ±0.5	3.5 ±0.5

Coupling agent (CA) content

The coupling agent effect was tested in composites with 20 wt% of fiber and the mechanical performance in tensile tests is reported on Table 2. For PP composites, the addition of coupling agent (PPMA) increased the mechanical resistance of the composites as a result of the fiber-matrix adhesion improvement. Incorporation of 2 wt% of PPMA increased the resistance in 21 wt% compared to the uncompatibilized composite. Larger content of coupling agent did not improve the composite performance. Similar behavior was observed for HDPE composites with the addition of PEMA, when the maximum resistance was obtained through the incorporation of 2 wt% or 6 wt%, resulting in 10 and 12 wt% of increase in resistance, respectively. The Young Modulus for PP composites was independent of the PPMA content.

Table 2. Tensile properties of composites of PP or HDPE with 20 wt% of curaua fiber as a function of the coupling agent (CA) content.

	PP matrix		HDPE matrix	
CA (wt%)	σ_{max} (MPa)	E (GPa)	σ_{max} (MPa)	E (GPa)
0	31.4 ±0,5	2.8 ±0.3	26.1 ±0.4	3.4 ±0.3
2	38.0 ±0.2	3.3 ±0.4	28.5 ±0.6	3.6 ±0.3
4	36 ±1	3.0 ±0.3	25.1 ±0.4	2.8 ±0.3
6	36 ±1	2.9 ±0.2	29.4 ±0.4	4.0 ±0.3
8	36.8 ±0.5	3.1 ±0.2	27.6 ±0.4	3.2 ±0.3
10	36 ±1	3.1 ±0.2	26.5 ±0.5	3.3 ±0.4

Curaua fiber (CF) vs. glass fiber (GF)

The properties of PP and HDPE composites were compared to the properties of commercially available composites reinforced with glass fibers, GF, Table 3. The comparison between PP composites containing 20 wt% of CF and 20 wt% of GF shows that the composite formulated with curauá fiber is lighter and its tensile properties are ca. 85 % of the properties observed for GF composites. The values are closer when the specific properties are considered. Evaluating the PP composite with 20 wt% of CF and 10 wt% of GF, which show the same density, it is observed that the properties of the curauá fiber composite are superior. This result is environmentally interesting, because the volumetric content of curauá fiber in this formulation (15 vol%) is higher than glass fiber (3.9 vol%) for similar mechanical performance, resulting in reduced use of matrix in the formulation, that is the a non-renewable and non-biodegradable material.

For HDPE matrix, composites with 30 wt% of curauá and glass fiber were compared. In Table 3, it is shown that the composite reinforced with curauá fiber is much less dense than the composite reinforced with glass fiber and this is a good advantage for some final application, e.g. automobile industry. The tensile properties are ca. 50 wt% of the properties shown by the commercial material containing GF, but considering the specific values they reach ca. 70 % of the GF composite properties.

Table 3. Density and tensile properties of PP or HDPE composites reinforced with curaua fiber or glass fiber [4,5].

Composite	Fiber (v/v %)	Density ($g.cm^{-3}$)	σ_{max} (MPa)	E (GPa)
PP matrix				
20 wt% CF/ 2 wt% PPMA	15	0.97	38,0 (39,1)*	3,3 (3,5)*
20 wt% GF	8.3	1.05	45 (43)*	4 (3,8)*
10 wt% GF	3.9	0.97	35 (36)*	2,8 (2,9)*
HDPE matrix				
30 wt% CF	24	0.99	30 (30)*	2.7 (2.7)*
30 wt% GF	14	1.30	57.5 (44)*	5.6 (4.3)*

*specific property – ratio between the property and density of the composite

Conclusion

Curaua fiber is efficient in promoting the reinforcement effect in PP and HDPE matrices. The determination of suitable content of fiber and coupling agent results in composites with good mechanical properties, competitive to the commercially available composites reinforced with glass fibers.

References

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