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Modification of Brazilian Natural Fibers from Banana's Tree to Apply as Fillers into Polymers Composites

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Lignocellulosic fibers, as banana fiber, are potential substitutes for non-renewable synthetic fibers, nevertheless being a polar polymer, they have low compatibility with polyolefins, the most common non-polar thermoplastics. This difficulty can be minimized by chemical treatment of the fiber. In this work, HDPE composites and natural fibers were treated with two interfacial agents - stearic acid (AS) and lauric (AL). The interfacial agents and three types of fibers banana here defined as external Fiber (Fext), internal fiber (Fint) and intermediate fiber (Finterm). The interfacial agents were dissolved in acetone/toluene mixed with banana fibers at 50 °C for 24 h. Banana fibers, impregnated with the interfacial agents, were mixed with high density polyethylene (HDPE) in a twin screw extruder. The extruded samples were injected into specimens for evaluation of mechanical properties: tensile strength and impact strengths. The elastic moduli of treated fibers and HDPE composites increased as compared to pure HDPE. For the compound having HDPE and Fext-AL, the highest value for the modulus was found. This interfacial agent improved the elastic modulus of the material thus suggesting that this agent may have allowed a better interaction between the fiber and the olefinic polymer.

1. Introduction

Agricultural wastes are constituted mainly by vegetable fibers whose the main is cellulose. Those natural residues could be blended with thermoplastic materials producing composites (Silva et *al*., 2008).
Natural materials as coconut, banana, palm, sisal, jute, sugarcane bagasse or piassava fibers have been applied to reinforcing polymeric composites. Its composites have advantages over inorganic fibers reinforcement as low costs, be a renewable material, lower density, higher solvent compatibility, higher thermal resistance, easily modified by chemical agents, low toxicity and low abrasive.
These characteristics became plant fibers an interesting material for technological application (Scarpinela, 2002),as carpets, vases, ropes (Passos, 2005)., tiles, automobile upholstery, mattresses, among others (Dahlke *et al.*, 1998). Although of these excellent properties, composites with plant fibers present low mechanical performance and thermoplasticity; low processing temperature, high moisture absorption and, mainly, low compatibility with commonly used thermoplastics (Espert *et al.*2004); Polyolefines are the most used class of polymers to plant fibers composites due its processing temperature below 200ºC (Ichazo e*t al*., 2001). Over this temperature starts thermal degradation of natural fibers (Joseph *et al*, 1996).
Chemical structure of plant fibers has hydrophilic groups (mainly OH) causing high polar characteristic while polyolefins presents a non-polar structure. Therefore, to obtain a uniform polymeric mixture reaching good properties is necessary enhancing compatibility between the two components. Better compatibility could be achieved by submitting the plant fiber to chemical treatment (Colom *et al.,* 2003).
There are some treatments reported in literature as mercerization, addition of silanyl or acetyl groups among others. All treatments intend to enhance interface of polymer-fiber, (Rout *et al*., 2003).

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Another treatment could be used is an application of compatibilizer agent, This compounds will be act in the interface polymer fiber.
The objective of this work was to produce composites with high-density polyethylene and three differ banana's fibers treated with stearic acid and lauric (compatibilizer agents). Final products were characterized by scanning electron microscopy, and mechanical behaviors were tested.

2. Experimental

2.1 Obtaining the banana fibers

Banana trees trunks (known pseudo stem) are formed by layers called sheath. Each sheath could be identified five differ fibers. Just three fibers types were used in this work, because these fibers have enough quantity. Fibers used in this work were: Internal fiber (Fint), "Intermediary fiber" (Finterm) and Fiber final" (Fext).
Musa balbisiana was disaggregated into mill (Trapp JK-700 model) then ground into brand knives mill (Primotecnica model 1003 LP) and sieved to the size of 0.15 mm.

2.2 Compatibilization process

First 10 grams of Octadecanoic acid (Stearic acid) or dodecanoic acid (Lauric acid) were solubilized in 100 mL toluene/acetone (1:1 v/v) in beaker. Then 90 g of grinded fibers were immersed in toluene/acetone solution under vigorous agitation at 50 ºC by 24 h.

2.3 Preparation of composites

High density polyethylene (HDPE) and banana fibers were introduced into co-rotational twin screw extruder with independents nine heating zone. Mixture elements type kneading blocks were used in two segments intercalated by conduction elements. Screw rotation was 300rpm, and feeder was 15 rpm. Temperatures were zone 1: 90 °C, zone 2, 3, 4 e 5: 140 °C, zone 6, 7, 8 e 9: 160 °C and header: 180 °C.

2.4 Preparation of samples

The specimens for the mechanical tests were obtained by injection with the thermal profile on the barrel of 150 °C, 160 °C in the first zone, in the second zone 175 °C, in the third zone 185 °C, 195 °C fourth zone and at 205 °C nozzle.
Twenty specimens were to each composite. The mold temperature, 60 °C, was maintained by a thermoregulation oil. Speed (flow) of injection maid was 26 cm3/s, switching to repression by volume was 3 cm^3, the injection pressure was 1,400 bar and of repression was 450 bar for 4 s, and 30 s of the cooling time.

2.5 Mechanical Properties

Were used 7 samples for each mechanical test, the higher and lower value of each test was removed; average and standard deviation were calculated of five points. Impact load Cell used has10 KN.
The tensile strength test (ASTM D 638, 2003) was held in a universal testing machine (Instron). The elastic modulus and elongation break were evaluated. The speed of this essay was of 25 mm/min, and the load cell was of 10 KN, the specimens were of the type I, in the form of a tie. For Impact Strength samples were submitted on impact assay by Izod method with impact speed of 3,46m/s at 25 ºC, Impact Energy Hammer of 2J for composites and 4J for pure HDPE.

2.6 Scanning Electron Microscopy (SEM)

Scanning electron microscopy (JEOL model JSMS610LV) were realized under the following conditions: electron acceleration 20 KV; magnification 50 to 500. The samples were fractured in liquid nitrogen and metalized with gold. This technique was used in order to observe how the fibers are in the polymer mass and evaluating the format of the fibers.

3. Results and Discussion

3.1 Mechanical properties of the composite HDPE/banana fibers with or without interfacial agents treatment

The mechanical properties of HDPE composites with banana fibers types of Fint, Finterm and Fext, the mass ratios of 10 % pure or impregnated were evaluated for their performance in the tests of impact and tensile testing. The impregnation aims at assessing the affinity of the interfacial fiber and the olefinic polymer, which may reflect improvements in mechanical properties, so the results of maximum stress, elongation break and elastic modulus were studied (Tomczak, F.; 2010). The elastic modulus of the fibers was determined by the initial slope of the stress-strain curve. Table 1 shows the results for the composites of HDPE and banana, pure and impregnated fibers. Figure 1 (a, b, c e d) show graphs of stress versus strain for composites HDPE / banana fibers (Fint, Finterm and Fext) and with interfacial agents (AS, AL).

Table 1: Data elongation break, elastic modulus and maximum stress for composites of HDPE/banana fiber ("Fint", "Finterm" and "Fext) impregnated with interfacial agents

Material		Elongation break (%)	Elastic Modulus (MPa)	Tension Streght (MPa)
HDPE		436. 3 ± 0.9	691,6 ± 19,0	20.6 ± 0.4
HDPE + Fint		41.8 ± 3.3	864.8 ± 17.8	21.1 ± 0.2
HDPE + Fint impregnated	AL	63.2 ± 2.9	813.3 ± 13.0	20.3 ± 0.4
	AE	42.5 ± 5.9	826.2 ± 17.8	20.2 ± 0.2
HDPE + Finterm		26.2 ± 2.4	838.6 ± 10.4	20.2 ± 0.2
HDPE + Finterm Impregnated	AL	29.0 ± 2.4	859.0 ± 7.6	20.3 ± 0.4
	AE	35.2 ± 7.7	861.5 ± 14.5	20.2 ± 0.3
HDPE + Fext		22.2 ± 4.7	984.4 ± 15.1	20.4 ± 0.3
HDPE + Fext Impregnated	AL	25.2 ± 2.0	888.6 ± 7.6	20.2 ± 0.3
	AE	22.3 ± 1.6	1036.8 ± 22.8	21.01 ± 0.1

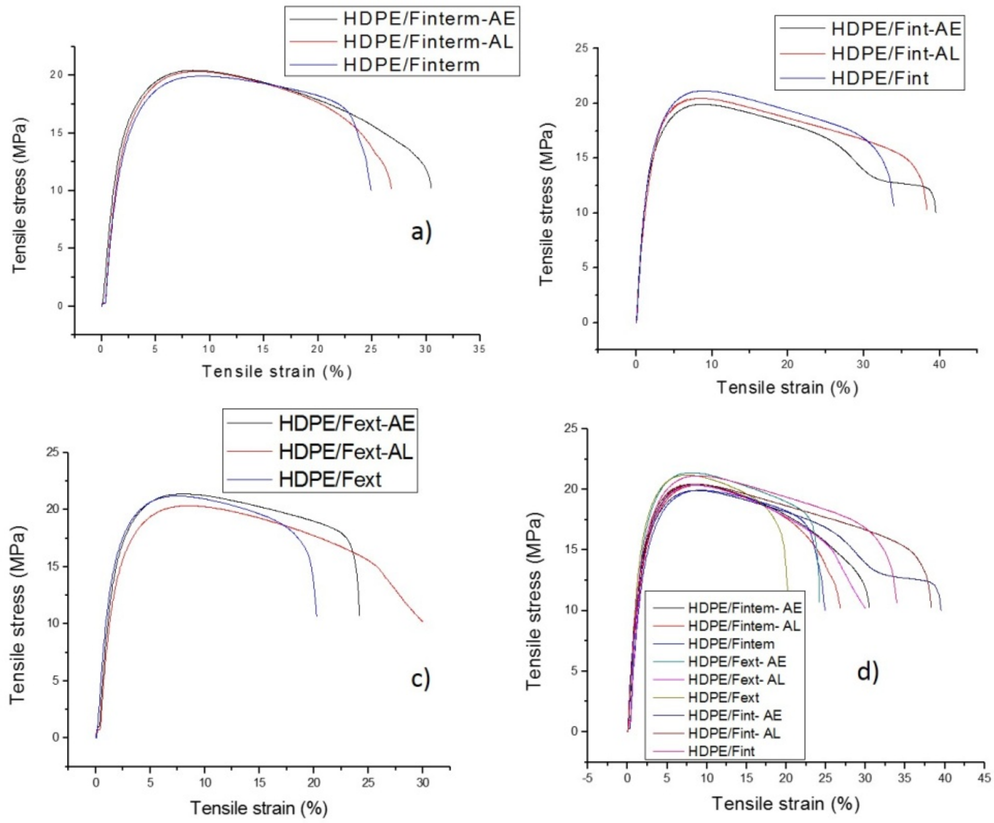

Figure 1: Tensile stress versus tensile deformation of HDPE composites/fibers of pure and impregnated with lauric acid (AL), stearic acid (AS) – a) Finterm, b) Fint, c) Fext and d) all banana fiber types (Fint, Finterm and Fext).

3.2 Tension Strength

Figures 1 (a, b and c) show the results of HDPE and banana fiber composites ("Fint", "Finterm" and "Fext") and impregnated pure, tensile stress versus strain. Figure 1 (d) shows a comparison of three types of banana fiber used as filler in HDPE composites. HDPE and banana fiber composites showed values of maximum stress (20-21 MPa), very close to the pure HDPE (20.6 MPa). The maximum stress values for composite with the impregnated fibers (~ 20 MPa) showed no changes in maximum tension i.e. impregnation did not affect the maximum charging tension that the material resists. One may suggest that the sizing agents present in the fibers did not alter the resilience of pure HDPE.

3.3 Elongation break

Through the data found in Table 1 shows that all banana fiber composites (Fint, Finterm and Fext) pure and impregnated with interfacial agents reduced the elongation break of HDPE pure (436.3 %). Comparing the results from HDPE/banana fibers composites without the interfacial agents (AS, AL) was observed fiber type Fint has a greater ability to elongate, i.e. its chains are more flexible and managed to obtain a higher % Strain before rupture when subjected to a load of the Finterm and Fext fibers. The latter two were very similar (~ 22 – 26 %) or have similar elongation capability.

Impregnation of the interfacial agent AL banana fiber type Fint made the elongation of the composite increased compared to pure fiber composite. The composites of HDPE / Fext impregnated with AL and AE results obtained elongation break almost equal to the composite with pure Fext.

3.4 Elastic Modulus

Analyzing the results of the elastic modulus of the pure HDPE (691.6 MPa) with the results obtained for the HDPE/banana fibers composites pure or impregnated (781 to 1,036.8 MPa), it is seen that all results increased the elastic modulus of pure HDPE. The composite of HDPE/Fext-AL (1036.8 MPa) showed the highest value among all studied, i.e. this interfacial agent increased the elastic modulus of the material and may suggest that this agent has enabled better interaction between fiber and the olefin polymer, resulting in more rigid composites as well showed little elongation break.

3.5 Impact Strenght

Table 2 shows the results of the impact of HDPE composites with fibers of the three types of banana (Fint, Finterm and Fext) used as a load test.

The addition of HDPE to the banana fibers decreased the impact strength of the composite compared to polyethylene pure. It can be seen that the impregnation of interfacial agents to banana fibers (Fint, Finterm and Fext) kept the values of impact strength of composites with untreated fibers. Similar results were obtained by Amin (2006) observed that higher impact resistance by adding 10% by weight of coconut fiber, but a reduction in impact strength of 36% compared to the pure HDPE occurred.

Table 2: Property of impact for HDPE composites with fibers of banana (Fint, Finterm and Fext) and pure coconut and impregnated with interfacial agents

Material		Resilience (J/m)	Energy (J)
HDPE		88.1 ± 2.4	0.1 ± 0.0
HDPE + Fint		39.7 ± 1.5	0.1 ± 0.0
HDPE + Fint impregnated	AL	39.1 ± 1.5	0.1 ± 0.0
	AE	36.7 ± 2.4	0.1 ± 0.0
HDPE + Finterm		41.7 ± 1.4	0.1 ± 0.0
HDPE + Finterm impregnated	AL	39.1 ± 1.9	0.1 ± 0.0
	AE	38.3 ± 1.4	0.1 ± 0.0
HDPE + Fext		45.2 ± 1.9	0.1 ± 0.0
HDPE + Fext impregnated	AL	46.3 ± 0.9	0.1 ± 0.0
	AE	42.9 ± 2.4	0.1 ± 0.0

3.6 Scanning Electron Microscopy (SEM)

The micrographs of HDPE composites with 10% by weight of banana fiber (Fint) pure or impregnated (AS and AL) are shown in Figure 2. The micrographs of the composite of banana fibers (Finterm and Fext) pure and impregnated were not shown, because it does not differ in terms micrographs of banana fiber (Fint). It is seen the surface roughness higher for composites with fibers treated banana than it's without of treatment.

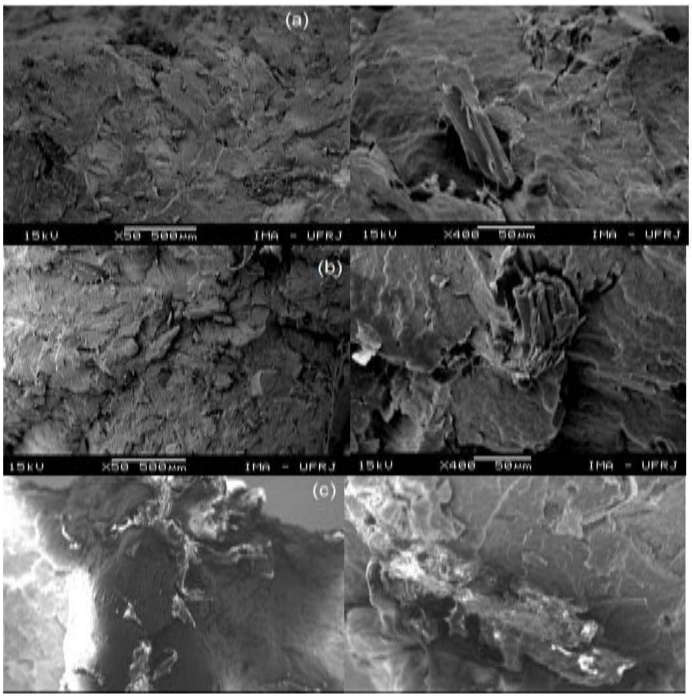

Figure 2: Micrographs of the composite HDPE +10% banana fiber (Fint) pure or impregnated (a) HDPE Fint + (b) + HDPE Fint-AS, and (c) HDPE + AL-Fint

4. Conclusion

The uses of banana fiber pure or impregnated with interfacial agents on the basis of HDPE composites allow gains in mechanical properties compared to the pure polymer. Among the mechanical properties studied, it was noted when there is a banana-type impregnated fiber Finterm the presence of the interfacial agents increase the elongation capacity of the lignocellulosic composite. The results showed that the elastic modulus of the interfacial impregnation agents led to an increase in the values of elastic modulus of pure HDPE. The composite of HDPE and Fext-AL (1036.8 MPa) showed a higher value, i.e., the interfacial agent increased the elastic modulus of the material, suggesting greater interaction between the fiber and the olefin polymer.
Comparing the tensile modulus of composites of HDPE with banana fibers (of three types), we note that these modules were very close to those of commercial products plastic timber. Thus, it is clear that the composite base of banana fiber has high potential for use as plastic lumber.

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