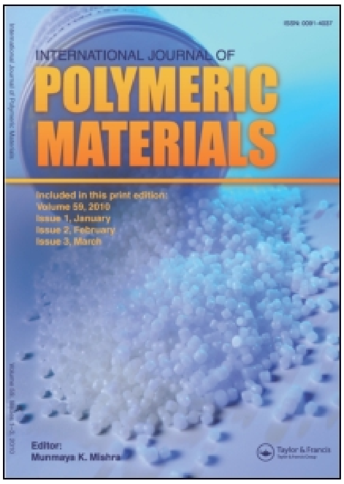

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THERMOPLASTIC COMPOSITES REINFORCED WITH BANANA (MUSA PARADISIACA L) WASTES

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Fiber reinforced composites of polyethylene and banana wastes were prepared and mechanically characterized by tension and flexion. Three different wastes were used: stem, leaf and pinzote fiber. The processing method to prepare composites with different volume fractions was developed and discussed here.

Keywords: thermoplastic composites, banana waste, biodegradable composites, recyclable composites

1. INTRODUCTION

The industrial development, the new products demand and the farming activities are linked to waste disposal, leading to the need to find ways to use these wastes. The banana farming generates huge quantities of waste normally used for animal feeding and fuel. It is considered that from each harvested banana plant, approximately 55 kg of vegetal material are wasted,

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they correspond to the 46% of the plan weight. More than 683 tons of this vegetal wastes are generated annually at the Mexican state of Tabasco.

On recent years, the recyclable and biodegradable composites have gained importance. This has led to the use of natural fibers as the composite reinforcing materials. The natural fibers have several advantages that make them attractive, they are cheap, available and have good mechanical properties [3].

The banana plant generates three different waste types, the stem, the leaf and the pinzote fiber, also known as raquis fiber. It was proposed to use them to reinforce high density polyethylene composites for applications were moderate loads are required. The natural fibers used to reinforce composites, normally present a low compatibility due to the hydrophobic nature of the thermoplastic polymers leading to low adhesion [2]. This compatibility can be improved by surface modification using physical or chemical methods [3]. Natural fibers are normally incorporated to a thermoplastic matrix as short fibers, this limits the reachable reinforcing level; when continuous fibers are used, if the interface is good, the stress transfer is more efficient leading to high reinforcing levels.

2. MATERIAL COLLECTION

The biological material was collected at the plantation "La Calendaria" located at Teapa at the Mexican State of Tabasco. The stem was cut in sections 30 cm long and longitudinally divided to ease the water draining. The leaves were cut in segments 20 cm long following the main vein and taking care not to tear or bend them. The pinzote was cut in segments 30 cm long and each segment was longitudinally cut in sections 2 cm thick. All the samples were stored at 5°C.

3. MATERIAL PRE-TREATMENT

The samples were washed with soapy water and rinsed with an excess of distilled water to eliminate from their surface pesticides, soil, and insects. At the same time, the damaged areas were disposed.

3.1. Stem Drying

The stem segments were dried in a conventional oven at 36°C for 96 hrs. Once dried, the stem was cut into 4×7 cm sections and stored in plastic bags.

3.2. Leaf Drying

The leaf sections were sandwiched between drying paper and corrugated board to protect the sample and to ease the humidity evaporation [4]. Then the samples were piled up and manually compressed between two wood boards; the hole set was placed in a conventional oven for 72 hrs at 35°C. Once dried, the samples were stored in plastic bags.

3.3. Pinzote Fiber Extraction

The pinzote fibers were chemically extracted using an alkaline digestion method [5]. The samples were placed in a 60 lt pot filled with 40 lt of 0.1 N NaOH solution. Steam heating (1.75 kg/cm^2) was used to boil the samples for 9 minutes. The samples were taken away from the pot and cooled at room temperature. The fibers were manually extracted by wet brushing using a wire brush and distilled water. The extracted fiber was sun dried for 4 hrs.

3.4. Humidity Content

The humidity content of the stem, leaf and pinzote were measured using the Mexican Standard NTRS-7 [6]. The samples were placed on constant weight aluminum trays and dried in an oven at 60°C for periods of 2 hrs and weighed until constant weight was reached again. 10 samples of each biological material were tested.

4. PROCESSING

4.1. Milling and Sieving

A two stage milling process was applied in order to get a material with a homogeneous fiber length and the highest unloading. The pre-milling was made in a Pagani blade mill the material obtained was sieved and milled for a second time in a Brabender blade mill and then sieved. The material used represents the 60% of the original material fed to the mills.

4.2. Mixing Process

The mixing was made in a Brabender Plasticorder PLE-330 fitted with a 50 grams camera heated at 180°C. The HDPE formulations prepared had 0, 10, 20, 30, 40 and 50% of reinforcing material (stem, leaf and pinzote). These materials were pre-conditioned by heating them at 60°C for 2 hrs under vacuum.

4.3. Laminating Process

The mixtures were laminated by compression using a hydraulic press (Carver) and a stainless steel picture frame mold. A mixture was placed in the preheated mold (180°C) and pressed for 6 minutes. The laminate was

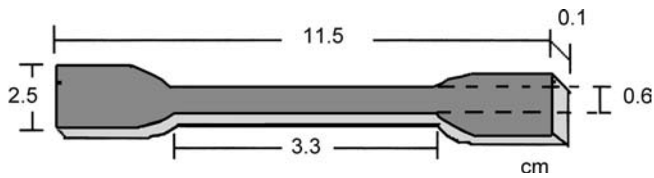

FIGURE 1 Tensile test specimen.

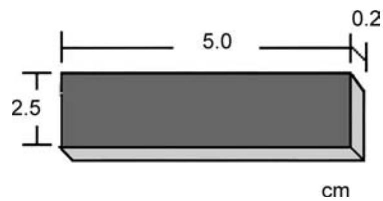

FIGURE 2 Bending test specimen.

water cooled to room temperature keeping the pressure and then demolded. The lamina dimensions were 14×15 cm with a thickness of 1 or 2 mm depending if they were going to be used for the tensile or flexion test.

4.4. Sample Cutting

The tensile test specimens were cut according to the ASTM standard D 638 M-89 [8], dumbbell type T-4, using a Pneumatic Cutter (Fig. 1). The flexion test specimens were cut according to the ASTM standard D 790 M-82 [9] using a Vacuum Router (Fig. 2). In both cases the width and thickness were measured using a micrometer.

4.5. Tensile and Flexion Test

The mechanical testing at tension and flexion were made in an Instron machine 1125 fitted with a 500 Kg load cell. The tensile test was run according to the ASTM standard D 638 M-89 [8] using a head speed of 5 mm/min and for the HDPE maximum deformation 500 mm/min. The flexion test was run according to the ASTM standard D 790 M-82 [9] using a head speed of 1 mm/min.

5. RESULTS AND DISCUSSION

5.1. Sample Humidity

Figure 3 shows the humidity content for each of the farm waste used. The highest value was shown by the pinzote, 96%. On the other hand, the stem

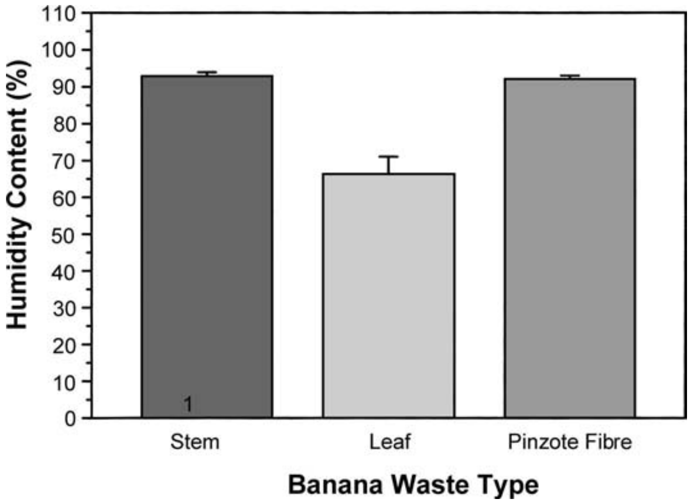

FIGURE 3 Humidity content.

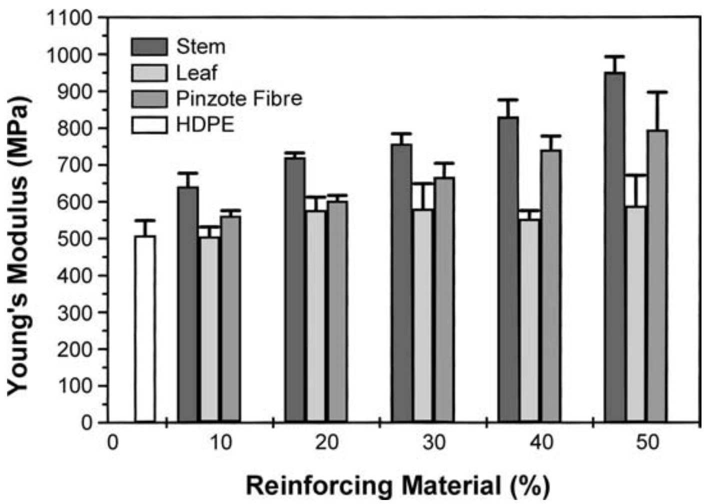

FIGURE 4 Young's modulus against reinforcing material content.

and the leaf showed a 93% and 60% of water content respectively. These values are in accordance with the reported in the bibliography [7].

5.2. Tension Test

Figure 4 shows the tensile modulus for all the formulations prepared. In general, the modulus tends to increase with the reinforcing material content and is always higher than HDPE modulus. The exception is the leaf composite, it only reaches the same modulus level as the matrix. This must probably be caused by its geometry: the grinded leave looks like small platelets, the stress transfer could be very poor.

Figure 5 shows the composite strength as a function of the reinforcement material content. The strength level for each formulation is approximately the same regardless the reinforcing material type but it drops as reinforcing content is increased.

Figures 6 and 7 show the composite deformation at maximum stress and at failure stress. In both cases, the deformation level falls with the increase of the reinforcing material content. The HDPE is a thermoplastic that tends to deform a lot under normal conditions. The presence of the reinforcing materials make the composite stiffer and consequently its deformation ability falls.

5.3. Flexion Test

Figure 8 shows the bending modulus as a function of the reinforcing material content. All the formulations show similar values in the range of 800 and 1000 MPa. The leaf composites show the lowest values.

Figure 9 shows the composite bending strength. Once again, there is no big differences between the formulations. The strength ranges between 27 and 33 MPa regardless the content or type of reinforcing material.

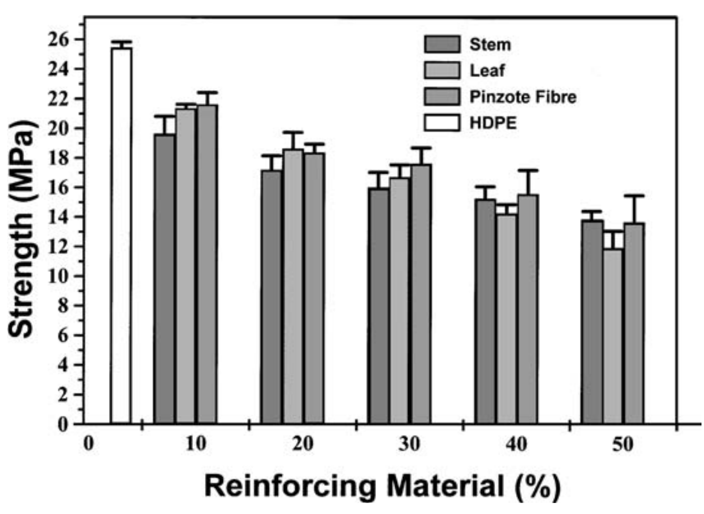

FIGURE 5 Tensile strength against reinforcing material content.

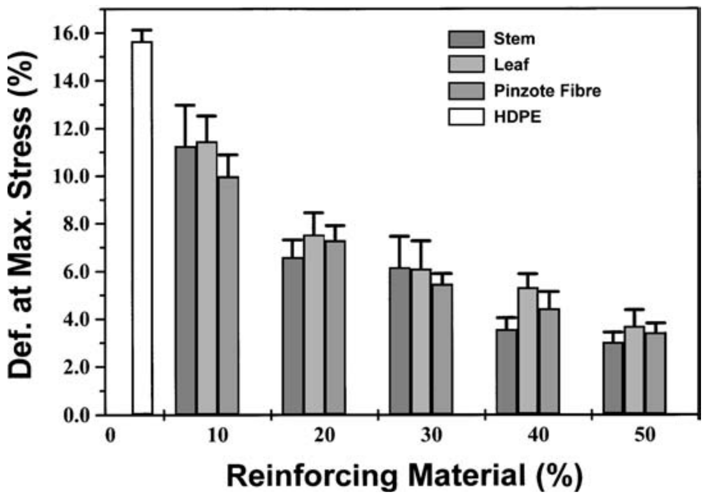

FIGURE 6 Tensile deformation at maximum stress.

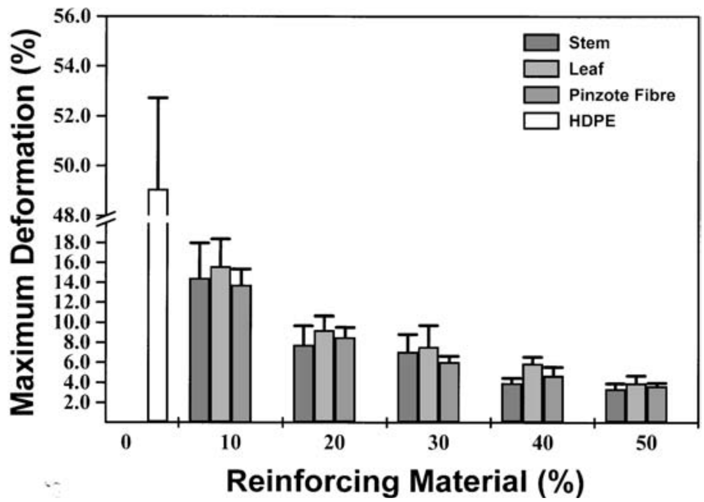

FIGURE 7 Maximum tensile deformation against reinforcing material content.

The 10% composites are too ductile and do not fail by flexion, for this reason the stress supported at 5% of deformation was plotted (Fig. 10). As it can be seen, there is no a significant difference between the formulations, the stress ranges between 27 and 33 MPa.

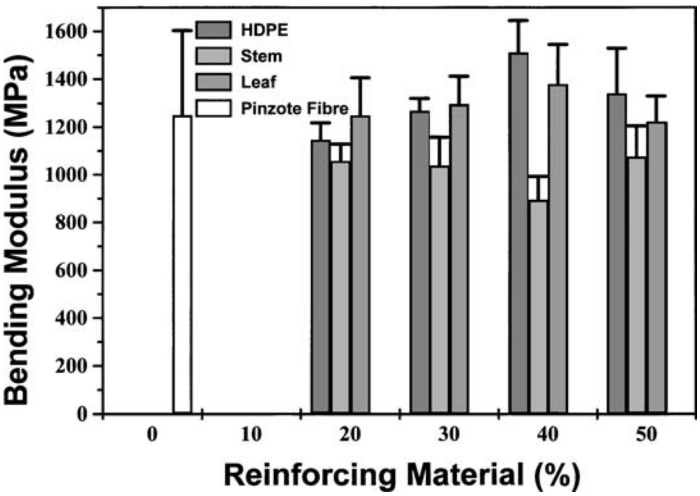

FIGURE 8 Bending modulus against reinforcing material content.

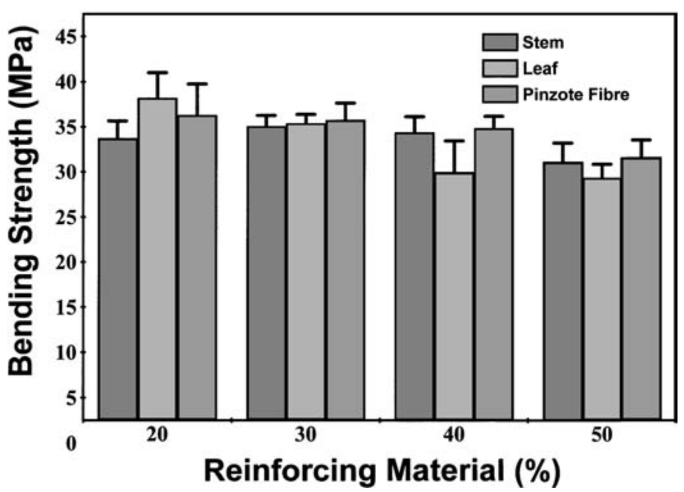

FIGURE 9 Bending strength against reinforcing material content.

Figure 11 shows the flexural deformation degree reached by the composites prepared (except the 10% composite). As it can be seen, the maximum deformation falls with the increase of the reinforcing material content and apparently the leaf composite has the highest deformation levels.

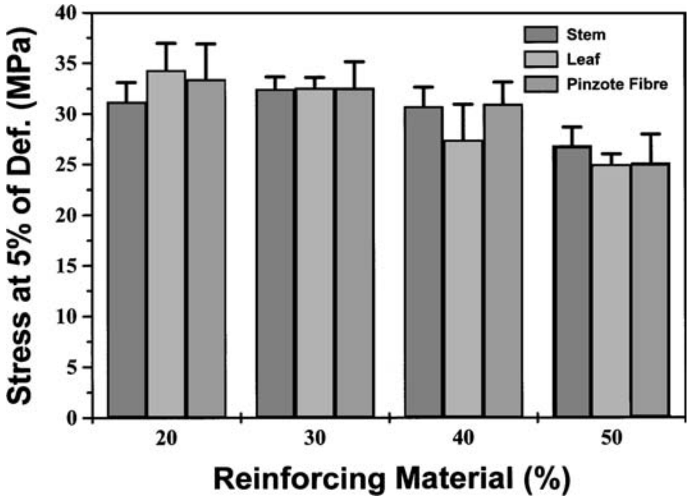

FIGURE 10 Bending strength at 5% of deformation against reinforcing material content.

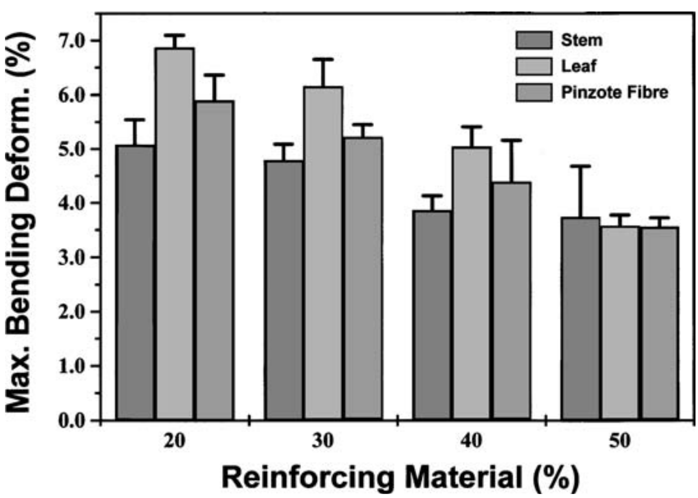

FIGURE 11 Maximum bending deformation against reinforcing material content.

6. CONCLUSIONS

- It is possible to prepare thermoplastic composites reinforced with banana stem, banana leaf and banana pinzote fiber.
- The composites prepared are stiffer than the HDPE (higher modulus and lower deformation).

- The leaf composites showed the lowest mechanical properties due to their geometry: small plates.
- The banana reinforcing materials used showed a low compatibility with the HDPE due to their hydrophilic nature.
- The composites prepared do not show a significative difference between then when they are tested by flexion. This is related to the test nature.

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