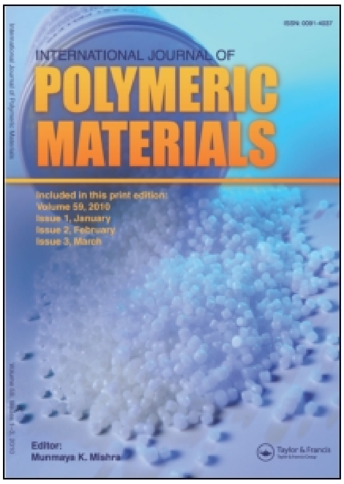

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Dynamic Mechanical Behavior of Piassava Fibers (*Attalea funifera*) Reinforced Polyester Composites

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This work compares the dynamic mechanical behavior of piassava fiber–reinforced polyester composites with the behavior of the neat resin matrix. The results obtained confirm previous data showing that the interface of piassava/polyester composites is stronger than the usual interfaces found when untreated lignocellulosic fibers are incorporated into common polyester matrices. This behavior was attributed to silica-rich protrusions found at the fibers' surface that aid to anchor the resin matrix and increase the stress transfer at the fiber–matrix interface.

Keywords: dynamic mechanical analysis, fiber-reinforced composites, interfaces, piassava fibers

INTRODUCTION

One of the greatest concerns regarding the use of lignocellulosic fibers as reinforcement in polymer matrix composites is the poor interface developed between the hydrophilic fibers and the usually hydrophobic matrices. To overcome this, several chemical and/or physical surface treatments were developed in order to guarantee a better fiber–matrix

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interfacial interaction [1]. Depending on the specific lignocellulosic fiber, treatments traditionally used by the timber industry, such as mercerization for jute [2] or acetylation for sisal [3] and sponge gourd [4], can be applied with success.

The use of any surface treatment, nevertheless, has the disadvantage of increasing the cost of the final composite part being manufactured. Moreover, some of the treatments can be extremely harmful if handled in large scale, such as those involving isocyanates and xylene, in which potentially carcinogenic products are manipulated. Although careful control of chemicals may be performed in a safe way, their use to manufacture "green composites" represents a clear drawback. Ideally, the best lignocellulosic fiber reinforced composite would be the one for which the fiber could be used without any prior surface treatment, or at least any prior chemical surface treatment. Few lignocellulosic fibers, however, appear to fulfill this requisite. Piassava fiber may be an exception because the mechanical behavior of untreated piassava fiber–reinforced polyester matrix composites attains strength levels comparable to those of some of the more commonly used lignocellulosic fiber composites [5].

In order to verify if the piassava fiber/polyester matrix interface is, in fact, stronger than the usual interfaces found when lignocellulosic fibers are incorporated to polymeric matrices, this work presents a study on the dynamic mechanical behavior (DMA) of piassava fiber polyester composites because DMA results provide useful information about the fiber–matrix interfacial compatibility.

RELEVANT CHARACTERISTICS OF PIASSAVA FIBERS AND THEIR COMPOSITES

One of the main aspects that affect interface adhesion in lignocellulosic-reinforced composites is the hydrophilic behavior of lignocellulosic fibers. The first possibility that was raised when high strength levels were obtained using untreated piassava fibers to reinforce polyester matrices was a smaller water affinity by piassava fibers. However, this hypothesis did not hold because the experimental results show that piassava fibers are not less hydrophilic than other common lignocellulosic fibers. In fact, measurements of the water loss of piassava fibers by thermal gravimetric analysis, TGA, revealed an amount of absorbed humidity (5.18 wt% [6]) similar to that of other lignocellulosic fibers, such as sponge gourd (5 wt% [7]), coir (8 wt% [8]) and flax (6.3 wt% [9]). Jute (10.2 wt% [10]) has a fairly higher value and for sisal the reported values range from as low as 3.43 wt% [3] to 11 wt% [11]. Therefore, one could expect fiber/matrix interfaces as weak as those presented by other lignocellulosic fiber composites, such as those reported for coir-reinforced composites, for example [12].

The other possible source of a good piassava fiber–polyester matrix interface arises from the analysis of the surface morphology of piassava fibers by scanning electron microscopy, SEM [6]. The piassava surface is covered by an array of ordered silica rich protrusions, and it was postulated that these protrusions, as well as the concave depressions left at the fibers' surface when the protrusions are removed, could be enhancing the mechanical interlock at the fiber–matrix interface. Figure 1 shows the regular arrangement of protrusions present at the surface of piassava fibers.

In fact, these protrusions may be strongly enhancing the mechanical interlock at the piassava/polyester interface, because the interfacial shear strength, τ, calculated for these composites [13] is similar to that found for glass fiber–phenolic composites, where it was suggested that the value of τ was only due to frictional work [14]. Table 1 shows the comparison of values reported for the critical length, λ_c and interfacial shear strength of piassava and glass fibers [13–14]. As stated earlier, the results presented for glass fiber to matrix interaction were those reportedly as only being frictional. The figures presented in

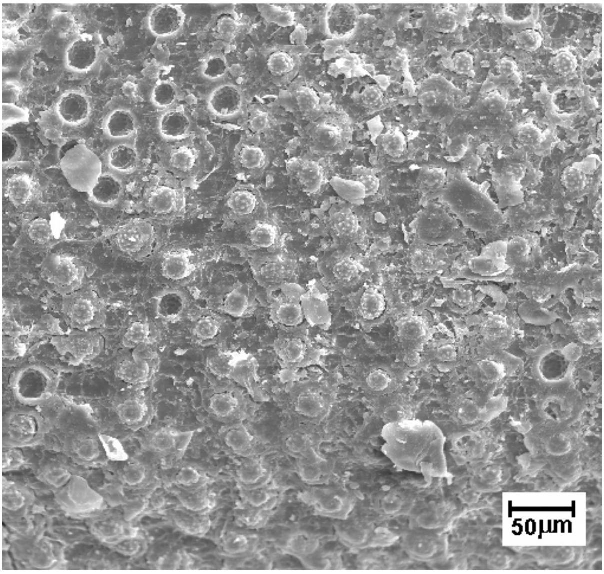

FIGURE 1 Regular array of protrusions observed at the surface of piassava fibers.

TABLE 1 Interfacial Shear Strength and Pullout Length of Piassava and Glass Fiber

Fiber	λ_c, mm	τ, MPa	Resin matrix
Piassava [13]	15	1.9–2.8	Polyester
Glass [14]	5–8*	2–4	Phenolic

*The authors suggest that the interfacial shear strength is only frictional.

Table 1 may, therefore, indicate that untreated piassava has a good interfacial interaction with orthophtalic polyester matrices.

EXPERIMENTAL

The composites analyzed were fabricated by the compression molding technique. The piassava fibers were placed longitudinally aligned inside a metal mold and, then, the resin matrix was poured into the mold. A commercial orthophtalic polyester resin mixed with 5 wt% of methyl-ethyl-ketone catalyst was used as matrix, and the cure of the composites was done at room temperature, $23 \pm 3°C$. Composites with 30 wt% of fibers were tested. The dynamic mechanical properties were measured using a TA DMA 280 instrument. The tests were performed at a frequency of 1 Hz, from $-100°C$ to 160°C at a heating rate of 3°C/min, using the cantilever mode. The neat resin was also tested, using the same setup parameters. The results presented are the average of triplicates.

RESULTS AND DISCUSSION

The experimental results obtained are shown in Figure 2. It can be seen that the incorporation of piassava fibers significantly increased the storage modulus, Figure 2a, in relationship to the value obtained for the neat resin, indicating that the fibers are efficiently reinforcing the matrix. The different behavior observed is entirely due to the reinforcing effect of the fibers and indicate that, indeed, the stress transfer at the interface is being accomplished. In fact, an increase of 46%, from 5800 MPa to 8500 MPa, was obtained when one compares the storage modulus of the neat resin to that of the composite at the lower range of temperatures analyzed.

The behavior of the loss modulus, Figure 2b, corroborates the trend observed for the storage modulus. The loss modulus was increased from 220 MPa for the neat polyester matrix to 600 MPa for the piassava

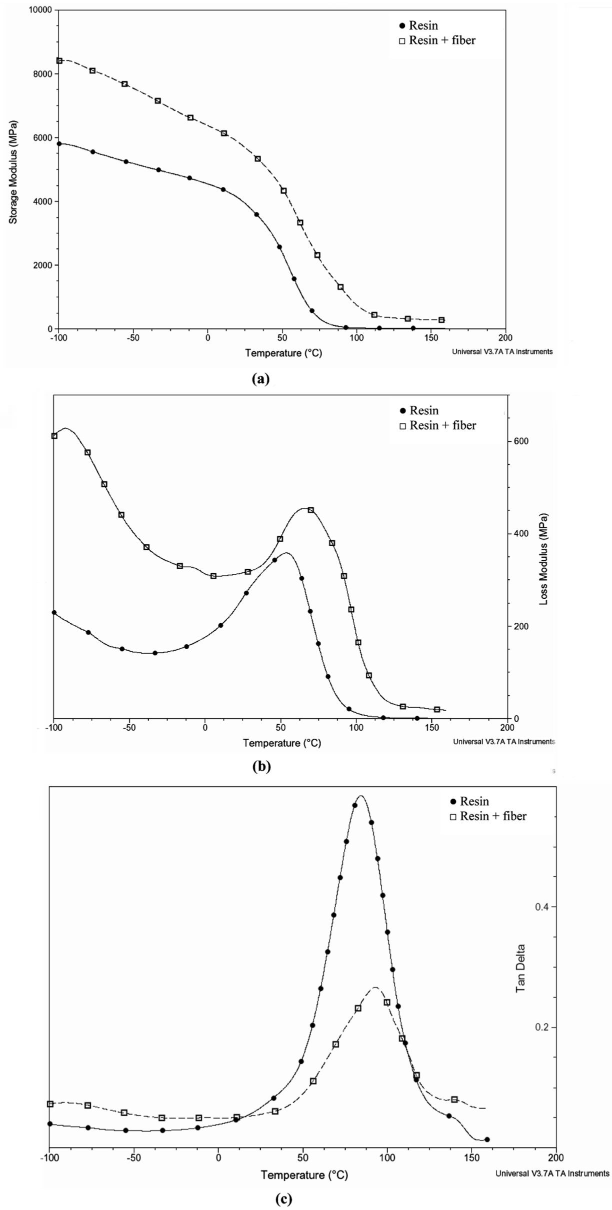

FIGURE 2 Effect of piassava incorporation on the values of: (a) E′, (b) E″, and (c) tan δ.

composite. Moreover, the temperature peak was shifted to from ~55°C to 70°C, indicating that the fibers are restricting molecular chain movement [3,15], and shifting the glass transition temperature to higher values. This result agrees with the observed trend for jute reinforced-vinylester matrix composites, where the alkali treatment of jute fibers promoted a better fiber–matrix interface interaction [16]. Therefore, the results shown in Figure 2 indicate that the modifications introduced by the incorporation of piassava fibers on the loss modulus versus temperature curve are a strong evidence of the good interaction of the untreated piassava fibers with the orthophtalic polyester resin.

The influence of the incorporation of the fibers on the behavior of tan δ is depicted in Figure 2c. One can see that the tan δ peak was strongly reduced when the fibers were incorporated to the composite, and that the tan δ peak was shifted to a higher temperature, from 86°C to 94°C. Both of these characteristics can be associated to restrictions of molecular chain mobility due to the incorporation of a stiff second phase [3,15].

Comparing the overall set of experimental results obtained, it is clear that the dynamic mechanical behavior of the piassava–polyester composite reveals that a good fiber–matrix interaction exists, although untreated fibers were used. This is an outstanding characteristic that can place piassava fibers as a suitable reinforcement for resin matrix composites.

CONCLUSIONS

Comparison of the dynamic mechanical behavior of untreated piassava–polyester composites and that of the neat polyester matrix show that piassava fibers have a unique behavior from amongst the more common used lignocellulosic fibers, showing a strong interfacial interaction with the orthophtalic polyester resin used as matrix even when untreated fibers are used. Therefore, composites with suitable mechanical behavior can be manufactured without any chemical fiber surface treatment. This aspect will certainly contribute to the manufacture of piassava composites with competitive low prices.

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