

Influence of fiber chemical modification procedure on the mechanical properties and water absorption of MaterBi-Y/sisal fiber composites

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Received 18 February 2005; received in revised form 13 September 2005; accepted 18 October 2005

Abstract

In this work, the effect of the two most used fiber treatments: acetylation and alkaline-treatment and its variables: time and temperature for one constant concentration of catalyst, on the final properties of MaterBi-Y/sisal fiber composites was studied. It was demonstrated that this kind of treatments leads to several morphological changes like voids creation and fiber fibrillation. Acetylation for 1 h is an acceptable option when lower water uptake amount is let or high impact energy is required. On the other hand, alkaline treatment for two days at room temperature and 5% w/v NaOH leads to the highest flexural properties with high impact performance and low changes in the water uptake amount.

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Keywords: B. Mechanical properties; B. Interface

1. Introduction

Materials with low environmental impact are of great interest in technological applications: composites based on natural fibers are an interesting alternative when moderate mechanical properties are required [1].

Each natural fiber is a composite material in which soft lignin and hemicellulose act as matrix and rigid cellulose microfibrils acts as reinforcement. Micro fibrils form hollow cells and there are helically wound along the fiber axis. Uncoiling of these spirally oriented fibrils consumes large amounts of energy and is one of the most predominant failure modes [2].

The most important factor in obtaining good fiber reinforcement in the composites is the strength of adhesion between fibers and matrix. The extent of adhesion depends upon the structure and polarity of these materials. Owing to the presence of hydroxyl and other polar groups in sev-

eral constituents of fibers, the moisture regain in high which leads to a poor wettability with the matrix and weak interfacial bonding between the fibers and more hydrophobic matrices. There exist several fiber treatments that are conducting on the natural fibers which modifying not only the interphase but also produce morphological changes on the fibers [2–5].

The polar groups present in natural fibers are responsible for their good adhesion with thermosetting matrices like phenolics, epoxies and polyesters. On the contrary, in the case of thermoplastic matrices, no reaction can take place and only physical and/or mechanical effects are active. Surface modifications of natural fibers not only decreases the moisture absorption but would increase the wettability of the fibers by the polymer matrix and the interfacial bond strength, both critical for obtaining better mechanical properties of the composites [6].

Among the many surface treatments undertaken, the most economically viable one is the alkaline treatment [7]. This process is a purifying treatment that removes impurities such as waxes, pectins, hemicelluloses and min-

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eral salts. The most important effect of alkaline treatment is the modification of the crystallographic cell from cellulose I to cellulose II. This treatment modifies the texture of the fibers and principally their accessibility in an aqueous media. Consequently, after this treatment the fibers have a greater moisture absorption capacity and more reactivity to aqueous chemical reagents, and are more accessible to dye molecules. Alkalinization process affects the surface morphology of natural fibers remarkably resulting in a more distinct exposition of the surface fibrils and a more pronounced surface relief. Due to the intra and interfibrillar swelling, the accessibility of fibers changes drastically [8,9]. Alvarez et al. [10] found that the velocity of the water-uptake process decreased due to the network formed by high content of fibers, which impairs the diffusion of the water through the matrix. However, the alkaline treatment makes the sisal fibers more hydrophilic and the composites made with this kind of fibers had higher water gain at the equilibrium in comparison with untreated fiber based composites.

Vázquez et al. [4] and Cyras et al. [5] observed that the alkaline treatment used on the sisal fibers produce fibrillation and collapse of the cellular structure due to the removal of the cementing material, which leads to a better packing of cellulose chains. The higher fiber density, allowed them to increase the fiber content in the extruder, limited by the fiber volume.

Extensive structural changes can be caused by the alkaline treatment of natural fibers, which, in turn depend strongly on the parameters of the treatment (i.e., Na(OH) concentration, temperature and time of the treatment).

Mechanical properties of the composites depend on the properties of the fibers but in the case of natural fibers, the mechanical property of the single fiber is not directly related to the mechanical property of the composites. Due to the shear stress that the fiber can be suffered, the fibers change their length and diameter, as well as their morphology [10]. Vázquez et al. [4] showed that the alkaline treatment on bagasse fibers produce better creep behavior due to the anchoring effect of fibers. Alvarez et al. [10] found that the critical strain energy release rate, G_{Ic} , of the composite based on sisal fibers and MateBi-Y increases when the fibers were treated, probably due to the fibrillar morphology that increase the toughening of the composite.

Lignin facilitates reactivity, thus allowing better response to chemical modifications such as acetylation. This treatment produces a rough surface, so the number of anchorage points increases, offering a good fiber–matrix mechanical interlocking [11].

Acetylation is a rather attractive method of modifying the surface of natural fibers and making it more hydrophobic. This is an important aspect because the higher water absorption of natural fibers produces major problems in many applications [12]. In addition, acetylation is one of the most studied reactions of lignocellulosic materials.

The aim of this paper is to analyze the two most used treatments on natural fibers: alkaline treatment and acetylation as a function of the time and temperature of the treatment. In spite that a lot of previous work were done studying the same treatments, most of the work did not take into account the time and temperature conditions. The relationship between the procedure and the fiber mechanical properties will allows us to determine the effect produced on their composites based on a fully biodegradable matrix. The effect of the addition of the treated natural fibers on the mechanical properties of the composite based on starch blends were not much studied before.

2. Experimental

A commercial starch based polymer, called MaterBi-Y[®], was used as a matrix. This material was kindly supplied by Novamont, Novara, Italy. The elastic modulus of this material, measured by ASTM 638, is 1.00 GPa, the maximum stress is 12.6 MPa and glass transition temperature is 105 °C.

Sisal fibers were supplied by Brascorda, Brazil. Fibers were used as received, alkaline treated and acetylated. The average length and fiber-diameter of the sisal fiber were determined by optical microscopy over 100 fibers. The length was 7.2 ± 0.6 mm and the diameter was 0.3 ± 0.05 mm. The density of the fibers was determined by picnometry in water, and it was 1370 kg/m^3 .

An average value of the tensile modulus of 15.5 ± 1.9 GPa, and a maximum stress of 471.6 ± 80.2 MPa were obtained for the fibers by ASTM D 3379-75. Composites with 15 wt.% short-sisal fiber content were fabricated. We make previous experiments with different fiber contents. As consequence of the chosen processing procedure, the maximum fiber content which could be introduced in the polymer was 15 wt.%. We tried to use higher fiber content but the dispersion of the fibers into the matrix was not good enough. So the final composites were no homogeneous and the properties decreased.

In all cases, the polymer pellets and the sisal fibers were mixed for 6 min at 180 °C in an intensive mixer at a 25 r.p.m. After mixing, the pellets were compression-molded into plaques at 180 °C and 70 MPa and rapidly cooled down with running water. Finally, the plaques were annealed in an oven for 1 h at 60 °C in order to release thermal stresses generated during molding.

2.1. Alkaline treatment

The fibers were treated with Na(OH) aqueous solution (5% w/v) for 24, 48 and 72 h at three different temperatures: 5, 25 and 40 °C. Then they were washed with distilled water until all the sodium hydroxide was eliminated, that is until the pH was neutral. Subsequently, fibers were dried at 60 °C until constant weight was found. The samples were named as: T524 (treated with Na(OH) at 5 °C during 24 h) and in this way all samples were identified.

2.2. Acetylation: treatment with acetic anhydride/lacid

Fibers were immersed in glacial acetic acid at room temperature for three different times: 1, 4 and 24 h. After that, fibers were decanted and soaked in acetic anhydride containing two drops of concentrated sulfuric acid for 5 min. The fibers were filtered, washed with distilled water until they were free from acid. Subsequently, fibers were dried at 60 °C until constant weight was found.

2.3. Flexural tests

Flexural tests were carried out using an Instron 4467 and the cross-head speed was chosen in according to ASTM D790-93 recommendations. An average value of at least four samples was determined.

2.4. Adhesion measurements

Symmetrical droplets were used. The droplet/fiber specimen was stuck at one end to a piece of hard paper and suspended on the cross-head of tensile tester equipment (INSTRON) with a 500 N load cell. Tests were performed at a cross-head speed of 1.2 mm/min. Tests were carried out at room temperature.

2.5. Puncture tests

Impact test were conducted on samples cut out from compressed plates of 3 mm thickness and 90 mm diameter. These tests were performed in a falling weight Fractovis of Ceast at 1 m/s. The maximum in the load–displacement curves is related to crack initiation. The average load at this point, P_{\max} , was transformed to a stress which represents the impact strength at crack initiation, σ_d :

$$\sigma_d = 2.5 \cdot \frac{P_{\max}}{t^2}, \quad (1)$$

where t is the disk thickness. The area under the load–displacement curve up to maximum load represents the energy at crack initiation and the total energy required to penetrate the specimen fully, E_{tot} is the total area under the load–displacement curve. By normalizing these value by sample thickness gives:

$$E_{\text{inic}} = \frac{1}{t} \int_0^{x_{\max}} F \cdot dx, \quad (2)$$

$$E_{\text{tot}} = \frac{1}{t} \int_0^{x_{\text{total}}} F \cdot dx. \quad (3)$$

The performance against impact perforation of the composites was evaluated by the ductility index, DI:

$$DI = \frac{E_{\text{prop}}}{E_{\text{total}}}, \quad (4)$$

where $E_{\text{prop}} = (E_{\text{total}} - E_{\text{inic}})$ is the energy required to complete disk penetration after crack initiation and reflects the post-maximum range.

2.6. Fiber length and diameter measurements

Fibers were extracted from composites by dissolution of MaterBi-Y matrix using acetone. Fiber diameter and length were measured using an optical microscope OLYMPUS SZH 10.

2.7. FTIR spectra

KBr disk method was followed in order to obtain FTIR spectra. 64 scans were carried out on wavenumber from 4000 to 600 cm^{-1} . The equipment used was an FTIR Genesis II.

2.8. SEM examination

The SEM photographs of fibers surfaces and cross-section and of fracture surface of composite materials of untreated and treated fibers were taking using a scanning electron microscope, Philips SEM 505.

2.9. Water absorption

Samples were immersed in distilled water at room temperature. Samples were removed from the bath at fixed times and were carefully dried with an absorbent paper. Weight change was determined by means of a microbalance calculated at 10 mg. At least, four specimens of each material were used.

3. Results and discussion

Fig. 1 shows the FTIR spectra of the untreated, alkaline treated and acetylated sisal fibers. The obtained peaks are explained on Table 1. Sisal fibers have 65.8 wt.% cellulose, 9.9 wt.% lignin and 12 wt.% hemicellulose.

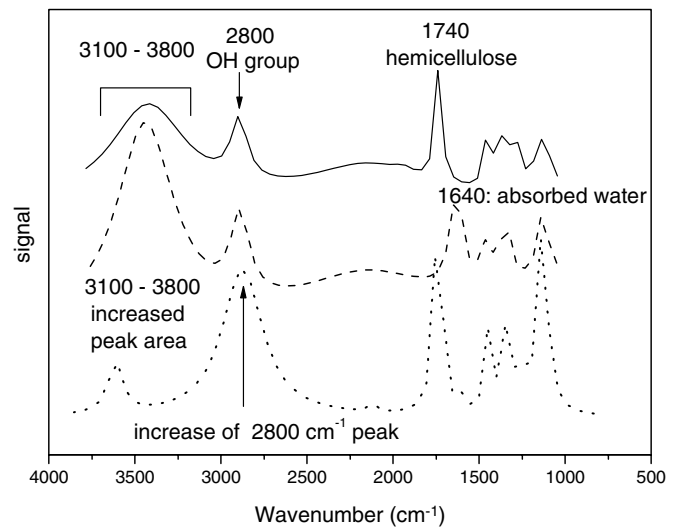


Fig. 1. FTIR measurements of : untreated sisal fiber, alkaline-treated (40 °C, 48 h) and acetylated sisal fibers (25 °C, 24 h).

Table 1
FTIR peaks position of original sisal fiber

Wavenumber (cm ⁻¹)	FTIR peak origin
3100–3800	OH stretching vibration
2970, 2924	C–H stretching vibration (cellulose–hemicellulose)
1735, 1715	C=O stretching vibrations (carboxylic acid and ester groups of hemicellulose)
1650, 1630	Absorbed water
1440, 1530	Lignin components
890	β-glucosidic linkage

Alkaline-treatment produces the partial dissolution of hemicellulose. In FTIR spectra, the carbonyl band at 1730 cm⁻¹ corresponds to hemicellulose and disappears after this treatment. Comparatively, the acetylated fibers have a similar spectrum to the original fibers [2]. An OH group appeared at 2800 cm⁻¹ in the acetylated sisal fiber. After acetylation, the OH peak changed from strong to very strong. This peak shifted to the lower side, indicating the protection of some free hydroxyl groups [13]. In the case of alkaline-treated fibers, the peak area at 3100–3800 cm⁻¹ increased considerably indicating the presence of an increased number of OH groups arising due to the cleavage of alkali-sensitive bonds. Removal of hemicelluloses caused changes in the peaks positions. The intensity of 1735 and 1715 cm⁻¹ peaks decreased because C=O groups are lower by the removal of hemicellulose. A little shoulder at 1630 cm⁻¹ appears due to the absorbed water in alkaline-treated fibers indicating a higher amount of absorbed water. FTIR spectra confirmed that alkaline-treated fibers have an open structure that leads to larger water absorption when the hemicellulose is dissolved [7].

Alkaline-treatment and acetylation change the supermolecular structure and morphology of fibers while the chemical structure does not change very much. Due to the intra and interfibrillar swelling, the accessibility of fibers changes drastically. The possible chemical reaction between the alkaline solution and the OH from the fiber is



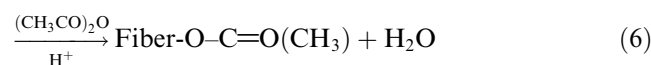
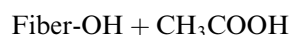
Table 2 shows the water absorption of untreated and treated fibers. The principal mechanism of water diffusion follows the Fick's law, especially at the short time. However, capillarity is another possible mechanism in the case of natural fibers [14].

Table 2
Equilibrium water absorption of untreated and treated fibers

Sample	M _∞ (%)	Sample	M _∞ (%)
WT	10.2 ± 0.5	T524	10.6 ± 0.7
T2524	10.9 ± 0.6	T548	10.0 ± 0.7
T2548	11.5 ± 0.8	T572	10.9 ± 0.6
T2572	11.3 ± 0.6	Ac 1 h	9.2 ± 0.6
T4024	10.2 ± 0.5	Ac 4 h	8.4 ± 0.7
T4048	10.1 ± 0.9	Ac 24 h	5.1 ± 0.8

Fibers treated at 40 °C during 72 h were very fragile, very defibrillated, without structural integrity and it was very difficult to work with these fibers is for this reason that this fibers were avoid to used in the rest of the work. It is evident from this table that water absorption remind almost constant with alkaline treatment. We expected that the values increase with this treatment and this result may be due to the more compact structure of treated fibers (Fig. 1) that do not allow the water entrance or changes of the fibers compositions [8,9].

On the other hand, the acetylated fibers absorb less water than the untreated ones due to the partial substitution of the OH groups during this reaction:



Acetylation introduces more voluminous groups in the lateral chains that produce a decrease in the segment mobility and increase the macromolecules stiffness. The water absorption occurs due the hydrogen bridge interactions between water molecules and fibers OH groups, so that, this treatment decreases fibers affinity by the water and the maximum water uptake increasing the dimensional stability.

From this study, acetylated fibers appear as the better option when low water uptake is required.

Fig. 2 shows the load–displacement curves obtained in flexural tests for composites with untreated and treated short fibers. When the specimen fails in the way that the slope of the force–deflection curve decreases gradually to zero, that is in the case of the untreated fiber composites, shear failure takes place. On the other hand, when the specimen fails abruptly that curve is practically linear, it can be attributed to flexural failure mode [2]. In the case of poor adhesion between fiber and matrix, the stress

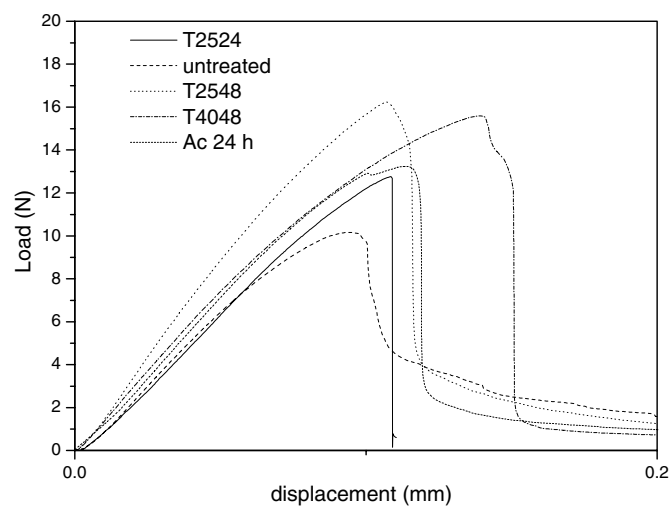


Fig. 2. Load–displacement curves obtained in flexural tests for composites with untreated and treated short sisal fibers.

concentration is entirely localized in the mesophase layer that is subjected to large shear deformation. In the case of good adhesion, the shear stress concentration is much lower and more diffusive. The load carried is seen to drop sharply with a decrease in adhesion and depends only weakly on the mesophase thickness. In the case of perfect bonding between fiber and matrix, the failure occurs only in tension with no fiber debonding leading to a catastrophic failure at lower elongation in the composites due to the reduction in the fiber pull-out and the lower debonding. On the other hand, a better interface leads to a lower value of the critical aspect ratio fiber value [15].

The mechanical behavior and durability of composite materials do not depend only on the properties of each component (matrix and fiber) but also on the interfacial properties. Fig. 3 shows the interfacial strength of composites with different fiber treatments. The values show that interfacial strength does not increase with alkali-treatment. It is clear from this figure that the dispersion of the results are quite high, mainly due to the differences in the fiber diameters.

In the case of acetylated fibers, the interfacial strength decreases with the treatment, showing the lower adhesion between fibers and matrix. With interfacial strength values and fiber strength, the critical aspect ratio can be estimated by using the Kelly–Tyson equation:

$$\left(\frac{l}{d}\right) = \frac{\sigma_f}{2 \cdot \tau}, \tag{7}$$

where σ_f is the fiber strength and τ is the fiber–matrix interfacial strength. Table 3 shows the critical aspect ratio obtained by the last equation. The reason why the l/d ratio decreases is related to the processing technique. The final fiber aspect ratio value depends on the used mixer equipment: intensive mixer and twin-screw extruder, and their internal design. Although the diameter was lower after NaOH treatment, the fibers are easier to break down due to the shear stress developed during the mixing, so the decrease on the length values is higher than that on the diameter values. If the fiber are not mixed with a polymer, the alkaline treatment produces a decrease on the diameter of the fiber [10]. In the case of acetylated fibers, modulus and strength decreased with the treatment and the fibers are easier to break, so the decrease in fibers diameter is partially compensated by the decrease in fibers length.

The interphase is a region between both phases: fibers and matrix. The main interaction in this region is the mechanical interlocking due to rough surface of the fiber, specially in the natural fibers with fibrils and also can be exists a chemical interaction between fibers OH groups and matrix (blend of starch and cellulose derivatives). The stress transference from the matrix to the fibers takes place when the experimental aspect ratio is higher than

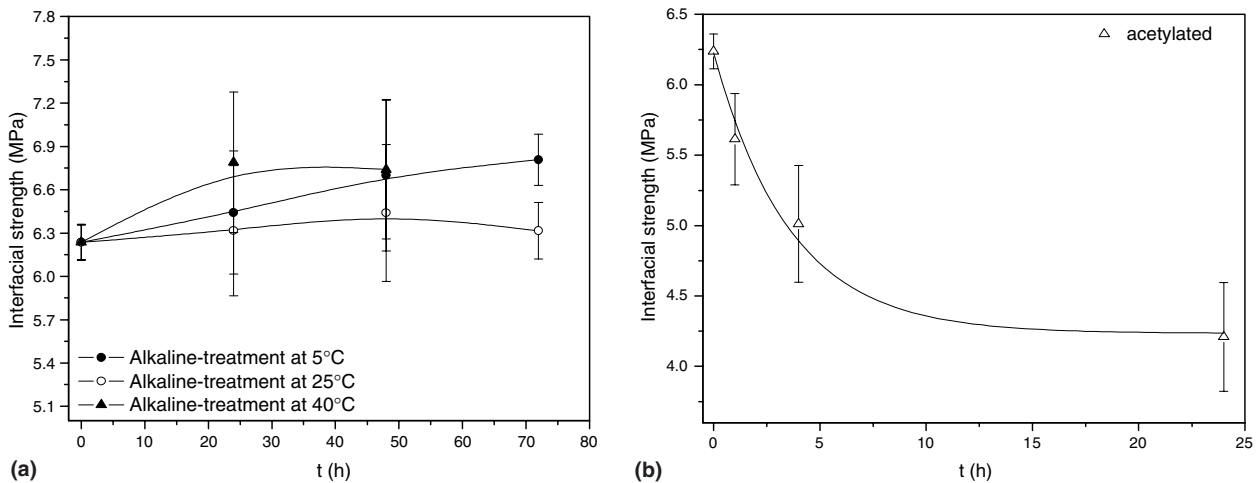


Fig. 3. Interfacial strength as a function of fiber treatment: (a) alkaline-treated and (b) acetylated.

Table 3
Fiber aspect ratio (experimental and critical values) as a function of treatment

Treatment	$l/d_{\text{experimental}}$	l/d_{critical}	Treatment	$l/d_{\text{experimental}}$	l/d_{critical}
ST	17.9 ± 3.0	37.8 ± 3.2	T524	19.5 ± 3.0	38.5 ± 2.6
T2524	19.5 ± 2.2	41.5 ± 4.7	T548	19.7 ± 3.1	44.9 ± 4.2
T2548	17.4 ± 2.1	32.3 ± 2.6	T572	18.7 ± 2.4	34.4 ± 3.1
T2572	15.0 ± 2.2	30.5 ± 4.1	Ac 1 h	18.5 ± 2.2	42.6 ± 2.8
T4024	15.9 ± 2.8	23.4 ± 3.9	Ac 4 h	20.0 ± 3.1	22.9 ± 3.2
T4048	14.5 ± 2.0	24.4 ± 3.1	Ac 24 h	20.1 ± 2.2	7.1 ± 0.8

Table 4
Flexural modulus of MaterBi-Y/short untreated and treated sisal fiber composites

Sample	E (GPa)	Sample	E (GPa)
WT (without treatment)	2.08 ± 0.24	T2572	1.99 ± 0.15
T524	2.11 ± 0.07	T4024	2.30 ± 0.18
T548	1.92 ± 0.13	T4048	2.05 ± 0.06
T572	1.75 ± 0.15	Ac 1 h	2.02 ± 0.11
T2524	1.74 ± 0.24	Ac 4 h	2.03 ± 0.22
T2548	2.51 ± 0.29	Ac 24 h	2.01 ± 0.17

the critical one. For fibers with an aspect ratio lower than the critical value, pull-out occurred more than fiber break-down. A weak interface between fiber and matrix leads to a lower reinforcement effect. For alkaline-treated fibers, in all cases, the critical aspect ratio is higher than the experimental one. Although, experimental values have a high dispersion and some fibers have higher values of the aspect ratio. Acetylated fibers show the lowest value of the critical aspect ratio, but this may be due to the low strength of that fiber that appears in equation [7].

Table 4 shows the flexural modulus of the composites. The results permit to say that there is an optimal condition on temperature and time for alkaline treatment (25 °C and 48 h). This conditions leads to a decrease in the spiral angle and increased molecular orientation and as consequence, an increasing of 20% in the flexural modulus. This behavior is in accordance with the increase of the single fiber tensile modulus, because a removal of cellulose fractions of low degree of polymerization which decrease the degree of crystallinity. The enhancement of fiber modulus of elasticity caused by some conditions of alkaline-treatment can be observed as an increase of the stiffness of the composite, which normally depends on the fiber–matrix adhesion [9]. Alvarez et al. [10] have demonstrated that the strength of alkaline-treated fibers increases in comparison with untreated fibers.

In untreated fibers, hemicelluloses are dispersed in the interfibrillar region and separates cellulose chains. These chains are in strain state. Alkaline treatment removes hemicelluloses, so the internal strain disappears and fibrils are able to rearranging in a more compact structure. These treatment leads to a decrease in the spiral angle and increased molecular orientation. A cellulose chain poses a closer packaging that leads to higher fiber strength [7]. In acetylated fiber, the reduction in strength may be due to the loss of hemicellulose of the fiber during the treatment [13]. As the modulus depend on the modulus of the fiber and also on the aspect ratio, if the aspect ratio were higher than the present one, the alkaline treated fiber composites could have higher modulus than the obtained after the processing in this work.

Fig. 4 shows the untreated and treated fiber surfaces. The raw fibers have a very corrugated structure. Alkaline-treatment affects the surface morphology of bast fibers remarkably, resulting in a more distinct exposition of the surface fibrils and a less pronounced surface relief. Intra-

crystalline swelling takes place and cellulose changes from I to II. For this reason, permanent changes of the fiber aspect are evident and at long time and high temperature the fibers collapse.

Sisal fiber is not a single filament like glass or carbon but is a bundle of cellular aggregate consisting of more than 100 irregular hexagonal hollow ultimate cells. When sisal fiber composites are studied, two types of interfaces must be considered. A higher binding strength at the former interface than the latter one is highly desired so that the ultimate cells might decohere from each other, probably leading to interfibrillar failure and uncoiling of the helical fibrils. The composites would be remarkably strengthened and toughened in this way. The acetylation treatment produces more interfibrillar failure, as it can be seen on Fig. 5.

Fig. 5 shows the fracture surface of composites with untreated and treated fibers. Fracture surface of untreated fiber composites shows holes and fiber ends indicating that the most of the fibers have come out without breaking during the fracture of these composite. This suggests poor adhesion between the matrix and the fibers. The fracture surface of treated fiber composites shows fiber breakage rather than pull-out, which in turn indicates a better interfacial strength [16]. The dissolution of cellulose constituents in alkali creates voids in the fiber structure and swelling was observed. The loss of hemicellulose and cementing constituents contributed to the closer packing of the cellulose chains, and the fibrils can reoriented in the tensile direction [7].

For composites based on acetylated fiber from 1 to 24 h, a progressive destruction of the mesh network and splitting of fibers into finer filaments occurred during treatment. This process is termed fibrillation; this is the breaking down of the fiber bundle into smaller ones, increasing the effective surface area available for wetting by the resin [17].

Table 5 shows the values of disk strength, the ductility index and fracture energy of the composites with different fiber treatments. An increase in the disk strength for the composite was observed when fibers were treated in all cases. In the similar way, the ductility index increases indicating that the material did not break down at the maximum load but suffers a post-maximum crack propagation leading to an increase in the energy needed to produce the hole. New energy dissipation mechanisms resulting from the presence of the fibers became active and it is related to the axial splitting of the natural fibers.

Fig. 6 shows the macrophotographs of the opposite side of the impacted areas of the composites with untreated and treated sisal fibers. Two lengths were measured at the hole. In all cases, radial and circumferential cracks were observed around the sample hole area. The 1 h acetylated fibers composites showed the highest amount of circumferential crack propagation and this explain the higher impact energy of those composites. Mouzakis et al. have determined that the circumferential shear-cracking phenomenon is more effective in toughness improvement than radial cracking mechanism [18]. The higher energy consumption

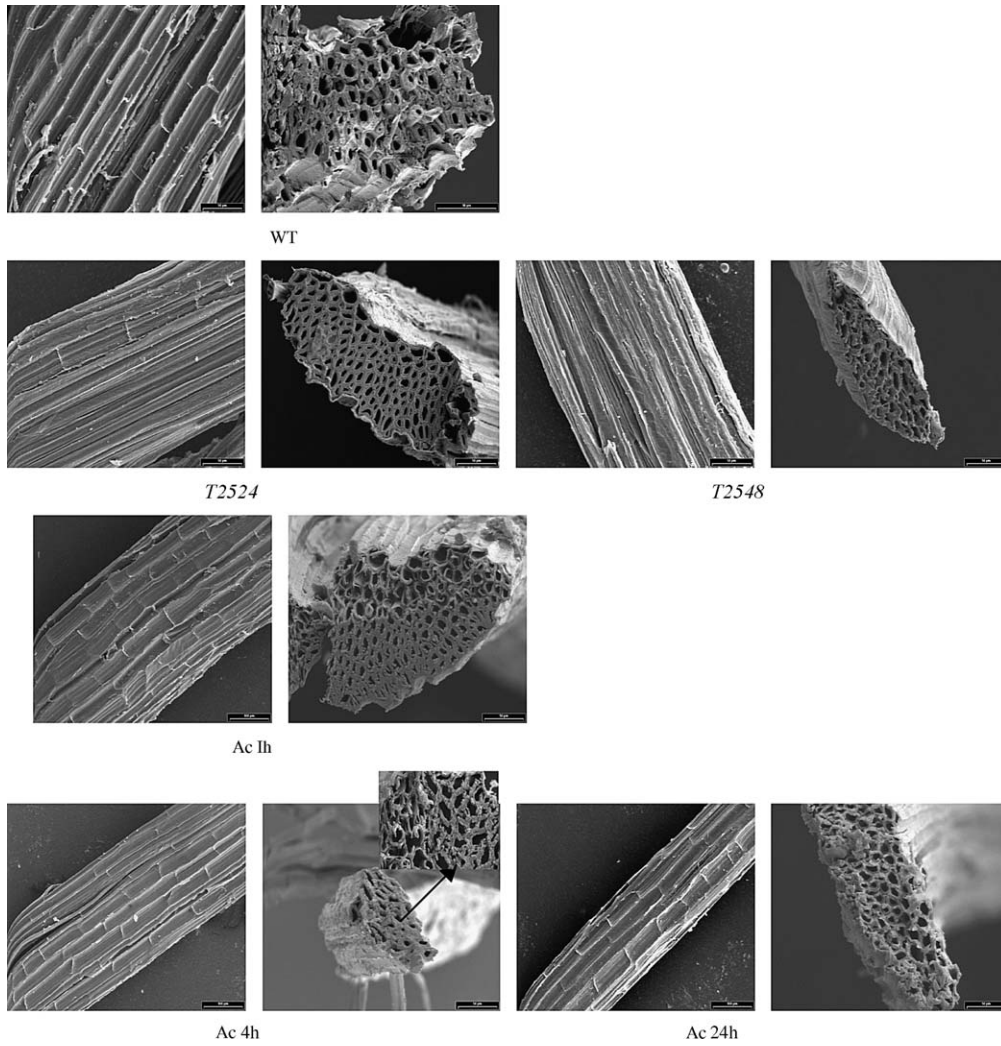


Fig. 4. Untreated and treated fiber surfaces.

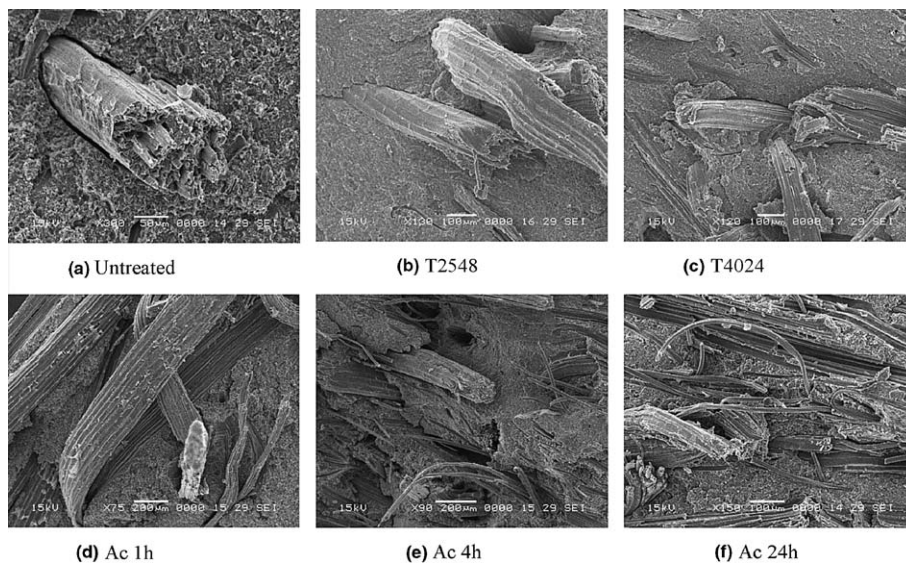


Fig. 5. Fracture surface of composites with untreated and treated fibers.

Table 5
Impact out of plane fracture properties

Treatment	σ (MPa)	E_{total} (kJ/m)	DI	Treatment	σ (MPa)	E_{total} (kJ/m)	DI
WT	106.4 ± 1.8	0.37 ± 0.14	0.18 ± 0.05	T524	119.1 ± 8.4	0.58 ± 0.06	0.26 ± 0.04
T2524	128.3 ± 5.2	0.59 ± 0.05	0.25 ± 0.10	T548	108.8 ± 1.3	0.52 ± 0.05	0.35 ± 0.03
T2548	125.3 ± 7.9	0.56 ± 0.06	0.27 ± 0.01	T572	100.5 ± 2.2	0.49 ± 0.05	0.38 ± 0.09
T2572	120.5 ± 11.7	0.54 ± 0.04	0.36 ± 0.03	Ac 1 h	123.3 ± 2.7	0.74 ± 0.04	0.43 ± 0.22
T4024	117.6 ± 1.4	0.57 ± 0.05	0.30 ± 0.05	Ac 4 h	115.2 ± 15.2	0.63 ± 0.09	0.32 ± 0.22
T4048	112.4 ± 2.2	0.50 ± 0.04	0.23 ± 0.10	Ac 24 h	114.2 ± 7.2	0.59 ± 0.04	0.35 ± 0.02

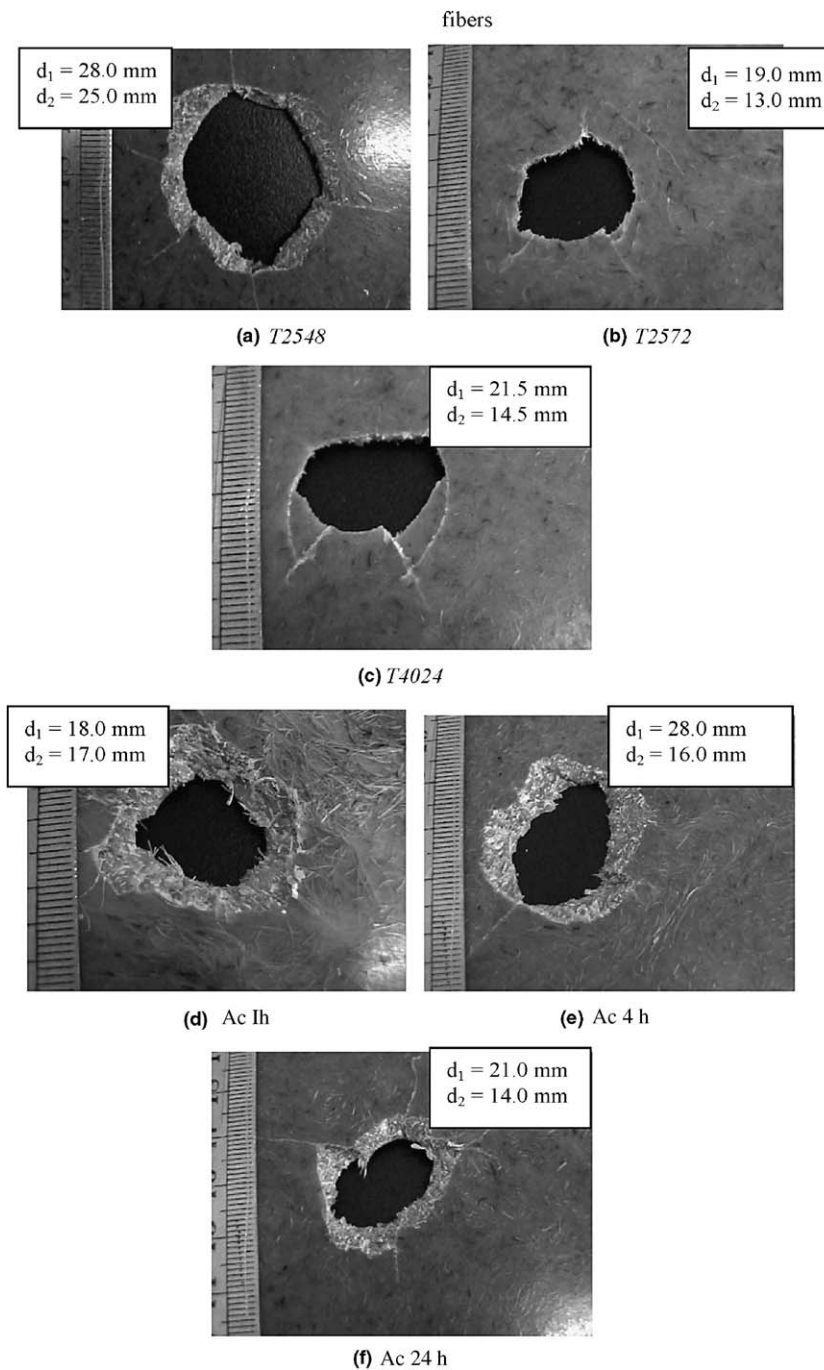


Fig. 6. Macrophotographs of the opposite side of the impacted areas of the composites with untreated and treated sisal fibers.

in the case of acetylated-treated fiber composites may be due to the better fiber–matrix interaction.

4. Conclusions

The effect of alkaline-treatment and acetylation on the sisal fibers/MaterBi-Y composites was studied. It was demonstrated that both treatments changed the morphology of the fibers; removing cellulosic and cementing materials, creating voids and producing fiber fibrillation. These effects leads to a better adhesion between fiber and matrix.

From the studies carried out in this work, we can conclude that, the alkaline-treatment at room temperature for 48 h is the best treatment because, the water uptake did not change very much whereas the mechanical properties were the highest. On the other hand, if the material will be used in an application where lower water uptake and/or high impact performance are required, acetylation for 1 h will be an interesting option.

Acknowledgements

Authors thanks the financial support of SECYT-PICT2003 No. 15074. CONICET (Argentina) is also gratefully acknowledged.

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