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Flexural properties of the composites polystyrene/fiber natural Alfa treated.

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Abstract

The influence of chemical treatment on the flexural properties of Polystyrene/plant fiber composites has been studied. The Alfa fiber is used as reinforcement after been treated with a NaOH aqueous solution 3% for 24, 48 and 72 hours at 25°C. The results obtained show that the chemical modification of the Alfa fiber affects the mechanical properties of the composites. The flexural strength and flexural modulus were clearly improved with the treatment compared to the composites with the untreated fiber. In addition, an increase of the mechanical properties is observed with the increase of the treatment time. This improvement in the flexural properties is attributed to the good adhesion between the matrix and the reinforcement. SEM results show that treated Alfa fiber with 3% NaOH for 72 h makes the fiber surface smooth after removal of the non-cellulosic components and the water absorption rate decreases with the during treatment. This decrease is due to the reduction of hydroxyl groups in the fiber, following the removal of amorphous compounds.

Keywords: *Chemical treatment, plant Alfa, Polystyrene, Flexural properties.*

I. Introduction

Currently, scientific and technological efforts are focused on minimizing the environmental impacts associated with the use of polymer materials. Therefore, attention is increasingly being focused on biodegradable composite materials such as those based on polystyrene, polypropylene, etc., with natural fillers such as cellulose, starch, and plant fibers.

The use of plant-based fillers as reinforcements for composite materials offers numerous advantages due to their biodegradability, low cost, and mechanical properties. However, the adhesion between the hydrophilic surface of the fillers and the hydrophobic polymer used as a matrix is weak, which reduces the reinforcement capacity [1] – [3].

However, incorporating natural fibers sach as Alfa [4] into polymer materials creates compatibility issues du to the hydrophilic nature of the fibers and the hydrophobic character of the polymer matrix. We often use various methods, including as acetylation [5], alkali treatment [6,7], and methylation [8], to alter the matrix or the natural fiber in order to compensate for this issue [9]. Alkali treatment is the most popular method for treating natural fibers [4]. Natural fibers are impacted by alkalinization, which offers distinct performance. Hemicelluloses, lignin, and impurities including wax and lipids are extracted using this treatment [10].

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The primary aim of this study is to examine the mechanical characteristics of polystyrene (PS) composites strengthened by Alfa natural fibers sourced from Alfa stalks. Alfa fibers have undergone chemical modification with sodium hydroxide solution to improve their affinity and adhesion to the polystyrene matrix. This approach would enable the development of a novel and eco-friendly composite material that poses no threat to the environment. To enhance the Alfa fibers-matrix interface, the effects of aqueous sodium hydroxide concentration and treatment duration have been examined. This study focuses on the development of the characteristics of composites made with PS as the matrix and both treated and untreated natural Alfa fibers. The experimental program consists of a series of texture assessments using FTIR, scanning electron microscopy (SEM) evaluations, water absorption and mechanical testing.

II. Material and methods

II.1 Materials

The polymer used in this work is polystyrene in the form of translucent granules. It was obtaining from the National Industrial Company (E.N.I.E.M), Algeria. It's melt index >12g/10min (200°C/5g) and the density of 1.05g/cm^3.

The alfa fiber is obtained from the alfa stem, from Djelfa, which underwent several preparation steps, consisting of a pretreatment in saline water for 24 hours at 60°C. This treatment aims to remove surface impurties sach as dust, waxes and soluble hemicelluloses, while also reducing the internal moisture content of the Alfa fibers [11]. The saline water increase the fiber roughness and improve wettability by the polymer matrix. As a result, the fiber-matrix interfacial

adhesion is Enhanced, leading to improved mechanical performance of the composite.

Followed by rinsing with distilled water and air-drying for 48h. subsequently, the Alfa fibers were subjected to alkaline treatment using a 3% sodium hydroxide (NaOH)solution during 24, 48 and 72 h at 25°C. After treatment, the Alfa fibers were neutralized with an acetic acid solution after being cleaned with distilled water. The fibers were dried for six hours at 60 °C.

II.2 Methods

Sample preparation

The treated and untreated alfa fiber of 5% to 30% (by weight) is mechanically mixed with polystyrene by a single-screw extruder TOSHIBA IS 150 E of 150 TONNES and then injected into molds to obtain plates. The samples for flexural testing are cut by a manual press.

Fourier transform infrared spectroscopy (FTIR) analysis

Fourier transform infrared spectroscopy (FTIR) analysis was performed to investigate the effect of the alkaline treatment on the Alfa fibers. The infrared spectra of the samples treated and untreated Alfa fiber were recorded using a vertex 70 spectrophotometer in ATR mode with a resolution of 2 cm^{-1}, in the region 4000 cm^{-1} to 400 cm^{-1}. The samples to be analysed are prepared in pellets form. This consists of a mixture of 0.001 g of previously groung fiber (treated or untreated) and 0.2 g of potassium bromide (KBr).

Scanning Electron Microscopy (SEM)

The morphology of the treated and untreated fibers by NaOH is observed by the Philips ESEM XL (tungsten filament) scanning electron microscope coupled to a complete energy dispersive microanalysis (EDS X) system.

Water absorption test

The water absorption test involves placing the sample in an oven at 70°C for 24 hours, then allowing them ton cool to room temperature in a desiccator. Next, they are weighed using a precision balance. After weighing, the samples are placed in distilled water at room temperature. According to ASTM D570, the changes in water absorption over time is modified. After wiping the samples with absorbent paper (to remove excess water in the surface), their weight is measured each time until saturation (in constant weight). Water absorption rate is determined by the following relation :

$$\text{Water absorption rate} = \frac{M_t - M_0}{M_0} * 100 \quad (1)$$

Where : M_t : the mass of the sample at time « t » (g).

M_0 : the mass of the sample at time « 0 » (g).

Flexural tests

The flexural properties of the composites, three-point bending tests were performed according to the NF T51-001 standard using dedicated mechanical testing setup.

The samples were tested using a Zwick/Roell Z 2.5 Machine (3mm/min). Flexural strength (Sf) and flexural modulus (Ef) were then obtained using the expressions :

$$s_f = \frac{3PL}{2bd^2} \quad (2)$$

$$E_f = \frac{ML^3}{4bd^3} \quad (3)$$

Where: **P:** The maximum load.
M: The slope of the initial straight-line portion of the load-displacement curve.
b and **d** are, respectively, the width and the thickness of the specimen.
L: The support span.

III. Results and discussion

III.1 Fourier transform infrared spectroscopy (FTIR) analysis

The changes in the surface structure of alfa fibers under alkaline treatment are observed using the infrared spectrum "**Figure 1**". The disappearance of the peak at 1735 cm-1, corresponding to the C=O carbonyl groups, is also observed due to the partial hydrolysis of hemicelluloses in an alkaline medium. The symmetrical and asymmetrical stretching vibrations corresponding to the C-H bonds of the (-CH2) groups of the cellulose and lignin segments are observed near 2924 cm-1, which are affected by the treatment.

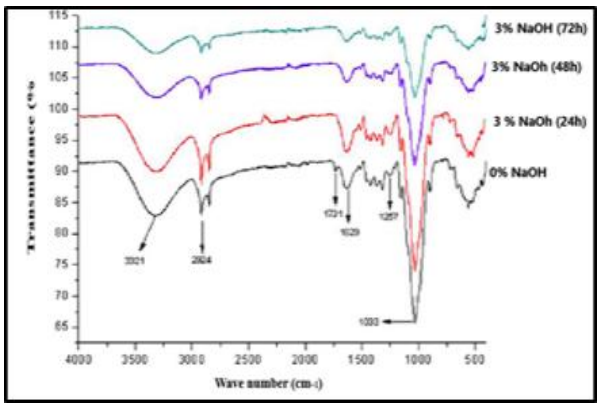

Figure 1. Infrared spectra in ATR mode of untreated alfa fibers and those treated with 3% NaOH for 24, 48 and 72 hours at 25°C.

III.2 Scanning Electron Microscopy (SEM)

Figure 2 shows the micrographs of fibers surface before and after treatment in 3% of aqueous caustic soda (NaOH) during 72 h. The change in the morphology of Alfa fibers during alkali treatment is very important.
We observe that the surface of untreated Alfa fibers surface is rough **(Figure 2(a))**. This can be referred to non-cellulosic components (waxy substances, oils and impurities) contained in these fibers [2]. The treated Alfa fibers (3% NaOH during 72h), surface becomes smooth after removal of the non-cellulosic components (**Figure 2(b)**).

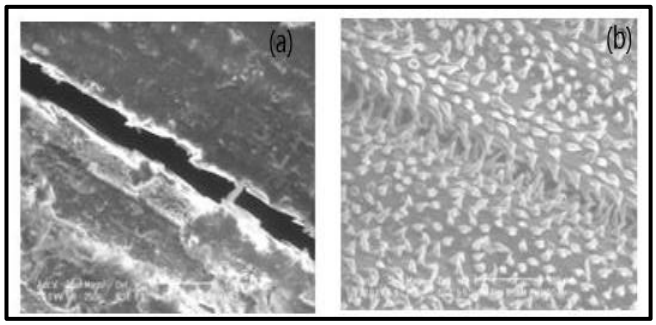

Figure 2. Different morphology of fiber Alfa :(a) untreated, (b) treated in aqueous caustic soda (3% NaOH during 72h).

III.3 Water absorption test

The evolution of the absorption rate of treated PS/Alfa fiber composites was studied. **Figure 3** present the results obtained with the materials immersed in water, with fiber contents of 5%, 15% and 25%. According to this figure, it is also observed the composites with untreated Alfa fiber that the water absorption rate increases with an increasing with proportion of Alfa fiber in PS matrix. This increase is linked to the macromolecular structure of Alfa fiber, which are rich hydroxyl groups (-OH). These groups form hydrogen bonds with water molecules.
Therefore, a greater fiber content leads to an increased concentration of hydroxyl groups, resulting in a higher of water absorption rate. These results are consistent with those found by Bessadok and al [12] and Pasquini and al [13].
Then, we observe that for the same treated Alfa fiber content, the water absorption rate decreases with the concentration and during treatment. This decrease is due to the reduction of hydroxyl groups in the fiber, following the removal of amorphous compounds.

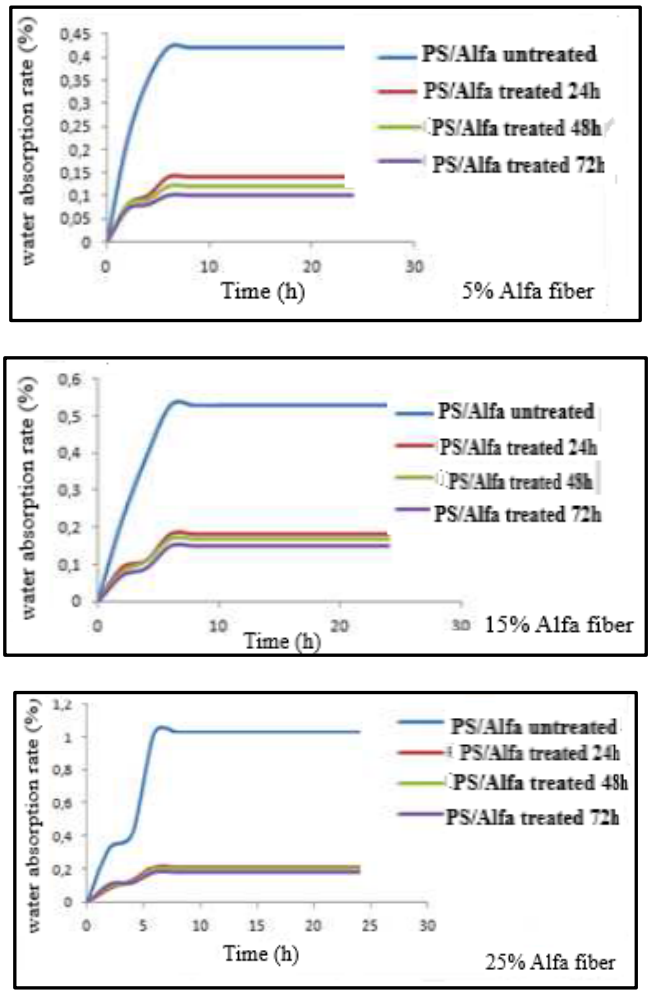

Figure 3. Evolution of the water absorption rate of PS/ Alfa fiber composites.

III.4 Flexural tests

The effect of fibers treatment with 3% NaOH for 24, 48, and 72 h at 25 ° C, that the flexural modulus and flexural strength can be seen in **Figure 4** and **Figure 5** respectively. Results show that mechanical properties are changed with fibers treatment. Figure 4 shows that the flexural modulus increased with the increase of the concentration of Alfa fibers treated varying from 5% to 30% (by weight) compared to the composites with untreated fibers. The increase in flexural strength is shown in Figure 5. It can be explained by a better fiber-matrix interaction [4]. Thus the mechanical properties are better with 3% NaOH for 72 h. The superior performance of 72h-treated fibers may result from more complete removal of surface impurities, leading to stronger interfacial bonding.
The results obtained indicate an improvement in the flexural properties of the composites developed, reinforced by fibers treated with sodium hydroxide [14].

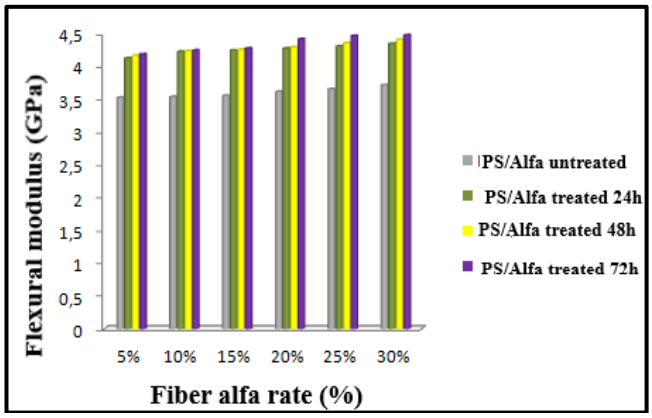

Figure 4. Flexural modulus of untreated Alfa/PS and treated Alfa/PS composites with 3% of NaOH for 24, 48 and 72 h at 25°C.

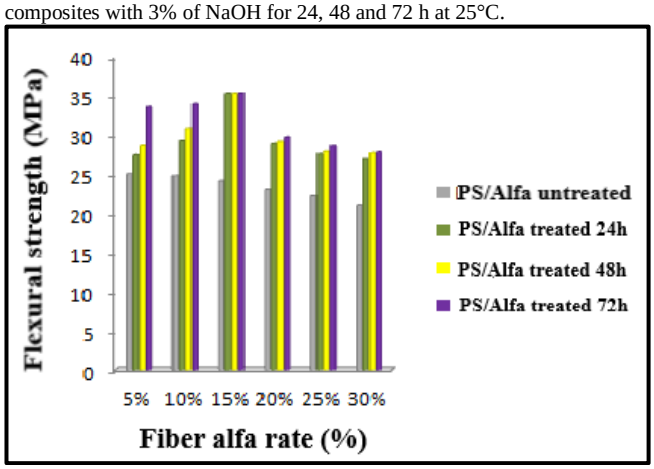

Figure 5. Flexural strength of untreated Alfa/PS and treated Alfa/PS composites with 3% of NaOH for 24, 48 and 72 h at 25°C.

IV. Conclusion

This study examines how the mechanical performance of PS composites is affected by both treated and untreated Alfa fibers. The micrographs showed a modification of the surface fiber including the disappearance of the waxy layer. Furthermore, these micrographs also revealed an increase in the roughness of the treated fibers compared to untreated Alfa fibers (elimination of non-cellulosic components).

Fourier transform infrared (FTIR) spectra revealed the change in the surface structure of the treated where the disappearance of the peak corresponding to the carbonyl groups of hemicellulose was observed. A decrease in the water absorption rate of the treated Alfa fibers was observed depending on the treatment. This is due to the elimination of non-cellulosic substances.

The Alfa fibers were treated by submerging them in a 3% sodium hydroxide solution (NaOH) for 24, 48, and 72 hours at 25°C. The findings demonstrate that the alkali treatment improved the flexural characteristics of their composites. These outcomes are explained by a significant improvement in the fiber's interfacial adhesion to the polystyrene matrix.

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