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Thermomechanical behavior of Tunisian palm fibers before and after alkalization

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HIGHLIGHTS

- Valorization of palm fibers from the oasis of Tozeur (southern Tunisia).
- An alkaline treatment is applied to the palm fibers with different conditions of concentration and time interval.
- Characterization of fibers (chemical, mechanical and thermal).
- The optimum processing condition gives more favorable mechanical properties than the untreated fiber.

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ABSTRACT

This work is integrated into the theme of valorizing natural and local resources, which the aim to have a composite material, based on palm fibers ready for use in thermal insulation. The palm fibers are well known by their strong mechanical properties and subsequently, the mechanical characteristics of composite material will be more significant. However, the field of composite materials still poses the adhesion problem between matrix and reinforcements. Hence, a treatment on the palm fibers may present a solution to limit its degradation in the long term and to improve the adhesion between the matrix and the fibers. A treatment was carried out by sodium hydroxide (NaOH), with several concentrations (0.5%, 0.75%, 1%, 2% and 5%) during different time intervals. The palm fibers were characterized before and after the treatment, mechanically (micro traction test) and thermically ATG). Fiber surface morphology is analyzed using scanning electron microscopy (SEM). The results show an improvement of the thermo mechanical characteristics after Alkalization.

1. Introduction

Currently, the plant fibers are used in composite materials, as reinforcements, and they replaced well other types of fibers such as carbon fibers and glass fibers, but the degradation of the fibers (bagasse fibers, luffa fibers, kenaf fibers, coir fibers, pineapple leaf fibers, Alfa fibers, sisal fibers, bamboo fibers and palm fibers...), remains a drawback that will decrease its mechanical properties and attack the composite behavior. By applying the chemical treatment this problem is eliminated. There are several methods of treatment, which can be classified into two categories: physical methods like: plasma treatment, ultraviolet irradiation and heat treatment and chemical methods like: alkaline treatment, acetylation and peroxide treatment. The most usable method is the chemical treatment and more precisely the treatment with NaOH (sodium hydroxide).

Several studies have investigated the procedure for handling different categories of fibers [1–14]. Every work always looks for the best strategy to get the best results for these multiple methods of treatment. Indeed, the treatment of bagasse fibers with a 1% NaOH solution results in an improvement of 13% of the composite tensile strength, 14% of the flexural strength and about 30% of the resistance to shocks [15].

Yousef [16] shows that strengthening the epoxy with the kenaf fibers, which were soaked in a 6% NaOH solution for 24 h and then washed and dried in an oven at 40 °C for 24 h increased the flexural strength of the composite material by about 36%, while the untreated fibers introduce an improvement of 20% only.

Meon, [17] shows that kenaf may be used as reinforcement in a thermoplastic composite. Where the fibers were soaked with 3%,

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6% and 9% sodium hydroxide (NaOH) for one day and then dried at 80 °C for 24 h. The tensile properties of the treated kenaf fibers had been improved significantly, at the optimum level of 6% NaOH in particular.

Rokbi [18] studied the Alfa fiber reinforced polyester matrix. These fibers were subjected to alkaline treatments with 1,5 and 10% NaOH for a period of 0,24 and 48 h at 28 °C. The results show that the behavior of bending strength of composites is improved for treatment of Alfa fibers with 10% NaOH in 24 h. Flexural strength and flexural modulus are improved from 23 MPa to 57 MPa and from 1.16 to 3.04 GPa.

The treatment of the palm fibers in a 1% NaOH solution for 1 h at 100 °C is the optimum treatment which gives the maximum tensile strength and the best fiber surface morphology [4]. However, treatment with hydrochloric acid is rejected because of its negative impact on the tensile strength and surface morphology of the fibers.

It should be mentioned that, treatment under high temperature is a method to be avoided; because it reduces the mechanical properties; this opinion is shown by several studies such as Norul Izani [19] and Mohanty [20].

Every year, thousands tons of palm tree waste are abandoned in the world. The use of this waste as reinforcements in composite material appears as a good solution to value. In this study, we were concentrated mainly on the palm fibers coming from the area of Tozeur located at the south of Tunisian.

In order to valorize the Degla palm fibers which occur in the form of waste and in purpose is to use it as reinforcements in a composite material based on gypsum, the objective of this work is to improve the thermomechanical properties of Degla palm fibers, where our research team identified recently their physical properties [21] such as density equal to 885 kg/m3, thermal conductivity between 0.095 and 0.109 $Wm^{-1}\ K^{-1}$, and thermal capacity between 1034 and 1227 $J.kg^{-1}.K^{-1}$. Thus, we studied of the treatment by alkalization of these fibers, under different conditions by varying the immersion time and the concentration of alkaline solution. In addition, the measurement of the moisture content and the elemental analysis were determined.

The mechanical and thermal analysis will be realized by a micro traction test and Thermogravimetric Analysis (TGA), respectively. The morphology of the fiber surface was characterized using scanning electron microscopy (SEM).

The results show that optimal thermomechanical properties of these natural fibers were obtained with treatment with 2% alkaline solution for 2 h.

2. Materials and methods

This study focuses mainly on the waste of palm fiber which comes from the region of Tozeur (southern Tunisia). The components of the date palm are multiple: the trunk, the flowers and the palm.

In this study, we are interested only in petiole fibers (Fig. 1).

Fig. 1. Photograph of petiole.

Moisture is a very important parameter to determine, so the fibers were dried in an oven for 24 h at 105 °C to guarantee the stabilization of mass. The moisture is determined according to Eq. 1.

$$\text{Moisture content}\,(\%) = \frac{\text{wetmass} - \text{drymass}}{\text{wetmass}} \times 100 \tag{1}$$

where wet mass is the initial mass of the sample and dry mass is the mass of the sample after drying in the oven. The chemical composition of the fibers was determined using the elemental analysis through THERMO FLASH 2000 (Organic Elemental Analyzer). It was performed on palm fiber whose purpose was to determine mass of each element: carbon (C), hydrogen (H), nitrogen (N), sulfur (S) and oxygen (O) (Fig. 2).

The alkaline treatment was realized by Sodium hydroxide. It was carried out at average room temperature of 23 °C. The Fibers Date Palm FDP (Fig. 3) are initially washed with water to remove dust and salinities, then manually dismantled and unbundled into five groups. The fibers FDP were immersed in NaOH solutions with different concentrations 0.5%, 0.75%, 1%, 2% and 5%, in a well-defined time interval: 2 h, 5 h 7 h and 24 h. In total, we obtained 20 groups.

Finally, the fibers were once more washed to remove residual NaOH remaining and were dried under atmospheric pressure and average room temperature.

The diameter of the fibers FDP is measured using Deltronic DH 400 (Fig. 4), used for contactless measurements of manufactured parts, with which the projected image on the screen is magnified 20 times. The tests were carried out at average room temperature.

Fig. 2. Photograph of THERMO FLASH 2000.

Fig. 3. Raw sample.