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Chemical modification of kenaf fibers

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Abstract

The interest in using natural fibers in composites has increased in recent years due their lightweight, non-abrasive, combustible, non-toxic, low cost and biodegradable properties. However, lack of good interfacial adhesion, low melting point and poor resistance to moisture absorption make the use of natural fiber reinforced composites less attractive. Chemical treatment of the fiber can clean the fiber surface, chemically modify the surface, stop the moisture absorption process and increase the surface roughness. In this study, kenaf bast fibers, supplied by MARDI, for use in fiber-reinforced composites, were modified using NaOH of different concentrations. Morphological and structural changes of the fibers were investigated using scanning electron microscopy (SEM). A series of fiber bundle tensile tests were also performed to evaluate the effect of the treatments on the fiber tensile strength. It has been found that the alkalization treatment has improved the mechanical properties of the kenaf fiber significantly as compared to untreated kenaf fiber. It is also interesting to note that 6% NaOH yields the optimum concentration of NaOH for the chemical treatment.
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1. Introduction

Kenaf (*Hibiscus cannabinus* L.) is a warm season annual fiber crop closely related to cotton and jute. Historically, kenaf has been used as a cordage crop to produce twine, rope and sackcloth [1]. Nowadays, there are various new applications for kenaf including paper products, building materials, absorbents and animal feeds. In Malaysia, realizing the diverse possibilities of commercially exploitable derived products from kenaf, the National Kenaf Research and Development Program has been formed in an effort to develop kenaf as a possible new industrial crop for Malaysia. The government has allocated RM12 mil for research and further development of the kenaf-based industry under the 9th Malaysia Plan (2006–2010) in recognition of kenaf as a commercially viable crop. Kenaf has a single, straight and branchless stalk. Kenaf stalk is made up of an inner woody core and an outer fibrous bark surrounding the core. The fiber derived from the outer fibrous bark is also known as bast fiber. Kenaf bast fiber has superior flexural strength combined with its excellent tensile strength that makes it the material of choice for a wide range of extruded, molded and non-woven products [2]. Kenaf fiber could be utilized as reinforcement material for polymeric composites as an alternative to glass fiber. Natural fibers such as kenaf have some advantages over traditional reinforcement materials such as glass fiber in terms of cost, density, renewability, recyclability, abrasiveness and biodegradability. The efficiency of the fiber-reinforced composites depends on the fiber–matrix interface and the ability to transfer stress from the matrix to the fiber. The main obstacles in the use of natural fibers in plastics have been the poor compatibility between the fibers and the matrix, and the inherent high moisture absorption, which could result in dimensional changes of the fibers that may lead to microcracking of the composite and degradation of mechanical properties. Various chemical treatments have been used to improve the mechanical performance of the natural fiber including jute and hemp by many researchers in the past [3–5]. In this study, caustic soda treatment was chosen because it is inexpensive and effective. Mwaikambo and Ansell [6] have treated hemp, jute, sisal and kapok fibers with various concentrations of NaOH and found that 6% was the optimum concentration in terms of cleaning the fiber bundle surfaces and retaining a high index of crystallinity.

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In this work, various concentrations of NaOH were used and the optimum concentration of NaOH to alkalize kenaf fibers was also determined.

2. Methods and materials

Kenaf raw fibers used in this work are supplied by MARDI (Malaysian Agricultural Research and Development Institute) and came in straight long fibers. The fibers have been separated from their stalks by water retting for about 20 days in MARDI. After the water retting process is completed, the fibers were then cleaned with water and dried under the sunlight before they were delivered to us.

2.1. Fiber chemical treatment

Kenaf fibers were immersed in NaOH solution with different concentrations (3%, 6% and 9% NaOH) for 3 h at room temperature. For the 6% NaOH concentration, two different conditions were used: (i) immersion at room temperature and (ii) immersion in water bath at 95 °C. After treatment, the fibers were thoroughly washed with running water and allowed to dry at room temperature for 48 h.

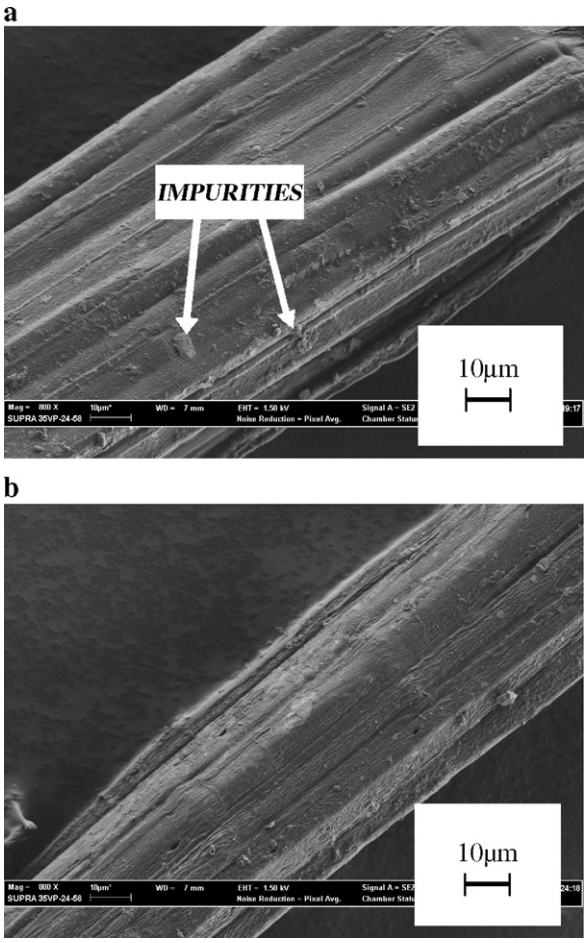

Fig. 1. SEM micrograph of (a) an untreated kenaf fiber and (b) 3% NaOH treated kenaf fiber.

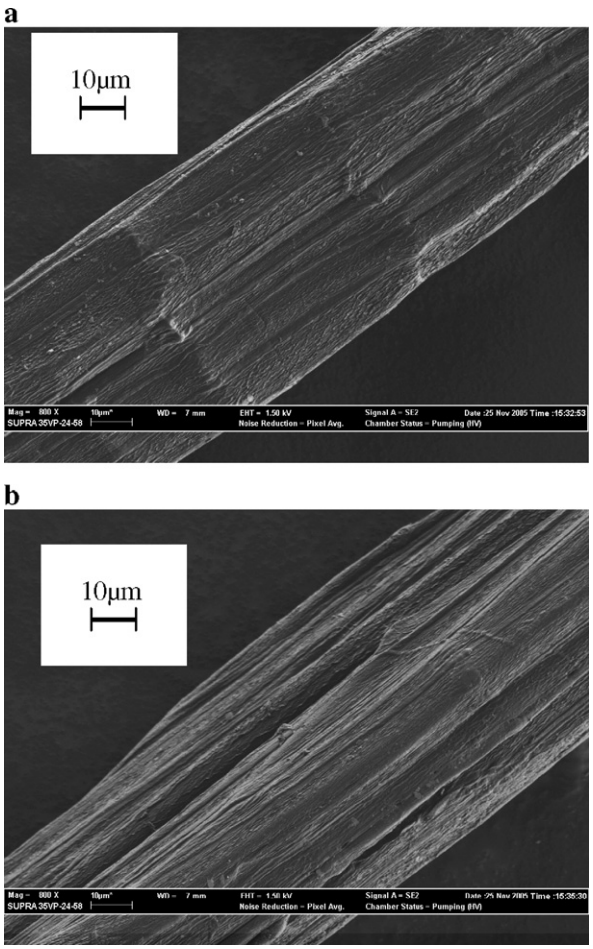

Fig. 2. SEM micrograph of (a) 6% NaOH treated kenaf fiber and (b) 9% NaOH treated kenaf fiber.

2.2. Scanning electron microscopy (SEM)

A scanning electron microscopy (SEM) machine Model Leica Cambridge AS-360 was used to study the surface morphology of the differently treated kenaf fibers. The microscopic analysis of fiber surface morphology is of utmost importance in characterizing the structural changes that have occurred upon treatment.

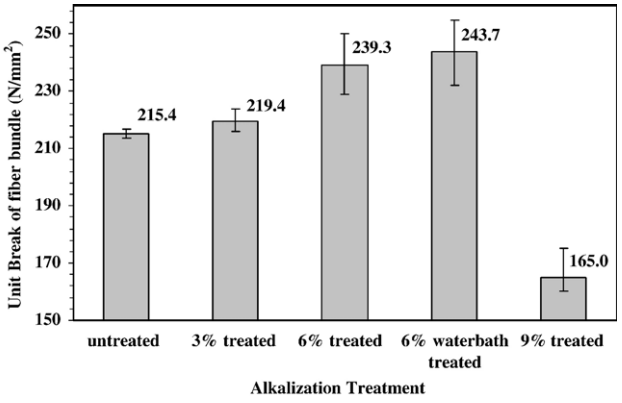

Fig. 3. Average unit break of kenaf fiber bundles.

2.3. Fiber bundle tensile test

Fiber bundle tensile strength tests were performed using a computer controlled Instron machine with a gauge length of 40 mm and a crosshead speed of 5 mm/min. For every set of chemical treatment, 5 specimens were tested to determine the average fiber bundle strength. The tests were conducted at a standard laboratory atmosphere of 23 °C and 50% relative humidity. The maximum breaking load was determined directly from the stress–strain curve and the unit break (UB) is calculated as follows [7]:

$$\mathrm{UB} = F/d \quad (1)$$

Where

F Maximum breaking load (N)
d Cross-sectional area of the fiber (mm^2)

3. Results and discussions

3.1. Fiber surface morphology

Scanning electron microscopy provides an excellent technique for examining the surface morphology of untreated and treated kenaf fibers. It is expected that the surface morphology of untreated fiber will be different to that of treated fiber particularly in terms of their level of smoothness and roughness. Therefore, studies of the fiber surface topography could provide vital information on the level of interfacial adhesion that would exist between the fiber and the matrix later when used as reinforcement fiber with and without treatment. All micrographs in this work are taken with 800 times (800×) magnification. Fig. 1(a) shows the SEM micrograph of an untreated kenaf fiber. Clearly, the impurities were observed on the surface of the untreated fiber. On the other hand, Fig. 1(b) shows similar fiber after 3% NaOH treatment. In both figures, there are still a lot of impurities that remain on the fiber surface. It indicates that 3% NaOH was not good enough to effectively remove the impurities from kenaf fiber surfaces. Fig. 2(a) shows the SEM micrograph of 6% NaOH treated kenaf fiber. It can be observed that almost all impurities have been removed from the fiber surface. The SEM micrograph of the 6% NaOH–water bath treated kenaf fiber showed similar appearance to the kenaf fiber treated with 6% NaOH at room temperature. Fig 2(b) shows the absence of impurities on the fiber surface treated with 9% NaOH. As compared to the untreated fiber, the 9% NaOH treated fiber has a cleaner surface but looks jagged and feels rougher when touched.

3.2. Fiber bundle tensile test

Fiber bundle tensile strength of differently treated kenaf fiber bundles has been measured and the results are shown in Fig. 3. For every set of treatment, 5 specimens were tested using the Instron machine, and their unit break was calculated using Eq. (1). The average unit break for every set of treatment, which represents the fiber bundle tensile strength was summarized in Fig. 3. From the figure, the average unit break of the bundle of 3% NaOH treated kenaf fibers is higher than that of the untreated kenaf fiber bundle. When the NaOH concentration is increased to 6%, a further increase of the average unit break is noticed. Kenaf fibers treated with 6% NaOH at high temperature show the highest average unit break over all. This is explained by the increase of uniformity that contributes to the increase in strength, due to the removal of the impurities. However, when NaOH concentration further increased up to 9%, the fiber bundle tensile strength was suddenly decreased. The value recorded was even lower than that of the untreated fibers. This could be the result of the damage caused by high concentration of NaOH. As reported by Mwaikambo and Ansell [6], a very high concentration of NaOH would certainly damage the fiber and consequently reduce the tensile strength of the fiber.

4. Conclusions

Kenaf fibers have been treated with NaOH solution of different concentrations. The morphological changes were examined using scanning electron microscopy. It has been shown that 3% NaOH was ineffective to remove the impurities on the fiber surface and 9% NaOH treatment showed the cleanest fiber surface. Tensile strength of kenaf fibers after treatment was measured through fiber bundle tensile test. From the fiber bundle test results, fiber treated with 6% NaOH in water bath (at 95 °C) showed the value of unit break (UB) followed by 6% NaOH at room temperature. The reason was attributed to the effectiveness of the cleaning process of fiber at elevated temperature as compared to room temperature condition. However, when the NaOH concentration is increased to 9%, the average unit break has shown a significant decrease. It is thought that 9% NaOH was too strong and might have damaged the fibers, thus resulting in lower tensile strength.

Acknowledgements

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