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Influence of soaking time on tensile strength of coconut fiber

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Abstract. The objectives of research are to determine the effect of long soaking of coconut fiber in alkali solution to the tensile strength of coconut fiber. The testing stages include preparation, soaking, drying, testing, and analysis. The materials used consist of coconut fiber, alkali solution, aquades, tensile test equipment, and furnace. Coconut fiber is soaked in an alkali solution with a concentration of 20% for 1, 5, 7, 9, and 11 hours. Then, the coconut fiber was rinsed with aquades before being dried in a furnace at 90ºC for 5 hours. Furthermore, tests of mechanical properties include a single fiber tensile of coconut fiber with ASTM 3379-02 standart. Based on the results and discussion, it can be concluded that (a) the alkali treatment decreases the amount of hemicellulose and cellulose in coconut fiber, (b) the lowest hemicellulose and cellulose content was obtained at 7-hour immersion i.e. 8.85% and 18.40%, (c) the maximum tensile strength obtained at 7 hours of soaking is 223.907 N/mm^2.

1. Introduction

The characteristics of the natural fiber-induced composites produced depend on fiber properties, fiber deployment, and the interaction of bonds between the fibers with the matrix, fiber size, fiber form, the number of fibers in the matrix, the processing technique. In addition to the chemical treatments that can determine the nature of a composite produced, it is also affected by some fiber conditions such as how the fibers are obtained, the size, and the shape of the fibers [1]. The size and shape of the fiber is necessary for certain purposes such as processing and engagement with the matrix. Fiber content can also affect the composite mechanical strength. Two factors that may affect the distribution of fillers are interactions between fillers, and filler length. The interaction between fellow lignocellulosic fillers through hydrogen bonds causes the buildup of fibers resulting in cracking or breaking of fibers. In addition, this type of filler may also affect the composite strength because different lignocellulosic fillers have different cellulose, lignin and hemicellulose contents [2].

The interconnection of the fiber with the matrix consists of several bonding models: (a) chemical bonds, (b) ionic electrostatic bonds, (c) molecular reaction inter discussions, and (d) mechanical bonds [3]. The alkali treatment of the fibers will give two effects to the fibers: (1) increasing the surface roughness of the fibers so as to produce better interlocking, (2) increasing the amount of loosened cellulose [4]. The composite strength of the treated NaOH composite increased significantly by about 53% compared to composites made from untreated fibers and 33% compared to the non-fiber composite

[5]. In this study, the aim to be achieved is to determine the effect of soaking coconut fiber in the alkali solution on the tensile strength of coconut fiber.

2. Material and methods

Materials used include coconut fiber obtained from Sidenreng Rappang Regency of South Sulawesi, 20% alkali solution, aquades, polyester matrix, and furnace. Coconut fiber is soaked in 20% alkaline solution for 1, 5, 7, 9, and 11 hours. Then rinsed with aquades before dried in a furnace at 90°C for 5 hours. After that, coconut fiber was tensile tested with ASTM 3379-02 standard as shown Figure 1.

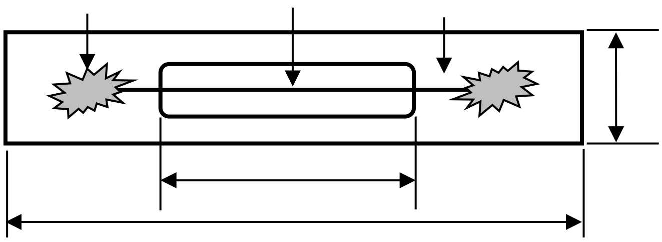

Figure 1. Specimen of single fiber test ASTM 3379-02for tensile test.

The amount of hemicellulose, cellulose, and lignin in the fiber at all treatments was analyzed by "Chesson" method by using sulfuric acid (H_2SO_4) [6]. A mixture containing 1 g of coconut fiber, called samples (A) and 150 ml of distilled water was heated in a glass tube at a temperature of 90-100 °C for 1 hour. The mixture was filtered and the residue washed with 300 ml of hot water. The residue was dried in an oven until its weight is constant, called samples (B). Dry residue (B) mixed with 150 ml of 1 N H_2SO_4 and heated in a glass tube at a temperature of 90-100 °C for 1 hour. The mixture was filtered and washed with 300 ml of distilled water and then dried residue, called samples (C). Dry residue (C) soaked with 10 ml of 72% H_2SO_4 at room temperature for 4 hours. After that, 150 ml of 1 N H_2SO_4 was added to the mixture and refluxed in a glass tube at a temperature of 90-100 °C for 1 hour. The solids are washed with 400 mL of distilled water, heated in an oven at 105 °C and weighed to constant weight, called samples (D). Finally, the solids (D) is heated until become ashes and weighed, called samples (E). The percentage of hemicellulose (H_C), cellulose (S_C), and lignin (L_C) are calculated using the following equation:

$$H_C = (B-A)/A \times 100\% \quad \text{..} \quad (1)$$

$$S_C = (C-D)/A \times 100\% \quad \text{..} \quad (2)$$

$$L_C = (D-E)/A \times 100\% \quad \text{..} \quad (3)$$

Tensile strength and strain of single coconut fiber was tested following ASTM 3379-02 by using a tensile testing LR10K Plus 10 kN Universal Materials Testing Machine (UMT). Measurements are made 3 times for each test variable. The value of the tensile strength that occurs can be calculated using the following equation:

$$\sigma = F/A \quad \text{..} \quad (4)$$

with σ = Maximum tensile stress (N/mm^2), F = Maximum load (N), A = Sectional area (m^2).

3. Results and discussion

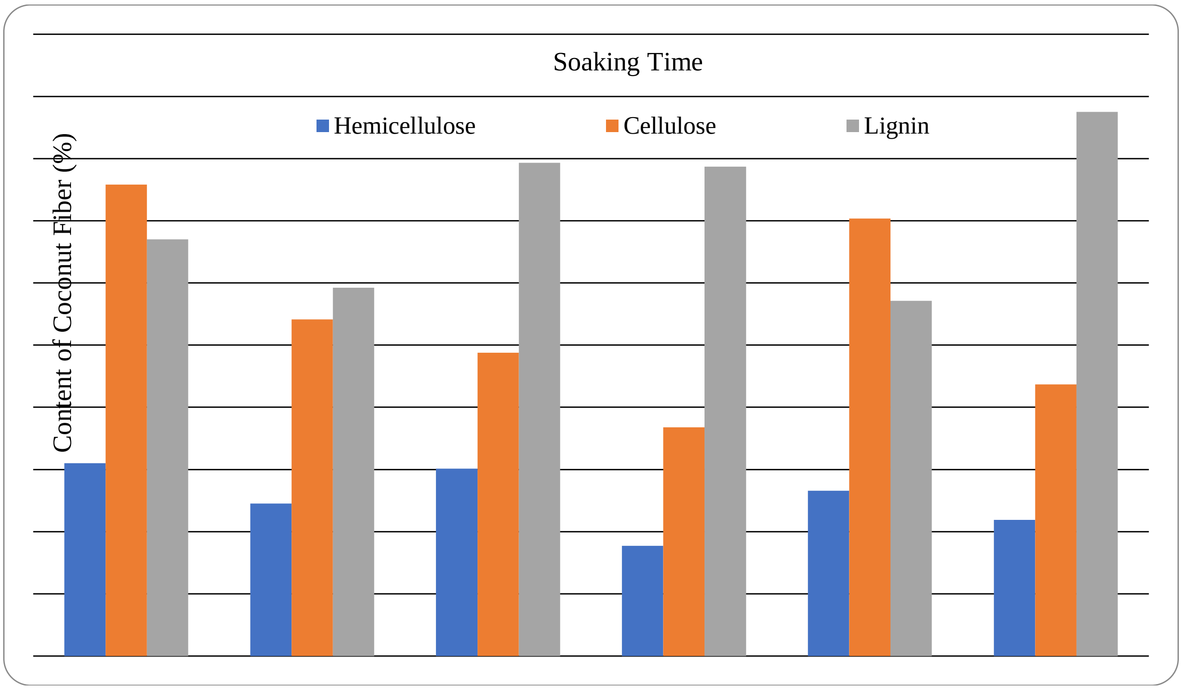

Figure 2. Value of the content hemicellulose, cellulose and lignin of coconut fiber.

Figure 2 shows the value of the content hemicellulose, cellulose, and lignin of coconut fiber which before and after treatment of 20% alkali with soaking periods of 1, 3, 5, 7, 9, and 11 hours.

Table 1. Tensile strength of coconut fiber after soaked in 20% NaOH solution.

Soaking Time	σ (N/mm^2)	ε (%)
0 h	186,420	28,330
1 h	177,551	29,638
5 h	194,310	35,403
7 h	223,907	27,228
9 h	139,493	26,553
11 h	150,035	28,850

Table 1 shows the tensile strength and strain of coconut fiber before and after treatment. Figure 3 shows the stress strain diagram of the coconut fibers which have been soaked in 20% NaOH solution for 1 hour.

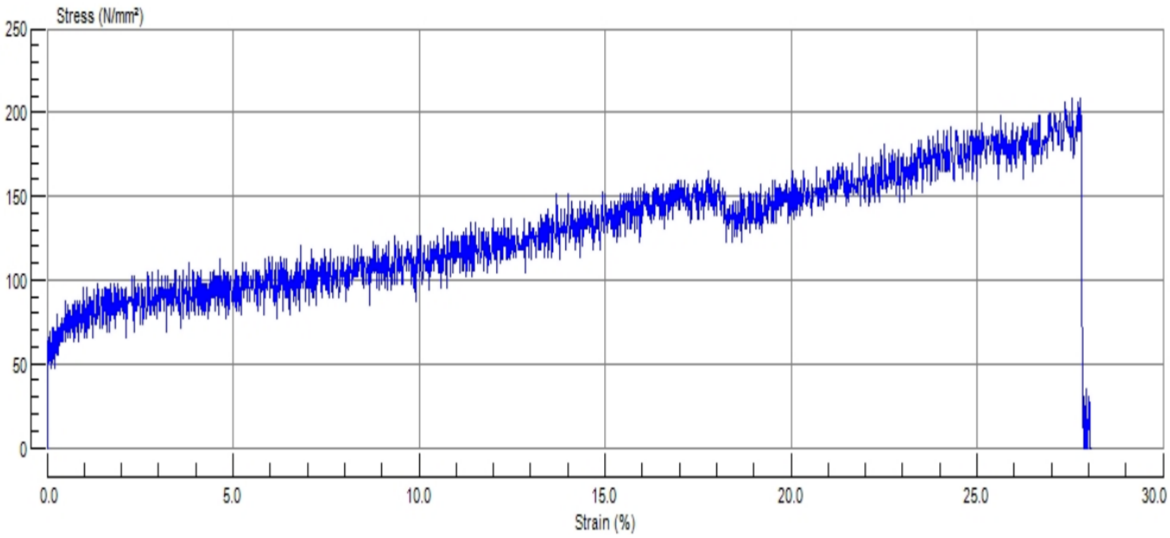

Figure 3. Stress and strain diagram for coconut fiber as result of UMT after treatment with NaOH 20% for one hour (1h).

Figure 2 shows the value of the content hemicellulose, cellulose, and lignin of coconut fiber which before and after treatment of 20% alkali with immersion periods of 1, 5, 7, 9, and 11 hours. Coconut fiber without soaking contains hemicellulose 15.5%, cellulose 37.9%, and lignin 33.5%. This is different from the content of hemicellulose, cellulose, and lignin coconut fiber reported by Ramakrishna namely hemicellulose 31.1%, cellulose 33.2%, and lignin 20.5% [4,7,8], and hemicellulose 7.6%, cellulose 44.1%, and lignin 37.1% [9]. These differences indicate that although the same type of plant but the place to grow the plant will determine the content of hemicellulose, cellulose, and lignin [4,10]. In this study, coconut fibers soaked in 20% alkaline solution contained hemicellulose, and cellulose was inversely proportional to soaking time (1, 5, 7, 9 and 11 hours) compared to without immersion. The lowest hemicellulose and cellulose content were obtained at 7-hour immersion i.e. 8.85% and 18.40%. This shows that the soaking time in alkali solution causes the degradation of hemicellulose, and cellulose [6,10,11].

Table 1 and Figure 3 shows the tensile strength, and strain of coconut fiber before and after treatment. Tensile strength of coconut fiber before soaking in 20% alkali solution was 186.420 N/mm2 while after treatment the fluctuating fiber tensile strength, and the highest was obtained at 7-hour immersion i.e. 223.907 N/mm2. Similarly, in pull out testing, the highest shear strength was obtained at 9-hour immersion, which was 183.824 N/mm2. While the highest strain is obtained at 5-hour immersion, which is 35.403%. Concluded that increasing the modulus of elasticity of flax fiber was 12%, 68%, and 79% after being given a 5% alkali treatment at 30 ° C with a treatment duration of 4, 6, 8 hours and the percentage of breaking stress reduced by 23% after being subject 8 hour alkali treatment [12,13]. In addition, conducted a study to determine the effect of reducing lignin content on fiber tensile strength. Coconut fiber fibers were treated with 0.7% NaClO2 with boiling old variations of 0, 15 and 90 minutes [12]. The longer the fiber is soaked causing the amount of lignin to decrease but the amount of cellulose and hemicellulose increases. While the tensile strength of the fiber decreased compared to untreated fibers but increased with increasing immersion time.

4. Conclusion

Based on the results and discussion, it can be concluded that: the soaking time of coconut fiber in an alkali solution can reduce the amount of hemicellulose and cellulose in coconut fiber. Duration of immersion 1, 5, 7, 9, and 11 hours obtained maximum tensile strength of 223.907 N / mm2 at 7-hour immersion.

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