Study on The Characteristics of NaCl Treated Kenaf Fiber Epoxy Composite Board

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Abstract. The treatment of kenaf fiber surfaces with chemicals has proven to be an effective method to improve composite properties. Meanwhile, sodium chloride (NaCl) is one of the chemicals that has great potential to be used for modifying natural fibers. Therefore, this study aims to investigate the characteristics of a composite board made from NaCl-treated kenaf fiber and epoxy. The method used was a completely randomized design with two factors, namely the level of NaCl in the treatment solution including 1, 3, and 5%wt, as well as the epoxy content of 10, 20, and 30%wt based on the dry weight fiber. The NaCl treatment was carried out by soaking the fibers in the solution for 1 hour at room temperature, rinsed using water until the pH of the water reached 7, and then dried in an oven at 80°C for 6 hours. Furthermore, the Kenaf fiber and epoxy were mixed manually, while the boards were manufactured using a heat pressing system at 120°C, with a pressure of 3.5 MPa for 10 minutes, and a thickness of 10 mm. The physical and mechanical properties were then evaluated based on JIS A5908. The results showed that the composite board properties were optimum at NaCl 5%, 20% of epoxy, modulus of elasticity and rupture of 2.02 GPa, and 18.63 MPa respectively, internal bonding 1.94 MPa, thickness swelling 2.89 %, and water absorption of 10.49%. The results showed that the physical and mechanical properties of the composite board increased with a high NaCl concentration.

1. Introduction
Due to ecological concerns, several efforts focused on replacing natural materials with synthetics have led to a new trend of interest. Meanwhile, recycling and environmental safety are important for the introduction of new materials and products. Natural fibers have several advantages such as being renewable, non-toxic, biodegradable, economical, and readily available [1], [2], while plants, in particular, have great potential and are widely used in construction technology and engineering due to the high cellulose content. However, several challenges including high water absorption and low mechanical properties compared to synthetic fibers, limit its application. To overcome this problem, several studies have been carried out on fiber surface modification [3], particularly to reduce water absorption, and increase mechanical properties.

Various experiments on natural fibers from plants like jute, sisal, banana, coconut, bamboo, hemp, and kenaf were performed. Kenaf is, meanwhile, a typical word for bark fibers of Hibiscus plants, the Malvacean family, and in particular, H. cannabinus L. Typically, these plants come from seed, although in tropical and subtropical locations, certain species are permanent plants. The plant grows to 2.5-4 m at the optimum temperature of 22-30°C and a minimum humidity of 150 mm with a soil pH of 6.0-6.8. pH [4].
Kenaf not only consumes nitrogen and phosphorus from the soil but is also very highly absorbed by carbon dioxide from the air. The light fiber composition is readily recycled and improves fuel consumption and emissions, particularly in the automobile industry [5–15]. Along with other natural fibers the plant has interesting mechanical and chemical properties including high tensile strength and modulus of elasticity compared to jute, sisal, hemp, and cotton [16–18]. However, there are certain limitations to the use of natural fibers as reinforcement in composite materials, such as the heterogeneity of its properties which affect the quality and production efficiency depending on natural conditions and treatments. Another challenge is the hydrophilic behavior which leads to high water absorption in a composite system.

Although the kenaf fiber reinforced with epoxy composites is widely used in various industries, it has low efficiency compared to synthetic fibers. This is due to the low mechanical properties, as well as water and moisture resistance, hydrophilic properties, poor fireproof, interrelated strengths, and bond between the fiber and matrix because of the wax, lignin, pectin, and dirt components in the layer above the fiber. Moreover, due to the presence in large groups of hydroxyls the polar and hydrophilic nature of composites affects the mechanical characteristics, while significant water absorption creates a fiber-to-matrix swelling, which causes porous products and dimensions [19–25].

Several methods of treatment have been reported, including mechanical processing which is generally used to prepare twisted or short fibers for composite board application [4,12,16, 26–28]. Meanwhile, in chemical retting, certain chemicals are used to dissolve pectin and separate the components to produce high-quality fibers, but this method is affected by pH. Different studies also combined chemical and warm-water retting methods to produce uniform and clean kenaf fibers. Water retting is a popular method through which bacteria break pectin down and produces good quality fibers [29–31], but it is time-consuming compared to warm-water retting.

Natrium chloride has great potential to be used in the chemical treatment of kenaf fiber and has a pH of ±83. A previous study used natural fibers submerged in water with NaCl which has been modified to eliminate most of the lignin, dirt, and an outer layer. Based on the results, fiber surfaces were reinforced and yielded strength as well as modulus higher than without treatment or soaked in a solution of acid [32–35]. Impurities are bound by Na+ and Cl− to form ionic bonds due to the respective polar differences. Furthermore, positive and negative ions from fibers modified with NaCl provide a high fiber-matrix bond strength [33]. Therefore, this study aims to determine the effect of different NaCl concentrations and epoxy content on the physical and mechanical properties of natural fibers to assess the optimal treatment conditions and their relationship with the matrix.

2. Methods

2.1. Materials
Kenaf fibers obtained from the stem of herbaceous annual plants in Bogor, West Java, Indonesia were used as raw materials. The fibers were cut into 25 mm and air-dried to a moisture content of 12 to 13%. Furthermore, NaCl grade AR/PA from Merk was used as a chemical substance for fiber treatment, while Epoxy from PT. Avia Avian, Indonesia containing resin and hardener was used as the adhesive agent.

2.2. NaCl Treatment
The kenaf fibers immersion varied with NaCl concentrations of 1, 3, and 5% (w/w) for 1 hour at room temperature. The ratio of the solution to fibers was 20:1 (w/w), after immersion, then the fibers were rinsed using water and were dried inside an oven at 80°C for 6 hours.

2.3. Board Manufacturing
Before using the glue, the kenaf fiber was uniformly blended in at a ratio of 1:1 for 15 minutes, particularly epoxy resin and hardener. With a total weight of 10, 20, and 30 % epoxy, the samples were mixed manually. Meanwhile, the composite board density target is 0.8 g/cm,3, so a 250 mm × 250 mm mat was employed in the production procedure for producing the test sample. A heat presser was pushed
for 10 minutes with a steady pressing pressure of 3.5 MPa at 120 °C whereas the goal thickness was 10 mm.

2.4. Board Evaluation
The particleboard was evaluated according to the JIS A 5908, each experiment was conducted in triplicate, while the mean and standard deviation values were calculated. Furthermore, tests were conducted to determine thickness swelling, water absorption, internal bond strength, as well as modulus of elasticity and rupture. The thickness swelling, water absorption, and internal bond strength tests were carried out on specimens cut 50 mm x 50 mm x 10 mm respectively for each board after immersion in water for 24 hours at room temperature. Also, a static three-point bending test was performed on a 200 mm x 50 mm x 10 mm specimen.

3. Result and Discussion

3.1. Thickness Swelling and Water Absorption
Figure 1 shows that the thickness swelling (TS) after 24 hours of water immersion at room temperature ranges from 2.89 – 6.72%. This result meets the requirements of the JIS A 5908 standard namely ≤ 12%. This shows that the treated kenaf board provides better performance due to the interaction between the fiber and resin. The highest TS value was obtained with 5% NaCl for 1 hour at 120°C and 20% epoxy content. However, the value decreased significantly with increasing NaCl concentration and epoxy.

Figure 1. Thickness swelling of NaCl-treated kenaf composite board with epoxy

Figure 2. Water absorption of NaCl-treated kenaf composite board with epoxy
The water absorption (WA) property of the board decreased after treatment with NaCl and epoxy resin. Figure 1 shows that the WA values of kenaf fiberboards ranged between 10.49 – 37.11%. The lowest value was found in the 20% epoxy and 3% NaCl treatment, the higher the NaCl level, the lower the water absorption, in contrast, the higher the epoxy content, the higher the water absorption.

3.2. Internal Bonding

The internal bonding (IB) strength of boards ranged from 0.95 – 1.94 MPa as shown in figure 3. All the values meet the requirement of the 18 types of JIS A 5098 (2003), while the highest was produced with 5% NaCl and 20% epoxy content. Based on the results, the internal bonding significantly increased with higher concentrations of NaCl,

![Figure 3. Internal bonding of NaCl-treated kenaf composite board with epoxy](image)

The chemical treatment of natural fibers including kenaf is usually carried out using reagents that contain functional groups capable of bonding with the hydroxyls. Previous studies reported different types of chemical treatment, which achieved varying degrees of success in improving the adhesion of the matrix in natural fiber composites [35-37]. A mechanical interlock was observed between the fiber and the matrix, thereby improving the surface adhesion due to the chemical treatment that provides numerous voids on the surface [25]. Moreover, the chemical treatment of fibers plays an important role in increasing the adhesion between hydrophilic natural fibers and the hydrophobic polymer matrix at the interface [38-40].

3.3. Flexural Strength

The variation of flexural strength concerning the different fiber treatments is shown in Figure 2. Based on the results, the highest flexural strength indicated by 2.02 GPa and 18.63 MPa for modulus of elasticity and rupture respectively were found in the treatment with 5% NaCl, for 1 hour. Meanwhile, the transfer of stress was observed due to an increase in mechanical bonding between kenaf fiber and adhesive.
Seawater was used in other studies as an alternative to fiber treatment, for example, sugar palm fibers immersed in seawater for 30 days were analyzed for the fiber-matrix interface adhesion [33-35]. In another study, sugar palm fibers were soaked in seawater for a similar period as an alternative to the chemical treatment of natural fibers to enhance the adhesion of the fiber-matrix interface. The results showed that the impact and bending strength of the treated composite material were higher compared to the control. These findings indicate an increase in the mechanical properties of the sugar palm fiber composites.

4. Conclusion
The effects of NaCl treatment under various conditions on the physical properties of kenaf fibers and different epoxy content were investigated. The results showed that the highest value for the physical and mechanical properties of the board was found in the treatment with 5% NaCl and 20% epoxy content as indicated by the modulus of elasticity and rupture of 2.02 GPa and 18.63 MPa respectively, internal bonding of 1.94 MPa, thickness swelling 2.89 %, and water absorption of 10.49 %.

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