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Effect of NaOH Treatment on Tensile Properties of Kenaf Core Fiber/Unsaturated Polyester Resin Biocomposites

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ABSTRACT

This study investigated the effect of chemical treatment on kenaf core fibre (KCF)-reinforced unsaturated polyester resin (UPE) biocomposite using different NaOH treatment concentrations. The concentrations used in this study are 0%, 2.5%, 5.0%, 7.5%, and 10.0% of NaOH. The UPE, which serves as a matrix, was hot-pressed with NaOH-treated KFM at 120ºC, heating pressure of 8 MPa, and 10 minutes of heating. Next, the composites were characterised according to their tensile and water absorption properties according to ASTM D5083 and ASTM D570, respectively. The result shows that the KCF/UPE biocomposite with the 2.5% NaOH treatment demonstrated the highest tensile strength and modulus. A water absorption study revealed that 5% of NaOH-treated KCF/UPE biocomposite showed the lowest water absorption result compared to the untreated KCF. The increment of NaOH concentration resulted in lower strength, modulus, and water absorption values. Overall, it can be concluded that alkaline treatment successfully enhanced the mechanical and physical properties of KCF-reinforced UPE biocomposites.

Keywords: kenaf core fibre (KCF); unsaturated polyester resin (UPE); tensile properties; NaOH treatment.

1. Introduction

A composite is a substance made up of two or more different components that, when mixed, surpass the individual materials. In composite, there are two components: fibre (reinforcing material) and matrix. Matrix materials can be made of polymers, ceramics, or metals. One significant type of thermoset polymer matrix is unsaturated polyester resins (UPE). They are widely used because they are simple to work with, inexpensive, have strong corrosion resistance, and come in various grades. Fibre can be in the form of particles, fibre, sheets, or cloth in composites. Nowadays, the phrase "Kenaf for bio-composites" seems natural since it is used in various applications like aerospace, construction, the automotive sector, and many more [1-2].

The kenaf plant's sole, straight, and branchless stalk comprises a woody core inside and a fibrous bark outside that encircles the core. By weight, the Kenaf's stalk has 35 percent to 40 percent bast fibre and 60 per cent to 65 per cent core fibres [3]. Thus, the abundance or high percentage of core fibres as waste products in the Kenaf processing centre has suddenly become a concern that must be resolved. However, the utilization of kenaf core fibre (KCF) is still at an early stage since its thermal and mechanical properties are still considered low compared to kenaf bast fibre. Furthermore, applying a chemical treatment to natural fibre and KCF would be essential in enhancing the mechanical properties of polymer biocomposites.

In this study, KCF was used as reinforcement in UPE biocomposites. Like other natural fibres, KCF is naturally hydrophilic and may result in a loss of mechanical strength in the composite due to poor adhesion to the hydrophobic matrix, which may result in chemical incompatibility [4-6]. Thus, chemical modification (NaOH treatment) is used to decrease the hydrophobicity of KCF as natural fibre and increase the interfacial bonding between matrix and fibre, thereby improving the mechanical properties of KCF-reinforced UPE biocomposites. Furthermore, the effect of NaOH chemical treatment on the physical properties of KCF-UPE biocomposites was investigated.

2. Materials and Methods

2.1 Materials

In this research, the raw materials that have been used were KCF that was collected from Lembaga Kenaf dan Tembakau Negara (LKTN) and UPE resin (UPR) as the matrix, methyl ethyl ketone peroxide (MEKP), which acted as a catalyst and cobalt naphthenate which acted as an accelerator were obtained from Revertex (Malaysia) Sdn. Bhd, Kluang, Johor, Malaysia. As for the chemical treatment, Sodium Hydroxide (NaOH) has been used in alkaline treatment without further purification.

2.2 Chemical Treatment of KCF

To achieve good penetration of the alkali solutions into the fibre bundles, kenaf core fibres were immersed in an aqueous NaOH solution (concentrations: 0, 2.5, 5.0, 7.5, and 10%, respectively; the ratio of KCF to NaOH solution was 1:20) for 40 minutes at 100°C. The fibres were washed with fresh tap water numerous times until they reached a neutral pH, ensuring that all NaOH had been removed. Finally, the KCF was dried in an oven at 80°C for 2 hours, resulting in a moisture content of less than 0.1 percent.

2.3 Fabrication of KCF-UPE Biocomposites

The polyester resin system was prepared by mixing UPE resin with 2 % methyl ethyl ketone peroxide (MEKP), which acted as a catalyst, and 1 % cobalt naphthenate as an accelerator. The resin system and KCF were mixed and stirred until homogeneously mixed. The mixed compound was then poured and spread into a 150mm x 150mm x 8mm mould according to the formulation in Table 1. Using the compression moulding machine, the mould underwent a curing process for 10 minutes with 120 ℃ and 8 MPa of pressure. Next, the mould was cooled off for about 5 minutes. The composite samples were cut in rectangular size according to ASTM D5083 for mechanical and physical properties characterisations.

Table 1: Formulation of untreated and NaOH-treated KCF-UPE biocomposites

Sample Design	UPE (wt%)	KCF (wt%)	NaOH treatment (%)
UK	85	15	-
TK2.5	85	15	2.5
TK5.0	85	15	5.0
TK7.5	85	15	7.5
TK10.0	85	15	10.0

3. Results and Discussion

3.1 Tensile Properties

The experimental results of tensile and modulus strength are shown in Fig. 1. It can be said that the chemical treatment affects the mechanical properties of the biocomposites. This means that the KCF that undergoes the NaOH chemical treatment has proven its function by increasing the tensile strength and modulus of the biocomposites. It can be observed that the KCF, which undergoes 2.5% NaOH treatment, demonstrated the highest tensile strength and modulus, followed by 5.0% and 7.5% NaOH treatment. The increase in tensile properties could be attributed to a more significant fibre-matrix interaction and physical bonding due to the removal of cementing materials and increased surface roughness of KCF by applying NaOH [7-8].

However, if the treatment concentration is too high, it could harm the fibres, decreasing their mechanical properties. It is assumed that treating the kenaf will make it easier for the fibre to penetrate the biocomposite matrix [9]. Edeerozey et al. [10] conducted another experiment treating the KF with 6% NaOH at different temperatures (room temperature and 95 °C), and they discovered that 6% NaOH produces the most significant results regarding mechanical qualities.

Generally, it has been observed that the alkaline treatment mostly uses NaOH solution and has a few large influences on the fibre. The first effect is a change in the fibre structure that makes the surface rougher. The mechanical interaction between the fibre and matrix can be improved by increasing surface roughness or area. The number of potential reaction sites is then increased by the exposure of the cellulose on the fibre surface brought on by the alkaline treatment [11]. The alkalisation process improves the chemical connection between the polyester and the fibre, giving the fibre better mechanical qualities. Because the filler cannot withstand stress transferred from the blend matrix, the tensile strength of composites without chemical treatment is often lower [12].

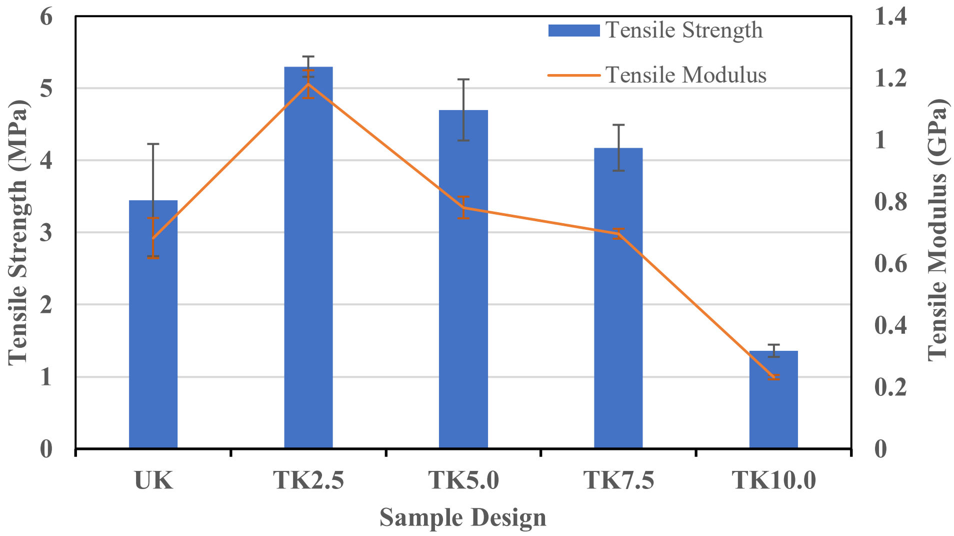

Fig. 1: Tensile strength and modulus of untreated and NaOH-treated KCF/UPE biocomposites

3.2 Water Absorption Properties

A water absorption test analyses how much water is absorbed after several days. After seven days, the water absorption properties of untreated and NaOH-treated KCF-reinforced UPE biocomposites were determined and presented in Table 2 and Fig. 2.

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Table 2: Water absorption of untreated and NaOH-treated KCF/UPE biocomposites

Sample design	Initial weight (g)	Weight after 7 days of immersion (g)	Water absorption (%)
UK	7.600	10.382	36.60
TK2.5	9.220	9.868	6.94
TK5.0	9.928	9.958	0.30
TK7.5	9.780	10.299	5.32
TK10.0	10.173	11.864	16.62

From the results (Table 2 and Fig. 2), it can be observed that the addition of NaOH chemical treatment has decreased water absorption at some point. Untreated KCF/UPE demonstrated the highest water absorption values at 36.60%, while the lowest water absorption belongs to the treated KCF/UPE biocomposite with 5% NaOH treatment. NaOH treatment is commonly used to eliminate the alkali-sensitive hydroxyl groups that will increase the hydrophobic nature and water resistance properties when reacting with water. According to Pandian et al. [13], the type of fibres used for reinforcement, the interfacial adhesion between the fibre and matrix, and the presence of voids in the composites significantly impact the natural fibre's ability to absorb water. Water absorption in composites causes the fibre to inflate until the cell walls are saturated with water; after that, the water is present as free water in the void structure, which can cause the composites to delaminate or generate voids. Water absorption weakens interfacial adhesion and results in the hydrolytic breakdown of the matrix and fibre [14]. It was believed that the optimum amount of alkaline treatment is 2.5 to 7.5%. Over-treatment can lead to the degradation of the fibre structure, resulting in a loss of mechanical strength and water absorption properties [15,16]. Thus, applying the correct amount of NaOH chemical treatment efficiently enhanced the water absorption properties of natural fibre-reinforced polymer biocomposite by improving fibre-matrix interfacial bonding.

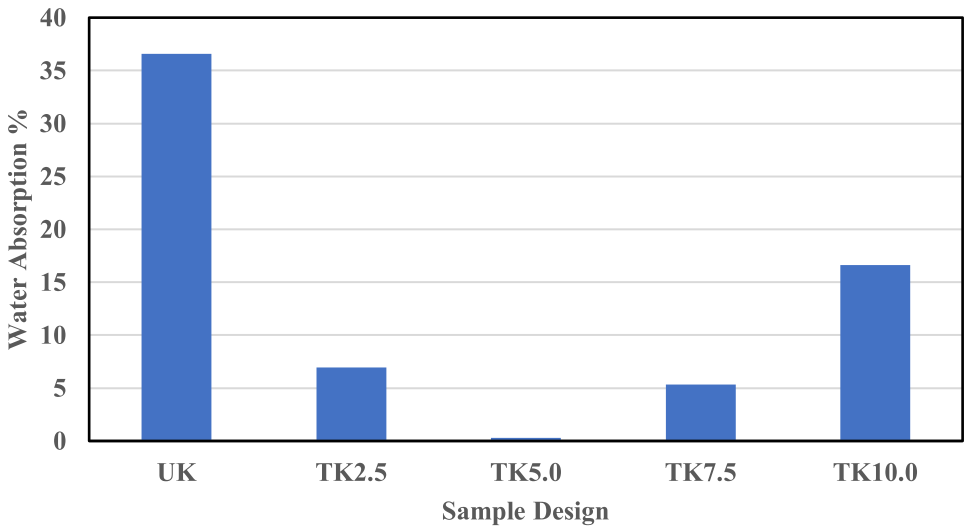

Fig. 2: Water absorption of untreated and NaOH-treated KCF/UPE biocomposites

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4. Conclusion

In contrast to conventional glass and carbon fibres, natural fibre is a renewable resource that can be cultivated quickly, and the supply can be considered endless. In this study, using KCF as reinforcement in UPE resin shows excellent environmental awareness and sustainability potential. Research findings reveal that low concentrations of alkaline treatment (2.5% NaOH) significantly improved mechanical properties (tensile strength and modulus). Higher alkali solution concentrations, however, caused delignification and could harm the fibre's quality. Because of this, only the ideal range of alkali concentration offers a more significant aspect ratio and wetting quality, as well as better interfacial adhesion. Applying alkaline treatment also contributed to a significant reduction in water absorption for a certain level of NaOH concentration, in which 5% of NaOH resulted in the highest performance. Removing defects from the KCF with NaOH has been proven successful, improving the fibres' characteristics and increasing the mechanical and physical properties of the KCF/UPE biocomposites.

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