Study of the effect of surface treatment of kenaf fibre on mechanical properties of kenaf filled unsaturated polyester composite

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Abstract. In this research, unsaturated polyester/kenaf fiber (UP/KF) composites was prepared by using hand lay-up process. The effect of surface treatment of kenaf fiber on mechanical properties of kenaf filled unsaturated polyester composites were studied. Different concentrations of stearic acid (SA) were applied, i.e. 0, 0.4, and 0.8 wt%. Tensile strength of untreated UP/KF composites was found to be higher for 40 wt% loading of kenaf fiber. The highest tensile strength value was obtained after treatment with 0.4 wt% concentration of stearic acid at 56 MPa and tensile modulus was at 2409 MPa. From the flexural strength result obtained, it is clearly seen that 40 wt% loading of kenaf fiber and treatment with 0.4 wt% concentration of stearic acid give the highest value at 72 MPa and flexural modulus at 3929 MPa.

1. Introduction
The demand of high performance materials has led to extensive research and development of new and improved materials, such as composite materials. In recent years, natural fibers seem to be a superior material which has emerged as an abundant and sustainable replacement for the nonrenewable and expensive synthetic fibers. Several natural fibers have been used as a reinforcement in composites materials for advanced applications such as banana, sisal, oil palm, jute, kenaf and coir. Among different types of fibers, kenaf fiber has been widely explored over the past several years [1-3].

Kenaf (Hibiscus cannabinus, L. family Malvacea) has been discovered to be one of the main resource of natural fibers to be used for composites, and several other industrial applications. Kenaf fiber has several advantages over other traditional reinforcement materials, as such it has attracted the attention of researchers globally. The availability of kenaf fiber in Asia is more and it is abundantly available, environmental friendly, renewable, and cheap. Moreover, it has advantages over the
synthetic fibers (glass, carbon and aramid fibers) such as light weight and full biodegradable. The biodegradability of kenaf fiber has a great contribution to a healthy ecosystem while their low cost and high performance satisfies the economic concern of manufacturers [4,5].

However, using kenaf also gives some disadvantages which occur during the processing stage of adding kenaf fiber into a polymer matrix. The lack of good interfacial adhesion between the fiber and polymer matrix, which results in poor mechanical properties in the final products.

Due to the chemical structure of natural fibers (such as kenaf) which is mainly has hydrophilic moiety (mainly OH), which will cause high polar characteristic. Therefore, it is important to enhance compatibility between the fiber and the polymer matrix in order to obtain a uniform composites with good properties. Several chemical treatments can be done to natural fibers in order to obtain better compatibility [6].

There were several attempts in the past years to modify the surface of natural fibers in order to enhance adhesion with the polymeric matrix. Various methods such as corona treatment [7], plasma treatment [8], mercerization [9], heat treatment [10], graft copolymerization [11,12] and silane treatment [9,13] have been reported to investigate the compatibility of natural fiber in polymeric composites, in most cases the results were positive[14-17]. However, these treatments have many disadvantages such as the use of expensive equipment or the use of expensive chemicals[18]. A very attractive treatment is to modify the surface of natural fibers with fatty acids such as stearic acid[19-24]. The principle of this treatment is the carboxyl group of stearic acid reacts with the hydroxyl groups of the fiber through an esterification reaction and, thus, reduces the hydroxyl groups number available to bonded with water molecules[25-27]. One more advantage of treatment with stearic acid is that it is not sensitive to oxidation during the processing temperatures of natural fiber/polymer composites [28].

In this study, bio-composites comprising kenaf fiber and unsaturated polyester were prepared by using hand lay-up process. The effect of surface treatment of kenaf fiber on mechanical properties of kenaf filled unsaturated polyester composite were studied with different loadings of kenaf fiber and stearic acid.

2. Experimental

2.1. Materials
Kenaf fiber was obtained from Rahamatullah Sdn. Bhd, Malaysia. The kenaf in this study were used in the form of mat. Unsaturated polyesters resin was supplied by Castmesch Technologies Sdn. Bhd. MEKP (solution in dimethyl phthalate) used was from Kaumjung AkzoNobel peroxide Ltd by trade name Butanox M60. Stearic acid was purchased from Acidchem International Sdn. Bhd, Malaysia.

2.2. Treatment with stearic acid
In this study, treatment of kenaf fiber by using stearic acid was carried out. Prior to treatment, kenaf fiber mat was cut to 20 cm×20 cm dimensions. Different concentrations of stearic acid were applied, i.e. 0, 0.4, and 0.8 wt%. Stearic acid was added to water and warm up at 75 °C to form a suspension. Kenaf fiber was then immersed in the suspensions containing stearic acid and stirred for 60 min at 70 °C. The treated kenaf fibers were then washed with distilled water until pH=7. The treated kenaf fiber layers were placed in a conventional oven to dry at 80°C overnight.

2.3. Composite preparation
Initially kenaf mat was cut to 20 cm×20 cm dimensions and treated with different concentrations of stearic acid, this followed by compressing the untreated and treated kenaf fibers with stearic acid using compress machine at 90 °C. The composites formulation is presented in Table 1. Then prior putting to the mold and hand lay-up resin to bottom of the kenaf, then the kenaf was put inside the mold. Resin impregnated into untreated and treated kenaf via hand lay-up method and 2% of MEKP was added as
a hardener for all the samples. This followed by separating it from mold using hack saw. The prepared composite was measured and cut to 2.5×20 cm about 13 samples were obtained.

| No. | Kenaf mats % | SA % | UP % |
|-----|--------------|------|------|
| UP  | 0            | 0    | 100  |
| KF1 | 10           | 0    | 90   |
| KF2 | 20           | 0    | 80   |
| KF3 | 30           | 0    | 70   |
| KF4 | 40           | 0    | 60   |
| KF1-SA0.4 | 10 | 0.4 | 90 |
| KF2-SA0.4 | 20 | 0.4 | 80 |
| KF3-SA0.4 | 30 | 0.4 | 70 |
| KF4-SA0.4 | 40 | 0.4 | 60 |
| KF1-SA0.8 | 10 | 0.8 | 90 |
| KF2-SA0.8 | 20 | 0.8 | 80 |
| KF3-SA0.8 | 30 | 0.8 | 70 |
| KF4-SA0.8 | 40 | 0.8 | 60 |

2.4. Tensile test
Tensile test was carried out by using an Instron Universal Testing Machine (Model 5569), with crosshead speed of 2 mm/min and sample size of 140×23 mm. The tensile strength and modulus of the kenaf fiber composites before and after treatment of kenaf were determined according to ASTM D3039.

2.5. Flexural test
Flexural test was conducted using an Instron Universal Testing Machine (Model 5569) equipped with a 1 kN load cell. Flexural strength and modulus were obtained at constant crosshead speed of 1 mm/min and sample size of 140×23 mm. The flexural strength and modulus of the kenaf composites before and after treatment were determined using three-point bending test method following D7264 test method. A span of 140 mm maintaining a span to depth ratio of 23:1. The load was placed midway between the supports. Each sample was loaded until the core broke and their average is reported.

3. Results and discussion
Tensile strength of unsaturated polyester/kenaf fiber (UP/KF) composites before and after treatment of kenaf with stearic acid (SA) are shown in Figure 1. The tensile strength results of UP by itself was very low, which is 26.734 MPa. KF/UP composites show a better tensile strength property. The tensile strength results of untreated KF/UP composites show low tensile strength value at low loading of KF, i.e. 31.804 MPa of 10 wt% loading of KF. However, the tensile strength value was increased at higher loading of KF, i.e. 35.664 MPa for 40 wt% loading of KF. This attributed to KF which is in mat form as a reinforcement in UP composite although at higher loading.

The tensile strength property increased significantly after treatment of KF with SA. The treatment of KF with 0.4 wt% of SA showed higher tensile property as compared to that of without treatment with SA. However, the tensile property decreased thereafter treatment with 0.8% of SA, but it is still higher as compared to the composites prepared without treatment with SA. The highest tensile strength property is the composite with 40% loading of KF and 0.4 wt% treatment with SA which is 56.893 MPa.

The enhancement in properties is probably due to the higher polymer-fiber interactions. The increase in tensile strength for the UP/SA treated with stearic acid can be attributed to many factors;
such as formation of bonds between UP and KF fiber, better dispersion of filler, and by higher wettability of KF by the UP matrix, which enhances the orientation and dispersion of KF in the polymer (Colom et al., 2003). The treatment of KF would also increase the wettability and matrix interphase region, hence improve the tensile properties of the composite. The treatment helps in improving surface interaction between resin and fiber due to the increase of surface roughness resulting in superior mechanical properties. As SA concentration increased to 0.8 wt%, it can be seen that the tensile strength of UP/KF composites decreased. This can be attributed to a weakening of the cohesive strength of the fiber as a result of higher concentration of treatment with SA.

Figure 1. Tensile strength of UP/KF composites before and after treatment of KF with SA.

Figure 2 shows tensile modulus of UP/KF composites before and after treatment of KF with SA. The tensile modulus results of UP by itself was very low, which is 1175.99 MPa. UP/KF composites show a better tensile modulus property. This is due to the increase of stiffness that inherent from KF. The tensile modulus results of untreated KF/UP composites show low tensile modulus value at low loading of KF, i.e. 1362.31 MPa of 10 wt% loading of KF. However, the tensile modulus value was increased at higher loading of KF, i.e. 1906.88 MPa for 40 wt% loading of KF. In other words, the tensile modulus of untreated UP/KF was increased by increasing the loading of KF up to 40 wt% loading of KF.
The tensile modulus property increased significantly after treatment of KF with SA. The treatment of KF with 0.4 wt% of SA shows higher tensile modulus as compared to that of without treatment with SA. However, the tensile property decreased thereafter with treatment with 0.8 wt% SA. The highest tensile modulus value is the composite with 40 wt% loading of KF and 0.4 wt% treatment with SA which is 2409.84 MPa. This is attributed to the better stress transfer from matrix to the treated KF due to the SA treatment that improved the stress transfer and led to uniform stress distribution in the composite. Tensile modulus also showed the same trend as tensile strength. The tensile modulus of UP/KF treated with SA decreased due to degradation of KF. However, the tensile modulus of 0.8 wt% SA treated composites were higher than untreated UP/KF composites.

Figure 2 shows the elongation at break of UP/KF composites before and after treatment of KF with SA. The elongation at break results of UP by itself was high, which is 2.3%. It can be seen clearly that the addition of KF showed significant decrease of the elongation at break of the composites. The reason of the decrease in elongation at break of the composites was due to the lower elongation at break of KF compared to UP matrix. According to Bismark et al., the elongation at break of KF is 1.6 % while and UP is around 2 %. Generally, increasing the fiber content in UP led to a lower elongation at break of its composite. In addition, as the fiber content increased to 40 wt%, the UP was insufficient to wet the fiber entirely and led to poor interfacial bonding between the fiber and the matrix. When forced is applied, the composite had tendency to fail rather to elongate. This result indicates that the polyester effectively transferred the tensile force to the kenaf fiber. The reinforcement of kenaf fiber eventually absorbed the tensile force.
Figure 3. The elongation at break of UP/KF composites before and after treatment of KF with SA.

The elongation at break property slightly decreased after treatment of KF with SA. The treatment of KF with 0.4 wt% of SA shows lower elongation at break as compared to that of without treatment with SA. However, the elongation at break decreased thereafter with treatment with 0.8 wt% SA. The elongation at break value of 40 wt% loading of KF and 0.4% treatment with SA which is 0.4% and it is 0.3% for the same content of fiber for 0.8 wt% treatment with SA. This decrements is attributed to the creation of a certain interface and the rigidity of the fibers are responsible of this decrease.

Flexural tests were also carried out to have a better understanding of the mechanical properties of the composites before and after treatment of KF with SA. Figure 4 shows the flexural strength of UP/KF composites before and after treatment of KF with SA. UP shows a flexural strength value of 40.48 MPa, however this value was increased after incorporation KF with UP. The results show an increment in the flexural strength value by increasing the loading of KF up to 40 wt%.

An improvement of the flexural strength was observed after treatment of KF with 0.4% of SA and when KF loading increased up to 40 wt%. This reveal a clear evidence that treatment of KF with 0.4 wt% of SA gives better compatibility between KF and its matrix. However, the flexural strength value decreased after treatment of KF with 0.8 wt% of SA. This can be due as we increase the SA concentration, KF became degraded.
Figure 4. Flexural strength of UP/KF composites before and after treatment of KF with SA.

Figure 5 shows the flexural modulus of UP/KF composites before and after treatment of KF with SA. The flexural modulus showed a similar trend as tensile modulus. The flexural modulus increased by increasing the loading of KF up to 40 wt% and it exhibits 3781.62 MPa with 40 wt% loading of KF. After treatment with 0.4 wt% and 0.8 wt% of SA, the flexural modulus was higher for treatment with 0.4 wt% of SA as compared to that of 0.8% of SA. The reason can be due to achievement of higher compatibility and interfacial adhesion between KF and its matrix by treatment with 0.4 wt% of SA. This finding is in agreement with a study by Huda et al., 2007, which also found the improvement in flexural modulus of the PLA/kenaf fiber composites when the fiber was treated with chemical treatment. They found that the increment is influenced by the good compatibility between fiber and matrix.

Figure 5. Flexural modulus of UP/KF composites before and after treatment of KF with SA.
4. Conclusion

The major challenge for natural fiber matrix is its affinity to water, it has high absorption to moisture which have serious consequences to its properties. The effect of surface treatment of kenaf fiber on mechanical properties of kenaf filled unsaturated polyester composites was studied. As the kenaf fiber loading increased from 10 to 40 wt%, the mechanical properties of UP/KF composites increased. This shows that the kenaf fiber acts as reinforced material. Treated kenaf fiber with stearic acid shows an improvement in tensile and flexural properties of UP/KF composites. Treatment with 0.4 wt% concentration of stearic acid gives the highest mechanical properties, but the mechanical properties of kenaf fiber treated with 0.8 wt% of stearic acid decreased as the fiber was damaged with higher concentration of SA. However, treatment with 0.8 wt% concentration of stearic acid still gives higher mechanical properties comparing to that of untreated UP/KF.

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