

The Effect of Different Fibre Lengths on the Mechanical Properties of Biocomposites

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Abstract: *Kenaf is a nonwoody fibrous plant, and its fibre can be potentially used as a reinforcement in the matrix to produce biocomposite materials. The properties of biocomposite materials are highly dependent on the reinforcing material and the matrix used as a binder. This study used kenaf fibre as a reinforcing material with different compositions (10, 20, and 30 wt.%) and different fibre lengths (1 cm and 3 cm) in the matrix using the casting process. Low viscosity epoxy resin (635 thin epoxy resin) with a viscosity of 6 poise was used as the matrix. The results showed that the highest flexural strength, impact strength and shore hardness were obtained at a 30 wt.% kenaf fibre composition with a 1-cm kenaf fibre length, namely, 85 MPa, 338 KJ/m² and 98 SHD, respectively. The length of the fibre in the matrix affects the mechanical properties of the resulting biocomposite. This condition is caused by kenaf fibres with a length of 1 cm being more dispersed in the matrix than fibres with a length of 3 cm.*

Keywords: *Kenaf fibre, biocomposites, mechanical properties*

1. Introduction

Kenaf belongs to the Malvaceae family and is a nonwoody fibrous plant. Kenaf fibres have the potential to be used as fillers or reinforcements in polymer matrices. The height of kenaf can exceed 3 m, with a diameter of 3 to 5 cm. If grown in good aeration and sufficient soil acidity, kenaf will have good fibre quality [1]. Some of the common fabrication processes that can be used to produce biocomposite materials are injection moulding, extrusion, casting, and compression moulding [2]. Barkoula et al. [3] reported that biocomposites produced using injection moulding produced lower impact strength values than those produced using compression moulding. Natural fibres and polypropylene (PP) as a matrix are a suitable combination that can be used to produce natural synthetic polymer composites [4]. Zampaloni et al. [5] used kenaf fibres as a reinforcing material and polypropylene (PP) as a binder (matrix). They arranged 130-mm-long kenaf fibres between two layers of PP sheets. They found that the distribution of kenaf fibres in the PP matrix was poor in the resulting biocomposite material. To obtain the distribution quality of kenaf fibre in the PP matrix, the kenaf fibre was chopped into a length of 20 mm and then mixed with the PP matrix using a mechanical stirrer. They found that the resulting biocomposite material formed a circular pattern in the PP matrix, so it was difficult to distribute the kenaf fibres evenly in the matrix. Lee et al. [6] conducted a study to investigate the effect of kenaf fibre orientation and lamination properties. They found that the mechanical properties increased with increasing fibre content with the orientation of the kenaf fibres parallel to the direction of the load. The highest tensile strength was obtained in the horizontal orientation at a 50% kenaf fibre content. They also reported that long fibres were easier to assemble and process than short fibres. This is because long fibres are easier to orient in the biocomposite manufacturing process [7]. Hao et al. [8] used kenaf fibre as the reinforcement and PP as the matrix to produce biocomposite materials. The ratio of kenaf fibre to the matrix used was 50/50 in injection moulding. The results obtained indicate that the mobility of liquid PP will increase at higher temperatures. This condition affects the bond formation of fibres in the matrix. The results obtained also indicate that the sample thickness of 6 mm is too thick. This is because a curing time of 1 min is not sufficient to transfer heat from the surface to the entire

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sample volume. Zamri et al. [9] conducted research on the effect of different fibre compositions and sizes using kenaf fibre as the reinforcement and polyester resin as the matrix. They found that the highest fibre loading concentration (70 vol%) resulted in the highest flexural and compressive strength properties in the resulting biocomposite material, namely, 280 MPa and 75.73 MPa, respectively. Suriani et al. [10] conducted a study using kenaf fibres and epoxy to produce hybrid polymer composite materials. They reported that the tensile strength of hybrid kenaf fibre/PET yarn increased with increasing fibre volume content. In addition, the combination of kenaf fibre and PET yarn succeeded in increasing the tensile strength value of the resulting biocomposite material. This research was conducted to investigate the effect of adding kenaf fibres with different fibre lengths (1 cm and 3 cm) as a reinforcement and epoxy resin as a matrix on the flexural strength, impact strength and hardness of the biocomposite material obtained.

2. Materials and method

2.1. Materials

The kenaf fibre used in this study has an average diameter of 30 μ m, obtained from The National Kenaf and Tobacco Board - Malaysia. As the matrix, an epoxy resin with a low viscosity value (6 poise) was used, namely, 635 thin epoxy resin obtained from US Composites. A 4:1 ratio between epoxy resin and hardener was used as recommended by the manufacturer.

2.2. Biocomposite manufacturing process

The manufacturing process used to produce the biocomposite materials based on a predetermined composition is as follows. (1) The epoxy resin and hardener (4:1 ratio) were stirred using a mechanical stirrer (RW-IKA) for 10 min at 200 rpm. (2) Kenaf fibre based on a predetermined composition was stirred in using the same parameters. (3) The resulting mixture was poured into moulds and placed in an oven (TE0-11, Indonesia) at a temperature of 150°C for 30 min. The weight percentages of kenaf fibre and epoxy resin and the length of kenaf fibre used are shown in Table 1.

Table 1. Percentages of kenaf fibre and epoxy resin and the fibre length in the biocomposites

Kenaf fibre (wt.%)	Epoxy (wt.%)	Fibre length (cm)
30	70	1 and 3
20	80	1 and 3
10	90	1 and 3

2.3. Characterization

The resulting biocomposite material was characterized using (1) a flexural strength test (ASTM D 790 standard), (2) an impact test (ASTM E 23 standard), and (3) scanning electron microscopy (Hitachi S-3400 N) to observe the dispersion of kenaf fibres in the epoxy matrix.

3. Results and discussions

3.1. Effect of kenaf fibre on the flexural strength

The flexural strength of biocomposite materials with variations in the composition of kenaf fibres (10, 20, and 30 wt.%) and different lengths of kenaf fibres (1 cm and 3 cm) is shown in Figure 1. The addition of kenaf fibre at 10 and 20 wt.% showed an increase in flexural strength for the two fibres with different lengths (1 and 3 cm). Kenaf fibre with a length of 1 cm has a higher flexural strength value (75 MPa) compared to kenaf fibre with a length of 3 cm (60 MPa). However, kenaf fibres with compositions of 20 and 30 wt.% showed different effects on the two lengths of kenaf fibres used. Different conditions were obtained for kenaf fibres with a length of 1 cm from 20 to 30 wt.%, indicating that the flexural strength value of the biocomposite obtained continued to increase up to 85 MPa.

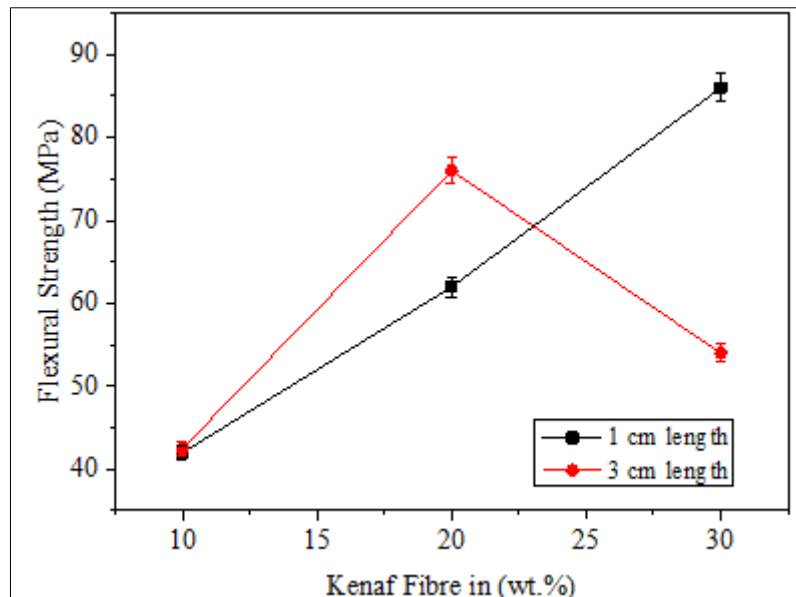


Figure 1. Effect of kenaf fibre on the flexural strength of biocomposite materials

Significant differences were obtained in biocomposite materials with the same composition of kenaf fibre (30 wt.%) and different lengths of kenaf fibre, namely, 85 MPa for kenaf fibre length of 1 cm and 53 MPa for kenaf fibre length of 3 cm. This significant difference is caused by the kenaf fibre with a length of 1 cm being able to fill almost all of the epoxy resin well, so that the number of voids formed in the epoxy resin is also less than that of the kenaf fibre, which is 3 cm long at the same composition of 30 wt.%. This condition resulted in the flexural strength value of the biocomposite material being significantly different even at the same composition [11-13].

3.2. Effect of kenaf fibre on the impact strength

Impact strength values with variations in the length of kenaf fibre (1 cm and 3 cm) and kenaf fibre filler loadings of 10, 20 and 30 wt.% are shown in Figure 2.

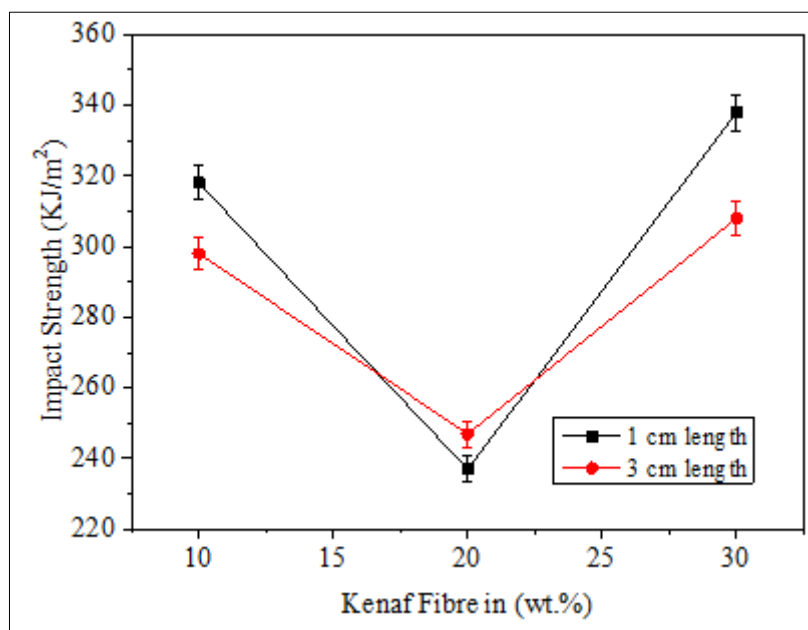


Figure 2. Effect of kenaf fibre on the impact strength of biocomposite materials

In general, Figure 2 shows the same pattern of the resulting biocomposite material for the two different lengths of kenaf fibre (1 cm and 3 cm) in terms of impact strength. The addition of 10 and 20 wt.% kenaf fibre for the two different lengths of kenaf fibre (1 cm and 3 cm) showed a drastic decrease in the impact strength value.

However, the addition of different lengths of kenaf fibre (1 cm and 3 cm) showed an increase in the impact strength value of biocomposites from 20 to 30 wt.%, where kenaf fibre with a length of 1 cm had a higher impact strength value at 30 wt.% fibre addition, i.e., 338 KJ/m². This is due to the perfect bond between the kenaf fibre as a reinforcement and the epoxy resin as a binder [8, 9]. Comparing kenaf fibres with different lengths (1 cm and 3 cm), kenaf fibres 1 cm long resulted in higher impact strength values at 30 wt.% composition. This is because kenaf fibres with a length of 1 cm can fill the entire area of the epoxy resin matrix [11-14].

3.3. Effect of kenaf fibre on the shore hardness

The effect of the addition of kenaf fibre (10, 20, and 30 wt.%) with variations in the kenaf fibre length (1 cm and 3 cm) on the shore hardness of the biocomposite material is shown in Figure 3. At the same load of 10 wt.% kenaf fibre in the epoxy resin, there were significant differences in the shore hardness values, namely, 97.9 SHD (length of 1 cm) compared to 90.8 SHD (length of 3 cm).

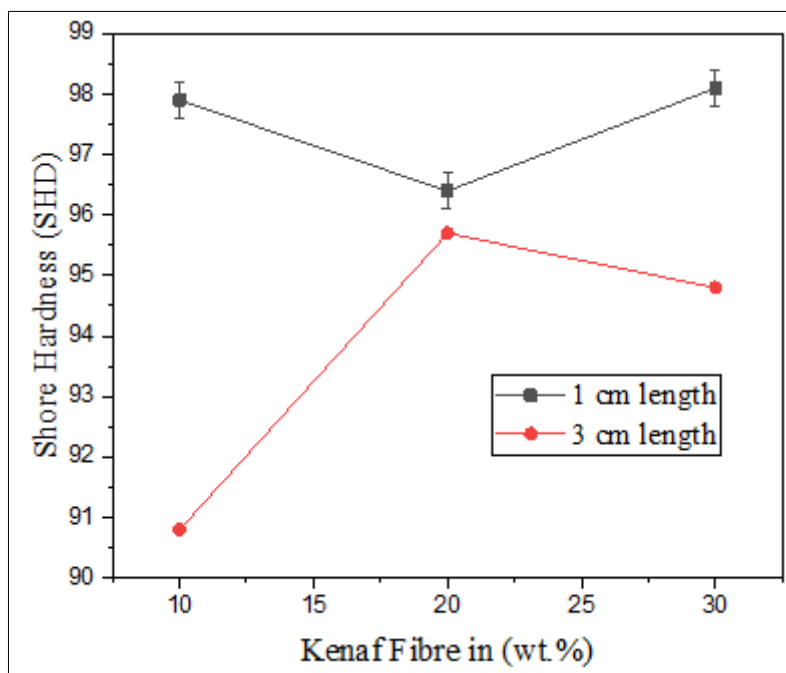


Figure 3. Effect of kenaf fibre on the shore hardness of biocomposite materials

This is because kenaf fibres with a length of 1 cm are better dispersed than kenaf fibres with a length of 3 cm in the polymer matrix so that the shore hardness value obtained is much higher [9]. At a load of 30 wt.% kenaf fibre with a length of 1 cm, a higher shore hardness value was observed compared to that obtained from kenaf fibre with a length of 3 cm, namely, 98 SHD vs. 94.8 SHD. Suriani et al. [10] also found that shorter fibres in the polymer matrix resulted in better mechanical property values, which was due to the shorter fibres being able to fill the entire polymer matrix so that there were fewer voids in the polymer matrix.

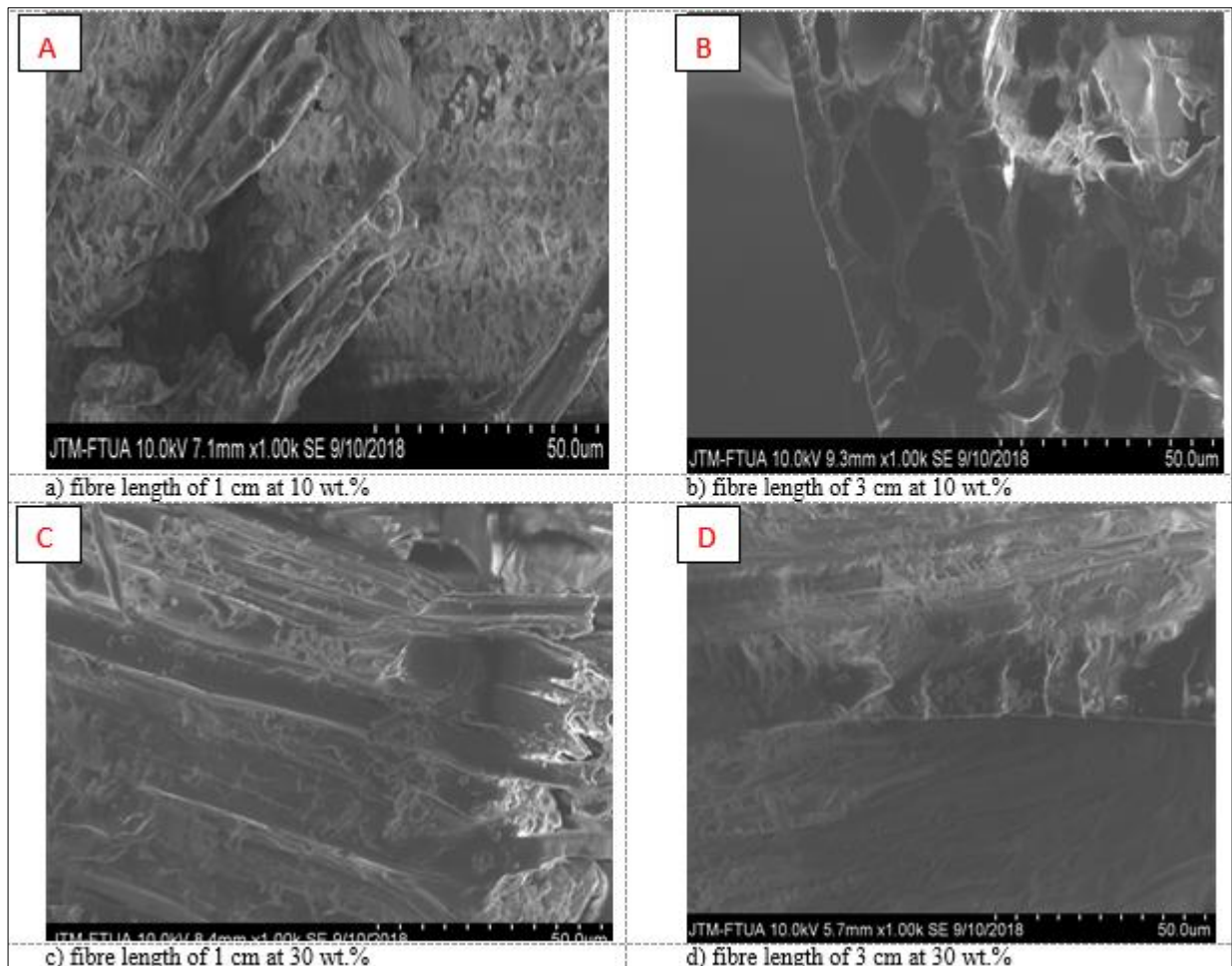


Figure 4. Scanning electron microscopy (SEM) images of the fracture surface of kenaf fibre/epoxy biocomposites

Figure 4 shows SEM images of the fracture surface of the resulting biocomposite material. Figures 4a and 4c show that 1-cm-long kenaf fibres at 10 wt.% and 30 wt.% compositions were well dispersed in the matrix (epoxy resin) compared to 3 cm long fibres at the same compositions of 10 wt. % and 30 wt.%. This condition resulted in better flexural strength, impact strength and shore hardness [9]. On the other hand, Figures 4 (b) and 4 (d) show that 3-cm-long kenaf fibres at the same composition, namely, 10 wt.% and 30 wt.%, tend to agglomerate and have some cavities. This condition has an impact on the low tensile strength, impact strength and shore hardness of the resulting biocomposite material [10].

4. Conclusions

The investigation of biocomposite materials using kenaf fibre as the reinforcement and low-viscosity epoxy resin as the matrix using the casting process was completed. The conclusions are as follows:

- The addition of kenaf fibre as a reinforcement succeeded in increasing the flexural strength, impact strength, and shore hardness of the resulting biocomposite material;
- Kenaf fibres with a length of 1 cm produce a biocomposite material that has a higher flexural strength, impact strength and shore hardness than kenaf fibres with a length of 3 cm;
- The length of the kenaf fibre used as reinforcement greatly affects the resulting biocomposite material. Longer kenaf fibres tend to agglomerate and cannot be well dispersed throughout the matrix, while shorter kenaf fibres are more easily dispersed and can fill the entire matrix better.



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