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Research Paper

Effect of Varying Fibre Loadings on the Impact Performance of Kenaf and Coir Reinforced Bioepoxy Composites

M.Z. Zainudin[1] , M.R. Mansor[1,*], M.B. Ali[2] , Y. Jameel[3], S.M. Sapuan[3], and Basori[4]

[1] Fakulti Kejuruteraan Mekanikal, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
[2] Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[3] Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400, UPM, Serdang, Selangor, Malaysia
[4] Department of Mechanical Engineering, Faculty of Engineering and Science, Universitas Nasional, Sawo Manila, Pasar Minggu, Jakarta 12520, Indonesia

* Correspondence: muhd.ridzuan@utem.edu.my

Abstract: This study describes the effect varying fibre loadings on the impact performance of kenaf and coir reinforced bioepoxy composites. A novel commercial type bioepoxy resin was applied to produce the composite, at fixed fibre loadings of 10, 20, 30, 40 and 50 wt%. Two types of bioepoxy composites were prepared, which are kenaf reinforced bioepoxy composites and coir reinforced bioepoxy composites, using untreated short fibre with average size between 3 mm to 5 mm. Hand layup process was applied to produce the composite samples, and later subjected to low velocity impact test according to ASTM D4812 standard. Results from the impact test showed that the highest impact energy and impact strength for kenaf reinforced bioepoxy composites and coir reinforced bioepoxy composites were obtained at 50 wt% fibre loadings. Comparison between both composites materials further revealed that coir reinforced bioepoxy composites showed higher impact energy and impact strength compared to kenaf reinforced bioepoxy composites for all fibre loadings (10 to 50 wt%). Furthermore, results obtained also showed that the neat bioepoxy has higher higher impact energy and impact strength compared to both kenaf and coir reinforced bioepoxy composites. This investigation has provided valuable insight on the application of bioepoxy in formulating green composites materials, and its effect to the impact mechanical property at varying fibre loadings.

Keywords: Impact Property; Bioepoxy; Kenaf; Coir; Fiber Loading

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1. Introduction

Biobased polymer matrix is gaining attention into the natural fibre composites (NFC) application, due to its environmentally friendly property compared to conventional synthetic based polymer matrix counterpart. The use of biobased polymer matrix provided the sought after advantages for NFC wider acceptance, such as higher biodegradability and recyclability performance in which it can offer especially towards producing fully green composite materials [1]. Many types of biobased polymer matrix were formulated by researchers, both for thermosetting and thermoplastic matrices. Among the examples of biopolymer matrix for NFC application are starch [2, 3], and polylactic acid (PLA) [4]. Ilyas et al. [5] also listed various biopolymers made from other renewable resources including plant origin protein and microbial fermentation.

Bioepoxy resin is another alternative in biobased matrix for producing NFC. Biobased epoxy is produced from many renewable resources such as nahar seed plant oil [6] and green tea leaves phenolic extract [7]. Abare et al. [8] investigated the physical, mechanical, and thermal properties of woven kenaf/bio-epoxy composites. Elsewhere, Franco-Urquiza and Rentería-Rodríguez [9] studied on the effect of nanoparticles to the kenaf fiber-reinforced bioepoxy composites using a hybrid manufacturing process (vacuum-assisted resin infusion and autoclave). Meanwhile, Mohit et al. [10] studied the effect of TiC nanoparticles reinforcement to the mechanical and thermal properties in coir fiber based bio/synthetic epoxy hybrid composites, at coir fibre loadings of 0, 5, and 10 wt%.

In this study, investigation on the effect to the impact mechanical property at varying fibre loadings for kenaf reinforced bioepoxy composites and coir reinforced bioepoxy composites is performed. The aim is to determine the optimum fibre loading for both composites in gaining the highest impact performance. Commercial type bioepoxy resin was used in formulating the composites. The novelty of this study is presented in the use of short fibre form and using hand layup sample preparation method.

2. Materials and Methods

2.1 Raw Materials

Kenaf bast fiber was obtained from Lembaga Kenaf dan Tembakau Negara (LKTN), Malaysia while coconut coir was sourced from Malaysian local supplier. The fibres were then chopped to an average length between 3 mm to 5 mm. Meanwhile, commercial type biobased epoxy resin (commercial name: SR GreenPoxy 28) was used as the matrix to prepare the composites, which was obtained from Sicomin Epoxy Systems, France. The bioepoxy resin was claimed to be produced with 28% of carbon originating from biomass. The hardener used for the curing process was SD 3304, which was also obtained from Sicomin. Figure 1 shows the kenaf bast fibre and coconut coir fibre used in this study. Furthermore, Table 1 and Table 2 summarized the materials properties for natural fibres and bioepoxy resin, respectively.

(a) (b)

Figure 1. (a) Kenaf bast fibre, (a) coconur coir fibre.

Table 1. Material properties of kenaf and coconut coir fibre [10].

Material Property	Kenaf Fibre	Coconut Coir Fibre
Cellulose	53.5	46.0
Hemicellulose	21.0	0.3
Lignin	17.0	45.0
Density (g/cm^3)	1.45	1.2
Elongation at break (%)	1.6	30.0

Tensile strength (MPa)	930.0	593.0
Elastic modulus (GPa)	53.0	4.0 – 6.0

As shown in Table 1, both kenaf and coir fibres encompassed varying chemical structure attributes, namely cellulose, hemicellulose and lignin which affected their mechanical properties. According to Sweygers et al. [11], the fibre cellulose is a linear carbohydrate polymer consisting of many glucose units which form the framework of the plant, which later can be structured into crystalline microfibrils that effects the fibre structural stability, stiffness and strength. Meanwhile, the fibre hemicellulose (which is a branched carbohydrate polymer) functions as the support material for the microfibrils, making it more hydrophilic compared to cellulose. In the other hand, the fibre lignin which comprised of aromatic rings and amorphous structure, filled up the spaces between the cellulose and hemicellulose, and contributed to higher compressive force capability by the fibres. Kenaf fibre in general has higher cellulose and hemicellulose contents compared to coir fibre, while coir fibre comprised of higher lignin content compared to kenaf fibre.

Table 2. Bioepoxy resin material properties.

Material Property	**Component A: Bioepoxy Resin (SR GreenPoxy 28)**	**Component B: Hardener (SD 3304)**
Density at 20 °C	1.17 ± 0.01	0.925
Viscosity at 20 °C (mPa.s)	21 000	21
Appearance	Translucid	Translucid
Curing time: 8 to 10 hours at room temperature		
Mix proportion by weight: 100 g of Component A per each 24 g of Component B		
Gel time: 7 hours at 20 °C		

2.2 Sample Preparation

The short fibers were mechanically mixed with bioepoxy and hardener at fixed fibre loadings of 10, 20, 30, 40 and 50 wt%. Control samples consisting of neat bioepoxy were also prepared. Two types of composites were produced for this study, which are kenaf reinforced bioepoxy composites and coir reinforced epoxy composites. The bioepoxy resin and hardener was mixed at 100g : 24g ratio as stipulated in the materials specification datasheet. Using hand layup method, the composites mixtures were later poured into a metal mould cavity and left to cure at room temperature for 10 hours. A dead weight of 5 kg was then placed on top of the composites spread, to remove excess matrix material from the mould cavity as well as removing any void formation due to trapped air. Prior to the mixing process, the fibres were dried at 60 °C for 24 hours in a drying chamber to remove the trapped moisture within the composites spread in the mould cavity.

2.3 Impact Testing

Impact tests were performed at Faculty of Mechanical Engineering and Technology, Universiti Teknikal Malaysia Melaka using Jinan Precision Impact Tester for low velocity impact test (0-11 m/s) using drop hammer, with detection range between 0 to 250 J. Five repetitions for each fibre loading were used during the test, and average value was taken as the final value. Sample size was prepared based on ASTM D4812 for unnotched sample condition, having dimensions of 64 x 12.7 x 3.2 mm.

3. Results and Discussion

The overall results obtained are summarized in Table 3. All samples were found to fail in complete break after subjected to the impact load (type C failure). As observed in

Figure 2, varying fibre loadings for both kenaf reinforced bioepoxy composites and coir reinforced bioepoxy composites resulted in mix impact properties performance, both in term of impact energy and impact toughness. For kenaf reinforced bioepoxy composites, the highest impact energy was observed at 50 wt% fibre loading (0.77 J), while the highest impact energy was also observed at 50 wt% fibre loading for coir reinforced bioepoxy composites (0.95 J). However, the impact energy for both natural fibre composites was lower than the impact energy of neat bioepoxy (at 0 wt% fibre loading) (1.35 J). Among the reason which contributed to this finding is both natural fibre composites were prepared without any fibre treatment (untreated fibre), which resulted in poor wettability between the fibres and the bioepoxy matrix, and subsequently reduced the fibre-matrix adhesion performance [12]. Moreover, results as shown in Figure 2 also indicated that the impact energy for coir reinforced bioepoxy composites was higher compared to kenaf coir reinforced bioepoxy composites for all fibre loadings. This finding is contributed to the higher ductility (elongation at break) of the coconut coir fibre compared to kenaf fibre. Fibre with higher ductility material property helps to absorb the impact load more effectively, hence increased the impact energy which can be absorbed by the composites. Saba et al. (2019) highlighted that the individual fibre property highly influenced the impact property of natural fibre composites [13].

Table 3. Impact properties of kenaf and coir reinforced bioepoxy composites.

Fibre Loadings (wt%)	**Impact Energy (J)**		**Impact Strength (J/m^2)**	
	Kenaf	**Coir**	**Kenaf**	**Coir**
0	1.35 (0.189)		355.21 (49.545)	
10	0.54 (0.179)	0.61 (0.100)	142.78 (47.083)	161.15 (26.351)
20	0.37 (0.197)	0.78 (0.276)	98.16 (51.753)	205.25 (72.509)
30	0.26 (0.115)	0.64 (0.201)	68.24 (30.155)	167.45 (52.703)
40	0.53 (0.120)	0.68 (0.205)	139.11 (31.496)	178.48 (53.790)
50	0.77 (0.120)	0.95 (0.310)	202.10 (31.496)	249.34 (81.322)

Value in parentheses corresponds to Standard Deviation.

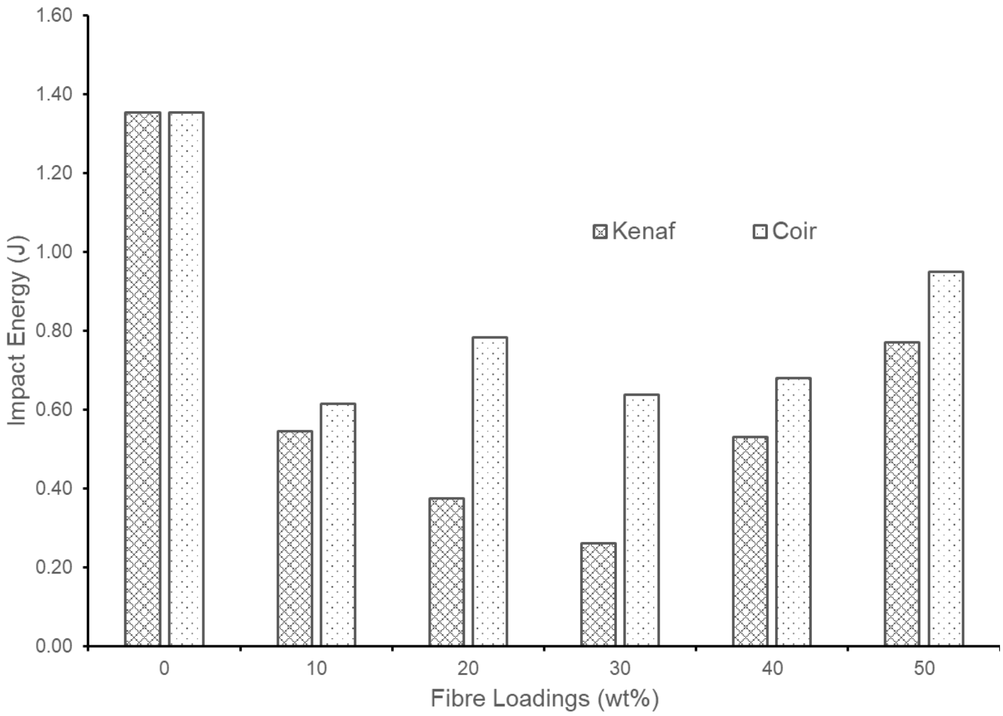

Figure 2. Impact energy of kenaf reinforced bioepoxy composites and coconut coir reinforced bioepoxy composites at varying fibre loadings.

Figure 3 shows the impact strength of kenaf reinforced bioepoxy composites and coirreinforced bioepoxy composites at varying fibre loadings. As observed in Figure 3, the optimum impact strength for kenaf reinforced bioepoxy composites of 202.10 J/m^2 was obtained at 50 wt% fibre loading, while the optimum impact toughness for coir reinforced bioepoxy composites of 249.34 J/m^2 was also obtained at 50 wt% fibre loading. The results obtained showed the influence of higher fibre loading towards improving the impact strength for both fibre reinforced bioepoxy composites and matched with previous findings by Huzaifah et al. [14]. They reported that the impact strength of natural fibre increased at higher fibre loadings was due to the presence of higher filler amount which amplified the composite's ability to absorb energy before breakage.

Similar to the aforementioned impact energy findings, the overall impact strength for coir reinforced bioepoxy composites was found to be higher compared to kenaf coir reinforced bioepoxy composites for all fibre loadings. Meanwhile, both composites also showed lower impact strength performance when compared to neat bioepoxy (at 0 wt% fibre loading). Bakar, Ahmad and Kuntjoro (2010) reported similar findings when investigating the impact properties of untreated kenaf reinforced synthetic epoxy composites at varying fibre loading. They found that the impact strength of untreated kenaf reinforced synthetic epoxy composites for fibre loading between 5 wt% to 25 wt% were lower compared to neat synthetic epoxy samples [15].

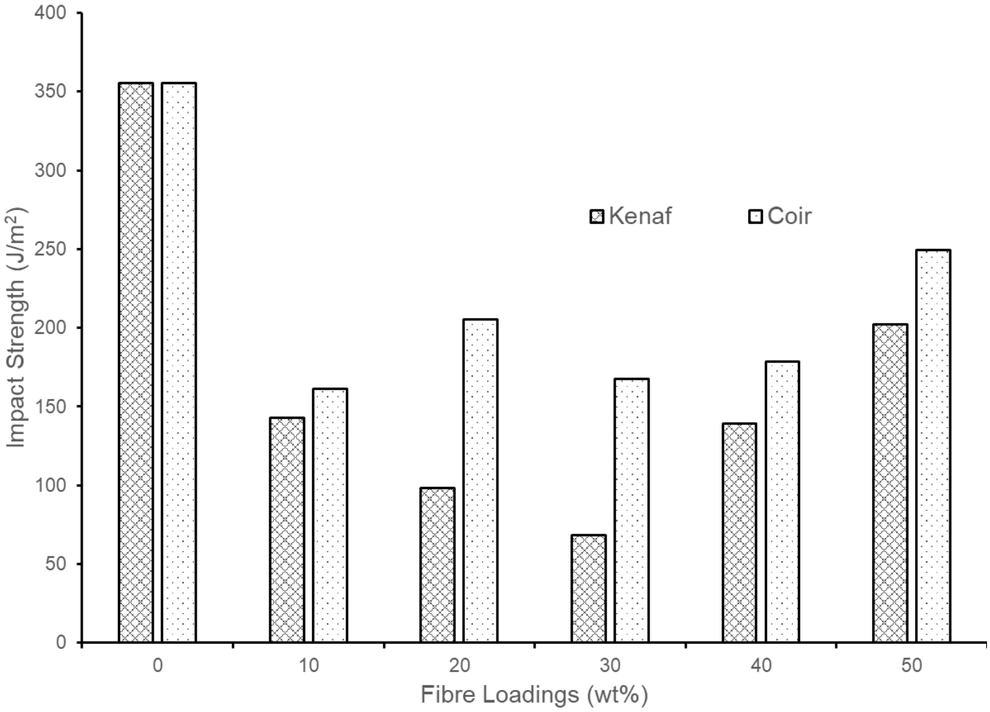

Figure 3. Impact strength of kenaf reinforced bioepoxy composites and coconut coir reinforced bioepoxy composites at varying fibre loadings.

4. Conclusions

Based on the results obtained, several notable conclusions from this study are outlined as below:

- Highest impact energy and impact strength for kenaf reinforced bioepoxy composites and coir reinforced bioepoxy composites were obtained at 50 wt% fibre loadings.
- Coir reinforced bioepoxy composites showed higher impact energy and impact strength compared to kenaf reinforced bioepoxy composites for all fibre loadings (10 to 50 wt%).
- Neat bioepoxy showed higher higher impact energy and impact strength compared to both kenaf and coir reinforced bioepoxy composites.

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