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Tensile and Morphological Properties of Biodegradable Composites Reinforced with Kenaf Core Fibres

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ABSTRACT

The combination of biodegradable polymers and affordable organic fillers has demonstrated efficacy in the production of economically viable composites, serving as a means to tackle environmental concerns and create products with enhanced mechanical characteristics. Poly (butylene adipate-co-terephthalate) (PBAT) is a high ductility and low crystallinity polymer. In the present research work, kenaf core reinforced composites were prepared via melt blending method using completely biodegradable PBAT. A polymer composite reinforced with 10wt %, 20wt %, and 30wt % amounts of kenaf core has been prepared and characterized for its tensile and morphological properties. The modulus of elasticity of all composites exhibited a higher value compared to the neat polymer, with the extent of improvement being dependent on the proportion of kenaf core incorporated. The PBAT composite with 30wt% kenaf core had a favorable modulus of elasticity, measuring 585 MPa. Morphological interpretation through scanning electron microscopy (SEM) reveals improved interaction and interfacial adhesion between PBAT and kenaf core. The distribution of the kenaf core inside the PBAT blend was uniform and consistent. The results reported in the present work support the idea that the above-mentioned natural fibers can be used as filler material to obtain environmentally friendly polymer composites with improved properties.

INTRODUCTION

Biodegradable polymers have been extensively researched and reported as environmentally benign alternatives to conventional thermoplastics in the packaging and agricultural sectors to reduce the environmental impact of plastic waste. Polyhydroxyalkanoates (PHA) and polylactic acid (PLA) are two outstanding examples of materials derived from renewable sources [1]. However, the relatively high cost and

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brittleness (primarily of PLA) limit specific industrial applications. Polybutylene adipate-co-terephthalate (PBAT) is an aliphatic-aromatic random copolyester that is biodegradable and chemically synthesized from fossil fuels. PBAT is characterized by its high flexibility and ease of processing; however, its low modulus and rigidity hinder its practical implementation in food packaging [2-4]. There have been reports of attempts to enhance the mechanical properties of these materials while maintaining their biodegradability and resistance to impacts. Studies have demonstrated that combining PBAT with other natural fillers holds the potential for developing fully biodegradable composites that exhibit enhanced rigidity. It is a highly advantageous material in the food packaging industry. Its high elongation at break, ease of processibility, and biodegradability make it a suitable substitute for low-density polyethylene [5, 6]. An additional critical approach to enhancing the modulus of polymeric materials involves the incorporation of natural fibers. Composites composed entirely of biodegradable polymers and natural fibers are highly sought after due to their low cost, enhanced mechanical properties, and environmental friendliness [7-9].

Kenaf (*Hibiscus cannabinus L.*), a member of the *Malvaceae* family, is an annual warm-season fiber producer. In addition to their low density and favorable thermal properties, kenaf fibers are ubiquitous, inexpensive, lightweight, environmentally sustainable perennial plants that make a negligible contribution to climate change [10]. Utilizing naturally occurring fibers (which are abundant) to improve the characteristics of bioplastic materials has several benefits. An illustration of how the utilization of these bio-composites mitigates carbon dioxide emissions is through the promotion of fiber cultivation and its associated benefits. Bio-composites are composed of biodegradable or non-biodegradable polymers filled with or reinforced with natural fibers [11]. Natural fibers generally exhibit lower elastic moduli and mechanical properties than glass fibers. However, when these characteristics are adjusted for specific gravity, natural fibers' specific strength and moduli become comparable to those of glass fibers [12, 13]. Due to their favorable cost, lighter weight, and environmental performance, bio-composites containing natural fibers can compete with conventional glass fiber composites, as suggested by similar characteristics.

This research intended to develop sustainable and cost-effective industrial bio-composites by producing new reinforcing composites from kenaf core and biodegradable polymer, PBAT. The primary objective of this work is to enhance the tensile strength properties and conduct a detailed morphological examination of the bio-composites.

MATERIALS AND METHODS

The PBAT (film grade EcoFlex) utilized in this investigation was procured from BASF Industry Co., Ltd. Least-processed long kenaf measuring between 45 and 250 μm in diameter and weighing 1.71 g/cm^3 in density was procured locally from National Kenaf and Tobacco Board (NKTB) in Pahang, Malaysia. Before compounding, the core part

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was reduced to 40 mesh using a pulverizer. The PBAT/kenaf core blend was produced by first making a masterbatch of pure PBAT using a Rheomixer at a temperature of 120 °C and a speed of 60 rpm. The masterbatch was then blended with varying proportions of kenaf core, specifically 10 % wt (KC10), 20 % wt (KC20), and 30 % wt (KC30). Subsequently, the PBAT/kenaf core blend, which had been dried, was pulverized into pellets measuring 1cm in size. These pellets were then subjected to hot pressing at 130 °C for 7 minutes, using a square plate with dimensions of 150 mm × 150 mm × 20 mm. After being removed from the compression mold, the specimen was post-cured for 20 minutes at ambient temperature. Subsequently, the produced bio-composite was stored in a dry cabinet to prevent moisture accumulation. Finally, a process sample was cut using standard testing methods.

Tensile Strength and Morphological Analysis

To determine tensile strength, the specimen composite was cut to the ASTM D638 Type IV standard of 115 mm × 61 mm × 3 mm, and the test was then examined using five replicates. Before the testing process began, as per ASTM regulations, all samples were kept for conditioning at 22 °C and 50 % relative humidity. The experiments were carried out on a 5 kN Blue Hill INSTRON Universal Testing Machine, and each composite specimen sample was evaluated and recorded for analysis. The tensile test specimen accumulated, and a cross surface of the cracked area was arranged for microscopic structure analysis. An EM-30AX scanning electron microscope was used to analyze the shattered morphological characteristics of the composite samples (Model: COXEM, Daejeon, Korea). The specimen's test was gold-coated and placed in a machine for testing.

RESULTS AND DISCUSSION

The impact of the kenaf core contents on the mechanical properties of the blends is illustrated in Figure 1. Apart from the nearly unaltered tensile modulus, all the tensile strengths and percentage of elongation at break exhibited a significant drop as the kenaf core increased. The diminished strength is ascribed to the lack of shear yielding during stretching. The elongation at break experienced a significant decrease, dropping from approximately 170 % to around 10 % with the addition of 30 weight percent of kenaf core. The KC10 material exhibited a significant flexural modulus of 300 MPa, with a minor increase observed when 20 and 30 % wt kenaf core was present.

Nevertheless, the flexural modulus of pure PBAT was inferior to that of the blended matrix due to the reinforcing influence of the kenaf core. In addition, the kenaf core's significant surface area and micropores offer more sites for anchoring. This, in turn, enhances the binding force between KC and PBAT and improves the nucleation capacity of PBAT. Ye et al. [14] have also demonstrated a similar finding, utilizing bamboo

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powder to increase the modulus of PBAT. Additionally, Xie et al. [15] have utilized large-size reeds to modify the tensile characteristics of PBAT bio-composite.

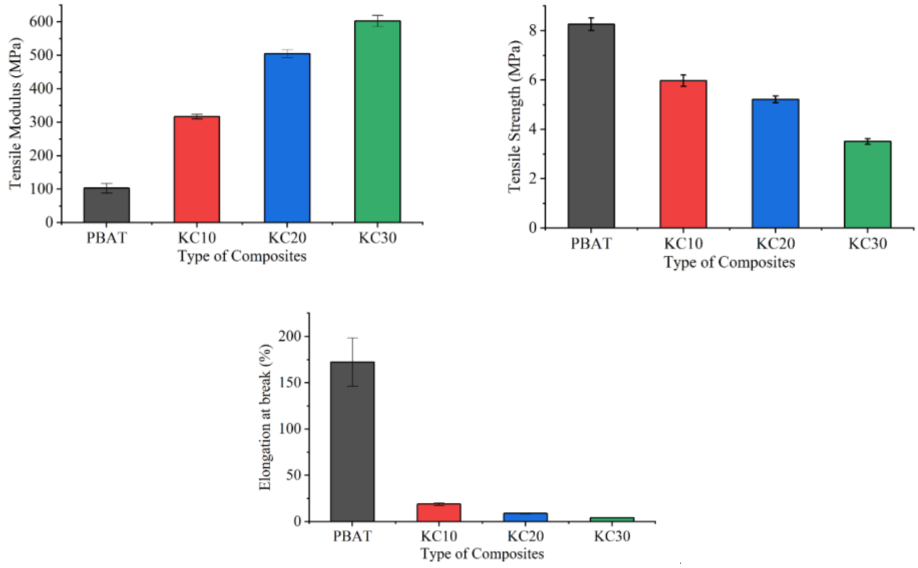

Fig. 1. Tensile modulus, tensile strength, and elongation at break of PBAT/kenaf core blend as a function of different amounts of kenaf core.

The presence of kenaf core agglomerates within the matrix was identified as the primary factor contributing to the material's weakness, as there was no connection at the interface. To assess the distribution of the kenaf core in the blends, the surfaces of the impact-fractured processed blends are examined using scanning electron microscopy (SEM). The results are presented in Figure 2.

The scanning electron microscope (SEM) pictures revealed that the kenaf core agglomerates were evenly distributed throughout the PBAT matrix, as shown in Figure 2. The disparity between the PBAT matrix and kenaf core was readily apparent, signifying the inadequate compatibility between the two distinct polymers (the synthesized polymer PBAT and the natural polymer kenaf core).

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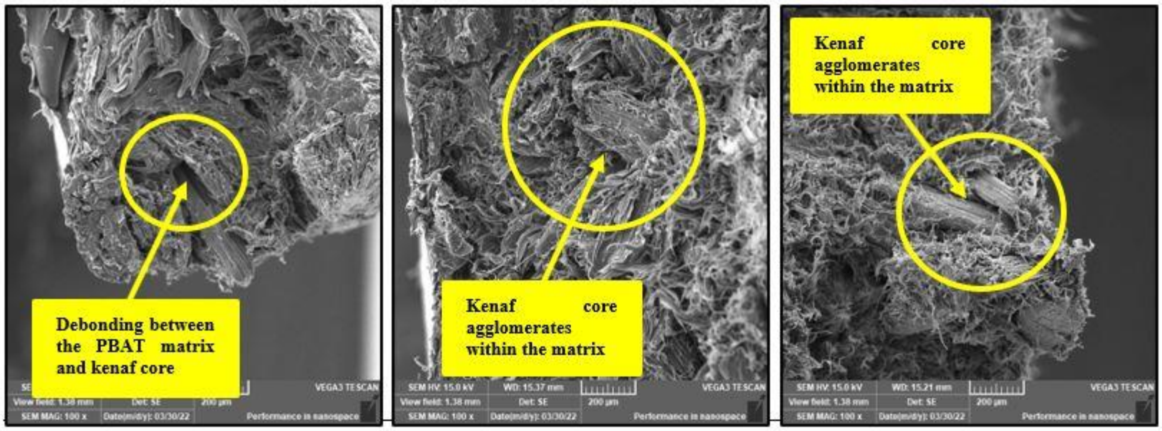

Fig. 2. SEM observation of PBAT/kenaf core blends at different kenaf powder loading (l-r, 10 % wt, 20 % wt, and 30 % wt) at 100× magnification

CONCLUSION

In this study, melt blending was used to incorporate kenaf core into PBAT polymer mixtures to increase the bio-content of the final product while preserving its biodegradable characteristics due to the substantial disparity in polar characteristics between the kenaf core and biomaterials PBAT, the kenaf core needed to be better dispersed in the composites. The matrix's structural integrity was damaged, and there was a lack of bonding at the interface when the kenaf core was added to PBAT; as a result, the tensile strength of the composites significantly deteriorated as the kenaf core content increased while the tensile modulus increased. The finding indicates that this blend could improve the capacity to produce and distribute this naturally occurring polymer bio-composite in future applications.

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CONFLICT OF INTEREST STATEMENT

The authors declare no competing interests.

AUTHORS' CONTRIBUTIONS

Muhamad Haikal Hamdan carried out data curation. Siti Noorbaini Sarmin and Zaimatul Aqmar Abdullah did the formal analysis. Siti Noorbaini Sarmin and Noorshashillawati Azura Mohammad made the funding acquisition. Ainul Munirah Abdul Jalil did project administration. Muhamad Haikal Hamdan wrote the original draft.

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