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Research Article

Investigation on Mechanical and Thermal Properties of a Kenaf/Jute Fiber-Reinforced Polyester Hybrid Biocomposite

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This study investigates the mechanical and thermal properties of biocomposite in relation to their hybridization. Compression moulding was utilised to produce hybrid biocomposites composed of polyester resin reinforced with kenaf, jute, and three distinct combinations of kenaf/jute fibers. To increase the bonding of kenaf and jute fibers with polyester resin, a 5 percent NaOH solution was administered to them. The following stacking sequences were used to manufacture a total of five different types of laminates: polyester resin 80 wt%/kenaf fiber 20 wt%, polyester resin 80 wt%/jute fiber 20 wt%), polyester resin 80 wt%/kenaf fiber 5 wt%/jute fiber 15 wt%, polyester resin 80 wt%/kenaf fiber 10 wt%/jute fiber 10 wt%, and polyester resin 80 wt%/kenaf fiber 15 wt%/jute fiber 5 wt%. In the mechanical and thermal tests, it was discovered that the polyester resin 80 wt%/jute fiber 20 wt% biocomposites had increased strength compared to the other hybrid biocomposites investigated.

1. Introduction

A growing demand for alternative raw materials [1] such as wood [2] is being seen in the furniture, automobile, and home industries accordingly of the exhaustion of natural wealth in these industries. Because of its environmentally friendly character, the utilisation of natural fiber as a reinforcement in polymers has expanded in popularity in recent years [3, 4]. Natural fibers are extremely durable, lightweight, and inexpensive when evaluated to synthetic fibers. Scientist has been looking for nonwood bio-based options for composite manufacture in order to meet this need. Several biomaterial-based composites have been proposed by researchers [5, 6] as a viable alternative to synthetic fiber and wood in numerous applications. In the meadow of material development, developing natural fiber-reinforced polymer composites has become a common technique. Material researcher is working on a variety of polymer composites that make use of readily available natural fiber. Reinforcing starch-based polymers with stronger and additional robust normal cellulose cellulosic fibers is one of the conceivable methods of improving mechanical and thermal qualities [7].

Lignocellulosic fibers have a lower density than synthetic fibers, and they are also totally biodegradable, making them an excellent option to artificial fibers. The use of lignocellulosic fiber reinforcement can also greatly get better the mechanical characteristics of starch-based matrixes [8]. Lignocellulosic fibers such as date palm, sisal, kenaf, jute, wood, banana, cellulose, orange, bagasse, and flax are a few examples of lignocellulosic fibers that have all been deliberate and established to be a useful technique to significantly improve the versatile properties of starch-based matrix [9–11]. In the polymer industry, hybridization has become a widely used technique that allows designers to create products among advanced mechanical properties while minimising the property of humidity absorption as well as reduced fiber/matrix bonding by reinforcing by means of two different natural fibers or natural and artificial fibers [12, 13]. Hybridization's impact on composites' dynamic and thermomechanical properties has been examined in numerous studies.

Some researchers reinforced it with natural, glass, or carbon fibers. This work [14] said that when glass fiber was mixed with oil palm in a phenol-formaldehyde-resin, it made the material stronger, more stable, and less water-absorbing. They [15] say that the mechanical properties of bamboo fiber/glass fiber polymer composites are better than bamboo fiber polymer composites, which are better than bamboo fiber composites. A study [16] found that the glass fiber hybridization had a positive effect on the tensile, flexural, impact, and water absorption properties of the hybrid composites, as well as their strength. At 8.55 wt percent of glass fibers in pine apple leaf fiber-polyester hybrid composites and 5.5 wt percent of glass fibers in sisal fiber-polyester hybrid composites, the ultimate tensile strength and impact strength are at their peak. The thermal and mechanical investigation of biohybrid jute/sisal fiber-reinforced epoxy biocomposites with varying jute/sisal fiber weight ratios revealed that hybridization improved the thermal study of the biocomposites. Additionally, biohybrid composites with a larger jute fiber content had higher storage modulus, loss modulus, and Tg [17].

Kenaf fiber is particularly compatible with polymers, and the matrix will cover the entire surface of the kenaf fiber, improving thermal stability. The combination of PALF and kenaf fiber will advance thermogravimetric, mechanical, and dynamic analysis [18]. Nonetheless, a small number of studies have been conducted with hybrid biocomposites made of a polymer with various forms of kenaf and jute fiber reinforcement. The goal of our research is to manufacture high-class biocomposite product at a little price by utilising natural fibers such as kenaf fiber and jute fiber. Various composite materials, including PR/KF, PR/JF, PR/KJF1, PR/KJF2, and PR/KJF3, are proposed to be created by reinforcing kenaf and jute fibers in various combinations with polyester resin and reinforcing kenaf and jute fibers in various mixtures. Therefore, it is proposed to assess the various properties of each and every biocomposite material, such as mechanical and thermal stability, in order to find the most cost-effective and superior biocomposite among all potential blends.

2. Materials and Experimental Details

2.1. Preparation and NaOH Treatment of Kenaf and Jute Fibers. Kenaf and jute fibers were obtained from the Mayiladuthurai neighbouring bazaar in Tamil Nadu, India. Polyester resin, NaOH, and hardener (HY951) were procured from Vinayaga Scientific, Tiruchirappalli, Tamil Nadu, India. The moisture content of the collected kenaf fiber and jute fiber is being removed by drying. The dried fibers are sliced into 20 mm lengths. NaOH treatment of kenaf fiber and JF fibers was performed first to remove the lignin, wax, and oils from the fibers cell wall's outer surface [19]. A 5 percent solution of NaOH was used to submerge the cleaned and dried kenaf fiber and jute fiber for 24 hours. It was then washed with water and neutralised with weak acetic acid before drying in an oven at 90 degrees Celsius for a period of 18 hours to dry the kenaf fiber and jute fiber. When a hydrophobic polymer matrix encounters a particle, weedy bonding occurs at the particle/matrix contact; hence, this treatment was aimed at boosting outside area while decreasing hydrophilic groups.

2.2. Preparation of Hybrid Biocomposites. Compression moulding was used to create the biocomposite materials used in this investigation. To make the biocomposites, the appropriate amount of kenaf fiber (10 wt percent), jute fiber (10 wt percent), and polyester resin was taken, along by way of the hardener araldite (HY951). In terms of weight, the polymer and hardener are mixed at a 10 : 1 ratio. Only the mixture can be placed after that. A pressure of 120 kgf/cm^2 was gradually applied to the laminate to ensure consistent resin dispersion throughout. It also aids in the removal of trapped air [20]. The samples were held under the same pressure for about 3 hours to achieve complete cure. Table 1 shows a variety of compositions.

2.3. Composite Characterisations. The tensile and flexural test specimens were produced in accordance with ASTM D638 and ASTM D790, correspondingly, and tested at a specific load on a Unitek—94,100 tensile testing machine. The Izod impact test on notched specimen is carried out using an EMIC pendulum machine per ASTM D-256. It weighs 0.6 kg and hits at 3.35 m/s. Sample dimension is $65 \times 13 \times 3$, depth of "V" notch is 2 mm, and angle is 45°. The machine's dial indication indicates the impact energy of various specimens. The impact strength was evaluated using five distinct specimens' mean values. TG was used to measure the thermal strength and thermal degradation of the biocomposite samples. Thermogravimetric analyzer NETZSCH STA 449F3 (JUPITER, Annamalai University) was utilised. Each sample was heated to 600 degree Celsius in a platinum pan at a rate of 5°C/min beneath nitrogen.

Table 1: Composition of biocomposites.

S. no	Sample	Composites	Biocomposites
1.	S1	PR/KF	PR 80 wt%/KF 20 wt%
2.	S2	PR/JF	PR 80 wt%/JF 20 wt%
3.	S3	PR/KJF1	PR 80 wt%/KF 5 wt%/JF 15 wt%
4.	S4	PR/KJF2	PR 80 wt%/KF 10 wt%/JF 10 wt%
5.	S5	PR/KJF3	PR 80 wt%/KF 15 wt%/JF 5 wt%

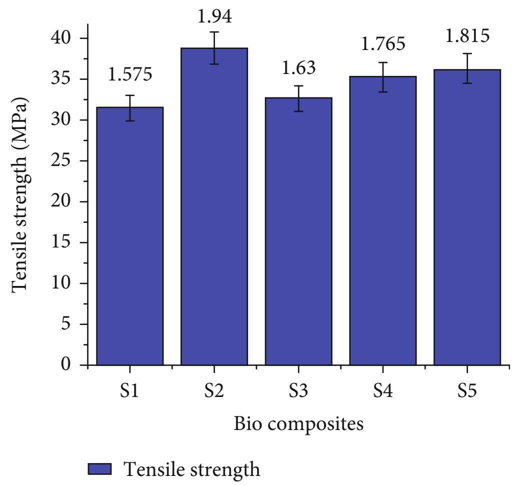

Figure 1: Variations of tensile strength with KF/JF fiber biocomposites.

3. Results and Discussion

3.1. Tensile Strength. Figure 1 depicts the achieved tensile strength on hybrid biocomposites as a function of kenaf fiber, jute fiber, and KJF reinforcement. The pattern clearly demonstrates an increase in tensile strength for kenaf fiber and JF reinforcement. Tensile strengths were 31.5, 38.8, 32.6, 35.3, and 36.3 MPa for PR/KF, PR/JF, PR/KJF1, PR/KJF2, and PR/KJF3 biocomposites, respectively. The highest tensile strength obtained in PR/JF (38.1 MPa) biocomposite is further evaluated to hybrid biocomposites PR/KJF1, PR/KJF2, and PR/KJF3. This might be attributed to the complement behaviour of two or more fibers in the hybrid composite, whereas jute fiber in the PR/JF biocomposite imparts higher tensile strength [21]. As a result, by correct material design, a balance of performance and cost might be achieved.

3.2. Flexural Strength. Figure 2 illustrates the flexural strength of PR/KF, PR/JF, PR/KJF1, PR/KJF2, and PR/KJF3 natural fiber-reinforced biocomposites. It had greater values than the biocomposites' tensile strength, which might be attributable to the fiber orientation in the biocomposites' outer layer. A similar pattern emerged in this finding as well; the PR/JF biocomposite had the highest flexural strength (78.90 MPa) when compared to the other biomaterials (PR/KF, PR/KJF1, PR/KJF2, and PR/KJF3 materials). As a result, polyester may bond effectively to jute fibers, resulting in excellent flexural strength [22].

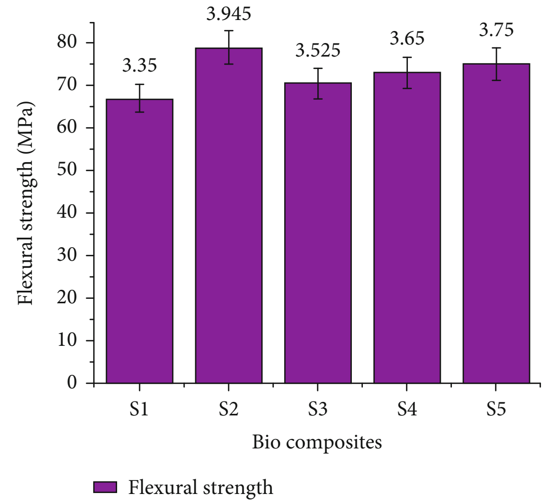

Figure 2: Variations of flexural strength with KF/JF fiber biocomposites.

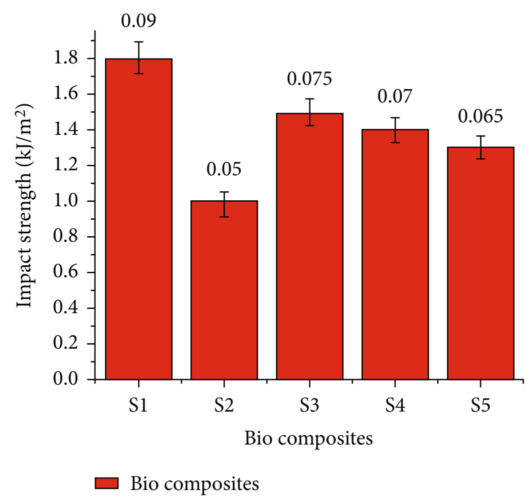

Figure 3: Variations of impact strength with KF/JF fiber biocomposites.

3.3. Impact Strength. This result followed the same pattern as tensile and flexural strength; Figure 3 shows the impact strength variation with PR/KF, PR/JF, PR/KJF1, PR/KJF2, and PR/KJF3 fiber reinforcement. Figure 4 shows that the capacity to oppose impact force is stronger in the biocomposite reinforced among PR/KF (1.8 kJ/m2) than in biocomposites reinforced with further fibers since the fibers contributed a little brittleness as a result of increased hardness, which resulted in a drop in impact strength. This highest in impact strength reflects the fiber's involvement and the biocomposites' capacity to absorb energy. This is appropriate to the fiber and matrix's strong interfacial bonding [23]. It furthermore depends on the characteristics of the fiber and resin.

3.4. Flexural Fracture Surface Morphology Evaluation. Figures 4(a)–4(c) represent the flexural fractured surface on PR/KF, PR/JF, and PR/KJF2 biocomposites. Figure 4(a) shows a SEM picture of the PR/KF biocomposite, which

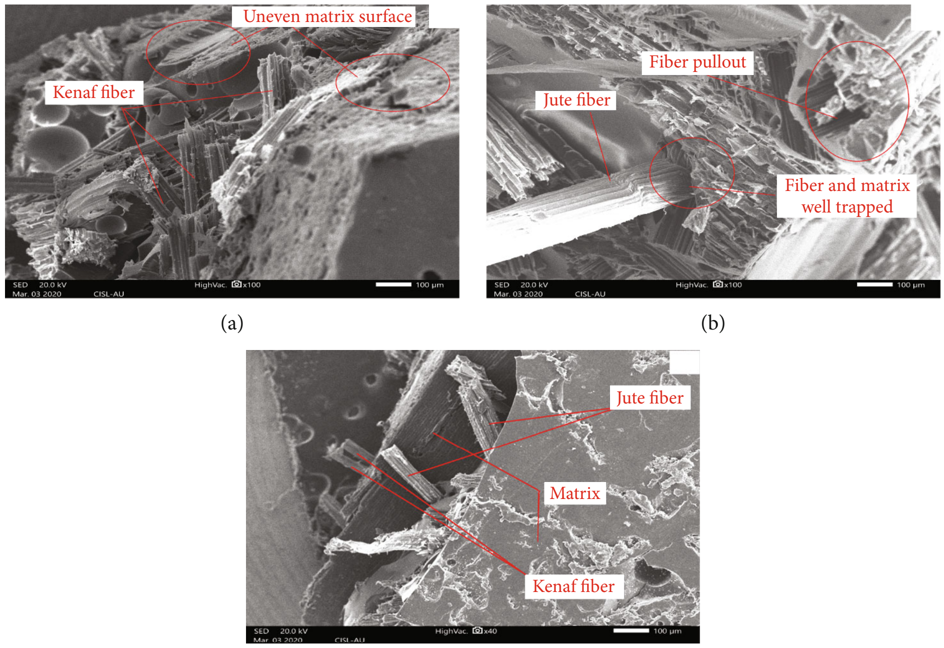

FIGURE 4: SEM image of a biocomposite fracture surface of flexural strength, for (a) PR/KF, (b) PR/JF, and (c) PR/KJF2.

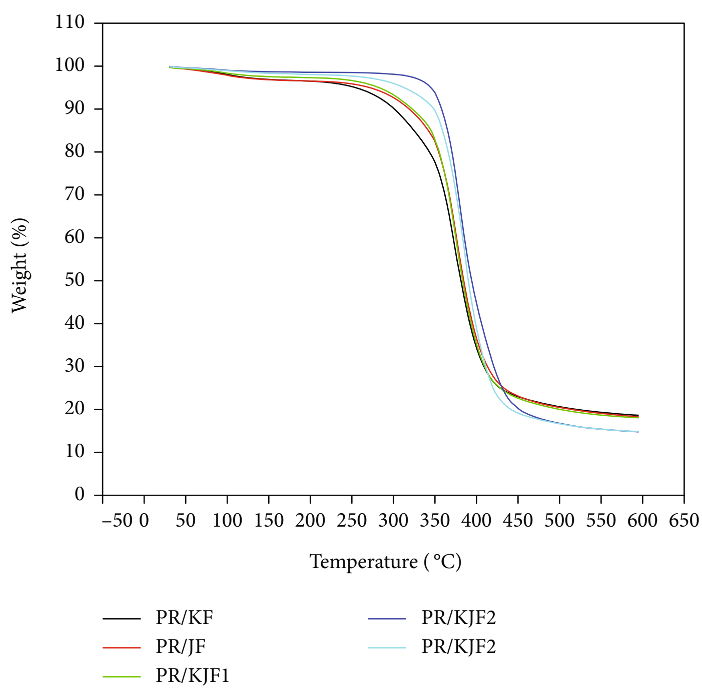

FIGURE 5: TGA curves for KF and JF biocomposites.

clearly displays the kenaf fiber and the poor interfacial bonding between the kenaf fiber and the resin [24]. Figure 4(b) shows an irregularly broken pattern in the PR/JF sample, indicating an interfacial zone between jute fiber and resin. Well-trapped fiber, lack of fiber cohesion, lack of voids, and good adhesion to the fiber-matrix interface characterise this material. It helps PR/JF (38.1 MPa) biocomposites have superior flexural strength. The flexural fractured surface of the PR/KJF2 biocomposite, which contains kenaf and jute fiber, is shown in Figure 4(c) as a series of small holes. As a result, the crack propagation is lengthened [25, 26].

3.5. Thermogravimetric Analysis (TGA). Figure 5 illustrates the outcome of the thermogravimetric analysis of all the PR/KF, PR/JF, PR/KJF1, PR/KJF2, and PR/KJF3 samples in the temperature variation of 0–600 degree Celsius in nitrogen atmosphere. The PR/JF biocomposites showed much greater thermal stability than the other four biocomposites, as shown in Figure 5. Thermogravimetric analysis is widely used to identify materials that have lost or gained mass owing to breakdown, oxidation, or the loss of volatiles. The first weight loss (9.2%) among 50 and 340 degree Celsius relates to the evaporation of absorbed moisture comfortable starting the biocomposites, as seen by the thermogravimetric analysis curve. The most major components of hemicelluloses, cellulose, and lignin are accountable for the drastic weight loss from 340 to 455 degree Celsius. Total weight losses of PR/KF, PR/JF, PR/KJF1, PR/KJF2, and PR/KJF3 biocomposites were 84.2, 81.4, 83.6, 86, and 87 wt percent, respectively, after decomposition. When compared to other composites, PR/JF had the smallest weight reduction (81.4%). Jute fiber has a much greater experimental thermal stability than the other four biocomposites mentioned in the literature [27, 28]. This indicates that the PR/JF composite had a high amount of fiber integration.

4. Conclusion

This study looked at the mechanical characteristics and thermal strength of polyester biocomposites reinforced with kenaf fiber and jute fiber. The evidence and discussion presented above led to the following conclusions.

(i) The PR/JF biocomposite outperforms the other four biocomposites in terms of mechanical strength, such as tensile and flexural strength

(ii) Also, PR/JF biocomposite demonstrated greater thermal stability and temperature degradation than other biocomposites, according to thermogravimetric analysis

(iii) In tensile strength, PR/JF biocomposite attained maximum tensile strength (38.1 MPa)

(iv) In flexural strength, PR/JF biocomposite had the highest flexural strength (78.90 MPa)

(v) Lastly, the impact strength PR/JF biocomposite reinforced among PR/KF (1.8 kJ/m^2)

Data Availability

The data used to support the findings of this study are included within the article. Further data or information is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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