Hindawi
Advances in Polymer Technology
Volume 2022, Article ID 4916499, 11 pages
https://doi.org/10.1155/2022/4916499

Research Article

Investigation on Physical and Mechanical Characteristics of Date Palm Fiber Reinforced Aliphatic Epoxy Hybrid Composites

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Received 12 January 2022; Accepted 5 March 2022; Published 26 April 2022

Academic Editor: M. Ravichandran

Automotive industry attention in using date palm fiber as an internal material has been sparked by its use as a polymer reinforced composite. Date palm fiber-reinforced aliphatic epoxy composites for semistructural applications are the key goals of this work. To make the various composites, they used a combination of manual lay-up and adhesive bonding. Date palm fiber/bamboo hybrid composite and uncontaminated composites were tested through density, tensile, flexural, and impact tests and also studied the effects of swelling, water absorption, and physical performance in greater depth. According to studies, hybrid composites constructed from date palm fiber and bamboo had the best mechanical properties. The date palm/bamboo hybrid composite was created to impact the toughness of 12.72 J/m in tensile, flexural strength, and impact toughness measurements. The reduced swelling and water absorption were 27.66 percent and 15.37 percent, respectively, when testing a date palm fiber/bamboo hybrid composite. Density ranged from 1.15 g/cm^3 to 1.25 g/cm^3 for bamboo fiber composite material and from 1.23 to 1.27 g/cm^3 for date palm fiber/bamboo composite material. High flexural strength is achieved by the bamboo composite specimen (bamboo: 6.18 MPa), followed by (PDF-*A*/*B*: 61.12 MPa, date palm fiber-AA/*B*: 61.08 MPa, date palm fiber-*L*/*B*: 60.82 MPa, and date palm fiber-*G*/*B*: 61.47 MPa), and the PDF composite specimens (date palm fiber-*A*/*B*: 61.112). Hybridized materials (date palm fiber/bamboo fiber) with a 50 : 50 ratio had higher impact strength.

1. Introduction

Research into amalgamated materials has grown over recent years, focusing on their mechanical and physical qualities for an extensive variety of applications [1]. Owing to their non-abrasive nature and less power ingesting as well as their high specific mechanical qualities and biodegradability natural fibers including oil and date palm, jute fiber, hemp fiber, kenaf fiber, sisal fiber, glass fiber, and pineapple leaf take numerous compensations for both people and environment [2][3]. Meanwhile, the demand for petroleum-based polymer composites is on the rise across a wide range of sectors and applications. Other than that, petroleum-based materials are not biodegradable, which has a bad effect on the atmosphere and humanoid health [4]–[6].

More and more people are turning to organic materials, such as food waste and agricultural residues, to make products or use them in innovative ways. Many low-to-medium-impact product applications could benefit from the use of residue or agricultural wastes as a substitute resource. Plant fibers' potential as reinforcing materials for composites made with synthetic fibers appears to be a long-term one [7]. Fibers from the date palm were successfully recovered by chemical degumming and are one of the world's most widely accessible natural fiber kinds. It is used to make ropes, sticks, and roof coverings. Fibers from the DPT are also rich in polysaccharides (44%), cellulosic (28%), hemicellulose (12.5%), inorganic (11.5%), lignin (18.5%), waxes, and fats (18.5%), which have excellent binding capabilities [8].

Date palm fiber reinforced mixture partake has been found to be suitable for an extensive variety of uses, including nonstructural and semistructural interior usage in automobile modules, according to a study by [9]. According to [10], date palm fiber strengthened soil bricks had a higher compressive strength and water repellency than wood chips, which was confirmed in their investigation. In addition to enhancing mechanical and physical qualities, temperature and rheological properties were also affected by the study of particulate date palm fiber. Agricultural waste date palm fibers were shown to greatly improve the bitumen matrices physicomechanical qualities when used as filler in asphalt. Figure 1 reveals the flowchart of applications of polymer matrix composites.

Because of this, the structural properties of a date palm leaf/glass strengthened mixture composites could be improved by alkaline treatment, as demonstrated in [11]. When it comes to tensile strength and modulus, bamboo plant fibers are superior to other natural fibers due to their similar mechanical properties to those of other conventional fibers [12]. Because of its great stiffness, bamboo is regarded as "nature's glass fibre" in Southeast Asia, since that is the most prevalent natural substance fibers. The inferiority microfibril inclination of the fiber axis with a longitudinal direction is also present in bamboo fibers [13, 14]. Relatively dense ($1.5\,g/cm^3$) and mechanical properties like bending load strength make bamboo superior to manufactured glass fibers in many applications.

Lattice platforms made from bamboo have long been used in construction. Using bamboo as an organic filler and thermoplastic composites, a study by [15]–[17] has generated robust natural fiber-based composites materials that are environmentally friendly. Investigation of bamboo fiber wastage and castor liquid polyurethane resin was carried out in comparison to Oriented Strand Board (OSB) [18, 19]. Wear resistance, flexural toughness, and elasticity were all higher in the experimental OSB than in commercial OSB. For example, an individual's specific strength and stiffness are frequently used to measure the mechanical performance of composites made from natural fibers [20, 21]. Similar to cellulose and microfibril angle, these reinforcements have a significant impact on the composite material for a wide range of applications. While natural residual waste can be an ecological sustainability resource and economically feasible for numerous uses, the discovery of biodegradable composite material has highlighted with concern about composite materials substances two or more types of fibers. The characteristics of the two phases are combined in composite materials. Instead, in hybrid materials, the elements join at a molecular level, resulting in an orbital interaction condition. This research is aimed at creating a combination composite material from agricultural waste residue fibers and bamboo fiber attention to the significance of ecologic and material effectiveness [22], whereas the date palm fibers are predicted to be hard and compressive strong, and these materials are predicted to be high in strength [23]. Adhesive matrix composite fiber strengthened with date palm/bamboo waste stains is expected to enhance workability of strengthened date palm trees. Date palm fiber biocomposites mechanical behavior should be improved for non- and quasifunctionalities. Table 1 shows the chemical composition of DPT and BF.

2. Materials and Method

2.1. Materials. Aliphatic is a class of biodegradable implantable polymers. Aliphatic combination composites with a blend of DPF dimensions from 0.8 to 1 mm were used in this investigation. In addition, epoxy resin was used as the matrix resin in the manufacturing of the date-palm/bamboo hybrid.

2.2. Fabrication of Date Palm/Bamboo Hybrid Composites. The simplest molding method for manufacture is hand lay-up. Woven or knitted fibers are initially manually put in the mould. The resin matrix is applied to the reinforcing material using a brush then heated with pressure to make a polymer composite. By using hand lay-up method, researchers created three distinct sample forms: date-palm fiber composite, bamboo fiber composite, and a hybrid date-palm/bamboo composite. Solitary sample is defined as a combination of date palm leaf stalk (A), fruit bundle stalk (AA), leaf sheath (G), tree trunk (L), and bamboo materials. Bamboo fiber is a fantastic material and an extremely eco-friendly alternative to synthetic fibers. It is made from a fast-growing, antibacterial, and deodorizing. In the meantime the, the reinforced date-palm blending consists of date-palm fruit leaf stalk and bamboo (A/B), date-palm fruit bunch stalk and bamboo (AA/B), date-palm leaf sheath and bamboo (G/B), and date-palm trunk and bamboo (L/B) mixtures. There are a wide range of date palm fiber/bamboo composites to choose from, each with its own unique chemical components (cellulose, hemicellulose, and lignin) and yield.

In establishing the composite samples, three distinct phases were employed. Components materials were first cleaned and dehydrated at 60°C for 24 hours to decrease humidity to 6*e*8 % before being used. A metal casting mould of 150 by 150 by 3 millimeters will be the next step. Throughout this stage, a 2 : 1 stoichiometric resin-to-hardener ratio was also rippled into the fibers mixture. After being heated to 110°C for 15 minutes and then cooled for 10 minutes with a cold hydraulic press, the very last combination was dispensed into the metallic cast mould and evenly banquet with a 50 : 50 weight proportion of fibers and composite resin. Later, the samples were extracted and sectioned in size-appropriate repetitions for every investigation.

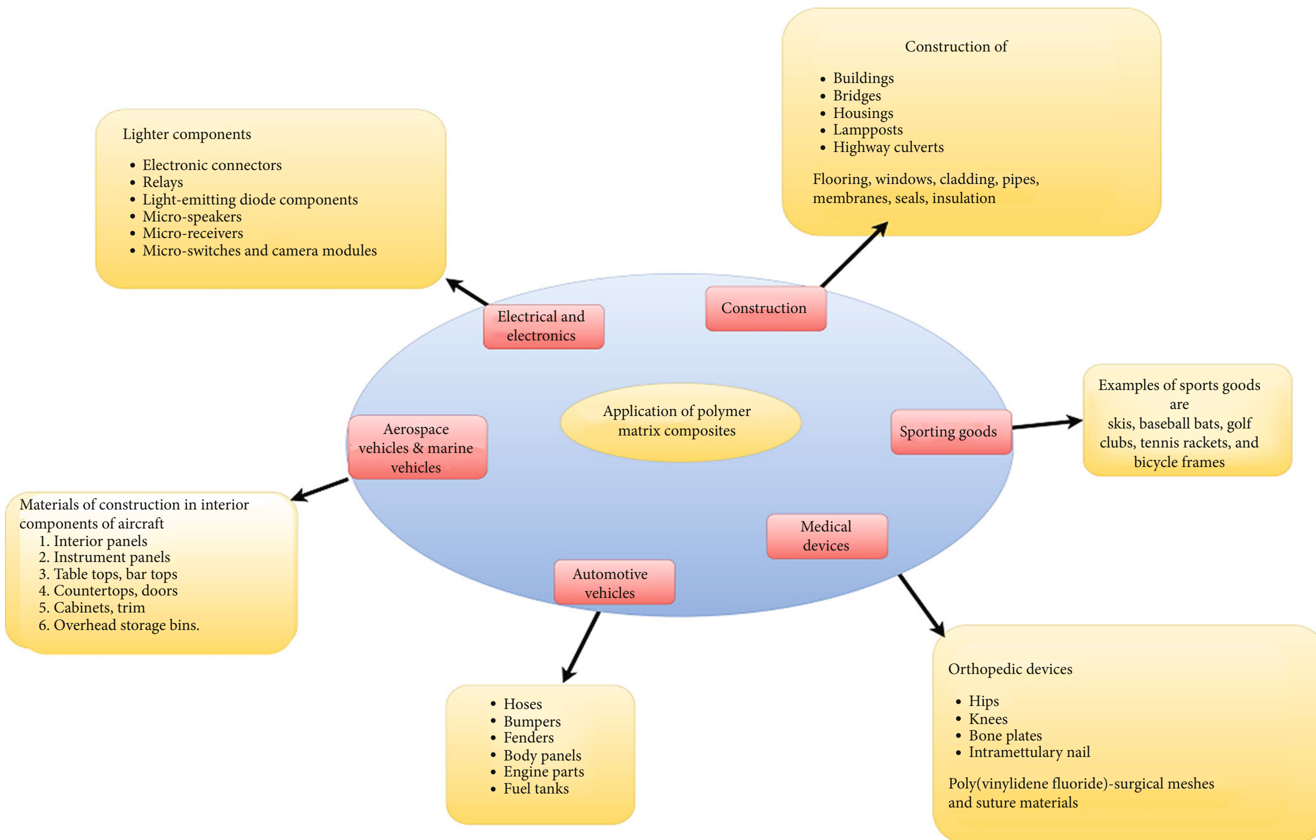

Figure 1: Applications of polymer matrix composites.

Table 1: Chemical composition of (DPT) and (BF).

Specimen	Leaf stalk (*A*) of date palm fiber	Fruit bunch stalk (AA) date palm fiber	Leaf sheath fiber (*G*) date palm fiber	Trunk fiber (*L*) date palm fiber	BF
Cellulose (%)	36.00	45.80	45.65	42.00	74.85
Hemicellulose (%)	16.84	27.50	25.45	11.25	13.55
Lignin (%)	21.65	12.50	19.80	31.25	11.25

3. Analysis of Natural-Hybrid Composite Materials

3.1. Thickness Swelling (TS) and Water Absorption (WA). The thickness swelling (TS) method is used to test the dimensional stability of composite panel materials. A composite structure's mechanical properties have been significantly altered by the physical parameters of thickness swelling. Specimen dimensions for all duplicates were 20 mm by 20 mm by 3 millimeters. Relative water absorption rates were determined using the ASTM-D 570 standard [24] for sample made of hot-moulded epoxy composites. All specimens were soaked in pure water at ambient temp for twenty four hours to conduct a soak test. For seven days, the thickness data of each specimen has been recorded before and after each day. Equation (1) was therefore utilized to calculate the specimen thickness swelling, where T0 represents the specimen thickness prior to soaking and T1 represents specimen thickness following soaking [25].

$$\text{Thickness Swelling}(\%) = \frac{T_1 - T_0}{T_1} \times 100. \tag{1}$$

When it comes to water absorption, the composite specimen used in this investigation passed the ASTM D 570-98 water absorption test. It has been noted that all mixture samples have been verified with their starting weight (W_d) and their final weight (W_n). For the next eight days, the test specimens will be submerged in distilled water. As a result, Eq. (1) has been used to calculate the composites' water absorption value (2):

$$\text{Water absorption}(\%) = \frac{W_n - W_d}{W_d} \times 100. \tag{2}$$

3.2. Density. Based on the composite's strength properties, it has been segmented into min, medium, and max densities. There is a min-thickness reinforced segment, which has greater voids and porosities, which includes materials that can absorb more humidity and retain extra water. The natural material, on the other hand, had a high density and high rigidity due to fiber compaction. It is also worth noting that hybrid fabrics have a tendency to soak up water or moisture. Consequently, the durability of the mixtures was aided by substance load capacity or fiber infusion in the context of hybrid material investigations. As a result, composite specimens were calculated using Eq. (3)'s general composite rule of mixture.

$$\text{Density}, \rho\left(\text{g/cm}^3\right) = \frac{\text{Mass}}{\text{Volume}} = \frac{m}{\text{V}}. \tag{3}$$

3.3. Tensile Properties. A tensile strength test was also conducted as part of composite material research. Figure 2 shows the photographic view of tensile testing machine. The tensile test is a critical test for determining the structural strength of composite materials. Hybrid composite materials' improved mechanical capabilities could be attributed to the natural fiber's higher cellulose content as a whole. In accordance with ASTM D3039 values, the structural characteristics of the test were measured by 120 × 20 × 4 mm for duplicates. In addition, tensile testing can reveal the elongation at break.

3.4. Flexural Properties. Tensile, compressive, and shear material qualities are affected by flexural strength and stiffness. It is necessary to conduct flexure tests on composite materials with whichever a spherical or four-sided cross-section, where the shear stress along the centerline is the failure mechanism. The flexural characteristics of composites have been measured using the ASTM D790 standard three-point bending configuration. A 3 jig with a bend speed of 3 mm/min was used to examine all kind of composite sample with specifications of 120 mm × 20 mm × 3 mm. This equations allows the universal testing machine of 20 kN to calculate the formulas for actual flex strength and modulus.

$$\text{Flexural strength} : \sigma_f = \frac{3P_f L}{2bh^2} \tag{4}$$

$$\text{Flexural modulus} : E_f = \frac{ML^3}{4bh^3} \tag{5}$$

3.5. Low-Velocity Impact Testing. These composite specimens were tested utilizing Izod impact trial equipment under ASTM D256 standard to assess their impact toughness. A total of three composite specimens were made, each measuring 70 × 15 × 3 mm.

4. Observations and Outcomes

4.1. Thickness Swelling (TS) and Water Absorption (WA). Due to exposure of fibers in the materials, there was a significant increase in the composite's overall thickness. As the composite soaks up water, it will expand in size due to the lignocellulosic material's hydrophilic qualities. Because of this, the sample capillary has grown, resulting in a larger sample size. Figure 3 also shows the results of TS vs. absorption duration for DPF, BF, and DPF/bamboo hybrid composite samples. It has also been shown that there are three distinct stages of TS (Figure 3). During the first day of immersion, the thickness swelled dramatically. It takes three days for the second stage of swelling to begin to show signs of thickening. After three days, the swelling has reached a point where it is no longer increasing in thickness.

The bamboo fiber composite (B) specimen's TS behavior increased by 16.92 percent, as seen in Figure 1, and was thus reported as having the highest TS qualities. Hybrid composite (G / B) has a TS score of 13.79 percent, followed by hybrid composite (A/B) at 12.98 percent, hybrid composite (AA/B) at 10.26 percent, date palm fiber composite (AA) at 9.28 percent, date palm fiber (G) at 8.94%, hybrid composite (L/B) at a TS score of 8.49 percent, and date palm fiber (L) at 6.54 percent. Initially, after only one day of soaking, there was a substantial rise in swelling thickness. A progressive thickening occurs over the course of three days during this second phase of swelling. Owing to the less hydrophilic character of the materials, the DPF composite had the lowest TS percentage of 6.52 percent. Because of this, the density of DPF/bamboo hybrid composite panels was absolutely connected with the thickness swell dispersion of the polymer. Water uptake or water absorption is another aspect that affects the stability of composite materials. Voids and fiber loading, matrix viscosity, and atmospheric conditions have all played a role in composite material's water absorption.

WA valuation must be carried out to establish the appropriate developments for composite constituents in terms of analyze and enhance their physical and dimensional behaviors. Water absorption percentage (WA) results are shown in Figure 4, with hybrid composite (G/B) at 12.45 percent, DPF composite (G), hybrid composite (A/B) at 10.73 percent, hybrid composite (AA/B) at 10.17 percent, and hybrid composite (L/B) at 9.78 percent. It was attributed to vacancy contented, fibrous solubility, and the viscous of the polymer matrix that the water absorption rate was higher. WA absorption is also assumed to include the hemicellulose, which is present in the form of small pores and fissures. Palm high hemicellulose content (17.9%) than bamboo (11.2%) and moisture qualities are being improved.

4.2. Density. Natural fiber composite material mechanical performance is mostly determined by density. Natural fiber material's density ranged from 0.5 to 1.5 g/cm^3 to 12.8 g/cm^3 compared to synthetic fiber material's range of 12.8 to 13.6 g/cm^3. According to Figure 5, the density of a single DPF composite material ranged from 1.15 g/cm^3 to 1.25 g/cm^3 for bamboo fiber composite material and from 1.23 to 1.27 g/cm^3 for date palm fiber/bamboo composite material. According to a DPF composite g/cm^3 density, the material is between 1.61 and 1.90. Composite samples examined in this work for their value volume, rigidity, and impacts performance, accordingly.

4.3. Tensile Properties. In the past, tensile toughness of complex materials was used as a measure of their ability to

Figure 2: Photographic view of tensile testing machine.

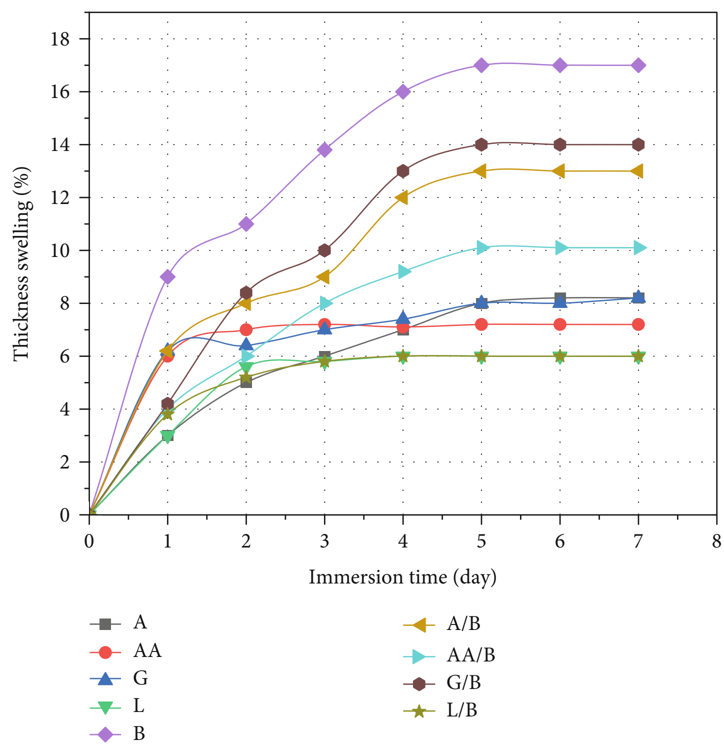

Figure 3: Thickness swelling for DPF and hybrid composites.

withstand longitudinal tensile stress. For the transverse tensile properties of a naturally biocomposite, the adhesive interaction, fiber content ratios, fiber capacity fraction, fiber span, and fiber width of a composite material are critical. Figure 6 shows the ductile features of aliphatic composites strengthened with natural fibers. The tensile properties attributes of DPF extraction and BF are revealed in the results.

Composite specimens made of date palm fiber (DPF) and combination composites were found to have the highest values when it comes to the composite's tensile modulus, as illustrated in Figure 7. Composites using DPF filler and epoxy have a high ductile modulus due of the improved interactions and integrated mixing of the materials. This can be observed in the graph. The high ductile modulus (date palm fiber-*G*: 6.33 GPa, date palm fiber-AA: 5.97 GPa, date palm fiber-*L*: 5.92 GPa, and date palm fiber-*A*: 5.59 GPa) was attributed to the date palm fiber (DPF) specimen.

According to findings, low modulus fibers are more likely to have high elongation values. Polymer composites reinforced with DPF are bonded to each other at the interaction by Saba et al. that revealed a 50% increase in tensile modulus for date palm stem fibers/epoxy evaluated to other

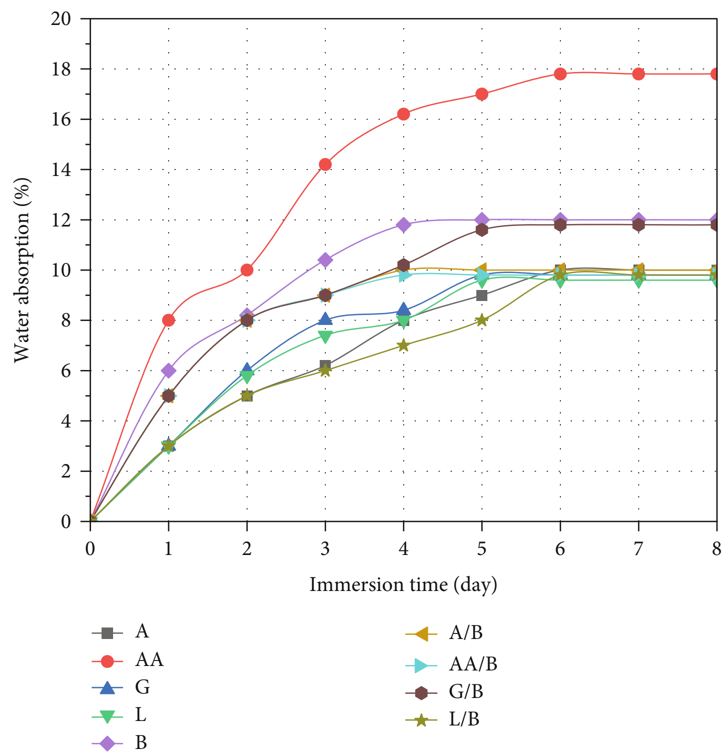

Figure 4: WA for DPF and hybrid composites.

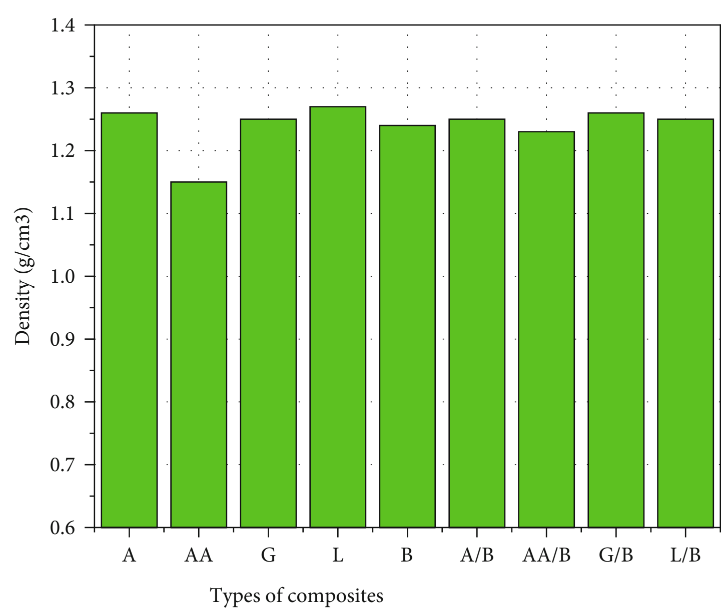

Figure 5: Densities of DPF and hybrid composites.

section of date palm fiber composites. Because of enhanced interactions among the essential resources of natural/natural hybrid composites, as revealed in a study by Ismail and coworkers, tensile characteristics and performance can be improved. To estimate the length at break, it is necessary to conduct testing in tensile mode, which is termed as fracture strain. Figure 8 depicts the natural plant fiber's resistance to length changes in a specific length. The bamboo fiber composite's break elongation (bamboo: 1.02 millimeters), hybrid composite specimens (date palm fiber-*G*/*B*: 0.94 millimeters, date palm fiber-AA/*B*: 0.86 millimeters, date palm fiber-*A*/*B*: 0.77 millimeters, and date palm fiber-*L*/*B*: 0.81 millimeters), and DPF composite specimens were as follows. In the mean time, Figure 6 shows the length at

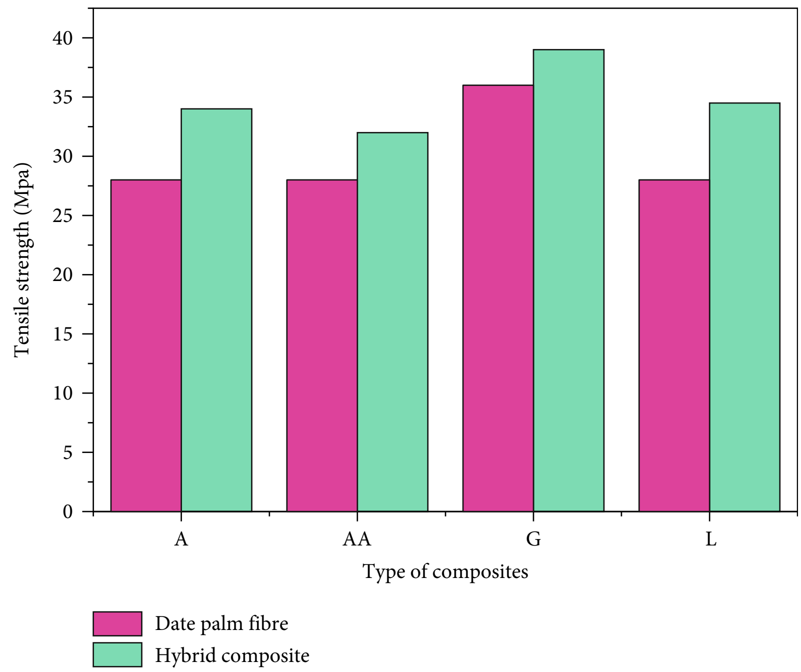

Figure 6: Tensile strength of DPF and hybrid composites.

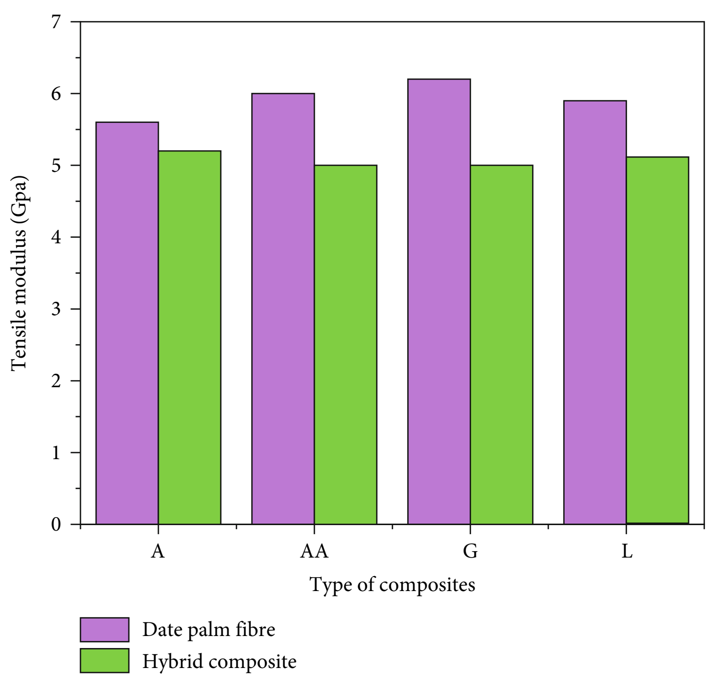

Figure 7: Tensile modulus of DPF with hybrid composites.

discontinuity of BF material (*B*: 1.02 millimeters) and hybrid (date palm fiber-*G*: 0.76 millimeters, date palm fiber-*A*: 0.67 millimeters, date palm fiber AA: 0.64 millimeters, and date palm fiber-*L*: 0.64 millimeters) bamboo filler's extension at intersections in hybridization dates. It is amazing how much palm fiber/bamboo has helped with reinforcement, especially in comparison to higher fiber loadings. To prevent fibers and matrix from slipping, filler particles can be included. This will boost the composite's tensile strength.

It has also been found in a prior study, which found that increased fiber loading at the break point of composite materials can lead to a significantly raised in extension at the point of breakage because of its reinforcing influence on the stress transfer. Modulus of elasticity at the breakage

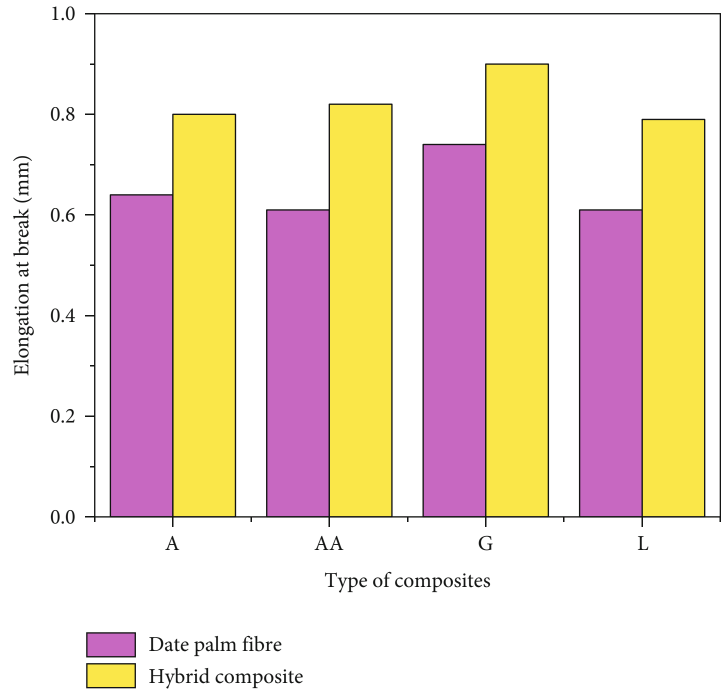

Figure 8: Elongation at break of DPF and hybrid composite fiber.

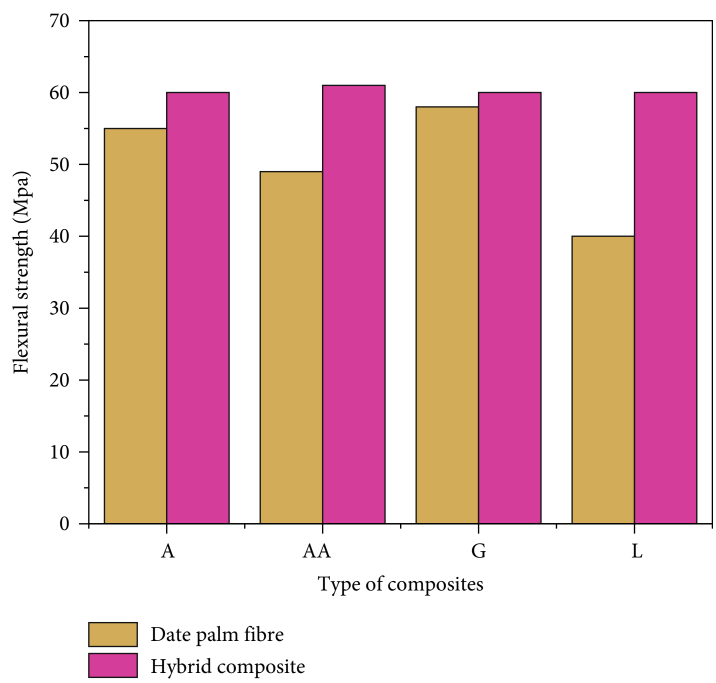

Figure 9: Flexural strength of DPF and hybrid composite fiber.

and tensile is significantly improved in DPF reinforced polymers manufactured from recycled polypropylene, low-density polyethylene (LDPE), and high-density polyethylene (HDPE). The mechanical parameters of tensile roughness, flexural modulus, and percentage of elongation in organic materials can be greatly improved by preparation of wheat straw. In fiber-matrix constituent interfacial bonding, hemicellulose and lignin breakdown straw biomass surface structure plays a vital role along with its porous.

4.4. Flexural Properties. Figures 9 and 10 state the flexural properties of the DPF, BF, and the date palm fiber/bamboo hybridization. As shown in Figure 9, the high flexural strength is achieved by the bamboo composite specimen

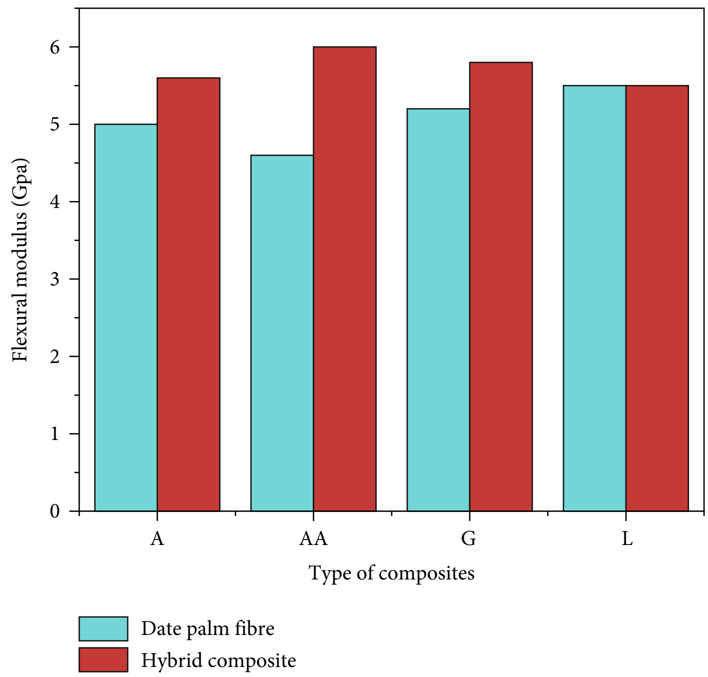

Figure 10: Flexural modulus of DPF and hybrid composite fiber.

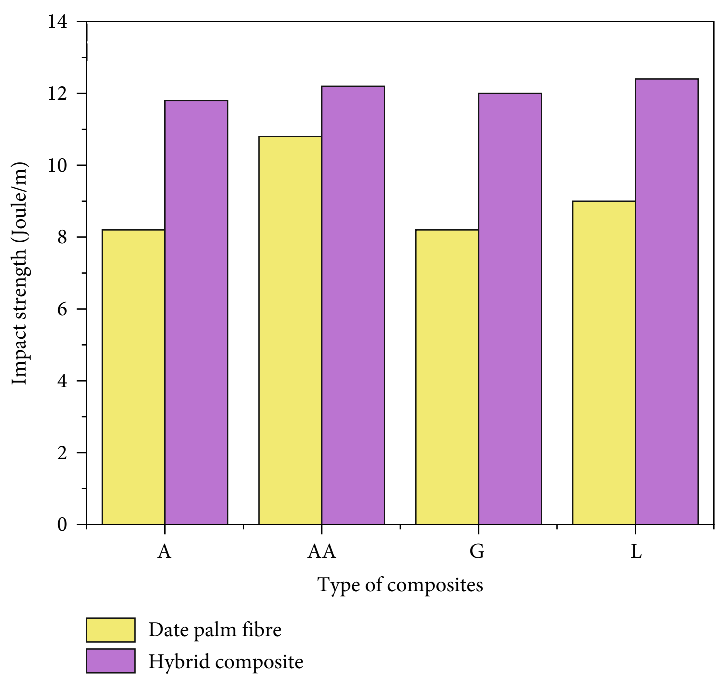

Figure 11: Impact strength of hybrid composites.

(bamboo: 6.18 MPa), followed by (DPF-*A*/*B*: 61.12 MPa, date palm fiber-AA/*B*: 61.08 MPa, date palm fiber-*L*/*B*: 60.82 MPa, and date palm fiber-*G*/*B*: 61.47 MPa) and the DPF composite specimens (date palm fiber-A/B: 61.112). A total of (date palm fiber-*G*: 58.30 MPa, date palm fiber-*A*: 55.25 MPa, date palm fiber-AA: 48.88 MPa, and date palm fiber-*L*: 40.36 MPa).

The flexural strength of the palm/bamboo fiber strengthened-epoxy composites with a 50/50 palm/bamboo fiber-filled composite has been enhanced by hybridization approach. [10] has indicated that the adhesiveness in the hybridizing progression contributes to outstanding flexural properties outcomes in natural fiber hybridization investigations.

Flexural modulus, on the other hand, was a key mechanical property in the investigation of composite stiffness. Figure 10 indicates that the flexural modulus of bamboo composites (*B*: 6.17 GPa), followed by hybrid composites and date palm fiber composite specimens, is higher than that of date palm fibers (date palm fiber-*L*: 5.56 GPa, date palm fiber-*G*: 5.32 GPa, date palm fiber-*A*: 5.07 GPa, and date palm fiber-AA: 4.66 GPa). The ductile modulus of various DP0046 materials has been increased by the use of hybrid composite materials (Figure 9). In comparison hybrid composite, bamboo fiber in the composite ingredient increased flexural strength by 42% and flexural modulus by 33%.

4.5. Impact Strength. The impact test to determine the specimens ability to grip and disperse energy from stimulus and load-bearing force was alternate performance in material attributes valuation. Due to the limited mechanical and physical qualities of natural fibers alone, the resin system was needed to withstand both internal and external forces. Bamboo fiber (BF) composite specimen (bamboo: 13.89 Joule/meter) dominated the impact strength variation, followed by hybrid composite samples (date palm fiber-*L*/*B*: 12.72 Joule/meter, date palm fiber-AA/*B*: 12.35 Joule/meter, DPF-*G*/*B*: 12.11 Joule/meter, and date palm fiber-*A*/*B*: 11.58 Joule/meter) and date-palm fiber composite specimens (date palm fiber-AA: 10.71 Joule/meter, date palm fiber-*L*: 9.19 Joule/meter, date palm fiber-*A*: 8.62 Joule/meter, and date palm fiber-*G*: 8.58 Joule/meter) in Figure 11. In comparison to DPF composites alone, the hybridized materials (date palm fiber/bamboo fiber) with a 50 : 50 ratio have a higher impact strength, as shown in Figure 11. For the hybrid composite ingredient used in this work, the use of BF as a filler contributed to an increase in fiber density, which resulted in superior tensile characteristics.

5. Conclusions

(i) Date palm fibers were employed as reinforcements to investigate the potential of organic waste impurities. Incorporating stronger bamboo fibers into hybrid composite materials has increased their unique features

(ii) Using date palm fiber in combination with other high-quality fiber pitches can yield fewer weight materials for several applications while reducing waste and deposition of agricultural wastes

(iii) Date palm/bamboo hybrid composites have variable mechanical capabilities depending on the chemical constituents of date palm fiber and bamboo fiber

(iv) The splintered surface structure of the hybridized materials demonstrated that bamboo fiber and date palm fiber were well hybridized, with less space among the mixed fiber and composites

(v) The impact resistance of bamboo fiber hybridized with date palm fiber such as *L* is good. Still, the tensile and flexural capabilities of other DPF hybrids such as *A* and *G* are superior

(vi) Studies conclude that date palm/bamboo hybridized composites were discovered to have more excellent properties than a date palm fiber composite that was not hybridized

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 is no conflict of interest regarding the publication of this article.

Acknowledgments

The authors appreciate the supports from Arba Minch University, Ethiopia, for providing help during the research and preparation of the manuscript. The authors thank to Prince Sattam bin Abdulaziz University, Saudi Arabia and G. Pulla Reddy Engineering College, Andhra Pradesh, SIMATS, Chennai, for providing technical assistance to complete this work.

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