Hindawi
Advances in Polymer Technology
Volume 2022, Article ID 4386650, 8 pages
https://doi.org/10.1155/2022/4386650

Research Article

Mechanical Behaviour and Thermal Properties of Pine Apple Leaf Fiber Reinforced Vinyl Ester Composites

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Received 6 January 2022; Accepted 23 March 2022; Published 19 April 2022

Academic Editor: M. Ravichandran

Despite its mechanical and environmental properties, pineapple leaf fibers (PALF) are used as a home threading material in India. In addition, the effects of abrasive combing and pretreatment techniques on fiber and composite characteristics were examined in this work. Using PALF vascular bundles separated from different regions of the leaves did not affect the mechanical aspects of pineapple leaf fiber-vinyl ester composites. PALF fibers performed equally in strengthening composite flexural properties under static loading, regardless of diameter or location, with a much lower weight percentage and combined pressure. Tests at higher speeds revealed that the PALF-vinyl ester composite was more robust with more delicate bundles. Reinforcing composites that do not require a high degree of hardness can benefit from the cleaner, more delicate bundles produced by abrasive combing.

1. Introduction

For a long time in India, pineapple leaf fibers (PALF) were employed as a home threading material. Agricultural trash as opposed to the PALF used in neighbouring nations to manufacture a variety of products, including garments [1, 2]. In pineapple plantations, leaves are burned or composted, generating smoke and other environmental pollution. PALF are the least investigated natural fibers, despite their environmental friendliness and mechanical superiority, especially when used as reinforcement in polymer composites [3, 4]. Instead of using PALF in textile applications requiring complex processing, polymer composites with PALF reinforcement could still be investigated [3]. Vinyl ester resins are employed in high-performance applications such as corrosion resistant industrial tanks and automotive and marine vehicle components. Pineapple leaf fiber reinforced vinyl ester composites manufactured by fluid compression moulding were found to take good mechanical and other qualities if optimised in a preliminary investigation. As far as we can tell, no other studies have attempted to differentiate and characterise the two forms of pineapple leaf fibers observed in leaf of pineapple, as described by [5]. There were no investigations done on corresponding performance in polymer composites as reinforcement. In spite the occurrence of predominantly vascular bundles, which the researchers calculated to constitute around 75 percent of fiber content in pineapple leaves, previous investigations generally used fine PALF bundles [6, 7]. Most researchers employed PALF with sizes smaller than 100 nm, either stated or inferred from their published work. But the only ones to characterise PALF that had a diameter of 45-205 m without first separating it into fibrous bundles and vascular bundles employed those that were 50-150 m in diameter [7–11].

Even within the same plant, the size and qualities of natural fibers such as PALF might differ. Qualify whether PALF can be used at random or exclusively from a certain area of the leaves in order to reduce unpredictability [8, 9]. Toxic build up can occur if PALF is stored in a humid Indian climate, where the fibers are more vulnerable to rotting. Because of this, it is beneficial to assess if the PALF reinforcing efficiency decreases over time [10]. The plant leaves are detached from the trunk once the pineapple fruit is harvested. The fibers are then physically scraped away from the leaves; retting or mechanical methods can be used to separate these fibers from the leaves. The cellulose strand bundle is then cleaned and allowed to dry. Physical, mechanical, or chemical extraction of natural fibers like PALF can have a significant impact on fiber costs, yield, and final fiber quality. Due to the inherent inefficiency of automation, PALF are still being manually segregated [11]. Tensile strength of the elementary fibers is only marginally higher than that of the technical fibers due to mechanical processes such as breaking, scotching, and hackling. Abrasive combining of pineapple leaf fiber vascular bundles was attempted by [12, 13] due to the difficulty in obtaining fiber defibrillation. In tests on single fiber tensile integrity, this simple approach generated bundles with a 50.3 percent reduced mean diameter ($p = 0.01$) than expected with little impact on fiber integrity. For the purpose of this work, the properties of vinyl ester composites reinforced with abrasive-combed pineapple leaf fibers were examined and contrasted against properties of vinyl ester components reinforced with rough bundles and fine fiber strands [14]. The mechanical characteristics, hydrophillicity, and fiber-matrix adhesion of natural fibers have all been improved by the use of various treatments and modifications, including PALF. All of the treatments examined by [15] employed a 0.5 percent solution of sodium hypochlorite (NaOCl) for 60 minutes of water bleaching. To get a desirable natural fiber fabric with little strength loss, a simple treatment using NaOH and sodium hydroxide was employed. If the pretreatment has any influence on PALF or PALF/vinyl ester composites, it must be studied [16]. Tests on untreated, pretreated, and abrasive-combed pineapple leaf fibers were conducted in this research. Study of the flexural and impact properties of this vinyl ester composite was carried out [17]. We learned more about PALF and how they could be employed as reinforcement in vinyl ester composites as a consequence of our research.

2. Experimental Procedure

2.1. Materials. Pineapple leaf fiber is a stiff, light-weight material that is used for formal wear, as well as a heavier-duty material that is utilised as a leather substitute in fashion and footwear. PALF also has the advantages of being low density, low cost, biodegradable, and renewable. Pineapple leaf fiber vascular bundles and fibers of six months of age were used in this study. In order to simulate the combing and separation process, huge vascular bundles were pulled

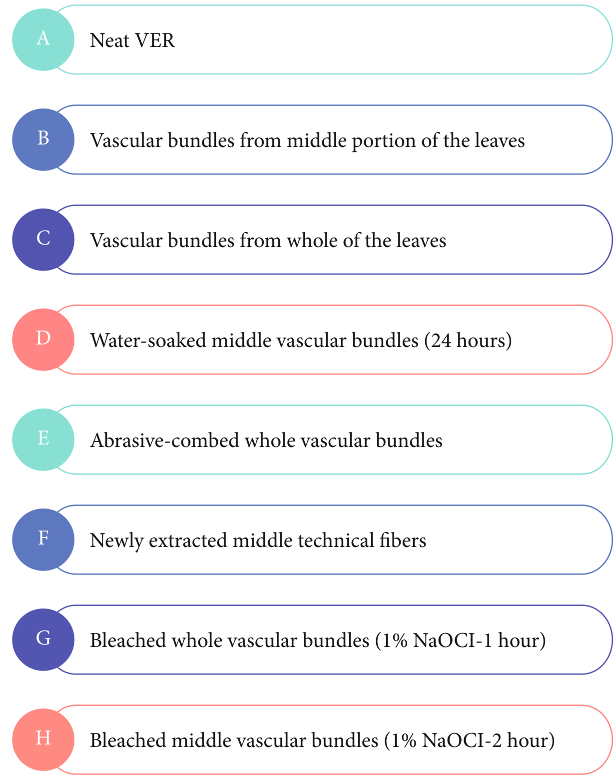

Figure 1: Pineapple leaf fiber sample designations and descriptions.

between #100 sandpapers, resulting in abrasive-combed PALF. The most common usage of NaOCl, generally known as bleach, is as a disinfectant. It is a broad-spectrum disinfectant that may also be used to disinfect substances. NaOCl aqueous solution was utilised for 1, 2, and 4 hours to clean the fibers. One group of fiber specimens was soaked in water for 24 hours. For a few rinses, we used tap water and then distilled water to clean the fiber samples. When vascular bundles were combed, leaf tissue was taken for thermogravimetric examination. The majority of the PALF names and descriptions may be found in Figure 1.

2.2. Specimen Preparation. To make the mould, three pieces of aluminium were used to create a hollow, and the pineapple leaf fiber bundles were sliced into 127 mm lengths. PALF was utilised in all samples at a concentration of 20 wt percent because higher concentrations would necessitate the use of pressure and a distinct mould. Newly extracted pineapple leaf fiber fine fiber strands were employed to reinforce composites in one set of specimens. The cover was lightly pressed to ensure that the sample dimensions remained constant. A minimum of 72 hours was required for all samples to cure at room temperature. For comparison, vinyl ester resin specimens were also made.

2.3. Thermo Gravimetric (TG) Analysis. Thermo gravimetric analyzer tracks changes in mass and weight as a function of temperature and time. These measures can reveal a lot about

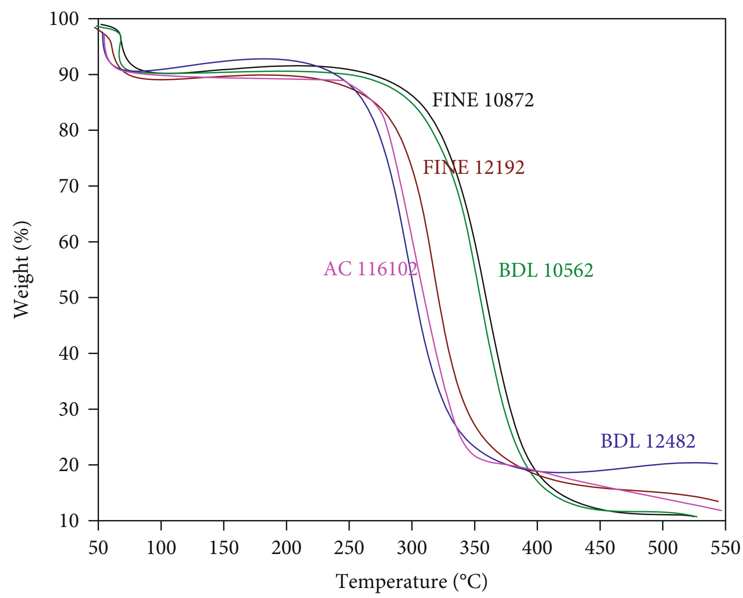

Figure 2: A comparison of nontreated and bleached PALF using thermal gradient analysis (TGA).

a material's thermal stability, oxidation resistance, composition, breakdown kinetics, and moisture content. A Perkin Elmer Diamond TG/DTA analyzer was used to measure the thermophysical characteristics of several fiber samples. Specimens were heated at a rate of 10°C/min in a nitrogen flow of 80 ml/min and scanned from 30 to 580°C.

2.4. Tests on Bending and Impact. Flexural testing establishes a material's resistance to flexing by measuring the force necessary to bend a beam of plastic material. Impact test determines engineering materials' toughness, strength, and notch sensitivity. The composite sheet flexural properties were examined with 5 kN load cell with sample measuring 63 mm in length, 12.8 mm in width, and 3 mm in thickness, using ASTM D790 standard. A crosshead speed of 2 mm/min and a span to thickness ratio of 16 were used. In order to conduct unnotched Charpy impact tests on 64 mm long, 13.2 mm wide, and 3 mm thick specimens, the impact tester and the ASTM D256 were employed. There were five specimens tested in each of the following assays; mean and standard deviation were given.

3. Results and Discussion

The thermal stabilities of untreated PALF vascular bundles and fine fiber strands were the same, indicating their similarity. After pretreating pineapple leaf fiber with aqueous sodium hypochlorite solution, pineapple leaf fiber thermal stability was reduced due to fiber degradation, as seen by decreased crystallinity indexes. Between 100 and 200°C, the PALF loses more weight due to the higher moisture absorption that occurs as a result of bleaching. When the curves were shifted by the average values of weight loss in the 100 to 200°Celsius range, there were no variations in weight loss between 100 and 200°Celsius, and it is shown in Figure 2. There was an increase in the amount of char products because the PALF was pretreated with NaOCl solution. Although NaOCl was formerly assumed to delignify PALF fibers, this was not the case.

Table 1: Crystallinity indexes of various PALF.

Types of pineapple leaf fiber	Crystallinity index
Soaked for 24 hours in water-	74.26
Abrasive-combed	73.12
Fine fiber strands	74.42
1% sodium hypochlorite (2 hours)	73.14
1% sodium hypochlorite (4 hours)	71.28

There are less epidermal tissues in fine and abrasive-comb PALF as a result of this contrast, and this is evident in products of former cases. Abrasive combing assisted in the separation of pineapple leaf fiber bundles and eliminated further epidermal tissues in the fiber surface. [18] found no difference in the crystallinity index between jute that had not been treated and jute that had been treated for 24 hours with up to 0.08 percent NaOH. Only bleached PALF showed a decrease in crystallinity during the pretreatment period. Various crystallinity indexes of various PALF are shown in Table 1. Due to increased fiber crystallinity, natural fiber tensile modulus and strength have decreased over the past few decades; this can be explained by this trend.

$$I_{XRD} = \frac{I_{200} - I_{am}}{I_{200}} \times 100. \quad (1)$$

Vinyl ester flexural strength of 20% untreated PALF substantially enhanced contrasted to Korte who observed a significant loss with comparable weight fractions of preserved fibers in epoxy. Based on the mechanical properties of

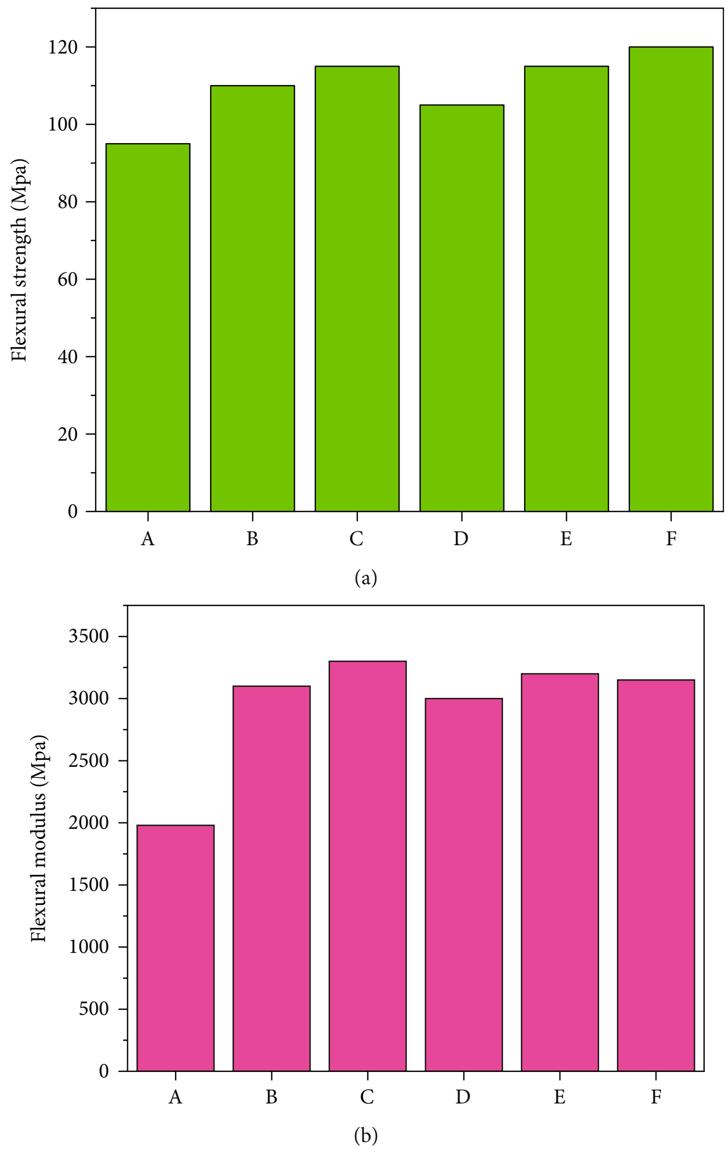

Figure 3: (a) Flexural strength and (b) modulus of neat vinyl ester reinforcement and pineapple leaf fibers reinforced vinyl ester composites.

composites, fiber reinforcing capacity in composites was equivalent to that seen in published data at the same fiber fractions. Due to incorrect fiber matrix bonding, the PALF fiber strength and modulus were larger or close to those published in the literature, despite lower mean values compared to those produced in single fiber testing, and it is shown in Figures 3(a) and 3(b).

The composite's bending stiffness was greatly improved ($p = 0.01$) after the addition of PALF. Stubbornness was unaffected by the addition of PALF sourced from various parts of the leaves, as was strength. Fiber diameter did not appear to affect the stiffness of composites in a significant way. When [19] employed PALF that were much finer, the bending was remarkably similar. Low fiber weight and high consolidation pressure proved to be ideal conditions for PALF vascular bundle and fine fiber strand reinforcement in vinyl ester composites. In pineapple leaf fiber vinyl ester composites, untreated pineapple leaf fiber from varied leaf positions had no significant effect on the flexural properties.

Figure 4 shows that soaking pineapple leaf fibers in water for 24 hours had no effect on the composite's flexural strength or modulus (a, b). In order to save time and money, the emphasis should be on thoroughly washing away soil and grime using plenty of water, rather than soaking for long periods. The loss in fiber strength and ductility caused by treating PALF in aqueous NaOCl solution lowered the composite's strength. At high quantities or over a lengthy period of time, sodium hypochlorite bleach has been known to produce chain and the subsequent deterioration of textiles. When PALF is bleached, it loses its ability to bend; hence, the stiffness of the composite increases significantly (H).

The idea of "normalised fiber strength" is discovered to the decisive element in composite flexural strength for fibers with same sizes, such as vascular bundles, and its effect is

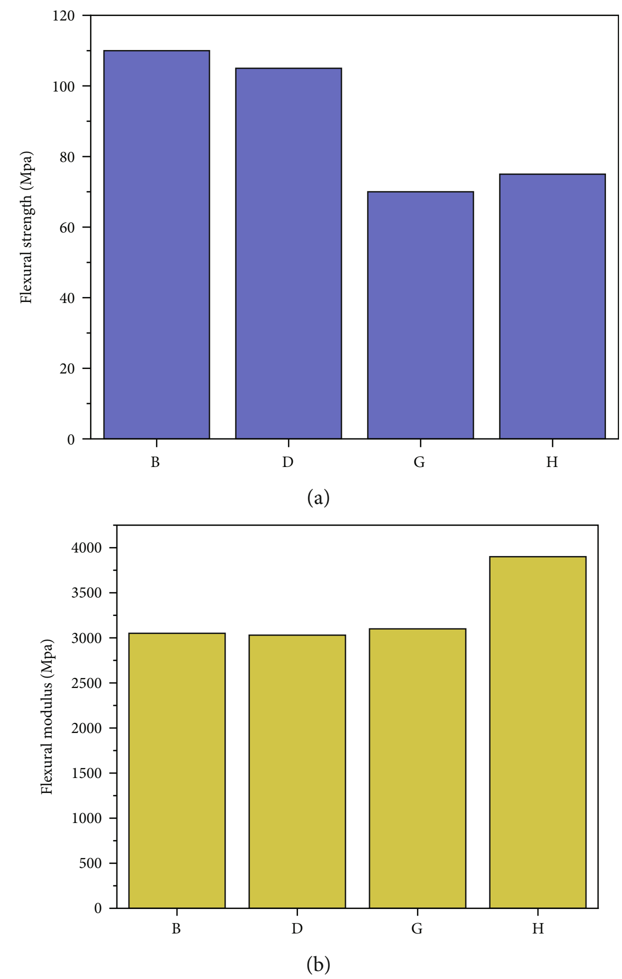

Figure 4: (a) Flexural strength and (b) modulus of neat vinyl ester reinforcement and pineapple leaf fiber-vinyl ester reinforcement composites.

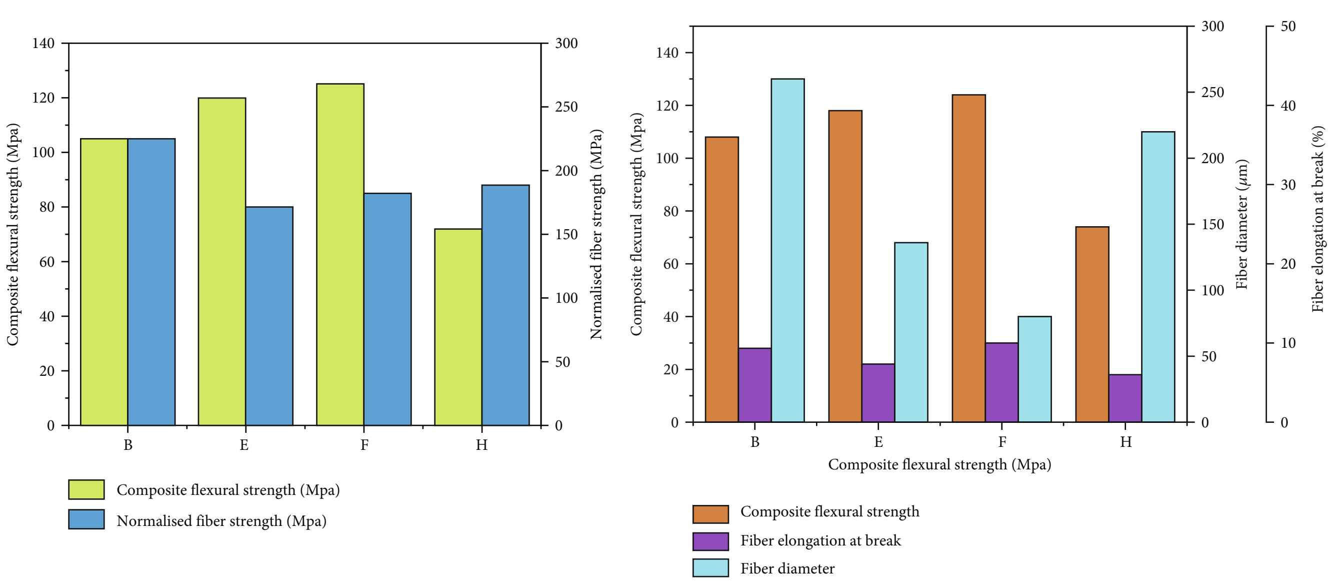

Figure 5: The effect of normalised fiber strength, fiber elongation at break, and fiber diameter on composite flexural strength.

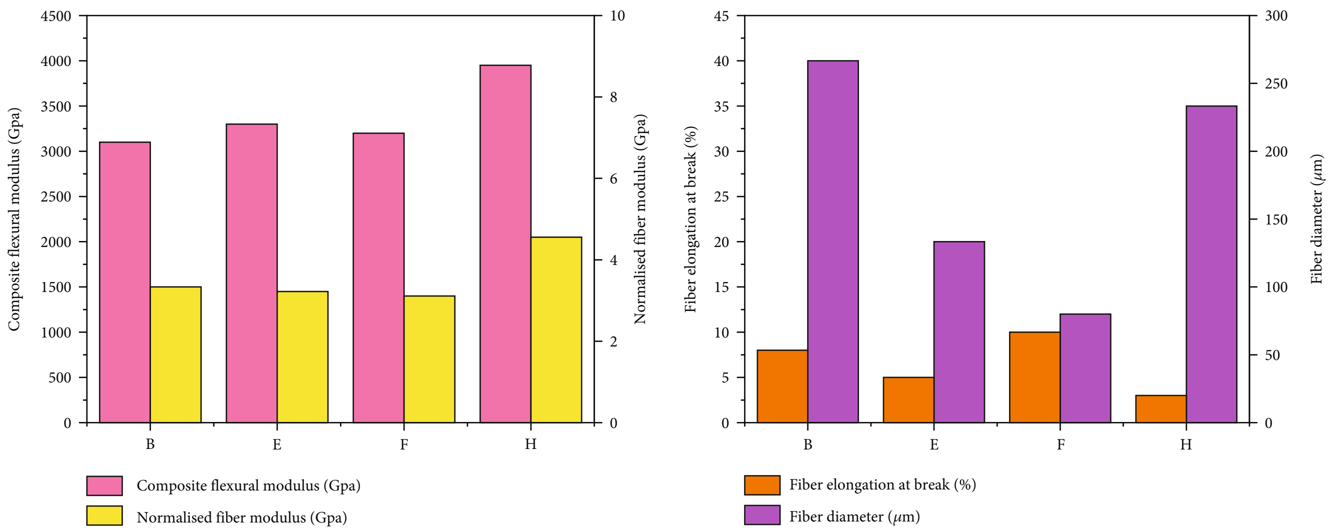

FIGURE 6: The impact on the composite flexural modulus, normalised fiber modulus, fiber elongation at break, and fiber diameter.

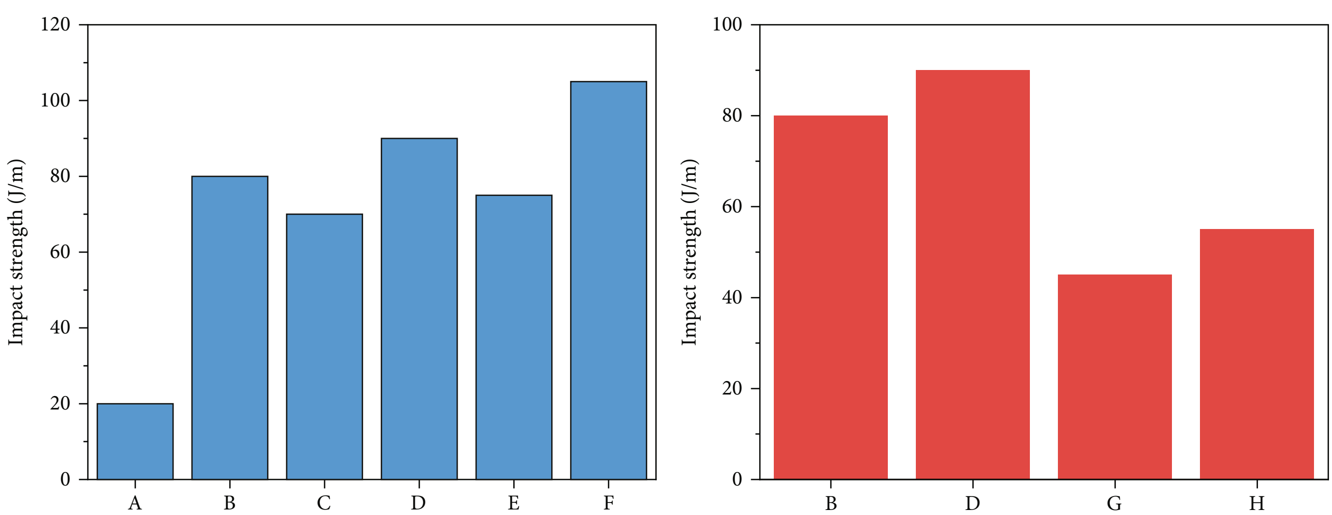

FIGURE 7: Impact strengths of VER composites with untreated pineapple leaf fibers and VER composites with treated pineapple leaf fibers.

shown in Figure 5. For flexural strength, finer fibers resulted in developed fiber-matrix interfacial shear stress and hence a higher level of interfacial shear stress. Composite flexural modulus has the same problem, and it is shown in Figure 6. With a mean value nearly equivalent to 35% washed pineapple leaf fibers reinforced composites adding 20 weight percent of untreated pineapple leaf fibers to vinyl ester boosted impact strength by 4 times, and it is shown in Figure 7.

Pineapple leaf fibers can be blended and used at random, as demonstrated by using vascular bundles from various regions of a leaf, which did not pointedly influence the impact strength of composites. We found pineapple leaf fiber strands directed to improved composite durability than vascular bundles (V), which means that PALF fiber diameter plays a significant role in decisive the impact strength of pineapple leaf fibers reinforced vinyl ester composites at less fiber weight portion overlarge number of fiber-matrix interactions, as demonstrated by the results of this study, and it is shown in Figure 8. Increasing the number of fiber matrix interfaces is expected to improve performance, as will increasing fiber weight fractions and consolidating pressures.

There were no apparent negative effects on the flexural properties of vinyl ester-reinforced pineapple leaf fiber composites (E) when fine fibers (F) were used in place of the fine abrasion-combed PALF bundles (E), although their use reduced the composite toughness. Because abrasive combing introduces flaws on the fibers, this behaviour could be explained by faults that is not detected through low speed fiber and composite flexural tests, which are common in the industry. According to the findings of this study, testing at higher speeds can detect poor fiber integrity, so it is necessary to compare the mechanical properties of fibers at both

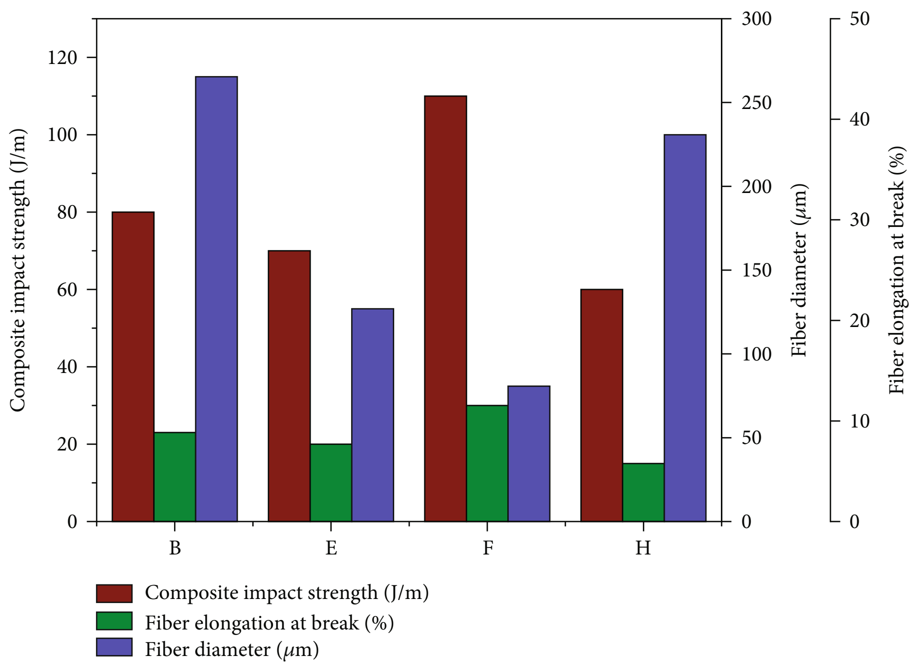

Figure 8: Fiber elongation at break and fiber diameter have an impact on composite impact strength.

low and high speeds. Higher fiber fraction and higher consolidating pressure should alleviate or even eliminate this flaw.

The extremely brittle fibers in bleached PALF (*H*) reinforced composites greatly lowered their toughness. A longer pretreatment duration did not diminish the toughness any more, which may be due to the lacking of additional degradation in pineapple leaf fibers. The PALF strength-treatment data and the substantial drop in PALF elongation at breaks can be seen as a result of this phenomena. The impact of abrasive combing on pineapple leaf fiber performance in pineapple leaf fiber vinyl ester composites requires additional research. This basic extraction process, however, appears to create finer PALF bundles of acceptable quality, as shown by the aforementioned data.

4. Conclusion

According to the findings of this investigation,

(i) PALF's reinforcing potential has not been compromised by prolonged storage in hot, humid environments. Some epidermal tissues on the fibers and PALF's position in the leaves did not affect the composite's flexural and impact capabilities

(ii) To improve the mechanical and thermal properties of PALF and promote the adherence of PALF to vinyl ester, extended soaking and pretreatment with diluted household NaOCl solution are ineffective

(iii) The flexural characteristics of pineapple leaf fiber reinforced vinyl ester composites can be improved by increasing the PALF volume fraction, although fiber width has minimal influence

(iv) The diameter of the PALF has a significant impact on the toughness of a pineapple leaf fiber reinforced vinyl ester composite. Cleaner and more delicate bundles are produced by abrasive combing in PALF extraction, suitable for supporting composites that do not require a lot of toughness

(v) Another finding of this research was the potential of PALF reinforced vinyl ester composites for producing interior car and home application quality products

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.

Acknowledgments

The authors appreciate the supports from Arba Minch University, Ethiopia. The authors thank Prince Sattam bin Abdulaziz University, Sri Sairam Engineering College, M. Kumarasamy College of Engineering,Lakireddy Bali Reddy College of Engineering for providing assistance to

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