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# Effect of Hybridization on Physical and Mechanical Properties of Kevlar-BorassusFlabellifer Leaf Fiber Reinforced Epoxy Composites

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**Abstract**

In this work, hybrid composites were produced from Borassus flabellifer leaf (BFLF) and Kevlar fibers in Epoxy matrix to establish their effect on physical and mechanical properties of the composites. Hand lay-up technique followed by compression was used to produce hybrid composites samples of different combinations of BLFL and Kevlar fiber. The mechanical and physical analyses were done using associated ASTM standards. The Results revealed that 2K10B had the lowest density of 1.023g/cm$^3$, about 22.91% lower compared to neat sample. The 6K6B sample had the preeminent properties; 53.14, 50.5, 14.8 and 48.54% water absorption, TS, flexural and impact strength respectively higher as compared with samples of 100% K while 11.1% and 44.27% less for elongation and elastic modulus respectively.

***Keywords:*** BorassusFlabellifer Leaf Fiber (BFLF); Tensile Strength (TS); Water Absorption; Impact Strength; Flexural; Hybridization

## Introduction

Hybrid composite are defined as a system where one type of reinforcing or filler material is incorporated in a mixture of different matrices, or two or more reinforcing or filling materials are present in a single matrix or both combined (Saba et al, 2014). The use of a synthetic fiber along with natural fiber for hybridization is said to enhance the properties of a composite materials. In a research publication by Patel et al (2018), eminent that the hybridization of fibers toughens the composite as it is combined with two or more different types of fiber thereby improving the mechanical properties when compare with non-hybrids composites. Hybridization of composite are fully utilized with the aim of reducing the use of synthetic fibers which are generally not environmental friendly and highly cost intensive in processing (Nunna et al., 2012).

*Borassus flabellifer* belongs to this family of palmyra palm trees which are grown most in tropical regions of Asian Countries, New Guinea and also in some parts of Africa. the plant has various application and economic values owing to its usage as a string wiry fibres, water tight buckets, hats. Also, Tough fibres from some part of the tree tub have found application in production of tooth picks, brooms, brushes and so many others (Reddy et al., 2015). Leaves from the plant are used as supporting beams, roof covering, carpets in construction sector and in textile industries for ropes productions (Sigh et al., 2021). Due to some of these applications, a number of research studies have been carried out to investigate the physical, mechanical and thermal stability properties of *Borassus flabellifer* fibers as reinforcement in composite materials, they have defined as a good reinforcement material for use even in thermoplastic (Reddy et al., 2009).

The potential application of these hybrid composite has been limited in industrial sector, hence more studies focuses on aspect of improving the physical-mechanical properties and impact resistance of the composites. Blending of Bamboo and Glass fibers (Samal et al, 2009) confirm an increased influence of hybridization and efficient fiber matrix interfacial adhesion when investigating the crystallization, melting behavior and thermal stability of the hybrid composites. Kenaf and Pineapple leaf fiber offered a very good potential for effective hybridization reinforced with high-density polyethylene to produce hybrid composite. Researchers have also studied the physical, mechanical and water absorption behavior of coir/glass fiber reinforced hybrid composites using epoxy as the polymer matrix; experimental results reveals that the composite with 10 wt% fiber loading at 15 mm length have the maximum tensile strength property and flexural strength (Vineet et al. 2014). In another research work, effect of fiber type, weight percentage loading and fiber size was investigated on the impact strength and hardness of wood and rice husk hybrid composite, in this work; results obtained from the characterization of these composites shows that the impact strength of hybrid composite of wood/rice husk fiber increased with increase in fiber loading (Kumar et al, 2017). Also, Hybridized composites material have been proven to have high tensile strength and impact resistance properties (Yahaya et al., 2016). The result of their study shows that woven kenaf as a natural fiber in the matrix of the composite tends to improve the tensile strength as well as the impact resistance property of the composite.

Despite all these works on hybridization of a synthetic to natural fiber, hybridization of BFLF-Kevlar is sparsely reported. Therefore, this work aimed at producing a hybrid composite reinforce with both Kevlar-BFL fibers and characterizing its physical and mechanical property.

## Experimental

### *Materials*

The materials used in this work include (1) sodium hydroxide pellets manufactured by Central Drug House (P), New Delhi, India. (2) *Borassus flabellifer* leaf sourced from Basawa in Zaria, Kaduna State, Nigeria. (3) Plain weaved Kevlar-29, 250gsm sourced from Wuxi GDE technology Co., Ltd China. (4) Epoxy resin/hardner (EPOCHEM 105) manufactured by EpoChem Chemicals in Nigeria. (5) Petroleum jelly manufactured by Apar Industries Ltd.

### *Extraction and Treatment of BFLF*

Fibers were extracted from the *Borassus flabellifer* leaf (BFL) using water retting method. 200 g of the BFL were soaked in 20 liters of water for 24 hr after which fibers were gently combed out of the stalk manually and were left to dry for 48 hr under room temperature and was later weaved as shown in plate I-a. In order to reduce the lignin content and increase surface roughness/porosity (adopted from Reddy et al., 2012), the extracted fiber was treated using alkaline method. 2 g of the fiber was soaked in 100 ml of 2 wt% NaOH solution for 4 hr, after which the fibers were filtered out of the solution and washed to neutrality, then weaved as shown in plate I-b.

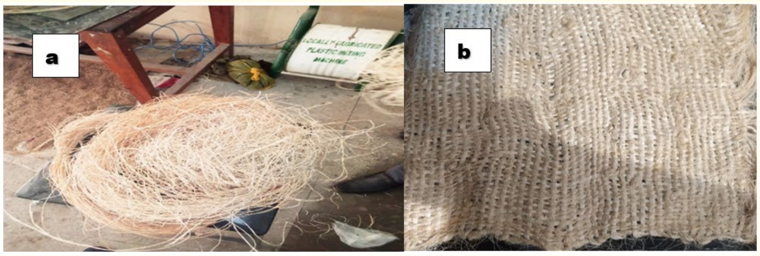


***Plate I:*** Pack of extracted BFL fiber (a) and Plain weaved BFL fiber (b).

### *Preparation of Matrix*

Epoxy having excellent chemical, heat resistance and strong adhesion properties (Sukanya et al., 2015) was used as the matrix for the composite production. Ratio of 2:1 was used for the mixture of Epoxy resin and Epoxy hardener adopted from (Ayo, 2018) and the solution was prepared stirred thoroughly under laboratory conditions for 2 minutes to form a homogeneous solution.

### *Mold Preparation*

A squared mold measuring 150 mm x 150 mm x 10 mm by dimension was fabricated using iron steel sheet. The molds were wrapped with foil paper to cover the inner parts of the mold and was coated by petroleum jelly to ensure smooth surface and also to ease the removal of the composite after production.

### *Production of Sample Composite*

Sample composites were produced using the hand lay-up method at room temperature with epoxy matrix as shown in Table 1.0.

| *S/N* | *Composite* | *Fiber Ratio* |
|---|---|---|
| 1 | Neat | N |
| 2 | 12 K/0 B | 100 % K |
| 3 | 6 K/6 B | 50%K50%B |
| 4 | 4 K/8B | 33%K67%B |
| 5 | 2 K/10B | 17%K83%B |
| 6 | 0K/12B | 100 % B |

***Table 1.0:*** Sample Composite Coding.

Where; N, K, B represent pure epoxy sample, Kevlar and BFLF respectively.

The coated mold of 150mm x 150mm x 10mm was used all through for the production of sample composites, reinforced fibers where compounded in the prepared matrix solution and were cured using hydraulic press at a temperature of $50^{o}C$ for 30 minutes at a pressure of 2.5 Psi. Neat, 12 layered Kevlar, and BFLF reinforced samples were produced using the matrix solution prepared in section 2.3, they serve as a control to observe the changes in properties of other samples. Hybrid composite samples 6K6B, 4K8B, and 2K10B were then produced by reinforcing Kevlar-29 with BFLF using the same prepared epoxy matrix solution.

### *Characterization of Sample Composite*

The produced composite samples were characterized for its physical, mechanical and thermal property all in accordance to ASTM.

***Physical property evaluation***

In order to determine the weight of the produce sample composites and their ability to absorb water, density and percentage water absorption were used to evaluate the physical properties of the sample composites. The basic method of determining the density of composite will be by measuring the mass and the volume of the sample and estimating the density based on Archimedes' principle (Marian, 2007). The composite samples were weighed using a digital weighing balance and then suspended in water in a calibrated measuring cylinder. The volume of the samples was determined by the displacement method. The densities of samples were then calculated using the expression in equation (2.1).

$$Density = \frac{Mass}{Volume} \qquad (2.1)$$

Samples were sectioned to a particular shape 6x1.2x5 $mm^3$, oven dried at 60°C for 4 hours and allow to cooled to remove moisture content and then weighed and recorded as initial weight (wi). The dried sample were then immersed in 250 ml distilled water for 24 hours, cleaned and dried by wiping with a clean cloth, and weighed to give final weight (wf), the process was carried out as recommended by ASTM D570-98 for water absorption of composites. The percentage moisture content was evaluated using the equation (2.2).

$$\%\ \text{moisture content} = \frac{Wf - Wi}{Wi} \times 100 \qquad (2.2)$$

***Mechanical property evaluation***

Mechanical properties such as tensile, flexural, and impact behavior of Kevlar reinforced composite and hybrid composite samples were evaluated. The average values, standard deviation and standard error were calculated so as to evaluate the accuracy of the result.

The strength of a composite material is generally determined using tensile test (Gautan et al., 2017). Three (3) specimens were cut into dog bone shape of 100 mm x 15 mm x 6 mm dimension according to ASTM D-3039 standard and a computerized universal testing machine model no.19536 presented in Plate II, having maximum capacity of 100kN was used to conduct the tensile analysis. The tensile properties such as Tensile Strength (TS), Elastic Modulus (MoE) and Percentage Elongation were automatically calculated by the machine.

***Plate II:*** Test Sample undergoing Tensile property test.

The impact strength of a composite material is the ability of that material to be able to withstand energy under plastic deformation (Gautan et al., 2017). An impact test was carried out on all the samples in accordance to ASTM D256-78 for charpy impact test, using Charpy Impact Testing Machine, Cat.Nr.412, Capacity 15 J & 25 J as presented in Plate III. The composite samples were cut to a rectangular shape of 100 mm x 13 mm x 8 mm and subjected to maximum impact energy of 25 J of the testing machine and impact strength was calculated using equation 3.5 (Azrin et al., 2011).

$$Impact\ Strength = \frac{Absorbed\ Energy\ Value(J)}{Cross\ Sectional\ Area\ (mm^2)} \qquad (2.3)$$

***Plate III:*** Impact Strength Testing on Sample Composite(s).

In order to determine the bending ability of the sample materials, flexural test is performed on the sample composites. Three-point bend test (Plate IV) which is the most common type used (Gautan et al., 2017) was performed on each of the samples using the Universal Testing Machine, model no. CatNr. 261 in accordance with ASTM D-790. Three (3) specimens were cut to a dimension of 100 mm x 30 mm x 5 mm, for each sample composite. The specimen was fixed on a two fixed rollers having a gauge length of 80 mm, load was gradually applied to the specimen until rupture, load and deflection were recorded. The results obtained were used to calculate the flexural strength using the equation 2.4 (adopted from Azrin et al., 2011).

$$Flexural\ Strength = \frac{3P_{max}L}{2bh^2}\left(\frac{kN}{mm^2}\right) \qquad (2.4)$$

Where $P_{max}$ is the maximum load (kN), $L$ is length between two supports (mm), $b$ is the sample width (mm) and $h$ is the thickness (mm) of the sample under test.

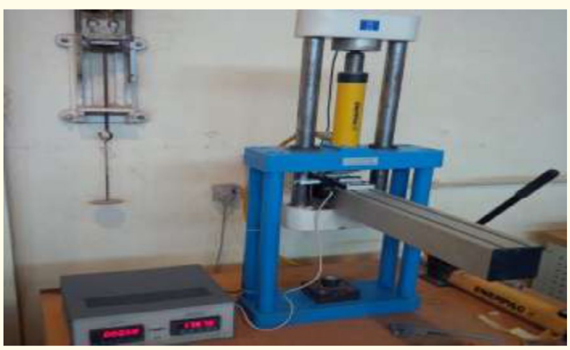

***Plate IV:*** Specimen tested for bending modulus in 3 bending.

## Results and Discussion

### *Hybridization Effect on Physical Properties*

The density of the hybrid composites which was evaluated using Equation 3.3 is presented in Table 3.1. In the table, 2K10B reinforced sample composite had the least density of 1.023 $g/cm^3$, while the sample composite with 100%B had the highest density of 1.297 $g/cm^3$ which is just slightly lower than that of the Neat composite. This trend can be attributed to the bulk weight of both the BFLF and the polymeric matrix. The effect of hybridization is clearly observed as the hybrid composites had densities lower than that of single fiber-reinforced composites. Hence, considering the production of light weight composite material, composite of Kevlar-BFLF reinforced with epoxy matrix having low density could be a good candidate. Same trend was report that a reinforced fiber having lower density are incorporated in a polymer matrix to produce light weight composite having enhanced physical and mechanical properties (Azrin et al., 2011; Bhagat et al., 2014).

| ***Sample(s)*** | ***Density($g/cm^3$)*** | ***Water Absorption (%)*** |
|---|---|---|
| N | 1.327 | 0.17 |
| 100 %K | 1.13 | 0.207 |
| 100 %B | 1.297 | 1.003 |
| 6K6B | 1.147 | 0.47 |
| 4K8B | 1.097 | 0.517 |
| 2K10B | 1.023 | 0.863 |

***Table 3.1:*** Density and Water Absorption of sample composites.

Evaluation of the hybridization effect on the water absorption ability of Kevlar/BFLF reinforced composite is also shown in table 3.1. The ability of a fiber reinforced composite to absorb water is mostly influenced by the nature of the incorporated fiber (Bhagat et al., 2014). Tested composite sample having 6 ply Kevlar-6 ply BFLF denoted has 6K6B had 0.47 average percent water absorption, 53.14% less than 100% BFLF reinforced composite This is due to the fact that Kevlar fiber as low affinity for moisture and the BFLF ability to absorb moisture has been reduced by modifying the chemical and physical structure of the fiber. It is also reported earlier, that hybridization of synthetic-natural fiber reduces moisture absorption of the produced sample composite (Pan and Zhong, 2015).

### *Hybridization Effect on the Mechanical Properties*

The influence of hybridization on the tensile properties which are Tensile strength, Elongation and Elastic Modulus of the composite samples were evaluated, shown in Figure 3.1, 3.2 and 3.3 respectively. However, it is earlier said that the mechanical properties of any composite be determined by the type of fiber, orientation, nature of matrix and the interface (Gautam et al., 2017). Hybrid composite reinforced with 6K6B had a tensile strength of 64.17 MPa, 43.97% lower as compared with the 100%K sample and 72.1% higher as compared with the 100%B reinforced sample composite as shown in Figure 3.1.

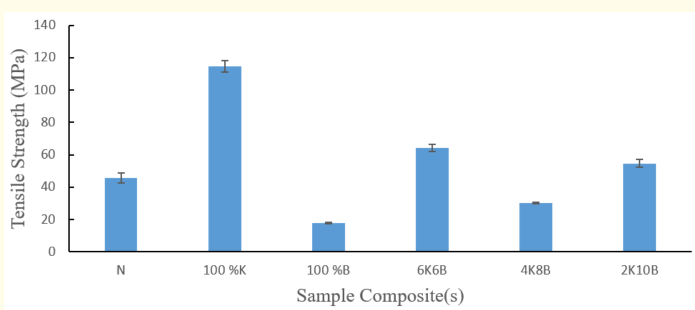


***Figure 3.1:*** Tensile Strength Variation of Hybrid Sample Composite(s).

Figure 3.2 shows the percent elongation of the composite samples. As seen in the figure, 6K6B reinforced composite had intermediary elongation between sample composites of 100%K and 100%B. The figure also indicates that the 6K6B reinforced composite had 31.77% elongation about 11.1% less compare to 100%K and just 6% higher than 100%B sample composite. The positive effect observed on the tensile properties as compared with a single reinforced composite may be attributed to the fact that hybridization improves some mechanical properties of a composite as it combines properties of individual reinforced fiber (Thwea and Liao, 2002).

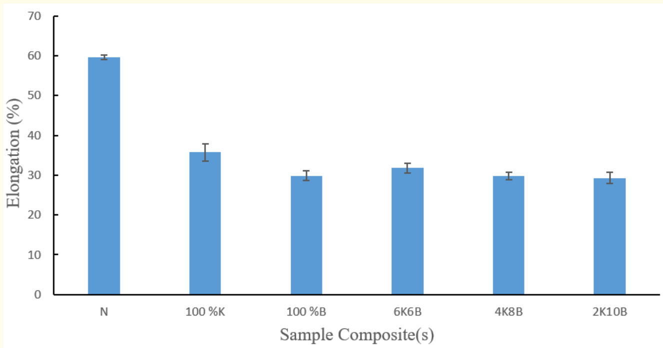


***Figure 3.2:*** Percent Elongation Variation of Hybrid Sample Composite(s).

The Elastic Modulus of the sample composite shown in Figure 3.3 reveals the effect of combining two reinforcement fibers in one matrix. As seen, 6K6B had elastic modulus of 122.84 MPa about 44.27% less compare with 100%K and 51.45% higher than that of 100%B reinforced sample composite, which means that hybridization have a positive significant effect on the elastic behavior of a composite. The improvement in the Elastic modulus of the hybrid composite sample could be related to the ability of the alkaline treatment which improves in the adhesion characteristics of the fiber surface by removing part of the lignin shell and increasing porosity (Paul et al., 2007; Nekkaa et al., 2006).

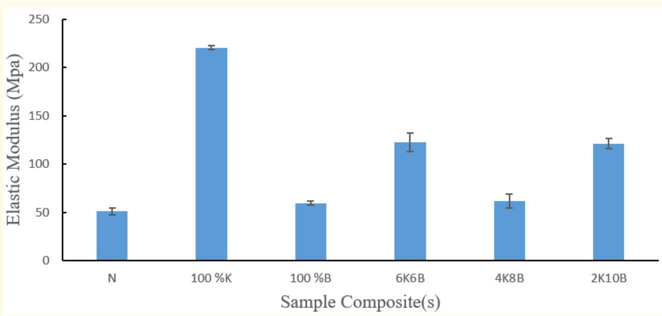


***Figure 3.3:*** Elastic Modulus Variation of Hybrid Sample Composite(s).

The result shown in Figures 3.4 and 3.5 present the effect of hybridization on the flexural and impact strength properties of the composite samples. From the results, it could be established that properties of composite sample can be enhanced by combining both the synthetic and natural fiber to produce a hybrid composite with enhanced properties, this was also reported in earlier research study on effect of hybridization on composite materials (Warbhe et al., 2016). 6K6B reinforced exhibited the highest flexural strength of 143.12 MPa and 2.37 $J/cm^2$ impact strength, about 75.6% and 14.8% respectively as compared with 100%B composite samples.

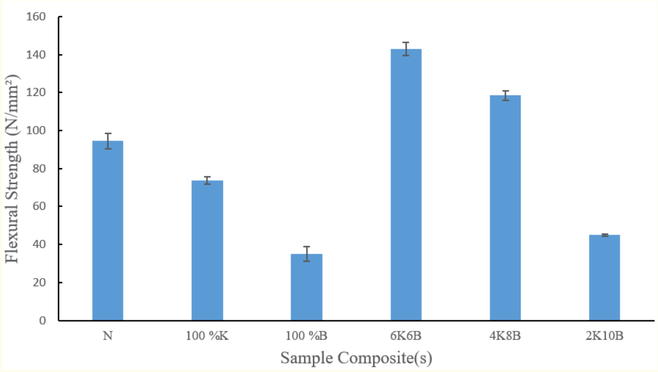


***Figure 3.4:*** Flexural Strength Variation of Hybrid Sample Composite(s).

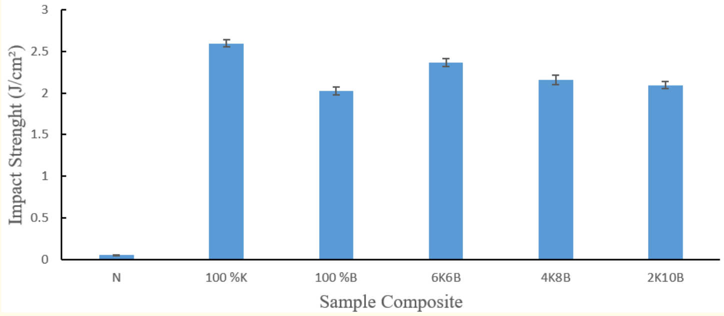


***Figure 3.5:*** Impact Strength Variation of Hybrid Sample Composite(s).

## Conclusion

Hybridization effect on density, water absorption ability tensile, impact and flexural properties for Kevlar-BFLF hybrid epoxy composites was evaluated. Sample composites were successfully produced using Hand lay-up method and the following conclusions are drawn from the experimental results.

Reinforcing epoxy matrix with Kevlar and BFLF produced a lighter weight material and widely reduce the ability of water intake of the material when expose to a water body. From the results of mechanical evaluation, 6K6B hybrid composite sample had an average tensile properties of 64.17 MPa, 31.77% and 122.84 MPa for tensile strength, elongation and elastic modulus respectively, significantly approaching measured values for 100% Kevlar reinforced composite. Also, hybridized composite had some preeminent properties that may favor its application in production of body armor material owing to its high resistance to impact and bending modulus, these properties are mostly considered as criteria that disperses energy impacted by a high velocity projectile. Further, these indicates that hybridizing with BFLF can reduce the usage of synthetic fiber.

## References

1. Ayo SA. "Development and Characterization of epoxy/Borassus Palm Leaf Stalk Fiber Reinforced Composite". Fibers and Polymer 19.2 (2018): 16-122.

2. ASTM D570-98. “Standard Test Method for Water Absorption of Plastics”. ASTM International, West Conshohocken (2018).
3. 3822-07. “Standard Test Method for Tensile Properties of Single Textile, ASTM International West Conshoshocken”. Philadelphia USA 8.1 (2007).
4. Azrin (2011).
5. Bhagat VK, Biswas S and Dehury J. “Physical, Mechanical and Water Absorption Behavior of Coir/Glass Fiber Reinforced Epoxy Based Hybrid Composite”. Polymer Composites (2014): 925-930.
6. Gautam G, Norkey G and Pandey AK. “Mechanical Characterization of Kevlar-29 Fiber Reinforced Polymer Composite”. ELK Asia Pacific Journals 6.6 (2017): 978-993.
7. Kumar R. “Effect of Fiber Type, Weight Percentage Loading, and Fiber Size on Impact Strength and Hardness of Wood and Rice Husk Hybrid Composites”. International journal of material science 12.3 (2017): 443-460.
8. Marian K. “Archimedes’ Principle in action”. Physics Education 42.5 (2007): 484-487.
9. Nekka S, Chebira F and Haddaoui N. “Effect of Fiber Treatment on the Mechanical and Rheological Properties of Polypropylene/Broom Fiber Spartium Junceum Composites”. JEAS 1.3 (2006): 278-283.
10. Nunna S., et al. “A Review on Mechanical Bahavior of Natural Fiber based Epoxy Composite”. JRP 31 (2012): 759-769.
11. Pan Y and Zhong Z. “The Effect of Hybridization on Moisture Absorption and Mechanical Degradation of Natural Fiber Composites: An Analytical Approach”. Elsevier-Composite Sci. and Tech 110 (2015): 132-137.
12. Patel N., et al. “Investigations on Mechanical Strength of Hybrid Basalt/Glass Polyester Composites”. International Journal of Applied Engineering Research 13.6 (2018): 4038-4088.
13. Paul A, Joseph K and Thorma S. “Effect of Surface Treatments on the Electrical Properties of Low Density Polethylene Composites Reinforced with Short Sisal Fibers”. Composite Sci. & Tech 51 (2007): 67-79.
14. Reddy KO., et al. “Effect of Chemical Treatment and Fiber Loading on Mechanical Properties of Borassus (Toddy Palm) Fiber/Epoxy Composites”. International Journal of Polymer Analysis and Characterization 20.7 (2015): 612-626.
15. Reddy KO., et al. “Thermal Degradation parameters and tensile properties of borassus flabellifer fruit fiber reinforcement”. Journal of reinforced plastics and composites 28.18 (2009): 2297-2301.
16. Saba N, Tahirand Jawaid M. “A Review on Potentiality of Nano-Filler/Natural Fiber Filled Polymer Hybrid Composite”. Polymers 2 (2014): 2247-2273.
17. Samal SK, Mohanty S and Nayak SK. “Polypropylene-Bamboo/Glass Fiber Hybrid Composites: Fabrication and Analysis of Mechanical, Morphological, Thermal, and Dynamic Mechanical Behavior”. Journal of reinforced plastics and composites 28.22 (2009): 2729-2747.
18. Singh JK, Rou AK and Kumari K. “A review on Borassus flabellifer lignocellulose fiber reinforced polymer composites”. Carbohydrate Polymers 262 (2021): 117929.
19. Sukanya P., et al. “An insight on the chemistry of epoxy and its curing for coating applications: A detailed investigation and future perspectives”. Polymer-Plastic Technology and Engineering 55.8 (2015): 35-54.
20. Thwea MM and Liao K. “Effects of Environmental aging on the Mechanical Properties of Bamboo-Glass Fiber Reinforced Polymer Matrix Hybrid Composites”. Compos Part A 33 (2002): 43-52.
21. Warbhe NO, Shrivastava R and Adwani PS. “Mechanical Properties of Kevlar/Jute reinforced Epoxy Composite”. International Journal of Innovative Research in Science, Engineering and Technology - IJIRSET 5.9 (2016): 16407-16418.
22. Vineet KB, Biswas S and Dehury J. “Physical, Mechanical and Water Absorption Behavior of Coir/Glass Fiber Reinforced Epoxy Based Hybrid Composites”. Polymer Composites 35.5 (2014): 925-930.
23. Yahaya R., et al. “Investigating Ballistic Impact Properties of Woven Kenaf-Aramid Hybrid Composites”. Fibers and Polymers 17 (2016): 275-281.