SSRG International Journal of Mechanical Engineering
ISSN: 2348-8360/ https://doi.org/10.14445/23488360/IJME-V13I9P104

Volume 13 Issue 9, 56-70, September 2026

Review Article

Development and Application of Banana Fiber Reinforced Epoxy Resin Composites for Automotive Interior Panels

Mbatha Abednigo Jabu[1], ID Ibraham[2], NZ Nkomo[3], MK Nemavhola[4]

[1,2,3]*Vaal University of Technology, Department of Mechanical Engineering, Industrial Engineering and Operation Management Private Bag X021, Vanderbijlpark, 1900, South Africa.*
[4]*Vaal University of Technology, Department of Chemical and Metallurgical Engineering Private Bag X021, Vanderbijlpark, 1900, South Africa.*

[1]*Corresponding Author : abednigom@vut.ac.za*

Received: 27 March 2026 Revised: 30 May 2026 Accepted: 24 July 2026 Published: 26 September 2026

Abstract *- Composites made of synthetic fibers are difficult to recycle and are not biodegradable, which causes pollution in landfills. Interior panels are not exposed to harsh conditions, and they should be recyclable after the lifespan of the vehicle. Natural fibers are gaining momentum in the automotive industry due to their acceptable mechanical properties and biodegradability. There is a need to develop sustainable materials in the automotive industry to promote lightweight, fuel-efficient, and recyclable materials. This study seeks to develop and fabricate composites using banana fibers to promote sustainable materials in the automotive industry. The banana fibers were extracted from banana stems using a blunt knife and dried in sunlight for 48 hours. They were then treated with 5% sodium hydroxide to remove impurities and improve the durability of the banana fibers, and SEM was carried out to check morphology and lateral size. The untreated banana fibers were smooth, translucent, and rounded in shape. In contrast, the banana fibers treated were rough and porous, which may enhance the interfacial bonding. The composite was fabricated using the hand lay-up method, with a banana fiber volume fraction ranging from 0.5% to 2%. The mechanical tests conducted on the fabricated composites included tensile strength, compressive strength, flexural strength, and Leeb hardness. Water absorption and biodegradability tests were also conducted on the composites. The results showed that the maximum moisture absorption was 10.2%, obtained after 2 hours at a temperature of 80°C. The maximum Leeb hardness was 523 at a 1% volume fraction, compressive strength was 4.31 MPa at a 1% volume fraction, flexural strength was 49.54 MPa at a 0.5% volume fraction, and tensile strength was 12.98 MPa at a 2% volume fraction. The biodegradability was 3.08% at a 2% volume fraction, and water absorption was 1.99% at a 2% volume fraction. The water absorption of banana fibers is a challenge that researchers need to address, as it reduces the lifespan of composites made from natural fibers.*

Keywords *- Banana fibers, Composite, Sustainability, Mechanical properties, and Natural fibers.*

1. Introduction

Synthetic fibers are not biodegradable and are therefore difficult to recycle. The production and use of synthetic fibers have significant negative impacts on the environment. They are a major source of microplastic contamination, as microfibers are released during manufacturing, processing, and use. In addition, the production of synthetic polyamide contributes to global warming through the release of nitrous oxide into the atmosphere [1]. As the cost of synthetic materials continues to rise, global efforts to develop sustainable materials and adopt circular economic approaches have intensified [2]. The automotive industry is currently at a turning point, driven by the need to identify environmentally friendly materials for lightweight vehicle design. Natural Fiber Reinforced Polymer Composites (NFRPCs) are gaining increasing attention due to their excellent technical properties and environmental benefits [3]. Composites made from natural fibers offer valuable performance characteristics such as a high strength-to-weight ratio, high corrosion resistance, good stiffness, and magnetic neutrality [4, 5]. With growing awareness of environmental challenges and stricter regulations aimed at reducing emissions and promoting sustainability, there is an urgent need for innovative materials and technologies that can support this transformation [6]. Recyclability is a key component of sustainable practices in the automotive industry. NFRPCs provide opportunities for improved recyclability, making automotive components more environmentally friendly [7, 8]. Impact resistance is another

crucial property for automotive parts, as it ensures occupant safety in the event of collisions or accidents. Studies have shown that incorporating natural fibers into composites can enhance their impact resistance [9]. Banana fibers contribute to a range of properties, including mechanical strength, dielectric behavior, swelling resistance, and thermal stability [10]. Although natural fiber composites are renewable and potentially fully biodegradable, they are sensitive to environmental conditions such as temperature and humidity. If these materials are made entirely from organic components and degrade prematurely, their cost-effectiveness may be compromised. While it is possible to develop fully biodegradable composites by selecting suitable polymers, controlling their biodegradation remains a challenge [11]. The study investigates how does the incorporation of banana fibers affects the flexural strength, tensile strength, compression strength, Leeb hardness, biodegradability and water absorption of epoxy composites. This study aims to investigate the use of epoxy resin and banana fibers in the fabrication of bio-composites for potential applications in the automotive industry. The use of natural fibers in polymer composites not only helps address environmental concerns but also provides opportunities to support rural economies and communities where these fibers are produced. However, since natural fibers generally have lower mechanical properties than synthetic fibers, further research is needed to explore the use of nano-filler materials to enhance their mechanical performance. Although banana fibers have been widely investigated as reinforcement in composites, most previous studies have focused on general mechanical characterization or non-automotive applications. The novelty of this study fabrication in the systematic investigation of banana fiber-reinforced epoxy composites specifically for automotive interior panel applications. Compared to other studies, this study assesses how different banana fiber volume fractions affect tensile strength, flexural strength, hardness, and water absorption to determine the ideal fiber content for striking a compromise between mechanical performance and environmental sustainability. Additionally, the study offers statistically verified correlations between composite qualities and fiber content, allowing for the improvement of material performance for lightweight automobile interior components. These results present useful design information that encourages the replacement of sustainable, biodegradable materials for traditional synthetic fiber composites.

2. Design and Methodology

The design and methodology involved in this study include the characterization of banana fibers, the fabrication process, and the evaluation of the mechanical properties. Water absorption and biodegradability of the fabricated composites were also tested.

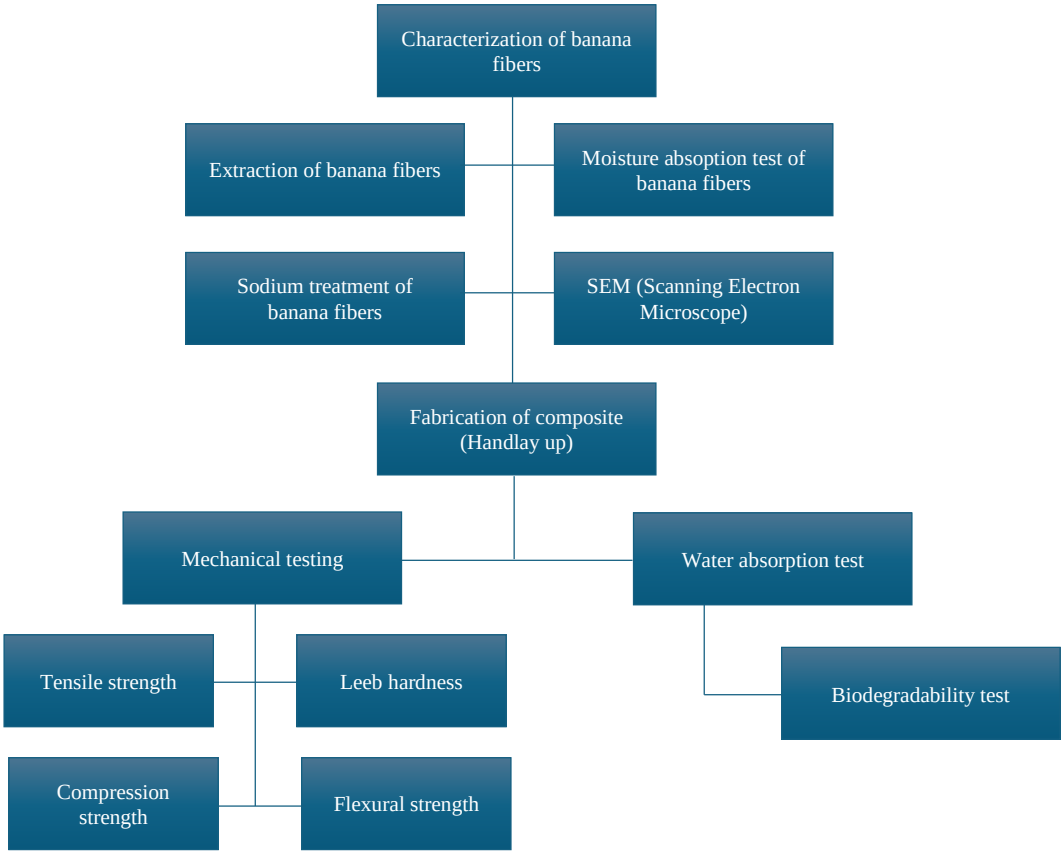


Fig. 1 Framework of the study

2.1. Characterization of Banana Fibers

The characteristics of banana fibers include the extraction process, drying, moisture absorption, chemical treatment, and SEM analysis.

2.1.1. Extraction Process of Banana Fibers

The banana stems after the retting process were scraped using a blunt knife until the fibers were exposed and free from adhering, as shown in Figure 2(a). Fibers were collected for the next process. The banana fibers were sun-dried for 48 hours. The fibers were placed in a plastic tray to avoid contamination, as shown in Figure 2(b). After the drying process, the fibers were subjected to hackling, which involves combing out residual particles adhering to the fibers to leave clean and good fiber.

Fig. 2 (a) Extraction process of banana fibers, and (b) Drying banana and hemp fibers.

2.1.2. Banana Fibers Moisture Absorption Test

Moisture regain test was conducted on the banana fibers in accordance with A0AC 930.15 [12]. An oven was preheated to a temperature of 80°C to remove moisture inside the oven, and before carrying out the test Afterwards, the borosilicate glass beakers used to store the fibers were placed in an oven at 80 °C for 15 minutes to remove any moisture from the containers. To prevent contamination from ambient moisture, each borosilicate glass beaker was placed on the weighing scale within one minute after removal from the oven. The weight of each empty beaker was then measured and recorded.

The banana fibers were weighed using tongs, as shown in Figure 3. After the cooling process, a scale was used to measure the banana fibers once more, and the mass was recorded. Until a steady mass was observed, this procedure was repeated three times...

Equation (1) was then used to determine the banana fibers' moisture absorptions.

$$Moisture\ regain = \frac{WS-(W2-W1)}{WS} X100 \quad (1)$$

Where W_S is the mass of banana fibers (g), W_1 is the mass of banana fibers and borosilicate glass combined in (g), and W_2 is the mass of the banana after it was heated to 135 °C in an oven until (g) did not change, indicating that the sample was completely oven-dry.

Fig. 3 Banana fibers in the oven

2.1.3. Chemical Treatment of Banana Fibers

Chemical treatment of banana fibers was done using 5% Sodium Hydroxide (NaOH) solution as the optimum percentage.

The solution was prepared by weighing and dissolving 5 grams of sodium hydroxide in distilled water using a magnetic stirrer, as shown in Figure 4, to make 5% solution.

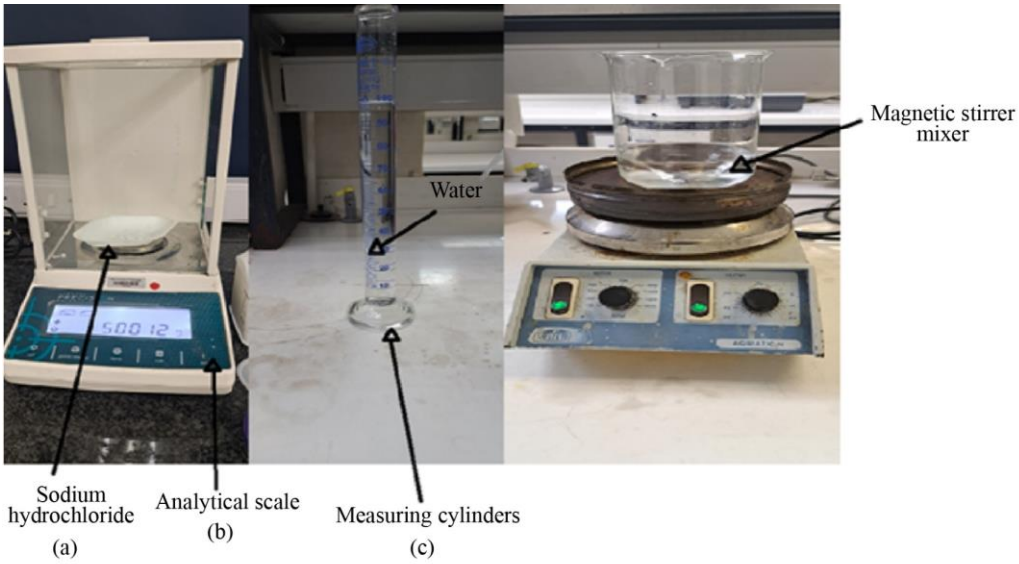


Fig. 4 Preparation of sodium hydroxide solution

The banana fibres were soaked in a 5% Sodium Hydroxide (NaOH) solution for 24 hours at room temperature, as shown in Figure 5. After 24 hours, the fibres were thoroughly rinsed with distilled water and sun-dried for 36 hours before the composite fabrication process.

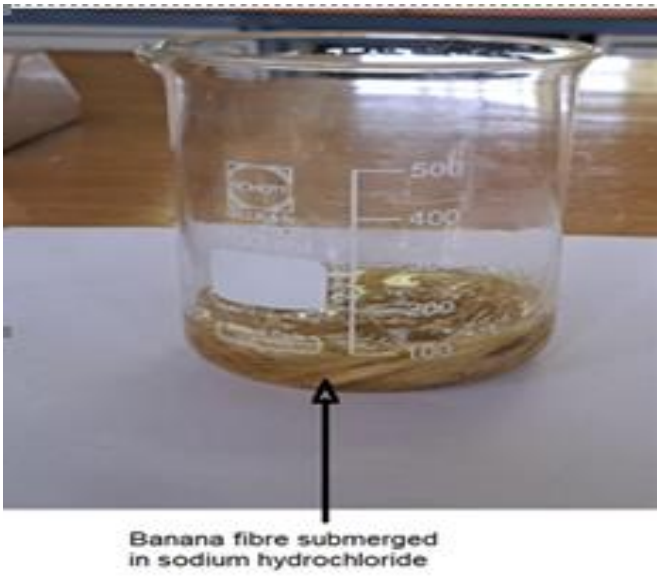


Fig. 5 Banana fibers in sodium hydroxide

2.1.4. Scanning Electron Microscope Morphology Analysis

The banana fibers morphology was studied using SEM before and after chemical treatment. The fibers where fibers were first coated to increase conductivity before analysis using an SEM.

Coating of Banana Fibers

Banana fibers were coated using a Quorum Q150R ES machine, shown in Figure 6. The process included first cleaning the Banana, ensuring they were free of any contaminants. Thereafter, the banana fibers were loaded onto the holder in the machine. The vacuum was then started to remove residual gases from the chamber, creating an environment for the sputtering process.

Fig. 6 Quorum Q 150R ES plus for coating fibers

The gold sputter coating was set according to the material and thickness of the materials, and sputter coating was initiated to allow the deposition of the material coating on the fibers. The coating ended after the desired coating thickness was achieved.

Scanning Electron Microscope

The banana fibers' morphology was examined using a Scanning Electron Microscope (SEM) model number JSM IT500LA JEOL, which is shown in Figure 7. The purpose of this test was to assess topography, roughness, lateral size characteristics, and fiber morphology.

Fig. 7 JSM IT500LA JEOL SEM Scanning Electron Microscope

The banana fibers were placed inside the specimen chamber on a sample holder. The SEM image was then seen using the navigation procedure for taking a CCD image using zero mag software to enhance the image. The acquired images were stored on an external drive.

2.2. Fabrication of Composite

The composite was fabricated using the hand lay-up method. A molding tray measuring 40 cm × 40 cm was used, as shown in Figure 8. The tray was coated with a release agent, and plastic was placed to prevent the composite from sticking. Banana fibers were weighed and placed inside the molding tray. The epoxy resin was weighed using a scale, and a catalyst was added. The mixture was then stirred to achieve a homogeneous consistency. Afterward, the resin was poured into the mold and kneaded thoroughly. The composite cured at room temperature for 24 hours.

Fig. 8 Fabrication process

2.3. Fabricated Composites Characterization

The composite characterization includes mechanical testing, water absorption and biodegradability test

2.3.1. Mechanical Testing

The mechanical testing includes Leeb hardness, tensile strength, flexural strength and compression strength.

Leeb Hardness Test

The bio-composite specimen LEEB hardness measurement was carried out in accordance with ASTM A-956 [13]. All the specimens fabricated according to the experimental design were tested using a model Time 5330 hardness tester. The dynamic rebound concept served as a basis for the test strategy. The composite specimens were cut to the proper size of 140 mm x 40 mm using an angle grinder and hacksaw.

Tensile Strength Test

The tensile strength test was carried out according to ASTM D3518/D3518M-18 [14], using an INSTRON type 3369 Universal Testing Machine (UTM). Specimens used for the tensile strength test were of dimensions 250 mm in length and 25 mm in width. The specimen's unsupported (gauge) length was 150 mm when it was inserted in the fixture.

Compression Strength Test

Composite specimens' compressive strength along the panel's plane. ASTM D3410/D3410M [15], which specifies a specimen size of 140 mm long by 13 mm wide with an unsupported gauge length of 13 mm when inserted in the fixture, was followed while performing the compression test.

Flexural Strength Test

The composite samples conducted a flexural strength test in compliance with ASTM D8058-19 [16]. The ASTM standard was followed when conducting a three-point bending test. Flexural strength testing was performed using an INSTRON type 3369 Universal Testing Machine. Samples measuring 160 mm by 40 mm were placed on the supports. Equation (2) was used to get flexural strength.

$$R = \frac{3PL}{2bd^2} \quad (2)$$

Where R is the specimen's flexural strength (MPa), P is its breaking load (N), L is its span length (mm), b is its breadth (mm), and d is its average thickness (mm).

2.4.1. Biodegradability

In this test, the biodegradation experiment has been carried out by the soil burial method. This test has been carried out according to ASTM D5338 standard. Standard testing for ASTM D5338 is a minimum of 90 days in an aerobic and controlled composting environment. This test is performed by evaluating the weight loss of the sample over time. The weight loss has been calculated by the following Equation (3).

$$Biodegradable\ test = \left(\frac{B_B - B_A}{B_B}\right) \times 100 \quad (3)$$

Where B_B mass of the specimen before burial (g), B_A is the mass of the specimen after weight loss after burial (g).

2.4.2. Water Absorption

The water absorption test was conducted according to ASTM D570 standard [17]. Composite specimens were immersed in distilled water at room temperature for 48 hours, or until they reached the saturation point. Equation (4) was used to get the percentage of water absorption. After which, the weight gain after wiping the surface moisture was measured. Thus, the weight gains were measured on an accurate balance with at least 0.1 mg accuracy. Equation (4) was used to calculate the water absorption of fabricated composites.

$$\text{Weight gain} = \frac{W_b - W_f}{W_b} \times 100 \quad (4)$$

Where W_b mass of the specimen before water absorption (g), W_f is the mass of the specimen after weight gain after water absorption (g).

3. Results and Discussion

The results discussed in the following subsections include the characterization of banana fibers, Mechanical testing, water absorption and biodegradability test.

3.1. Characterization of Banana Fibers Results

The banana fiber characterization results include the SEM morphology results and the moisture regain test.

3.2. Moisture Regains Analysis for Banana Fibers

Figure 9 shows the moisture regain analysis results for banana fibers,

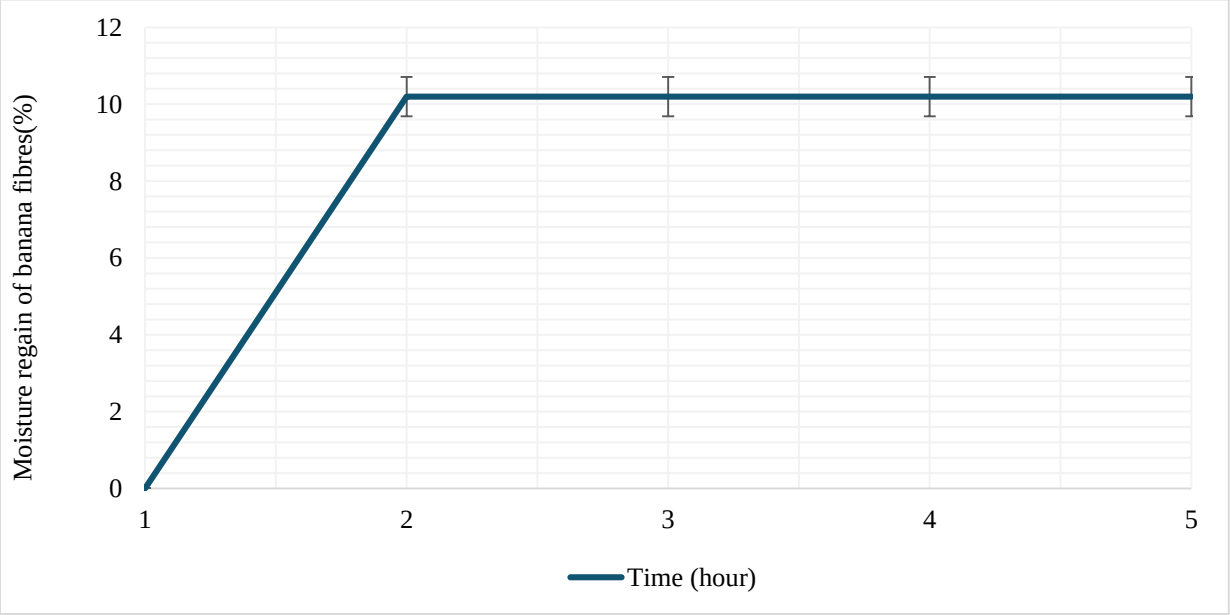


Fig. 9 Moisture regain analysis of banana fibers

The banana fibers final moisture regain was 10.2 % at 2 hours, as shown in Figure 9.

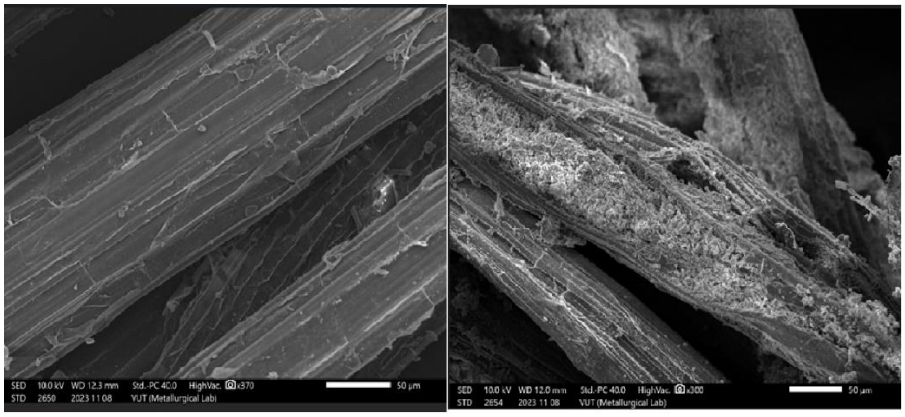
There was a sharp increase in moisture absorption from initial exposure up to 2 hours.

This observation aligns with findings by Saheb et al. (2012), who stated that the moisture absorption of banana fibers is between 10 to 11%.

Treated banana fibers generally have a moisture regain of 10 to 11 %, and untreated fibers have a moisture regain of 13.36% [18]. A moisture regains of up to 50 % is generally considered acceptable for composite manufacture [19].

3.3. SEM Surface Morphology Analysis of Treated and Untreated Banana Fibers

To determine the morphology, lateral size, and roughness of the treated and untreated banana fibers, a Scanning Electron Microscope (SEM) test was carried out, as shown in Figure 10.



(a) Untreated banana fibres (b) Treated banana fibres

Fig. 10 (a) SEM micrograph of untreated banana fibers, and (b) Morphology of treated banana fibers.

A SEM model number JSM IT500LA JEOL with a high voltage of 10.0 Kv was used to capture the morphology of banana fibers. Figure 10(a) shows the morphology of untreated banana fibers, and Figure 10(b) shows the morphology of banana fibers that has been treated with 5% of NaOH. The untreated banana fibers, Figure 10(a), are smooth, translucent and rounded in shape. However, treated banana fibers shown in Figure 10(b) are rough and porous, which could help with the interfacial bond of fibers with matrix, as it has been stated by Zakaria et al (2023) that the use of NaOH concentration results in a much rougher surface on natural fibers and creates many micropores [20]. The banana fiber diameters of treated and untreated fibers ranges were 50 µm.

3.3.1. EDS Composition Analysis of Treated and Untreated Banana Fibers

Chemical composition of the untreated banana fibers was obtained using The EDS as shown in Figure 11.

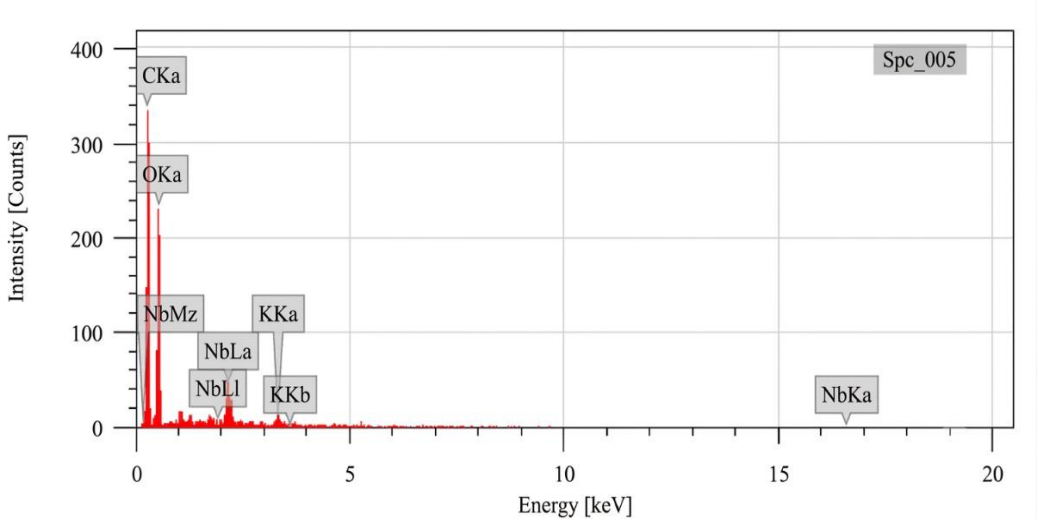


Fig. 11 EDS results showing elements detected on untreated banana fibers

Figure 11 shows the corresponding peaks for the elements detected by the EDS analysis. The elements present include C (Carbon), O (Oxygen), Nb (Niobium), and K (Potassium). Ka, Kb, Li, La, and Mz refer to electron shells, which hold electrons. The carbon element has the highest intensity with a peak value of 338, followed by oxygen with approximately 238 intensities. Niobium has the lowest intensity value, which is below 60. Lastly, potassium has the lowest value, which is below 10. Table 1 gives a more detailed EDS breakdown of the constituents' untreated banana fibers.

Table 1. Showing the EDS report on the elements of the untreated banana fibers

Element	Line	Mass%	Atom%
C	K	43.42±0.43	55.49±0.55
O	K	43.39±0.92	41.63 ±0.88
K	K	3.09±0.41	1.21±0.16
Nb	L	10.09±0.86	1.67±0.14
Total		100	100

The untreated banana fibers have a mass that contains a carbon percentage of 43.42±0.43 and 55.49 ± 0.55 atoms, which helps with high rigidity, strength-to-weight ratio, and chemical and heat resistance. Followed by a mass of oxygen which contains oxygen percentage of 43.39±0.92 and atom percentage of 41.63 ±0.88, which helps with help with elasticity and moisture regain for the hemp fibers.

Potassium was also detected, having a mass that contains 3.09±0.41 and 1.21±0.16 atom percentage, which helps with the maintenance of fluid and electrolyte balance. Lastly, Nb (Niobium) also detected, having a mass that contains 10.09±0.86 % and 1.67±0.14% atom, which improves their strength of the fibers, particularly at low temperatures.

The chemical composition of the treated banana fibers was characterized using EDS, and the results are as shown in Figure 12.

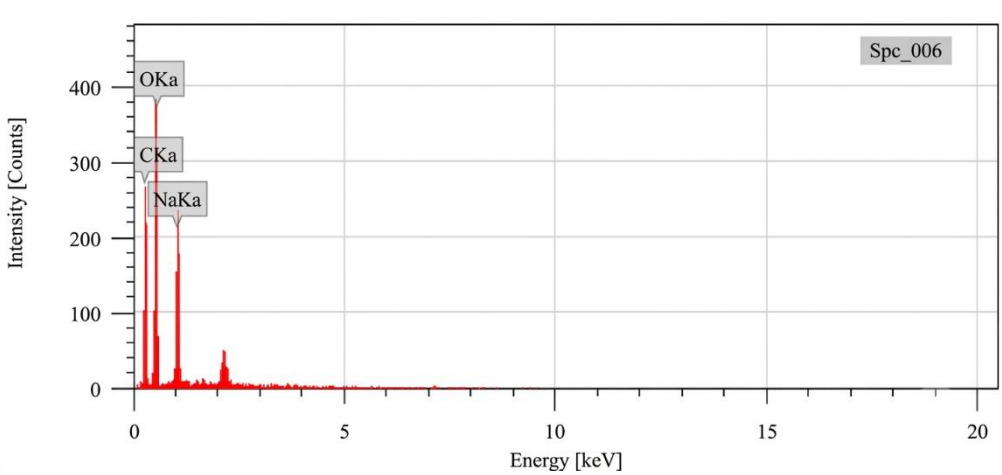


Fig. 12 EDS results showing elements detected on treated banana fibers

Figure 12 shows three elements that were detected during EDS analysis of the treated banana fibers, which showed the presence of Oxygen (O), Carbon (C) and Sodium (Na). The results show a high peak of oxygen with approximately 380 intensity, followed by carbon with an intensity of 270 and lastly sodium with an intensity of 240. Nb (Niobium) and K (Potassium) were detected prior to treatment of the banana fibers. Table 2 gives a more detailed EDS breakdown of the constituents of the sodium hydroxide-treated banana fibers.

Table 2. Showing the EDS report on elements of the treated banana fibers

Element	Line	Mass%	Atom%
C	K	33.64±0.38	42.58±0.48
O	K	46.81±0.79	44.49 ±0.75
Na	K	19.55±0.54	12.93±0.36
Total		100	100

Table 2 shows different elements found inside the treated banana fibers as detected by EDS analyses. The three primary elements that were detected on treated banana fibers are carbon (C), oxygen (O), and sodium (Na).

The elements present include 33.64 ± 0.38% carbon, which was detected after banana fibers were treated with sodium hydroxide, which strengthens cell walls. However, the mass % of banana was 43.42±0.43 before treatment with sodium hydroxide.

The mass of oxygen was 43.39±0.92 before fibers were treated with sodium hydroxide, and after treatment, it went slightly up to 46.81±0.79, which is oxygen that maintains the structural integrity and moisture regain of fibers.

The mass of sodium was only detected after treatment of banana fibers with sodium hydroxide, which is 19.55±0.54 and contributes to maintaining atmospheric pressure and the

efficiency of water consumption. Nb (Niobium) and K (Potassium) were not detected after banana fibers were treated with sodium hydroxide. The banana fibers had an atom that contained 55.49 ± 0.55 carbon, and after being treated with sodium hydroxide, it decreased to 42.58 ± 0.48.

The Oxygen had 41.63 ±0.88 before it was treated, and it increased to 44.49 ±0.75. Lastly, the sodium had an atom that contained 12.93±0.36.

3.4. Mechanical Properties Characterized

The mechanical properties characterization includes Leeb hardness, tensile strength, compression strength, and flexural strength.

3.4.1. Effects of Banana Fibers on the LEEB Hardness of the Composite

Figure 13 presents the effects of varying banana fiber volume fraction on the composite hardness.

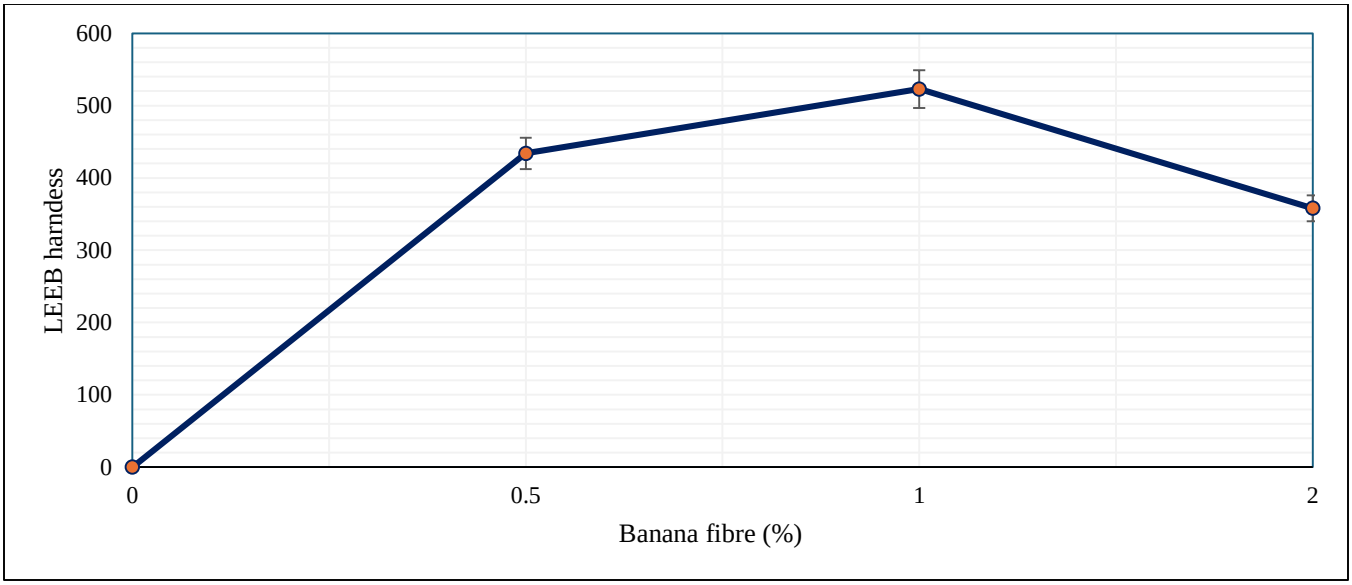


Fig. 13 Effects of banana fiber volume fraction on the LEEB hardness of the composite

Figure 13 shows that the addition of 0.5 % banana fiber resulted in a decrease in hardness of 434 from the control specimen. However, the addition of banana fiber to 1.0% resulted in an increase in LEEB hardness of 523 from that of 0.5 % fiber content. However, the addition of 3% fiber content resulted in a decrease in the LEEB hardness to 358.

The results shown in Figure 13 show that the addition of banana fibers up to 0.5% fiber loading decreased the composite's Leeb hardness.

This phenomenon can be attributed to the ductile banana fibers, and Leeb hardness is a dynamic hardness test that measures the rebound velocity of a steel ball or other impact body after striking a composite material.

The ductility of the banana fibers results in poor stress transfer; this is reflected in the hardness. However, the addition of 0.5 to 1% banana fibers decreased the composite hardness, which is consistent with the study by Gupta et al., 2020, Neher et al., 2020, Islam et al., 2015, and Ismail et al., 2018, which stated that the hardness of the composite decreases with fiber volume fraction. The Leeb Hardness decreased with the addition of 2 % banana fiber volume fraction.

The epoxy resin is brittle, and the banana fibers are ductile. As the volume fraction of banana fibers increases, the was corresponds to a general decrease in hardness. This is due to fibers increasing the ductility of composite and reducing rebound hardness. This can be attributed to fibers are ductile and transmitting high energy of impact loading, resulting poor hardness.

3.4.2. Effects of Banana Fibers on the Tensile Strength of the Composite

The effects of varying banana fiber on the tensile strength of the bio composite are as shown in Figure 14.

Figure 14 shows a general increasing trend in tensile strength with an increase in banana fiber volume fraction. The graph shows that the tensile strength increases from 8.27 MPa to 8.64 MPa as the volume fraction increases from 0.5 to 1%. Further addition of banana fiber volume fraction from 1% to 2% resulted in an increase in tensile strength, giving a value of 12.98 MPa. The results in Figure 14 indicate that a high-volume fraction above 2% banana fibers can be used to obtain incrementally higher tensile strength. The dominant failure mode of the composite observed under tensile loading was largely fiber breakage and matrix cracking.

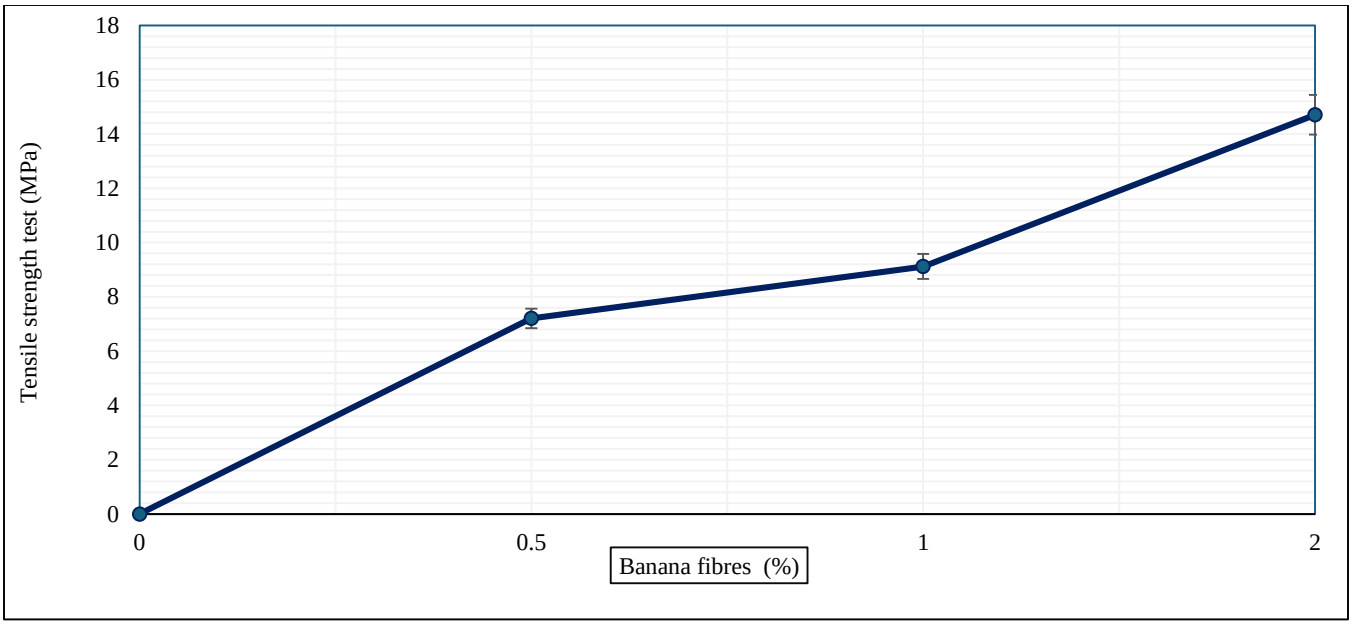


Fig. 14 Effects of banana fiber volume fraction on the tensile strength of the composite

The increase in tensile strength from 0.5 to 2% as banana fiber volume fraction increases is consistent with a study by Sengottaiyan et al., 2025. The treatment of the banana fibers with alkali treatment, eliminating surface contaminants and improving bonding, is largely responsible for the high tensile strength observed due to improvement in fiber-matrix adhesion

3.4.3. Effects of Banana Fibers on the Compression Strength of the Composite

The effects of varying banana fibers on the compression strength of the bio composite are as shown in Figure 15.

The increase of compression strength from 0.5 to 1% volume fraction and the decrease of the compression strength from 1 to 2% were addressed by a study by Mani et al. (2025), who stated that understanding the effect of fiber volume fraction on compressive strength requires an understanding of two fundamental processes. First, an improvement in compressive strength results from the fiber's capacity to withstand fracture, outweighing the impact of produced porosity. On the other hand, the compressive strength decreases when the porosity increases as the volume fraction [26].

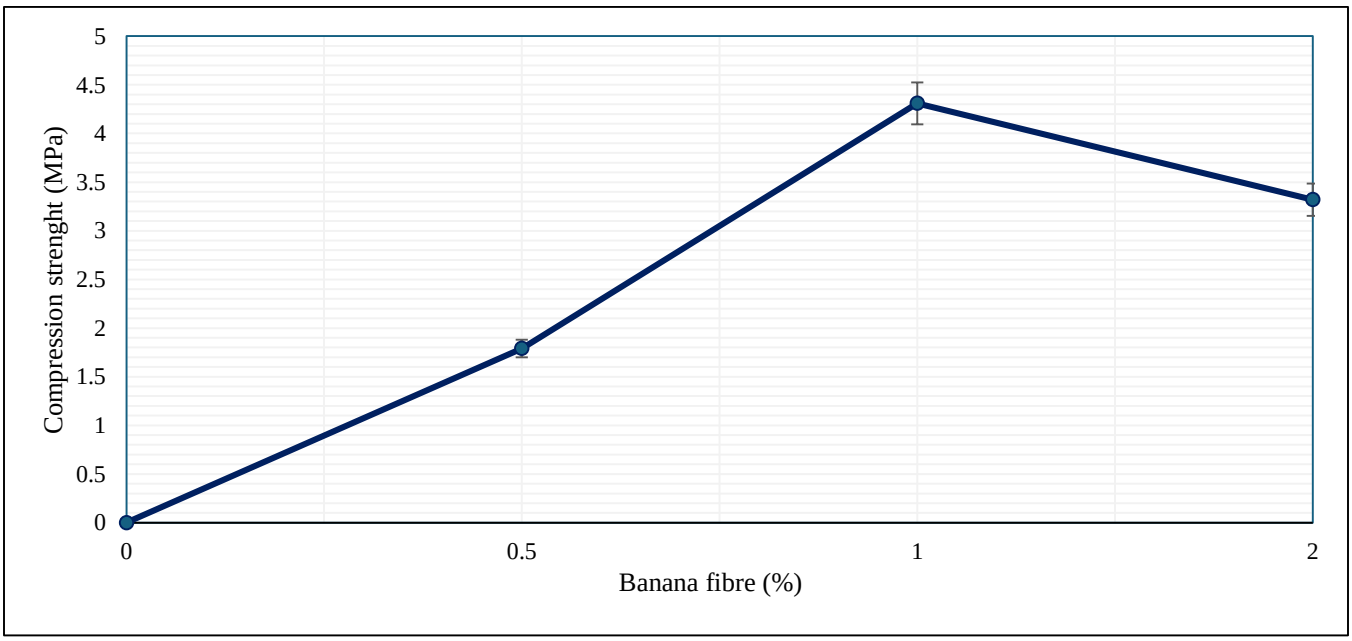


Fig. 15 Effects of hemp fibers volume fraction on the compression strength of the composite

3.4.4. Effects of Banana Fibers on the Flexural Strength of the Composite

The effects of varying banana fibers on the flexural strength of the bio composite are as shown in Figure 16. The flexural strength of banana fibers decreases as the volume fraction does, as shown in Figure 16. The initial flexural strength at 0.5% volume fraction was 49.54 MPa. As the volume fraction increased to 2%, it gave a slight decrease in flexural strength, giving a value of 45.29 MPa.

The volume fraction decreased further when the volume fraction was increased from 1% to 2%, giving a value of 36.51 MPa. The study is consistent with a study by Balacha et al. (2023), who got a similar observation that flexural strength decreases with the addition of fiber volume fraction [27]. The decrease in flexural strength could be attributed to the fact that fiber volume fraction gets too high, there may be insufficient matrix to adequately wet and bind the fibers, leading to poor adhesion, fiber aggregation, and the creation of voids. These limitations weaken the composite's capacity to transfer stress between fibers and matrix, causing the flexural strength to decrease.

3.5. Effects of Banana Fibers on the Biodegradable of the Composite

The effects of varying banana fibers on the biodegradable of the bio composite are as shown in Figure 17.

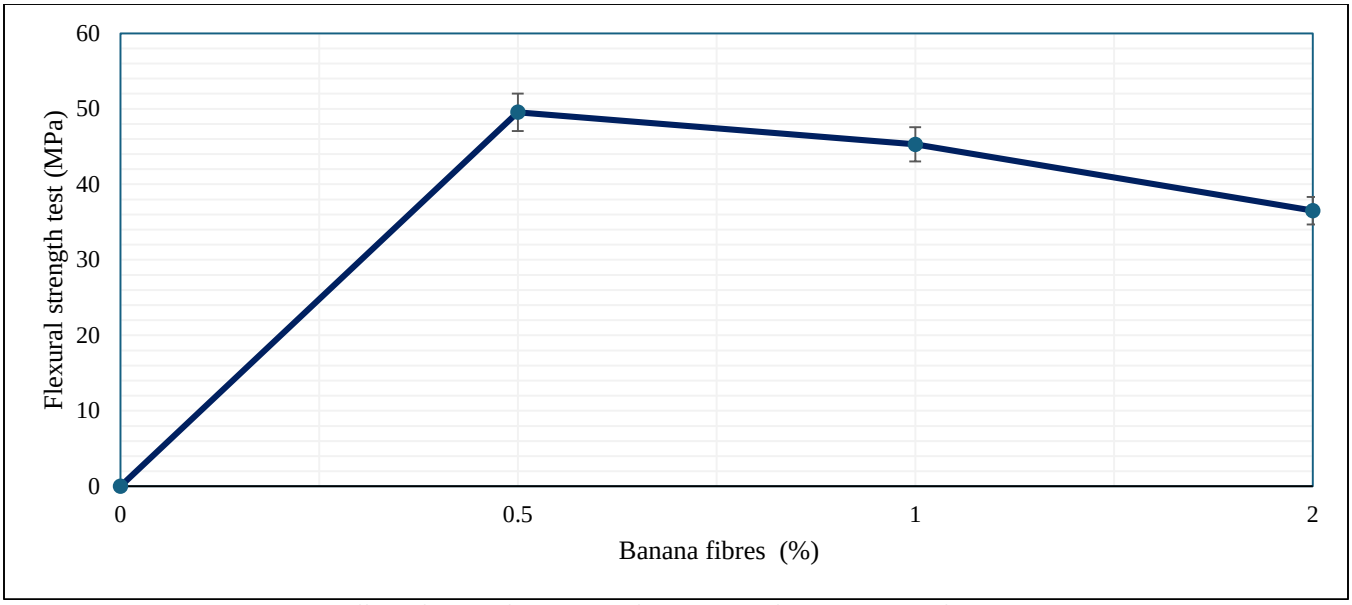


Fig. 16 Effects of banana fibers volume fraction on the flexural strength of the composite

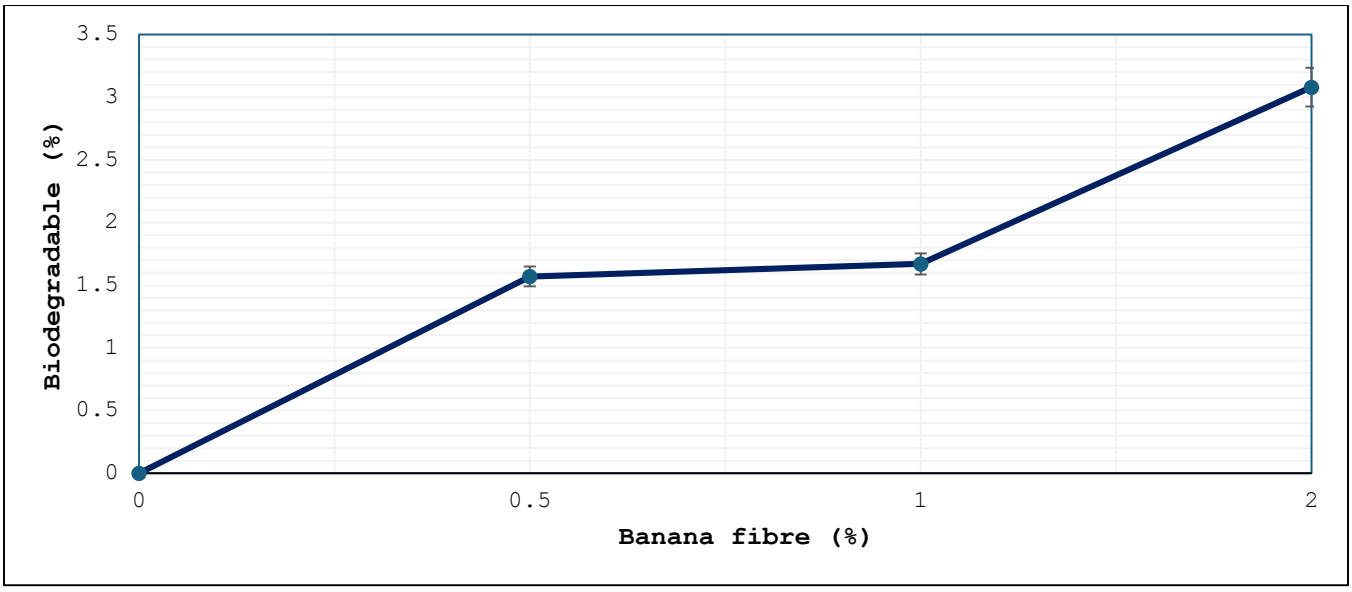


Fig. 17 Effects of banana fiber volume fraction on the biodegradable of the composite

The results are consistent with the study by Bharath et al. (2010) who stated that the reaction between the chains of polymers or additives that make up the substance and the protein molecules that the organism secretes causes the weight to drop. This process keeps going, and over time, it steadily loses weight [28].

3.6. Effects of Banana Fibers on the Water Absorption of the Composite

The effects of varying banana fibers on the water absorption of the bio-composite are as shown in Figure 18.

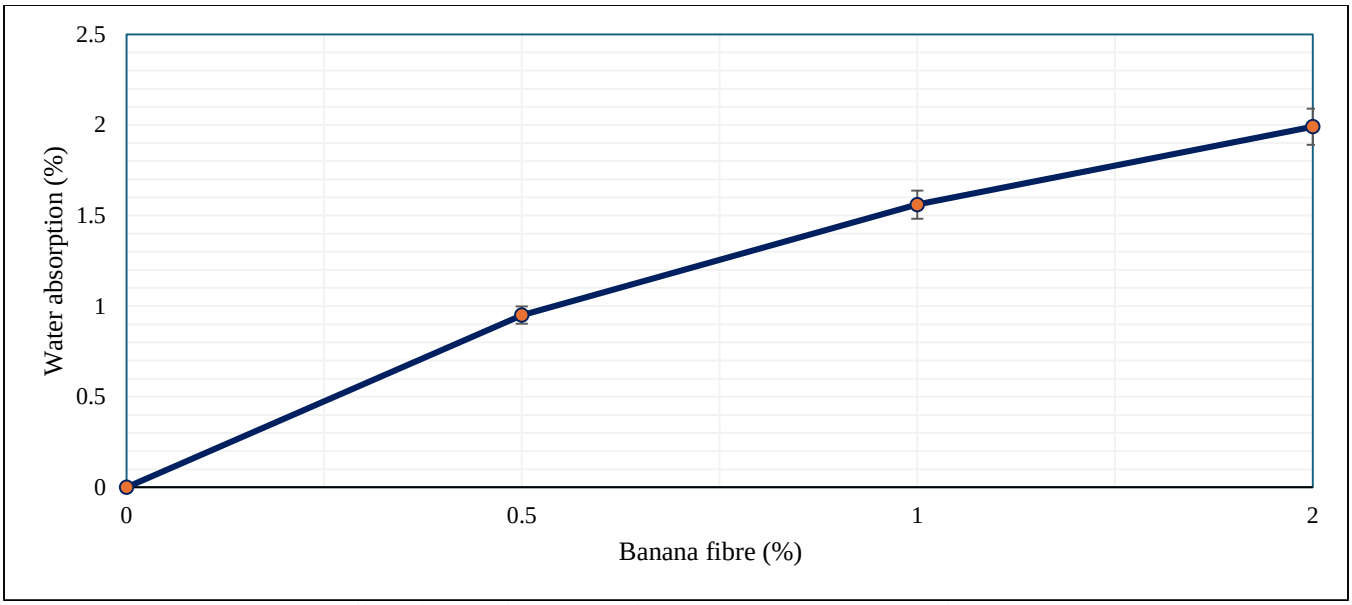


Fig. 18 Effects of banana fibers volume fraction on the water absorption of the composite

Figure 18 shows the water absorption of the composite containing banana fibers. The water absorption at 0.5% volume fraction of banana fibers is 0.95%, as the volume fraction increases to 1%, the water absorption also increases to 1.56%. A further increase of banana fiber volume fraction from 1 % to 2 % results in increased water absorption to 1.99%. Figure 18 shows that water absorption is increasing with volume fraction from 0.5% to 2%. The results are consistent with a study by Sengottaiyan et al., 2025 who stated that banana fibers contain hydrophilic components, including cellulose, hemicellulose, and lignin that hold moisture. However, the water absorption of the banana fibers is decreased due to the alkali treatment, which has been carried out, which lowers the fibers' attraction for water by eliminating contaminants and surface wax.

3.7. Comparisons of this Study with other Studies

Table 3 presents the results of current studies along with comparisons to published research.

Table 3. Comparisons of this study with other studies

Properties	Current study	Comparison with published studies	
Tensile strength	12.98 MPa at 2% volume fraction	14 MPa Kenaf at 15% volume fraction [29]	Sisal tensile strength is 7.24 MPa 100% sisal fibers [30]
Compression strength	4.31MPa at 1% volume fraction	A compressive strength of 31Mpa is obtained for 15 % Ensete fiber content and 85 % resin [31]	Areca sheath fiber had 31.02 MPa [32]
Flexural strength	49.54MPa at 0.5% volume fraction	40.1MPa polylactic acid with hemp [33]	100% sisal fiber, displays the flexural strength of 5.18 MPa [30]
Leeb hardness	523HL at 1% volume fraction	Ramie 30% volume fraction attained 92 Shore D hardness [34]	5% had Highest Leeb hardness of sawdust fiber [22]. The increase in fiber content decreases Leeb hardness.
Water absorption	1.99% at 2% volume fraction	Jute exhibits the least water absorption, with 1.5% after 24 h and 2% after 48 h[35]	Sisal exhibits the highest weight gain, with 4.5% after 24 h and 6% after 48 h [35] Hemp shows 3.5% after 24 h and increases to 4% after 48 h [35]

Biodegradability	3.08 at 2% volume fraction	Kenaf lost weight of 38% after 4 weeks [36]	Hemp fiber lost 0.99% in 90 days [37]

4. Conclusion

The study experimental investigated how different amounts of banana Fibers influence their mechanical properties, water absorption and biodegradable. Based on the experimental findings, the following conclusions can be drawn.

- The maximum banana fiber moisture absorption of 10.2 % was recorded after 2 hours at a temperature of 25℃. Interior panel composites are generally not exposed to harsh moisture operating conditions. However, interior panels are frequently cleaned using a wet cloth, and hence it is necessary to control the moisture and water absorption.
- When observed under SEM, the banana fibers showed a smooth, translucent and rounded shape. However, after it was treated with sodium hydroxide, the surface roughness increased irregularity, presenting a more textured appearance. This modification suggests that the treatment successfully changed the fibers' structural characteristics, which may improve their suitability for composite manufacture due to increase in bond strength.
- Banana fiber in this study was treated using alkaline treatment to modify its surface morphology and enhance the hemp fiber interface.
- Banana fiber composite gave a maximum Leeb hardness of 523 at 1% volume fraction; the addition of fiber volume fraction decreased the Leeb hardness.
- The composites made of banana fibers only gave a maximum tensile strength of 14.71 MPa at a 2% volume fraction.
- The compression strength of the banana fibers only composite was 4.31 MPa, and it was obtained at a volume fraction of 1%.
- The highest flexural strength of the banana fiber only composite was 49.54 MPa at a volume fraction of 0.5%. Furthermore, as the banana volume fraction increased, the flexural strength decreased, reaching 36.51 MPa at a volume fraction of 2%.
- The biodegradability of banana fibers only composites increased as the volume fraction of the composite increased from 0.5% to 2%. The initial weight loss was 1.57% at 0.5 volume fraction of composite and 3.08% weight loss at 2% volume fraction.
- The composite made of banana fibers had a maximum water absorption of 1.99% at a volume fraction of 2%.

In conclusion, the increased need for environmentally friendly and renewable resources has speeded up the development of biocomposites, particularly those composed of natural fibers and biodegradable polymers. These materials have several benefits, especially in the automotive industry, where their mechanical and thermal characteristics make them a competitive substitute for conventional materials. They may be a helpful answer to the waste management issue associated with polymer-based materials due to their compostability.

The developed natural fiber composite shows promise for environmentally friendly and lightweight automobile interior applications by lowering the need for synthetic materials while preserving respectable mechanical performance. However, more study is advised to investigate fire resistance, thermal stability, long-term durability, and the viability of large-scale production. To facilitate industrial adoption, future research should assess the composite in real-world service circumstances and conduct cost and life-cycle evaluations.

The study was carried out in compliance with recognized standards of ethical responsibility and research integrity. To ensure that no endangered or protected plant species were exploited, the banana fibers utilized in this study were sourced legally. By using renewable resources and agricultural byproducts that might otherwise contribute to waste, the materials were sourced with sustainability in mind. There are no conflicts of interest with regard to this work's release.

Funding Statement

This study is funded by Vaal University of Technology

Acknowledgments

This research work was supported by Vaal University of Technology. The authors wish to thank the Department of Industrial Engineering, Operation management and Mechanical Engineering at Vaal University of Technology for facilitating this work.

Reference

[1] V. Indira et al., *Environmental Degradation due to Synthetic Fibres*, Natural Fiber Composites for a Sustainable Environment, CRC Press, pp. 279-293, 2026. [Google Scholar] [Publisher Link]

[2] L. Lebreton et al., "Evidence that the Great Pacific Garbage Patch is Rapidly Accumulating Plastic," *Scientific Reports*, vol. 8, no. 1, pp. 1-15, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[3] Sifiso John Skosana, Caroline Khoathane, and Thomas Malwela, "Driving Towards Sustainability : A Review of Natural Fiber Reinforced Polymer Composites for Eco-Friendly Automotive Light-Weighting," *Journal of Thermoplastic Composite Materials*, vol. 38, no. 2, pp. 754-780, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[4] Nageh M. Ali, Xin Wang, and Zhishen Wu, "Integrated Performance of FRP Tendons with Fiber Hybridization," *Journal of Composites for Construction*, vol. 18, no. 3, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[5] Maher A. Adam et al., "Analytical and Experimental Flexural Behavior of Concrete Beams Reinforced with Glass Fiber Reinforced Polymers Bars," *Construction and Building Materials*, vol. 84, pp. 354-366, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[6] Estelle Pallaro et al., "Sustainable Production and Consumption in the Automotive Sector: Integrated Review Framework and Research Directions," *Sustainable Production and Consumption*, vol. 4, pp. 47-61, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[7] Macaulay M. Owen et al., "Characterization of Recycled and Virgin Polyethylene Terephthalate Composites Reinforced with Modified Kenaf Fibers for Automotive Application," *Polymer Composites*, vol. 43, no. 11, pp. 7724-7738, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[8] Xianhui Zhao et al., "Recycling of Natural Fiber Composites: Challenges and Opportunities," *Resources, Conservation and Recycling*, vol. 177, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[9] Ana M. Díez-Pascual et al., "Influence of Carbon Nanotubes on the Thermal, Electrical and Mechanical Properties of Poly (Ether Ether Ketone)/Glass Fiber Laminates," *Carbon*, vol. 49, no. 8, pp. 2817-2833, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[10] Waseem Shahri, Inayatullah Tahir, and Burhan Ahad, *Abaca Fiber: A Renewable Bio-Resource for Industrial Uses and Other Applications*, Biomass and Bioenergy: Processing and Properties, Springer, pp. 47-61, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[11] Sultan Ullah et al., "Review : Natural Fiber-Based Biocomposites for Potential Advanced Automotive Applications," *Journal of Engineered Fibers and Fabrics*, vol. 20, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[12] J.Y. Ahn et al., "Comparison of Oven-drying Methods for Determination of Moisture Content in Feed Ingredients," *Asian-Australasian Journal of Animal Sciences*, vol. 27, no. 11, pp. 1615-1622, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[13] ASTM A956, *Standard Test Method for Leeb Hardness Testing of Steel Products*, Advancing Standards Transforming Markets, pp. 1-13, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[14] ASTM D3518, *Standard Test Method for In-Plane Shear Response of Polymer Matrix Composite Materials by Tensile Test of a ±45° Laminate*, Advancing Standards Transforming Markets, pp. 1-7, 2007. [Google Scholar] [Publisher Link]

[15] ASTM D6641, *Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture*, Advancing Standards Transforming Markets, pp. 1-13, 2023. [CrossRef] [Publisher Link]

[16] ASTM D8058-17 , *Standard Test Method for Determining the Flexural Strength of a Geosynthetic Cementitious Composite Mat (GCCM) Using the Three-Point Bending Test*, Advancing Standards Transforming Markets, pp. 1-6, 2017. [CrossRef] [Publisher Link]

[17] ASTM D570-98(2018), *Standard Test Method for Water Absorption of Plastics*, Advancing Standards Transforming Markets, pp. 1-4, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[18] V.K. Gupta, and S.S. Bairwa, "Effect of Alkali Treatment on Physical Properties of 100% Polyester Fabrics," *Melliand International*, vol. 26, no. 4, pp. 188-189, 2020. [Google Scholar] [Publisher Link]

[19] Rui-Hua Hu, Min-young Sun, and Jae-Kyoo Lim, "Moisture Absorption, Tensile Strength and Microstructure Evolution of Short Jute Fiber/Polylactide Composite in Hygrothermal Environment," *Materials & Design*, vol. 31, no. 7, pp. 3167-3173, 2010. [CrossRef] [Google Scholar] [Publisher Link]

[20] Sarah Yasmien Zakaria et al., "A Review on the Effects of Sodium Hydroxide Pre-Treated Natural Fibres on the Surface Morphology and Sound Absorption Performance," *AIP Conference Proceedings*, vol. 2881, no. 1, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[21] Upendra Sharan Gupta et al., "Study on the Effects of Fibre Volume Percentage on Banana-Reinforced Epoxy Composite by Finite Element Method," *Advanced Composites and Hybrid Materials*, vol. 3, no. 4, pp. 530-540, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[22] Budrun Neher et al., "Fabrication and Characterization on Physico-Mechanical and Structural Properties of Sawdust Reinforced Acrylonitrile Butadiene Styrene (ABS) Composites," *Materials Sciences and Applications*, vol. 11, no. 9, pp. 644-658, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[23] Mahfujul Islam et al., "Study on Physio-Mechanical Properties of Rice Husk Ash Polyester Resin Composite," *International Letters of Chemistry, Physics and Astronomy*, vol. 53, pp. 95-105, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[24] Mohammad Ismail et al., "The Investigations on the Physico-Mechanical Properties of Jute Fiber Reinforced Unsaturated Polyester Resin (UPR) Composites," *Chemical Science International Journal*, vol. 22, no. 1, pp. 1-14, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[25] Saravanakumar Sengottaiyan et al., "Influence of Treatment and Fly Ash Fillers on the Mechanical and Tribological Properties of Banana Fiber Epoxy Composites : Experimental and ANN- RSM Modeling," *Composite Interfaces*, vol. 32, no. 7, pp. 953-986, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[26] Shyamkumar Mani et al., "A Comprehensive Review on Multilayered Natural-Fibre Composite Reinforcement in Geopolymer Concrete," *Cleaner Materials*, vol. 16, pp. 1-15, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[27] Robson Balcha et al., "Mechanical Behaviour Assessment of Banana Fibres Reinforced Polymeric Composite with Aluminium-Powder Filler," *Jordan Journal of Mechanical and Industrial Engineering*, vol. 17, no. 2, pp. 269-279, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[28] K.N. Bharath, R.P. Swamy, and Kumar G.C. Mohan, "Experimental Studies on Biodegradable and Swelling Characteristics of Natural Fibers Composites," *International Journal of Agriculture Sciences*, vol. 2, no. 1, pp. 1-4, 2010. [Google Scholar] [Publisher Link]

[29] Pengju Pan et al., "Kenaf Fiber/Poly (ε-caprolactone) Biocomposite with Enhanced Crystallization Rate and Mechanical Properties," *Journal of Applied Polymer Science*, vol. 107, no. 6, pp. 3512-3519, 2008. [CrossRef] [Google Scholar] [Publisher Link]

[30] K. Sunil Kumar et al., "Mechanical Characterization of Sisal Fiber-Groundnut Shell Powder Reinforced Epoxy Composites," *Scientific Reports*, vol. 15, no. 1, pp. 1-17, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[31] Gurumurthy Ramaiah et al., "Industrial Crops & Products Extraction of Ensete Fibers and its Woven Fabric Green Composite Development for Ceiling Board Applications," *Industrial Crops and Products*, vol. 223, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[32] M.G. Madhu, and Kishor Buddha, "Mechanical Evaluation of Epoxy Polymer Composites Reinforced with Areca Leaf Sheath Fiber," *ACS Omega*, vol. 10, no. 24, pp. 25663-25674, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[33] Srenatthan Palanisamy, Kulandaivelu Palanisami, and Vairavel Madeshwaren, "Nano Iron Particles Influence on Mechanical Properties and Morphological Analysis of Polymer Composites," *Matéria Journal*, vol. 30, pp. 1-17, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[34] Ajithram Arivendan, Winowlin Jappes Jebas Thangiah, and Dawood Ahmed Desai, "Ramie Natural Fibre - Reinforced Biodegradable Composites: Mechanical, Absorption and Thermal Behaviour Study," *Iranian Polymer Journal*, vol. 33, no. 1, pp. 35-43, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[35] B. Deeban et al., "Mechanical , Moisture Absorption, and Morphological Analysis of Epoxy Composites Reinforced with Natural Fibres," *Iranian Polymer Journal*, vol. 35, pp. 611-635, 2026. [CrossRef] [Google Scholar] [Publisher Link]

[36] A.A. Yussuf, I. Massoumi, and A. Hassan, "Comparison of Polylactic Acid/Kenaf and Polylactic Acid/Rise Husk Composites: the Influence of the Natural Fibers on the Mechanical, Thermal and Biodegradability Properties," *Journal of Polymers and the Environment*, vol. 18, no. 3, pp. 422-429, 2010. [CrossRef] [Google Scholar] [Publisher Link]

[37] Nurhan Çevik Elen, Musa Yıldırım, and Yasin Kanbur, "Examining the Mechanical and Biodegradable Characteristics of Hemp Fiber Added PLA Bio-Composites with Various Modifications," *Journal of Thermoplastic Composite Materials*, vol. 38, no. 9, pp. 3535-3558, 2025. [CrossRef] [Google Scholar] [Publisher Link]