REVIEW ARTICLE

Evaluation of the Physico-Mechanical Characteristics of Composites using Banana Fiber: In-Depth Review Findings

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ABSTRACT: In today's quickly modernizing world, the use of composite materials and environmental pollution, as well as the employment of renewable and biodegradable resources, are intimately related. Finding sustainable materials is the focus of an environmental researcher. Both natural and synthetic fibers come in a variety of shapes and sizes. Recently, natural fibers have attracted the attention of scientists, engineers, and researchers as an alternative reinforcement for fiber-reinforced polymer composites. Because of their low cost, low density, non-toxicity, acceptable mechanical quality, high specific strength, non-abrasive nature, eco-friendliness, and minor waste disposal difficulties, they are utilized to replace more conventional fibers like glass, aramid, and carbon. Researchers have looked into the potential applications of natural fibers in great detail. Other fibers, such as banana, jute, coir, abaca, sisal, straw wheat, rice husk, pineapple leaf fiber, cotton, oats, and bagasse, have grown in importance over the past ten years. The banana (*Musa sapientum*) plant is a massive herb, a major fruit crop, and an ancient species that is planted all over the world. Bangladesh produces the most bananas in the world. The banana plant also produces banana fiber, a kind of textile fabric, in addition to the delicious fruit. Paper, polymer composite reinforcement, and teabags are a few applications for banana fiber. Banana fiber can be produced from the stems of banana plants, which are native to Southeast Asia and are discarded when the fruit is collected. When banana fibers are utilized as reinforcement, the physical, chemical, and mechanical properties of the polymer composites have greatly improved. The current study provides a thorough investigation of banana fiber reinforced composites and their potential applications. Combining banana fiber with some modern technology will help to reduce waste, boost energy efficiency, and enhance sustainability. In this study, banana fibers are investigated in terms of their utilization, mechanical qualities, and potential applications.

KEYWORDS: Banana fiber, polymer composites, chemical compositions, mechanical properties, compression moulding

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INTRODUCTION

A sizable fraction of the several synthetic materials that have been considered as iron and steel substitutes for use in automobiles are plastics. In order to solve the lack of plastic materials over the past ten years, synthetic materials have been researched as alternatives, and the study of filled plastic composites has shown tremendous interest in doing so [1].Almost everything is made of plastic, from simple everyday items to intricate buildings, machine parts, etc. [2, 3]. Due of its low weight, low water absorption, high rigidity, and strength, plastics are used extensively. Actually, the reinforcing of plastics is frequently done with synthetic fibers like nylon, rayon, aramid, glass, polyester, and carbon. There is currently a need to look for an alternative, which is only natural, due to the unpredictability of the pricing, supply, and availability of petroleum and it's by products. Vegetable and plant fibers have recently shown themselves to be a viable substitute for synthetic fibers. Natural fibers are less expensive, biodegradable, and safe for human consumption. Additionally, natural fiber reinforced fibers are seen to have good promise as a replacement in the future. Natural fibers are taken from various plant sections and categorized in accordance with their source.

It's noteworthy to note that while natural fibers like abaca, jute, vetiver, palmyra, coir, banana, bagasse, sisal, etc. are widely available

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in developing nations like Bangladesh, India, Sri Lanka, and some African nations, they are not always used to their full potential. These fibers are being utilized in a traditional way to make goods including wall hangings, table mats, handbags, and purses as well as yarn, rope, mats, and matting. In addition to being employed in the paper business, fibers including cotton, pineapple, and banana are also used to make clothing. Plant fibers utilized as reinforcement materials in composite fabrication include flax, sisal, cotton, ramie, hemp, jute, banana, bamboo, pineapple, kenaf, and wood, which has long been a source of lignocellulose fibers. Natural fiber composites are extremely eco-friendly and are widely utilized in a variety of industries, including transportation (aerospace, railroad coaches, autos, etc.), construction (partitions, ceiling paneling), structures, and military applications. Figure 1 depicts the classification of natural fibers.

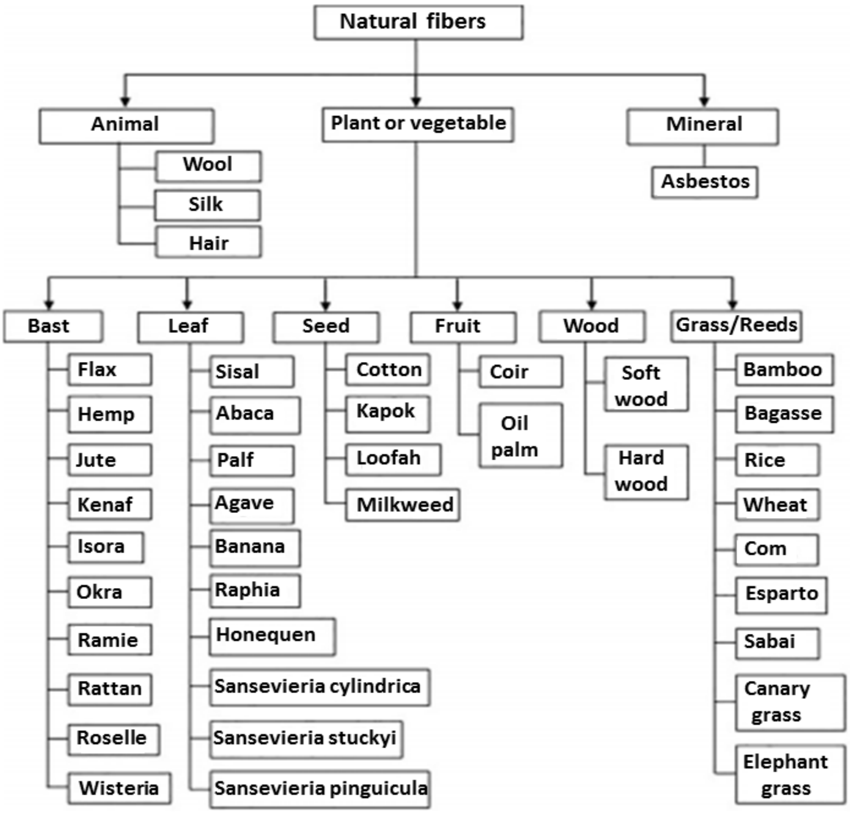

Figure 1: Sorting natural fibers into categories.

Due to the presence of cellulose in the cell structure, the majorities of plant fibers have a moisture content of 8–13% and are hydrophilic in nature. Plant fibers contain additional natural compounds besides cellulose. The most crucial is lignin. Plant fibers are influenced by their lignin content in terms of form, characteristics, and structure. The level of polymerization is another crucial aspect of plant fiber. The maximum degree of polymerization, which is around 1000, is found in bast/stem fibers like flax, jute, hemp, kenaf, and ramie, according to Joseph et al., [4]. In order to give polymers certain desirable features, such as reducing shrinkage after molding and creep resistance, a variety of cellulosic products and wastes, such as shell flour, wood flour, etc., have been utilized as fillers [5-7]. Banana fiber differs from other natural fibers in that it has a number of unique qualities. Banana trees are used to harvest banana fiber. One of the strongest natural fibers in the world is banana fiber, sometimes referred to as Musa fiber. The natural fiber is created from the biodegradable stem of the banana tree. The outer sheaths of banana plants yield thicker, stronger fibers, whereas the inner sheaths yield softer fibers. Banana leaves and the pseudostem banana core, according to Bilba [8], were studied as two parts of a banana tree. Since banana leaf fibers had less double links than other fibers, it was thought that the presence of more hydrogen in banana leaf fibers was related to this. The tall herbaceous plant known as the banana (2–16 m) has a pseudo-stem comprised of tightly overlapping long fibers. Banana fiber has strong tensile, flexural, and resistant properties, according to Samel [9]. Further research revealed that the majority of studies used pseudo-stem banana fiber, including William Jordan [10], Shih, and Yeng-Fong [11].

The sound of a stone striking an automobile can be muffled using banana fiber. Banana fiber is the first high-quality fiber component. Ibrahim [12] asserts that lignocellulose waste can be converted into banana fiber and banana microfibrils using alkaline pulping and steam evaporation. All lignocellulose fibers, including cellulose, hemicelluloses, and lignin, are said to be chemically identical, according to William Jordan [10]. For the same plant species, they will be the same. Lignocellulose has a wide range of mechanical properties. This may be influenced by storage, transportation, and the life cycle of the extracted fiber. According to Shih [11], raw banana fibers that have been manually detached from the stem are used to enhance the properties of natural banana fibers that have undergone chemical surface modifications. The banana fiber is treated three times: once with NaOH, twice with saline acetone, and once with detergent. As we have noted in several papers [13], encouraging natural fibers in composite materials can greatly reduce the greenhouse effect. Therefore, the aim of our study was to investigate the physico-mechanical characteristics of thermoplastic/thermoset composites based on banana fiber.

Banana Fibers: Structure and Characteristics

Banana trash from banana growing is widely available around the world as banana fibers. Banana fibers are extremely advantageous due to their low density, light weight, low cost, water and fire resistance, and excellent tensile strength [14]. They are also environmentally benign. The banana plant and extracted banana fibre as shown in Figure 2[15].

Figure 2: Banana plant and banana fiber[15]

Embedded cellulose microfibrils in an amorphous matrix of hemicelluloses and lignin make up the lignocellulosic materials known as banana fibers. The mechanical properties of fibers are influenced by both their cellulose concentration and micro fibril-angle. Banana fiber can get the necessary mechanical properties by having a high cellulose concentration and a low microfibril angle. Contrarily, lignins are linked to hemicelluloses and considerably increase the lignocellulosic material's natural resistance to degradation [14, 16].

Using a process called water retting, banana fibers are removed. Banana stems from a farm were acquired and submerged completely in clean, drinkable water for six weeks. The stems were then taken out of the water, loosened, and cleaned in a tank of fresh water. As a result, the fibers were sun-dried before being manually combed to further unravel them. After that, the isolated fibers were trimmed to the required lengths [17].

Natural fibers are primarily categorized as mineral, animal, and vegetable fibers. Based on their main structural components, cellulose, hemicellulose, and lignin, vegetable fibers, also known as lignocellulosic fibers, are classified chemically as wood and nonwood fibers. Due to its widespread natural occurrence, cellulose is the most common biopolymer on the planet. In addition to being a food additive, it is utilized in a variety of industries, including packaging, textiles, and paper. Long chains of glucose anhydride unit molecules, which can total up to 15,000 molecules in length, make up the polymer known as cellulose. The cohesiveness of the glucose anhydride particle is caused by beta bonds [1,4]. This bonding arrangement causes the cellulose molecule to have a linear form, as seen in (Figure 3) [17]. Hemicellulose is a naturally occurring polymer made of carbohydrate monomers, just like cellulose. Monomers of glucose, arabinose, mannose, galactose, and xylose make up hemicellulose [18]. Figure 4[18] shows a typical hemicellulose molecule in detail.

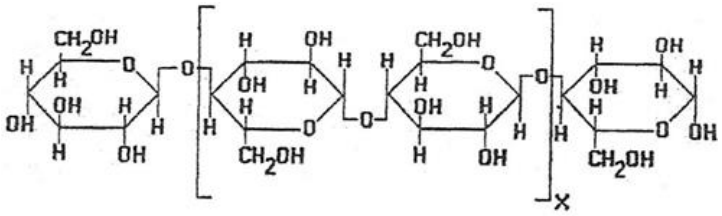

Figure 3: Cellulose molecule [18]

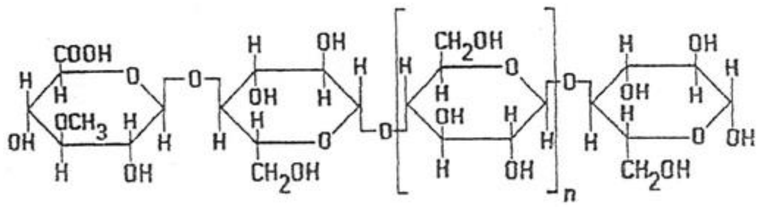

Figure 4: Structure of Hemicellulose [18]

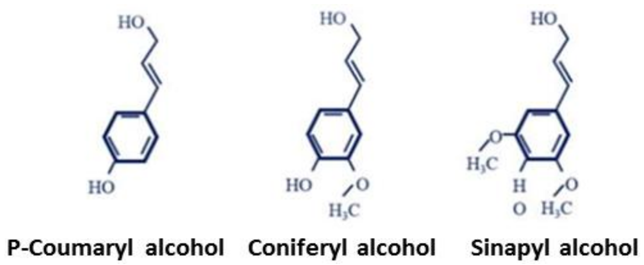

Figure 5: Structure of lignin precursors [18]

About 30% of the organic carbon in the biosphere is made up of the huge, diverse macromolecule lignin. Unlike the other carbohydrate-based substances cellulose and hemicellulose, lignin is entirely amorphous and acts as the glue that holds the cells together, contributing to the integrity of the cell wall. According to (Figure.5) [18,19], three predecessors determine the aromatic structure of lignin.

One of the earliest plants in the world to have been domesticated is the banana, which is a well-known fact. Arabic-speaking people use the word "banana" to refer to a 'finger'. There are just 20 kinds used for food out of the 300 species that make up the Musaceae family. The production of bananas worldwide, in tropical and subtropical areas, is over 70 million metric tons per year [20-22].Banana (100 g pulp) has the following nutritional value: 18.8 g of carbohydrates, 1.15 g of protein, 0.18 g of fat, 73.9 g of water, 0.83 g of other minerals, and 81 kcal [12]. Typically, banana plants produce 30 big leaves, each measuring between 30 and 60 cm in width and approximately 2 meters long [23].By Justiz-Smith et al. [24], fiber samples were put through a series of standardized characterization tests, including checks for ash and carbon content, water absorption, moisture content, tensile strength, elemental analysis, and chemical analysis. Additionally, they collected micrographs of the fiber strands' longitudinal and cross-sectional areas in bananas. Table 1 [24, 25] provides a list of the physical and chemical characteristics of cellulosic fibers.

Additionally, Murali Mohan Rao and Mohan Rao [26] used optical laser beam equipment to analyze the banana's cross-sectional size. Their findings revealed that the banana fiber used for the analysis has a cross-sectional area of 0.3596 mm^2.At various degrees of the fiber cross-orientation, section's the cross-sectional dimensions of the fibers are measured. The analysis led to the prediction that the cross-sections of the fibers are roughly round. Additionally, it was shown that the type of fiber and cross-sectional curvature affect the amount of laser beam diffraction. As a result, rather than providing the precise cross-sectional area, the test provides relative morphologies of the fiber. Using optical microscopy, Kulkarni et al. [27] looked into the cellular makeup of banana fiber. It demonstrates that banana fiber is made up of four different types of cells: xylem, phloem, schlerenchyma, and parenchyma. The various cells identified in fibers of varying diameters are listed in Table 2. Additionally, they noticed in this investigation how the mechanical property fluctuated in relation to the fiber diameter, as shown in Table 3.

Table 1: Physical and chemical properties of natural cellulosic fibers [24, 25]

Physical properties	Fibers		
	Banana	Coir	Bagasse
Moisture content (wt%)	85.6	27.1	52.2
Water absorption (%)	40	169	235
Ash content (%)	8.3	5.1	4.5
Carbon content (%)	50.9	51.5	53
Chemical properties			
Cellulose (wt%)	43.46	32.65	30.27
Hemicellulose (wt%)	38.54	7.95	56.73
Lignin (wt%)	9	59.40	13.00

Table 2: Number of different cells and banana fiber helix angle with different diameter[27]

Diameter of fiber (μm)	Avg. no. of xylem cells	Avg. no. of phloem cells	Avg. no. of sclerenchyma cells	Total no. of cells	Fraction of sclerenchyma cells to the total no. of cells	Helix or Microfibrillar angle (θ)
100	3	6.25	53	62.25	0.850	12 ± 1^o
150	3	8.00	70	81.00	0.875	11 ± 2^o
200	4	7.75	92	103.25	0.886	11 ± 1^o

Table 3: Different diameter banana fibers mechanical characteristics Gauge length:50 × 10^{-3}[27]

Sample no.	Diameter of fiber (μm)	IYM (GN/m^2)	SD IYM (GN/m^2)	BS (MN/m^2)	SD BS (MN/m^2)	% Strain	SD % strain
1	50	32.70	8.19	779.07	209.30	2.75	0.95
2	100	30.46	4.68	711.66	239.61	2.46	0.79
3	150	29.74	8.56	773.00	297.10	3.58	1.11
4	200	27.69	7.08	789.28	128.55	3.34	0.68
5	250	29.90	4.05	766.60	165.51	3.24	1.28

IYM: Initial Young's modulus; BS: breaking strength

Physico-Descriptive Information

Understanding how natural fiber reinforced polymer composites react to environmental factors, such as moisture absorption dependent on humidity, is crucial during the production process. Numerous studies and discussions have been conducted on the effects of environmental conditions on natural fiber reinforced composites. The physical and chemical behavior of freshly created composites affects their viability for commercial use [28].

The densities and water absorption capabilities of banana fiber reinforced high density polyethylene composites were evaluated by Neher et al. [29]. The examples were created utilizing the hot press molding process on Paul-Otto Weber hydraulic press equipment with fiber contents of 0, 5, 10, 15 and 20 weight percent. It was found that when fiber loading increased, so did the composites' density. Composites absorb more water as their fiber loading and aging rates rise. Water may enter the samples from the interfacial or cutting side of the specimen, allowing hydrogen bonding between the water molecule and the OH group of the cellulose molecule. The opening 24 hours saw a rapid uptake of water, which has since stabilized. As the passage of time goes on, the water uptake reaches a steady state, beyond which the water behaves like a free entity in the void structure and does not contribute to future expansion.

The water absorption behavior of untreated banana fiber reinforced polyester composites was investigated by Muktha and Gowda [30]. Randomly oriented fibers of length 10 ± 1 mm in volume fractions of 5%, 10%, 15%, 17.5%, and 20% were used to create the samples of 3 and 5 mm thickness. A water absorption test was performed in accordance with ASTM D 570-98 guidelines. It was discovered that the 3 mm thick samples' capacity to absorb water is lower than the 5 mm thick samples'.

The influence of nonwoven banana fiber loading (10, 20, 30, 40, and 50 wt%) on the water absorption behavior of produced composites was noticed by the authors [31]. It has been noted that as fiber loading and duration increase, so does water uptake. Comparing composites with and without chemical treatment, the composites' rate of water absorption decreased. This improvement might be brought about by the removal of extra OH groups from the surface of the fiber by the NaOH solution, which hardens the fiber and lowers its permeability.

The effects of chemical treatment and the addition of a compatibilizer on the water uptake behavior of composites reinforced with banana fibers in low density polyethylene were examined by Prasad et al. [32]. Compression molding was used to create composites with various fiber loadings. The samples were evaluated in accordance with ASTM D570-98 guidelines. The outcome demonstrated that composites' rate of water absorption increases when fiber content rises from 10 to 30 weight percent. The fiber's hydrophilic properties were mostly to blame for this behavior. The primary component of natural fibers is cellulose, which has hydroxyl groups (—OH) that form hydrogen bonds with other molecules.The incompatibility between banana fibers and the matrix material causes more microvoids to form in polymer composites, which is another factor contributing to greater water uptake. When compared to untreated fiber reinforced composites, the modified composites' ability to absorb water dropped noticeably. The samples with fiber treated with acrylic acid and low density polyethylene grafted with maleic anhydride showed the greatest results. This enhancement results from the treatment of acrylic acid, which replaces the OH group with hydrophobic ester groups. Additionally, the acrylic acid-treated fibers and the low density polyethylene matrix are chemically linked by the maleic anhydride graft, which reduces the formation of micro-voids.

The water absorption behavior of recycled high density polyethylene biocomposites reinforced with banana fiber and filled with fly ash cenospheres was investigated by Satapathy and Kothapalli [33]. According to the experimental findings, all prepared specimens absorbed more water linearly as immersion time increased. The water absorption was further lowered with the addition of fly ash cenosphere filler to the biocomposite after MA-g-HDPE and banana fiber were incorporated into the recycled high density polyethylene matrix. The fly ash enospheres in the fiber and matrix voids prevent water from penetrating deeper into the specimen. Better interaction between the fiber and matrix as a result of the addition of MA-g-HDPE leads to a reduction in the rate of water absorption.

The water absorption properties of ultrasonically treated banana fiber reinforced vinyl ester composites were studied by Ghosh et al. [34]. The fibers were first treated with alkali, and then they underwent ultrasonic treatment. The samples were made using a hand layup technique. The earliest phases see a sharp rise in water absorption. The process of absorbing water first adheres to Fickian diffusion, but later adopts non-fickian diffusion.

Banana Fiber Reinforced with Thermoplastic/Thermoset Composites

Thermoplastic and thermoset polymers have been employed in a number of light-duty applications including construction, automotive, aerospace, and electronic components. Despite the fact that these materials have good qualities, they are brittle by nature. The onset and spread of the crack happen extremely quickly. Thus, the creation of polymer matrix composites (also known as polymer matrix materials) is a solution to these issues [35,36]. Interfacial adhesion, shape and orientation of the dispersion phase added, and matrix characteristics are some of the variables that affect the overall property of polymer matrix composites. Therefore, it is crucial to understand how these materials behave before applying them in the actual world.

Low-density polyethylene composites reinforced with banana fibers has their mechanical behavior investigated by Zaman et al., [37]. Compression molding was used to create specimens of unidirectional composite material. Under UV light, 2-ethylhexyl acrylate (EHA) and methanol (MeOH) were used to treat banana fibers. In terms of polymer loading and mechanical characteristics, monomer concentration and radiation dose were tuned. In comparison to untreated composites, specimens reinforced with banana fiber that had undergone chemical treatment had better mechanical properties. Optimized banana fibers were once more exposed to an aqueous starch solution (3-7%, w/w) for 2–8 minutes in order to increase the characteristics. The finest mechanical capabilities were displayed by composites comprised of banana fiber that had been treated with 6% starch and soaked for 5 minutes.

The mechanical characteristics of banana fiber/PP composites were examined by Zaman et al. [38] in relation to UV light and monomer concentrations. Different UV radiation doses were applied to banana fibers and matrices. Comparing treated and untreated equivalents, it was discovered that the mechanical characteristics of composites based on irradiated banana fibers and matrices increased dramatically. The 2-hydroxyethyl methacrylate (HEMA) solution was applied to optimized banana fibers, which were then baked at various temperatures for various curing durations to create composite materials. With the amount of polymer loading and mechanical qualities, monomer concentration, curing temperature, and curing time were tuned, and treated composites outperformed untreated composites in terms of mechanical properties.

The mechanical characteristics of banana fiber reinforced low-density polyethylene composites were established by Zaman et al., [39]. Banana fibers were treated with methylacrylate (MA) in MeOH solution and 2% benzyl peroxide using the thermal curing process in order to enhance the mechanical qualities. Regarding polymer loading and mechanical qualities, curing temperature, curing duration, and monomer concentration were all optimized. The majority of the characteristics revealed that curing at 70°C for 30 minutes, 25% MA, and improved mechanical properties. Optimized banana fibers were subjected to a starch solution (2–5% w/w) for 2–8 minutes to further improve the characteristics. In comparison to composites treated with monomers, those constructed of BF treated with 4% starch for 6 minutes had the best mechanical properties.

Using continuous banana fiber and polymer in a weight-to-volume ratio of 70:30, Amir et al., [40] generated high-performance polypropylene composites. The authors made an effort to comprehend the impact of various continuous banana fiber configurations on the mechanical behavior of constructed composites. The three types of fibers employed in this study were raw banana fiber, banana yarn fiber, and banana fiber mat. Test specimens for tensile and flexural strength were evaluated in accordance with ASTM D638 and D790 standards; respectively. In comparison to unreinforced polypropylene, banana yarn reinforced polypropylene composites showed maximum tensile and flexural strength with increases of 294% and 94%, respectively. Raw banana fiber and banana fiber mat reinforced composites, the other two configurations, yielded inconsistent outcomes. Intact and homogeneous bonding between the fiber yarn and the matrix material was confirmed by the surface morphology of broken tensile samples.

The flexural and tensile strength of chopped banana fiber reinforced polypropylene composites was evaluated by Sankar et al., [41]. Composites with polymer to fiber ratios of 80%:20% and 85%:25% were created using chopped fibers with a length of around 1 to 1.5 mm. Before creating the composite, the fibers' surfaces were modified using a 6% NaOH solution treatment and a 1% HCl treatment. According to ASTM D790 and ASTM D638 standards, the flexural and tensile tests were conducted, respectively. Composite specimens were found to have good flexural and tensile characteristics.

By adjusting the alkali treatment concentration, Gunge et al., [42] assessed the mechanical characteristics of woven banana fiber reinforced polyvinyl alcohol composites and found that a concentration of 6 wt% NaOH is close to ideal. Joseph et al., [43] evaluated the impact of mercerization treated banana fiber reinforced phenol formaldehyde composites and found that NaOH treatment increases the resilience of composites.

The tensile and flexural characteristics of untreated and alkali-treated banana fiber composites were studied by Subramanya et al., [44]. Using the vacuum bag method, samples containing 30 weight percent short fibers, measuring 5 to 12 mm in length, and epoxy resins were created. When compared to samples with untreated fibers, the tensile and impact strength of composites reinforced with treated banana fiber increased. Alkali treated composites showed a notable increase in tensile strength of 15.8%. The rough surface of the treated fibers and epoxy resin showed good adherence in the scanning electron microscopic images. Impact strength for the alkali-treated fiber reinforced polymer composites was 0.14 J/m, 27.28% higher than for the untreated fiber reinforced polymer composites.

The impact of fiber orientation (0°, 15°, 45°, 75°, and 90°) on the tensile characteristics of banana fiber reinforced polymer composites was examined by authors [45]. The composites were created using the hand lay-up process. The tensile test demonstrates a direct relationship between fiber orientation and tensile strength. The sample with 0° fiber orientation had the maximum strength of 23.79 MPa, and as the fiber orientation increased, the strength also declined. A sample with a 90° fiber orientation was reported to have a minimum tensile strength of 7.59 MPa.

The mechanical characteristics of untreated banana fiber reinforced epoxy composites, alkali-treated banana fiber reinforced epoxy composites, and nanoclay-filled banana fiber reinforced epoxy composites were compared by Mohan and Kanny[46]. Banana fibers' critical length of 40 mm and fiber concentration were set at 40% and 40%, respectively, in epoxy resin. According to ASTM standards, flexural, tensile, and short beam shear tests were performed. The yield stress, ultimate tensile strength, and elastic modulus values of Nano-clay filled fiber reinforced polymer composites increased by 11%, 26%, and 25% in comparison to untreated fiber reinforced polymer composites, according to the experimental results of tensile tests. Additionally, it was shown that treated fiber composites had greater flexural strength, flexural modulus, and strain at break than untreated fiber composites by 2 times, 7 times, and 23%, respectively. The flexural, tensile, and interfacial characteristics of surface-modified composites were higher than those of untreated fiber composites but lower than those of nanoclay-filled fiber reinforced polymer composites.

The influence of fiber loading (10, 20, 30, 40, and 50%) on the mechanical characteristics of non-woven banana fiber reinforced epoxy composites was investigated by Gairola et al., [31]. For samples with 30wt% fiber content, maximum tensile and flexural strengths of 65.6 and 38.1 MPa, respectively, were noted. At 40 weight percent of fiber, the maximum hardness and impact strength were found to be 45.6 HV and 28.6 J, respectively.

The mechanical behavior of vinyl-ester resin composites reinforced with banana fiber was determined by Ghosh et al., [47]. Hand layup was used to make composite specimens. The prepared samples' tensile, flexural, and impact characteristics were assessed in accordance with the standards. The experimental findings show that banana fiber reinforced composites had ultimate tensile strengths between 112 and 115 MPa while plain vinyl-ester resin had ultimate tensile strengths between 67 and 71 MPa. In comparison to pure resin, the ultimate tensile strength of composites reinforced with banana fiber increased by 67%.Composites reinforced with banana fibers have higher strengths because the matrix's fibers are subjected to additional load. The mean values of flexural strength of the manufactured banana fiber reinforced composites were 10.7% higher than those of the pure resin matrix. When compared to vinyl-ester resin, the composite specimens' impact strength increased by 37%. The matrix's fibers prevent cracks from spreading under impact loading conditions.

The mechanical characteristics of epoxy composites reinforced with needle-punched nonwoven banana fabric were established by Murugan and Kumar [48]. Nine samples were created for this study using different fiber lengths (4, 6, and 8 cm) and volume fractions (20, 30, and 40%) of the total volume of composite material. The experimental study showed that composites' mechanical strength rose up to a fiber length of 6 cm before declining after that. Additionally, it was discovered that after reaching a fiber volume fraction of 30%, the mechanical strength of composites starts to decline.

The influence of fiber inter-ply orientation on the mechanical and free vibration behavior of polyester matrix composites reinforced with banana fiber was examined by Chandrasekar et al., [49]. Using cross-ply laminates ([90°/0°/90°] and [0°/90°/0°]), [0°/45°/0°], four-layered angle ply laminates ([90°/0°] s), and quasi-isotropic laminates ([0°/90°/45°]s, [0°/45°/90°]s, characterizing 50 ± 2 wt% banana fiber reinforced polymer composites was done According to the research, composites with [0°/90°/0°] laminates have better elastic modulus, tensile strength, impact strength, and natural frequency. Quasi-isotropic laminate composites have better flexural characteristics than other configurations.

Utilization of Banana Fiber

Banana fiber previously had relatively little usage and was mostly utilized to create composite materials such as ropes, carpets, and other materials. The usage of banana fibers in insulation materials, concrete blocks, compacted earth blocks, automobile parts, and other specialized composite applications has been studied extensively. Banana fibers are utilized as reinforcement in thermoset plastic products, building materials, and applications in the automotive and transportation industries [50-52]. Banana fiber has been acknowledged for all of its positive attributes as environmental consciousness and the necessity of environmentally friendly fabrics have grown, and its use is now expanding in other industries as well, including clothing and home furnishings. But since the Edo era, it has been employed in Japan to create traditional garments like the kimono and Kagoshima (1600-1868). People there still favor it for summer clothing because it is lightweight and comfortable to wear. Fine pillow covers, tablecloths, curtains, bags, neckties, and other items are also made from banana fiber. Banana silk fiber rugs are likewise highly well-liked all around the world.

A brand-new textile fiber is banana fiber. It is also more detailed, shinier, thinner, and greener. 100 NM of yarn can be spun from banana fiber. Fabric made of banana fiber is incredibly thin, shiny, and somewhat flexible. The lightweight and glossy nature of banana fibers makes them appealing.Highly textured yarn, used for knitting, weaving, decoration, and other decorative uses, is spun using these fibers. In some nations, clothing crafted from banana fiber denotes aristocratic status. In Europe, these fibers are utilized to make socks. These fibers are used to make clothing in the Philippines. Since the 13th century, growing bananas for use in textile production has been a custom in Japan. The under floor protection panels found in opulent vehicles like Mercedes are made of polypropylene reinforced with banana fibers.

Application Prospects for Banana Fiber

In terms of performance, banana fiber outperforms bamboo and ramie fiber. It has numerous positive qualities, including a high tensile strength, luster, low weight, and an excellent capacity to absorb moisture. The majority of banana fiber is utilized to create handmade goods and interior decor. Numerous goods, including paper bags, filter paper, greeting cards, decorative papers, pen stands, lamp shades, and others, can be made using a wide range of these materials. There may be a market for these goods. There are sizable markets for papers made from banana fibers in 25 different nations, including Europe. These papers have a 700-year lifespan, are chemical-free, and are eco-friendly. Banana fibers are being used sparingly by businesses to create mats, ropes, and composite materials.

Additionally, banana fiber is widely used in a variety of products, including 100% chemical-free tissue paper, superior filter papers, paper bags, craft papers, high-quality greeting cards, wedding cards, carry bags, nursery pouches, art papers, decorative papers, tissue papers, bond papers, and paper goods like pen stands, table decorations, land shades, etc. The market for products derived from banana fiber is very strong. Manufactures of handicrafts, house decorations, door mats, Pooja mats, and meditation mats all employ banana fiber. Banana-fiber-based paper has excellent export potential.

CONCLUSIONS AND FUTURE OUTLOOK

Bangladesh is one of the top producing countries of bananas globally; the trash produced by banana plants may result in a number of issues. The effective utilization of banana fiber obtained from the waste has economic advantage for rural and industrial sectors. The possibilities of banana fiber stresses, as well as their real and mechanical properties and their material configuration, are examined in the current work. When compared to other normal filaments, the characteristics of banana strands are better. With the aid of this composite invention, further applications and the use of less expensive goods in outstanding machinery are possible. They are used in a variety of designing disciplines and high-end applications like recreation and outdoor gear, transportation endeavors, aviation, and other industries by combining the advantageous qualities of two distinct materials, cost-effective assembly, adaptability, and other factors. If we are talking about the future of banana filaments, they are really bright since, generally speaking, they are more earth-friendly, lighter, and less expensive than glass fiber or other synthetic fiber composites. Banana fiber is typically useful for materials, building development, and other things when compared to other fibers. The best strength, moisture absorption, hardness, and fineness are found in banana fiber. With this context, it follows that the composites represent the most necessary innovation in the rapidly evolving new thing.

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