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Empirical Study on the Developmental Process of Banana Fiber Polymer Reinforced Composites

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ABSTRACT

Recently, there has been a high increase in research in the field of natural fiber composite. These composites have been the dominant emerging materials thereby substituting conventional materials in agriculture, construction, aerospace and automotive industries. They have lots of advantages and applications which are economical and biodegradable. Such of these natural fibers includes banana, hemp, flax, Abaca, bamboo sisal, jute, acacia, etc. This work aimed at studying the different processes involved in the development of Banana Fiber Reinforced Polymer composite (BFRPC) with special reference on the extraction methods, the treatment method, the molding techniques, their properties and applications in industries. It is hoped that publication of this book will provide the readers better knowledge and understanding on the manufacturing processes of Banana Fiber Composites.

Key words: Banana fiber, BFRPC, Extraction, Molding, Properties, Treatment

INTRODUCTION

Banana fiber is a natural fiber placed in the superimposed leaves which form the pseudo-stem and provide resistance to the banana plant. These fibers run longitudinally along the leaves. [1], [2]. This natural fiber from banana can also be found in the banana-fruit-bunch, also known as the peduncle, or from the banana leaf stalk. It is classified as a hard fiber since it includes strands of whole vascular bundles, including xylem, phloem and true fibers. They are composed mostly of lignified and rougher surface fibers than cotton and kapok and soft fibers such as flax, ramie, jute and hemp. Its inherent drawback is the poor quality and higher irregularity, owing to the multi-cellular nature of the fibers since the individual cells are cemented with lignin and hemi-cellulose and thus form a composite fiber. Banana fiber is also classified as medium quality fiber and performs very well in combination with other fibers for making fine articles like handicrafts, currency, etc. [3]. Also, by adding banana fiber into polymer (thermoplastic and thermoset), a polymer composite with a high specific stiffness and strength can be produced [4]. Furthermore, the couplings between banana fiber and polymer are considered a challenge because the chemical structures of both fibers and matrix are various. As the fiber is hydrophilic in nature while most matrix are hydrophobic. These reasons for ineffectual stress transfer during the interface of the produced composites. Accordingly, modification of banana fiber using specific treatments are certainly necessary. As a result, these modifications lead to an excellent enhancement compatibility between the fiber and polymer matrix, hence improving the fiber property [5]. Such improvements in the fiber property thereby leads to a better application of the entire fiber composite.

This paper therefore studied the different processes involved in the development of Banana Fiber Reinforced Polymer composite; the extraction methods, the treatment method, the moulding techniques, their properties and applications in industries.

BANANA FIBRE EXTRACTION

There are different methods of extracting fiber from the banana plant. However, several of these methods is based on the availability of tools and equipment, and choice of the user. It can be done by water retting, chemical retting, by hand scraping, by mechanical method using Raspador or decorticating machines, etc.

Figure 1: Banana Fiber. [7]

Naturally-occurring banana fiber were extracted by [5] using chemical retting method. The banana trunks were cut into equal parts of four each weighing 2kg. The trunks were completely immersed into the four labeled NaOH containers, covered and allowed to ret for 6 weeks (1008hrs). The pH was monitored daily and was later oven-dried for 72hrs. Reference [6] also carried out banana fiber extraction using hand method. The fibers were extracted from the stems by hand and dried in sunlight for 12 hours until all the moisture is removed from the fiber. The dried fibers are made in the configuration of woven fabric. Reference [7] extracted banana fiber by hand scraping method. The banana stems were de-sheathed and the sheaths flattened. A knife was inserted between the outer and middle layer, and a 50-80mm wide strip is separated and pulled off along the length. All the fibers are removed in strips from each sheath. The strips are then scraped by pulling them through/between a wooden block and a serrated knife (400-2000 serrations/m or no serration) under considerable pressure. The banana fibers were also extracted mechanically by [8] using a special automated machine. Using this method, a cleaned portion of the banana stem is placed on the machine's fixed platform and gripped at both ends by jaws. This prevented the stem from moving relative to one another and prevented the fibers from breaking too soon. The fibers were then cleaned and allowed to dry for three hours at 20ºCelsius in a chamber. Reference [9] extracted banana fibers by crushing technique. The banana stem was first cut into small pieces by a roller crusher. Then, the small pieces were extracted into coarse fiber by a pin-roller. Before the coarse fibers were put in a dehydrator, they were boiled at 90^0c for 10 h to remove their fat and later dried in the rotary dryer. Reference [10] extracted banana fiber from the stems using agro-based machine (in the fig. 2 below). The banana stems are cut into sections of 120-160 cm in length. Stems are fed in through rotating blade of the machine, which crushes and removes the fleshy part and pulpy tissues of the stem, leaving behind fibers. Stem is fed multiple times, in order to get purely extracted fibers. Fibers are further combed and washed in running water to remove the tissues present on it. This machine reduces drudgery of manual extraction of fiber and provides a clean working environment. Extracted fibers are dried for 48 hours.

Figure 2: Fiber Extraction machine [10]

Banana fiber extraction was done by [11] using two methods; the Bacnis method and the Loenit method. The Bacnis method involves the pulling apart of the banana trunks and the sheath separated according to their position in stalk. After that, they are made flat, and the pulpy part is chopped off and the strips are removed to separate the fiber from the stem. One sheath at a time, the strips are removed from the stalk using the Loenit method. In order to scrape away the plant tissue between the fibers, the strips are thus pushed beneath a knife blade that is pressed firmly against the strip. The fiber is then allowed to air dry. Strips are transported to the stripping knife for cleaning in either of these procedures after being wrapped into bundles weighing between 23 and 27 kg.[11].

Reference [12] also extracted banana fiber using hand scraping method. The banana fibers were neatly separated by hand; adhering pith, if any, were removed and the fibers were cut to uniform size of 30 mm length. Mechanical Extraction of Banana Fiber was carried out by [7]. In this method, trunks are cut into sections of 120-180 cm in length. The sections (one half the length at a time) are then crushed between rolls and the pulpy tissues are separated by two large revolving drums, the rim of which are fitted with scrapping blade which peel-off the sheath while it is pressed against a bed plate, oven dried, graded and baled. The extracted fibers are sun-dried which whitens the fiber. Reference [11] also extracted banana fiber using mechanical means.

The trunks are divided into 120–180 cm length segments once the dark outer sheaths have been removed. After the sections are crushed between rolls, the pulpy tissues are removed by two enormous rotating drums, one half the length at a time. The blades on the lip of the drums are designed to scrape the sheath as it is pressed up against a bed plate, oven dried, graded, and baled [11]. The banana fibers were drawn from the banana plants' pseudo-stems by [13] using defibering machine. The pseudo-stems were first air-dried at 18ºC average temperature for 72hrs. The stems were fed to the paddle wheel; the pulp was separated from the stem and the fibers extracted. Bundles of fibers were then placed in water for 12 hours at room temperature to remove impurities and facilitate their separation before being left at room temperature for 6 hours.

Even-though these methods involved in banana fiber extraction are mostly dependent on the availability of the equipment and the choice of the user. However, the mechanical method is the most preferable since it eliminates relative movement of the stem, avoids premature breakage of the fibers and increases fiber production at faster rate as compared to manual process.

TREATMENT OF BANANA FIBER

Banana fiber treatment has been considered by many researchers in modifying the fiber surface so as to enhance proper adhesion between the hydrophilic fiber and the hydrophobic matrix. Banana (*Musa oranta*) fiber treatment was studied by [14] using permanganate chemical treatments. The 15-20cm length fiber was alkali-treated at room temperature. The alkali treated fibers were soaked with KMnO4 solution in acetone having the concentration 0.0555% for 1 min. The treated-fibers were thoroughly washed for several times with distilled water until pH 7, were decanted and air-dried for 48 hours. Reference [15] treated banana fiber using two enzymatic formulation: Biopectinase M01 (made of pectinase and hemicellulase) and Biopectinase K (made of poligalacturonase). Conditions of enzymatic treatment was optimized to produce a textile grade of banana fibers. The treatment time (1 to 8h) and enzyme concentration (1% to 5%) related to fiber weight (r.f.w.) were considered. The usage of Biopectinase K (100% related to fiber weight) at 45 °C and pH 4.5 for six hours, followed by bath renewal after three hours, was determined to be the ideal treatment condition. These fibers can be used to produce yarns, according to the results of the initial spinning trials. Alkaline treatment was applied by [16-17] in treating banana fibers. The fibers were immersed in 6% NaOH solution for 2h at room temperature. After-which the fibers were thoroughly washed by immersion in water tanks, followed by running water. The material is then filtered and dried at 80ºC for 24 h. Reference [18] treated banana fiber using a combination of NaOH and Na_2SO_3, which indicated good bonding of the composite and makes it useful at low tensile loading or under compressive loading such as in ceiling or floor tiles and parapet wall tiles. Two basic chemical treatments were employed by [19] for surface modification of Banana and Kenaf fibers. Fibers (Banana and Kenaf) were treated with 10% NaOH and 10% Sodium Lauryl Sulfate (SLS) for 30 minutes and then washed with distilled water and dried. Banana fiber were treated by [13]. The fibers were chemically-treated with alkali. This treatment induced such modification where fibers were immersed in 5% NaOH aqueous solution for 1h at room temperature (1:15 fiber-to-solution weight ratio). The treated fiber was then washed thoroughly with distilled water to remove excess NaOH from the surface and oven dried at 110ºC. Chemical treatment of banana stem fiber and banana stem fiber/coir hybrid fiber was done by [20]. The fiber was cut into approximately 15 cm long. Then, the lignin from fibers were removed by a bleaching operation with a 7 mg/L $NaClO_2$ solution at pH 4 (buffered by CH_3COOH and CH_3COONa) for 90 min at 353–363 K. Then, the bleached fiber was treated with a 0.2% sodium metabisulfite ($Na_2S_2O_5$) solution for 15 min and finally washed with distilled water.

These treatments which involves Alkali treatment, enzymatic treatment, sodium metabisulfite ($Na_2S_2O_5$) treatment, Sodium Lauryl Sulfate (SLS), combination of NaOH and Na_2SO_3treatment, etc., in all yielded a positive result. But the use of alkali (NaOH) is most preferable since at final stage it yielded better bonding of the fiber and matrix into composite, thereby resulting to a better mechanical property.

MANUFACTURING OF BANANA FIBER COMPOSITE

Different methods of manufacturing banana fiber composite have been reported by many researchers, these methods are the usual conventional method of producing other natural fiber composite, but with slight modification of the equipment. These methods include the hand lay-up method, compression moulding, filament winding, injection moulding, resin transfer moulding, pultrusion and vacuum bag moulding.

According to [21-23], the composite was fabricated using the hand lay-up technique. The mould used for fabricating the composite is made up of aluminum with a de-bonding agent applied on the inner side. The fiber is dipped in the resin and aligned in the mould where the resin is also poured. The upper side is pressed using a roller under room temperature until the matrix is set properly. The setup is left to cure for 24 hours at room temperature and cut for testing. Reference [12] moulded the banana fiber reinforced polyester composites using hand method. The 30mm length fibers were evenly arranged in a mold and pressed into a mat. The composite sheets were prepared by impregnating the fiber with the polyester resin and the air bubbles were removed carefully with a roller. The closed mold was kept under pressure for 12 h to enhance curing at room temperature, and then taken out of the mould. The de-moulded samples were post cured for a period of 24 h at room temperature. Compression moulding technique was used by [9] to prepare banana fiber reinforced PF composite. In this procedure, heat and pressure are applied to the fiber and polymeric materials simultaneously. To do this, hot plates are placed inside a hydraulic press. Silicone mould was used as release agent. 50KN pressure was applied to get the desired shape and homogeneity. Heating was done electrically and the temperature was set at 180ºC. On reaching 180ºC, it was kept heating for about 20 min. After-which the initial pressure was set at zero and an additional pressure of 50KN was applied to avoid voids and to have a thickness. Cooling was done by tap water through the outer area of the heating plates of the machine and the composite was de-moulded.

Reference [16-26] manufactured the banana fiber reinforced epoxy and eco-polyester composites using compression molding technique. Measured quantities of epoxy resin and polyester were mixed with their respective catalyst. The mold was sprayed with Polytetrafluoroethylene (PTFE) release agent and a piece of Teflon cloth was placed on the bottom. A pre-weighed short non-woven banana fiber (55% weight) was placed in the mold and the resin was poured on the fiber network, followed by a layer of Teflon cloth. The mold was closed and the mixture cured at 60^0C (for epoxy) or 80ºC (for polyester) and 2.43MPa, for 3 h (epoxy) or 1.5h (polyester) in a hydraulic press. De-moulding was done at 60^0C for both types of composites. Banana fiber reinforced composite material was prepared by [31]. The extracted banana fibers, were sun-dried, oven-dried and cut into different length. It was mixed with matrix mixture with their respective values by simple mechanical stirring and mixture are slowly poured in different moulds. Releasing agent is used on mould sheet which gives ease to removal of composite from the mould. The liquid mould, after pouring, is heated to 30°C for about 24 hours. A constant load is applied on to the mould. The specimen is then taken out from the mould, after curing. Reference [32] applied the hand lay-up technique in preparing the natural fiber reinforced epoxy hybrid composites. The process involves the application and spreading of wax on the mould surface, then the layer of matrix was applied and spread throughout the mould uniformly. Furthermore, is the placement of the areca woven mat, pouring and spreading of the matrix respectively on the mould and compressed by roller. After which the banana woven mat is now placed and resin is poured onto it and the rolling process repeated. Finally, last layer of areca fiber is placed and remaining matrix material is poured and roller force is applied. The mould was closed and compressive load applied on it, to maintain uniform thickness. After 24hrs the laminate is taken out. The fabrication of banana fiber PF macro-composites by [33], employed the compression moulding (CM) and resin transfer moulding (RTM) methods. In the CM technique, the composite samples were prepared by prepreg method. The resin was poured into the pressed matted fiber in the mould until it was completely soaked. The curing process was completed when the mold was sealed and heated to 130°C for 20 minutes at a pressure of 10 kg/cm^2. In RTM, the dry banana fiber that was put into the mold cavity was injected with phenol formaldehyde. The ideal pressure was kept at 1 kg/cm^2. Vacuum was applied in tandem. By squeezing out any remaining air in the mold, the resin distributes throughout it and impregnates the fiber. The prepared samples were subjected to post-curing operation at 70°C for 1 h for complete curing and then removed from the mould. The pseudo-stem banana woven fabric reinforced epoxy composite was prepared by [6], using the hand lay-up method. The Matrix (epoxy resin and hardener) were mixed in a portion of 4:1 by volume. To prevent air trapping, the matrix material was injected into the mold gradually. To make the mixture a little tacky, it was left for two hours. Then the banana fiber woven fabric was laid on the matrix layer and covered by another layer of matrix. The composite was cured at room temperature until it was dry and then detached from the mould.

Reference [9] also prepared banana fiber composites using the Hand Laminating method. The base plate is fixed inside the frame for fabrication. 70% of resin hardener mixture and remaining natural fibers are used. The mixed resin and hardener is filled in the pattern. The prepared fibers are randomly poured in the resin hardener mixture without any gap. The roller is rolled in the mould. Again, the mould is filled in pattern by next layer and fibers poured randomly. This process is simultaneously done till the height of the mould 10mm.The lid is fixed on the top of the frame to distribute the load evenly on the mould. The setup is kept in the dry place for 24 hours. After which the mould is taking away from the pattern. Thus, it’s shown in the figure below

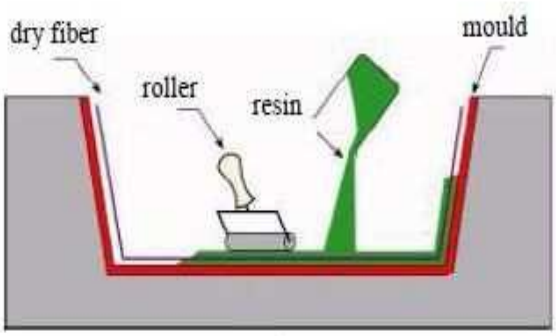

Figure 3: Hand Laminating Method [9]

By employing the hot pressing method, Reference [29] produced Banana Stem Fiber and Banana Stem Fiber/Coir Hybrid Fiber Reinforced Maleic Anhydride Grafted Polypropylene/Low-Density Polyethylene Composites. The dried BSF (at 5, 10, 20, and 30wt %) and 5wt % MAPP were initially mixed thoroughly with LDPE with a single-screw extruder at 433 K. The releasing agent was sprayed on the mold. The mixture was cut into small pieces and spread uniformly on the surfaces of the molds. Polymer composite sheets were prepared by the hot pressing of the mold at 433 65 K for 30 min and the pressure applied ranged from 50kN, depending on the loading of the reinforcing material. Tap water was used to cool the exterior of the heating plates. The specimen was demoulded and post-cured at 50ºC for 12 h.

Hence, the hand layup method is most preferred for making banana fiber composites because of its simple procedure and low cost. At some other times, when requirement is high, other machine molding processes can be employed.

MECHANICAL PROPERTIES OF BANANA FIBER COMPOSITE

The mechanical properties of banana fiber composite could vary based on some factors such as the fiber length, curing temperature, nature of treatment, mould preparation, type of matrix, etc. These properties have been studies by many researchers. Reference [33] analyzed the mechanical properties of banana empty fruit bunch fiber (BEFB) reinforced polyester composites. The incorporation of the BEFB fiber into the polyester matrix shows the moderate improvement in the tensile properties of the composites. The flexural strength is decreased and the modulus increased. The flexural strength decreases further with the increase in volume fraction of fiber. Reference [28] studied the mechanical properties of banana/kenaf polyester hybrid composites using sodium lauryl sulfate treatment which yielded a better result. The SLS treatment provided a better improvement in the tensile strength for non-woven and woven hybrid composites when compared with alkali treatment. The flexural strength of alkali and SLS treated non-woven and woven composites increased by percentage. The impact strength of SLS treated random mix hybrid composite and woven hybrid composites also had a significant increase. Reference [34] discovered that the modification of Brazilian banana fiber HDPE composites allows gains in the mechanical properties compared to the pure polymer. The results showed that the elastic modulus of the interfacial impregnation agents led to an increase in the values of elastic modulus of pure HDPE. The composite of HDPE and external fiber-AL showed that the interfacial agent increased the elastic modulus of the material, suggesting greater interaction between the fiber and the olefin polymer. Reference [13] observed that the mechanical properties of alkali treated banana fiber recorded decrease in the mechanical properties. Young's modulus and ultimate tensile strength decreased as fiber diameter increased in treated and untreated banana fibers due to the presence of a hollow fibril in the center of each fiber cell thereby modifying the fiber’s real cross-section. The mechanical properties of the treated fibers showed decrease and such variations were related to the removal of lignin and hemicellulose from the surface of the fibers, possibly causing weakening in the fiber’s outer wall. The mechanical property of banana stem fiber reinforced natural rubber composite was investigated by [27]. The investigation showed that the strength and modulus were found to increase upon reinforcement of the natural rubber with banana fibers. The angle of fiber orientation to the loading direction was found to have significant effect on the tensile strength, failure strength and elongation at break of the composites. Reference [30] showed that the mechanical properties of untreated/alkali treated banana fiber/epoxy, untreated/alkali treated banana fiber/vinyl ester and treated banana/coconut shell powder/epoxy, treated banana/coconut shell powder/vinyl ester hybrid composites gave a better result. The tensile, flexural and impact strength of both the epoxy/vinyl ester and hybrid composite were improved on alkali treatment. The result therefore showed that alkali treatment provided better mechanical properties as in table 1 below. Banana fiber phenol formaldehyde (PF) composite were studied by [35] using silane treatment, acetylation, cyanoethylation, latex treatment and mercerization with phenol formaldehyde (PF) resin. The treated fiber when compared with the untreated fiber, showed decrease in the tensile strength and modulus for all the treatments except cyanoethylation. Comparing the treated and untreated PF composites, the tensile and flexural properties of the PF fiber-reinforced composites were found to be increased by all the treatments except latex coating. Incorporation of heat treated, vinyl silane treated and acetylated fiber-reinforced PF composites was found to have higher impact strength than that of untreated fiber composites. Reference [29] examined the influence of chemical treatment on the properties of banana stem fiber reinforced maleic anhydride grafted polypropylene/low-density polyethylene composites. The mechanical properties of the composite achieved better result when chemically modification by bleaching, alkalization, and acetylation. All of the treated fibers exhibited better mechanical properties than the untreated ones. Table 1 below shows the results of some reviewed work on the properties of banana fiber treated polymer composite.

Table 1: Review of studies on properties of banana fiber treated polymer composites

Surface Treatment Agents	Matrix	Tensile Strength (MPa)	Impact Strength (j/M^2)	Flexural Strength (MPa)	Tensile Modulus (GPa)	Moulding method	Source
NaOH & Na_2SO_3	Natural rubber	4.0	_	_	0.147	Compression moulding	[36]
NaOH & Sodium Laulryl Sulfate.	Polyester	40-55	13-21	57-68	_	Hand moulding	[28]
NaOH	Epoxy	22.63	8.11	51.28	_	Hand moulding	[30]
NaOH	Vinyl ester	17.65	3.41	48.205	_	Hand moulding	[30]
Silane	_	45	_	70	_	Hand Lay-up	[37]
NaOH	Polyester	_	12	1800	1.2	Hand Lay-up	[12]
Silane treated	Polyester	45-61	26-28	2400-6000	0.10-1.8	Hand Lay-up	[12]
Vinyl-Silane	Phenol-Formaldehyde (PF)	225±11	12±0.9	_	5.5±0.06	_	[35]
Amino-Silane	Phenol-Formaldehyde (PF)	360±9.2	3±0.5	_	5.21±0.07	_	[35]
Latex	Phenol-Formaldehyde (PF)	398±9	10±1	_	4.64±0.09	_	[35]
Cynoethyl	Phenol-Formaldehyde (PF)	605±12	8±0.6	_	25.4±0.39	_	[35]
Acetyl	Phenol-Formaldehyde (PF)	422±9.5	14±0.6	_	4.7±0.04	_	[35]
Acetyl	MAPP/LDPE	44	12.5	50	_	Hot-press moulding	[35]
Stearic acid & Lauric acid	HDPE	20-21	_	_	0.781-1.0368	Extrusion	[35]

The mechanical properties of these composites revealed that composites with good strength could be successfully developed using banana fiber as the reinforcing agent.

APPLICATIONS OF BANANA FIBER COMPOSITE

Banana fiber composite can be applied in several engineering materials and industries. However, these applications are dependent on the mechanical property of the composite.

Reference [33] found that since the BEFB/polyester composite has shown considerable work of fracture (impact strength), the composite may be considered for tough engineering materials. Hence it can therefore be used for industrial applications like partition panels, packaging, automotive industry, etc. Modification of Brazilian banana fiber HDPE composites by [34] showed that the tensile modulus of the fiber composites (of three types), were very close to those of commercial products plastic timber. Hence the composite has high potential for use as plastic lumber. Reference [27] discovered that the angle of fiber orientation to the loading direction recorded significant effect on the tensile strength, failure strength and elongation at break of the composites. This therefore makes it applicable in parapet wall tiles, in ceiling or floor tiles. [29] studied the Influence of chemical treatment on the properties of banana fiber reinforced maleic anhydride grafted polypropylene/low-density polyethylene composites. It showed that all of the surface treatments improved the mechanical properties of the composites. The hybrid fiber composites could be used as a substitute for wood since it also had a wood-like appearance.

Reference [9] found that the load carrying capacity of banana fiber PF composites is more than that of plywood and also the composite is more flexible than plywood for the same thickness. Thus, it can be used for light weight applications. Reference [31] discovered that the increase in the fiber length and fiber loading of banana fiber increased the mechanical properties of banana fiber-based epoxy composites. Therefore, making it useful in automobile industries, banana fiber composite wall, floor topping of houses, window application and construction industries. Reference [5] showed that at fiber yield of 0.25% to 0.55%, banana fiber of commercial significance for application in new materials development like body parts of cars, partitioning panels, ceiling boards, plumbing yarn, etc. was obtained. Reference [14] on the study to attribute some properties which will enhance the adhesion between matrix and banana fiber during the manufacture of composite discovered that banana fiber can be used in textile, pa-per, and furniture industry as it has high cellulose content, thus reducing deforestation. Also, since treated banana fiber has good surface properties compared to raw banana fiber, it can be used in manufacturing composite materials. So, it is a potential alternative for synthetic fiber. Reference [38] concluded that banana fiber can be used as reinforced agent successfully in the composite industry as a sustainable building material since the mechanical properties of the Banana Fiber Reinforced Polymer Composites plays a significant role in the polymer composite materials. Reference [39] revealed that untreated and varnish coated banana fiber composite material has good fire-retardant characteristics which promotes the use of this composite material as a false roofing material instead of thermocole. Hence Banana Fiber Polymer Composite (BFPC) can be applied in different engineering industries ranging from automobile, construction, housing, etc., depending on the mechanical property.

CONCLUSION

This study showed a brief overview of several processes involved in the development of Banana Fiber Reinforced Polymer Composites (BFRPCs). Each of these processes showed the most preferable as follows; in the extraction method, the mechanical method is the most preferable since it eliminates relative movement of the stem, avoids premature breakage of the fibers and increases fiber production at faster rate. For the treatment method, alkali is most preferred since at final stage it yielded better bonding of the fiber and matrix into composite, thereby resulting to a better mechanical property. For the molding technique, the hand layup method is most preferred because of its simple procedure and low cost. Therefore, with the use of these methods, most mechanical properties of the composites revealed good strength and could be successfully developed using banana fiber as the reinforcing material. These types of composites can therefore find correct applications in different engineering industries. This work therefore provides a foreknowledge and understanding on the manufacturing processes of Banana Fiber Composites.

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REFERENCES

[1]. Z. Ortega, A. N. Benítez, M. D. Manzon, P. M. Hernandez, I. Angula, "Study of Banana Fiber as Reinforcement of Polyethylene Samples Made by Compression and Injection Moulding," *Journal of Bio-based Materials and Bioenergy,* 2010, Vol.4, 114-120.

[2]. Z. Ortega, M. D. Manzon, P. Soto, I. Guinea, L. Surrez, "Use of banana fiber in composite parts for automotive sector," *Proceedings of the 15th European conference on composite materials*, 2012, 1-8.

[3]. www.swicofilcom.2015 [18th September 2017]

[4]. T. Corbière-Nicollier, B. G. Laban, L. Lundquist, Y. J. Leterrier, A.E. Månson, O. Jolliet, "Life Cycle Assessment of Biofibers Replacing Glass Fibers as Reinforcement in Plastics," *Resources, Conservation and Recycling,* 2001, Vol 33, 267–28.

[5]. K. Ebisike, D. B. E. Attah, I. M. Momoh, B. Babatope, S. O. O. Olusunle, "The Tensile Properties of Naturally-Occurring Banana Fibers," *Pacific Journal of Science and Technology,* 2013, Vol 14, 36-39.

[6]. M. A. Maleque, F. Y. Belal, S. M. Sapuan, "Mechanical properties study of pseudo-stem banana fiber reinforced epoxy composite," *The Arabian Journal for Science and Engineering,* 2007, Vol 32.

[7]. D. P. Ray, L. K. Nayak, L. Ammayappan, V. B. Shambhu, D. Nag, "Energy Conservation Drives for Efficient Extraction and Utilization of Banana Fibre," *Certified Journal*, 2013, Vol 3.
[8]. Mazharul Islam Kiron Banana Fiber: Properties, Manufacturing Process and Applications [18th February, 2021].
[9]. A. Joseph, B. Baby, A. B. Thomas, Krishnan S. S, "Preparation and Characterization of Banana Reinforced Phenol Formaldehyde Composite," *European Journal of Advances in Engineering and Technology,* 2015, Vol. 2. pp:85-90. 2015.
[10]. N. H. Padmaraj, A. Suresh, V. Nayak, O. Anand, E.J. Dsouza, "Experimental study on natural fiber in reinforced epoxy hybrid composites," *International Journal Of Core Engineering & Management,* 2016, Vol.3.
[11]. "Natural Plant / Bast Fibers - Banana," http://www.textileschool.com/articles/373/natural-plant-bast-fibres-banana. [17th March 2018].
[12]. L. A. Pothan, Z. Oommen, T. Sabu, "Dynamic Mechanical Analysis of Banana Fiber Reinforced Polyester Composites," *Composites Science and Technology,* 2003, Vol.63, 283–293.
[13]. J. C. M. Osorio, R. R. Baracaldo, J. J. O. Florez, "The influence of alkali treatment on banana fiber's mechanical properties," *ing.inv.* 2012, vol 32, 83-87.
[14]. Md. M. Rashid, S. A. Samad, M. A. Gafur, A. M. S. Chowdhury, "Study of Different Chemical Treatments for the Suitability of Banana (Musa oranta) Fiber in Composite Materials," *International Journal of Scientific & Engineering Research,* 2015, Vol.6.
[15]. Z. Ortega, M. Morón, M. D. Monzón, P. Badalló, R. Paz, "Production of Banana Fiber Yarns for Technical Textile Reinforced Composites," *Materials,* 2016, Vol.9, 1-16.
[16]. L. Herrera Estrada & S. Pillay, U. Vaidya, "Banana fiber composites for automotive and transportation applications," 2017.
[17]. C. C. Emekwisia, I. C. Ezema, V. S. Aigbodion , "Mercerization Effect on the Mechanical and Physical Properties of Banana Fiber Polyester Composite", *International Journal of Engineering Applied Sciences and Technology,* 2019 4 (5), 124 - 132. http://www.ijeast.com.
[18]. K. Sreekumar, M. S. Sreekala, S. Thomas, "Mechanical behavior of sisal and banana fiber reinforced hybrid epoxy composites" Journal of Materials Research and Technology, 2020, 10(1), 154-162. https://www.sciencedirect.com/science/article/abs/pii/S221478532038442X.
[19]. J. K. Vijayaraj, K. Sreekumar, M. S. Sreekala, "Banana Fiber-Reinforced Epoxy Composites: Mechanical Properties and Fire Retardancy". ResearchGate, 2024, https://www.researchgate.net/publication/353424785_Banana_Fiber-Reinforced_Epoxy_Composites_Mechanical_Properties_and_Fire_Retardancy.
[20]. N. S. S. Sreejith, K. Sreekumar, M. S. Sreekala, "Investigating Influences of Synthesizing Eco-Friendly Waste-Coir-Fiber Nanofiller-Based Ramie and Abaca Natural Fiber Composite" Parameters on Mechanical Properties. NCBI, 2022, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8837429/
[21]. N. E. Nwankwo, C. I. Nwoye, S. B. Yusuf, O. E. Alade, S. E. Okiye, W. A. Badmus, "The Reliability Level in Determining the Yield Strength of Glass Fibre-SiC Reinforced Epoxy Resin based on Input Volume Fractions of Glass Fibre and SiC", Journal of Inventive Engineering and Technology, 2024, 5 (2), 60-70. www.jiengtech.com.
[22]. C.C. Emekwisia, I. C. Ike-Eze Ezema, V. S. Aigbodion, "Effects of Chemical Reagents on the Properties of Oil Palm Fruit Fiber Composite", Journal of Advancements in Material Engineering, 2020, 5 (1), http://doi.org/10.5281/zenodo.3708978. www.matjournals.com .
[23]. A. K. Mohanty, M. Misra, L. T. Drzal, "Natural fiber reinforced composites: Sustainable materials for emerging applications", Journal of Polymers and the Environment, 2021, 29(1), 121-138. https://link.springer.com/article/10.1007/s10924-020-01837-4
[24]. S. K. Rao, B. R Rao, K. S. Rao, "Banana fiber reinforced epoxy composites: A review", Journal of Composite Materials, 2017, 51(18), 2657-2669. https://www.tandfonline.com/doi/abs/10.1177/0021998316637601.
[25]. S. K. Rao, B. R. Rao, K. S. Rao, "Banana fiber reinforced polyester composites: A review", Journal of Composite Materials, 2018, 52(12), 1565-1578, https://www.tandfonline.com/doi/abs/10.1177/0021998317729406.
[26]. S. K. Rao, B. R. Rao, K. S. Rao, "Mechanical properties of banana fiber reinforced epoxy composites", Journal of Composite Materials, 2019, 53(19), 2665-2674. https://www.tandfonline.com/doi/abs/10.1177/0021998318811189
[27]. I. C. Ezema, A. R. M. Ravindranatha, S. O. Camelus, A. D Omah, "Effect of Surface Treatment and Fiber Orientation on the Tensile and Morphological Properties of Banana Stem Fiber Reinforced Natural Rubber Composite," *Journal of Minerals and Materials Characterization and Engineering*, 2014, vol.2, 216-222.

[28]. M. Thiruchitrambalam, A. Alavudeen, A. Athijayamani, N. Venkateshwaran, E. Perumal, "Improving mechanical properties of banana/kenaf Polyester hybrid composites using sodium laulryl Sulfate treatment," *Materials Physics and Mechanics,* 2009, vol.9, pp.165-173.

[29]. G. A. M. Khan, M. S. A. Sham, M. R. Kabir, M. A. Gafur, M. Terano, M. S. Alam. "Influence of Chemical Treatment on the Properties of Banana Stem Fiber and Banana Stem Fiber/Coir Hybrid Fiber Reinforced Maleic Anhydride Grafted Polypropylene/Low-Density Polyethylene Composites," *Journal of Applied Polymer Science*. 2013, vol.128, pp. 1020-1029.

[30]. J. Santhosh, N. Balanarasimman, R. Chandrasekar, S. Raja, "Study of properties of banana fiber reinforced composites," *International Journal Of Research In Engineering And Technology*. 2014, vol.3.

[31]. S. Mahaboob, "Banana fiber reinforced composite materials," A Student Presentation. 2016. https://www.slideshare.net.

[32]. K. N. Indira, J. Parameswaranpillai, S. Thomas, "Mechanical Properties and Failure Topography of Banana Fiber PF Macrocomposites Fabricated by RTM and CM Techniques," *ISRN Polymer Science,* 2013, vol.2013, 8

[33]. R. A. V. Prasda, R. K. Mohana, V. Nagasrini, "Mechanical properties of banana empty fruit bunch fiber reinforced polyester composites*," Indian Journal of Fiber and Textile Research*. 2009. vol. 34, pp.162-167.

[34]. S. R. Albinante, E. Pacheco, L. Visconte, G. Platenik, L. N. Batista, "Modification of brazilian natural fibers from banana's tree to apply as fillers into polymers composites," *Chemical Engineering Transactions.* 2014. vol.37, 715-720.

[35]. S. Joseph , P. Koshy, S. Thomas, "The role of interfacial interactions on the mechanical properties of banana fiber reinforced phenol formaldehyde composites," *Journal of Composite Interfaces,* 2012, vol. 12, 581-600.

[36]. I. C. Ezema, A. R. R. Menon, S. O. Edelugo, A. D. Omah, I.U. Agbo, "Ply Tensile Properties of Banana Stem and Banana Bunch Fibers Reinforced Natural Rubber Composite," *Nigerian Journal of Technology (NIJOTECH),* 2012, vol. 31, 25–30.

[37]. H. Shah, B. Srinivasulu, S. Shit, "The Effect of Surface Treatment on the Properties of Woven Banana Fabric Based Unsaturated Polyester Resin Composites," *International Journal of Scientific Engineering and Technology*. 2012, vol.1, 86-90.

[38]. H. Das, P. Saikia, D. Kalita, "Physico-Mechanical Properties of Banana Fiber Reinforced Polymer Composite as an Alternative Building Material," *Key Engineering Materials, 2015,* vol.650, pp. 131-138.

[39]. A. V. Kiruthika, T. R. K. Priyadarzini, K. Veluraja, "Preparation, properties and application of tamarind seed gum reinforced banana fiber composite materials," *Fibers and Polymers,* 2012 vol.13, 51–56.