A Review of Banana Fiber: Impact of Treatment, Filler Materials, Hybrid Composite, and Application

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Abstract: This review paper examines the significance of comprehending the attributes of banana fibers and their initial processing in influencing the mechanical, thermal, and morphological aspects of composites. The study's findings indicated that the application of alkaline solutions or other chemicals to banana fibers had a substantial influence on the performance of the composite material. Modifications in fiber treatment parameters have the potential to modify composite characteristics, such as the interplay between fibers and matrix. Incorporating filler elements significantly affects the composite by enhancing its rigidity and grip while also altering physical characteristics like heat conduction and resistance to corrosion. The utilization of banana fiber components, in conjunction with other fiber and filler materials, showcases ingenuity in creating sustainable composites for various industrial applications. The study emphasizes the necessity of creating more robust, less weighty, and ecologically conscious composites across several industrial domains. The study also emphasizes the potential of banana's fiber-enhancing composites in several industries, such as automotive, construction, aerospace, electronics, and sports.

Keywords: Banana fiber; treatment; filler; hybrid; applications

1. Introduction

The proliferation of plastic consumption has experienced a substantial surge in recent decades. The inception of the plastic industry worldwide may be traced back to 1907 with the creation of Bakelite, the pioneering synthetic plastic. However, a significant increase in worldwide plastic manufacturing only took place throughout the 1950s. Over the course of the following 70 years, the yearly output of plastic experienced over 230-fold growth, ultimately reaching 460 million tons in 2019, as depicted in figure 1. More precisely, worldwide plastic output has increased by a factor of two in the past two decades. The citation is from Ritchie et al. (2023). Plastics are utilized across several industries and consumer goods owing to their robustness, ability to withstand corrosion, versatility, and cost-effectiveness in manufacturing. Nevertheless, the unrestrained utilization of plastic has resulted in numerous substantial adverse effects on both the environment and human beings. Below are the detailed negative consequences associated with the increasing utilization of plastics, encompassing environmental contamination, threats to animals, climate change, human well-being, and challenges in recycling. In order to mitigate the adverse consequences of the increasing utilization of plastic, it is imperative to implement various strategies. These include minimizing the usage of disposable plastics, creating eco-friendly substitutes, enhancing recycling methods, conducting public awareness campaigns, and enacting governmental rules that promote effective management of plastic trash (Khoaele et al., 2023).

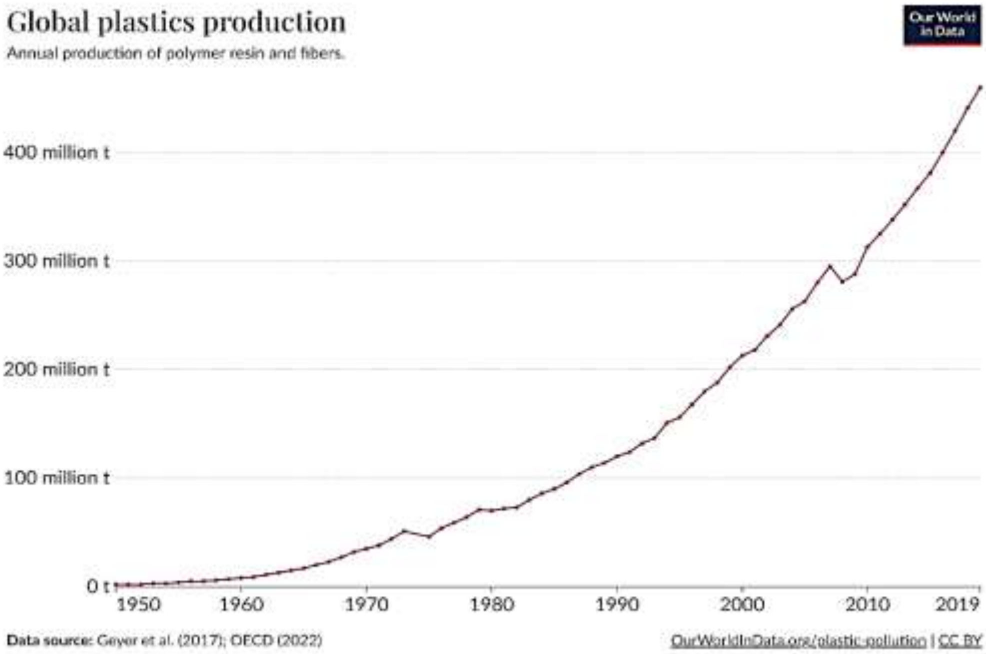

Figure 1. Global plastic production

Natural fibers serve as substitutes for synthetic fibers, which are generated from natural sources like plants, animals, or minerals. These fibers are changed into robust materials that cater to various human requirements. Certain options exhibit high availability, sufficient strength, and ecologically conscious attributes. Plant-based natural fibers, including pineapple, areca, hemp, jute, ramie, sisal, and banana, as well as animal-based fibers like silk (from silk worms) and wool (from sheep), are commonly used in textile production (Zwawi, 2021). The availability of natural fiber varies depending on the source. For instance, coir fiber is the predominant source of fiber in the furniture sector (Zaman, 2020). Natural fibers possess a primary benefit in their renewability and inherent degradability, rendering them more ecologically advantageous compared to synthetic fibers. The biodegradability of the product also minimizes waste and environmental pollution. For instance, the amalgamation of banana, pineapple, and jute fibers exhibits exceptional thermal conductivity and thermal resistance, making it suitable for use as insulating material (Muthukumar et al., 2020). The advancement of eco-friendly technologies and practices in the manufacturing and utilization of natural fibers is increasingly crucial for maintaining a harmonious equilibrium between human necessities and environmental preservation, while simultaneously diminishing reliance on synthetic materials that adversely affect the environment.

The process of producing composites using natural fiber amplifiers, like as banana fibers, requires multiple phases of surface treatment to prepare the fibers for use in composite manufacturing. Initially, the fibers derived from the inner part of the banana peel or from leftover materials in the banana industry are gathered and chosen according to their robustness, length, and width. Subsequently, the fiber undergoes a cleaning process to eliminate impurities such as soil or undesirable botanical remnants. The subsequent pivotal stage is surface treatment, encompassing procedures such as fiber desiccation, application of binding agents, submersion in a chemical solution, or application of a coating to augment the adhesion with a polymer matrix. Next, the treated banana fibers are combined with polymer matrices, additional fibers, or fillers, and subjected to composite production under certain pressure and temperature conditions. Utilizing banana fiber offers several benefits, such as excellent mechanical durability, biodegradability, affordability, and the ability to effectively handle surplus banana waste. Consequently, it serves as an environmentally sustainable and cost-effective option for composite manufacturing. Previous researchers have conducted a review article on banana fiber composites, but there is still a need for further detailed discussion on the specific effects of treatments, filler materials, hybrid composites, and their possible applications in different industries (Sajna et al., 2014).

2. Extrasion, Treatment, and Characteristic of Composite

The main objective of surface treatment on banana fibers is to enhance the adhesion between the fiber and the polymer matrix during composite manufacture. The objective is to enhance the quality of the interaction between the two materials, resulting in a composite that possesses increased strength, enhanced durability, and superior mechanical performance. The effectiveness of the interaction between the banana fiber and the treatment employed is significantly influenced by surface treatment parameters, including temperature, time, and solution concentration. Various media treatments, including bonding agents, alkaline treatments, acid treatment, and surface coatings, are frequently employed to enhance the adhesion between the fiber and the polymer matrix (Asaithambi et al., 2014).

Kumar & Raja (2021)conducted an alkaline treatment on banana fibers. The fibers were initially processed by cutting them into smaller sizes measuring approximately 15-20 mm in length. Afterwards, the material was immersed in a solution of NaOH with a concentration of 5% for a duration of 6 hours at a temperature of 60 ◦C. Following this stage, the fiber collection is subjected to a sequence of washing protocols that entail alternating exposure to acetone and filtered water at a temperature of 28 ◦C. The washing procedure is iterated multiple times by introducing a water solution consisting of equal parts aceton and water in new quantities, until a pH-neutral solution with a pH value of 7 is achieved. The subsequent bleaching process involves the utilization of a sodium hypochlorite (NaClO) solution to eliminate any remaining lignin residue. The resulting group of whitened fibers is then filtered and subjected to another round of purification using water. Ultimately, the fiber bundle is subjected to a two-step drying process: initially at ambient temperature and subsequently in a vacuum oven for a duration of 48 hours at a temperature of 60◦C. The untreated stems are first subjected to an alcohol bath to remove the oil, followed by immersion in purified water for a duration of 2 hours at a temperature of 60◦C to eradicate any mineral residue. Lastly, the sample was subjected to vacuum drying in an oven for a duration of 48 hours at a temperature of 60°C. In addition, they have included data on the chemical composition and inherent qualities of fibers, particularly banana fibers, from prior investigations, as presented in Table 1.

Tabel 1. Chemical composition and properties of natural fibers (S. S. Kumar & Raja, 2021)

Properties	Banana Fiber	Coconut Fiber	Prosopis Juliflora Bark
Cellulose (%)	60–65	21–40	61–65
Lignin (%)	5–10	15–47	15–18
Moisture (%)	10–11	16–17	29–33
Density (g/cm3)	0.95–1.35	1.45–2.8	0.580–0.73
Elongation (%)	4.5–6.9	17–47	3.91–5.88
Young’s modulus (GPa)	27–32	3.7–4.2	26–30
Fiber length (cm)	34–85	10–30	Bark thickness (mm) 1.09–2.53
Fiber diameter (μm)	80–250	50–300	52 × 103–60 × 103
Tensile strength (MPa)	58–63	170–225	115–528

Understanding the chemical composition and inherent characteristics of fibers is crucial in the manufacturing and performance of composites, since it directly influences the interaction between natural fibers and their matrix. The chemical composition and physical properties of natural fibers, including their strength, stiffness, corrosion resistance, and ability to adhere to the polymer matrix, will impact the mechanical, thermal, and structural properties of the composite material produced. By acquiring a comprehensive knowledge of these characteristics, the design and manufacturing procedures of composites can be enhanced to fabricate materials that possess the intended performance, suitable for many applications, including but not limited to the automotive, construction, and manufacturing sectors (Badrinath & Senthilvelan, 2014; Bhoopathi et al., 2014).

In their study, Paramasivam et al. (2022) conducted a thorough analysis of banana fibers and investigated techniques to enhance the extracted fibers' quality through the utilization of enzyme-based degumming methods. The Raspador machine is used to harvest fibers from the stems of five different cultivars: Grand Naine (AAA), Red Banana (AAa), Poovan (AAB), Popoulu (Aab), and Karpuravalli (ABB). Following that, the fibers were treatment with pectinase, lacase, and a blend of both enzymes at varying doses. Karupuravalli exhibited the maximum fiber yield at 2.49%, whereas Grand Naine had the lowest fiber yield at 1.10%. Specifically, Red Banana fibers exhibit exceptional values for qualities such as rupture strength (975.97 gf), rupture extension (3.17%), tex (33.7), stiffness (28.40 cN/tex), and 180.25 MPa correspondingly. The utilization of scanning electron microscopy (SEM) revealed that the lacase enzyme exhibited superior efficacy in enhancing the surface quality of the fiber, with the combined treatment of pectinase and lacase following closely behind. The ratio is 25:75. Eliminating pectinolytic chemicals from the cells within the fiber cell walls leads to a smoothing of the surface of the banana fiber.

The extraction and treatment of banana fibers involve subjecting them to various concentrations of alkaline solutions (1%, 3%, 5%) and sodium lauryl sulfate (SLS) (5%, 10%, 15%). In addition, these treated fibers are mixed with polyvinyl acetate (wood glue) to create non-woven banana fibers. This study examines the influence of reinforcing soil with banana fiber on its pressure resistance, as assessed by the California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) tests. In their study. Datuin et al. (2022) discovered that the incorporation of banana fiber sheets resulted in an elevated CBR ratio and enhanced resistance to ground pressure. Interestingly, sheets treated with SLS exhibit enhanced performance in comparison to sheets treated with alkaline, particularly when not subjected to soaking. However, the opposite pattern is observed under soaking conditions. Statistical analysis, specifically one-way analysis of variance, is employed to compare and assess the effects of various treatments on banana fibers. The results suggest that, in the majority of instances, there were no notable disparities or significance identified between these therapies.

Utilizing banana fiber as a renewable component can significantly enhance the stiffness of polylactic acid (PLA) and expedite the process of biodegradation. However, the issue lies in creating excellent adhesion between the banana fibers, which have hydrophilic features, and the polylactic acid, which has hydrophobic characteristics. In order to tackle this issue, Al-Daas et al. (2023) employed a chemical process on the fibers utilizing sodium hydroxide. They manipulated three variables, namely temperature, concentration, and time of the treatment. Utilizing surface response methods to assess the interactions among various elements, whereas ANOVA examines statistical interactions. The treatment of the foundation has a substantial impact on the morphology, composition, mechanical characteristics, and morphology of the final composite. Specifically, the Young's modulus value shown a rise in composites utilizing treated fibers compared to composites utilizing untreated fibers, accompanied by a modest improvement in tensile strength. Nevertheless, the elongation value of the fiber has somewhat decreased after undergoing post-alkaline treatment. Electron microscope analysis revealed that residues, such as hemicellulose and candles, were effectively eliminated and the connection between fiber strands was improved, resulting in an enhanced surface structure. Subsequent examination of Fourier's infrared transformation spectroscopy revealed the successful removal of rotational effects and emphasized enhanced interactions between PLA and banana fibers.

Comprehending the attributes of banana fiber and its preliminary processing is vital in influencing the mechanical, thermal, and morphological aspects of the resultant composite. The application of alkaline solutions or other chemicals to banana fibers has a substantial influence on the performance of composites. Modifications in fiber treatment parameters, such as the concentration and duration, can lead to substantial alterations in the resultant composite properties. Electron microscope examinations reveal that the chemical treatment of banana fibers has an impact on both the structure and surface morphology of the fibers. This, in turn, impacts the interaction between the fibers and the matrix in the composite material. In summary, the findings underscored the significance of enhancing the treatment process for banana fibers to enhance the quality of composites. Additionally, they verified that a deeper comprehension of the attributes of these fibers can substantially impact the qualities and ultimate performance of the composite material (Badrinath & Senthilvelan, 2014; Bhoopathi et al., 2015).

3. Effect of Filler Material

The use of filler material in the fiber-reinforced composite of bananas yields diverse effects that impact the characteristics of the composite. Selecting and incorporating material fillers, it is crucial to take into account the required attributes in composite applications, including the kind, size, and amount of material fillers, which greatly influence the resulting composite qualities. For instance, it has been found that the addition of fly ash as filler material improves the mechanical properties and decreases the moisture absorption resistance of banana fiber-reinforced polyester composites (Venkateshwaran et al., 2019). Mohan & Kanny (2016) introduced nanoclay particles into banana fibers and examine their morphological and structural characteristics. Nanoclays were incorporated into the fibers through shear-induced force facilitated by an alkaline (NaOH) natrium hydroxide chemical treatment. Approximately 6 wt.% of nanoclays were integrated into the banana fibers using this method. Short banana fiber-reinforced epoxy composites were fabricated via a resin casting technique, wherein the critical length (lc) and critical volume fraction (Vfc) of the fibers were established. A comparison was made between nanoclay-infused fibers, untreated fibers, and those treated with alkaline solution. The findings indicate a beneficial impact on the tensile strength, interfacial properties, and thermal behavior of fibers due to the infusion of nanoclay. Tensile, shear, and dynamic mechanical analyses (DMA) were conducted on the composites, demonstrating significant enhancements in these properties specifically in composites infused with nanoclay-incorporated fibers.

Girimurugan et al. (2021) conducted an evaluation of the impact strength and strength of a bio-composite material. This material was composed of an epoxy resin matrix that was reinforced with banana fiber and Camellia Sinensis particles. This article examines the impact and mechanical properties of a biocomposite consisting of an epoxy resin matrix reinforced with banana fibers and camellia sinensis particles. Four composite samples were created following the ASTM standard. These samples consisted of a fixed weight percentage of the matrix material (65%) and varied weight percentages of banana fibers (35%, 33%, 31%, 29%) and Camellia Sinensis particles (0%, 2%, 4%, 6%). The composite specimens were later subjected to Izod and Rockwell strength testing, following the ASTM standard. The experimental findings demonstrated that including Camellia Sinensis particles into the epoxy resin/banana fiber composite matrix substantially enhanced its strength, while simultaneously decreasing the energy impact and strength of the composite.

In their study, Niyasom & Tangboriboon (2021) demonstrate the potential of utilizing natural reinforcements, such as gooseberry fibre, banana fiber, and egg shell powder, to significantly improve the mechanical strength of concrete composites. Incorporating garlic fiber and banana fiber into the concrete composite at a weight ratio of 0.05 led to a significant enhancement in traction, with values of 187.63 ± 28.45 MPa and 142.59 ± 24.73 MPa, respectively. The composite concrete, which incorporated egg shell powder at a weight ratio of 0.05, exhibited a tensile strength of 157.33 ± 35.63 MPa. The type mass and real type mass of concrete compound incorporating garlic fibers, banana fibers, and egg shell powder at a 0.05-weight ratio (each formula 2, 4, and 6) were found to be lower than that of conventional concrete with a high weight, suggesting the development of lightweight concrete. Furthermore, the incorporation of egg shell powder into the concrete composite significantly enhances the compressive strength and maximum load capacity, resulting in values of 22.08 ± 0.66 MPa and 55.68 ± 1.64 kN respectively. These values are achieved in combination with the contributions from goiter and banana fiber after 28 days of curing. Integrating eggshell powder into the concrete composite offers the advantage of reduced water absorption in comparison to goiter and banana fiber. This results in enhanced resistance to water penetration and greater densification. Hence, the incorporation of bio-based fillers, particularly eggshell powder, into concrete composites yields substantial enhancements in their mechanical, physical, and thermal characteristics. Consequently, this leads to improved energy efficiency, durability, environmental friendliness, long-term usability, and sustainability.

Thermogravimetry analysis (TGA) is a method used to measure the concentration of polymers by subjecting a sample to a controlled temperature and observing changes in weight over time or with increasing heat. Temperatures in polymer applications typically fall within the range of approximately 1000 °C. In 2022, Sivakumar et al. conducted an assessment of cassava starch powder composites including banana leaf fibre as a thermoplastic material. Heat degradation is associated with composite weight decrease. The composite material contains banana leaf fiber in a percentage that varies between 0 and 80 percent of the total fiber weight. The rise in surrounding temperature resulted in a decrease in the weight of the sample due to detrimental effects, which commenced at temperatures below 200 °C, potentially as a result of the volatilization of water vapor from the sample. The breakdown of cellulose and hemicellulose takes place within the temperature range of 200 to 270 °C, while the ultimate decomposition of lignin and cellulose occurs between 270 and 370 °C. The highest level of solid fragmentation took place at a temperature of 350 °C, which led to the degradation of solids and fibers. In order to completely decompose the degraded wastes, higher temperatures are needed, which aligns with prior research findings. At first, biocomposites experienced weight reduction as a result of water evaporation, followed by subjecting them to temperatures ranging from 150 °C to 380 °C in order to decompose hemicellulose, cellulose, and lignin. As the proportion of fiber in the weight grows from 0% to 80%, the pace of weight loss decelerates. Enhances the fiber content and lowers the degradation temperature of the composite, resulting in reduced weight loss and increased degradation temperature. It suggests that starches and fibers possess excellent resistance to heat and demonstrate significant compatibility. The incorporation of fibers into composites greatly enhances their heat resistance by virtue of the robust adhesion between the matrix and the fibers.

4. Hybrid Composite

A banana fiber-enhanced hybrid composite is a material that combines banana fiber with one or more types of fiber or other reinforcing material. This composite hybrid holds great importance due to its major qualities. Combining banana fiber with another fiber or material enhances mechanical performance by using the distinct strength and features of each amplifier type. Furthermore, a composite hybrid enables the customization of qualities based on specific requirements. For instance, the inclusion of kenaf fiber enhances the material's strength, while the addition of banana fiber reinforces its environmental sustainability characteristics (Alavudeen et al., 2015). Furthermore, its adaptability enables its utilization in sectors such as automotive, which want materials that are both lightweight and robust. Furthermore, the utilization of banana-enhanced composite hybrids promotes sustainability through the use of naturally degradable components. Ultimately, its utilization encourages the investigation and advancement in material technology, encompassing the creation of processing methods and material composition for broader applications. The incorporation of banana fiber with other enhancers in hybrid composites results in a material with exceptional characteristics, enabling its utilization in many industrial sectors and fostering the advancement of eco-friendly materials (Devireddy & Biswas, 2016). The composite physical properties, such as water absorption, are influenced by three factors: the reinforcing layer, fiber treatment, and temperature (Oyewo et al., 2022). Additionally, the temperature of fluids has an impact on the mechanical properties of composites (Srinivasan et al., 2021). Multiple investigations have demonstrated that the mechanical properties are significantly influenced by variables such as thickness, length, and fiber volume fraction (Sampath et al., 2022).

The researchers produce and assess polyester composites that are strengthened with snake grass and banana fibers. They employ hand lay-up procedures to arrange the fibers in a random configuration. The chemical employed is methyl ethyl ketone peroxide (MEKP), with naphthalene cobalt serving as a catalyst. The fiber's relative volume constitutes a portion ranging from 5% to 25% of its weight, with a 1:1 ratio. The qualities of traction strength, flexibility, and pressure strength were assessed in accordance with ASTM standards. A clear relationship was discovered between the volume of fiber present and the enhanced abilities of traction, flexion, and pressure strengths, as illustrated in Figure 2. Increasing the volume percentage of banana fiber in a composite typically leads to enhancements in certain mechanical properties, including tensile strength, flexibility, and compressive strength. The presence of a higher quantity of banana fibers in the composite matrix enhances its ability to withstand mechanical loads and distribute the applied stresses throughout the compound. Nevertheless, there are constraints to this augmentation, since an excessively large proportion volume may result in inadequate dispersion of the fibers inside the matrix. This can lead to suboptimal reinforcing and may potentially cause instability in the composites. Hence, it is necessary to carefully examine the optimization of the volume fraction of banana fiber in order to achieve a harmonious combination of mechanical reinforcement and convenience of manufacturing process (Balaji et al., in 2021).

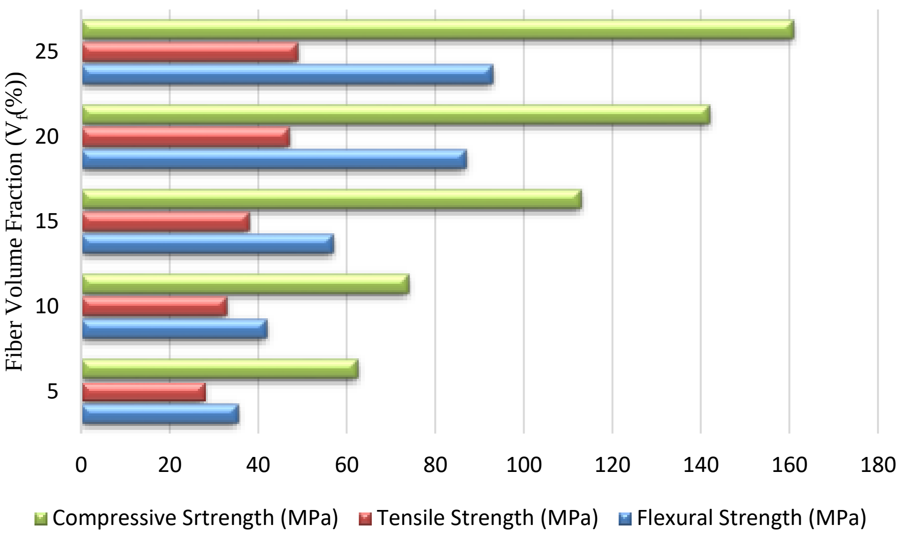

Figure 2. Mechanical properties of banana/snake grass fiber reinforced hybrid composites

Madhu et al. (2022) assessed the effects of different lamination arrangements of epoxy hybrid compounds reinforced with prosopis juliflora bark, kaca, and carbon fiber on interlaminar impact resistance and sliding strength. The study examined five distinct composite laminations. The production of this hybrid composite laminate involves the use of manual hand-layup procedures. Fractographic analysis using an electron scanning microscope is used to look at things like the composition of cavities, the adhesion between fibers and matrix, and the cohesive properties of a broken sample. The insufficient adhesion between the fiber and the matrix in specific regions of composite lamination has led to the formation of microfractures and a deficiency in effective load transmission between fiber layers. Subsequent microscopic examination uncovers instances of fiber deterioration and enlargement, as well as strong fiber adhesion. This type of swelling is observed in specimens subjected to punching tests, while closely bound fibers demonstrate the composite lamination's capacity to absorb energy during cracking, thus enhancing the behavior of the punching force. Microscopic analysis also revealed strong adhesion between the fibers and matrix, indicating a direct relationship with high impact resistance. The study stresses how important it is for the hydrophilic fiber and the hydrophobic matrix to stick together well in order to get great impact strength properties.

Mondloe et al. (2022) looked into how useful it would be to use a hybrid composite material made of banana fiber and a belt that is embedded in an epoxy matrix. They did this to see if it could be used in tribology. The hybrid composite is fabricated utilizing a manual lay-up technique, whereby biofiber is combined with epoxy resin. The resin's strength is improved by subjecting it to an alkaline treatment with sodium hydroxide (NaOH). Traction strength properties are assessed using a universal test machine, while particular wear levels are measured using pin-on-disc equipment that adheres to ASTM standards and calibration processes. The study produced epoxy composites using banana straps, with five variations in the volume fractions of banana fiber and straps. The objective is to determine the optimal composite hybrid epoxy banana strap for tribological applications. The results indicated that composites consisting of 20% coconut beads, 20% bananas, and 60% epoxy exhibited the slowest rate of depletion, whereas composites including 0% coconuts, 40% bananas, and 60% epoxy demonstrated the maximum level of mechanical strength. These findings indicate that alterations in the ratio or composition of fibers in a composite can exert varying effects on the mechanical characteristics and fatigue resistance of the composite.

In 2022, Stalin et al. conducted an initial trial to examine the mechanical properties of a composite hybrid vinyl ester. The vinyl ester was reinforced with fibers from typha angustata, vetiver, pisang, and mat. By employing compression printing methods, a total of eight variations of hybrid mattress composites, consisting of one or two layers, were manufactured with orientations of 45° and 90°. The two-layer typha fiber composite mattress had great grip and flexibility. Its ultimate tensile strength was around 60 MPa, its Young's modulus was 3.56 GPa, and its strain at failure during the pull test was 1.39%. Furthermore, its level of flexibility was measured to be approximately 79 MPa. The typhus angustata/Pisang composite had higher impact strength and toughness after being hybridized. The impact strengths were about 238 kJ/m2 and the strengths were 82. An electron microscope scan analysis is used to assess the surface morphology of the broken composite material. By using this method, the surface shape of a fissure can be carefully studied at a microscopic level. This makes it easier to find things like microcracks, the bonding between matrices and fibers, and patterns of fracture. By conducting this study, one can thoroughly assess the overall integrity and robustness of the interface in the composite material. This analysis aids in comprehending the mechanisms of damage and facilitates the enhancement of the design or fabrication of more long-lasting composites in subsequent endeavors.

Gray-relational analysis, utilizing the Taguchi methodology, is employed to optimize the influential parameters on the tensile strength, flexibility, and impact resistance of epoxy-based composite bananas and bubbles. Key elements, including the weight proportion of the banana, the strap proportion, the alkaline treatment percentages, the pressure, and the temperature during the compression printing process, are taken into account to improve the mechanical qualities. The research revealed that the highest mechanical qualities were achieved by combining 20% bananas, 15% cloves, and 3% alkali, subjecting them to a pressure of 16 MPa, and maintaining a temperature of 100°C. This combination outperformed the other 15 experimental combinations. Nevertheless, the signal-to-noise ratio table indicates more combinations that are considered excellent configurations for mechanical attributes. These configurations include 20% banana, 15% coconut belt, 5% alkaline treatment, 16 MPa pressure, and 100°C temperature.

When evaluating the influence of several parameters, it was shown that bananas have the most effect on enhancing the mechanical strength of natural composites. This is followed by coconut fibers, the proportion of alkaline treatment, pressure, and temperature. In addition, the comparison of data obtained from simulated and real neural tissue demonstrates a significant correlation, confirming the effectiveness of the 5-3-1 tissue topology approach. This approach involves the utilization of five factors, three hidden nodes, and one response to study the parameters that influence force mechanisms. Furthermore, the scanning electron microscopy (SEM) investigation of hybrid fiber composites treated with sodium hydroxide (NaOH) revealed enhanced interface adhesion, even in the presence of interface fissures (Sumesh & Kanthavel, 2022).

The utilization of banana fiber and E-glass as amplifiers is primarily driven by their cost-effectiveness and wide availability. The fiber's density is typically evaluated by the water transfer method. Firstly, the fiber is subjected to a solution containing NaOH and NaCl with a concentration of 5% to improve the bonding qualities between them. Additional treatment entails the utilization of Hardner-HY951. Specimens of 300 x 300 mm2 were produced utilizing the hand lay-up method to create fiber-reinforced composites with volume percentages of 20% and 30%. Modifying the proportion of the composite volume has an impact on the young module, resulting in an augmentation of the material's stiffness. The testing was conducted utilizing a 100KN computer-integrated Universal Testing Machine (UTM), with data collection performed using Kalpak software. The samples were produced following the usual protocols for the pull test, the three-point bend test, and the strength test. A tensile strength test was conducted on fiber-reinforced composites (FRCs) containing a 30% fiber volume fraction, specifically using P-single and E-glass fibers. The pull test findings demonstrated that the incorporation of banana fiber hybrid and E-glas led to a 56% increase in stiffness, thereby enhancing the ultimate elasticity and pull strength. The user is referring to the University of Technology Sydney (UTS). Furthermore, the incorporation of E-glass textiles and banana fabrics in composite lamination led to enhanced mechanical properties of the lamination (Ravitej et al., 2021).

Diverse research examining the reinforcement of banana fibers with composites and other materials reveals a broad spectrum of noteworthy characteristics. The incorporation of banana fiber with another fiber or material in this hybrid composite exhibits significant promise for enhancing the mechanical properties of the composite. This combination not only enhances the structural integrity of the composite but also enables the attributes to be customized according to specific application requirements. For instance, Compression molding was employed to create polyester matrix composites by combining two distinct fibers: short banana (B) and naturally woven coconut sheath (C). Different composites were fabricated, maintaining an identical overall fiber weight percentage while altering the relative weight percentage of each fiber. Surface treatment of both banana and coconut sheath fibers was conducted using a 1 N (molarity) alkali solution to enhance interfacial adhesion. The study involved analyzing static mechanical properties and dynamic characteristics, such as natural frequency and damping, with the impulse hammer technique used to assess composite dynamics. Optimal mechanical performance was achieved when the highest proportion of banana fiber was present in the composites. Moreover, mechanical properties exhibited variations based on the layering pattern employed. Regardless of the fiber weight percentages and layering arrangement, alkali treatment positively influenced the assessed properties. The CBC layering pattern, known for its porous structure derived from coconut sheath fibers, demonstrated superior damping, indicating enhanced energy absorption capability (K. S. Kumar et al., 2016).

5. Potential Application

The utilization of banana fiber-reinforced composites holds significant promise across multiple industries owing to their combination of robustness, longevity, and low weight characteristics. Within the automotive sector, these composites have the potential to fabricate robust and lightweight vehicle components, thereby enhancing fuel efficiency. Corrosion-resistant banana fibers can be utilized in the construction industry to create strong and long-lasting building construction. Within other industries, such as the energy sector, there exists significant potential for utilizing these composites to manufacture goods that are both robust and lightweight while also being ecologically benign. Banana fiber-enhanced composites offer versatile features that may be tailored to meet specific requirements, making them highly suitable for various industrial applications.

Utilizing biodegradable banana fibers, robust glass fibers, and hydrophobic epoxy resins might enable the creation of lightweight composite structures that are well-suited for automotive and structural applications due to their favorable mechanical and thermal characteristics (Arpitha et al., 2023). The incorporation of jute fiber and groundnut husk powder enhances the development of novel, eco-friendly, and economical composite materials exhibiting favorable mechanical characteristics. These materials find wide-ranging applications in sectors such as construction, automotive, and packaging industries (Sai et al., 2023). Fiber panels have numerous benefits, such as their low moisture content, which makes them a promising candidate for use as an amplifier material in geopolymer composites (Addis et al., 2023). Moreover, the hand layup approach yields a bamboo-banana fiber-reinforced polyester hybrid composite that exhibits exceptional characteristics like superior strength, lightweight nature, and reduced elongation. Consequently, this material holds significant promise for application in tiny wind turbines (Ainebyona, 2020).

6. Conclusions

The review thoroughly examines the use of banana fibers in strengthening composite materials, highlighting their significant contribution to the development of new and practical composites. A thorough study of how fiber types and the first treatment affect the mechanical, thermal, and morphological properties of composites has revealed a lot of potential for making these materials work better and be used in more ways. This conclusion will discuss the significance of comprehending the properties of banana fibers, the effects of treating fibers early, and the consequences of incorporating fillers in the design of environmentally sustainable and industrially advantageous composites.

1. It is crucial to optimize the treatment process of banana fiber to enhance the quality and performance of the composite. Additionally, a thorough comprehension of the fiber's characteristics can greatly impact the final attributes of the compound material.

2. The incorporation of the filler material into the fiber-reinforced composite of the banana also exerts a substantial influence on the composite's characteristics. One significant effect is mechanical reinforcement, wherein the incorporation of fillers in the form of small particles and fibers can enhance the stiffness, traction strength, and pressure resistance of the composite. Choosing the right fillers can also change the physical properties of composites, making them better at conducting heat, resisting corrosion, and breaking down naturally, all of which are important for environmentally friendly uses. The characteristics of the material filling have a big impact on the composite manufacturing process. Therefore, careful consideration of these features is essential prior to incorporating them into composite applications.

3. Composites that enhance Banana fibers possess significant promise across various industries, including automotive, construction, and energy, owing to their amalgamation of strength, sustainability, and lightweight characteristics.

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