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Extraction of Bamboo Fibers

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***Abstract*: Researchers are attempting to replace old non-renewable materials with sustainable eco-friendly materials that can be recycled or biodegradable due to growing environmental concerns and the rapid depletion of non-renewable resources. Due to their similar mechanical properties, bamboo fibre is a viable competitor to replace synthetic fibres like glass, carbon, and others in polymer composites reinforced with natural fibre. The qualities of bamboo fibres and bamboo fibre reinforced polymer composites depend on a variety of factors, including fibre extraction processes, moisture content, fibre size, temperature, and length, resin application, and composite preparation methods. Different bamboo fibre extraction techniques and their qualities have been covered in this review. There are three primary ways to remove fibres: mechanically, chemically, and by combining chemical and mechanical approaches. Mechanical extraction techniques are more environmentally benign than the other two of the three fibre extraction methods.**

***Keywords*: Mechanical extraction, chemical extraction, combined mechanical and chemical extraction, bamboo fibre.**

1. Introduction

Carbon, graphite, and glass fiber-reinforced polymer composites have been used in a variety of industries due to their low cost of production and superior mechanical qualities. Due to their great performance, these polymer matrix composites have received much research. Since they cannot be recycled or degraded, it is unknown how they will be disposed of at the end of their useful lives. In light of the importance of climate change and the environment, experts are interested in switching from synthetic to natural fibres. Natural fibres are divided into two categories: plant fibres like bamboo, sisal, hemp, and flax, as well as animal fibres like silk, wool, and hair that contain protein [1].

Plant fibres are primarily composed of lignin, pectin, cellulose, and hemicellulose. The type of cellulose and crystallinity [2] determine the effectiveness of plant fibre reinforcing Plant fibres can be divided into seven categories: grass, stem, wood, fruit, seed, bast, and leaf [3]. Bamboo is a member of the grass family Bambusoideae and has various advantages over other plant fibres, including low cost, low density, rapid growth, stiffness, and high mechanical strength [4] through [8]. Some of the drawbacks of bamboo for diverse applications include difficulty in obtaining straight and fine fibres, degradation with temperature during manufacture, and high moisture content [6], [9].

A. Global Bamboo Distribution

The world's continents on which bamboo is produced can be divided into the following regions: Asia-Pacific American bamboo region African bamboo region European bamboo region and the bamboo region. India, China, and other countries in the Asia-Pacific bamboo region Thailand, Cambodia, Burma, Bangladesh, Japan, and Philippines, Sri Lanka, Vietnam, Indonesia, Korea, and Malaysia. nations in the American bamboo region include Honduras, Nicaragua, Costa Rica, Guatemala Brazil, Venezuela, and Columbia. Brazilian bamboo nations in the region include Eastern Sudan and Mozambique. European nations in the bamboo region include Belgium, Italy, Germany, France, England, and Holland. There are about 65% of bamboo plants in the world. The rest are on other continents, with Asia being the only exception. As a result, the Asian continent is the area with the biggest globe population of bamboo.

B. Structure of Bamboo Fibers

Bamboo grass is made up of culms, which are hollow cylinders with several diaphragms inside, and rings on the exterior. The term "internode" refers to the void or chasm between the two rings. Each species has a varied average distance between nodes [11]. The bamboo culm wall contains a number of vascular bundles, which give the culm its strength [12]. As a result, the bamboo species can be identified by its average size, density, and number of vascular bundles. The anatomy of a bamboo culm provides insight into their physical characteristics and practicality [12]. The fibre density rises as the bamboo culm's upper diameter decreases. As a result, the bamboo culm's upper section is stronger than its base section [13].

C. Bamboo's Chemical Makeup

The three main substances that make up bamboo—lignin, cellulose, and hemicellulose—account for 90% of its weight. Pectin, fat, protein, tannin, ash, and colours are some of bamboo's other key components. These elements control the bamboo's physiological activities [14]. With age, bamboo's chemical makeup continues to change. Age causes the cellulose content to decrease, which has a direct impact on the chemical makeup of bamboo. The lignin in bamboo gives it its rigidity and yellow colour. All lignin content cannot be eliminated by various treatments since lignin is extremely resistant to

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different alkalis. Bamboo's non-cellulosic components help to give it qualities including density, wetness, flexibility, and strength [15].

D. Extraction of Bamboo Fibers

Automotive, textile, and construction industries are among the industries that employ bamboo fibres. However, the process of separating the bamboo fibres from the bamboo culm involves complicated actions. The quality and yield of bamboo fibres were decided by the different extraction techniques, and they were also chosen based on the various application fields. The three main kinds of bamboo fibre extraction techniques are mechanical, chemical, and chemical and other extraction methods combined [13].

2. Methods

A. Techniques for Mechanical Extraction

Mechanical extraction techniques come in a variety of forms, including the steam explosion process, crushing, grinding, rolling in a mill, and retting. These techniques are used to harvest bamboo fibre for usage in a variety of industries to create bamboo fibre reinforced composites.

1) Steam explosion method

This technique uses less energy and requires the separation of plant cell walls in order to produce pulp. The lignin content can be removed from the plant surface using the steam explosion method, but the resulting fibres are stiff and dark [16]. One study demonstrated that it is difficult to effectively isolate individual fibres from fibre bundles. Fiber bundles between 125 and 210 mm in diameter were created using a sifter machine and mesh filter. The fibres were then dried for two hours at 120°C. Since the purpose of this process is to eliminate lignin content from woody materials, it is noteworthy as a way to totally remove it from fibres. Thus, bamboo fibre cotton is created by eliminating the lignin from the fibres [17]. Raw bamboo was cut into pieces and heated to 175°C for 60 minutes at 0.7-0.8MPa in an autoclave to create the similar steam explosion. The steam was then immediately let out for five minutes and nine further times. To guarantee that the cell walls were broken, the same procedure was repeated. The ash component of the fibre was then eliminated by washing it in hot water between 90 and 95°C, followed by drying it for 24 hours at 105°C in the oven. The amount of lignin was mostly concentrated on the surface of the fibres, which decreased the adhesion between the resin and the removed fibers [18]. Bamboo fibres get softer and are cracked fibre cell walls during the steam explosion process, making extraction possible. Low shear resistance was present in the crushed cell walls that were struck against the bamboo fibre surfaces. The unexpended cells were removed from the fibres using isocyanate silane after the researchers ultrasonically treated the fibres with partially degraded lignin. According to the findings, bamboo fibres that had been steam exploded had a higher tensile strength than fibres that had been silane treated [19]. The interfaces between the fibres and the soft cells are porous, and as a result, the tensile strength of these fibre reinforced thermoplastics is decreased. To obtain robust adhesion between the fibre and the matrix, the surface must be properly treated [20].

2) Crushing

A roller crusher is used in this process to first chop up the raw bamboo into tiny pieces. Then a pin-roller was used to separate the coarse fibres from the tiny bamboo pieces. To remove the fat, the fibres were then boiled at 90°C for 10 hours, dried in a rotary drier, and then placed in a dehydrator [18]. This method's primary drawback is that it only produces short fibres, which turn into powder when mechanically over-processed [20].

3) Grinding

For this step, a bamboo culm with no nodes was chopped into strips and submerged in water for 24 hours. Then, using a knife, the soaked strips were divided into smaller pieces. Long bamboo strips were chopped into small bamboo chips by passing wider strips through an extruder. For 30 minutes, these tiny bamboo chips were processed at a fast speed to produce short bamboo fibres. The fibres were divided into different sizes using sieves with a range of apertures. After 72 hours, the isolated fibres were ultimately dried in an oven at 105°C [21]. Due to the increase in transverse length of long fibres, the tensile modulus of the composite is increased since long fibres can carry high tensile loads. The rheological and morphological behaviour of the bamboofibre composite was investigated by several researchers, who extracted bamboo fibres using the same technique [22]. This technique has also been employed in investigations, where nanoclay is combined with dry bamboo strand particles [23].

4) Rolling mill

In this step, the bamboo stalk was divided into thin strips with a 1mm thickness by cutting it into little pieces at the nodes. The strips were soaked in water for an hour in order to make it easier to separate the fibres from the strips. Then, they were moved slowly and with light pressure through the rolling mill. The fibres were removed from the coiled strips using a razor blade after they had been soaked in water for 30 minutes. The resulting fibres, which ranged in length from 220 to 270mm, were allowed to dry in the sun for two weeks [4].

In a different investigation, bamboo strips from the bamboo culm were cut, crushed between two pairs of steel cylinders, and fibres were extracted without soaking in water. In a different study, the lignin content of sliced bamboo strips is softened by steaming and soaking in water before the fibres are run through the roller. The extracted fibres ranged in length from 30 to 60 cm [25].

5) Retting

In this method, the bamboo culm's cylindrical portion was peeled to produce the strips. For three days, the bundles of strips were submerged in water. The wet strips were hammered, scraped with a knife with a sharp edge, and combed [26]. In this method, the scraping procedure had a significant impact on the fibre quality, and the fibres broke less frequently. Another study simply cuts raw bamboo into multiple longitudinal pieces without removing the bamboo node or epidermis. There is no scraping or combing involved. After being cleansed with running water, the bamboo strips underwent a two-month fermentation process in water at room temperature. The fibre bundles were separated using two different retting processes, aerobic and anaerobic retting.

B. Techniques for Chemical Extraction

Chemical extraction techniques, including chemical Alkali or acid retting, as well as retting, are used to remove or decrease the fibres' lignin content. These Chemical extraction techniques also impact other components of fibre like hemicelluloses and pectin [28]-[30].

1) Chemical retting

Natural Retting Assisted by Chemical (CAN) Researchers used the retting technique to decrease Water and lignin content in the fibres a bamboo culm using a slicer, slice into thin slabs in a longitudinal manner. The carefully separated fibres were submerged in Solution of $Zn(NO_3)_2$ with 1%, 2%, and 3% (owf) concentrations at a material-to-alcohol ratio of 1:10 These Fibers were submerged in neutral solution for 116 hours at 40 °C pH was then maintained in a BOD incubator for 1hour in water. Compared to alkali and acid retting, this method was able to remove more lignin, although the treated the moisture content of fibres was high [29]. In a different study, 2 cm chips of bamboo culm are cut into the bamboo and then

Roasting takes 30 minutes at 150°C. then came the chips air dried after being submerged in water for 24 hours at 60 °C before removing further impurities. Moreover, the fibre 2% sodium silicate and 2% water were used to boil the bundles.

Sodium sulphite, 2% sodium polyphosphate and 0.5% solutions of NaOH (w/v) at 20:1 for 60 minutes at 100°Cratio of bamboo to alcohol. Next, the fibres were rinsed. treated with 0.04% xylanase and heated water at 70 °C with 0.5% diethylene triamine pentacetic acid for 60 minutes, use pH 6.5. The resulting fibres were once more baked for 60 minutes at 100 °C with the same nonetheless, using 0.7% NaOH. thereafter, the fibres were 0.5% bleach was used after being placed in a plastic bag. 4% H_2O_2, sodium hydroxide, and sodium silicate 50 minutes long. The alcohol ratio remained at 20 and a pH of 10.5 was maintained. In the end, the fibres treated for 10 minutes with 0.5% sulfuric acid and 5 days of emulsification later, refined bamboo fibres were acquired. The research revealed that bamboo fibres had outer macro fibrils have a smaller orientation angle, and compared to cotton, ramie, and flax fibres, Bamboo fibre is appropriate for use as a fibre reinforcement in assemblages [31].

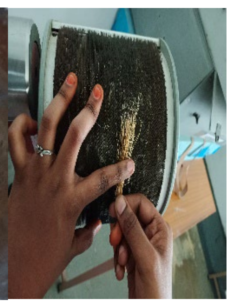
2) Alkali or acid retting

In the alkali retting method, bamboo strips were heated in a stainless-steel container with 1.5N NaOH solution at 70°C for five hours. The fibres were then removed from the alkali-treated bamboo strips by pressing them with a press machine and a steel nail. Last but not least, these isolated fibres were washed in water and dried in an oven. This extraction approach results in reduced fibre damage [32]. In a different investigation, bamboo strips the size of chips were soaked in NaOH with 4% mass per volume for 2 hours to affect the cellulosic and non-cellulosic components of bamboo fibres. This process was repeatedly carried out at a specific pressure in order to extract the fibre in pulp form. Large fibre bundles were created during this extraction process, which was problematic [33]. Small bamboo strips were immersed in a 1N sodium hydroxide solution for 72 hours in another study. The fibres were extracted using trifluoroacetic acid (TFA) and alkaline solutions since the lignin component is soluble in both acidic and alkaline environments. The researchers also took into account the amount of lignin in the intermediate lamellae. The alkali treatment left lignin in the central lamellae, but the TFA process eliminated a significant amount of it, according to the results [34]. Alkali treatment improves the surface adhesion and interfacial bonding of composites compared to other techniques [35], [36].

C. Combined Mechanical and Chemical Method

After being chopped into a thin bar (300mm x 30mm x 5mm3), bamboo had its fibre removed using one of three techniques: chemical, alkali, or steam. First, 5 kg of bamboo strips were placed into an autoclave and heated to 175 °C at 0.8 MPa for 55 minutes while being depressurized nine times to remove ashes. After this, the bamboo strips were repeatedly washed in water and dried in an oven. Second, 5 kg of strips were put in a 1.5 N NaOH container. then heat at 70 °C for 5 hours. Thirdly, degumming was used in the chemical process, and this cure also utilised a high percentage of NaOH in comparison to the alkali solution. Tensile strength and modulus of fibre epoxy composites were reduced by chemical and steam explosion extraction as compared to both untreated and alkali processed. Along with chemical extraction changing the chemical structure of fibres using chemicals, steam explosion damages fibres with high temperatures. Comparing an alkali process to a steam explosion and chemical extraction, the alkali process has little impact on the characteristics of fibres. In contrast to chemical and steam explosion extraction, alkali extraction had a high contact angle.

The highest values in the alkali extraction of fibres are also embedded length (Le) and droplet height (h).



3. Conclusion

Bamboo fibre has several advantages over other plant fibres because of its rapid growth and great strength.

Bamboo fibre has several advantages over glass fibres, and because of this, researchers are very interested in employing bamboo fibre as reinforcement in polymer composite materials. Bamboo fibres have been extracted using a variety of processes depending on their use in various fields of research and industry. Numerous extraction techniques have been examined in this study, some of which having advantages over others. Chemical and steam explosion techniques are used to eliminate the lignin component from the bamboo, changing its microstructure. These procedures can only be used to harvest short fibres.

When compared to chemical procedures and the steam explosion method, the retting process and rolling mill method can create long fibres. While extracting fibres, the retting procedure allowed for the control of fibre length.

The fibres recovered by crushing and grinding could be employed for matrix crystallisation in particle form. Alkali treatment in chemical extraction methods reduces lignin concentration in fibres and improves interfacial adhesion between fibre and matrix. Compared to previous chemical procedures, the chemical retting process eliminated more lignin. Different fibre extraction techniques and its qualities are categorised to help researchers use bamboo fibre successfully for various industrial applications. For the purpose of replacing synthetic fibre composites with bamboo fibre reinforced composites, a thorough investigation must be conducted.

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