



BAMBOO FIBER: A GREEN GOLD

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ABSTRACT

In conclusion, bamboo fiber represents a promising and sustainable alternative to traditional textile fibers, offering a range of benefits from environmental sustainability to exceptional performance characteristics. Its rapid growth, minimal environmental impact, and versatile applications make it a key player in the future of textile manufacturing. However, to fully realize its potential, it is imperative to address the challenges associated with its processing and to ensure transparent and accurate labeling practices. Continued research and innovation in this field will undoubtedly contribute to the growth and sustainability of bamboo textiles, aligning with the global shift towards eco-friendly and responsible consumption. This review aims to provide a comprehensive understanding of bamboo fiber, highlighting its properties, applications, and the advancements needed to overcome current challenges, thereby paving the way for its broader adoption in the textile industry. associated with its use in textile manufacturing.

KEYWORDS: Fiber, Environmental, Textils, Bamboo

Bamboo fiber has garnered significant attention in recent years as an innovative and sustainable material for textile manufacturing. This rapid surge in popularity can be attributed to the increasing global awareness of environmental issues and the urgent need to find alternatives to traditional textile fibers such as cotton and synthetic polymers, which have substantial environmental footprints. Bamboo, a fast-growing perennial grass, is renowned for its rapid growth rate, with some species capable of growing up to 91 cm (35 inches) within 24 hours. This remarkable growth, coupled with bamboo's minimal requirements for water, pesticides, and fertilizers, positions it as a highly sustainable resource. Bamboo cultivation contributes positively to soil health and carbon sequestration, enhancing environmental credentials (Kozłowski and Mackiewicz-Talarczyk, 2020).

The chemical composition of bamboo is primarily characterized by a high cellulose content, typically ranging from 60% to 70%, along with hemicellulose, lignin, and various other organic and inorganic substances. This composition not only imparts strength and durability to bamboo but also transforms it into a versatile fiber suitable for a wide range of textile applications. The natural structure of bamboo fibers, with their inherent smoothness and round cross-sections, results in exceptionally soft, breathable fabrics and comfortable to wear. Additionally, bamboo fibres possess natural antibacterial properties, attributed to a bio-agent called "bamboo kun," which helps reduce bacterial

growth and unpleasant odours in fabrics made from bamboo (Janzen D., 1976).

The extraction and processing of bamboo fibers can be broadly categorized into mechanical and chemical methods, each with distinct advantages and challenges. Mechanical processing, often called bamboo linen, involves physically separating the fibers from the bamboo stalks through a series of steps including retting, crushing, and combing. This method is considered environmentally friendly as it does not involve harmful chemicals; however, it is labour-intensive and yields a coarser fabric than chemically processed bamboo. On the other hand, chemical processing, which produces bamboo viscose or rayon, involves dissolving the cellulose in a chemical solution and then extruding it to form regenerated fibers. While this method results in a softer and more consistent fabric, it raises significant environmental concerns due to the use of toxic chemicals like carbon disulfide and the potential for water pollution if the effluents are not properly managed (Zuo *et al.*, 2018).

Bamboo fiber's unique properties and environmental benefits have led to its adoption in various sectors within the textile industry. In apparel, bamboo fabrics are favored for their softness, breathability, and moisture-wicking capabilities, making them ideal for activewear, underwear, and baby clothing. In home textiles, bamboo fibres are used to produce luxurious bed linens, towels, and bathrobes that offer superior comfort and absorbency. Moreover, bamboo's natural antibacterial and hypoallergenic properties make it suitable for medical textiles such as bandages, surgical gowns, and

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masks. Beyond conventional applications, bamboo fibre is also being explored in technical textiles, including UV-protective clothing and environmentally-friendly packaging materials (Prakash V., 2020).

Despite its numerous advantages, adopting bamboo fiber in textiles is not without challenges. One major issue is the inconsistency in labeling and marketing practices, with some products being misleadingly labeled as "bamboo" when they are, in fact, bamboo viscose. This not only confuses consumers but also undermines the perceived sustainability of bamboo textiles. Additionally, the environmental impact of chemical processing methods remains a significant concern, necessitating the development and implementation of more sustainable practices. Researchers and industry stakeholders are

actively working towards improving the sustainability of bamboo fiber production, including developing closed-loop systems that recycle chemicals and reduce waste (Akinlabi *et al.*, 2017).

CHEMICAL COMPOSITION OF BAMBOO

Bamboo primarily comprises cellulose, hemicellulose, lignin, and smaller quantities of other substances such as pectin and inorganic materials. The chemical composition varies depending on the bamboo species but typically includes 60-70% cellulose, 20-25% pentosans, 20-30% hemicellulose, and 20-30% lignin. This composition contributes to bamboo's durability, strength, and resistance to mould, fungal, and borer attacks (Mousavi *et al.*, 2022).

Extraction Methods of Bamboo Fibre

Mechanical Extraction

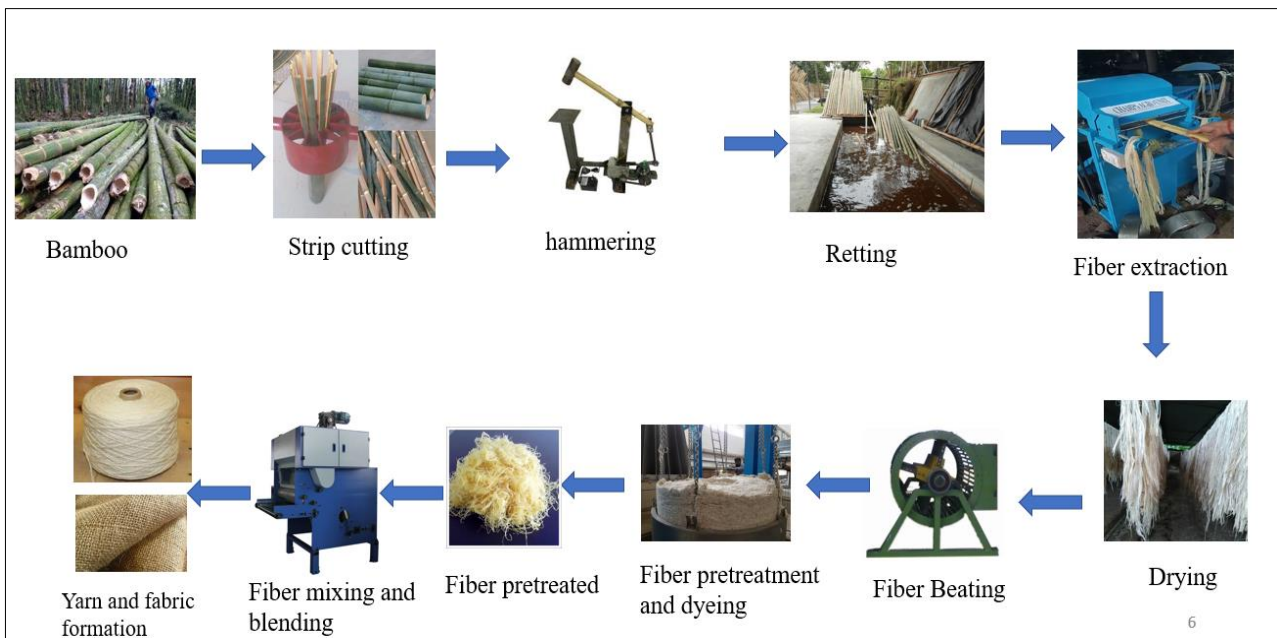


Figure 1: Mechanical route of bamboo fibre extraction

Mechanical extraction of bamboo fiber involves several key processes that transform raw bamboo into usable textile fibers. These processes are crucial in ensuring the quality and sustainability of the final product.

The first step in the mechanical extraction process is harvesting mature bamboo stalks. Bamboo matures in about 3 to 5 years, depending on the species and environmental conditions. Once mature, the stalks are cut and selected based on their quality and diameter, affecting the fiber's strength and length (Liu *et al.*, 2012).

After harvesting, the bamboo stalks undergo a cleaning process to remove impurities such as dirt and

outer layers. This step is essential to prepare the bamboo for the next phase of extraction.

RETTING

The retting process is essential for extracting bamboo fibers by breaking down the plant's cellular structure to separate the fibers from the woody core and surrounding tissues. Various retting methods, each with unique advantages and challenges, include dew retting, water retting, enzymatic retting, and chemical retting. Dew retting is a natural, environmentally friendly process where bamboo stalks are laid out and allowed to decompose through microbial activity. It is low-cost and simple but highly weather-dependent, slower, and can

result in uneven fiber quality. Water retting involves submerging bamboo in water to promote the microbial breakdown of pectin, offering faster and more uniform results, but it requires significant water usage and management. Enzymatic retting uses specific enzymes to degrade pectin, producing high-quality, uniformly retted fibers with a faster and more controllable process, though it is costly and requires careful management. Chemical retting, involving acidic or alkaline solutions like sodium hydroxide or hydrochloric acid, is the fastest method and produces highly uniform fibers suitable for industrial production. Still, it poses significant environmental concerns, health risks, and higher operational costs. The choice of retting method depends on factors such as resource availability, environmental impact, desired fiber quality, and production scale, with traditional methods being more eco-friendly but less efficient, and modern methods offering greater precision and speed at higher costs and environmental impacts. Once retted, the bamboo stalks are ready for the mechanical extraction of fibers. This process typically involves two main methods: crushing and combing (Singh and Dessalegn, 2021).

CRUSHING

In this method, the bamboo stalks are crushed and mechanically processed to separate the fibers from the woody parts of the plant. This can be done using machines that apply pressure and shear forces to break down the bamboo into its constituent parts. The fibers are then further cleaned and refined to remove any remaining impurities.

COMBING

Combing is another mechanical method used to extract bamboo fibers. It involves combing through the crushed bamboo material to separate the long, desirable fibers from shorter, less usable ones. This process helps ensure that the extracted fibers are high quality and suitable for textile production.

After extraction, the bamboo fibers undergo further processing to improve their properties for textile applications. This may include bleaching to achieve a desired color or to remove any remaining impurities, as well as mechanical or chemical treatments to enhance the fibers' strength and flexibility.

Overall, the mechanical extraction process of bamboo fiber is a complex yet essential series of steps that transform raw bamboo into a sustainable and versatile textile material. By carefully selecting, cleaning, retting, and mechanically extracting the fibers, manufacturers can produce bamboo textiles that are not only eco-friendly but also durable and comfortable for various applications in the fashion and textile industries.

CHEMICAL EXTRACTION

Chemical extraction of bamboo fiber involves a series of steps that use chemicals to break down the bamboo components into cellulose, the primary component of the fiber. This method complements mechanical extraction by efficiently separating the fibers from the bamboo stalks and is particularly useful for producing high-quality, fine fibers suitable for textiles and other applications (Tahir *et al.*, 2011).



Figure 2: Chemical route of Bamboo fiber

PREPARATION AND PRE-TREATMENT

The process begins with harvesting mature bamboo stalks, similar to mechanical extraction. The stalks are then cut into smaller pieces and undergo a series of pretreatment steps to prepare them for chemical extraction. This typically involves cleaning the bamboo to remove dirt and debris and then chipping or shredding the stalks to increase their surface area, which enhances the efficiency of chemical reactions.

CHEMICAL PULPING

The main chemical extraction process for bamboo fiber is known as pulping. Pulping involves breaking down the bamboo into its constituent fibers through chemical treatments. There are two primary methods of chemical pulping used for bamboo fiber extraction:

KRAFT PULPING

In this method, bamboo chips are cooked in a mixture of chemicals, primarily sodium hydroxide (NaOH) and sodium sulfide (Na₂S). The mixture, known as white liquor, breaks down the lignin and other binding agents in the bamboo, separating the cellulose fibers. The resulting pulp is washed to remove residual chemicals and lignin, leaving behind purified bamboo fibers.

SULFITE PULPING

This method involves using sulfurous acid (SO₂) or other sulfites to break down the lignin in the bamboo chips. Sulfite pulping is less commonly used for bamboo compared to kraft pulping but can produce fibers with specific properties depending on the process parameters.

BLEACHING AND REFINING

After pulping, the bamboo fibers undergo bleaching to improve their brightness and remove any remaining lignin and impurities. Bleaching agents such as chlorine dioxide (ClO₂), hydrogen peroxide (H₂O₂), or oxygen (O₂) are commonly used for this purpose. The bleached fibers are then washed thoroughly to remove the bleaching agents and residual chemicals, ensuring they are clean and ready for further processing.

FIBER TREATMENT AND MODIFICATION

Once bleached, the bamboo fibers may undergo additional treatments to modify their properties for specific applications. This can include mechanical refining to control the fiber length and diameter, as well as chemical treatments to enhance their strength, dyeability, or moisture absorption properties. Surface treatments may also be applied to improve compatibility

with other materials or to add functional characteristics to the fibers.

SPINNING AND TEXTILE PRODUCTION

The processed bamboo fibers are then spun into yarns using traditional spinning techniques such as ring spinning or modern methods like open-end spinning. These yarns can be used alone or blended with other natural or synthetic fibers to create a wide range of textiles, including clothing, household textiles, and technical textiles. Bamboo fibers are known for their softness, breathability, and antimicrobial properties, making them popular in eco-friendly and sustainable textile markets.

PROPERTIES OF BAMBOO FIBRE

Bamboo fiber possesses several unique properties that make it a desirable material for various textile and non-textile applications (Akinlabi *et al.*, 2017). These properties contribute to its growing popularity in the sustainable and eco-friendly market sectors. Here are some key properties of bamboo fiber:

SOFTNESS

Bamboo fibers are naturally smooth and round without sharp spurs, which makes them very soft to the touch. This softness is comparable to silk or cashmere, making bamboo textiles comfortable to wear against the skin.

BREATHABILITY

Bamboo fibers have micro-gaps that provide ventilation and moisture absorption. This makes bamboo textiles highly breathable, keeping the wearer cool in warm weather and comfortable during physical activity.

MOISTURE-WICKING

Bamboo fiber has excellent moisture absorption and wicking properties. It can absorb and evaporate sweat quickly, making bamboo textiles ideal for activewear, socks, and other moisture-wicking garments.

THERMO-REGULATION

Bamboo fibers have natural thermo-regulating properties, meaning they help keep the wearer cooler in summer and warmer in winter. This makes bamboo clothing versatile and suitable for various climates.

ANTIBACTERIAL AND ODOR-RESISTANT

Bamboo fiber contains a natural antimicrobial agent called "bamboo kun," which inhibits the growth of bacteria on the fabric. This property helps bamboo

textiles stay fresher and odor-free for longer periods between washes.

HYPOALLERGENIC

Bamboo fiber is naturally hypoallergenic and is less likely to cause allergic reactions compared to other fibers. This makes it a suitable choice for people with sensitive skin or allergies.

UV PROTECTION

Bamboo fibers naturally provide UV protection, shielding the skin from harmful UV rays. This property makes bamboo textiles suitable for outdoor and sun-protective clothing applications.

BIODEGRADABLE

Bamboo fiber is biodegradable and environmentally friendly. It decomposes naturally in soil without causing pollution, making it a sustainable alternative to synthetic fibers.

DURABILITY

Bamboo fibers are strong and durable, despite their softness. When properly cared for, bamboo textiles can last a long time, maintaining their shape and integrity through repeated washings.

VERSATILITY

Bamboo fiber can be blended with other fibers such as cotton, wool, or polyester to enhance its properties or create specific textures and functionalities in textiles. This versatility expands its range of applications in fashion, home textiles, and technical textiles.

Bamboo fiber combines comfort, sustainability, and functionality, making it a preferred choice for eco-conscious consumers and industries seeking innovative textile solutions. Its natural properties contribute to a comfortable wearing experience while minimizing environmental impact, aligning with global efforts towards more sustainable practices in fashion and beyond (Sadrmanesh and Chen, 2019).

Applications of Bamboo Fibre



Figure 3: Applications of Bamboo fibre

TEXTILES AND CLOTHING

Bamboo fibres are extensively used to produce clothing items such as underwear, sports gear, t-shirts, and socks. Bamboo's softness, breathability, and antibacterial properties make it an ideal choice for apparel. Additionally, bamboo textiles are gaining

traction in producing hygiene items like sanitary napkins, masks, and bandages.

HOME FURNISHINGS

Bamboo fibre is also used in home furnishings, including bed linens, towels, and upholstery fabrics. Its durability and natural antibacterial properties make it suitable for household applications.

TECHNICAL TEXTILES

Bamboo fibre extends to technical textiles, which are utilized in products requiring specific functional properties. This includes UV-protective clothing, medical textiles, and even food packaging materials. The versatility and sustainability of bamboo fibre make it an attractive option for various technical applications.

CHALLENGES IN BAMBOO FIBRE UTILIZATION

Despite its many advantages, using bamboo fibre in textiles faces several challenges. One major issue is the accuracy of labelling and environmental claims. There is often confusion between natural bamboo fibre and bamboo viscose, leading to misleading marketing practices. Additionally, the environmental impact of chemical extraction methods raises concerns about the sustainability of bamboo textiles. Ensuring bamboo fibre production adheres to eco-friendly practices is crucial for its long-term viability.

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