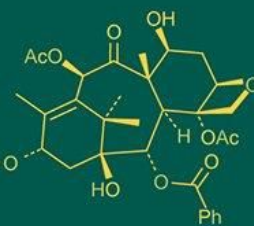
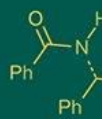


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Emerging opportunities in sustainable banana fabric production: A review study

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Abstract

There are multitudinous types of natural fiber, including hemp, flax, jute, wood fiber, rice cocoons, oats, bagasse, banana fiber, and pineapple fiber. India occupies alternate place in banana product. The product of bananas in India is 13.5 million tons per time. Banana fiber is pulled from pseudo stems, which suffer a process called decortication, where the external layers are scraped down to reveal the fibers. The fibers are also combed to remove impurities and spun into yarn or thread suitable for weaving or suturing. Banana fiber is a natural bast fiber rich in cellulose, distinguished by its excellent mechanical strength and performance properties. Banana fiber possesses high unambiguous strength rates that are analogous to those of conventional paraphernalia analogous as glass fiber. It's used as a raw material in sedulity for the product of papers, tea bags, and currency and corroborated as a polymer emulsion. It's biodegradable and has no negative environmental impact, making it an ecofriendly fiber. This study is designed in order to use banana fiber for cloth purposes because after gathering the fruits, the pseudo stems are not being used for any good purpose. They are thrown down as waste and come a disposal problem. thus, to avoid the destruction of banana box, banana fabric produced from banana fiber has surfaced as a promising volition to conventional cloth fiber.

Keywords: Sustainable, biodegradable, greenhouse gases, decortication, banana fiber

Introduction

Natural fibers are becoming very useful on a worldwide scale these days due to environmental concerns. It has been discovered that producing synthetic fibers from petroleum-based materials is hazardous, non-biodegradable, and energy-intensive. The low cost and favourable mechanical properties of natural fibers make them more widely used in the composites industry (Ortega *et al.*, 2016) ^[20]. Banana is cultivated in more than 130 countries in tropical and subtropical parts of the world. As per the National Horticulture Board, India is the main producer of banana annual fruit crop with annual production of 32 million tons, which accounts for 28% of the total world production. India occupies second place in banana production. Banana crop bears fruit once in its life span. After harvest, about 60% of biomass is left as waste, leading to environmental problems such as the emission of greenhouse gases (Srivastava, 2023) ^[31]. Banana, the large-scale evergreen herbaceous plant belonging to the Musaceae family and Musa genus, with high calcium and magnesium and high assimilation of nitrogen emission (Amini, 2019) ^[1]. Green Chemistry is described as the "design of chemical products and processes to limit or eliminate the usage and production of hazardous compounds. This overview and the concept of Green Chemistry were developed approximately 33 years ago, at the start of the 1990s. These had a huge impact on sustainable design. Green Chemistry's goal of reducing risks at all stages of the life cycle has been proven to be economically beneficial (Anastas, 2010) ^[2].

Fibers derived from plants have received considerable attention in recent years as an alternative to reinforcements derived from synthetic fibers. Plant fibers are easier to manufacture than manmade fibers because of their lower cost, great flexibility, reduced density, environmental friendliness, and improved stiffness (Bekraoui, 2022) ^[6]. There are many types of natural fiber, including hemp, flax, jute, wood fiber, rice husks, oats, bagasse, banana fiber, and pineapple fiber.

The production of bananas in India is 13.5 million tons per annual. Banana cultivation is done in all parts of the country, including Uttar Pradesh, but is mainly grown in Gujarat, Kerala, Tamil Nadu, Maharashtra and Andhra Pradesh, Karnataka and Bihar.

The above ground portions of the banana plant, particularly the pseudo-stem and peduncle, serve as the primary sources of fiber. Banana fiber is extracted from pseudo-stems, which undergo a process called decortication, where the outer

layers are scraped away to reveal the fibres. The extracted fibers are subsequently combed to eliminate impurities and then spun into yarn or thread, making them suitable for weaving or knitting applications.

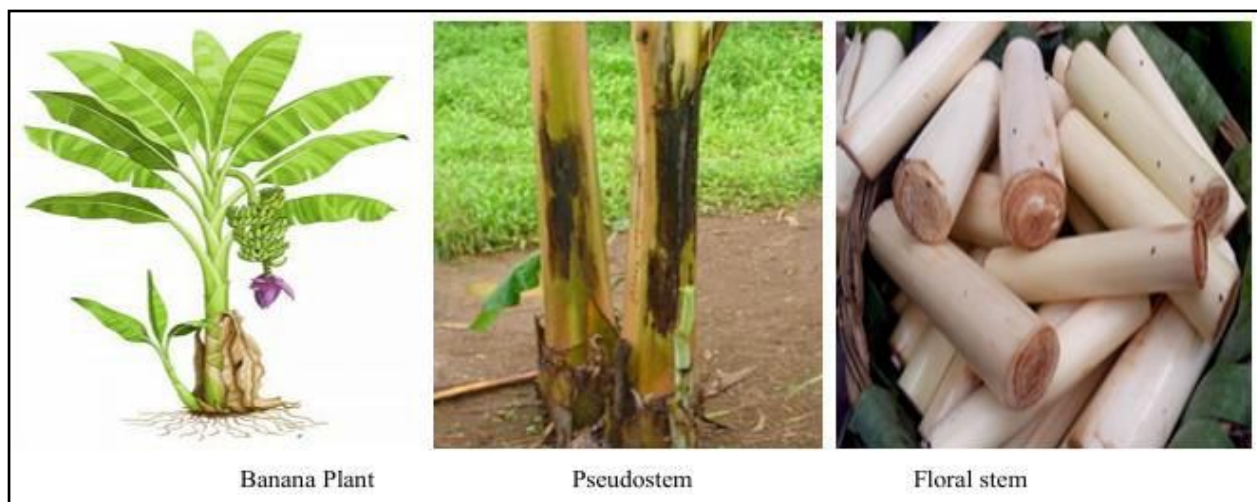


Fig 1: Different parts of the Banana plant (Repon *et al.*, 2016)

Banana fiber is used as a raw material in industry for the production of papers, tea bags, currency and reinforced as a polymer composite. Natural fiber is used as an alternative resource to synthetic fiber. Usually, plant fibres are classified as xylem and phloem fibres, the latter can be obtained from the outer cortical region of the stem. Banana plant is rich in phloem fibre, also called Cortical or Pericyclic fibres (Foster, 1942) ^[3].

Properties of Banana fiber

1. Morphological structure of Banana fiber

Banana fiber is a dialect cellulosic fiber, which is obtained from the pseudo-stem of the banana plant. Banana fiber is a bast fiber that exhibits excellent mechanical properties, including high strength and durability. Banana fiber has great strength properties, similar to glass fiber. The pseudo-stem is a barrel-shaped, grouped accumulation of leaf tail bases. Banana fiber is a byproduct of banana development and is either not appropriately used or is only partially used as such. Helpful utilizations of such strands would regularise the interest, which would be reflected in a fall in the costs. Banana strands have good strength, are lightweight, more modest extension, are impervious to fire, moisture absorption (Ragab, 2024) ^[19].

Banana fiber has many cells, just as the majority of natural fibers.

Banana fiber cells have a thick cell wall and an uneven, primarily non-spherical shape. Its core lumen is long and quite thin (Ramesh *et al.*, 2017) ^[26].

2. Physical properties

i) Tenacity

Tenacity is the customary measure used to evaluate the strength of a textile fibre. It is defined as the ultimate

(breaking) force of the fibre, expressed in gram-force units, divided by its denier. Since denier represents the linear density of the fibre, tenacity does not correspond to force per unit cross-sectional area. Instead, it is a quasi-dimensionless parameter that is analogous to specific strength and allows comparison of fibres with different thicknesses (Chauhan and Sharma, 2014) ^[34].

ii) Fineness

The interior portion of the stem yields banana fibers, which are smooth, very fine, and naturally shiny (Arafat *et al.*, 2018) ^[4].

iii) Thickness

The thickness of the fiber decreases from the outer to the inner sheaths and ranges from 0.05 to 0.25 mm. In contrast to bio-extracted fiber, which has a pristine surface, physically extracted fiber typically has a rough surface. The presence of sticky plant materials is the cause of this. Mechanical extraction techniques degrade the quality of the fiber (Jayaprabha *et al.*, 2011) ^[12].

iv) Diameter

The diameter of the extracted banana fibre ranged between 240-260 μm (Raghavendra *et al.*, 2012) ^[33].

vi) Tencile Strength

The extracted fibres were cut into lengths of the order of 7 cm and were checked for their uniformity in diameter, using a microscope. The radius of the fibre was measured using the comparator to an accuracy of 0.001 mm. The fibres with a radius of the order of 0.05 mm to 0.08 mm were used for tensile strength measurement (Kiruthika, 2009) ^[15].

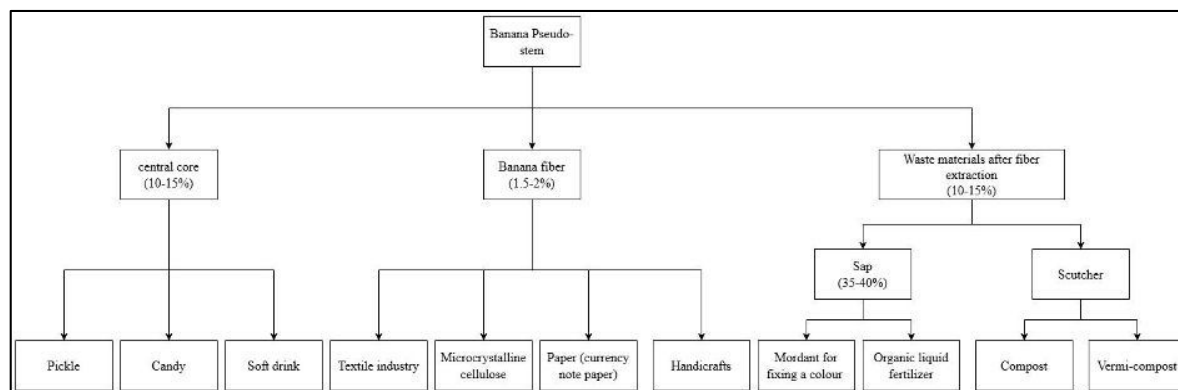


Fig 2: Banana Pseudo-Stem Fiber Composition

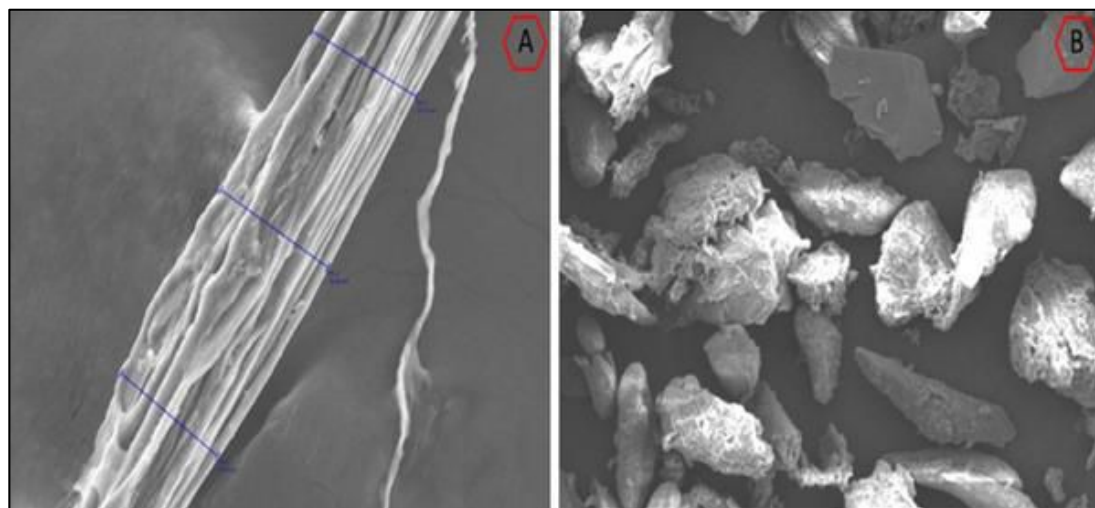


Fig 3: SEM image of (A) banana fibers and (B) banana particles (Balaji A *et al.*, 2024)

Banana fibers (Prata species) were affected by UV irradiation for seven and fifteen days at $\lambda_{\text{max}} = 400$ nm. Thermal analysis (DTA/TG) revealed an activation energy of $188.2 \text{ kJ} \cdot \text{mol}^{-1}$ for untreated fibers, whereas structural investigations employing FT-IR and SEM verified surface and chemical changes brought on by UV exposure (Benedetto, 2015) [27].

2. Chemical properties

i) Chemical contains

Banana is a natural lignocellulosic plant fiber, is harvested from the banana plant's leaf or pseudo-stem, which grows abundantly in tropical locations. The fiber has cellulose content of 71.08 %, hemicellulose content of 12.61 %, and lignin content of 7.67 %. Cellulose is the major source of excellent performance in plant fibers, because of its crystalline nature and β -4 linked D-glucan chain structure. Hemicellulose has an amorphous structure because of its short and branched chains containing pendant side groups. Lignin is a 3D copolymer that is primarily responsible for plant fiber cell stiffness (Gupta *et al.*, 2021) [10]. Retted banana fiber was observed to contain a relatively high amount of waxes and fats, accounting for about 1.2% of its composition.

Retting substantially lowers the hemicellulose and lignin content present in the banana pseudo-stem. Consequently, the quality of the extracted pseudo-stem fibres varies depending on the climatic conditions, soil characteristics, and irrigation practices of the cultivation area (Rajput, A. R, 2022) [35].

Banana as a Sustainable fiber

Banana fiber is natural bast fibre. The pseudo stem of the banana plant yields banana fiber (Rajput, A. R. 2022) [35]. Banana fiber may be harvested and produced without the use of chemicals. Banana fiber is completely natural, biodegradable, and environmentally benign (Rajput and Khot 2022) [35]. Once a banana tree has produced fruit, it must be discarded because it can no longer be used to grow fruit. The demand for bananas will rise as the population grows, and as more banana trees are planted, the amount of trash produced by banana plants will also rise annually. Thus, attempts should be made to turn this waste into money (Ebisike *et al.*, 2013) [9]. India produces 27.01 million tons of bananas annually on 0.765 million hectares, but most stems and leaves are discarded, creating vast waste despite being a rich source of textile fiber. Banana fibers are biodegradable, strong, breathable, and eco-friendly, requiring fewer resources than synthetic and other natural fibers (Deka *et al.*, 2014) [7].

Endues

Due to a lack of sufficient sustainable technology for economic application, the fibers end up as trash. Banana fiber may be used as a raw material in a variety of goods, such as paper, cardboard, tea bags, and currency notes, as well as strengthened as a polymer composite in stylish garment material (Kuan, 2021 and Patil, 2020) [14, 23]. Banana fiber is used as a raw material in industry for the production of papers, tea bags, currency and reinforced as a polymer composite. With so many great features, this fiber

is gaining popularity in the fashion industry, with numerous well-known fashion lines and designers using banana-based fabric. In comparison to other synthetic fibers, banana fiber is both environmentally friendly and recyclable. Synthetic fiber production procedures have been proven to be hazardous, nonbiodegradable, and energy-intensive (Sodhi, 2022) ^[30]

Banana Fiber had an extremely limited application in the past and was used to make ropes, matting, and some other composite materials. With increased environmental consciousness and the importance of eco-friendly materials, banana fiber has been recognized for all of its beneficial properties, and its application is expanding in various industries such as clothes and home furnishings, sleepwear, casual women's wear, bridal clothing, and home décor (Gupta, 2023) ^[11]. However, in Japan, it is utilized to make customary clothing such as a kimono and kamishimo (Vigneswaran, 2015) ^[32]. People there still like it as summer outfits since it is lightweight and comfortable to wear. Banana fiber is also used to manufacture high-quality pillow covers, neckties, wallets, tablecloths, and curtains, among other things. Carpets constructed with banana silk yarn fibers are likewise quite popular all over the world. The fiber component of the pseudo-stem that was left over after starch extraction was used to make paper pulp (Price, 2017; Price, 2016) ^[24, 25].

Conclusion

Banana fiber has enormous promise in the worldwide textile and composite sectors as an environmentally benign and sustainable substitute for synthetic fibers. Its excellent mechanical properties, biodegradability, breathability, and versatility make it a valuable raw material for applications ranging from paper and currency to garments, home furnishings, and composites. Despite being a by-product of banana cultivation, the fiber remains underutilized, with large amounts of biomass still discarded as waste. Rural communities and women through training and cottage industries. With the increasing demand for sustainable materials, banana fiber offers a promising pathway aligned with the principles of Green Chemistry and the circular economy. Upcoming research on optimizing extraction, treatment, and dyeing processes will further enhance its performance, durability, and market value, paving the way for banana fiber to emerge as a mainstream material in both industrial and fashion sectors.

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