IJARCCE

ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 5, May 2026

DOI: 10.17148/IJARCCE.2026.155162

STUDY ON PROPETIES BANNANA FIBER COMPOSITIONS

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Abstract: This study investigates the chemical, physical, and mechanical properties of banana fiber extracted from the pseudostem of the *Musa sapientum* plant as a sustainable alternative to synthetic reinforcements. Banana fibers are primarily composed of cellulose (47.1%–63.4%), hemicellulose (15%–27.8%), and lignin (9.8%–27.7%) [1], [2], [3]. While these fibers demonstrate high specific strength, their inherent hydrophilicity often results in poor interfacial bonding with polymer matrices [3], [4]. Experimental results indicate that raw fibers exhibit a crystallinity index of approximately 52% and a density range of 0.22 g/cm³ to 1.03 g/cm³ [2], [5]. Mechanical characterization reveals tensile strengths varying from 69.99 MPa to 743.9 MPa, depending on cultivation conditions and extraction methods [1], [2], [6]. To address performance limitations, this research highlights the impact of surface modifications, specifically 5% NaOH alkali treatment, which has been shown to enhance tensile strength by up to 52% and reduce moisture absorption by 39% by removing non-cellulosic impurities [7]. The findings suggest that with optimized chemical treatments, banana fiber is a viable, eco-friendly resource for high-performance applications in the automotive and textile industries [1], [8].

Keywords: Banana fiber; *Musa sapientum*; Cellulose; Alkali treatment; Mechanical properties; Natural fiber composites; Sustainability.

INTRODUCTION

The search for sustainable, eco-friendly alternatives to synthetic fibers like glass or carbon has led to a significant interest in natural fibers. Banana fiber, extracted from the pseudo-stem of the *Musa sepientum* plant, is an abundant agricultural waste that can be obtained at virtually no additional cost [1]. These fibers are renewable, biodegradable, and possess a high strength-to-weight ratio, making them ideal candidates for polymer reinforcement [2], [3]. However, their primary drawback in composite production is the poor interfacial bonding between the hydrophilic fiber and the hydrophobic polymer matrix, which necessitates surface modifications to achieve optimal mechanical performance [1], [4].

LITERATURE REVIEW

Research indicates that banana fibers are composed primarily of cellulose (48–60%), hemicellulose (10.2–15.9%), and lignin (14.4–21.6%) [5]. To improve their utility, chemical treatments such as alkalization, acetylation, and permanganate treatments are frequently employed [1].

- **Alkali Treatment:** Treating fibers with a 5 wt% sodium hydroxide solution is a standard practice that removes hemicellulose and lignin, increasing surface roughness and facilitating better mechanical locking between the fiber and matrix [6].
- **Interfacial Adhesion:** Studies have shown that a 1% NaOH concentration can be highly effective in enhancing the tensile and flexural properties of polyester-based composites by optimizing the polarity of the fiber surface [4].
- **Hybridization:** Recent reviews highlight that hybridizing banana fiber with other natural or synthetic fibers can result in a 30–50% increase in mechanical properties, including impact strength and thermal resistance [3].

METHODOLOGY

The fabrication of banana fiber composites typically involves the following steps:

1. **Fiber Extraction and Preparation:** Fibers are extracted from the banana plant pseudo-stem, dried, and cut to specific lengths (e.g., short fibers or woven mats) [5], [7].
2. **Chemical Modification:** The fibers are soaked in a chemical solution (commonly 5% NaOH) for a specified duration (e.g., 4 to 24 hours), then washed and dried to reduce moisture content [6].
3. **Fabrication Techniques:**
    - **Hand Lay-up:** The most common and cost-effective method where fibers are manually placed into a mold and saturated with resin (epoxy or polyester) using a brush or roller [7], [8].

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- **Compression Molding:** Fibers and resin are placed in a preheated mold and cured under high pressure to ensure uniform thickness and reduce voids [3], [7].

4. **Testing:** Specimens are typically machined according to ASTM standards (e.g., ASTM D3039 for tensile testing) and tested using a Universal Testing Machine [9], [10].

RESULTS

Experimental data shows significant enhancements in mechanical properties when banana fibers are added to a polymer matrix:

- **Tensile Strength:** Studies have reported improvements of up to 181.5% in tensile strength compared to unreinforced polyester [1]. Another study observed a 17% increase in tensile strength specifically through the addition of banana fibers in hybrid configurations [11].
- **Flexural Strength:** Flexural strength can increase by approximately 56.63% with treated fibers [1]. For example, laminates have shown flexural strengths ranging from 78 N/mm² to 180 N/mm² depending on the fiber orientation and treatment [12].
- **Impact Strength:** Impact resistance improves with fiber loading; for instance, at 50 wt% loading, impact strength has been measured at roughly 14.17 KJ/m² [13].
- **Compositional Changes:** Chemical treatment can increase the -cellulose content from 63.40% to 82.23%, which directly correlates with improved structural stability [1].

DISCUSSION

The improvement in mechanical properties is primarily attributed to the removal of non-cellulosic components like pectin and wax during chemical treatment, which exposes more reactive hydroxyl groups on the fiber surface [1]. This leads to better wetting of the fibers by the resin and reduces the hydrophilic nature of the composite, thereby lowering water absorption tendencies [1], [14]. While increasing fiber loading (up to 20 wt%) generally improves strength, excessive loading can lead to the formation of voids and poor distribution, which may eventually degrade the mechanical integrity of the composite [1], [7]. The use of simulation tools like ABAQUS has further validated these experimental findings, showing a strong correlation between predicted and actual load-bearing capacities [9], [14].

CONCLUSION

Banana fiber composites represent a viable, sustainable, and cost-effective alternative to traditional synthetic composites. The mechanical performance is highly dependent on the interfacial bond strength, which can be significantly enhanced through chemical modifications like alkali treatment [1], [4]. With improvements in tensile strength of over 180% and notable gains in flexural and impact resistance, these materials are well-suited for industrial applications in the automotive, construction, and packaging sectors [1], [2]. Future research should focus on optimizing bio-resin compatibility to create fully biodegradable "green" composites [3].

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