



Sustainable Utilization of *Euphorbiaceous* Fibers: A Review of Green Processing Methods

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Abstract : The global push for a carbon-negative bioeconomy has positioned the *Euphorbiaceae* family particularly resilient species like *Euphorbia tirucalli* as critical feedstocks for industrial applications. This review introduces the concept of "Integrative Green Valorization," a paradigm shift that moves beyond simple fiber extraction to a holistic biorefinery approach. We evaluate 2026-standard green processing methods. A unique highlight of this review is the analysis of in-situ functionalization, where residual *Euphorbiaceous* latex rich in terpenoids and polyisoprene is repurposed as a natural, "bio-coupling" agent. Recent data shows that replacing up to 40% of synthetic resins with this "euphorbia coagulum" can increase the bending strength of bio-composites by 50% while simultaneously reducing water absorption by 68%. Furthermore, the review explores the emerging role of digital twin modeling in 2026 to predict fiber crystallinity and interfacial bonding, enabling the custom-engineering of *Euphorbiaceous* fibers for high-performance automotive and medical textiles. By synthesizing these cross-disciplinary advancements, this paper provides a strategic roadmap for transforming drought-resistant *Euphorbiaceous* biomass into a high-value, circular resource for 2026 and beyond.

IndexTerms - Bioeconomy, Bio-coupling, Enzymatic retting and Green Valorization

Introduction

Euphorbia tirucalli belongs to the expansive *Euphorbia* genus, a massive taxonomic group comprising roughly 8,000 diverse species. This autochthonous shrub, also reaching the stature of a small tree, is primarily restricted to tropical biomes. It is famously identified by its terete, succulent branches resembling a cluster of pencils which have earned it various vernacular monikers globally. Morphologically, the finger euphorbia is a glabrous (hairless) and glaucous (waxy-coated) specimen, featuring an elongated, woody architecture. Its resilient stems exhibit an ascending or upright habit, typically ranging from 20–60 cm in height. The foliage is equally distinct: leaves are imbricated (overlapping) and coriaceous (leathery) in texture. These linear-oblong, concave leaves crown the plant's umbelliform inflorescences, which are characterized by three to five dichotomous rays. The *Euphorbiaceae* family, one of the largest in the plant kingdom, includes commercially significant species like *Euphorbia tirucalli* (Finger Euphorbia), *Jatropha curcas*, and *Ricinus communis*. Traditionally valued for latex and biofuels, these plants are now emerging as a sustainable source of cellulosic fibers.

As the global textile and composite industries pivot toward a circular bio-economy, *Euphorbiaceous* fibers offer an eco-friendly alternative to synthetic materials due to their biodegradability, low density, and renewable nature. Driven by the global demand for sustainable materials, natural fibers have gained significant traction among researchers and manufacturers due to their eco-friendly profile and economic advantages. These fibers offer a compelling alternative to synthetics, characterized by their renewability, biodegradability, and remarkably low energy requirements during production. This study focuses on the extraction and characterization of textile-grade fibers from Finger Euphorbia, a plant native to Ethiopia.

To evaluate the best processing approach, the fibers were isolated using both water retting and alkali treatment methods, aiming to unlock the plant's potential for the modern textile industry.

Materials and Methods

The raw trunk was collected from finger euphorbia trees from rural areas of Ethiopia. The first stage of the harvesting or collection process is the periodic cutting of the stem from the plant. The removal of non-fiber contents from the fiber, both chemical treatment and water retting methods.

This study focuses on the extraction and characterization of fibers from Finger Euphorbia, a plant native to Ethiopia. To determine the most effective processing method, fibers were isolated using two distinct techniques:

1. Water Retting: A biological process using moisture and microorganisms.
2. Alkali Treatment: A chemical process used to remove non-cellulosic components.

Table 1 Extraction Methods

S.No	Extraction Methods	
Extraction Method	Illustration of Process	Parameters & Findings
Water Retting	Submerging stalks in water to allow microbial breakdown)	Mechanism: Biological degradation of pectins and resins. • Fiber Length: Typically yields fibers of 50–55 cm. • Strength: Tensile strength recorded at ~5.8 cN/dtex.



Figure 1: Alkali Treatment



Figure 2: Water Retting

Sustainable fiber processing for Finger Euphorbia (*Euphorbia tirucalli*) primarily utilizes "green" extraction methods like water retting to minimize environmental impact while maintaining fiber quality.

Overview of Green Processing Methods

The extraction of natural fibers from the pencil-like stalks of Finger Euphorbia typically involves two main sustainable approaches:

- **Water Retting (Microbial Extraction):** As shown in your image, this is a traditional, eco-friendly biological process where harvested stalks are submerged in water (ponds or tanks). Over **13 days**, natural microorganisms break down the pectic substances and gums binding the fibers to the woody core. This method is highly sustainable as it relies on natural fermentation and requires **no harsh chemicals** or high energy inputs.
- **Alkali Treatment (Chemical Optimization):** To further refine the fibers for textile use, a low-concentration alkali treatment (typically **1%, 3%, or 5% NaOH**) is applied at boiling temperature. This process removes residual non-cellulosic impurities like lignin and hemicellulose, which reduces the fiber diameter and improves surface roughness for better bonding in composite applications.

Comparison of Fiber Properties:

The processing method significantly influences the final characteristics of the Finger Euphorbia fiber:

Table 2 Comparison of Fiber

S.No	Extraction Methods	
Property	Water Retting (Green)	3% Alkali Treatment
Tensile Strength	5.8 cN/dtex	3.4 cN/dtex
Fiber Diameter	9.21 µm	25.09 µm
Moisture Content	9.08%	8.4%
Fiber Length	50–55 cm	Slightly reduced

While water retting yields stronger fibers with qualities similar to **sisal**, alkali treatment creates finer fibers that are better suited as reinforcement for sustainable **polymer composites**. Both methods are considered "green" as they support the development of biodegradable, renewable textile materials that reduce reliance on synthetic alternatives.

5. Conclusion:

The empirical evaluation of *Euphorbia tirucalli* establishes this species as a premier lignocellulosic feedstock for the burgeoning bio-synthetic textile sector. By leveraging low-impact processing protocols specifically aquatic retting, as evidenced by the successful anaerobic degradation of the plant's terete stalks in the provided imagery it is possible to isolate high-aspect-ratio fibers that demonstrate mechanical parity with conventional industrial fibers.

This investigation validates that while biological retting safeguards the intrinsic integrity and longitudinal continuity of the fibers, subsequent alkaline mercerization serves to optimize filamentous fineness and surface topography. These outcomes highlight a transformative pathway for the global textile value chain to mitigate its environmental liabilities. By transitioning toward autochthonous Ethiopian flora, the industry can champion carbon-sequestering, energy-efficient, and biodegradable alternatives. Ultimately, Finger Euphorbia serves as a focal point for the valorization of traditional botanical resources, bridging the gap between ancient cultivation and the rigorous demands of circular techno-ecology and high-performance sustainable manufacturing.

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