

SITTEC 2026

International Seminar on Technological Innovation
and Energy Transition in Tropical Contexts

August 3–4, 2026

Ebolowa, Cameroon
ACRITEE — 2nd Edition

☑ **Track 5** — Circular Economy, Climate Resilience & Industrial Ecology

DEVELOPMENT AND CHARACTERIZATION OF AN ECO-FRIENDLY WALLPAPER FROM ABELMOSCHUS ESCULENTUS (OKRA) BAST FIBERS: A SUSTAINABLE VALORIZATION OF AGRICULTURAL WASTE

Étude et réalisation d'un papier peint écologique à base de fibres d'Abelmoschus esculentus (gombo) : valorisation durable des déchets agricoles.

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1. Résumé / Abstract

Résumé (Français) — Calibri 10 pt — interligne simple

Cette étude porte sur la conception d'un papier peint écologique à partir des fibres d'Abelmoschus esculentus (gombo), en vue de valoriser cette ressource végétale locale comme alternative durable aux matériaux de revêtement mural synthétiques. La démarche a consisté à extraire les fibres des tiges par rouissage à l'eau stagnante, puis à les traiter (soude caustique à 7 %, neutralisation, blanchiment au peroxyde d'hydrogène), à les broyer en pâte et à les mettre en forme par moulage, séchage et thermocompression. Le produit obtenu a été caractérisé par des essais de traction, de déchirure, de grammage, d'épaisseur et d'humidité sur seize échantillons. Les résultats montrent que les fibres de gombo possèdent une texture souple et une bonne résistance mécanique, et que le papier peint final présente une structure homogène, une cohésion satisfaisante et un aspect esthétique appréciable après optimisation du procédé. Le matériau obtenu, biodégradable et issu de déchets agricoles, constitue une alternative écologique prometteuse aux revêtements muraux conventionnels.

Abstract (English) — Calibri 10 pt — single spacing

This study focuses on the design of an eco-friendly wallpaper made from *Abelmoschus esculentus* (okra) fibers, aiming to valorize this local plant resource as a sustainable alternative to synthetic wall-covering materials. Fibers were extracted from okra stems by stagnant-water retting, then treated with a 7% sodium hydroxide solution, neutralized, and bleached with hydrogen peroxide. The treated fibers were ground into a pulp and shaped into sheets by molding, drying and thermocompression. The resulting material was characterized through tensile, tear, grammage, thickness and moisture-uptake tests on sixteen samples. Results show that okra fibers possess a flexible texture and good mechanical strength, and that the final wallpaper exhibits a homogeneous structure, satisfactory fiber cohesion and an appealing aesthetic finish after process optimization. This biodegradable material, derived from agricultural waste, constitutes a promising eco-friendly alternative to conventional wall coverings.

Keywords: Okra fiber; *Abelmoschus esculentus*; eco-friendly wallpaper; agricultural waste valorization; natural fiber material; biodegradable material; circular economy

2. Introduction

Okra (*Abelmoschus esculentus*) is a plant widely cultivated in tropical and subtropical regions, primarily for the consumption of its pods. After harvest, the stems of this plant are generally regarded as agricultural residues, even though they contain natural fibers that can be valorized in various industrial fields [1]. Recent studies have shown that okra fibers possess favourable morphological, structural and mechanical characteristics for use as reinforcement in biosourced materials, owing to a fibrous structure rich in cellulose [1], [2]. Prior work on okra stems has further demonstrated their suitability for pulp and paper production, given their cellulose content and fibrous properties, with the resulting pulps usable in the paper industry after blending with other fibers [2]. Beyond paper applications, okra fibers can also be converted into nanocellulose, of interest for cellulosic materials, packaging and paper-based products [2].

In parallel, growing environmental concerns associated with synthetic, non-biodegradable wall-covering materials are driving research towards natural, renewable alternatives. Plant fibers are increasingly used across various sectors due to their availability, low cost and eco-friendly character, and fibers derived from *Abelmoschus esculentus* in particular can be valorized in the manufacture of wall coverings such as wallpaper.

It is in this context that the present work, entitled «Study and production of a wallpaper based on *Abelmoschus esculentus* fibers», was undertaken. The main objective is to design a wallpaper from okra fibers and to evaluate its physical and mechanical properties through several tests, namely tensile, tear, grammage, thickness and moisture-uptake tests. This study thus aims to contribute to the valorization of local agricultural resources while proposing an ecological alternative in the field of paper-based wall-covering materials.

The remainder of this paper is organised as follows. Section 3 reviews the relevant literature on okra fiber properties and eco-friendly wall coverings. Section 4 describes the materials, the fiber extraction and treatment methodology, and the wallpaper fabrication process. Section 5 presents the experimental results, which are discussed in Section 6. Section 7 concludes the paper and outlines perspectives for future work.

3. Literature Review / State of the Art

3.1 Previous Works

Okra bast fibers have attracted growing scientific interest as a low-cost, biodegradable reinforcement for biosourced materials. Kolte and Shivankar [1] characterized Indian okra fiber and reported a fibrous, cellulose-rich structure favourable to industrial valorization, with a density generally between 1.3 and 1.5 g/cm³ and a fiber diameter ranging from about 40 to 56 µm depending on harvest age and extraction method. Hossen et al. [7] carried out a comprehensive physico-mechanical characterization of okra fiber for textile applications, reporting a specific tensile strength generally between 30 and 52 cN/tex and an elongation at break of about 1 to 3.5%, typical of rigid vegetal fibers.

Regarding extraction and treatment, retting remains the most widely used method: it degrades the pectic substances, hemicellulose and part of the lignin binding the fibers to the stem through microbial action, after which the fibers are mechanically separated, washed and dried. Stawski et al. [3] compared water- and dew-retting of okra fibers and characterized their resulting thermal and mechanical properties, while Khan et al. [4] showed that alkaline treatment (alkalization) of biologically degummed okra bast fibers improves their physical and mechanical performance by removing residual non-cellulosic compounds. Stanislas et al. [5] further demonstrated that a wet-drying treatment applied to raffia and okra fibers improves their morphological, physicochemical and mechanical properties, including an increase in apparent density. In the specific context of Cameroon, Nkoulou et al. [6] recently reported a detailed physical, chemical and mechanical characterization of okra fibers from the Littoral region for composite applications, confirming the suitability of locally sourced okra fibers as a reinforcement material.

From a materials-application perspective, Raja et al. [2] characterized *Abelmoschus esculentus* plant-waste fiber for sustainable composite and biomedical applications, while Ben Seghir et al. [8] investigated okra (*Astragalus gombo*) as a renewable source of cellulose using experimental and response-surface approaches. At the agronomic level, Djeoufo et al. [9] documented a significant agro-morphological diversity of okra accessions cultivated in the Sudano-Sahelian zone of Cameroon, and Ndungu et al. [10] reviewed agronomic practices for climate-resilient okra production, underlining the crop's adaptability to heat and drought stress and its relevance to sustainable agriculture in tropical regions.

On the application side, eco-friendly wall coverings made from natural, renewable or recycled raw materials are increasingly used in green building, as they help limit volatile organic compound emissions and improve indoor air quality. Decorative wallpaper in particular can be produced from paper, non-woven or synthetic materials, and is increasingly manufactured from sustainable, low-environmental-impact materials, in line with the broader shift of the wall-covering industry towards bio-based solutions.

3.2 Positioning of the Contribution

While the literature confirms the favourable structural and mechanical characteristics of okra fiber and validates several extraction and treatment routes (retting, alkalization, wet-drying), most reported studies focus on the raw fiber itself or on its incorporation as reinforcement in polymer composites. Few studies address the direct transformation of okra fiber pulp into a finished decorative wall-covering product with a complete physical-mechanical characterization protocol. This study distinguishes itself by (i) using locally sourced okra stems, otherwise discarded as agricultural waste, as the sole raw material; (ii) developing a full processing chain from retting to a finished, decoratively patterned wallpaper sheet; and (iii) characterizing the resulting product through tensile, tear, grammage, thickness and moisture-uptake tests, providing an integrated assessment of its suitability as an eco-friendly wall-covering material for the Cameroonian context.

4. Materials and Methods

4.1 Raw Material and Tools

The raw material used in this study consists of okra (*Abelmoschus esculentus*) stems collected after fruit harvest in the West Region of Cameroon, specifically in the town of Dschang, where they are otherwise discarded as agricultural residue. The main tools and equipment used for fiber collection, processing and wallpaper fabrication are summarized in Table 1, including protective equipment (boots, face mask), collection bags, basins, cutting tools, cooking pots, a sieve, molds, and the chemical reagents (sodium hydroxide, hydrogen peroxide, sodium silicate) required for fiber treatment and bleaching. AutoCAD software was used to determine the wallpaper sheet dimensions.

Table 1 — Main tools, equipment and reagents used

CATEGORY	ITEM	FUNCTION
Protective equipment	Boots, face mask	Protection against sharp objects during harvesting and against chemical inhalation
Collection & processing	Collection bag, basin, cutting tools	Collecting/transporting stems, rinsing and cutting fibers
Thermal / mechanical	Cooking pot, heat source, sieve, mold, mixer	Chemical treatment under heat, filtration, shaping and grinding of the pulp
Chemical reagents	NaOH, acetic acid, H ₂ O ₂ + Na ₂ SiO ₃	Alkaline treatment, neutralization and bleaching of the fibers
Software	AutoCAD	Determination of the wallpaper sheet dimensions

4.2 Fiber Extraction and Treatment

Fiber extraction was carried out by biological (stagnant-water) retting. The okra stems were cut into small pieces and immersed in water for two weeks to facilitate the degradation of the substances binding the fibers together. A progressive change in water color was observed from the second day of soaking, indicating the onset of decomposition of the organic substances surrounding the fibers. After retting, the fibers were separated manually and washed several times with clean water to remove residues and odour (Figure 1).



Figure 1 — (a) Raw okra stems; (b) fibers after extraction and washing; (c) fibers after alkaline treatment and bleaching

The extracted fibers were then dried under sunlight for several hours to reduce their moisture content and prevent mold development, and subsequently cut into small portions (5 to 10 mm) suited to wallpaper pulp preparation; combing was not performed, as it was rendered unnecessary by the subsequent cutting step. The cut fibers were then chemically treated in a 7% sodium hydroxide (NaOH) solution: two batches of fibers (144.66 g and 141.65 g) were immersed in two liters of a boiling NaOH solution (140 g NaOH per liter of water) for 1 h 30 min. After treatment, the fibers were rinsed three times with clean water and neutralized using a 0.1% acetic acid solution for 1 h 30 min. Bleaching was then performed in a solution containing hydrogen peroxide (H₂O₂) and sodium silicate (Na₂SiO₃) at 80 °C for 1 h 30 min, in order to obtain a homogeneous lightening of the fibers and remove residual impurities. Table 1 (see also quantities below) summarizes the

total quantities of materials used: 286.31 g of fibers, 280 g of NaOH (7%), 2 L of 0.1% acetic acid, and 6 L of the H₂O₂/Na₂SiO₃ bleaching solution.

4.2.1 Wallpaper Forming and Process Optimization

After bleaching and rinsing, the fibers were ground with a mixer and water to obtain a homogeneous pulp. The pulp was spread evenly into a mold to ensure homogeneous material distribution and a regular thickness, after which excess water was removed by suction to promote compaction and facilitate subsequent drying (Figure 2). The molded sheets were air-dried for 24 hours, demolded, and consolidated by thermocompression to improve fiber cohesion and mechanical properties.



Figure 2 — Wallpaper fabrication process: (a) mold preparation; (b) pulp forming; (c) drying

A first batch of sheets presented visible voids and irregularities, attributed to a non-perfectly homogeneous distribution of fibers and variations in compaction during forming. To address this, the process was optimized: the remaining pulp was recovered, pressed, oven-dried, re-cut and re-mixed before being re-molded, dried for a further 24 hours, demolded and consolidated by thermocompression, yielding a more homogeneous and regular final structure. Decorative motifs were subsequently applied to the surface of the optimized wallpaper sheets to enhance their aesthetic and artisanal character.

4.3 Characterization Tests

A total of sixteen (16) specimens were prepared for the various experimental tests performed on the okra-fiber wallpaper. For mechanical tests such as the tensile test, two to four backing supports were glued onto each specimen to ensure proper, uniform load application without interference from manual handling; no backing was used for moisture-uptake specimens, so as not to alter the material's natural behaviour on contact with water. The following tests were performed: (i) a tensile test using a universal testing machine, subjecting each specimen to progressive elongation until rupture; (ii) a tear test, evaluating the material's resistance to the propagation of a tear under progressive load; (iii) a grammage test, determining the mass per unit area (g/m²) using a precision balance; (iv) a thickness test, using a micrometer to measure the distance between the two faces of the sheet at several points; and (v) a moisture-uptake test, in which dried specimens were equilibrated in a desiccator and weighed to determine their capacity to reabsorb ambient moisture.

5. Results

5.1 Fiber Extraction and Wallpaper Fabrication

Extraction of okra fibers by stagnant-water retting yielded natural fibers with a flexible texture and good mechanical strength. After treatment and drying, the fibers displayed a homogeneous appearance and a natural coloration favourable to their use in wallpaper fabrication, confirming that okra fibers constitute an exploitable raw material for eco-friendly materials. In the first fabrication trials, the resulting wallpaper sheets displayed localized voids and pores, attributable to a non-perfectly homogeneous fiber distribution and variable

compaction during sheet formation; these directly affected the aesthetic appearance, apparent density and, to some extent, the mechanical strength of the material. Following process optimization (re-pressing, oven-drying, re-cutting and re-mixing of the pulp), the fabricated wallpaper exhibited a homogeneous texture, good fiber cohesion and a satisfactory aesthetic finish, with acceptable resistance and good adhesion after drying confirming the feasibility of using okra fibers for eco-friendly wall-covering design.

5.2 Mechanical and Physical Characterization

The tensile test results show an essentially elastic mechanical behaviour with a very good linear correlation between force and elongation. The three tested specimens displayed different stiffness values, with the stiffest specimen showing a force-elongation slope of 1167.4 and the least stiff specimen a slope of 740.66, indicating some variability in fiber distribution and cohesion between samples. The tear, grammage, thickness and moisture-uptake tests (Figure 3) further characterized the physical structure of the wallpaper: the grammage and thickness measurements confirmed a reasonably regular sheet structure consistent with the observed fiber distribution, while the moisture-uptake test revealed the hygroscopic character of the material, consistent with the cellulosic nature of the okra fibers. The finished wallpaper, presented in Figure 4 with an applied decorative motif, displays a homogeneous, regular structure and a satisfactory aesthetic finish.

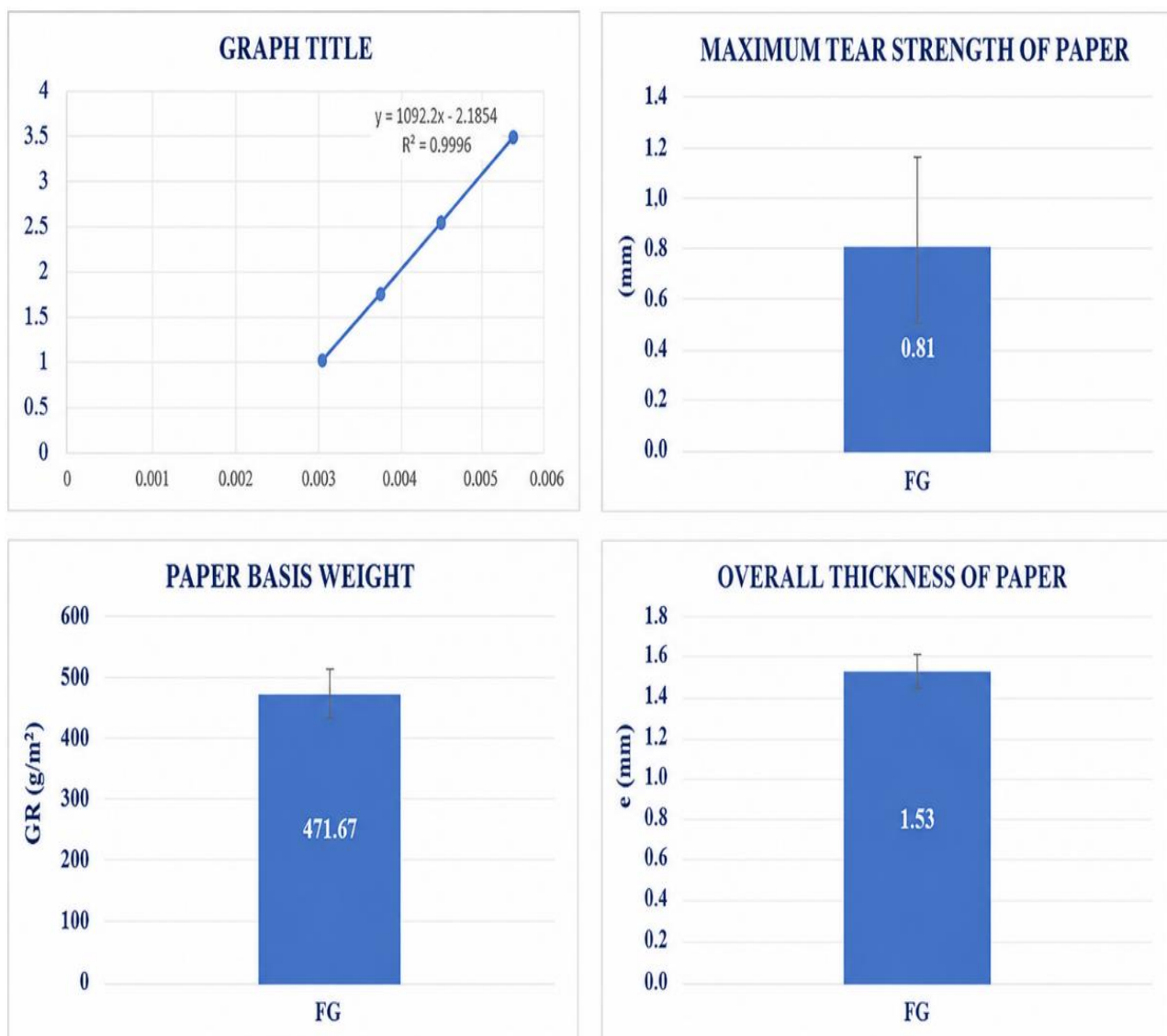


Figure 3 — Mechanical and physical characterization results: (a) tensile force-elongation curve; (b) tear test curve; (c) grammage; (d) thickness measurements

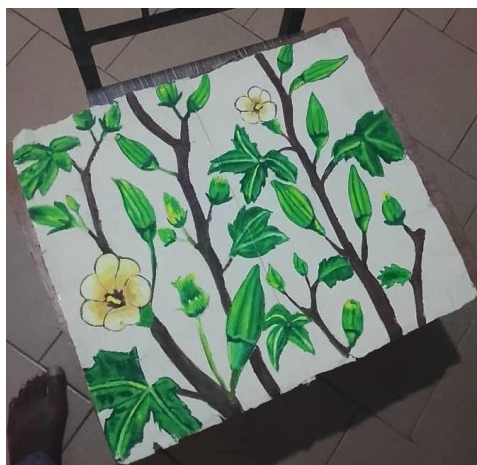


Figure 4 — Final okra-fiber wallpaper with applied decorative motif

6. Discussion

The results confirm that okra fibers extracted by stagnant-water retting possess favourable characteristics for wallpaper fabrication, in line with the fibrous, cellulose-rich structure reported by Kolte and Shivankar [1] and the good physico-mechanical performance documented by Hossen et al. [7]. The essentially elastic, linearly correlated tensile behaviour observed here is consistent with the rigid, low-elongation character typical of bast fibers such as okra, jute and kenaf [7]. The variability observed between the stiffest (1167.4) and least stiff (740.66) specimens echoes the sensitivity of okra fiber mechanical performance to extraction and treatment conditions reported by Stawski et al. [3] and Khan et al. [4], and suggests that further standardization of the alkaline treatment and pulp-forming steps could reduce this variability.

The porosity and voids observed in the initial wallpaper batches, and their subsequent reduction through process optimization (re-pressing, re-cutting and re-mixing), corroborate the sensitivity of natural-fiber sheet structure to fiber distribution and compaction highlighted in wet-drying treatment studies such as Stanislas et al. [5], who showed that mechanical reprocessing (wet-drying) can measurably improve the morphological and physicochemical properties of raffia and okra fibers. This supports the choice of an iterative, optimization-based fabrication approach in the present study rather than a single-pass process.

The hygroscopic behaviour revealed by the moisture-uptake test is consistent with the cellulosic composition of okra fiber and with the locally characterized properties reported by Nkoulou et al. [6] for okra fibers from the Littoral region of Cameroon, confirming that this hydrophilic character is an intrinsic property of the raw material rather than a fabrication defect. As noted by Ben Seghir et al. [8], this hygroscopicity, while a limitation for humid-environment applications, is also indicative of the material's renewable, cellulose-based nature and its biodegradability a key advantage over synthetic wall coverings.

From an agricultural-valorization perspective, the diversity of okra accessions documented in Cameroon by Djeoufo et al. [9] and the crop's resilience to heat and drought stress described by Ndungu et al. [10] suggest that a stable, locally sourced supply of okra stems is realistically achievable for this application, supporting the scalability of the proposed valorization pathway. Nonetheless, several limitations must be acknowledged: fabrication was carried out on a single prototype batch with a limited number of specimens (sixteen), and the process particularly pulp homogenization and compaction remains manually intensive and not yet standardized for larger-scale, reproducible production. Future work should therefore focus on optimizing and mechanizing

the pulp-forming step, testing complementary treatments (e.g., further alkalization or wet-drying cycles as in [4], [5]) to reduce mechanical variability, and conducting a comparative techno-economic assessment against conventional synthetic wallpapers.

7. Conclusion

This study demonstrated the feasibility of producing an eco-friendly wallpaper from *Abelmoschus esculentus* (okra) bast fibers, valorizing an agricultural residue that is otherwise discarded after fruit harvest. The fiber extraction (stagnant-water retting), chemical treatment (alkaline treatment, neutralization, bleaching) and wallpaper forming (pulp grinding, molding, drying and thermocompression) stages were successfully completed, and the resulting material was characterized through tensile, tear, grammage, thickness and moisture-uptake tests. The fibers exhibited a flexible texture and good mechanical strength, and the optimized wallpaper displayed a homogeneous structure, satisfactory fiber cohesion and an appealing aesthetic finish, directly addressing the study's objective of designing a usable, ecological wall-covering material from okra fiber.

These results highlight the potential of okra fibers for the fabrication of eco-friendly decorative wall coverings, while contributing to the valorization of agricultural waste and the promotion of sustainable, locally sourced materials in the construction and interior-decoration sectors. Future work will focus on mechanizing and standardizing the pulp-forming process to reduce mechanical variability between specimens, exploring complementary fiber treatments to improve moisture resistance, and conducting a techno-economic comparison with conventional wallpaper materials to support the scale-up of this eco-material for the Cameroonian market.

8. Acknowledgements

The authors wish to thank the teaching staff of the Textile and Clothing Industries (ITH) Department of ENSET Douala for their valuable advice and support.

9. References

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