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ANATOMICAL CHARACTERIZATION AND FUNDAMENTAL COMPRESSION BEHAVIOUR OF KENAF *(HIBISCUS CANNABINUS L.)* FOR POTENTIAL ORIENTED STRAND BOARD (OSB) APPLICATION

Karakterisasi Anatomi dan Perilaku Kompresi Fundamental Kenaf (Hibiscus cannabinus L.) untuk Potensi Aplikasi Oriented Strand Board (OSB)

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ABSTRACT

This study evaluates the anatomical characteristics and basic mechanical behaviour of kenaf (*Hibiscus cannabinus* L.) core with the objective of assessing its suitability as a raw material for oriented strand board (OSB). Anatomical observations (cross, radial and tangential sections) revealed three distinct stem components (bast, core, pith) and showed variation in fibre and vessel element lengths along the stem (top, middle, bottom). Compression testing perpendicular to the grain provided baseline mechanical data relevant to strand production and panel performance. Based on anatomical features and compression response, kenaf core is proposed as a viable alternative biomass feedstock for wood-based composites such as OSB, particularly for short-rotation and urban biomass sources. The work demonstrates promise but highlights the need for further quantitative processing and full-scale panel manufacture/testing (modulus of rupture, modulus of elasticity, internal bond, dimensional stability) to confirm industrial feasibility

Keywords: Kenaf Anatomy; Kenaf Core; Natural Fibre Composites; Oriented Strand Board; Wood-Based Panels

ABSTRAK

Penelitian ini mengevaluasi karakteristik anatomi dan perilaku mekanis dasar dari empulur kenaf (*Hibiscus cannabinus* L.) dengan tujuan untuk mengkaji kesesuaiannya sebagai bahan baku *oriented strand board* (OSB). Pengamatan anatomi (irisan melintang, radial, dan tangensial) menunjukkan tiga komponen batang yang berbeda (serat kulit, empulur, dan pit) serta variasi panjang serat dan elemen pembuluh di sepanjang batang (bagian atas, tengah, dan bawah). Pengujian kompresi tegak lurus serat memberikan data mekanis dasar yang relevan dengan produksi strand dan kinerja panel. Berdasarkan fitur anatomi dan respons kompresinya, empulur kenaf diusulkan sebagai bahan baku biomassa alternatif yang layak untuk komposit berbasis kayu seperti OSB, khususnya untuk sumber biomassa rotasi pendek. Penelitian ini menunjukkan potensi yang menjanjikan, namun menekankan perlunya pemrosesan kuantitatif lebih lanjut serta pembuatan dan pengujian panel skala penuh (*modulus of rupture, modulus of elasticity*, ikatan internal, stabilitas dimensi) untuk mengonfirmasi kelayakan industrinya

Kata kunci: Anatomi Kenaf; Empulur Kenaf; Komposit Serat Alam; Oriented Strand Board; Panel Berbasis Kayu

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A. INTRODUCTION

Kenaf (*Hibiscus cannabinus* L.) is a fast-growing, short-rotation crop with high biomass yield, making it a sustainable raw material. Its core and bast fibers provide versatile applications in fiber products and composite boards, aligning with global goals for renewable resources and reduced reliance on forest timber.

Kenaf has been widely investigated as an alternative lignocellulosic resource due to its favorable anatomical, mechanical, and ecological properties. The bast fibers are long, cellulose-rich, and low in lignin, supporting textile and reinforced composite applications, while the core fibers are increasingly used in oriented strand board (OSB) and particleboard production. Recent studies highlight kenaf's role in lightweight composites, thermal insulation panels, concrete reinforcement, and bio-based polymers (Yusri *et al.* 2023; Saad & Kamal 2012; Khairul Izwan *et al.* 2023; Mohd Nor *et al.* 2025). Research also emphasizes the advantages of kenaf over traditional wood, including rapid growth, lower environmental impact, and compatibility with circular economy approaches (Ahmad *et al.* 2025).

Despite promising developments, challenges remain in optimizing kenaf's industrial utilization. Variation in fiber anatomy across different stem sections affects composite quality and consistency. Limited understanding of chemical composition interactions with resins hinders achieving optimal bonding in engineered boards. Furthermore, mechanical and thermal performance often fall short compared to conventional timber products, restricting wider adoption. Economic competitiveness, scaling of processing technologies, and limited global supply chains also constrain commercialization. Addressing these gaps requires systematic studies on anatomy–property relationships and improved processing methods for core utilization (Mohd Nor *et al.* 2025; Ahmad *et al.* 2025).

Several recent studies focus on natural fiber composites and kenaf-based applications, emphasizing mechanical reinforcement, biopolymer integration, and environmental benefits (Ilyas *et al.* 2020; Hossain *et al.* 2021; Shubbar *et al.* 2024). However, few have specifically synthesized anatomical insights with technological applications of kenaf core in OSB and related composites. This research aims to consolidate current knowledge on kenaf core anatomy and its application in engineered boards, with emphasis on OSB.

This study investigates the anatomical characteristics of the kenaf core and provides baseline mechanical property data relevant to strand production and OSB manufacturing, drawing from anatomical observations and compression testing of kenaf core samples.

B. METHODS

Kenaf stems were harvested at maturity from experimental plots at Tanjung Putus, Kuantan, Pahang, Malaysia. Kenaf stems were visually separated into three longitudinal portions: top, middle, and bottom. The stems was processed to separate bast fibres from core using a specialized decortication machine; cores were air-dried to equilibrium moisture prior to anatomical and mechanical testing.

Anatomical Analyses

Transverse, radial and tangential sections of the woody core were prepared using a microtome or razor technique and stained as necessary for light microscopy. Photomicrographs were captured at magnifications appropriate for cell measurement. For each stem position (top, middle, bottom), fibre length and vessel element length were measured from micrographs using image analysis software. Representative images are provided to illustrate the structure of the core.

Compression Test (Perpendicular to Grain)

Compression testing perpendicular to the grain was carried out on core specimens in accordance with a modified ASTM D143-22 procedure for small clear specimens of wood adapted for short core samples. Specimens were sawn into prismatic blocks measuring 20 mm × 20 mm × 30 mm, with the loading direction perpendicular to the grain. All specimens were conditioned at 20–23 °C and 50–65% relative humidity for at least 48 h prior to testing. Tests were conducted on a universal testing machine equipped with a 10 kN load cell, and compression was applied at a constant cross-head rate of 2 mm/min. Load and displacement were recorded continuously to generate stress–strain curves, from which compressive strength perpendicular to grain and modulus of elasticity were calculated in accordance with ASTM procedures. Regression analysis models were used to predict the value were derived from the model:

$$Y = a + bX1 + cX2 + \ldots\ldots\ldots + nXn$$

where, Y is the compression property.

C. RESULTS AND DISCUSSION

Macroscopic and Microscopic Anatomy

Three major anatomical sections are readily visible in the transverse section of the kenaf *(Hibiscus cannabinus* L.*)* stem: the bast, core (woody fraction), and pith (Figure 1). This structure represents the inherent variety of lignocellulosic materials and is in line with results published in earlier research (Rowell 2012; Akil *et al.* 2011).

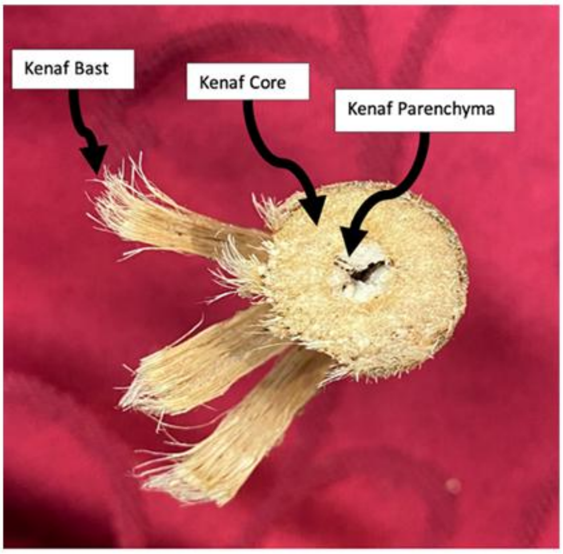

Figure 1. Three parts of kenaf stem

As seen in Figure 2, the bast region, which is the outermost layer of the stem, is primarily made up of long, thin fibers with a high aspect ratio. These fibers have distinct hollow lumens and thick secondary cell walls that are high in cellulose. Tensile strength and stiffness are greatly influenced by the high cellulose content (usually 60–70%) observed in previous investigations (Mohanty *et al.* 2005; Rowell 2012). Furthermore, bast fibers' comparatively low microfibril angle increases their reinforcing effectiveness, making them ideal for composite applications. These findings are consistent with earlier research that found bast fibers' better mechanical qualities make them the main load-bearing component of kenaf.

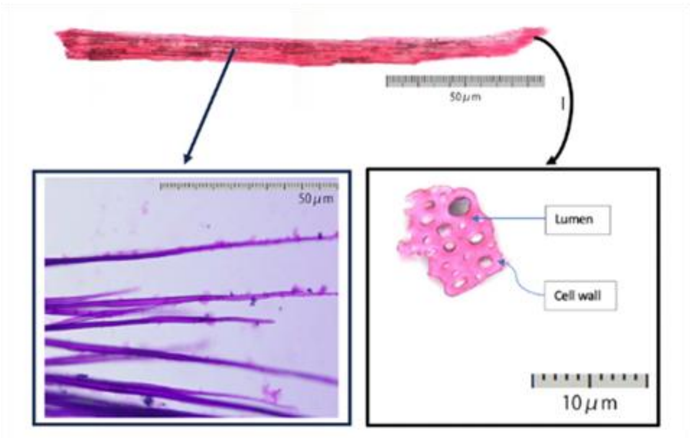

Figure 2. Kenaf fibre in the bast

The core exhibited a typical woody cellular structure (fibres and vessel elements) across top, middle and bottom sections (Figures 3, 4 and 5), with similar general anatomical patterns but measurable differences in cell lengths between positions. Photomicrographs confirm these anatomical features. The core, or woody part, on the other hand, has a more complex structure like hardwood tissue with average bulk density of 63.30 g/L. The core is made up of a mixture of shorter fibers, vessel elements, and parenchyma cells, as seen in Figures 3 to 5. While the fibers offer mechanical support, the vessel components enable fluid transport. Measurable differences in cell morphology are apparent, despite the general anatomical structure remaining constant along the stem axis (top, middle, and bottom parts). Specifically, the middle area of the stem tends to have larger vessel diameter and fiber length than the top and bottom sections, suggesting a higher level of maturity. This axial variation is in line with earlier research by Akil *et al.* (2011) and Khalil *et al.* (2010), who noted comparable gradients in fiber density and shape along the kenaf stem.

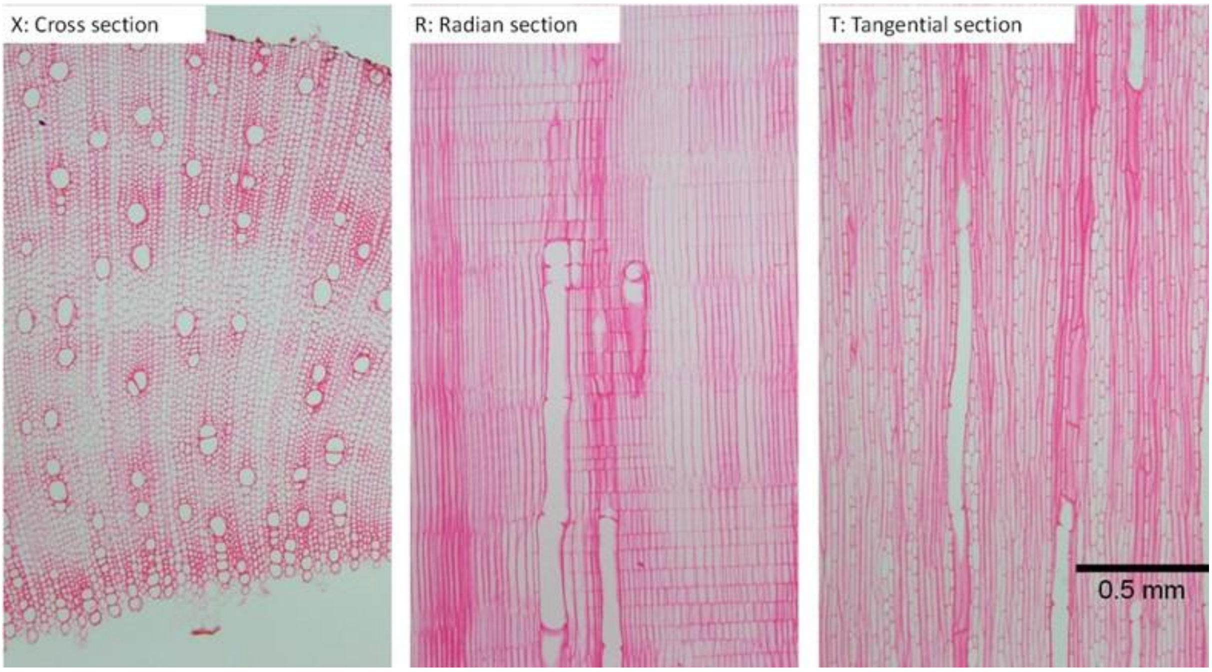

Figure 3. Optical microscopic photos of woody part of kenaf core (top portion)

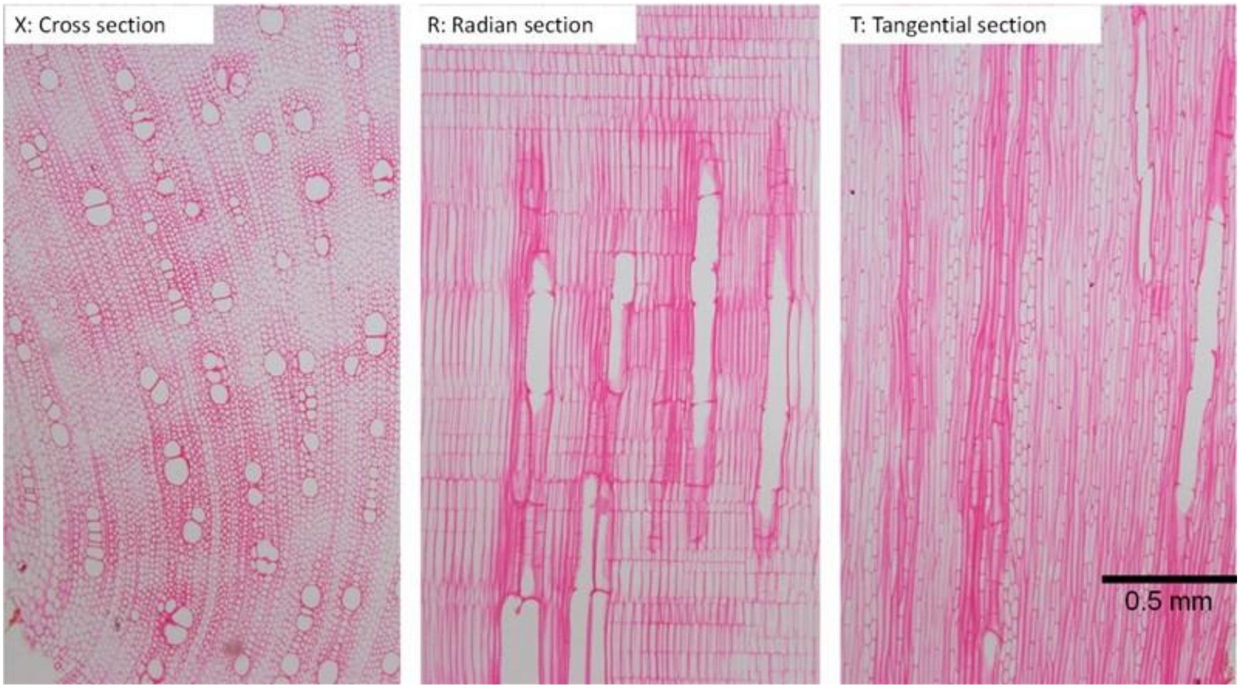

Figure 4. Optical microscopic photos of woody part of kenaf core (middle portion)

Fiber and Vessel Element Length Variation

Along the kenaf stem, measurements reveal notable variations in the lengths of the fiber and vessel elements. While vessel parts are longer at the bottom than at the top, the center section has somewhat shorter fibers than the top and bottom. These differences are connected to the stem's growth and development (ontogenetic variation).

Kenaf fibers are made of sclerenchyma cells that are strong due to their thick cell walls. Cell elongation and growth determine fiber length. The middle section's shorter fibers might point to a time of transition where cell wall thickening takes precedence over elongation. Akil et al. (2011) showed a similar variation in fiber length throughout the stem, which is supported by more recent research demonstrating that fiber characteristics change with stem position and maturity.

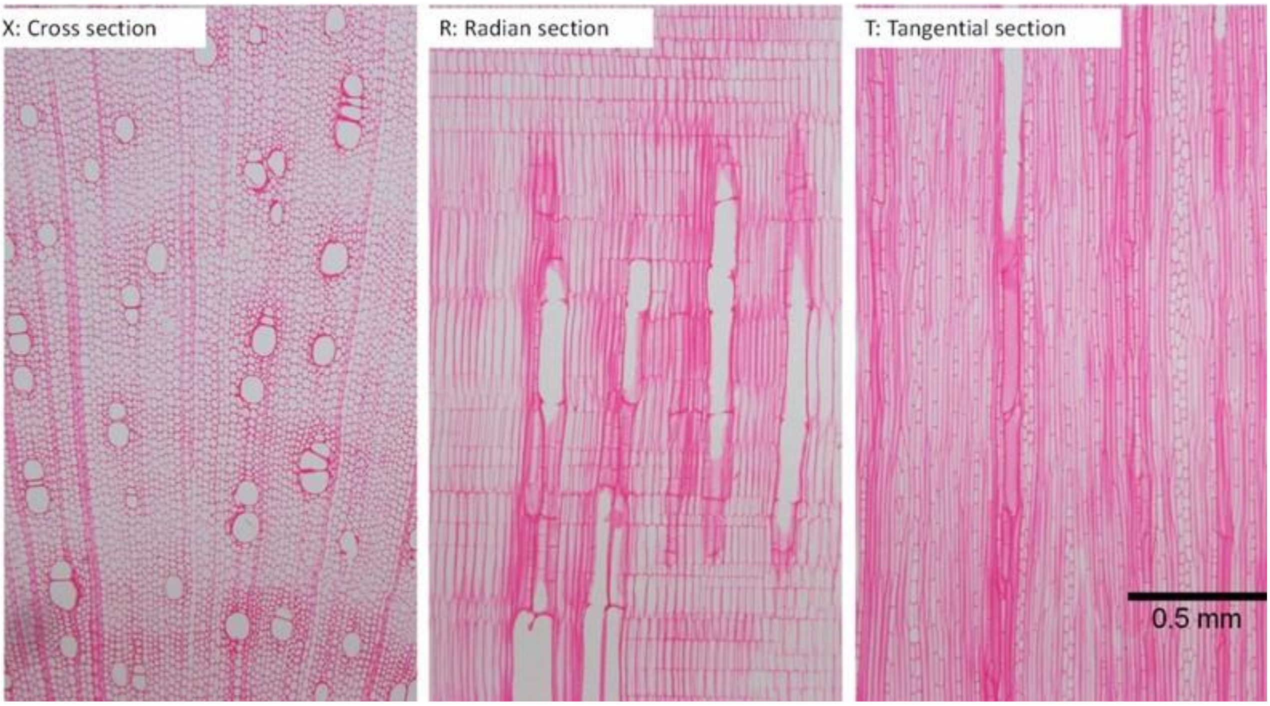

Figure 5. Optical microscopic photos of woody part of kenaf core (bottom portion)

Conversely, vessel elements have bigger lumens and are in charge of transporting water. The plant is supported by better water movement due to the longer vessels at the base of the stem. This pattern is in line with the typical anatomy of plants, where more developed vascular tissues are found at the lower part of the stem (Huang *et al.* 2025).

The performance of the material is impacted by these variations. In composites, longer fibers (both top and bottom) enhance mechanical strength and bonding. Increased permeability from longer vessels (bottom) facilitates resin penetration during processing, but too much permeability can result in uneven resin dispersion.

Stem position is significant and should be considered when using kenaf for composite and engineering applications, as seen by the overall difference in fiber and vessel element length.

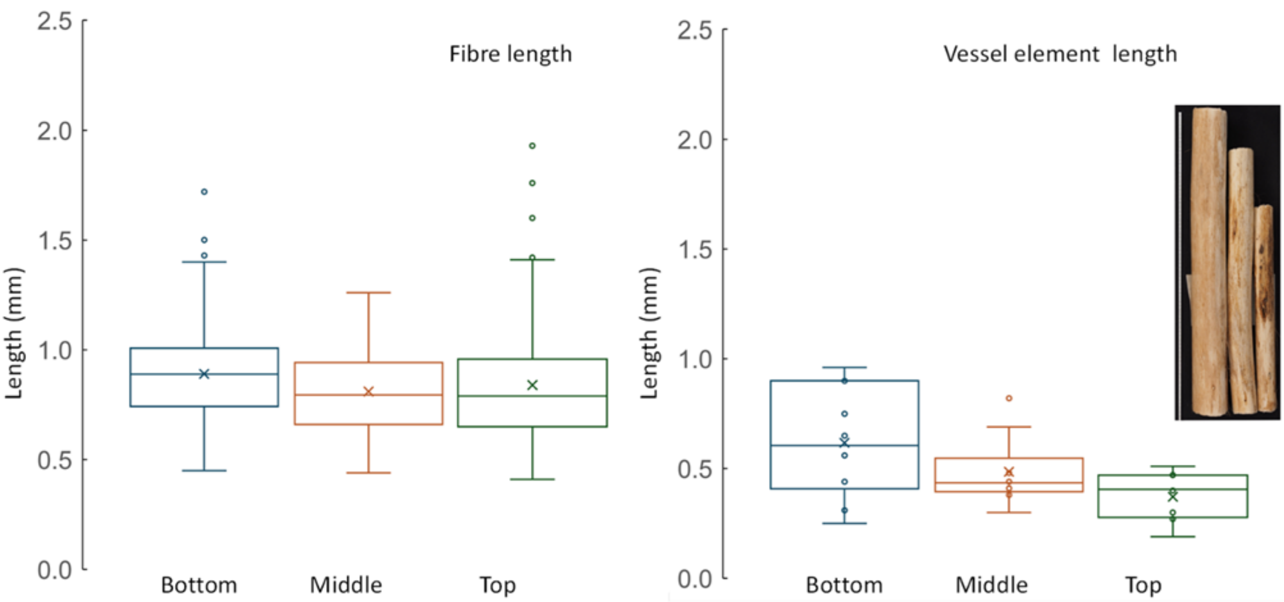

Figure 6. The length of fibres and vessel elements in the woody part of the kenaf core

Compression Behaviour Perpendicular to The Grain

Compression tests perpendicular to the grain produced characteristic stress–strain responses appropriate for a brittle-ish woody core material (bottom, middle and top). A regression analysis of this data revealed that there is a relationship between kenaf core diameter and compression properties. The equations developed (Y = 5.4363x – 26.013) were found to be highly significant and with the correlation of determination (R^2) of over 50%. The figure presented in the source (Figure 7) provides the basic compressive behaviour and indicates the kenaf core has sufficient compressive resistance to survive mechanical handling in strand production and mat-forming operations. However, to predict OSB panel performance, additional data (bending strength, internal bond, density profile) from produced panels are essential. The compressive properties will affect out-of-plane stiffness and thickness recovery after loading.

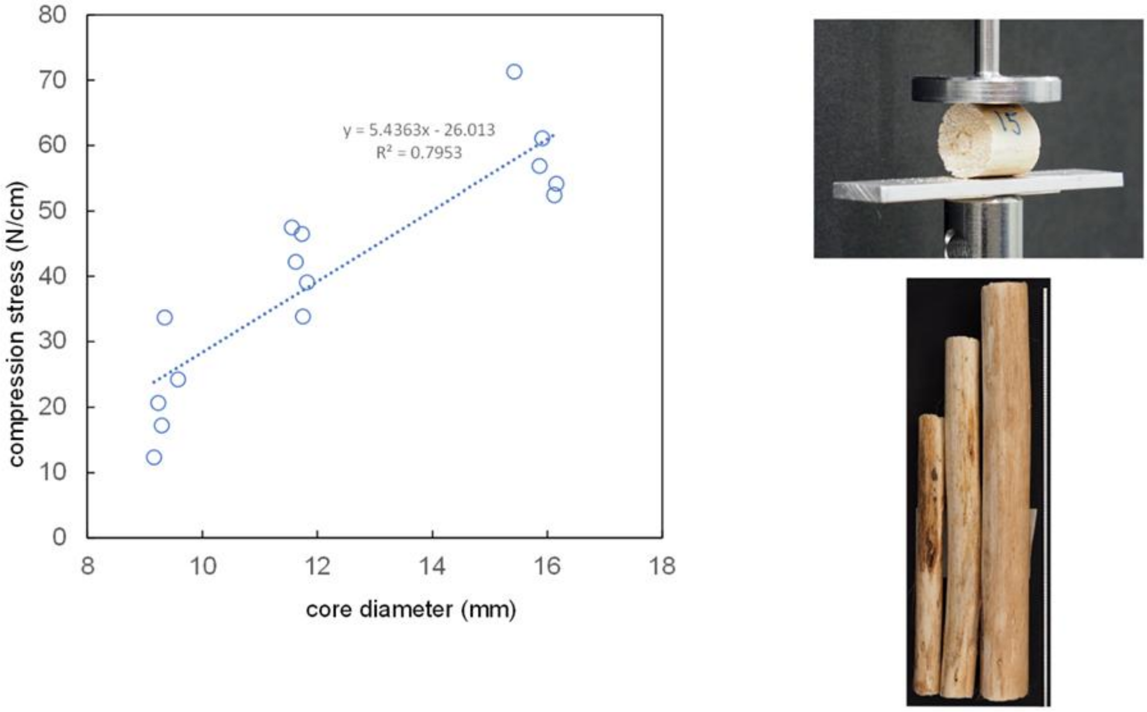

Figure 7. Compression property perpendicular to grain

The kenaf core, which is made up of short fibers, vessel elements, and parenchyma, exhibited typical brittle woody behavior in compression tests conducted perpendicular to the grain. The core has sufficient compressive strength to endure manipulation during strand production and mat formation, according to the data (Figure 7).

Like other lignocellulosic materials, the kenaf core's cell wall thickness and lumen structure affect its stress-strain response (Ansong *et al.* 2023; Misnon *et al.* 2025). Despite its brittleness, the core offers enough resistance to avoid crushing during processing.

Additional information such as bending strength, internal bond, and density profile is required to forecast OSB panel performance. Out-of-plane stiffness and thickness recovery are influenced by compressive strength; stronger cores result in less permanent deformation, whereas weaker cores may decrease panel uniformity (Huang *et al.* 2025; Han *et al.* 2022). Overall, if manufacturing and resin dispersion are adjusted, the kenaf core exhibits good potential for tailored panel applications.

D. CONLUSION

Based on the anatomical and mechanical characterization, this study offers the following conclusions regarding the use of kenaf core:

1. **Preliminary Feasibility**: Kenaf core demonstrates fundamental anatomical and mechanical characteristics that suggest it is a potential alternative feedstock for wood-based composites such as Oriented Strand Board (OSB).
2. **Anatomical Suitability**: The presence of woody fibers and vessel elements confirms the availability of usable biomass; however, the observed positional variations in fiber and vessel length along the stem must be integrated into industrial processing strategies to ensure panel consistency.
3. **Handling Durability**: Compression testing perpendicular to the grain indicates that the core possesses sufficient resistance to withstand the mechanical stresses typical of strand production and mat-forming operations.
4. **Study Limitations**: While these baseline results are encouraging, this study remains limited to characterization and does not include the fabrication of finished panels.

5. **Future Requirements**: To fully confirm industrial viability, pilot-scale manufacture of OSB panels is essential to evaluate critical performance metrics such as the Modulus of Rupture (MOR), Modulus of Elasticity (MOE), internal bond strength, and dimensional stability.

AUTHOR'S DECLARATION

The author's declaration should include a statement of any potential conflicts of interest and confirm that all authors have contributed significantly to the research and manuscript preparation. It should include a statement regarding ethical approval if applicable, and ensure that all authors have reviewed and approved the final version of the manuscript. The examples are as follows:

- Conflicts of Interest: None. Please state if any.
- We here by confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images, that are not ours, have been included with the necessary permission for republication,which is attached to the manuscript.
- No animal studies are present in the manuscript.
- No human studies are present in the manuscript.
- No potentially identified images or data are present in the manuscript.

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