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Physical and Mechanical Characterization of NK 7328 Sumo Corncob Blocks for Sustainable Furniture Applications

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ABSTRACT*: NK 7328 Sumo corncob block is abundant agricultural residue with potential as a renewable lignoselulosic biomaterial for sustainable furniture applications. However comprehensive physical and mechanical chracterization of corncob block has not been investigated yet. This study aimed to characterize the physical and mechanical properties of NK 7328 Sumo corncob blocks, including dimensions, mass, density, and moisture content. Mechanical testing via compression test (parallel and perpendicular to the structure) and three-point bending test was conducted using a Universal Testing Machine and supporting manual compression test. The results indicated that corncob blocks possess low density, moderate moisture content, and relatively uniform dimensions, reflecting their lightweight lignoselulosic nature. Mechanical testing revealed anistropic behavior, with average compressive stresses of 7.41 ± 1.52 MPa (parallel) and 17.04 ± 4.48 Mpa (perpendicular). The coresponding compressive modulus of elasticity was 225.31 ± 33.32 MPa (parallel) and 104.57 ± 19.14 MPa (perpendicular), respectively. The average flexural stress was 6.75 ± 0.42 MPa with a flexural modulus of elasticity of 365.87 ± 88.17 MPa. These properties were includid by NK 7328 Sumo corncob block's porosity, anisotropy, and internal heterogeneity. This findings sugest that NK 7328 Sumo corncob are suitable for lightweight, non-structural, semi-functional, and decorative furniture components, although their mechanical strength and stiffness limit their use in primary load-bearing applications.*

Keywords: *NK 7328 Sumo corncob block; Physical Characterization; Mechanical Characterization anisotropy; sustainable furniture*

1. INTRODUCTION

Corn (*Zea mays L.*) is a significant agricultural commodity and abundance in Indonesia, generating substantial post-harvest residues, notably corncobs. According to (BPS, 2025), Indonesia produced 15.14 million tons of dry shelled corn from 2.55 million hectares of harvested area in 2024. Globally, corn ranks among the highest-volume cereal crops, producing considerable quantities of post-harvest agricultural residues (FAO,2024). In Indonesian local post-harvest practices, such as sun-drying, smoking, and shelling corncobs for feed, corncobs remain the primary structural residue. However, local

communities have yet to fully utilize these corncobs block residues, which are typically disposed of by burning to reduce waste volume, used as animal bedding, composted, or accumulated around storage areas, resulting in space occupation and decomposition (Fitri et al., 2023). Consequently, converting corncobs into value-added materials is cru cial for enhancing agricultural waste utilization and advancing sustainable material development. As also mention by Maqsood et al. (2025) emphasized that corn residues remain underexploited despite their potential for conversion into higher-value products, including biomaterials, biofuels, and bioactive compounds.

As lignocellulosic biomass, corncob provides a robust scientific foundation for material development. Louis and Venkatachalam (2020) analyzed dried corncob and reported its dry basis composition as 45.01% cellulose, 33.12% hemicellulose, 13.81% lignin, 3.10% ash, and 4.96% other extractives. This dry-basis composition is pertinent, given that the higher moisture content in fresh corncob can alter its apparent composition on a wet weight basis. Pinto et al. (2012) identified corncob as a potential raw building material owing to its low density and distinctive physical characteristics. These findings collectively indicate that corncob possesses both chemical and physical attributes conducive to its development as a renewable biomaterial.

Nonetheless, the structural complexity of corncob governs its material behavior. (Takada et al., 2018) reported that corncob comprises three primary tissue fractions including pith, woody ring, and chaff with each exhibiting distinct morphological and compositional characteristics that affects mechanical behavior and necessitates direct evaluation to understand its suitability as a functional biomaterial. This inherent structure imparts heterogeneity and anisotropy to the material. Zou et al. (2021) demonstrated that such microstructural variation affects stress transfer and mechanical response under loading. Additionally, Marcuello et al. (2020) showed that relative humidity influences the elastic modulus of lignocellulosic polymers at the nanoscale. Collectively, these complex and variable characteristics indicate that direct evaluation of corncob is essential prior to its application as a functional material.

Previous investigations have primarily focused on processed or engineered forms of corncob and corn-derived residues. For example, Ramos et al. (2021) examined corncob particleboards bonded with polyvinyl alcohol (PVA), reporting thermal conductivity values comparable to conventional insulation materials, thereby demonstrating corncob's value-added potential in building applications. Choi et al. (2022) developed corncob-based composite boards with enhanced thermal performance through the incorporation of microencapsulated phase change materials. Akinyemi et al. (2016) evaluated composite particleboards composed of corncob particles and sawdust, concluding that these boards are more suitable for indoor, non-load-bearing applications. Okeke et al. (2024) reviewed corncob-based building materials and identified compressive strength as a significant limitation for structural use. In the context of product design, Masri (2020) demonstrated that corncob-based products can be developed into practical and marketable commodities when production efficiency and material performance are adequately addressed. More recent studies have also investigated corncob waste as a filler in biocomposites, reinforcement in

polymer composites, particulate material for particleboard, and as a modified component in cement mortar systems (Gairola et al., 2022; Fouly et al., 2021; Nkomo & Alugongo, 2025; Deng et al., 2025).

The importance of physical and mechanical characterization in biomass material development is further corroborated by studies on lignocellulosic and biomass-based materials. For instance, Hanifah et al. (2025) reviewed cellulose isolation and characterization methods from biomass. Amrillah et al. (2024) evaluated cocoa pod husk as a cellulose-rich agricultural waste, demonstrating that its material potential depends on measurable compositional properties. Putra and Thamrin (2022) assessed the physical and mechanical performance of bioplastics derived from banana starch to determine functional feasibility. Rahmatullah et al. (2024) developed biodegradable bioplastics reinforced with natural fibers, while Rahmatullah et al. (2025) evaluated a biocomposite bioplastic system through physical and mechanical testing. These studies collectively indicate that biomass valorization necessitates objective and quantifiable technical evidence.

Despite these advancements, most corncob-related research has concentrated on processed forms, such as particleboards, composite boards, extracted fractions, and engineered panels. Direct physical and mechanical characterization of corncob in block form with controlled dimensions remains scarce. This distinction is critical, as block-form corncob retains its native heterogeneity, anisotropy, and porosity, which may yield mechanical responses distinct from those of processed or composite products. Therefore, baseline characterization of corncob blocks is imperative prior to their combination with binders or application in furniture-related material development. Accordingly, the present study diverges from previous corncob-based material investigations by evaluating untreated corncob in block form, whereas most recent studies have emphasized processed, bonded, reinforced, or modified systems (Gairola et al., 2022; Fouly et al., 2021; Nkomo & Alugongo, 2025; Deng et al., 2025). all previous research has primarily focused on processed corncob forms, such as particleboards and composites, which alter the native structural features of the material. Direct physical and mechanical characterization of corncob in its native block form remains limited, despite its importance for preserving inherent heterogeneity, porosity, and anisotropy that influence performance. Reliable baseline data on dimensions, density, moisture content, compressive strength, and flexural behavior are essential to assess the feasibility of corncob blocks for sustainable furniture applications, particularly for lightweight, non-structural, semi-functional, or decorative components. however, sustainable furniture material development requires demonstrable technical data beyond mere renewable origin. The findings of Akinyemi et al. (2016) underscore the necessity of evaluating physical and mechanical properties when agricultural residues are directed toward indoor and non-load-bearing applications.

This study aims to fill this gap between direct physical and mechanical characterization of corncob by systematically characterizing the properties of untreated corncob blocks. Through comprehensive testing, including compression and three-point bending, the research provides foundational technical evidence to evaluate the suitability and limitations of corncob blocks as renewable biomaterials for

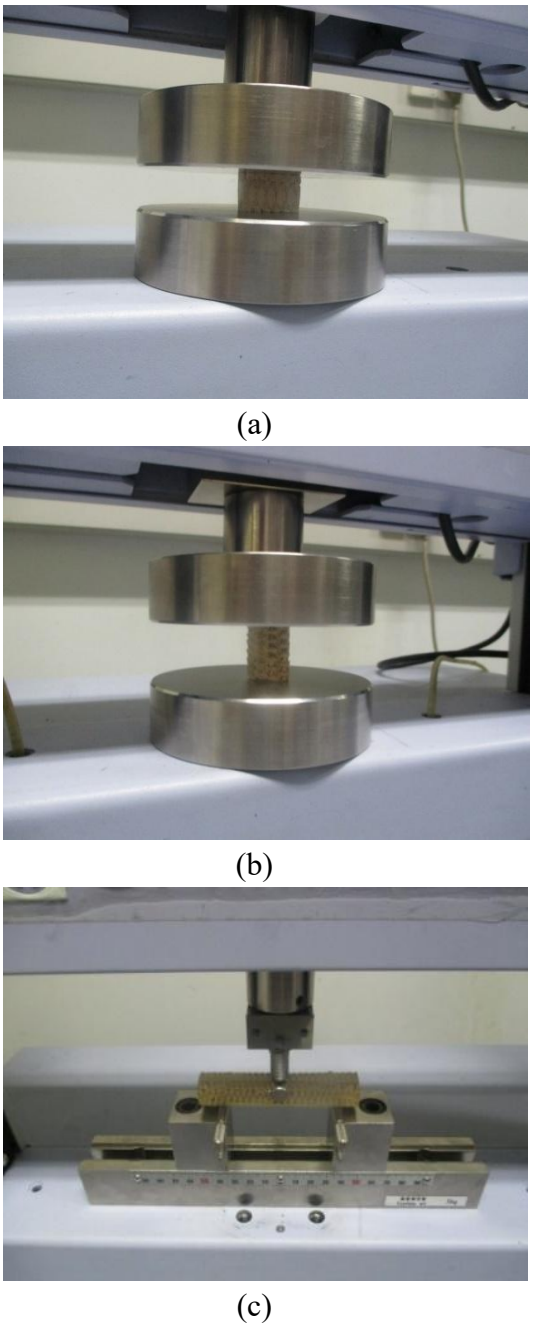
lightweight, non-structural, semi-functional, and decorative furniture components.

2. MATERIALS AND METHODS

2.1. Materials preparation and data analysis

The corncob material utilized in this study was derived from the NK 7328 Sumo variety, sourced from Limbangan District, Garut Regency, West Java, Indonesia. The corncobs were harvested approximately 90 to 115 days after planting. Selection criteria prioritized physical integrity, excluding specimens exhibiting visible defects such as cracks, decay, or pest damage. Following kernel removal, the selected corncobs were thoroughly cleaned to eliminate residual kernels, dust, and loose particles. Subsequently, the corncobs were cut and shaped into block specimens (14.66 mm height x 14.81 mm width x 24.23 mm length) conforming to the dimensions required for testing as shown Table 1. No adhesive, reinforcement, or densification treatments were applied. These untreated corncob blocks were examined to establish baseline physical and mechanical properties prior to any processing involving binders or additional materials.

The experimental work was conducted between October 2025 and January 2026. Supporting manual compression tests were performed at PT Matahati Kreasi Nusantara Laboratory, Bandung, utilizing a Krisbow Machino Pressure Hydraulic 12 Ton device. The principal mechanical tests were carried out at the Laboratory of Material and Structural Mechanics, BRIN Serpong, employing a Shimadzu Autograph AGS-X 10 kN Universal Testing Machine (UTM). Specimen dimensions were measured with a Taffware digital caliper, and mass was determined using a SORU digital balance with a maximum capacity of 500 g and a readability of 0.01 g. Initial moisture content was assessed using a BR038 Wood Moisture Meter.



(a) (b) (c)

Figure 1. Schematic illustration of the testing configurations: (a) compression parallel to the material structure, (b) compression perpendicular to the material structure, and (c) three-point bending test.

Specimens were allocated into four distinct test groups as follows: (1) thirty-eight (38) specimens for manual compression testing parallel to the material structure; (2) five (5) specimens for UTM-based compression testing parallel to the material structure; (3) five (5) specimens for UTM-based compression testing perpendicular to the material structure; and (4) five (5)

specimens for three-point bending testing. The manual compression test provided supplementary data, whereas the UTM-based compression and bending tests constituted the primary mechanical evaluations. The testing configurations, illustrating loading orientations and support arrangements, are presented in Figure 1.

The data were analyzed descriptively and inferentially to establish the baseline physical and mechanical characteristics of corncob blocks. The results were presented as mean and standard deviation for each test group. Differences in compression properties between loading orientations were analyzed using Welch's t-test at a significance level of 0.05. The test was applied to maximum load, maximum compressive stress, maximum compressive strain, and compressive modulus of elasticity. Welch's t-test was selected because the comparison involved two independent groups with small sample sizes and unequal standard deviations. Stress-strain curves were used to interpret stiffness, peak response, deformation behavior, and post-peak failure patterns. The UTM-based compression and bending results were used as the primary basis for interpretation, whereas the manual compression test provided supporting descriptive information.

2.2. Physical Characterization

Prior to mechanical testing, specimens underwent physical characterization. Parameters measured included dimensions, mass, density, and moisture content. Dimensions were recorded using a digital caliper, and mass was measured via a digital balance. Moisture content was determined with the BR038 Wood Moisture Meter to characterize the initial moisture state of the specimens. Specimen volume (V) was calculated as the product of length (l), width (w), and height (h) as shown in Eq. (1). Density (ρ) was calculated as the ratio between mass (m) and volume (V) using and Eq. (2).

$$V = l \times w \times h \qquad (1)$$

$$\rho = \frac{m}{V} \qquad (2)$$

where V is specimen volume, l is length, w is width, t is thickness, ρ is density, and m is specimen mass.

2.3. Mechanical Characterization

Mechanical characterization include compression testing and three-point bending testing. Compression testing was conducted in two loading orientations, namely (1) parallel and (2) perpendicular to the material structure. As soon in Figure 1(c). For compression parallel to the material structure, the load was applied along the dominant internal direction of the specimen. For compression perpendicular to the material structure, the load was applied across the dominant internal direction. Both compression tests were conducted using the Shimadzu Autograph AGS-X 10 kN Universal Testing Machine (UTM) at a loading speed of 1.3 mm/min. Loading continued until maximum load or visible failure was observe. We measured compression parameters included maximum load, compressive stress, compressive strain, and compressive modulus of elasticity.Which calculated using Eq. (3), Eq. (4), and Eq. (5).

$$\sigma c = \frac{Fmax}{A} \qquad (3)$$

$$\varepsilon = \frac{\Delta L}{L0} \qquad (4)$$

$$E = \frac{\Delta \sigma}{\Delta \varepsilon} \qquad (5)$$

where σc is compressive stress, Fmax is maximum load, A is loaded cross-sectional area, εc is compressive strain, ΔL is deformation, L0 is initial specimen length in the loading direction, Ec is compressive modulus of elasticity, Δσ is stress difference, and Δε is strain difference. The compressive modulus of elasticity was calculated using

the secant approach within the strain range of 0.05% to 0.25%.

The measured bending parameters reuslt and compass maximum load, flexural stress, flexural strain, and flexural modulus of elasticity. The calculation follow the general framework of ASTM D790, with modification to accommodate athe geometry and inheren characteristics of corncob block specimens. Flexural stress, flexural strain, and flexural modulus of elasticity were calculated using Eq. (6), Eq. (7), and Eq. (8),respectively.

$$\sigma f = \frac{3PL}{2bd^2} \quad (6)$$

$$\varepsilon f = \frac{6Dd}{L^2} \quad (7)$$

$$Ef = \frac{L^3 m}{4db^3} \quad (8)$$

where σf is flexural stress, P is maximum load, L is span length, b is specimen width, d is specimen thickness, εf is flexural strain, D is mid-span deflection, Ef is flexural modulus of elasticity, and m is the slope of the initial linear region of the load-deflection curve. Supporting manual compression testing employed the Krisbow Machino Pressure Hydraulic 12 Ton device on thirty-eight specimens loaded parallel to the material structure. Maximum load readings were recorded at peak load and converted to Newtons for stress calculation. Due to the manual equipment's inability to capture continuous load-displacement data, this test served exclusively as supplementary descriptive data.

3. RESULTS AND DISCUSSION

3.1. Physical Characteristics of Corncob Block Specimens

Physical measurements describe the initial physical properties of corncob block specimens. (Rahmatullah et al., 2025) stated that the mechanical behavior of lignocellulosic materials is influenced by specimen dimensions, mass, moisture content, and density. Table 1 presents the dimensions, mass, moisture content, and density of the corncob block specimens.

Table 1. Initial physical characteristics of corncob block specimens

No	Test group	Dimensions			Mass (g)	Moisture content (%)	Density (g/ cm^3)
		Height (mm)	Width (mm)	Length or Span (mm)			
1.	Compression parallel to the material structure	14.66 ± 0.48	14.81 ± 0.32	24.23 ± 0.82	2.412 ± 0.125	7.72 ± 0.31	0.459
2.	Compression perpendicular to the material structure	14.06 ± 0.41	14.11 ± 0.20	23.70 ± 0.22	2.266 ± 0.142	7.57 ± 0.26	0.482
3.	Three point bending	15.15 ± 0.06	15.23 ± 0.09	70.00	8.934 ± 0.538	7.99 ± 0.23	0.553

Table 1 shows that each test group had relatively uniform dimensions and mass, except the three-poin bending specimen due to measurement tool's requirement. The moisture content ranged from 7.57 ± 0.26% to 7.99 ± 0.23%, indicating that the specimens were tested under comparable initial moisture conditions. This comparable

initial moisture condition is important because moisture can affect stiffness and deformation behavior in corncob lignocellulose particularly during the early stage of loading (Marcuello et al., 2020) The estimated density ranged from 0.459 to 0.553 g/cm³. This low density, consistent with corncob being identified as a low-density biomass (Pinto, Cruz, et al., 2012) is closely related to its porous internal structure. This porosity can reduce stress-transfer efficiency during mechanical loading (Zou et al., 2021), confirming corncob blocks as lightweight lignocellulosic materials

The density of the specimens falls within the particleboard density range of 0.40–0.90 g/cm³ specified in SNI 03-2105-2006 (BSN, 2006b) Their moisture content was also below the maximum moisture content limit of 14% specified in the same standard (BSN, 2006b). These results show that corncob blocks meet the general physical range of particleboard in terms of density and moisture condition. However, physical suitability alone is not sufficient to determine their functional suitability for furniture applications. This interpretation is consistent with corn-residue particleboard research, which shows that physical properties need to be evaluated together with mechanical performance before a biomass-based material can be considered for functional applications (Astari et al., 2024).

3.2. Compression properties of Corncob Blocks

The compression properties of corncob blocks were analyzed using Welch's t-test to determine the statistical significance of differences between loading orientations. The compression properties of corncob blocks under different loading orientations are presented in Table 2.

Table 2. Compression properties of corncob blocks under different loading orientations

No	Parameter	Parallel to the material structure	Perpendicular to the material structure	p-value	Interpretation
1.	Maximum load (N)	1607.75 ± 327.08	3388.20 ± 940.78	0.011	Significantly different
2.	Maximum compressive stress (MPa)	7.41 ± 1.52	17.04 ± 4.48	0.006	Significantly different
3.	Maximum compressive strain (%)	5.99 ± 1.76	37.95 ± 6.60	<0.001	Significantly different
4.	Compressive modulus of elasticity, Ec (MPa)	225.31 ± 33.32	104.57 ± 19.14	<0.001	Significantly different

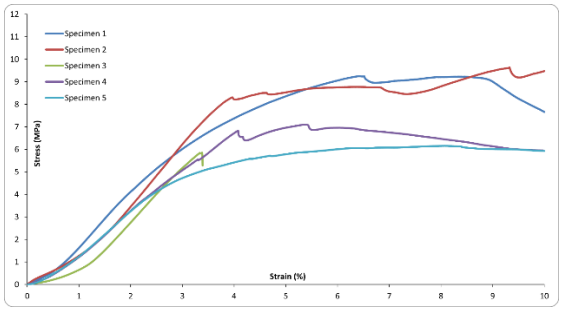
Values are presented as mean ± standard deviation. Differences between loading orientations were analyzed using Welch's t-test at $\alpha = 0.05$.

As shown in Table 2, Welch's t-test confirmed that all compression parameters differed significantly between parallel and perpendicular loading orientations ($p < 0.05$). This result indicates that the perpendicular direction exhibited higher peak stress and greater deformation capacity despite having lower initial stiffness. Conversely, the parallel direction showed higher initial stiffness but failed at lower stress and strain.

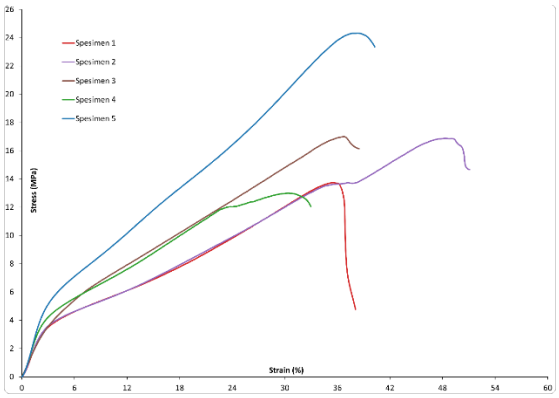
Therefore, the higher peak stress in the perpendicular direction should not be interpreted as higher stiffness. Instead, it reflects progressive compaction of the porous corncob structure before reaching peak stress. A similar relationship between pore structure and mechanical response has been reported in modified corncob-based mortar, where the internal pore system affected the load-bearing response and deformation behavior of the material (Deng et al., 2025).

The orientation dependent compression behavior was further clarified through the stress-strain curves presented in Figure 2. Figure 2(a) shows the stress-strain curves of corncob blocks compressed parallel to the material structure. The curves generally showed a steeper initial slope and reached peak stress at relatively low strain. This response indicates that the load was transferred more directly along the dominant internal structure of the corncob block. However, the material had limited deformation capacity in this direction, as shown by the lower maximum compressive strain. The sharper increase in stress at the early stage of loading is consistent with the higher compressive modulus of elasticity obtained in the parallel direction.

Figure 2(b) shows the stress-strain curves of corncob blocks compressed perpendicular to the material structure. The curves showed a more gradual stress increase and a wider deformation range before reaching peak stress. This behavior indicates that perpendicular loading promoted gradual pore collapse and compaction across the internal tissue structure. The larger strain value in this direction confirms that the material absorbed deformation through progressive densification rather than through a stiff elastic response. Therefore, the perpendicular direction produced higher compressive stress and strain, while the parallel direction showed higher initial stiffness.



(a)



(b)

Figure 2. Stress-strain curves of corncob blocks under compression loading: (a) parallel to the material structure and (b) perpendicular to the material structure.

The stress-strain curves of corncob blocks against orientation loaded effect is clearly shown by the representative overlay curves in Figure 3. The parallel direction exhibited a steeper initial slope, indicating higher initial stiffness, whereas the perpendicular direction showed a more gradual stress increase but reached higher peak stress and much larger strain. This difference confirms that corncob blocks behave as anisotropic porous materials rather than homogeneous solid materials (Dauletbek et al., 2022).

The compression properties shows that corncob blocks cannot be treated as homogeneous solid materials. Although anisotropy and pore collapse are common

responses in lignocellulosic biomass, this study provides direct quantitative evidence for intact untreated corncob blocks by comparing stress, strain, and modulus responses under parallel and perpendicular compression. This finding is importantly genuine because the specimens were tested as pure corncob blocks without adhesive, densification, or reinforcement, which provides baseline data for their development as lightweight furniture-related biomaterials. Figure 3 also shown that the mechanical performance depends on the direction of loading and the internal porous structure. This finding is important for further material development because high peak stress alone is not sufficient. Instead of stress and strain properties, the corncob block's stiffness and deformation stability must also be considered when corncob blocks utilized directly toward furniture-related applications.

This consideration is also relevant to corncob-based composite systems, where the mechanical contribution of corncob depends on its interaction with the matrix, internal structure, and ability to transfer load within the material system Fouly et al., 2021; Gairola et al., 2022).

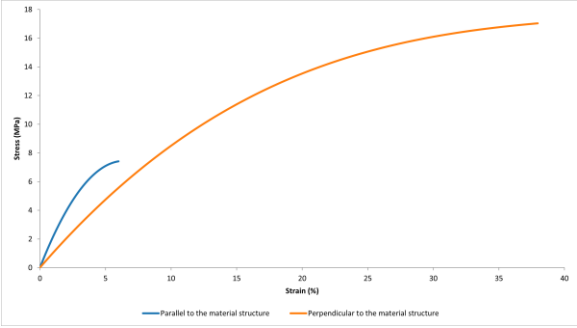


Figure 3. Representative overlay stress-strain curves of corncob blocks under compression parallel and perpendicular to the material structure.

Takada et al. (2018) reported that corncob consists of pith, woody ring, and chaff fractions with different morphological characteristics. Zou et al. (2021) also showed that the layered structure of corncob affects stress transfer and mechanical response. The present results extend these findings by showing that loading orientation quantitatively changes the compressive stress, strain, and modulus response of intact corncob blocks. Therefore, the mechanical behavior observed in this study is not only a general biomass characteristic, but also a specific technical consideration for positioning untreated corncob blocks in lightweight and non-structural furniture applications.

To support the mechanical interpretation, the physical appearance of the specimens before and after compression testing is presented in Figure 4. The visual documentation provides direct evidence of how the corncob block structure responded to different loading orientations. This comparison is necessary because the stress-strain curves and statistical values explain the mechanical response, while the specimen appearance shows the actual deformation pattern after loading.

Figure 4 shows the representative appearance of corncob block specimens before and after compression testing under parallel and perpendicular loading orientations.



(a)



(b)



(c)



(d)

Figure 4. Representative appearance of corncob blocks before and after compression testing: (a) before compression parallel to the material structure, (b) after compression parallel to the material structure, (c) before compression perpendicular to the material structure, and (d) after compression perpendicular to the material structure.

The visual changes in Figure 4 support the orientation-dependent compression properties shown in Table 2 and Figure 2. The specimen compressed parallel to the material structure showed more localized deformation, while the specimen compressed perpendicular to the material structure showed greater overall deformation. This difference indicates that perpendicular loading promoted progressive pore collapse and compaction within the porous corncob structure. The failure appearance confirms that the compressive response of corncob blocks was affected by loading orientation and internal porosity.

In addition to the UTM-based compression test, a supporting manual compression test was conducted to provide supplementary observations on the compressive response of corncob blocks under simpler loading conditions. This test was not intended for direct quantitative comparison with the UTM results because the manual system did not provide controlled crosshead speed, precise specimen alignment, or continuous deformation recording. Therefore, the manual compression data were used to support the interpretation of deformation behavior, specimen variability, and visible structural collapse.

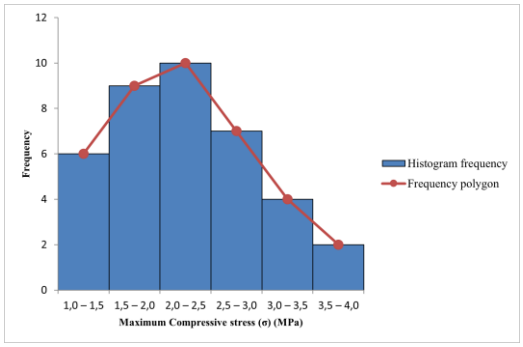
We conducted a supporting manual compression test to observe the compressive response of corncob blocks using 38 specimens. The manual compression results are presented in Table 3.

Table 3. Supporting manual compression test of corncob blocks

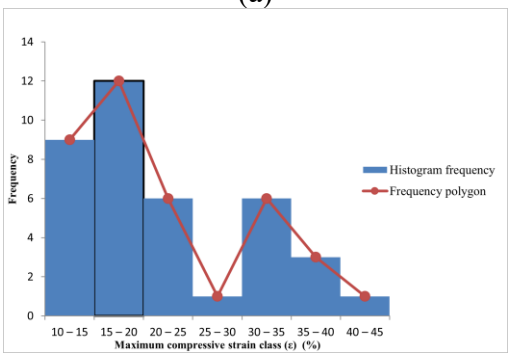
No	Parameter	Value
1.	Number of specimens (n)	38
2.	Maximum compressive stress (MPa)	2.249 ± 0.696
3.	Maximum compressive strain (%)	21.894 ± 8.744

The supporting manual compression test involved 38 specimens and produced an average maximum compressive stress of 2.249 ± 0.696 MPa and an average maximum compressive strain of 21.894 ± 8.744%. The lower stress value compared with the UTM-based compression results should not be interpreted as a contradiction because the manual test used a simpler loading system without controlled crosshead speed, precise specimen alignment, or continuous deformation recording. Therefore, the manual compression results should be interpreted as supplementary evidence rather than as the primary mechanical properties. The relatively large strain variation indicates that deformation behavior was sensitive to internal differences among specimens, such as pore distribution, local compactness, cutting quality, and tissue structure. This result supports the UTM findings that corncob blocks do not behave as homogeneous solid materials.

Figure 5 presents the distribution of maximum compressive stress and maximum compressive strain obtained from the supporting manual compression test.



(a)



(b)

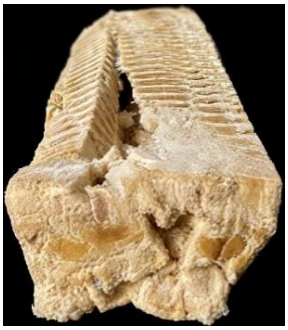
Figure 5. Distribution of manual compression test results of corncob blocks: (a) maximum compressive stress and (b) maximum compressive strain.

The distribution in Figure 5 shows that maximum compressive stress was mainly concentrated in the range of 1.5–3.0 MPa, with the highest frequency in the 2.0–2.5 MPa class. This pattern indicates that most specimens had relatively close stress values under manual compression. In contrast, maximum compressive strain showed a wider distribution, especially between 10% and 35%. This wider strain distribution suggests that deformation behavior was more variable than stress response. The result supports the UTM findings that corncob blocks do not behave as homogeneous solid materials because their compressive response is strongly affected by their porous and heterogeneous internal structure.

Figure 6 shows the representative appearance of corncob block specimens before and after the supporting manual compression test.



(a)



(b)

Figure 6. Representative appearance of corncob blocks in the supporting manual compression test: (a) specimen before manual compression, (b) specimen after manual compression.

The visual appearance in Figure 6 supports the manual compression results presented in Table 3. The specimen after testing showed permanent deformation and local collapse, indicating that the porous corncob structure was compressed under manual loading. The 38 tested specimens also showed visible variation in deformation pattern, which supports the relatively large variation in maximum compressive strain. This condition confirms that the manual

compression response was affected by the heterogeneous internal structure, pore distribution, and local compactness of each corncob block. Because the manual system did not provide controlled crosshead speed, precise alignment, or continuous deformation recording, its results were not used for direct quantitative comparison with the UTM-based data.

Overall, the supporting manual compression test strengthens the interpretation obtained from the UTM-based compression test. The manual results showed permanent deformation, local collapse, and variation among specimens, which are consistent with the porous and heterogeneous structure of corncob blocks. However, due to the limitations of the manual loading system, these results should be used only as supporting evidence for deformation behavior and not as direct mechanical performance data for comparison with the UTM results.

3.3. Flexural Properties under Three-Point Bending

The three-point bending test was conducted to evaluate the flexural response of untreated corncob blocks as potential lightweight furniture-related materials. Unlike compression loading, bending produces combined stress conditions because the upper region of the specimen experiences compression while the lower region experiences tension. Therefore, this test is necessary to determine whether corncob blocks can resist bending deformation in addition to compressive loading. The flexural properties were evaluated through maximum load, maximum flexural stress, maximum flexural strain, and flexural modulus of elasticity. The representative appearance of corncob block specimens before and after three-point bending is presented in Figure 7 to show the visible deformation and local damage caused by flexural loading.

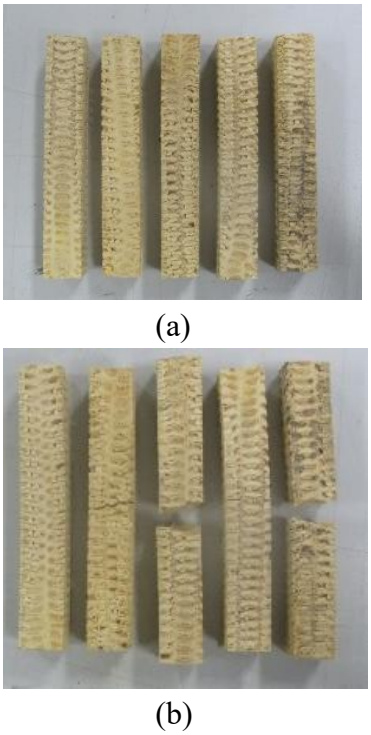


Figure 7. Representative appearance of corncob blocks before and after three-point bending: (a) specimen before testing and (b) specimen after three-point bending.

Figure 7 shows the representative appearance of corncob block specimens before and after the three-point bending test. The flexural properties of corncob blocks under three-point bending are presented in Table 4.

Table 4. Flexural properties of corncob blocks under three-point bending

No	Parameter	Value
1.	Maximum load (N)	224.75 ± 14.33
2.	Maximum flexural stress (MPa)	6.75 ± 0.42
3.	Maximum flexural strain (%)	2.23 ± 0.53
4.	Flexural modulus of elasticity (MPa)	365.87 ± 88.17

As shown in Table 4 and Figure 8, the three-point bending test showed that corncob blocks had measurable flexural resistance, with an average maximum flexural stress of 6.75 ± 0.42 MPa and a flexural modulus of elasticity of 365.87 ± 88.17 MPa. The relatively small variation in flexural stress indicates that the ultimate bending resistance was fairly consistent among specimens. However, the higher variation in flexural modulus shows that initial bending stiffness was more sensitive to internal structural differences. Compared with processed particleboard systems based on corn residues or corncob particles, untreated corncob blocks in this study represent a baseline material condition without resin bonding, particle rearrangement, or densification (Astari et al., 2024 ; Nkomo & Alugongo, 2025).

The flexural properties presented in Table 4 show that corncob blocks had measurable bending resistance, while Figure 7 provides visual evidence of deformation and local damage after three-point bending. To further explain this flexural response, the flexural stress-strain curves of corncob blocks under three-point bending are presented in Figure 8.

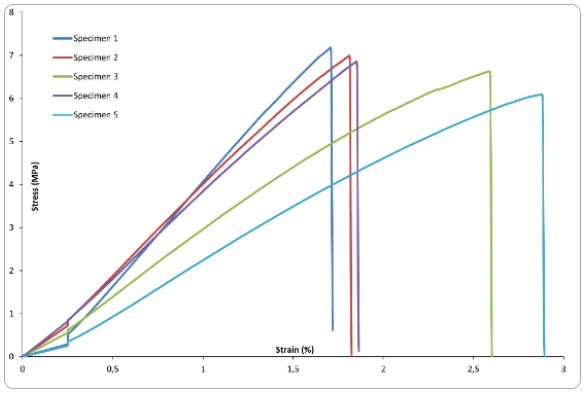


Figure 8. Flexural stress-strain curves of corncob blocks under three-point bending.

This behavior is related to the heterogeneous and porous structure of corncob. During bending, the upper region of the specimen experienced compression, while the lower region experienced tension. Because corncob does not have a continuous and uniform load-bearing structure, local differences in pore distribution and tissue compactness can affect stiffness and deformation before failure. Therefore, the flexural results should be interpreted as the baseline response of untreated corncob blocks without adhesive, reinforcement, densification, coating, or lamination.

The mechanical comparison shows a clear limitation for furniture applications. The maximum flexural stress of the corncob blocks was 6.75 ± 0.42 MPa, which is lower than the minimum bending strength requirement reported in SNI 03-2105-2006, namely 82 kgf/cm² or approximately 8.04 MPa (BSN, 2006b). The flexural modulus was 365.87 ± 88.17 MPa, which is also lower than the minimum flexural modulus requirement of 2.04 × 10^4 kgf/cm² or approximately 2,000 MPa (BSN, 2006b). This limitation is consistent with EN 312-based P2 particleboard requirements for interior fitments, including furniture, and commercial P2 particleboard data, which show higher bending strength and stiffness than untreated corncob blocks (ECS, 2010; Unibois, 2025).

The comparison with MDF, plywood, and blockboard further explains why the current material should not be positioned as a direct substitute for engineered furniture panels. MDF relies on controlled fiber bonding, resin addition, density control, and panel consolidation to improve bending strength and stiffness (Xu et al., 2025). Plywood and blockboard rely on bonded layers, veneer arrangement, adhesive bonding, and panel construction to improve

dimensional stability and load distribution (BSN, 2000; BSN, 2002; BSN, 2006a). In contrast, the specimens in this study were tested as pure corncob blocks, so their lower flexural stiffness is technically reasonable and should be interpreted as a baseline condition before material modification.

Based on the physical, compression, manual compression, and flexural results, the main advantage of corncob blocks lies in their low density, renewable agricultural-waste origin, and potential for lightweight applications. Their main limitations are low flexural stiffness, anisotropic response, porous structure, and deformation variability among specimens. Therefore, their current form is more suitable for decorative panels, fillers, interior accents, decorative blocks, and low-load furniture parts that do not receive continuous mechanical loads. Further development should focus on improving stiffness, dimensional stability, surface protection, and durability through binder addition, densification, lamination, coating, or hybridization with other materials. This direction is consistent with recent studies showing that improved bonding, lignin-based adhesive systems, and reconstructed lignocellulosic structures can enhance the performance and water stability of panel and wood-based materials (Ait Benhamou et al., 2026 ; Xia et al., 2024).

4. CONCLUSIONS AND RECOMMENDATIONS

NK 7328 Sumo corncob blocks showed measurable physical and mechanical properties as a renewable biomaterial. The material had low density of 0.459–0.553 g/cm³ and moderate moisture content of 7.57–7.99%, indicating a lightweight lignocellulosic material under comparable initial moisture conditions. The average compressive stress was 7.41 ± 1.52 MPa in the parallel direction and 17.04 ± 4.48 MPa in the perpendicular direction, while the average flexural stress was 6.75 ± 0.42 MPa. The compressive modulus of elasticity was 225.31 ± 33.32 MPa in the parallel direction and 104.57 ± 19.14 MPa in the perpendicular direction, whereas the flexural modulus of elasticity was 365.87 ± 88.17 MPa. These results indicate that the mechanical response of corncob blocks was affected by porosity, anisotropy, and internal heterogeneity. Therefore, corncob blocks are more suitable for lightweight, non-structural, semi-functional, and decorative furniture components than for primary load-bearing applications.

Further studies should include chemical characterization, microstructural observation, durability testing, and prototype-level evaluation under actual service conditions. Future development should also examine binder addition, coating, densification, lamination, or reconstructed corncob-based systems to improve stiffness, dimensional stability, water resistance, and mechanical reliability.

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