

Unlocking Sustainable Performance: The Influence of Weave Structure on Unidirectional Kenaf Fabric Properties

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ABSTRACT

This study investigates the physical, mechanical, and permeability properties of novel unidirectional kenaf woven fabrics (UD-K) with Plain, Twill 2/2, and 8-end Sateen weave structures. Addressing a knowledge gap in pure woven kenaf, this research utilised kenaf as the dominant weft yarn and nylon as the warp and produced the fabric on a loom. Results showed that weave structure significantly influenced fabric characteristics. Physically, fabric density, thickness, and weight consistently increased from Plain to Twill to Sateen weaves, attributed to their interlacing patterns, allowing denser yarn packing. Kenaf yarn crimp, however, was highest in Sateen and lowest in Twill. Mechanically, the Sateen weave exhibited superior tensile strength and elongation in the kenaf-dominant direction, significantly outperforming Plain and Twill due to optimal load distribution. For permeability, air permeability decreased inversely with fabric density (Plain→Twill→Sateen). Notably, the Sateen weave displayed a dramatically higher water vapour permeability than Plain and Twill, suggesting unique moisture-transport pathways. This research provides essential baseline data,

demonstrating that weave structure is a critical parameter for tailoring UD-K fabric properties. These findings enhance the understanding of natural fibre textiles and highlight their potential for technical applications, from high-performance composites to functional textiles.

ARTICLE INFO

Article history:

Received: 23 August 2025

Accepted: 26 November 2025

Published: 25 February 2026

DOI: <https://doi.org/10.47836/pjst.34.1.23>

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Keywords: Functional fabrics, kenaf, moisture management, sustainable textiles, unidirectional fabric, weave design engineering

INTRODUCTION

As environmental consciousness continues to rise, there is a heightened emphasis on finding cost-effective materials. This shift has quickly redirected attention towards the development, generation, and innovation of environmentally friendly materials. Consequently, numerous new terms, such as renewable, sustainable, and bio-based materials, have entered the lexicon of materials scientists (Mishra et al., 2002; Misnon et al., 2014; Nishino et al., 2003). Kenaf, *Hibiscus cannabinus L.* is a promising natural fibre due to its renewability, biodegradability, and potential to reduce reliance on non-sustainable resources. Kenaf fibre possesses good mechanical strength, low density, and a relatively fast growth rate, making it suitable for various applications (Akil et al., 2011; Hamidon et al., 2019; Harussani & Salit, 2022). So far, kenaf fibre has been established as a substitute in pulp and paper, nonwoven mats for automotive applications, fibreboard, and composite materials (Babatunde et al., 2015; Magurno, 1999).

The mechanical strength of kenaf fibre is intrinsically linked to its fundamental properties, such as fibre diameter and length (Akil et al., 2011; Girijappa et al., 2019; Kılınc et al., 2017). While research on kenaf fibre composites has seen considerable growth, a significant gap exists in the fundamental understanding of the inherent properties (such as weave structures, densities, thicknesses, and crimps) of woven kenaf fabrics themselves, which directly influence their performance metrics, including strength and permeability. The existing literature predominantly investigates the performance of kenaf fibres within composite materials, often overlooking crucial baseline data concerning the structural and physical characteristics of the woven fabric prior to its incorporation into composites (Alias et al., 2018; Balakrishnan et al., 2024; Ismail et al., 2019; Sanjay et al., 2018; Sivakumar et al., 2018). Furthermore, despite the recognised advantages of unidirectional (UD) textile structures for achieving superior strength and stiffness in specific loading directions, to the best of our knowledge, no prior studies have focussed on the fundamental properties of unidirectional woven kenaf fabrics. Existing works involving kenaf in a unidirectional context are typically limited to hybrid composites rather than the pure woven fabric itself.

This lack of comprehensive data on native and particularly unidirectional kenaf fabric properties hinders the optimisation of their performance and full potential, both as standalone textiles and as reinforcement in composite applications. Therefore, targeted research is essential to bridge this knowledge gap and unlock new possibilities for the broader utilisation of this sustainable natural fibre in diverse textile applications. This study, therefore, addresses this critical gap by presenting the first comprehensive characterisation of pure unidirectional woven kenaf fabrics, establishing essential baseline data that is currently absent from the literature.

Therefore, this work aims to analyse the physical (fabric density, thickness, yarn crimps, and weight), mechanical (tensile strength), and permeability (air and water vapour

permeabilities) properties of unidirectional woven kenaf fabrics with Plain, Twill, and Sateen weave structures. By addressing these critical knowledge gaps, this study contributes to the fundamental understanding of these materials and facilitates their broader application in textiles and composites.

MATERIALS AND METHODS

Two types of yarn, nylon and kenaf, were employed in this work. A proprietary local company supplied kenaf fibre with a size of 1000 tex. This yarn had been spun from kenaf staple fibres, where numerous visible, loose, protruding fibres were observed on its surface. A commercial supplier supplied the nylon yarn, spun from a nylon filament fibre with a smooth surface, and had a size of 100 tex.

Fabric Production

The unidirectional kenaf woven fabric (UD-K) was woven using a manual handloom, Leclerc Nilus II Contremarche 8s. Nylon was used as warp (machine length direction), while kenaf yarn was used as weft (machine width direction). The fabrics were produced in different fabric structures, including Plain (Plain), Twill 2/2 (Twill), and 8-ends Sateen (Sateen). It is noted that when the weft yarns dominate the fabric face, as is the case in this study, the structure is more precisely designated as a 'Sateen' weave rather than a 'satin' (Grosicki, 2014). This configuration ensures that the primary load bearing kenaf fibres are oriented in the weft direction, providing unidirectional reinforcement. The 8-end Sateen was selected for its long float length to contrast the short floats of the Plain and Twill weaves and study the extreme effect on fabric properties. The kenaf-weft/nylon-warp configuration was chosen because the strong, flexible nylon could withstand high warp tension during weaving, while the stiffer kenaf was optimally placed as the dominant load-bearing weft.

Prior to testing, all fabric samples were conditioned in a standard atmosphere according to ASTM D1776 at $21 \pm 1^\circ\text{C}$ and $65 \pm 2\%$ relative humidity for a minimum of 24 hours. All subsequent characterisation and testing were conducted under these same controlled environmental conditions.

Fabric Physical Characterisation

Table 1 presents the tests and standard methods used to determine the physical characteristics of UD-K fabric. Woven hemp fabrics were characterised by their weight, thickness, fabric density or fabric count, while their yarn was characterised by their yarn count (linear density) and crimp (for kenaf and nylon).

Table 1

Standard methods used to determine fabric properties

Standard Method	Properties	Testing
ASTM D3775	Fabric Density	Warp (end) and filling (pick) count of woven fabrics
ASTM D3776	Fabric Weight	Mass per unit area (weight) of fabric
ASTM D1777	Fabric Thickness	Thickness of Textile Materials
ASTM D1907	Yarn Count	Yarn size (linear density)
ASTM D3883	Yarn Crimp	Yarn crimp and yarn take-up in woven fabrics

Tensile Strength

Tensile properties of UD-K fabric were characterised using a universal testing machine, Tensolab 2515, following the ASTM D5034 standard method. The test was performed using a gauge length of 75 mm with a cross-speed of 10 mm/min. 10 specimens with a dimension of 17.5 cm × 7.5 cm were tested for each of the samples. The cross-sectional area used to convert load into stress was calculated from the test specimen's width and the thickness of UD-K obtained from the fabric characterisation. The tensile moduli of the UD-K were determined from the initial linear part of the curves (Misnon et al., 2015).

Permeability Properties

The air permeability of UD-K fabrics was evaluated using the air permeability tester, Mesdan Air Tronic, following the standard method ASTM D737. An average of 10 values was taken and recorded from each sample. The fabric clamp test area for the sample was 10 cm², with the air pressure maintained at 200 Pa. The airflow rate through the specimen (in cm³/sec.cm²) was then measured and recorded.

The water vapour transfer of UD-K fabrics was analysed by the cup method using the SDL Atlas M261 instrument following BS 7209. A specimen was sealed over the mouth of the test cup, which contained the predetermined quantity of water. Successive weighing (before and after the test) of the assembled cup was performed, and the water vapour permeability (*WVP*) through the specimen was determined in g/m²/day using the following Equation:

$$WVP = \frac{24 \times M}{A \times t} \quad [1]$$

where:

M is the loss in mass of the water (g),

A is the exposed specimen area (m²), equivalent to the test cup's internal area of 0.0054 m², and

t is the test duration (hours), and the test was conducted over 24 hrs.

RESULTS AND DISCUSSION

Unlike the typical woven fabrics, the UD weave fabrics feature a dominant yarn oriented along a specific axis (either in warp or weft) (Lemmi et al., 2021). This design ensures that the superior characteristics of the fabric are primarily contributed by the dominant yarn, making it ideal for use in applications where direction-dependent reinforcement is critical, such as in aerospace, automotive, and civil engineering fields. In this study, the fabric was explicitly designed with kenaf yarn serving as the dominant material in the weft direction.

Yarns' Linear Densities and Strengths

The yarns' linear densities were measured to confirm their actual size according to ASTM D1907. As expected, the kenaf yarn exhibited a significantly larger count than the nylon yarn. Specifically, the kenaf yarn measured 996.07 ± 0.064 tex, while the nylon yarn was 100 ± 0.063 tex. The distinct appearances of the yarns are presented in Figure 1, highlighting the smooth nature of the nylon filament yarn (a) and the visible, loose, protruding fibres characteristic of the kenaf staple yarn (b).

In terms of strength, the nylon demonstrated significantly higher properties than the kenaf yarn. Nylon possessed a strength of 263.57 MPa and an elongation of 20.99% before failure. In contrast, the kenaf yarn exhibited a lower strength of 97.90 MPa and considerably less elongation at 2.69%. These contrasting tensile characteristics are attributed to their inherent material compositions and processing, as nylon is a synthetic filament with superior ductility and strength. Kenaf is a natural yarn spun from short-staple fibres, which inherently limit its stress absorption and elongation capacity before rupture. Despite the lower individual strength of the kenaf yarn, it serves as the dominant weft yarn in this UD-K fabric design, providing the primary load-bearing functionality. At the same time, the nylon warp primarily holds the kenaf in place and maintains fabric integrity.

Physical Properties of UD-K Fabrics

The visual appearance of the face and back of the Plain, Twill, and Sateen UD-K fabrics is presented in Figure 2. As anticipated, the Plain weave exhibits a uniform and tight interlacement, while the Twill weave displays a distinct diagonal rib pattern. The Sateen weave, characterised by its longer floats, presents a notably smoother surface. These visual differences are indicative of the varied interlacing patterns that will influence the subsequent physical, mechanical, and permeability properties of the fabrics. Physical properties of UD-K woven fabrics, density, yarn crimp, thickness, and weight, were tabulated in Table 2. These properties are crucial for understanding their structural integrity and potential applications, which are significantly influenced by the weave structure. As unequivocally demonstrated in Table 2, the fabric density, thickness, and weight all increased consistently

and substantially across the sequence of weave structures (Plain → Twill → Sateen). This strong positive relationship was quantified using the Pearson correlation coefficient, which showed a good strong correlation ($r = +0.8788$) between fabric density and thickness across the three weave structures.

Fabric density, or fabric count, refers to the number of warp or weft per unit length. For the UD-K fabrics, the densities of both the dominant kenaf (weft) yarns and the nylon (warp) yarns were measured. As observed, the number of kenaf yarns per 2cm progressively increased from Plain (11) to Twill (17) and then to Sateen (19) weave structures. A similar trend was noted for the nylon, with counts of 9 for Plain, 10 for Twill, and 11 for Sateen. This increase in fabric density across the different weave structures is directly related to interlacing patterns. A schematic cross-section of the UD-K woven fabric structure is provided in Figure 3 to illustrate the mechanism of weft yarn packing. The diagram views the fabric along the warp direction, showing the arrangement of nylon (warp, shown as black lines) and kenaf (weft, shown as white circles) yarns. This horizontal perspective clearly demonstrates how the weft yarns are positioned during the weaving process. Plain weave Figure 3(a), with its simple over-and-under interlacing and frequent crossovers, creates a tight structure that physically limits the space for weft yarn packing. In contrast, the longer floats and fewer interlacing points in the Twill Figure 3(b) and especially Sateen Figure 3(c) weaves allow the kenaf yarn to be beaten into a denser configuration, resulting in the higher fabric densities reported in Table 2.

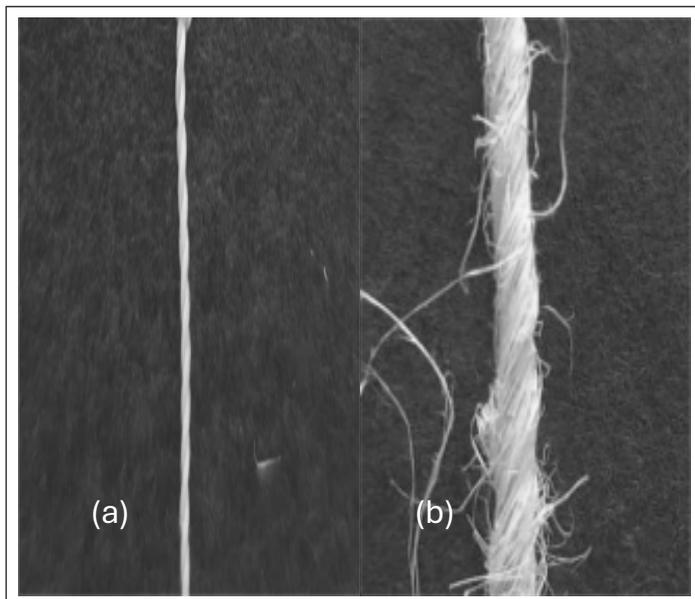


Figure 1. Yarns used to produce UD-K: (a) Nylon and (b) Kenaf

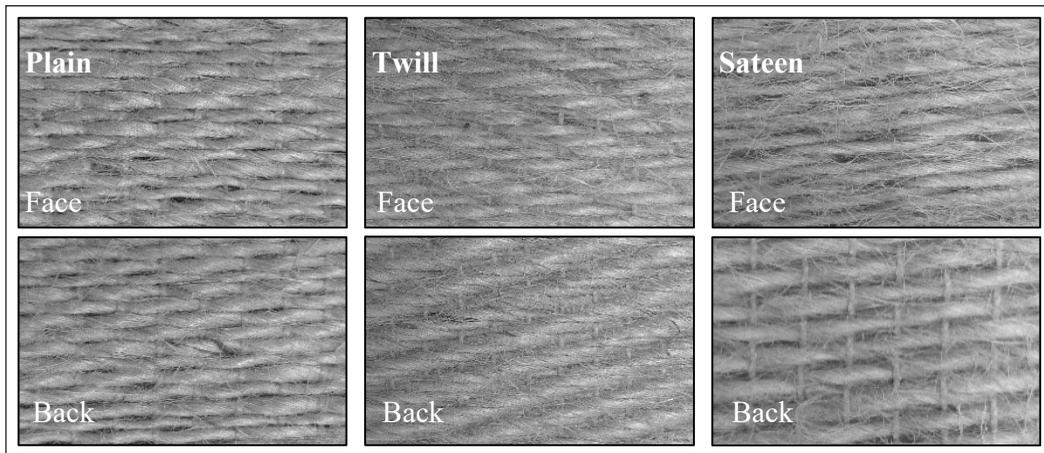


Figure 2. UD-K woven fabric produced (Plain, Twill, and Sateen)

Table 2
Physical properties of UD-K woven fabrics

Properties		Plain	Twill	Sateen
		Plain 1/1	Twill 2/2	8-end Sateen
Fabric Density (/2cm)	Kenaf direction	11	17	19
	Nylon direction	9	10	11
Crimp Percentage (%)	Kenaf direction	5.53 (0.66)	3.6 (0.37)	7.13 (1.05)
	Nylon direction	12.8 (0.923)	4.2 (0.6)	8 (7.6)
Fabric Thickness (mm)		1.45 (0.14)	2.87 (0.13)	3.76 (0.31)
Weight (g/m ²)		626 (28.44)	891 (54.07)	985 (101.42)

Note. Value in parentheses is the standard deviation

Yarn crimp, a measure of the waviness imparted to a yarn due to interlacing in the fabric, plays a significant role in determining fabric characteristics such as extensibility, thickness, and packing density. The crimp percentages for the constituent yarns are presented in Table 2. As expected, the crimp of the kenaf weft yarn—the dominant, load-bearing component in this unidirectional fabric—varied notably with the weave structure. The nylon warp crimp also followed a similar trend but was less critical to the primary mechanical performance in the weft direction. For the kenaf yarns in the UD-K fabrics, the crimp percentages varied notably with the weave structure, as presented in Table 2. The Plain weave exhibited a kenaf yarn crimp of 5.53%, which was intermediate between those of the Twill and Sateen structures. The kenaf yarn in Twill showed the lowest crimp at 3.6%, while the kenaf yarn in Sateen demonstrated the highest crimp at 7.13%. This trend is directly attributed to the fundamental differences in interlacing. Plain weave, with its maximum number

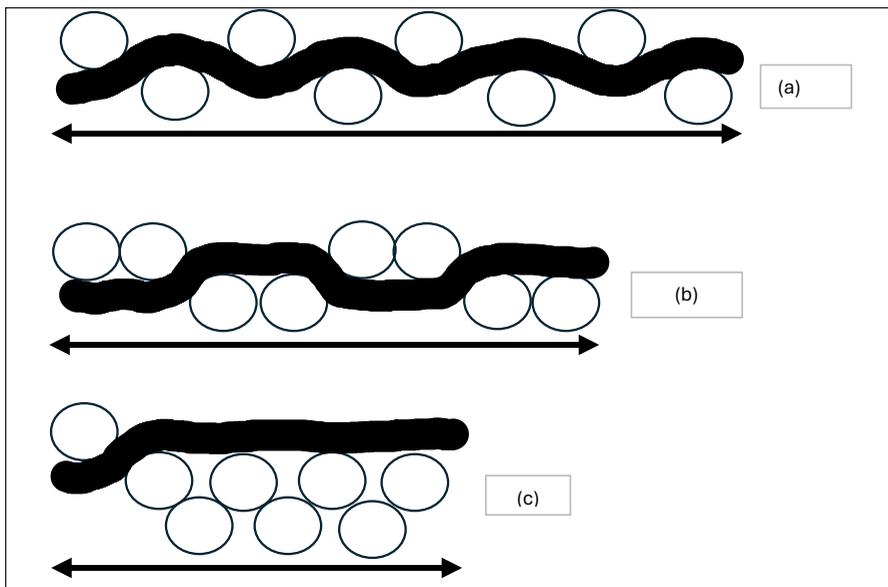


Figure 3. Schematic cross-section of nylon and kenaf yarns in the UD-K woven fabric viewed along the warp direction for (a) Plain, (b) Twill, and (c) Sateen. The black line represents nylon yarn, and the circle represents kenaf yarn

of interlacing points per unit area (every kenaf yarn interlacing with every nylon yarn), imposes significant crimp on both sets of yarns Figure 3 (a). Twill weave, having fewer interlacing points than Plain weave due to its diagonal pattern, results in a lower crimp, allowing the yarns to lie flatter within the fabric structure Figure 3 (b). Conversely, the kenaf yarn in Sateen weave, characterised by the longest floats and the fewest interlacing points, might intuitively be expected to have low crimp. However, the high crimp observed in the Sateen weave kenaf yarn suggests that while the individual interlacing points are fewer, the substantial difference in tension between the warp (nylon) and weft (kenaf) yarns, combined with the larger diameter of kenaf yarn and its high packing density, forces the kenaf weft yarns into greater undulations at the infrequent interlacing points Figure 3 (c). This increased crimp in Sateen could contribute to greater fabric thickness and potential extensibility in the weft direction. The higher standard deviation for the Sateen crimp also suggests greater variability in the crimp levels within this weave, potentially due to longer float lengths allowing for more localised variations in the yarn path.

In terms of thickness, the fabric thickness increased progressively from Plain to Twill and then to Sateen weave structures. The Plain weave exhibited the lowest at 1.45 mm, followed by the Twill weave at 2.87 mm, and the Sateen weave was the thickest at 3.76 mm. This trend correlates well with the observations of fabric density and yarn crimp. Plain weave, with its tightest interlacing pattern and highest number of crossovers, tends to compact the yarns more, resulting in a thinner fabric. In contrast, Twill and especially

Sateen weaves, characterised by longer floats and fewer interlacing points, allow the yarns to lie less constrained and more freely, leading to increased fabric thickness Figure 3. The higher crimp observed on the kenaf yarns within the Sateen weave also contributes to its greater thickness, as the yarn's undulations add to the overall fabric depth at Table 2. The lower compaction and higher volumetric occupancy of yarns in Twill and Sateen structures are key factors contributing to their increased thickness.

In terms of fabric weight, the weight of UD-K woven fabrics increased significantly with the complexity of the weave structure. The Plain weave fabric weighed 628 g/m², while the Twill weave was heavier at 891g/m². The Sateen weave exhibited the highest weight at 985 g/m². This observed trend is directly linked to fabric density. The number of kenaf yarns (and nylon yarns) per unit area increased from Plain to Twill to Sateen weaves. Since the kenaf yarn is considerably heavier (996.07 tex) than nylon yarn (100 tex), and the fabric is designed to have kenaf as the dominant weft yarn, a higher packing density of kenaf yarns directly translates to a greater mass per unit area. Therefore, the Sateen weave, with its highest kenaf yarn count, naturally resulted in the heaviest fabric. The higher standard deviation for Sateen fabric weight may also be associated with the higher variability in kenaf yarn density and crimp observed in this weave.

Mechanical Properties of UD-K Woven Fabrics

The mechanical properties of UD-K woven fabrics are crucial for their use as reinforcing materials. The dominant kenaf yarns primarily govern these properties and are significantly influenced by the fabric's weave structure, and the results are shown in Table 3 and Figure 4.

As illustrated in Figure 4 and accompanying Table 3, the Sateen weave exhibited the highest strength of 92.90 MPa. This is a noticeable improvement compared to the Twill weave (80.61 MPa) and the Plain weave (77.23 MPa). While there is some overlap in standard deviation between Plain and Twill weaves, suggesting their strengths are not statistically different, the Sateen weave exhibited a noticeably higher mean strength than both, consistent with the enhancement expected from its weave structure. This strength trend directly correlates with the fabric density and fabric weight discussed earlier in Table 2. Plain weave, characterised by its lower kenaf yarn density and highest interlacing frequency, restricts yarn straightening and load distribution, resulting in lower strength and longer floats. Conversely, the Sateen weave, characterised by the highest kenaf yarn density 19 yarns/2 cm shows at Table 2 and longest floats, allows the dominant kenaf yarn to bear the load more effectively with less interference from interlacing points, resulting in superior strength (Azeem et al., 2018; Ferdous et al., 2014; Gabrijelčić et al., 2008).

The typical stress-strain curves shown in Figure 5 further illustrate these differences, with the Sateen fabric demonstrating the ability to withstand higher stress and undergo greater deformation before rupture. This occurs because the long floats in the Sateen weave

Table 3
 Mechanical characterisation results of UD-K woven fabrics

UD-K Fabrics	Tensile Strength (MPa)	Elongation (%)
Plain	77.23 (5.62)	5.4 (0.97)
Twill	80.61 (3.20)	8.52 (1.030)
Sateen	92.90 (6.38)	8.70 (0.72)

Note. Value in parentheses is the standard deviation

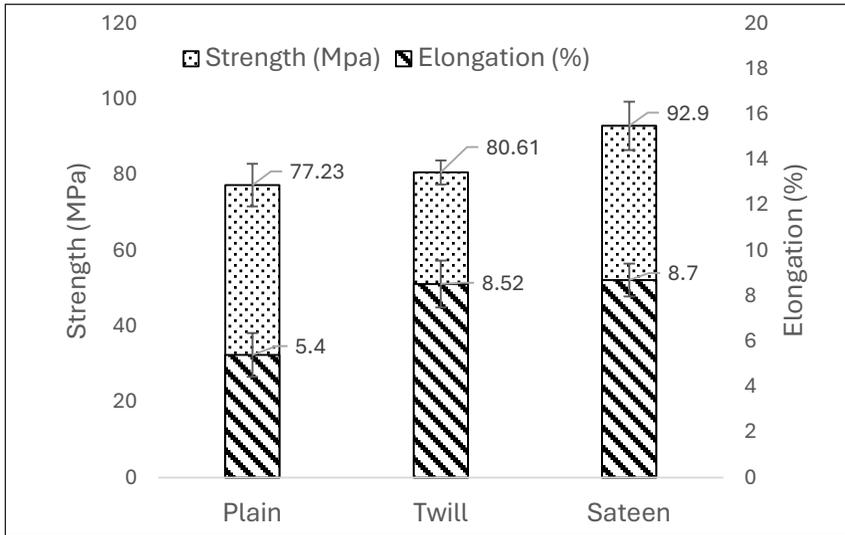


Figure 4. Mechanical characteristics of UD-K woven fabrics

minimise the point of stress concentration at interlacing regions, allowing for more uniform distribution of tensile load along the length of the kenaf yarns. In contrast, the frequent interlacing in the Plain weave creates recurring points of bending and friction, which act as stress concentrators and hinder efficient load transfer, leading to premature failure at lower overall stress. This mechanistic difference in how the weave geometry governs load distribution after the initial decrimping phase is consistent with the behaviour observed in other woven natural fabrics (Misnon et al., 2015).

Regarding elongation, the Plain weave showed the lowest elongation at 5.40%. In contrast, the Twill and Sateen weaves exhibited substantially higher and comparable elongation values of 8.52% and 8.70%, respectively. Based on their standard deviations, the elongations of Twill and Sateen weaves are not statistically different from each other, but both are markedly higher than that of the Plain weave. This behaviour is directly related to crimp Table 2. The Plain weave’s higher interlacing frequency means less available yarn length to straighten under tension, thus limiting its extensibility. The higher elongation in Twill and Sateen weaves is likely due to their lower number of interlacing

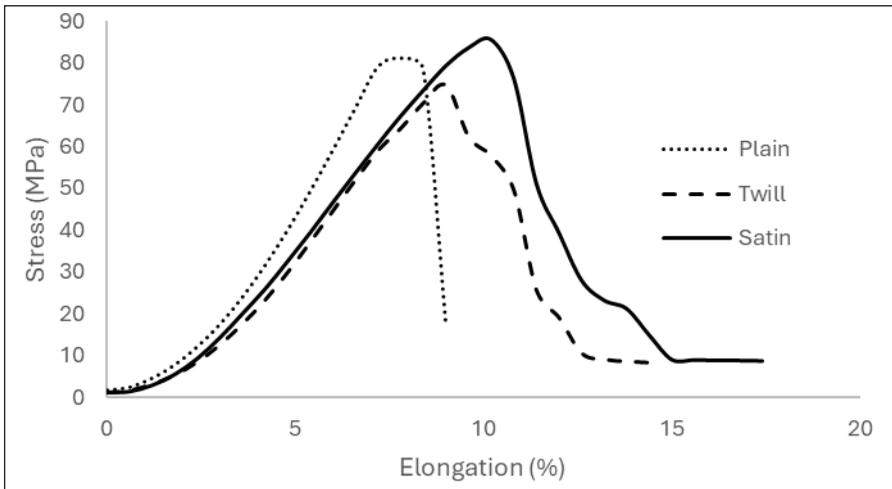


Figure 5. Typical stress-strain curves of UD-K woven fabrics

points per unit area, which allows greater yarn mobility and enables crimped yarns to straighten more effectively under load (Azeem et al., 2018). While the Twill weave had the lowest crimp (3.6%), its elongation was considerably higher than that of the Plain weave. The Sateen weave, despite having the highest crimp (7.13%), also demonstrated the highest elongation, suggesting that the initial straightening of its highly crimped, less constrained floats contributes significantly to its extensibility before the yarns bear the full load shows Figure 5. The visual inspection of tested specimens shows Figure 6 indicates typical failure modes involving fractured yarns and pull-out, which is consistent with the nature of natural fibre fabrics under tensile load. The tensile strength of the Sateen weave (92.90 MPa) significantly surpasses the range reported for balanced plain weave

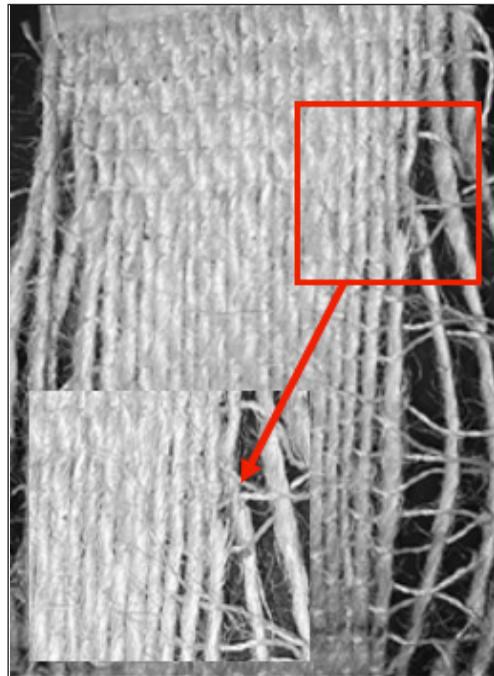


Figure 6. Typical tested specimen showing fractured yarns and pull-out

hemp fabrics (23-26 MPa) (Mison et al., 2015) and exceeds that of various woven hemp-linen blend fabrics (37.2 to 53.3 MPa) (Vasile et al., 2024). This clearly underscores the distinct advantage conferred by the unidirectional architecture in maximising the load-bearing capability of the kenaf yarns.

Permeability Properties of UD-K Woven Fabrics

The air and water vapour permeability properties are crucial for their comfort, protective, and functional applications. These properties in UD-K fabrics are highly dependent on the weave structure, which dictates the pore size, pore distribution, and overall fabric compactness. Table 4 presents the permeability results of the produced UD-K woven fabrics.

Air permeability quantifies the ease with which air passes through a fabric, reflecting its openness. The air permeability rates for the UD-K woven fabrics are presented in Figure 7. The Plain weave exhibited the highest air permeability at 998.10 cm³/sec.cm². This value is considerably higher than both the Twill (550.40 cm³/sec.cm²) and Sateen (488.87 cm³/sec.cm²) weaves. In comparison, there is a clear distinction between Plain weave and the other two. The air permeability values for Twill and Sateen are relatively close, with their standard deviations showing some overlap, suggesting they are not statistically different from each other. The higher air permeability of the Plain weave is attributed to its simpler, more open interlacing pattern, which creates larger and more numerous pores for air passage compared to the Twill and Sateen weaves. Conversely, the increased fabric density and thickness shows in Table 2 of the Twill and Sateen structures, resulting from

Table 4
The results of permeability for UD-K woven fabrics

Fabric	Air Permeability (cm ³ /sec.cm ²)	Water Vapour Permeability (g/m ² /day)
Plain	998.10 (88.37)	589.44 (37.15)
Twill	550.40 (42.67)	554.44 (56.74)
Sateen	488.87 (14.92)	3070 (288.77)

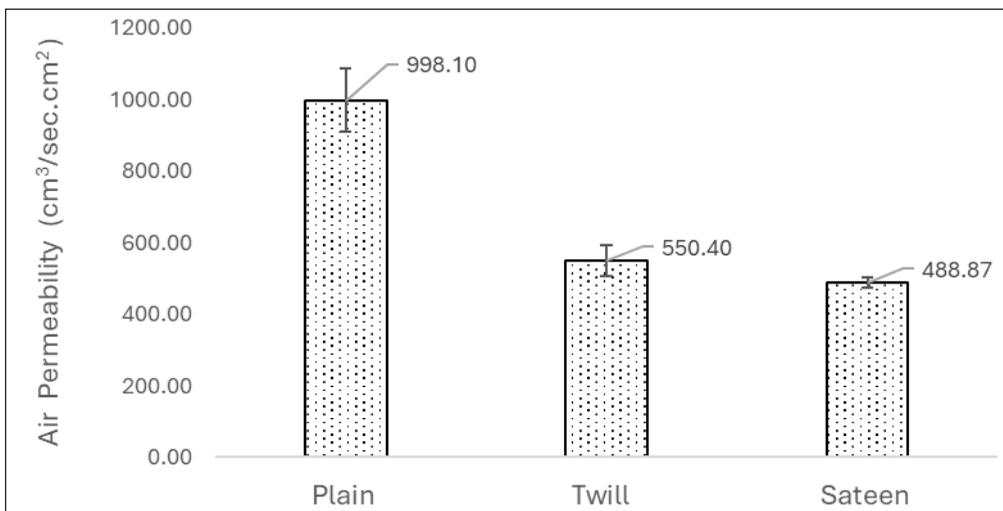


Figure 7. Air permeability rates of UD-K woven fabrics

their longer floats and greater yarn packing, effectively reduce the available air pathways, thus leading to lower air permeability (Ogulata, 2006). The Sateen weaves, despite being the thickest and densest, showed only a marginal decrease in air permeability compared to Twill, indicating that once a certain level of compaction is reached, further reductions in airflow become less pronounced refers to Figure 2 and Figure 3.

Water vapour permeability (WVP) measures a fabric's ability to allow moisture vapour to pass through, a critical property for comfort in apparel and specific technical applications. The WVP results for the UD-K fabrics, presented in Figure 8, clearly show an unambiguous contrast in water vapour permeability among the different weave structures. The Plain weave exhibited a WVP of 589.44 g/m²/day, which is comparable to the Twill weave's 554.44 g/m²/day. Their standard deviations overlap significantly, indicating no statistical difference in WVP between Plain and Twill. However, the Sateen weave demonstrated a dramatically higher water vapour permeability of 3070.00 g/m²/day. This value is approximately five to six times greater than that of Plain and Twill weaves, representing a substantial and clear difference. This value is substantially higher than that of conventional cotton (1132 g/m²/day) and even exceeds that of many high-performance synthetic materials designed for moisture management, such as polyester interlock (1875 g/m²/day) (Kim, 2021). This positions the UD-K Sateen fabric as a highly promising sustainable material for advanced functional textiles where superior breathability is critical.

This remarkable result can be explained by the distinct mechanisms of airflow versus water vapour diffusion. Air permeability is primarily governed by through-thickness pore size and tortuosity, which are restricted in the dense Sateen structure. However, water vapour transfer is dominated by adsorption-diffusion-desorption through the hydrophilic

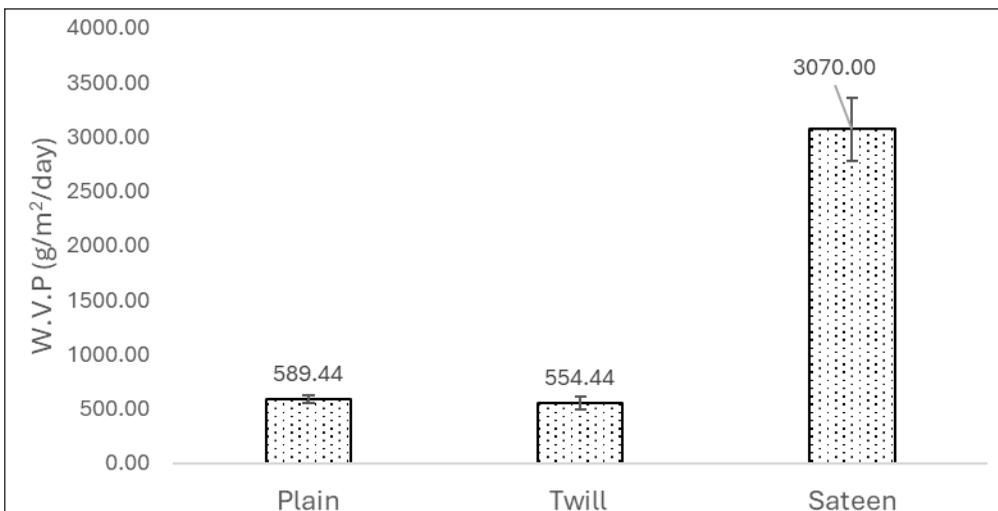


Figure 8. Water vapour permeability rates of UD-K woven fabrics

kenaf fibres and capillary flow along the fibre surfaces (Adámek et al., 2023; Bhattacharyya, 2024; Hrishikesh & Mhetre, 2014). The Sateen weave's long floats and high yarn crimp create an intensive, interconnected network of pathways along the kenaf yarns refers to Figure 3. This geometry facilitates rapid surface diffusion and capillary wicking of moisture vapour across the fabric, by passing the restrictive through-thickness pores that limit airflow. The less frequent interlacing reduces the number of points at which this capillary flow is interrupted, thereby dramatically enhancing overall water vapour transport.

The implications of these weave-dependent properties are critical for the design of natural fibre reinforced composites. The structural advantages of Sateen weave observed in this study—namely its superior tensile strength and higher fabric density—are directly relevant to composite performance (Azeem et al., 2018). This structure is predicted to yield composites with enhanced mechanical properties for two primary reasons. First, the higher fabric density translates directly to a greater volume fraction of the load bearing kenaf fibres in the composite. Second, the longer floats and reduced number of interlacing points minimise yarn crimp and create a straighter, more efficient load path for stress transfer from the polymer matrix to the reinforcing fibres. Therefore, selecting a Sateen weave for UD-K fabrics presents a promising strategy for optimising sustainable composites.

CONCLUSION

The characterisation of the constituent yarns confirmed that the kenaf weft yarn, while significantly coarser and weaker than the nylon warp, served effectively as the dominant load-bearing component. The physical properties of the UD-K fabric were profoundly affected by the weave structure. Fabric density, thickness, and weight consistently increased from Plain to Twill to Sateen weaves, a direct consequence of their interlacing patterns, allowing for higher yarn packing. Conversely, the kenaf yarn crimp was lowest in Twill but highest in Sateen, indicating that despite fewer crossovers, the Sateen weave's longer floats, and yarn dimensions induced greater undulations.

In terms of mechanical performance (tested in the kenaf-dominant weft direction), the Sateen weave exhibited superior tensile strength (92.90 ± 6.38 MPa) and elongation ($8.70 \pm 0.72\%$) compared to Plain and Twill weaves. This enhancement is attributed to the Sateen weave's higher kenaf yarn density and less frequent interlacing, allowing for more effective load distribution and yarn straightening. Permeability properties also showed distinct trends. Air permeability decreased from Plain to Twill to Sateen, correlating inversely with increasing fabric density. Notably, the Sateen weave demonstrated a remarkably higher water vapour permeability (3070.00 ± 288.77 g/m²/day) compared to Plain and Twill weaves, suggesting that its unique structure facilitates enhanced moisture vapour transport through complex diffusion and capillary mechanisms.

In brief, this research provides the first comprehensive baseline data for pure unidirectional kenaf woven fabrics, demonstrating that weave structure is a powerful tool for tailoring their properties. The findings highlight the significant potential of these sustainable fabrics for technical applications requiring specific directional performance biodegradable composites, functional textiles with engineered moisture management, and other advanced material systems where customisation of strength and permeability is critical.

ACKNOWLEDGEMENT

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors would like to thank Universiti Teknologi MARA, Malaysia, for providing research facilities and Midwest Composites Sdn. Bhd., Malaysia, for providing kenaf yarn.

REFERENCES

- Adámek, K., Havelka, A., Kůs, Z., & Mazari, A. (2023). The correlation between air and water vapour permeability of textiles. *Coatings*, *13*(1), Article 163. <https://doi.org/10.3390/coatings13010163>
- Akil, H. M., Omar, M. F., Mazuki, A. A. M., Safiee, S., Ishak, Z. A. M., & Bakar, A. A. (2011). Kenaf fibre reinforced composites: A review. *Materials & Design*, *32*(8-9), 4107-4121. <https://doi.org/10.1016/j.matdes.2011.04.008>
- Alias, A. H., Tahir, P. T., Abdan, K., Salit, M. S., Wahab, M. S., Berkalp, O. B., Lee, C. H., & Lee, S. H. (2018). Effects of fabric counts and weave designs on the properties of laminated woven kenaf/carbon fibre reinforced epoxy hybrid composites. *Polymers*, *10*(12), Article 1320. <https://doi.org/10.3390/polym10121320>
- Azeem, M., Ahmad, Z., Wiener, J., Faraz, A., Siddique, H. F., & Havelka, A. (2018). Influence of weave design and yarn types on mechanical and surface properties of woven fabric. *Fibres & Textiles in Eastern Europe*, *26*(1), 72-78. <https://doi.org/10.5604/01.3001.0010.7795>
- Babatunde, O. E., Yatim, J. M., Ishak, M. Y., Masoud, R., & Meisam, R. (2015). Potentials of kenaf fibre in bio-composite production: A review. *Jurnal Teknologi (Sciences & Engineering)*, *77*(12), 1-7. <https://doi.org/10.11113/jt.v77.6304>
- Balakrishnan, T. S., Sultan, M. T. H., Shahar, F. S., Nayak, S. Y., Shah, A. U. M., Sebaey, T. A., & Basri, A. A. (2024). Hybridisation of woven kenaf and unidirectional glass fibre roving for unsaturated polyester composite. *Iranian Polymer Journal*, *33*(9), 1231-1244. <https://doi.org/10.1007/s13726-024-01319-4>
- Bhattacharyya, S. (2024). A review on moisture transmission properties through textile clothing. *International Journal of Advanced Research*, *12*(12), 1086-1093. <https://doi.org/10.21474/IJAR01/20115>
- Ferdous, N., Rahman, M. S., Kabir, R. B., & Ahmed, A. E. (2014). A comparative study on tensile strength of different weave structures. *International Journal of Scientific Research in Engineering and Technology*, *3*, 1307-1313.

- Gabrijelčić, H., Černoša, E., & Dimitrovski, K. (2008). Influence of weave and weft characteristics on tensile properties of fabrics. *Fibres & Textiles in Eastern Europe*, 16(2), 45-51.
- Girijappa, Y. G. T., Sanjay, M. R., Parameswaranpillai, J., & Siengchin, S. (2019). Natural fibres as sustainable and renewable resources for the development of eco-friendly composites: A comprehensive review. *Frontiers in Materials*, 6, Article 226. <https://doi.org/10.3389/fmats.2019.00226>
- Grosicki, Z. (2014). *Watson's textile design and colour: Elementary weaves and figured fabrics*. Woodhead Publishing.
- Hamidon, M. H., Sultan, M. T. H., Ariffin, A. H., & Shah, A. U. M. (2019). Effects of fibre treatment on mechanical properties of kenaf fibre reinforced composites: A review. *Journal of Materials Research and Technology*, 8(3), 3327-3337. <https://doi.org/10.1016/j.jmrt.2019.04.012>
- Harussani, M. M., & Salit, M. S. (2022). Development of kenaf biochar in engineering and agricultural applications. *Chemistry Africa*, 5, 1-17. <https://doi.org/10.1007/s42250-021-00293-1>
- Hrshikesh, C. V., & Mhetre, S. B. (2014). Water vapour permeability and measurement principles. *Fibre2Fashion*.
- Ismail, A. S., Jawaid, M., Sultan, M. T. H., & Hassan, A. (2019). Physical and mechanical properties of woven kenaf/bamboo fibre mat reinforced epoxy hybrid composites. *BioResources*, 14(1), 1390-1404. <https://doi.org/10.15376/biores.14.1.1390-1404>
- Kılınç, A. Ç., Durmuşkahya, C., & Seydibeyoğlu, M. Ö. (2017). Natural fibres. In M. Ö. Seydibeyoğlu, A. K. Mohanty, & M. Misra (Eds.), *Fibre technology for fiber-reinforced composites* (pp. 209-235). Woodhead Publishing. <https://doi.org/10.1016/B978-0-08-101871-2.00010-2>
- Kim, H.-A. (2021). Moisture vapour permeability and thermal wear comfort of ecofriendly fibre-embedded woven fabrics for high-performance clothing. *Materials*, 14(20), Article 6205. <https://doi.org/10.3390/ma14206205>
- Lemmi, T. S., Barburski, M., & Samuel, B. T. (2021). Analysis of mechanical properties of unidirectional flax roving and sateen weave woven fabric-reinforced composites. *Autex Research Journal*, 21(2), 218-223. <https://doi.org/10.2478/aut-2020-0001>
- Magurno, A. (1999). Vegetable fibres in automotive interior components. *Die Angewandte Makromolekulare Chemie*, 272(1), 99-107. [https://doi.org/10.1002/\(SICI\)1522-9505\(19991201\)272:1%3C99::AID-APMC99%3E3.0.CO;2-C](https://doi.org/10.1002/(SICI)1522-9505(19991201)272:1%3C99::AID-APMC99%3E3.0.CO;2-C)
- Mishra, S., Tripathy, S. S., Misra, M., Mohanty, A. K., & Nayak, S. K. (2002). Novel eco-friendly biocomposites: Biofibre reinforced biodegradable polyester amide composites-fabrication and properties evaluation. *Journal of Reinforced Plastics and Composites*, 21(1), 55-70. <https://doi.org/10.1106/073168402024282>
- Misnon, M. I., Islam, M. M., Epaarachchi, J. A., & Lau, K. T. (2014). Potentiality of utilising natural textile materials for engineering composites applications. *Materials & Design*, 59, 359-368. <https://doi.org/10.1016/j.matdes.2014.03.022>
- Misnon, M. I., Islam, M. M., Epaarachchi, J. A., & Lau, K. T. (2015). Analyses of woven hemp fabric characteristics for composite reinforcement. *Materials & Design*, 66, 82-92. <https://doi.org/10.1016/j.matdes.2014.10.037>

- Nishino, T., Hirao, K., Kotera, M., Nakamae, K., & Inagaki, H. (2003). Kenaf reinforced biodegradable composite. *Composites Science and Technology*, 63(9), 1281-1286. [https://doi.org/10.1016/S0266-3538\(03\)00099-X](https://doi.org/10.1016/S0266-3538(03)00099-X)
- Ogulata, R. T. (2006). Air permeability of woven fabrics. *Journal of Textile and Apparel, Technology and Management*, 5(2), 1-10.
- Sanjay, M. R., Puttegowda, M., Jawaidd, M., Sentharamaikannan, P., Senthil, S., & Pradeep, S. (2018). Characterisation and properties of natural fibre polymer composites: A comprehensive review. *Journal of Cleaner Production*, 172, 566-581. <https://doi.org/10.1016/j.jclepro.2017.10.101>
- Sivakumar, D., Ng, L. F., Lau, S. M., & Lim, K. T. (2018). Fatigue life behaviour of glass/kenaf woven-ply polymer hybrid biocomposites. *Journal of Polymers and the Environment*, 26, 499-507. <https://doi.org/10.1007/s10924-017-0970-0>
- Vasile, S., Vermeire, S., Vandepitte, K., Troch, V., & De Raeve, A. (2024). Effect of weave and weft type on mechanical and comfort properties of hemp-linen fabrics. *Materials*, 17(7), Article 1650. <https://doi.org/10.3390/ma17071650>