ADVANCED RESEARCH JOURNAL
Volume 13 Number 1, 2025, 41-56
DOI: 10.71350/3062192591

ISSN: 3062-1925

Article

A woolenization of Urena lobata fiber

Abu Sayed [1], **Md. Saifur Rahman**[1], **Ajajul Islam** [1], **Sujan Miah** [1], **Hazera Akter** [2], **Md. Al Mahmud** [1], **Abdur Rahman** [1], **Manik Miah**[1], **Md Saraj Mia**[1], **Aman Ullah Aman** [1]

[1] Tangail Textile Engineering College, Tangail, Bangladesh
[2] University of South Asia, Savar, Bangladesh

Abstract

The goal of this effort is to convert the coarse structure of Urena lobata fibers (ULF), an indigenous plant from tropical regions producing bast fiber, into a wool-like substance that may be employed in the textile industry. This yarn is treated with 10% (NaOH), 10% (Na_2CO_3), and 10% ammonia during the woolenization process. Each process seeks to copy the benefits of wool by changing the fiber qualities to increase their softness and moisture behavior. Tensile strength, Young's modulus, elongation at break, moisture content, and moisture recovery samples were evaluated by the ISO standard. SEM helps to define the post-treatment geometry of the fiber surface. The Results reveal treated yarn to be the stiffest with the greatest Young's modulus (21.65 GPa) and tensile strength (2347.54 cN). Tensile strength and modulus drop with increased NaOH concentration, even if elongation at break and moisture recovery substantially improve. The 20% NaOH-treated sample demonstrates the highest elongation (7.34%) and moisture recapture (17.49%), therefore showing greater flexibility and hygroscopicity—two critical properties of wool. With only a few adjustments, milder treatments such as 10% Na_2CO_3 and ammonia retain greater fiber integrity.

Article History
Received 30.08.2025
Accepted 03.12.2025

Keywords
Woolenization; tensile strength; Young's modulus; elongation at break; moisture content; moisture recovery

Introduction

Urena lobata is a bast fiber-producing plant from the Malvaceae family, commonly known by names such as Caesar weed, Congo jute, and Aramina. Particularly in tropical regions of Africa, such as Ghana, Nigeria, Madagascar, and the Democratic Republic of the Congo, it thrives in warm, subtropical conditions. With leaves of all sizes and forms, this perennial plant may reach a height of 2 to 5 meters. Its fibers resemble those of jute, roselle, and kenaf, and are robust. It is renowned for being smooth, light in color, and soft. Utilized in eco-textiles, ropes, and mixed with other natural fibers like cotton or jute, it is biodegradable. The goal of this work was to replicate the properties of wool in order to soften Urena lobata, a naturally coarse and underutilized bast fiber, for use in textiles. From a scientific standpoint, this is significant since it encourages the adoption of a

[1] **Corresponding Author** Abu Sayed Tangail Textile Engineering College, Tangail, Bangladesh

biodegradable, renewable plant fiber as a sustainable alternative to synthetic or animal fibers. Additionally, in places where wool is expensive or difficult to get, it provides a useful and economical way to produce textiles. Its fibers have long been used to construct fishing nets, lines, sacks, ropes, carpets, twines, and strings, and its stems are utilized for tying (C. E. Njoku et al., 2019; Sipai Babu et al., 2016). It is a strong and widely available natural fiber, but its coarse texture limits its use in soft textiles. Animals provide wool, a natural fabric composed of complex proteins. It is extracted from the fleece or hair of animals such as camels, goats, and sheep. Wool has been used to manufacture clothing and other fabric goods for thousands of years in various regions of the globe. Because of its special inherent qualities that other natural or synthetic fibers lack, wool is still valued today (Mia et al., 2017). Woolenization is a process that improves the fiber's softness, flexibility, and spinnability, making it more suitable for clothing and other textile applications (Mia et al., 2017). By modifying Urena lobata to behave like wool, the study supports sustainable fashion, reduces reliance on non-renewable resources, and encourages the development of natural fiber-based industries. The woolenization process aims to overcome these limitations by making the fiber more flexible, finding the similarities between ULF and Wool, making it easier to combine with other fibers, and improving its market value. The woolenization procedure increases the fiber's softness, elasticity, elongation, spinnability, moisture content, moisture regain, and also the similar properties of ULF and Wool. The study also advances novel fiber treatment methods. (Stocchi et al., 2007). That could result in reasonably priced, superior textile materials and lessen dependency on imported wool. The process of woolenization ULF significantly enhances the way the lobata fibers hand feel and look. Strong alkali is applied to Urena lobata fiber during this process, causing notable alterations to its physical composition (Chioma E. Njoku et al., 2022). Additionally, there is significant length loss accompanied by lateral swelling. This causes a high degree of crimp or waviness and makes the fiber soft to the touch. The fiber is referred to as modified Urena lobata because of the crimp, which gives it a "wool-like" appearance (Mia et al., 2017). Urena lobata yarn's tensile strength, also known as tenacity, is a measurement of the amount of stress (force per unit area) that the yarn can bear before breaking. Strength is normalized by the linear density (mass per unit length) of the yarn, and is commonly stated in textile science as centinewton per tex (cN/tex). The specimen's elongation at breaking load, represented as a percentage of its initial length (Ghosh & Mal, 2019; Sharif Ullah et al., 2017). A yarn's stiffness under tensile loading is measured by its Young's modulus, also known as its modulus of elasticity.(Sharif Ullah et al., 2017)The percentage of water in yarn compared to its overall weight is known as its moisture content.(Jones et al., 1341)The amount of water that a yarn or fiber absorbs about its oven-dry weight is known as moisture regain(Jones et al., 1341). Examining the surface morphology of yarns using scanning electron microscopy (SEM) reveals information on fiber alignment, roughness, and the impact of chemical treatments. For instance, following alkali treatment, the yarn's SEM pictures reveal smoother surfaces, demonstrating enhanced fiber structure and functionality. Urena lobata, also referred to as Congo jute or Caesar weed, is a plant belonging to the Malvaceae family that is found across India, especially in Andhra Pradesh and certain areas in the north and south. There are several medicinal and utilitarian uses for the plant's leaves, roots, stem, and bark, among other parts. These include lipid-lowering, antidiabetic, antibacterial, anti-inflammatory, antidiarrheal, and antioxidant qualities. Because of these many advantages, Urena lobata has a lot of promise for further study to find further therapeutic uses (Sipai Babu et al., 2016).Urena lobata fibers could reinforce gypsum cement plaster to address issues like early shrinkage and low strength. The fibers, after being treated with a mild sodium hydroxide solution (0.06 M), were mixed into the plaster in different amounts ranging from 0% to 3.5%. It was found that the treated fibers helped the plaster set more effectively, boosted its strength, and reduced shrinkage by filling tiny gaps and creating better bonding within the material. On the other hand, adding small amounts of untreated fibers didn't produce the same positive results and even had some negative effects. These findings suggest that properly treated Urena lobata fibers could be a valuable, natural way to make plaster more durable and reliable for construction use (Kengoh et al., 2021).Performance of Unidirectional Biocomposite Developed with Piptadeniastrum Africanum Tannin Resin and Urena Lobata Fibers as Reinforcement (Gnassiri Wedaïna et al., n.d.). The preparation and analysis of handsheets developed from cellulose-rich Urena lobata, an agricultural weed. The study highlights a sustainable approach to utilizing this underused natural fiber, offering potential for eco-friendly material applications in paper-based products through efficient use of agricultural waste (Rahman et al., 2024). No work has been done on Urena lobata fiber Woolenization until now.

Materials

Urena Lobata, also known as caesarweed or congo jute, is a bast fiber similar to jute and is cultivated. The plants are harvested 3 to 5 months after planting when the stems become fibrous and slightly woody. A sickle is used to cut mature, straight plants near the ground, remove the leaves, and bundle the stalks for transportation. After that, these bundles are immersed in water for retting, which takes 14–16 days and uses microbiological action to assist in loosening the fibers. The fibers are manually removed from the softened stems by expert personnel after retting, and they are then cleaned and separated from woody remnants. Then wash the fibers to remove dust, dirt, and other impurities. This sequence is shown in Figure 1. After drying, the fibers go through a final process called emulsification, in which they are treated with a solution of 73% water, 25% oil, and 2% emulsifier to improve texture and durability. It is presented in Figure 1.

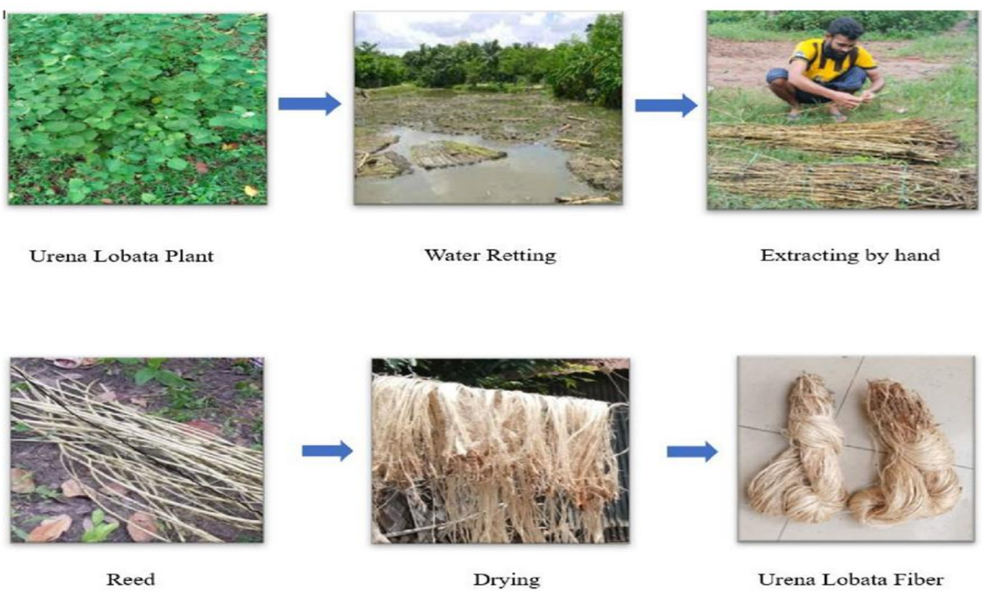

Figure 1. Fiber collecting process from the field

Finally, a traditional hand wheel (charkha) is used to twist the fibers into yarn after they have been carded to align them. Because of its strength, biodegradability, and environmental friendliness, the resultant yarn can be used for sustainable packaging, ropes, fabrics, and handicrafts. After spinning the Urena lobata fibers into yarn, they are treated with an alkali as part of the woolenization procedure. A variety of alkaline concentrations, such as 10%, 15%, and 20% sodium hydroxide (NaOH), 10% sodium carbonate (Na_2CO_3), and ammonia, are used to treat the yarn. The yarns are left undisturbed for 1 hour at room temperature in the chosen alkali concentration. After soaking, the fibers are thoroughly rinsed with distilled water to remove any residual alkali. After neutralizing them with a diluted acetic acid concentration, they are rinsed again with distilled water to guarantee total neutralization. After treatment, the fibers are dried for 48 hours at 70°C in an oven.

Table 1. Yarn samples with various chemical treatments and concentrations

Sample No.	Chemical &Concentration
1	Raw yarn
2	10% NaOH
3	15% NaOH
4	20% NaOH
5	10% Na2CO3
6	10% Ammonia

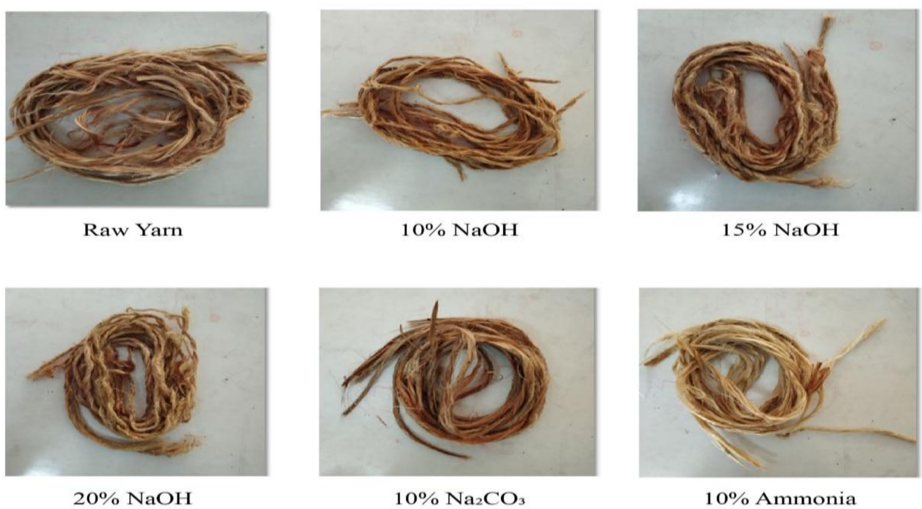

Figure 2. Different sample for the experiment

Method

In textile testing, the maintenance of standardized atmospheric conditions is critical to achieving accurate, consistent, and reproducible results. As specified by ISO 139 and ASTM D1776, the standard testing environment has been maintained at a temperature of 21 ± 2°C and a relative humidity of 65 ± 2%. This controlled setting, referred to as the

Standard Atmosphere for Conditioning and Testing Textiles, is necessary due to the hygroscopic nature of textile materials. Before testing, specimens must be conditioned under these conditions for a minimum of 24 hours to ensure stabilization of their physical properties and reliability of test data (Suganthi T, n.d.).

Tensile strength

The physical properties of a single UL yarn, including its tensile strength, have been evaluated by ISO 2062:2009. This outlines a method to measure the breaking force and elongation of yarns using a constant rate of extension (CRE) tensile tester. In this procedure, yarn samples, conditioned under standard atmospheric conditions, are clamped in the machine and subjected to a steadily increasing load until rupture. We tested in both treated and untreated conditions. These are 5%NaoH,10%NaoH.15%NaoH,20% NaoH, 10%Na2co3,10% ammonia, and an untreated sample. We collected more than six samples of each. Which are 10 millimeters long. The breaking force and the elongation at break are recorded, providing critical insights into the mechanical performance of the yarn. Due to the natural variability of bast fibers like Urena lobata, multiple samples are tested to ensure accurate and representative results. This analysis aids in assessing the yarn's suitability for various textile applications.

Young modulus

By measuring the ratio of stress to strain in the elastic portion of the yarn, the Young's modulus test determines the yarn's stiffness or elasticity. Tensile force is exerted steadily until the yarn breaks, while a yarn specimen of a certain gauge length is held between two clamps. Young's modulus, which measures the yarn's resistance to elastic deformation, is computed using the first linear section of the stress-strain curve. In a variety of textile applications, including knitting and weaving, where strength and flexibility are critical, this attribute is vital for assessing the mechanical behavior of yarns.

Elongation at break

According to ISO 2062:2009, the elongation at break of yarn is determined by subjecting a yarn specimen to tensile stress under standardized atmospheric conditions. The yarn is mounted between two clamps of a tensile testing machine, which extends the specimen at a constant rate until it breaks. The elongation at break is defined as the percentage increase in the length of the yarn from its original length to the point of rupture. Before testing, a specified pre-tension is applied to remove slack and align the fibers properly. Multiple specimens are tested to ensure reproducibility and statistical reliability. The final result is expressed as the average percentage elongation at break, indicating the yarn's ability to stretch before failure.

Moisture content

The moisture content test is a technique used to determine the amount of moisture present in a textile fiber or yarn, expressed as a percentage of the total weight of the fiber or yarn. This is critical because yarn weight, strength, and quality can be affected by its moisture level. The standard methods for determining moisture content in yarn are found in ISO 3344. The standard atmosphere typically involves specific temperature and humidity conditions, such as 20°C ± 2°C and 65% ± 2% relative humidity.

Moisture content (MC) was determined using:

$$MC (\%) = ((Ww - Wd) / Ww) \times 100$$

Where,

Wet Weight: Weight of the material as it is (with moisture)

Dry Weight: Weight of the material after drying (usually in an oven)

Moisture regain

Moisture regain testing of yarn determines the amount of water a textile material absorbs after being oven dried at 105°C ±2°C for 1.5–2 hours, ensuring complete moisture removal without damaging the fiber or yarn, and exposed to a standard atmosphere (usually 20°C ±2°C and 65% ±2% relative humidity) for at least 24 hours. It's a crucial measurement for understanding a yarn's properties and behaviour under different conditions. The standard method for determining moisture regain of yarn is ISO 6741-1.

Moisture regain (MR) was determined using:

$$MR(\%) = ((Ww - Wd) / Wd) \times 100$$

Where,

Wet Weight = weight of the material in its normal condition

Dry Weight = weight after drying all moisture (oven-dry)

SEM test of yarn

Yarn SEM Testing Occurred by Zeiss Smart m/c to the analysis of yarn surfaces using Scanning Electron Microscopy (SEM). This powerful technique provides high-resolution, magnified images of the yarn's surface structure, revealing details about fiber morphology, defects, and irregularities. As a result, it is a valuable tool for understanding yarn characteristics and quality. SEM testing involves using a focused beam of electrons to scan the surface of a yarn sample. The interaction of the electrons with the sample generates signals that are used to create magnified images. In SEM testing, a yarn sample is first prepared (usually by cutting it into short lengths and mounting it on a stub with conductive adhesive). Because yarn is non-conductive, it is often coated with a thin layer of metal (like gold or platinum) to make it conductive. The sample is then placed inside the SEM chamber, where a focused beam of electrons scans the surface. As the electrons interact with the yarn, they produce signals that are used to generate detailed images.

EDX

The Energy Dispersive X-ray Spectroscopy (EDX) test is a good approach to learn about the different components that make up Urena lobata yarn. Usually, this kind of study is done using a SEM and an EDX detector. When you hit the yarn sample with a beam of high-energy electrons, it puts out X-rays that are specific to the elements in the yarn. By locating and examining these X-rays, we may learn about the many sorts of elements that are there, such as carbon, oxygen, calcium, magnesium, and silicon, and how much of each is present. EDX analysis may help us understand how contaminants, surface treatments, and chemical changes impact how effectively Urena lobata, a natural bast fiber, performs. It is very useful for looking at things that are left behind following alkaline treatments or retting. We can use the information we receive to figure out things like how well the fibers keep moisture, how long they endure, and how well they take up color.

Results and Discussions

Tensile strength (cN)

Figure 3 illustrates the tensile strength of Urena lobata yarn subjected to different chemical treatments. The untreated yarn exhibited the highest tensile strength, measuring 2347.54 cN. Upon chemical treatment, a significant reduction in tensile strength was observed. Yarn treated with 10% NaOH retained more strength (1602 cN) than the samples treated with 15% NaOH (1150.97 cN) and 20% NaOH (1270.61 cN). Treatment with 10% Na_2CO_3 yielded 1315.27 cN, while the yarn treated with 10% Ammonia demonstrated comparatively better strength at 1721.25 cN..Chemical impacts on the fiber structure cause Urena lobata yarn's tensile strength to fluctuate. High NaOH concentrations (15–20%) weaken the yarn by breaking down cellulose. Fiber alignment is improved, and strength is maintained with a moderate 10% NaOH treatment. Additionally, alkali treatments result in swelling, which increases surface area while decreasing structural integrity. Milder chemicals, such as 10% ammonia, improve strength retention by partially altering the fiber without causing major harm. Although less forceful, sodium carbonate (Na_2CO_3) only slightly improves the situation. The untreated yarn, on the other hand, has the maximum tensile strength of all the examined samples because it retains its natural, intact structure.

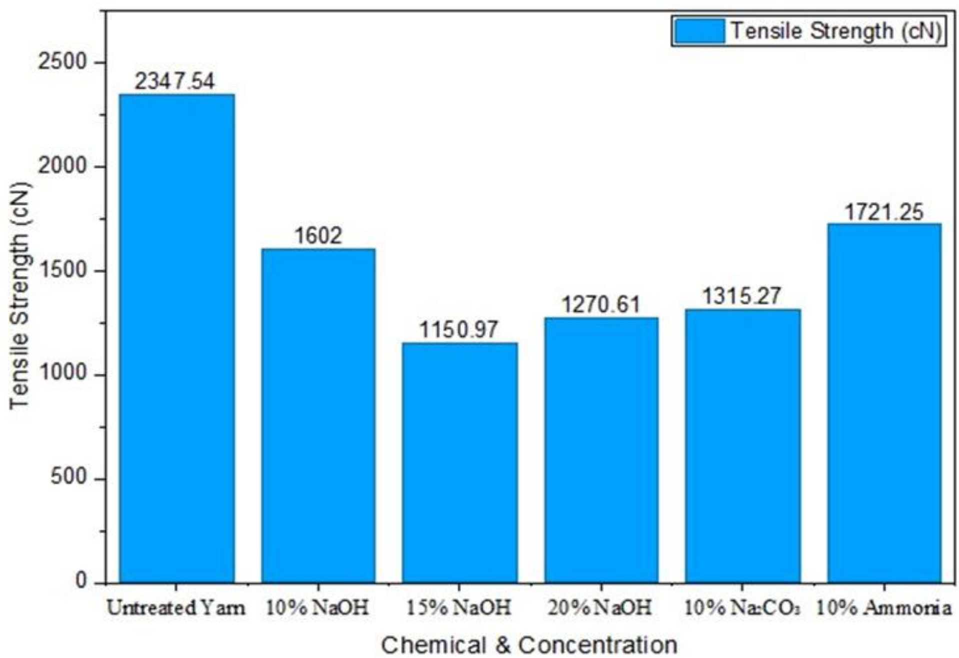

Figure 3. Tensile strength of different treated yarns

Young's modulus

The Young's modulus values (in GPa) of Urena lobata yarn after several chemical treatments are shown in Figure 4 in comparison to the yarn that has not been treated. At 21.65 GPa, the untreated yarn had the greatest Young's modulus, demonstrating its exceptional stiffness and deformation resistance. The modulus dropped to 18.44 GPa after 10% NaOH treatment, and further decreases were seen as the concentration of NaOH increased: 15% NaOH produced 15.21 GPa, and 20% NaOH produced the lowest modulus at 13.97 GPa. This pattern implies that the stiffness of the fiber gradually decreases with increasing NaOH concentrations. A modulus of 18.03 GPa, which was marginally lower than that of the yarn treated with 10% NaOH, was obtained after treatment with 10% Na_2CO_3, suggesting a mild impact on fiber stiffness. At 19.90 GPa, the yarn treated with 10% ammonia had a comparatively high modulus. Young's modulus is generally decreased by alkali treatments, according to the data, and the yarn treated with 20% NaOH has the lowest Young's modulus value. Better softness is indicated by the lowest Young's modulus values. The structural effects of alkali treatments on the yarn result in a drop in Young's modulus. The untreated yarn's natural cellulose structure is retained, giving it the maximum rigidity (21.65 GPa). The cellulose gradually loses rigidity, and its modulus decreases from 18.44 GPa (10% NaOH) to 13.97 GPa (20% NaOH) as a result of the cellulose being gradually weakened or partially destroyed by increasing concentrations of NaOH.This pattern demonstrates how increased NaOH concentrations weaken the fiber's resistance to deformation by more severely disrupting its molecular bonds. With values of 18.03 GPa and 19.90 GPa, respectively, the fibers maintain more of their rigidity under the less forceful 10% Na_2CO_3 and 10% Ammonia treatments.

The general decrease in Young's modulus suggests that alkali treatments, particularly at higher concentrations, soften and increase the flexibility of the yarn, which might be advantageous for applications that call for less rigid materials.

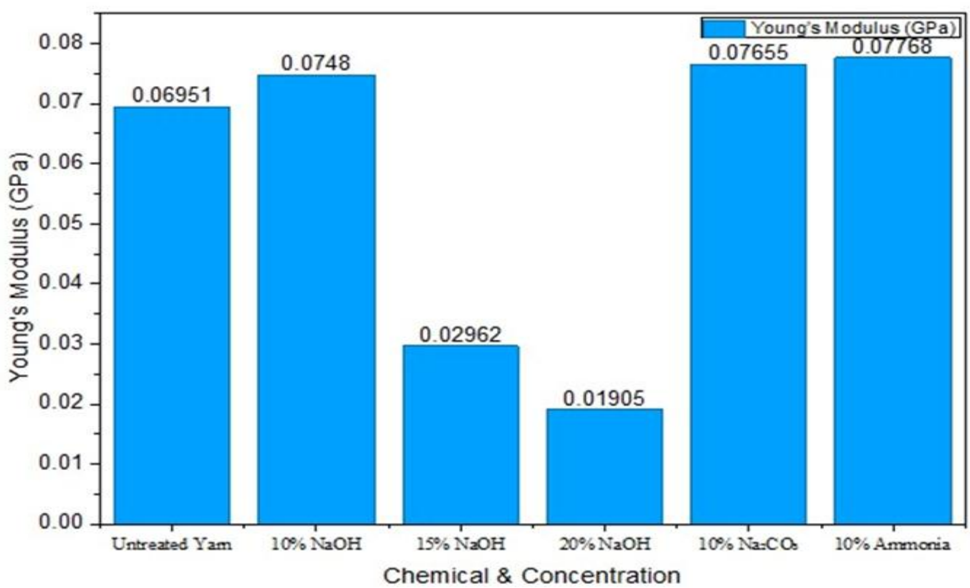

Figure 4. Young's Modulus of different treated yarns

Elongation at break

The elongation at break (%) for Urena lobata yarn exposed to several chemical treatments is shown in Figure 5, demonstrating how the treatments affect the yarn's ductility and flexibility. The yarn that has not been treated exhibits a mild elongation of 3.73%. The elongation is reduced to 2.36% after treatment with 10% NaOH, suggesting enhanced brittleness. The elongation, however, rises to 4.28% with 15% NaOH and peaks noticeably at 7.34% with 20% NaOH, indicating that greater NaOH concentrations improve the yarn's capacity to extend before breaking. However, 10% Na_2CO_3 produces the least amount of elongation (1.89%), suggesting a more solid structure. 10% ammonia-treated yarn has a somewhat better elongation of 2.41%, although it is still less than that of the untreated sample. Elongation at break varies as a result of the fact that larger NaOH concentrations expand and soften the fiber structure, increasing flexibility, whereas milder or less disruptive treatments, such as ammonia and Na2CO3, retain or decrease ductility, making the yarn more fragile.

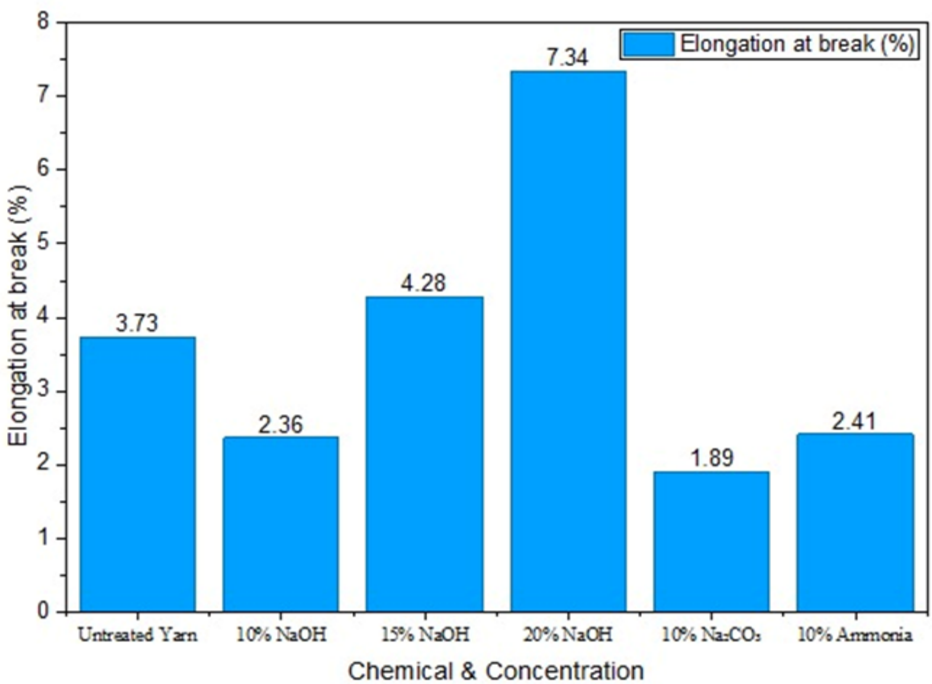

Figure 5. Young's Modulus of different treated yarns

Moisture content

The moisture content (%) of Urena lobata yarn under various chemical treatments is shown in Figure 6, emphasizing how these treatments affect the yarn's hygroscopic behavior—a crucial component of comfort and wool-like qualities. The initial moisture level of the untreated yarn is 10.65%. The moisture content rises to 12.11% after treatment with 10% NaOH, and by 15% NaOH (12.77%) and 20% NaOH, which has the maximum moisture content at 14.89%, additional increases are seen. This pattern implies that a higher concentration of NaOH improves the fiber's capacity to absorb and hold onto moisture, most likely as a result of more porosity and amorphous areas. 10% Na_2CO_3 treatment provides a moisture content of 11.25%, whereas 10% ammonia treatment yields 10.97%, both of which are just marginally better than the untreated sample. Since the treatment enhances the fiber's amorphous and porous areas, which improve its capacity to absorb and hold onto water, the moisture content rises as the concentration of NaOH increases. Because milder treatments like 10% NaCO3 and 10% ammonia only slightly alter the fiber's structure, they only result in modest increases.

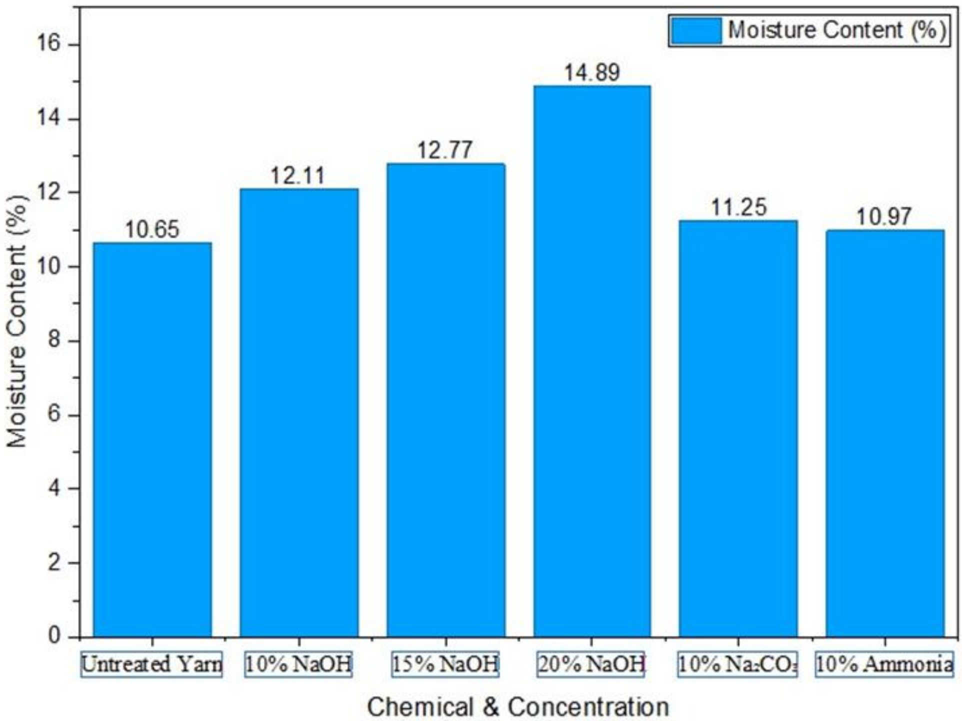

Figure 6. Moisture content of different treated yarns

Moisture regain

The capacity of several chemically treated Urena lobata yarn samples to absorb environmental moisture—a crucial sign of comfort and wool-like behavior—is shown in Figure 7. At 11.92%, the untreated yarn, which serves as the baseline, has the lowest moisture recovery. 10% NaOH raises this value to 13.93% after treatment, while 15% and 20% NaOH further raise it to 15.87% and 17.49%, respectively. These findings clearly show an improvement in moisture regain as the concentration of NaOH rises, indicating a higher capacity for moisture absorption as a consequence of structural changes in the fiber. However, 10% ammonia and 10% NaCO3 treatments provide moisture regains of 12.67% and 13.43%, respectively, which are just marginally higher than the untreated yarn. Since the treatment produces more porous and amorphous fiber architectures that better absorb moisture, moisture regain rises with greater NaOH concentrations. Less severe treatments, such as 10% ammonia and 10% NaCO3, only slightly enhance the fiber structure.

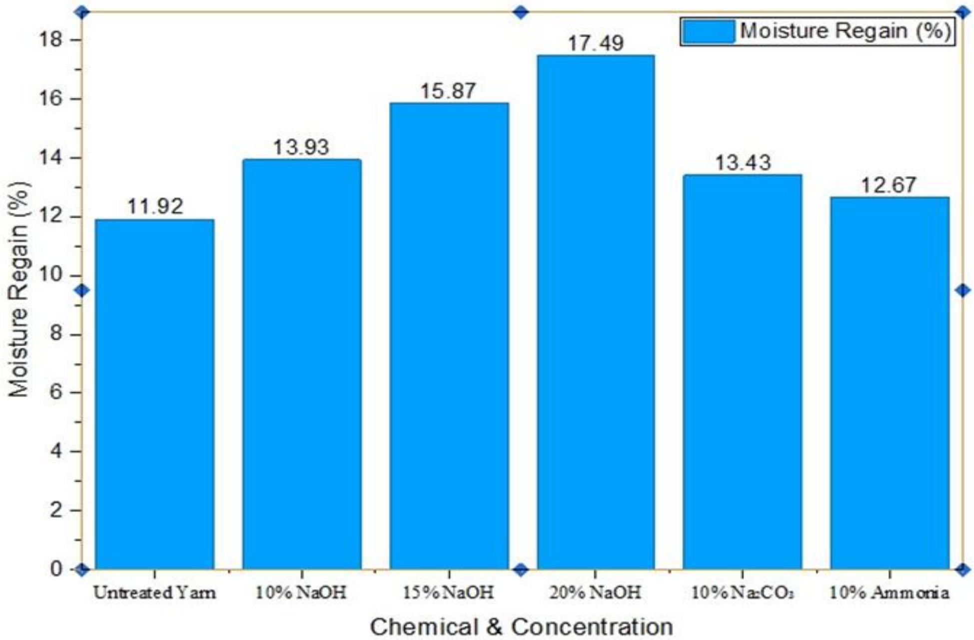

Figure 7. Moisture regain of different treated yarns

SEM

A comparison of untreated and treated Urena lobata yarn (ULY) fibers is shown in the scanning electron microscope (SEM) Figure 8.

Untreated ULY: As seen by scanning electron microscopy (SEM), untreated Urena lobata yarn has a rough, uneven, and non-uniform fiber surface. Dark specks and thin fibers on the surface of the micrographs depict a loose arrangement of fibrils and detachment of layers, which means low structural integrity and low cleanliness that as shown in Figure 8. These remarks confirm the assumption that raw fiber does not exhibit consistent alignment of the fiber, and it is over-contaminated.

Treated ULY: The SEM shows the figure of the treated ULY surface that is noticeably smoother and more aligned. By efficiently lowering the quantity of surface contaminants, the treatment produces a cleaner morphology and better fiber homogeneity. Increased surface cohesiveness in the treated fibers indicates how well the applied treatment changed and improved the Urena lobata yarn's structural properties.

The current experimental evidence supports the above supposition that surface treatment significantly alters the morphological attributes as well as surface characteristics of natural fibers, and hence may also increase the overall performance of such natural fibers in textile and composite end-use applications.

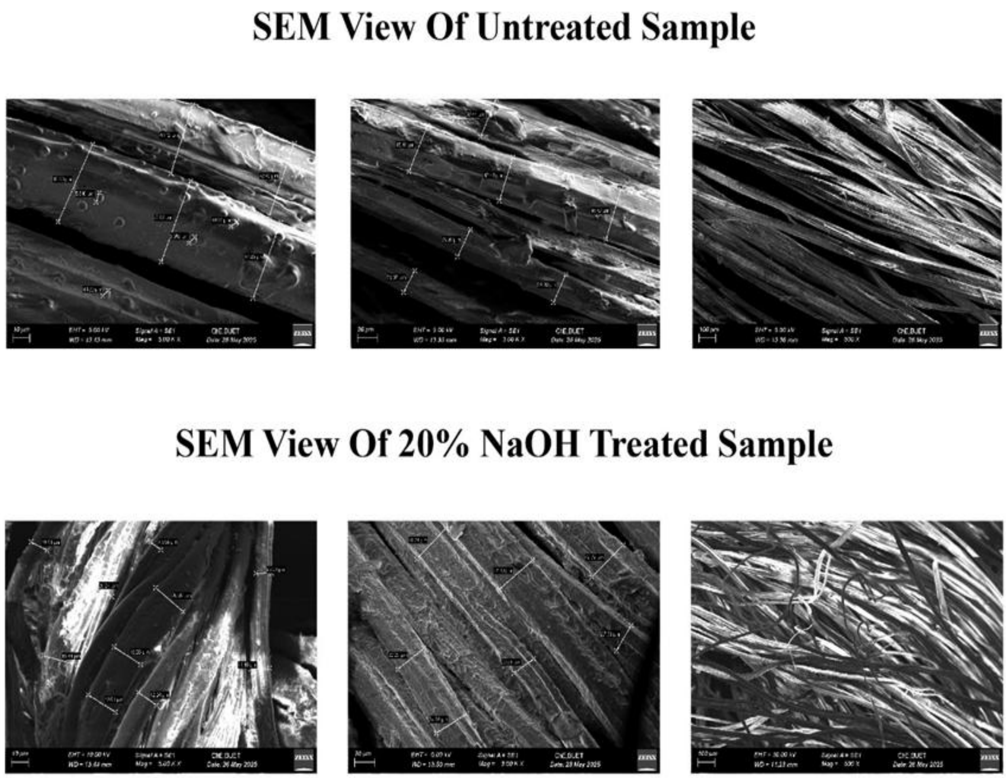

Figure 8. Scanning electron microscope (SEM) of the Untreated ULY and the treated sample with 20% NaOH

Table 2. EDX results of untreated Urena lobata yarn

Element	Weight %	Atomic %	Net Int.	Error %	Relative Sensitivity Factor	Absorption Correction Factor	Fluorescence Correction Factor
C K	69.01	74.94	207.28	10.11	0.9386	0.1825	1.0
O K	30.5	24.86	87.36	11.94	0.9462	0.0726	1.0
MgK	0.05	0.03	1.16	71.01	0.9573	0.4501	1.0022
AlK	0.03	0.02	0.93	71.86	0.9597	0.5966	1.0035
SiK	0.08	0.04	2.45	37.94	0.962	0.7142	1.0051
S K	0.16	0.07	4.52	23.92	0.9661	0.8636	1.0103
K K	0.04	0.01	0.81	69.35	0.9716	0.9525	1.0282
CaK	0.11	0.03	1.97	51.09	0.9733	0.9659	1.035
FeK	0.02	0.0	0.22	75.13	0.9824	0.9944	1.1609

Table 3. EDX results of treated Urena lobata yarn

Element	Weight %	Atomic %	Net Int.	Error %	Relative Sensitivity Factor	Absorption Correction Factor	Fluorescence Correction Factor
C K	58.84	65.82	138.2	11.05	0.9363	0.1668	1.0
O K	40.37	33.89	115.08	11.98	0.9442	0.0844	1.0
MgK	0.04	0.02	0.7	87.09	0.9557	0.4243	1.0021
AlK	0.04	0.02	0.91	80.16	0.9582	0.5717	1.0034
SiK	0.03	0.01	0.71	81.04	0.9605	0.6931	1.005
S K	0.14	0.06	3.35	46.35	0.9647	0.8517	1.0105
K K	0.08	0.03	1.5	68.09	0.9704	0.9479	1.0291
CaK	0.33	0.11	5.11	31.44	0.9722	0.9624	1.0333
FeK	0.13	0.03	1.17	66.62	0.9816	0.9935	1.1467

There was a significant difference between the untreated and treated Urena lobata yarn when analyzed with the energy-dispersive X-ray (EDX). Energy-dispersive X-ray (EDX) analysis of both untreated and treated Urena lobata fibers (see Tables 2 and 3) reveals notable compositional differences, underscoring how treatment alters the fiber surface chemistry. The raw fiber primarily contains carbon (69.01 WT %) and oxygen (30.50 wt%), consistent with its lignocellulosic composition—cellulose, hemicellulose, and lignin being carbon-rich—and numerous oxygen-bearing functional groups. Trace amounts (≤0.16 wt%) of Mg, Al, Si, S, K, Ca, and Fe likely stem from soil residue or inherent plant metabolism. Then fibers are treated with alkali concentration. After treatment, carbon decreases to 58.84 wt%, while oxygen increases to 40.37 wt%, suggesting removal of outer surface components (e.g., waxes, hemicellulose, lignin), thereby enriching accessible oxygenated groups (hydroxyl, carbonyl, carboxyl). Meanwhile, the treated sample of calcium increases from 0.11 to 0.33 wt% and iron from 0.02 to 0.13 wt%, possibly due to mineral deposition or enhanced detection after surface cleansing. These compositional shifts imply an elevated oxygen-to-carbon ratio, promoting greater hydrophilicity and chemical reactivity—beneficial for functionalization or enhancing composite interactions. Variation in minor elements again points to alterations in surface contamination or mineral adsorption attributable to treatment.

Similarities of 20% treated Ulf and wool yarn

From Table 4, the performance and application of ULF and wool yarns are comparable due to their shared characteristics. The soft feel of both yarns suggests a comparable tactile characteristic that is desired in textile goods. The tensile strength of ULF Yarn is 20.49 cN/tex, which is equivalent to that of Wool Yarn (20.72 cN/tex) and indicates similar strength properties. In terms of elongation at break, Wool Yarn exhibits more stretchability than ULF Yarn, which has a lower value (7.34%) than Wool Yarn (21.15%) (Wu et al., 2024). Both values are within the predicted range for natural and modified fibers. Similar moisture retention qualities are shown by ULF Yarn's moisture content of 14.89%, which is within the range of Wool Yarn (13–16%). Similarly, ULF Yarn's moisture recapture of 17.49% overlaps with Wool Yarn's range of 13–18%, indicating a similar capacity to recover moisture from the air. These parallels imply that ULF Yarn is a good substitute for Wool Yarn in comparable textile applications as it replicates many of the latter's physical and functional characteristics.

Table 4. Similarities of 20% treated ULF and wool yarn

Name	Tensile Strength (cN/tex)	Elongation at Break (%)	Moisture Content (%)	Moisture Regain (%)	Softness
ULF Yarn	20.49	7.34	14.89	17.49	Soft Feel
Wool Yarn	20.72 (Oboda & Abou-Taleb, 2023)	21.15(Wu et al., 2024)	13-16(Naebe et al., 2013)	13-18(Naebe et al., 2013)	Soft Feel(Naebe et al., 2013)

Conclusion

In order to create sustainable textile substitutes with qualities similar to those of wool, this study shows that woolenizing Urena lobata fibers is both feasible and efficient. The physical and mechanical characteristics of the fibers were significantly altered by adding different concentrations of alkaline treatments, particularly sodium hydroxide, to improve softness, elasticity, and water affinity—all of which are essential for textile applications. Despite having a high tensile strength and stiffness, the untreated ULF yarn lacked the comfort and flexibility that are desired in clothing. The fiber structure was considerably changed by chemical treatments, especially those using 20% NaOH. In order to replicate the behavior of wool, this sample had the maximum elongation at break and moisture recovery values, which are signs of improved ductility and moisture handling." An ideal equilibrium between structural softness and mechanical durability must be achieved; nevertheless, as evidenced by a related decrease in tensile strength and Young's modulus. The enhanced porosity and smoothness of the fiber surface after treatment were verified by the SEM studies, which enhanced the tactile qualities. In contrast, modest treatments such as 10% Na_2CO_3 and ammonia produced a moderate change in the fiber, providing a balance between the texture of wool and structural integrity. In addition to offering a practical means of improving neglected bast fibers, the study supports the textile industry's larger push for sustainable and biodegradable materials. ULF may be made into a competitive substitute for traditional wool by improving the woolenization process, which will lessen reliance on synthetic and animal fibers. Future studies should examine the performance of woolenized ULF in actual textile manufacturing settings and investigate its mixing with other natural fibers. Woolenization offers a viable modification technique for turning stiff natural fibers, such as Urena lobata, into valuable, eco-friendly materials with a wide range of applications in eco-textiles, therefore supporting the worldwide sustainable development goals.

Competing interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.”

Abbreviation

ULF	Urena Lobata Fiber
NaOH	Sodium Hydroxide
Na_2CO_3	Sodium Carbonate
SEM	Scanning Electron Microscopy
EDX	Energy Dispersive X-ray Spectroscopy
ISO	International Organization for Standardization
MC	Moisture Content
MR	Moisture Regain
cN	Centinewton (unit of force)
GPa	Gigapascal (unit of Young’s modulus/stiffness)
cN/tex	Centinewton per tex (unit of yarn tenacity)
ASTM	American Society for Testing and Materials

Orcid ID

Abu Sayed https://orcid.org/0009-0003-3551-6832

Ajajul Islam https://orcid.org/0009-0001-6174-1326

Sujan Miah https://orcid.org/0009-0008-4674-4685

Hazera Akter https://orcid.org/0009-0000-9740-6354

Md. Al Mahmud https://orcid.org/0009-0003-4371-1654

Abdur Rahman https://orcid.org/0009-0000-7426-8972

Aman Ullah Aman https://orcid.org/0009-0001-6429-0524

References

Ghosh, A., & Mal, P. (2019). Testing of fibres, yarns and fabrics and their recent developments. In *Fibres to smart textiles* (pp. 221–256). CRC Press. https://doi.org/10.1201/9780429446511-12

Gnassiri Wedaïna, A., Pizzi, A., Nzie, W., Danwe, R., Konaï, N., Amirou, S., Segovia, C., & Kueny, R. (n.d.). Performance of unidirectional biocomposite developed with Piptadeniastrum africanum tannin resin and *Urena lobata* fibers as reinforcement. https://doi.org/10.32604/jrm.2020.012782

Jones, J. H., Briggs, L. J., & Ona, D. (1341). *CS11-41 yarns, cotton; moisture-regains: Moisture regains of cotton yarns* (Second edition).

Kengoh, J. B., Peter Etape, E., Victorine Namondo, B., Foba-Tendo, J., Nafu, Y. R., & Fabien, B. E. (2021). Influence of *Urena lobata* fibre treatment on mechanical performance development in hybrid *Urena lobata* fibre/gypsum plaster composites. *Advances in Materials Science and Engineering, 2021*. https://doi.org/10.1155/2021/5514525

Mia, R., Islam, Md. A., Ahmed, B., & Mojumdar, J. I. A. (2017). Woolenization of jute fibre. *European Scientific Journal, 13*(30), 314. https://doi.org/10.19044/esj.2017.v13n30p314

Naebe, M., Yu, Y., McGregor, B. A., Tester, D., & Wang, X. (2013). The effect of humidity and temperature on Wool ComfortMeter assessment of single jersey wool fabrics. *Textile Research Journal, 83*(1), 83–89. https://doi.org/10.1177/0040517512441988

Njoku, C. E., Omotoyinbo, J. A., Alaneme, K. K., & Daramola, M. O. (2019). Chemical modification of *Urena lobata* (Caeser weed) fibers for reinforcement applications. *Journal of Physics: Conference Series, 1378*(2). https://doi.org/10.1088/1742-6596/1378/2/022015

Njoku, C. E., Omotoyinbo, J. A., Alaneme, K. K., & Daramola, M. O. (2022). Characterization of *Urena lobata* fibers after alkaline treatment for use in polymer composites. *Journal of Natural Fibers, 19*(2), 485–496. https://doi.org/10.1080/15440478.2020.1745127

Oboda, E. R., & Abou-Taleb, E. M. (2023). Evaluating the tensile strength and elongation properties of produced yarns using direct twist technique. *International Design Journal, 13*(1).

Rahman, S., Hasan, K., Repon, M. R., & Haque, M. M. (2024). Preparation and characterization of handsheet using cellulose based agri-weed: A sustainable utilization of *Urena lobata* fiber. *Heliyon, 10*(7). https://doi.org/10.1016/j.heliyon.2024.e29170

Sharif Ullah, A. M. M., Shahinur, S., & Haniu, H. (2017). On the mechanical properties and uncertainties of jute yarns. *Materials, 10*(5). https://doi.org/10.3390/ma10050450

Sipai Babu, S., Bindu Madhuri, D., & Ali, S. L. (2016). A pharmacological review of *Urena lobata* plant, 9.

Stocchi, A., Lauke, B., Vázquez, A., & Bernal, C. (2007). A novel fiber treatment applied to woven jute fabric/vinylester laminates. *Composites Part A: Applied Science and Manufacturing, 38*(5), 1337–1343. https://doi.org/10.1016/j.compositesa.2006.10.010

Suganthi, T. (n.d.). *Thermo-physiological comfort of layered knitted fabrics for sportswear*. *Tekstil ve Konfeksiyon, 27*(4), 352–360. https://dergipark.org.tr/en/download/article-file/393360

Wu, S., Wang, Z., Wang, X., & Jiang, J. (2024). Highly soft, abrasion-resistant, and moisture-absorbent wool/PA56 blended yarns for seating fabrics. *Polymers, 16*(14). https://doi.org/10.3390/polym16142052