ENHANCING THE PROPERTIES OF NATURAL HOLLOW FIBERS FOR WOUND DRESSING APPLICATIONS THROUGH HYDROTHERMAL AND ALKALI TREATMENTS

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This research investigates the effect of alkali and hydrothermal treatments on natural hollow fibers, specifically those of kapok and milkweed. Such natural fibers have high wax content, which makes their surface hydrophobic. Alkali treatment removes such components from the fiber surface, improving water absorbency and surface roughness. Hydrothermal treatment, when combined with alkali treatment, further enhances fiber properties. The study analyses the impact of both treatments on the surface morphology, crystallinity index, and water absorption of these fibers. A comparative study of water absorbency between treated natural hollow fibers and commercial surgical cotton wool is presented. The hydrothermally treated kapok fibers exhibited better water absorbency capacity than commercial surgical cotton wool. The results indicate that the combined treatments significantly improve the water absorbency and other properties of the fibers, making them comparable to commercially available surgical cotton wool.

Keywords: kapok fiber, milkweed fiber, alkali treatment, hydrothermal treatment, water absorbency

INTRODUCTION

Currently, researchers are focusing on sustainable and biodegradable materials such as natural fibers as environmentally friendly alternatives to synthetic fibers for a wide range of applications.[1] The major component of natural fibers is cellulose, followed by hemicelluloses, lignin and wax. The proportion of these components significantly influences the characteristics of the fiber. Cellulose is a relatively stable polymer. The cellulosic fibers have good flexibility and elasticity, compared to mineral fibers, such as glass and carbon. The cellulose fibers are environmentally friendly and renewable resources. Kapok and milkweed fibers have attracted research interest due to their hollow structure. Their lignocellulosic and hydrophobic nature also provides resistance to microbial attack. Both kapok[2] and milkweed fibers are classified as seed fibers.

Kapok fiber is obtained from the seed pods of the kapok tree (*Ceiba pentandra*), a species of the Bombacaceae family. Originally native to tropical India, the tree is now widely cultivated across Southeast Asia.[3] Kapok fiber is a single-wall hollow and unicellular natural fiber like cotton. It is seven times less dense and buoyant than cotton. Kapok fiber is moisture-resistant, buoyant, resilient, soft, and brittle. In general, it is used in life jackets, sleeping bags, insulation, and upholstery as a filling material. Kapok fiber has water-repellent properties due to the fiber's chemical composition, comprising, besides cellulose, and pentosan, lignin and waxy cutin on the fiber surface. The hollowness of kapok fiber is approximately 77%, and the density of the fiber wall material is 1.31 g/cm^3. Kapok fiber has a low density of 0.29 g/cm^3 due to the huge lumen and the thin cell wall, which enables the fiber to be compressed more easily. Kapok fibers typically contain 35%-50% cellulose, 22%-45% hemicelluloses, 15%-22% lignin, and 2%-3% wax.[4,5]

Milkweed (*Asclepias syriaca* L.) is a perennial plant multiplying by seeds or creeping roots and secretes a milky juice from all the parts. The milkweed plant is about 2 m in height, its flowers are purple, and some of them develop into pod-containing floss fiber attached to the seed.

Milkweed floss is a hollow cellulosic fiber composed of approximately 40–45% cellulose, 35–40% hemicelluloses, 15% lignin, and 2–3% wax.[6] Milkweed floss has high oil sorption capacity due to its high wax content on the fiber surface and hollow structure, similarly to kapok fiber. Research has shown that the milkweed floss fiber had an absorption capacity 120 times its weight, depending on the structure of the sorbent and the oil properties. Milkweed has a low density – of about 0.90 g/cm^3.[7] The spinnability of the milkweed fiber is very poor, it was found unsuitable to be processed through spinning due to the brittle nature and low elongation of the fiber. The low breaking elongation of milkweed fibers results in their higher initial modulus, which could be considered as a positive aspect for their technical applications.[8,9] Milkweed fibers inherently have high moisture content and moisture regain, which could be a contribution of their hollow channel structure along the fiber length. This characteristic makes the fibers suitable to be used as moisture absorptive material.[10] Due to the high moisture transmission behaviour of milkweed fibers, they could be utilized as raw material for producing fabrics with desirable comfort properties. Also, the hollow structure and high wax content of mlkweed fibers contribute to their lightweight nature, excellent oil sorption, and insulation properties. These features, combined with their low density, make them suitable for technical textiles, including medical, as well as for thermal, and acoustic applications.[11,12,13]

Commercial surgical cotton wool is often blended with wool to enhance its absorbency. It serves various purposes in the medical field, such as surgical dressing,[14] wound cleaning, and more. Beyond medical applications, it is also utilized in the cosmetic industry.[15,16] Primarily, surgical cotton is used in hospitals, dispensaries, and nursing homes to absorb body fluids efficiently. This cotton is typically produced using non-spinnable cotton, or comber waste from spinning mills. The fibers undergo pre-treatment processes involving alkalis and hydrogen peroxide during scouring and bleaching processes to ensure they are thoroughly cleaned. Finally, the cotton is sterilized to prevent microbial contamination and reduce the risk of infections.[17]

Various studies have been conducted on cotton-like materials, treated with alkali,[18] enzymes, plasma *etc*., to analyse the characteristics of fibers. To the authors' knowledge, studies on the effects of hydrothermal treatments and alkali treatment on hollow fibers are limited. Therefore, this study investigates the effects of alkali and hydrothermal treatments on kapok and milkweed fibers, and evaluates their potential as alternatives to surgical cotton wool for wound dressing applications.

EXPERIMENTAL

Materials

Raw kapok and milkweed floss fibers were collected from the Kanchipuram District, Tamil Nadu, India. The chemicals used for alkali treatment and chemical composition analysis included sodium hydroxide (NaOH), concentrated sulfuric acid (H_2SO_4, 96.5%), xylene, acetic acid, and carbon tetrachloride (CCl_4), all of analytical reagent grade. Commercial surgical cotton wool I.P. wadding (Anant Surgical, 40 g roll, non-sterile) was used as a reference for comparison.

Alkali and hydrothermal treatments

Preliminary trials were conducted using varying concentrations of NaOH (1%, 5%, 10%, 15%, and 20%) to determine optimal alkali treatment conditions. Based on weight loss percentage and water absorption capacity, 5% NaOH was found to be the most effective and was selected for further treatment.

In this research work, two different types of treatments were involved to treat the natural hollow fibers; the procedure is given below:

1. The hydrothermal treatment[7] was performed as a two-step process. First, a known quantity of fiber was immersed in distilled water and boiled for 1 hour, maintaining a material-to-liquor (M:L) ratio of 1:20. After cooling to room temperature, the fibers were treated with 5% NaOH for 15 minutes at room temperature. The treated fibers were thoroughly washed with warm and cold water, pH-neutralized using acetic acid, and dried in a hot air oven at 60 °C.

2. For the alkali treatment,[7] the fibers were immersed in 5% NaOH solution for 24 hours at room temperature, maintaining an M:L ratio of 1:20. After treatment, the fibers were thoroughly rinsed with cold water, neutralized using acetic acid, and dried in a hot air oven at 60 °C.

Characterization techniques

Chemical composition analysis

The chemical composition of untreated kapok and milkweed fibers was determined using the Chesson-Datta method.[19,20] One gram of oven-dried fiber (A) was refluxed with 150 mL distilled water at 100 °C, filtered, washed with 300 mL of hot water, and dried at 75 °C (B). Subsequently, the residue was refluxed with 150 mL of 1N H_2SO_4 at 100 °C for 1 hour, filtered, and dried (C). For lignin analysis, the residue was soaked in 100 mL of 72% H_2SO_4 at room temperature for 4 hours, then refluxed with 150 mL of 1N H_2SO_4, filtered, and dried at 105 °C (D). The final residue was heated at 475 °C

for 3 hours (E). Hemicelluloses, cellulose, and lignin contents were calculated using standard equations:

$$Hemicellulose\ \% = \frac{C-B}{A} \times 100 \quad (1)$$

$$Cellulose\ \% = \frac{D-C}{A} \times 100 \quad (2)$$

$$Lignin\ \% = \frac{E-D}{A} \times 100 \quad (3)$$

$$Ash\ \% = \frac{E}{A} \times 100 \quad (4)$$

The wax content of the fiber was identified by the reflux method[21] by using Soxhlet apparatus, where a known amount of fiber (F) was put in 150 mL of carbon tetrachloride (CCl_4) and refluxed for 1 h. The refluxed fiber was washed with water, dried, and weighed to obtain the final weight (G).

$$Wax\ Content\ \% = \frac{F-G}{F} \times 100 \quad (5)$$

Moisture content of the fiber refers to the amount of moisture present in the fiber, which was determined as per ASTM D2654-22:[22]

$$Moisture\ Content\ \% = \frac{a-d}{d} \times 100 \quad (6)$$

where a = mass of material before drying, and d = mass of the dried material.

Analysis of physical properties of fiber

The tenacity of the fiber was determined as per ASTM D3217-20[23] using an Instron-3369 with a 100N loadcell, a gauge length of 3mm, and a speed rate of 2 mm/min. The fineness value of the fiber was assessed as per ASTM D1448-11[24] by using a FibroMic XT Digital fiber fineness (Micronaire) tester, with 4.00±0.01 g fiber samples. The density of the treated and untreated fiber was determined by the Density Gradient Column method as per ASTM 1505–03 (2005).[25]

The density of the specimen (a bundle of fibers) was determined by matching with that of the liquid column gradient.[26] A 100 mL test tube was used as a column, containing liquids of different densities, xylene (0.88 g/cm^3) and carbon tetrachloride (1.59 g/cm^3). The specimen was submerged in the column, and the closest calibrated glass float serves to determine the density of the sample.

Surface morphology

The surface morphology of treated and untreated kapok and milkweed fibers was analysed using a scanning electron microscope (Tescan-Vega3 SEM) at 464× magnification. The fiber diameter and lumen diameter were analysed using a polarized microscope. The hollowness of the fiber was identified by the ratio of lumen diameter (µm) and fiber diameter (µm), expressed in percentage.[27]

$$Degree\ of\ hollowness = \frac{d}{D} \times 100 \quad (7)$$

The influence of chemical treatment on changes in the chemical structure of the fiber was determined by FTIR spectroscopy. The spectra were recorded using a JASCO FTIR in the transmittance mode (range 349 to 4000 cm^{-1}).

The crystallinity index of the fibers was analysed using a Shimadzu (XRD-6000) XPert PRO X-ray diffraction instrument to examine the crystalline patterns of the fiber. The diffractograms were recorded in the range of 2θ = 5° to 70°, at room temperature (step size: 0.02°; scan rate: 200 s/step). The crystallinity index (CI %) was calculated according to Segal's empirical equation, where I_{200} is the total intensity of the (200) peak for cellulose I and I_a is the amorphous intensity.[28,29]

$$CI = \frac{Ic-Ia}{Ic} \times 100 \quad (8)$$

where I_a – intensity of amorphous region and I_c – intensity of crystalline region.

Water absorption capacity

The water absorption capacity of the fiber varies depending on the type of treatment and the testing conditions. In this research, alkali and hydrothermal treatments were applied to improve the physical properties of the fibers. One of the primary improvements observed was an increase in water absorption capacity, measured using the procedure described previously.[7] A known quantity of fiber was immersed in distilled water and stirred at 700 rpm at time intervals of 15, 30, 45, and 60 minutes. After each time interval, the fiber was filtered using presaturated Whatman No. 4 filter paper to eliminate any influence from the filter medium. Filtration was considered complete when the time between successive water drops exceeded one minute. A schematic diagram of the water absorption test setup is provided in Figure 1. The water absorption capacity (WAC) was calculated using the following equation:

$$WAC(\%) = \frac{(m2-m1)}{m1} \text{ X } 100 \quad (9)$$

where m1 – initial weight of the fiber and m2 – final weight of the fiber.

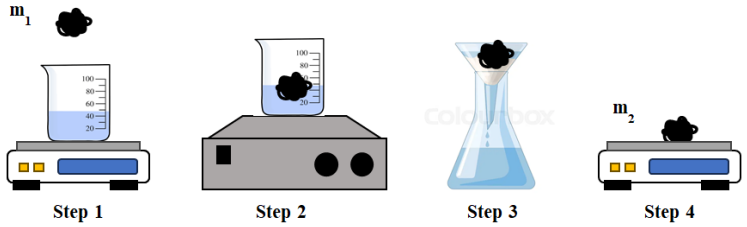


Figure 1: Schematic representation of absorption capacity test method

RESULTS AND DISCUSSION

Alkali treatment of raw fiber

Two different treatment protocols were employed: hydrothermal treatment and direct alkali treatment. In the hydrothermal method, the fibers were first boiled in distilled water at 100 °C for 1 hour. The fibers were then immersed in 5% NaOH solution for 15 minutes at room temperature.

$$(C_6H_{10}O_5)n + (C_5H_8O_4)n + RCOOR' + H_2O \xrightarrow{\downarrow \Delta} (C_6H_{10}O_5)n + (C_5H_8O_4n) + R'OH\ (alcohol) + Degraded\ Products \quad (10)$$

$$(C_6H_{10}O_5)n + (C_5H_8O_4)n + NaOH + H_2O \xrightarrow{\downarrow} (C_6H_9ONaO_5)n + (C_5H_{10}O_5)n + Degraded\ Products \quad (11)$$

In the alkali treatment, the fibers were immersed in 5% NaOH solution at room temperature for 24 hours.

$$(C_6H_{10}O_5)n + (C_5H_8O_4)n + RCOOR' + NaOH + H_2O \xrightarrow{\downarrow} (C_6H_9ONaO_5)n + (C_5H_{10}O_5)n + RCOONa\ (soap) + R'OH\ (alcohol) + Degraded\ Products \quad (12)$$

Cellulose undergoes partial alkali treatment, retaining its overall structural integrity. Sodium hydroxide deprotonates the hydroxyl groups in cellulose, initiating chemical changes. Hemicelluloses, being more prone to alkaline hydrolysis than cellulose, break down into soluble sugar derivatives, such as xylose, arabinose, and uronic acids. Similarly, waxes – composed of esters of long-chain fatty acids and alcohols – undergo saponification in the presence of sodium hydroxide, yielding soap (sodium salts of fatty acids) and alcohols. The combined effects of cellulose deprotonation, hemicellulose hydrolysis, and wax saponification contribute to the overall reaction during alkali treatment. After the treatment, the fibers were thoroughly washed and pH-balanced using acetic acid. This process significantly enhances the strength, dyeability, and appearance of cellulosic fibers.

Chemical composition of fiber

Cellulose is the major component of most plant-based natural fibers, such as cotton, jute, and flax. However, other components like hemicelluloses, lignin, and wax also influence the physical properties of the fiber. To determine the potential applications of natural fibers, their chemical composition must be analysed. A schematic representation of the chemical composition of natural hollow fibers is shown in Figure 2. The raw kapok and milkweed fibers were analysed for their chemical composition using the Chesson-Datta method. The results for both kapok and milkweed fibers are presented in Table 1.

Both fibers are rich in cellulose and contain significant amounts of hemicelluloses and lignin. The presence of lignin and hemicelluloses increases the brittleness of the fiber. The degree of polymerization (DP) of hemicelluloses is approximately 100, whereas the longer polymer chain of β-1,4-linked cellulose, with a DP above 3000, contributes significantly to the tensile strength of the fiber.[30]

The alkali treatment of natural cellulosic fibers leads to the removal of hemicelluloses, lignin, wax, and partial disintegration of the cellulose structure, depending on alkali concentration, treatment temperature, and duration. The primary objective of the alkali treatment is to remove non-cellulosic compounds, thereby enhancing the crystallinity of the fiber. For kapok and milkweed, the presence of hemicelluloses and lignin contributes to fiber brittleness. Based on both literature and experimental findings, 5% NaOH is sufficient to remove non-cellulosic components. However, direct alkali exposure for extended periods can result in fiber degradation. Therefore, two different treatment methodologies were employed in this study, as described in the Experimental section.

The hydrothermal treatment facilitates the removal of surface waxes, increases fiber flexibility, and enhances the accessibility of internal structures. As a result, the exposure time required for alkali treatment can be reduced, which helps retain the basic structural integrity of the fiber, while still achieving effective removal of non-cellulosic components. Both alkali and hydrothermal treatments were applied to kapok and milkweed fibers, and their physical properties were evaluated accordingly.

Physical properties of fiber

As per the standard procedure, the physical properties of both treated and untreated fibers were measured, and the results are given in Table 2.

The hydrothermal and alkali treatments reduced the tenacity of both fibers. The tenacity of

hydrothermally treated fiber was greater than that of alkali-treated fiber.

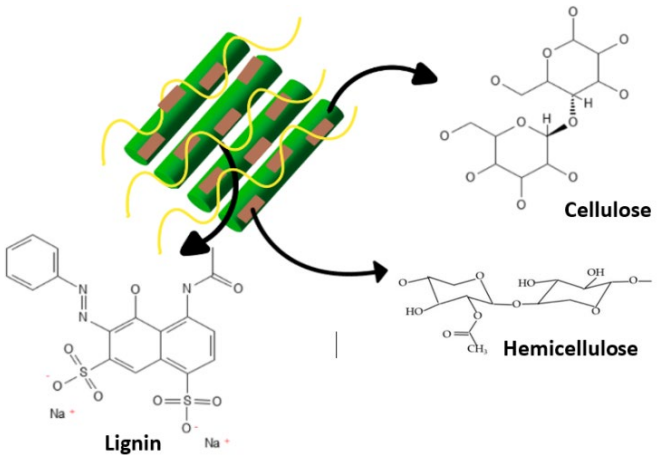


Figure 2: Schematic representation of natural hollow fiber chemical composition

Table 1
Chemical composition of raw fibers

Chemical compounds (%)	Kapok	H1	A1	Milkweed	H2	A2
Cellulose	60.211	56.047	54.858	60.089	54.231	54.958
Hemicelluloses	20.093	16.771	12.465	19.441	14.235	12.872
Lignin	14.208	11.341	11.99	16.566	12.907	9.554
Wax	2.869	0.838	0.839	3.113	0.519	1.321
Ash	0.552	0.436	0.802	0.78842	0.903	1.46
Moisture content	2.1 ± 1.0	3.8 ± 1.2	4.4 ± 1.0	1.9 ± 1.0	3.9 ± 1.0	3.0 ± 1.0
Weight loss after treatment	-	10.69	14.562	-	13.206	16.834

Note: Kapok – untreated kapok, milkweed – untreated milkweed, A_1 – alkali treated kapok fiber, A_2 – alkali treated milkweed fiber, H_1 – hydrothermal treated kapok fiber, H_2 – hydrothermal treated kapok fiber

Table 2
Physical properties of fibers

Properties	Raw kapok	A_1	H_1	Raw milkweed	A_2	H_2
Tenacity (g/den)	1.7	1.36	1.44	2.55	2.04	2.16
Elongation at break (%)	1.8	-	-	1.6	-	-
Crystallinity index (%)	54.01	41.77	50.67	65.8	52.49	77.39
Density (g/cm^3)	1.301	1.387	1.41	0.963	1.459	1.473
Fineness (denier)	0.7	0.58	0.62	0.85	0.52	0.63
Degree of hollowness (%)	77	70.28	71.42	71.5	47	46.7
Fiber diameter (µm)	24.20±2.00	21.77±2.00	20.37±2.00	28.14±2.00	17.44±2.00	19.41±2.00
Lumen diameter (µm)	18.63±2.00	15.29±2.00	14.55±2.00	20.12±2.00	8.19±2.00	9.06±2.00

Note: Kapok – untreated kapok, milkweed – untreated milkweed, A_1 – alkali treated kapok fiber, A_2 – alkali treated milkweed fiber, H_1 – hydrothermal treated kapok fiber, H_2 – hydrothermal treated kapok fiber

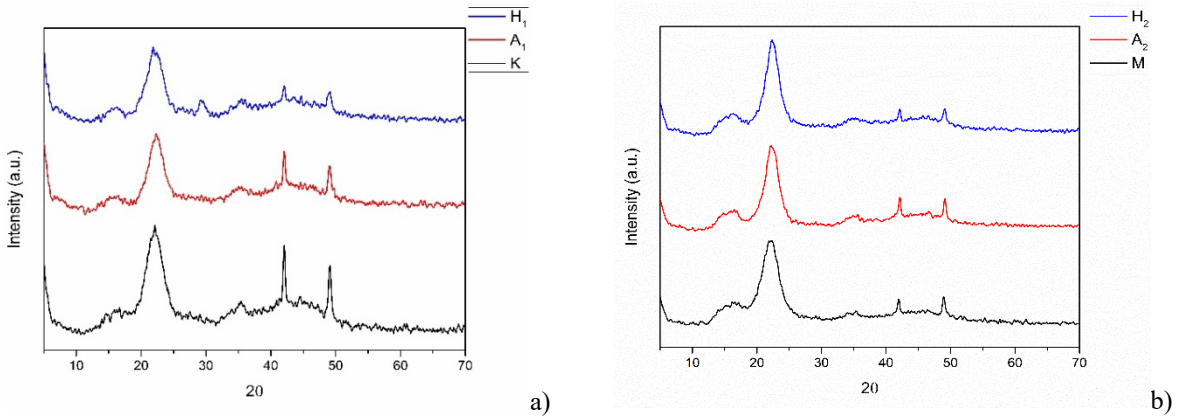


Figure 3: XRD patterns of kapok (a) and milkweed (b) fibres

This is due to the enhanced stability and accessibility of hydrothermally treated fibers. The same trend was observed for both fiber types. The reduction in strength observed in alkali and hydrothermal treatments was 20% and 15%, respectively, for both fibers. When comparing the properties of the fibers with respect to crystallinity index (CI%), density, fineness, and diameter, a similar trend was observed: raw fiber > hydrothermally treated fiber > alkali-treated fiber.

The degree of hollowness was reduced by up to 7 ± 1% in the case of kapok fiber, and by 26 ± 1% for milkweed fiber. This reduction is attributed to the low density and thin cell wall thickness of the fibers. The crystallinity index of kapok fiber decreased from 54.01% (untreated) to 50.67% (hydrothermally treated) and 41.77% (alkali-treated). In the case of milkweed fiber, the CI decreased from 65.8% to 47.39% following the hydrothermal treatment. This reduction is due to the increased accessibility of the polymer structure and removal of non-crystalline components from the fiber. The XRD patterns are shown in Figure 3.

Surface morphology of fibers

Both hydrothermal and alkali treatments removed the non-cellulosic components from the fibers, resulting in a reduction in diameter, as observed in the polarized microscopic image shown in Figure 4.

Significant changes in fiber morphology were observed through Scanning Electron Microscopy (SEM), as shown in Figure 5. The circular hollow cross-section of both fibers had collapsed and was transformed into a flat, ribbon-like structure with multiple multidirectional twists due to the effects of alkali and hydrothermal treatments. This indicates that the surface morphology of both fibers was significantly affected by the treatments.

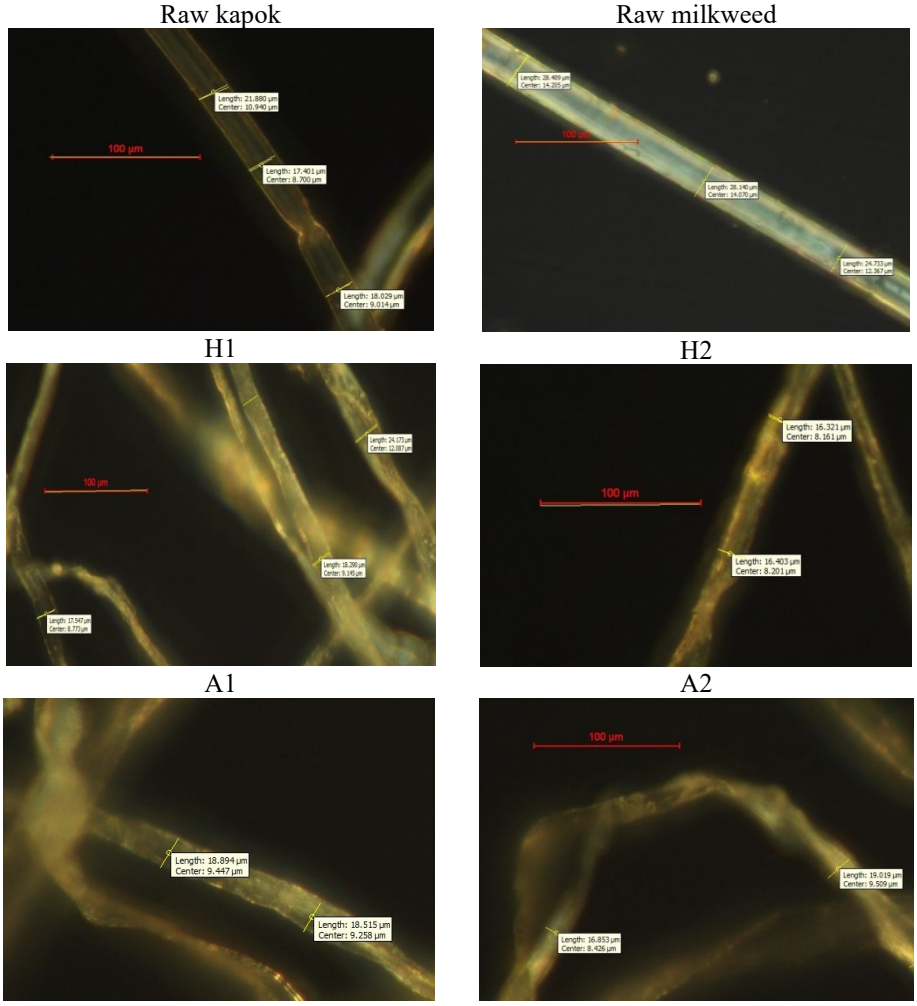
FTIR analysis of fibers

Due to alkali and hydrothermal treatments, the removal of hemicelluloses, lignin, and wax was observed based on changes in transmittance (%) at specific peaks in the FTIR spectra, as presented in Table 3 and shown in Figure 6.

By comparing the spectra of untreated and treated milkweed fibers, the following observations were made. An increase in absorption bands between 3860.79–3329.39 cm^{-1} was observed in all treated samples, indicating an increase in cellulose hydroxyl groups in the fiber walls. The most notable feature is the broad band centered at 3332.39 cm^{-1}, assigned to O–H stretching vibrations. A strong peak around 2901.38 cm^{-1} corresponds to asymmetric and symmetric stretching in CH_2 and CH_3 groups. The absorption peak at 1159.01 cm^{-1} is due to aromatic C=O stretching of S and G units in lignin. Similarly, when comparing the spectra of untreated, alkali treated, and hydrothermally treated kapok fibers, high intensity peaks between 3859.83–3329.50 cm^{-1} were observed for all treated samples, indicating higher content of cellulose hydroxyl groups. The broad band centered at 3859.83 cm^{-1} is attributed to intramolecular hydrogen bonding from phenolic lignin groups and O–H stretching. A strong peak at 2901.00 cm^{-1} corresponds to C=O stretching of conjugated hemicelluloses. The absorption peak at 1159.01 cm^{-1} is related to p-hydroxy phenylpropane (H) units of ketones, carboxylic groups, and esters in lignin.

Raw kapok

Raw milkweed



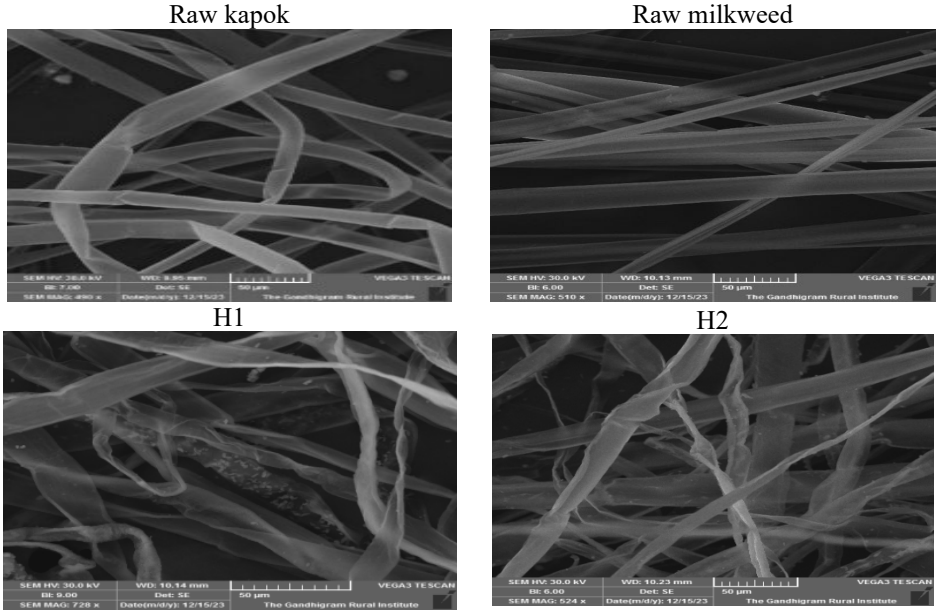
H1 H2

A1 A2

Figure 4: Polarized microscopy images of fibres

Raw kapok

Raw milkweed



H1 H2

A1 A2

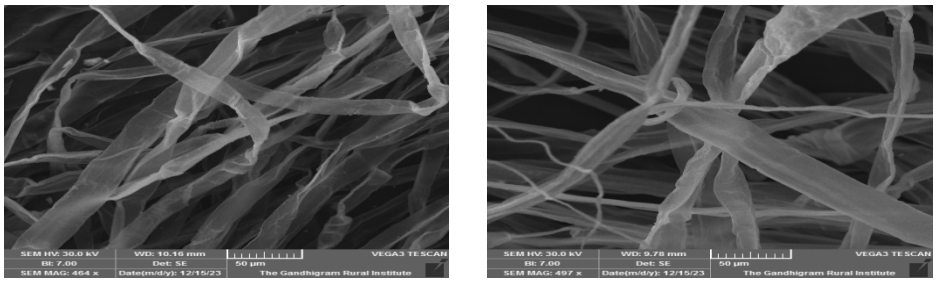
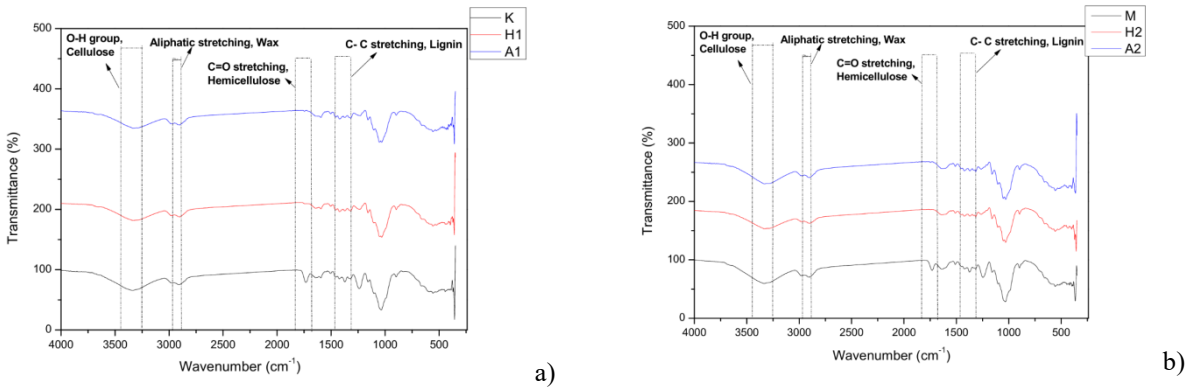


Figure 5: SEM images of fibres

Table 3
FTIR absorption bands of the fibers and their assignments

Raw kapok	A_1	H_1	Raw milkweed	A_2	H_2	Peak assignment	Description
3338.18 (96.817)	3329.5 (75.421)	3334.32 (70.025)	3335.28 (89.629)	3329.5 (76.731)	3332.39 (64.043)	O-H stretching	OH group
2901.38 (75.203)			2901.38 (70.195)			C-H stretching of aliphatic (=CH_2 and CH_3)	
	2901.38 (75.546)	2901.38 (75.809)		2901.38 (72.284)	2900.41 (73.057)	C-H symmetric and asymmetric stretching	
1730.8 (84.738)			1730.8 (82.078)			C=O stretching	Hemicelluloses
1640.16 (86.668)			1639.2 (84.197)			O-H Deformation	H_2O
1594.84 (86.441)	1593.88 (67.143)	1593.88 (64.452)		1543.74 (63.327)		C=C stretching	Lignin
1423.21 (84.828)	1421.28 (78.672)	1421.28 (73.744)	1423.21 (84.846)	1423.21 (75.134)	1424.17 (76.832)	C-H deformation	Cellulose and lignin
1373.07 (79.797)			1375 (79.039)			C-H deformation	Cellulose, hemicellulose, and lignin
				1336.43 (85.051)	1336.43 (86.511)	O-H in plane deformation	Cellulose
	1230.36 (90.919)	1231.33 (88.635)				C-O stretching	Acetyl group
897.70 (91.853)	896.73 (81.891)	896.73 (79.262)	897.7 (86.138)	896.73 (83.403)	896.73 (80.172)	Glucose ring stretching, C1-H deformation	Hemicellulose, cellulose, β-glucoside linkage
	660.5 (74.679)			659.536 (64.611)	657.607 (72.249)	C-OH bending	



a) b)

Figure 6: FTIR spectra of (a) kapok and (b) milkweed fibres

Water absorption capacity of fibers

In the experiment, the fibers were immersed in water and agitated by the centrifugal force using a magnetic stirrer at 700 rpm. Measurements were taken at equal intervals every 15 minutes, with fiber weight recorded up to 60 minutes. After 60 minutes, the fibers began to reach saturation, which was fully attained around 75 minutes; therefore, the experiment was extended to 120 minutes. The experimental results are shown in Figure 7.

Natural fibers typically exhibit a moisture regain value between 5% and 15%, depending on their chemical composition and the presence of hydroxyl (–OH) groups. The alkali treatment improved the absorption behaviour of the fibers due to the removal of surface compounds, such as wax and lignin. In raw kapok and milkweed fibers, the water absorption capacity increased steadily over time up to 60 minutes, after which equilibrium was reached. For untreated kapok fiber, the water absorption capacity increased from 4% at 15 minutes to 12% at 60 minutes. In alkali-treated kapok fiber, it increased from 8.5% at 15 minutes to 25.6% at 60 minutes. Hydrothermally treated kapok fiber exhibited a 20% increase at 15 minutes and 25% at 60 minutes. Thus, hydrothermal treatment significantly enhanced the water absorption capacity of kapok fiber. For milkweed fiber, alkali treatment improved water absorption capacity from 7.6% at 15 minutes to 19.6% at 60 minutes. Hydrothermal treatment yielded 5.2% at 15 minutes and 22% at 60 minutes. From these results, it was observed that both treatments improved the water absorption capacity in a similar trend for both fibers. When comparing raw kapok and milkweed fibers, similar trends were noted. However, kapok exhibited a greater improvement in water absorption due to a smaller reduction in hollowness (6%, from 77% to 70.28%) compared to milkweed (26%, from 71.5% to 46.7%).

The water absorption capacity (WAC) of commercial surgical cotton increased by 23.4% from its initial weight within 15 minutes. After 30 minutes, the fibers reached saturation, achieving a WAC of 25.3%. Hydrothermally treated kapok fibers demonstrated a similar trend in water absorbency, indicating a significant enhancement in absorption behaviour. This suggests that hydrothermal treatment improves the absorbency of kapok fibers, making them comparable to commercial surgical cotton wool. The absorbency of surgical cotton wool (25.3%) is attributed to the presence of cotton and wool fibers, with wool having a high natural water affinity. However, hydrothermally treated kapok achieved similar absorbency despite lacking a wool component, due to its hollow structure.

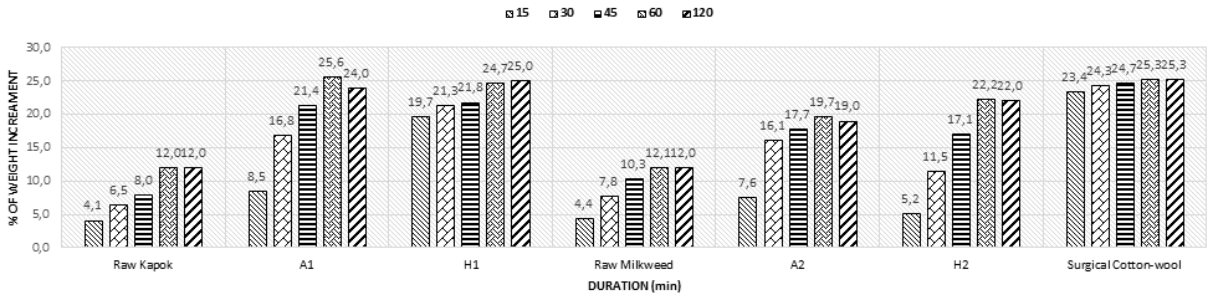


Figure 7: Water absorption capacity of fibers

CONCLUSION

In this study, hydrothermal and alkali treatments were carried out on kapok and milkweed fibers, focusing on changes in morphology, chemical composition, crystallinity, water absorption, and density. These treatments resulted in the removal of waxes from both fibers, significantly improving their hygroscopic properties, with kapok showing a notably higher value than milkweed. Chemical composition analysis revealed a reduction in hemicellulose and lignin contents after the treatment. In the case of kapok, hemicelluloses decreased from 20.09% to 12.46%, and for milkweed, from 19.44% to 12.87%. The lignin content was reduced from 14.20% to 11.99% in kapok, and from 16.57% to 9.55% in milkweed, due to the breakdown of structural components. The crystallinity index (CI%) values showed that raw kapok had a CI% of 54.01%, which dropped to 50.67% after the hydrothermal treatment and to 41.77% after the alkali treatment. Milkweed initially had a CI% of

65.8%, which reduced to 52.49% after the alkali treatment and to the 47.39% after hydrothermal treatment. The density increased in both fibers after the treatment. For kapok, the density rose from 1.301 g/cm³ to 1.41 g/cm³, and for milkweed, from 0.963 g/cm³ to 1.473 g/cm³. The degree of hollowness decreased from 77% to 70.28% in kapok and from 71.5% to 46.7% in milkweed. Morphological analysis confirmed that the alkali treatment caused more severe structural changes in milkweed, resulting in flattened, ribbon-like fibers with multiple twists, whereas kapok retained its structure comparatively well. When comparing the water absorbency of the treated fibers with that of surgical cotton wool, hydrothermally treated kapok displayed similar results, making it a promising material for wound dressing applications. Overall, kapok exhibited superior properties after both treatments compared to milkweed.

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