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Research Article

Extraction of Fiber from *Schoenoplectus acutus* Plant and Characterization of Its Properties

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This work aims to extract and characterize the fibers from the *Schoenoplectus acutus* plant and assess their suitability for use as textile fibers. The fibers from *Schoenoplectus acutus* plants were extracted using alkaline extraction, water retting, and manual methods; their physical, mechanical, and chemical properties were examined. The result showed that the fiber has a tensile strength of 254.2 MPa, 302.6 MPa, and 183.4 MPa for manual, water-retted, and alkaline extraction methods, respectively. The mean values of fiber fineness were 1.32 ± 0.2 Tex for alkali-extracted fibers, 1.43 ± 0.2 Tex for water-retted fibers, and 1.64.01 ± 0.4 Tex for manually extracted fibers. The fiber contained 58% cellulose, 25.4% hemicellulose, and 13% lignin for manual extracted fibers, whereas fibers obtained from the water-retted method had 62.8% cellulose, 20.3% hemicellulose, and 10% lignin. Similarly, alkaline extracted fibers contained 60.2% cellulose, 17.8% hemicellulose, and 6.8% lignin. Generally, the extracted fiber has acceptable mechanical properties, linear density, and moisture regain, which can serve as an alternative source of textile fibers.

1. Introduction

Today, scientists, researchers, and manufacturers are highly concerned about environmental pollution caused by synthetic fibers. As people's awareness of the damage that synthetic materials do to the environment has increased, researchers are looking for new ecofriendly materials [1, 2]. Owing to their biodegradability, sustainability, and nontoxic nature and their wide range of applications, natural fibers are used as a substitute for synthetic fiber [3–6]. Even though natural fibers have some disadvantages, such as incompatible and hydrophilic properties, they can be modified using several surface modifications and chemical treatments [7, 8].

Currently, there is a lot of interest in the potential use of coarse natural fibers as a reinforcement element in composite materials [9–12]. This is due to the renewability, low density, low cost of production, etc. Different research studies have shown that natural fibers are used in different application areas, such as reinforced composites, particle boards' automotive devices, insulation boards in biomedical applications, etc. [13–17]. Numerous industries, including industrial construction, maritime, electrical, home appliances, automotive, and sporting goods, use this type of composite material [18]. New designs for composites have been created to enhance, modify, and introduce new goods in a responsible and environmentally friendly approach [19, 20].

Natural fibers come from plant, animal, and mineral sources, with plant fibers being primarily composed of cellulose and animal fibers primarily of protein. Vegetable fibers come from various parts of plants, including stems, fruit, seeds, and leaves. Leaf fibers are stronger than bast fibers, while bast fibers come from the outer layers of plant stems [21]. The fibers derived from diverse sources exhibit distinct properties and might have special benefits [22, 23].

Natural fibers consist of various compositions such as cellulose, hemicellulose, lignin, wax, ash, pectin, and moisture content, which vary in different natural fibers [24]. The percentage of chemical components in a fiber depends on the kind of plant, the rate at which it grows, the part of the plant, etc. [25]. Cellulose is the most significant and readily

available renewable resource for textiles; it has distinct structural qualities [26]. The tensile characteristics, crystallinity, and density of natural fibers are closely correlated with their chemical characteristics, such as their high cellulose content [7, 27]. The characteristics of natural fibers are mostly determined by the type of plant, the environment in which it is cultivated, its age, and the extraction technique employed [28]. The process of removing fibers from plant parts, such as stems, fruits, leaves, bark, and roots, is known as fiber extraction [29].

There are multiple methods to extract fibers from plant sources; the most popular ones include chemical, enzymatic, water retting, and mechanical extractions [24]. The choice of extraction relies on the type and structure of the plant, the type of fiber and its intended use, the cost of extraction, the required time for extraction, the plant's efficacy, etc.; they are the key factors that influence the choice of the extraction method [30]. Generally, more fiber sources need to be researched because the usage of natural fibers for different applications is growing.

The aim of this study is to extract and characterize the fibers from the hardstem bulrush (*Schoenoplectus acutus*) using manual, water retting, and chemical extraction methods.

This plant is abundantly found in the wetlands and water bodies of Ethiopia. Ethiopia has an estimated total area of 1.13 million km^2. Out of that, 22,500 km^2, or 2%, of these are wetlands and 0.7% are water bodies, which include marshes, rivers, lakes, ponds, reservoirs, and other wetlands [31, 32]. Larger wetlands can be found throughout the nation near large rivers like the Abay, Awash, and Baro, as well as the rift valley lakes such as the Abaya, Hawassa, and Chamo-associated wetlands [33, 34].

Schoenoplectus acutus is a giant species of sedge in the plant family Cyperaceous that is characterized by a thick, rounded green stem that can reach heights of 1–3 m (3–10 ft.). *Schoenoplectus acutus* grows near lakes, streams, marshes, and wetlands where the water table is as high as 5 feet (1.5 m) above the soil surface or as low as 0.33 feet (0.1 m). Sites with saturated soil or standing water for most of the year are ideal for *Schoenoplectus acutus* growth. It is an important aquatic or semiaquatic species that serves as a cover for many creatures and birds. In Ethiopia, it is used as a ceremonial plant, particularly on Holy Saturday (the Eve of Easter). In addition, the ecological relevance of bulrush near shorelines is noteworthy because it minimizes erosion and functions as a barrier against wind and water forces, encouraging the growth of other plant species.

2. Materials and Methods

2.1. Materials. Ethiopian *Schoenoplectus acutus* plants were collected around Lake Tana in Amhara regional state, Ethiopia. For extraction purposes, sodium hydroxide (NaOH), river water, and distilled water were used. For content determination, ethanol, sulfuric acid (H2SO4), potassium hydroxide (KOH), nitric acid (HNO_3), and petroleum ether were used. A digital balance, a conditioner chamber, a ruler, stirring rods, and a single fiber strength tester are among the tools or apparatus utilized in this study.

2.2. Methods

2.2.1. Manual Method. In this method of extraction, the green *Schoenoplectus acutus* plant was exposed to sunlight for one day to dry up the moisture from the stem. To get inside the white part containing the fibrous material that runs along the length of the stem, splitting has been applied. After splitting the stem into two parts, the fibers were carefully separated from other nonfibrous materials using hands and a simple combing machine as shown in Figure 1.

2.2.2. Water-Retting Method. The sample was immersed in large plastic bucket (bath) containing water sourced from the Blue Nile (Abay) river at room temperature in an open system for three weeks. Water retting is a naturally occurring process in which the lignin in the *Schoenoplectus acutus* is dissolved using microorganisms, thus enabling the bundle of the fiber to be easily separated into fibers. Following the interval, nonfiber components and lignin were easily eliminated by frequently washing with tap water.

2.2.3. Chemical Extraction Method. After being properly cleaned with distilled water, the dried stems were treated with various concentrations of caustic soda (2%, 3%, 5%, and 6%). Furthermore, the time of extraction and temperature were also controlled based on the concentration of caustic soda and the liquor ratio. A material-to-liquor ratio of 1 : 20 at boiling temperature for 3 hours, and 3% caustic soda were the ideal conditions for extracting *Schoenoplectus acutus* fibers [35]. Fiber extracted using three different extraction methods are shown in Figure 2.

2.3. Determination of Chemical Contents. The chemical compositions of natural plant fibers vary depending on the type of species, age, climate, soil composition, and extraction method, all of which have an impact [36].

The chemical composition of *Schoenoplectus acutus* fibers was examined using standard isolation techniques for the primary chemical components. Cellulose, hemicellulose, and lignin were determined according to the Technical Association of the Pulp and Paper Industry (TAPPI) standards [37].

2.3.1. Determination of the Cellulose Content. Fiber samples weighing 3 grams were treated for 30 minutes with 40 ml of 80% acetic acid and refluxed with 2 ml of strong nitric acid. Following a 5-minute centrifugation at 15,000 rpm in hot 95% ethanol, the samples were filtered by suction. Hot benzene was used for washing, followed by 95% ethanol and petroleum ether. After that, the sample was put inside a crucible that had been weighed and heated to 105°C for an hour. Once the crucible cooled down in a desiccator, it was weighed. To measure the amount of ash present, the crucible and its contents were placed in a furnace heated at 500°C for 3 hours followed by cooling in a desiccator and weighed [38]. Finally, the content of cellulose was calculated using the following equation.



Figure 1: Fiber extraction using manual combing machine.

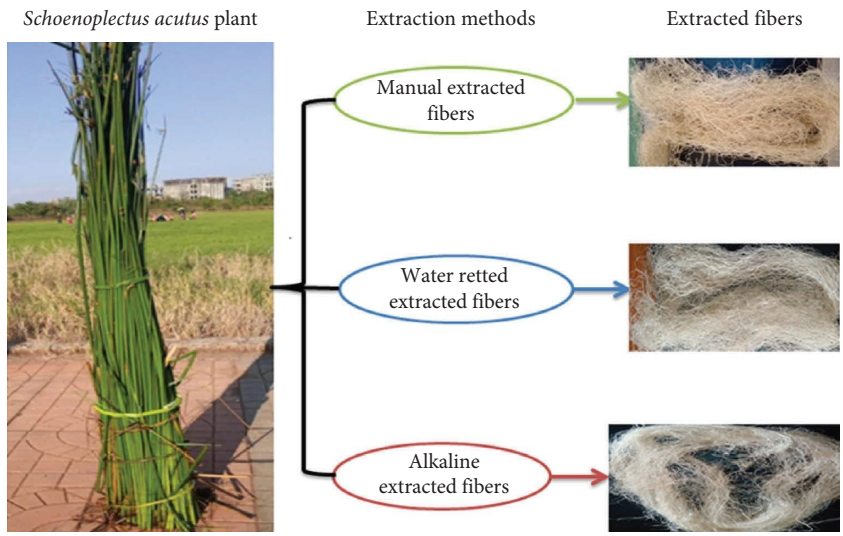


Figure 2: Fiber extraction methods.

$$\text{Cellulose}\,(\%) = \frac{W_d - w_a}{W_o} * 100, \quad (1)$$

where W_a = weight of sample ash after 500°C, W_d = weight of the sample after drying at 105°C, and W_o = original weight of the sample.

2.3.2. Determination of the Hemicellulose Content. One gram of the extracted fiber sample was treated with, 5% KOH, and the mixture was left to stand for two hours. The filtrate was collected after filtering and washing the mixtures in a proper KOH solution. The hemicellulose was precipitated with the addition of ethanol, and it was then separated by centrifugation for 15 minutes. After being separated, the hemicellulose was placed into a crucible and cleaned with ethanol and ether. The separated hemicellulose were dried for one hour at 105°C in the oven and placed into a desiccator, for 30 minutes to cool, and their weight was determined (W_1). The dried sample was placed in a furnace at 500°C for 3 hours, cooled, and then weighed (W_p). Finally, the amount of hemicellulose was determined using the following equation:

$$\text{Hemicellulose}\,(\%) = \frac{W_p}{W_1} * 100, \quad (2)$$

where W_p = dried weight of precipitated hemicellulose and W_1 = dried weight of the fiber sample.

2.3.3. Determination of the Lignin Content. The lignin content of *Schoenoplectus acutus* fiber was analyzed by a gravimetric method under the ASTM D1106 standard. 2 grams of fiber were put into a beaker, and after adding 72% H_2SO_4, the mixture was left to stand for two hours. After filtration to eliminate any remaining acid, hot water was used to wash the residue. The sample was dried for one hour at 105°C in an oven before weighing (W_d). After that, the material was heated to 500°C for three hours in a furnace, cooled, and then weighed within a closed container (W_a) [38, 39]. The content of lignin was calculated using the following equation:

$$\text{lignin}\,(\%) = \frac{W_d - W_a}{W_1} * 100, \quad (3)$$

where W_1 = weight of the oven-dried sample, W_a = weight of the ash sample, and W_i = initial weight of the dried sample.

2.4. Characterization of Schoenoplectus acutus Fibers. Evaluating the physical and chemical properties of the extracted fiber is essential to determining whether or not it could be used as a renewable supply of textile fiber. All specimens were conditioned before testing at the standard atmospheric conditions of $21 \pm 1^{\circ}C$ and $65 \pm 2\%$ (ASTM D1776-98 (2017)). All tests were done as per ASTM test standards.

2.4.1. Fiber Length. To determine the length of the fiber, 30 samples were taken and measured from each method of extraction, and the average values were used for comparison between the different extraction methods.

2.4.2. Fiber Fineness. Fiber fineness was evaluated using the ASTM D1577-07 (2018). For each extraction method, 20 samples were randomly taken, and each fiber length was measured and weighed on an electronic balance. Finally, the single fiber fineness was calculated using the following equation:

$$\text{Tex} = \frac{\text{mass}\,(\text{g})}{\text{length}\,(\text{m})} * 1000. \tag{4}$$

2.4.3. Microscopic Structure. The fiber structure was evaluated per the ASTM D276 (2021). An optical microscope was used to capture a longitudinal image of the fiber, which was then loaded into image analysis software to determine the diameter of 20 samples at five different locations.

2.4.4. Tensile Strength. The tensile strength test was carried out per ES ISO 5079 (2020), on a Tinius Olsen H1KS single-fiber strength tester at 20°C and 65% relative humidity. The fibers' gauge length was 25 mm, and a speed of 75 mm/min was maintained. At both ends, the fibers were clamped, and force was applied.

2.4.5. Moisture Content and Moisture Regain. The moisture content was measured according to ASTM D1776/D1776M (2020). To determine the sample's moisture content and regain, it was weighed using an electronic balance and dried at 105°C until constant weight was achieved.

2.4.6. Fourier Transform-Infrared Spectroscopy (FTIR). The functional groups on *Schoenoplectus acutus* plant fiber were analyzed using an FTIR spectrometer. Using the absorbency mode as a function of wavenumber, the Perkin Elmer FTIR instrument was used to record the samples' infrared spectra in the 400–4000 cm^{-1} frequency range.

3. Results and Discussion

3.1. Determination of Cellulose, Hemicellulose, and Lignin Contents. A fiber's characteristics are influenced by its lignin, hemicellulose, and cellulose concentrations. Good mechanical qualities are ensured by a higher cellulose content, whereas high hemicellulose levels weaken the fiber by causing cellulosic microfibrils to disintegrate [40]. Chemical treatment is applied to natural fibers to improve their surface geometry, remove impurities, raise fiber strength, and improve the interaction between the fibril and the matrix [41]. Alkaline extraction removes the majority of the hemicellulose and the lignin content during the extraction process, which in turn influences the fiber structure, characteristics, and morphology [42, 43]. As seen in Table 1, the cellulose content of the fiber extracted using alkaline extraction was found to be 60.2. Whereas the cellulose content of the fibers extracted using water retting was found to be higher (62.8%), leading to high tensile strength. The amount of hemicellulose in manually extracted fibers was higher than in alkaline and water retting methods, which was about 25.4%. Table 1 shows the comparison of the chemical composition of extracted fibers with other natural fibers.

3.2. Fiber Length. One of the most essential fiber characteristics is its length. A longer average fiber length is easier to process, which leads to an increase in yarn production. Increased fiber length results in increased fiber overlapping in the yarn, which leads to higher resistance to slippage [47]. The strength of yarn spun from long fibers is higher than that of yarn produced from short fibers [48]. As depicted in Figure 3, the mean value of the fiber length extracted by water retting is 482 mm, followed by the manual method (454 mm) and the alkaline method (434 mm). There was a difference in the values of the three extraction methods. Compared to manual and water-retting methods, the length of the fiber obtained from alkaline treatment is the lowest. This is mostly because hemicellulose, lignin, and other noncellulose components were efficiently removed during alkali extraction, which increased the breakdown of fiber bundles into individual fibers, resulting in a reduction in fiber length. There is also a higher probability of breaking hydrogen bonds between the hydroxyl groups (-OH) of cellulose, hemicellulose, and lignin [49].

3.3. Fineness. The fineness of a fiber is one of its most essential characteristics; it affects the material's porosity, filtration resistance, and surface area, all of which have an impact on the fiber's functionality and uses [50]. A variety of parameters, including weighing and measuring, fiber maturity, growth conditions, and extraction conditions, can influence the fineness of the fiber [35]. In this study, fiber fineness was measured by single-fiber principles, which measure the length and mass of a single fiber. The average values of extracted fiber fineness were 1.28 ± 0.2 Tex for alkali-extracted fibers, 1.41 ± 0.2 Tex for water-retted fibers, and 1.52 ± 0.4 Tex for manually extracted fibers. As shown in Table 2, the fiber fineness in alkaline extraction is the lowest compared to manual and water-retting methods. This is due to the effective removal of lignin, which makes the fibers have a high probability of being separated into finer fibers.

Table 1: Chemical composition of *Schoenoplectus acutus* fiber compared with other natural fibers.

Fiber		Chemical properties			Reference
		Cellulose (%)	Hemicellulose (%)	Lignin (%)	
Schoenoplectus acutus	Manually extracted	58 ± 1.2	25.4 ± 0.22	13 ± 0.8	From this study
	Water retted	62.8 ± 0.6	20.3 ± 1.6	9 ± 0.4	
	Alkaline extracted	60.2 ± 1.3	17.8 ± 2.0	6.8 ± 1.1	
Other natural fibers	Cyperus papyrus (alkali treated)	61.82 ± 2	11.82 ± 0.4	23.61 ± 0.23	[44–46]
	Cyperus papyrus (water retted)	57.98 ± 0.8	13.45 ± 1	25.42 ± 1.2	
	Prosopis juliflora	61.65	16.14	17.11	
	Nettle	53–86	4–10.3	3.5–9.4	
	Rice husk	35–45	19–25	20	
	Flax	64.1	16.7	2.0	
	Jute	64.4	12	11.8	
	Cotton	82.7	5.7	—	
	Kenaf	45–57	8–13	21.5	
	Ramie	68.6–85	13–16.7	0.5–0.7	
	Sisal	60–78	10–14.2	8.0–14	
	Pineapple	70–83	—	5–12.7	
	Hemp	68	15	10	
	Coir	32–43	0.15–0.25	40–45	
	Banana	56–63	20–25	7–9	
	Agave	68.42	4.85	4.85	
	Abaca	56–63	20–25	7–9	

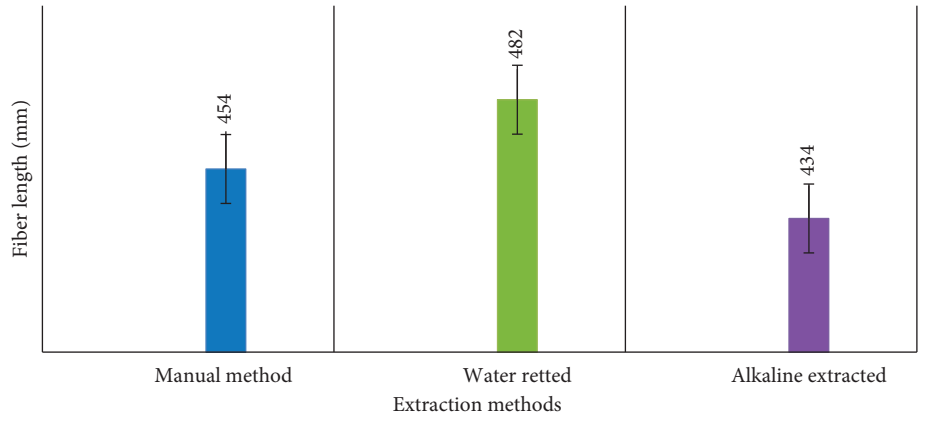


Figure 3: Extracted fiber length.

Table 2: The fineness of extracted *Schoenoplectus acutus* fiber.

Parameter	Extraction methods		
	Manual	Water retting	Alkaline
Fiber fineness (Tex)	1.52 ± 0.4	1.41 ± 0.2	1.28 ± 0.2

3.4. Microscopic Structure of Schoenoplectus acutus Fiber. Analyzing longitudinal and cross-sectional views gives detailed information about the fiber's surface morphology. The structure or shape of a fiber plays an important role in its strength [51]. It can also determine the qualities of fibers or textiles, which influences the properties of yarn and fabric [52].

Figure 4 displays the longitudinal image of the extracted *Schoenoplectus acutus* fiber. The fiber's surface morphology is similar to that of other natural fibers in that it consists of many fibrils that are linked together lengthwise by a non-cellulosic substance to create a bundle [11]. Like other natural fibers, impurities were also visible on the surface of *Schoenoplectus acutus* fibers. Fibers of uniform cross section exhibited a good aspect ratio [53].

3.5. Tensile Strength. Tensile strength is the ability of a textile fiber to withstand a stretching load when applied in the longitudinal direction. It is one of the most important fiber characteristics that determine its application areas. The mean values of tensile strength of *Schoenoplectus acutus* were 254.2 MPa for manually extracted fibers, 302.6 MPa for water-retted fibers, and 183.4 MPa for alkaline-extracted

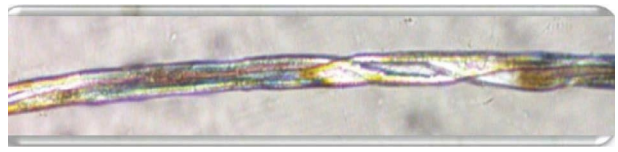


Figure 4: Longitudinal view of *Schoenoplectus acutus* fiber at 500x.

Table 3: Comparison of tensile strength and elongation properties of *Schoenoplectus acutus* fiber with other natural fibers.

Natural fibers		Tensile strength (MPa)	Elongation at break (%)	Reference
Schoenoplectus acutus fiber	Manually extracted	254.2 ± 4.3	1.25 ± 0.4	From this study
	Water retted	302.6 ± 3.8	1.38 ± 0.5	
	Alkaline extracted	183.4 ± 5.2	1.10 ± 0.2	
Other natural fibers	Cyperus papyrus (alkali treated)	310.05 + 0.1	2.02 ± 0.15	[22, 44, 54, 55]
	Cyperus papyrus (water retted)	260.25 ± 1.5	2.79 ± 0.5	
	Cyperus pangorei	196 ± 56	1.69	
	Nettle	650	1.7	
	Palm	97–196	2–4.5	
	Flax	88–1500	1.2–1.6	
	Jute	400–800	1.8	
	Cotton	400	3–10	
	Kenaf	295	2.7–6.9	
	Bagasse	20–290	1.1	
	Ramie	500	2	
	Sisal	600–700	2–3	
	Pineapple	170–1672	1–3	
	Hemp	550–900	1.6	
	Coir	220	15–25	
	Piassava	134–142	6.4–21.9	
	Bamboo	503	1.4	
	Coconut	131–175	15–40	

fibers. As seen in Table 3, the tensile strength of a fiber extracted by the water-retting method is higher than that of the manual method, followed by the alkaline extracted method, which resulted in low values. This is due to the alkaline solution's elimination of the lignin content, which would have increased the fiber's strength [56, 57].

The tensile strength of materials with low lignin and high cellulose content is higher; however, many variables might affect this value, so the relationship is not always linear [7]. It is also affected by the position of lignin on cellulose, which affects its tensile strength since it is surrounded by cellulose and hemicellulose. Table 3 shows the tensile strength of *Schoenoplectus acutus* plant fiber in comparison with other conventional natural fibers.

3.6. Moisture Content and Moisture Regain. Due to the presence of water-loving groups on their surface, the majority of natural fibers tend to absorb moisture when exposed to the atmosphere [58]. The chemical and physical makeup of the textile fiber, its characteristics, the ambient temperature and humidity, and other factors will all affect the absorbency of a textile fiber [35]. The hydroxyl groups of hemicelluloses, cellulose, and lignin are linked to the hydrophilic characteristic of these materials because they form hydrogen bonds that hold water molecules in place [59]. Moisture regain and moisture content are common ways of expressing the percentage of water vapor that is absorbed by a textile fiber. As shown in Figure 5, the alkaline-extracted fibers had the highest moisture content (10.21%) and regain (11.3%), followed by water-retained fibers (9.98%) moisture content and (10.87%) regain, with the manually extracted fibers having the lowest moisture content (8.42%) and (9.35%) regain. The reason is that, in comparison to water-retained and manual extraction, the alkaline extraction method efficiently removed nonfibrous components that hindered the moisture absorbency of a fiber. Therefore, the type of extraction techniques significantly affected the moisture content and moisture regain of *Schoenoplectus acutus fiber*. In general, the moisture content value of the extracted fiber ranges from 8.42 to 10.21%, which is similar to other natural plant fibers ranging from 5 to 17% [12].

3.7. Fourier-Transform Infrared Spectroscopy (FTIR) Analysis. Natural fibers are composed of cellulose, hemicellulose, lignin, and other substances [60]. The functional groups of the extracted fibers were characterized using Fourier-transform infrared spectroscopy. FTIR is an efficient analytical device for identifying functional groups and describing covalent bonding information. By creating an infrared absorption spectrum, it was used to detect the existing chemical bonds present in the extracted fiber. Table 4 displays the wavelengths of the peaks, as well as their functional groups.

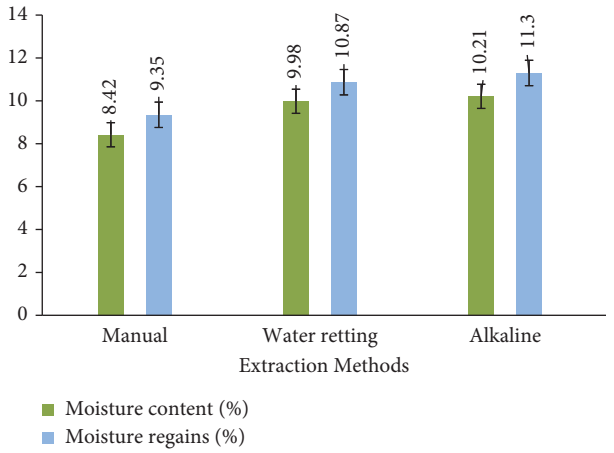


Figure 5: Moisture content and moisture regain of extracted fibers.

Table 4: FTIR peaks and corresponding constituents.

S/N	Wave number (cm^{-1})	Phenomenon	Functional group	Reference
1	1200-1070	CO stretch	Ethers	[61]
2	1670-1615	CC stretch	Alkenes	
3	1800-1680	CO stretch	Carbonyls groups	
5	1465-1440	CH_3	Methyl groups	
6	1475-1400	CH_2	Methylene groups	
7	3000-2850	CH	Alkyl groups	
8	3550-3000	NH stretch	Primary amines	
9	3600-3200	OH stretch	Alcohols, water	

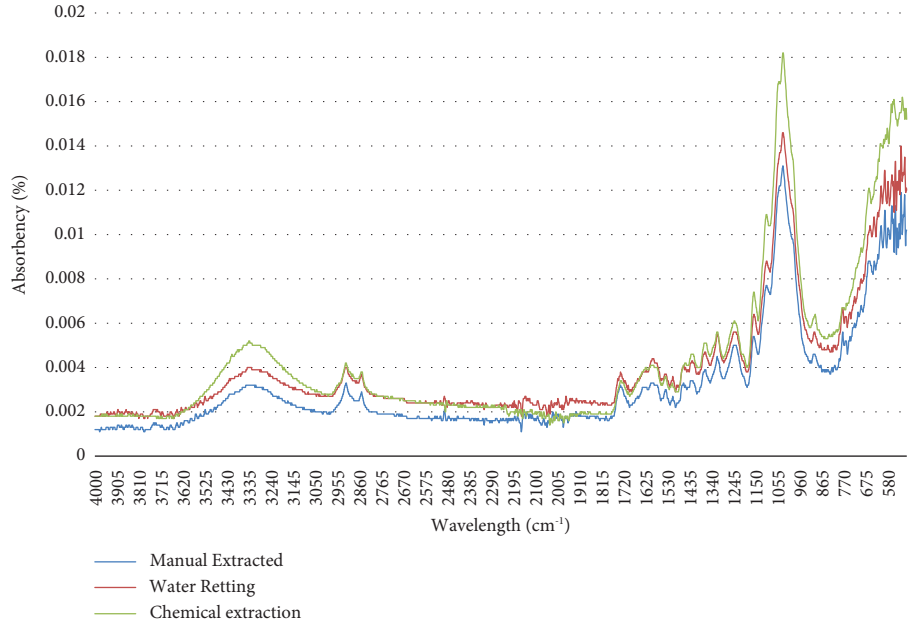


Figure 6: FTIR Spectrum for extracted *Schoenoplectus acutus* fibers.

Figure 6 shows the FTIR spectra of extracted *Schoenoplectus acutus* fibers. The presence of cellulose and its structure causes O-H stretching, as evidenced by the maximum peak at 3335 cm^{-1}. Similarly, the C-H stretching was recorded at 2918 cm^{-1}. The peaks at 1702 cm^{-1} represented carbonyl stretching C-O for acetyl groups in hemicellulose and the aldehydic group of lignin, while a peak at 1243 cm^{-1} suggested C-C stretching of the lignin's aromatic ring [62, 63]. The peak at 1034 cm^{-1} band denotes alkoxy C-O ordinary bond bending vibration.

4. Conclusion

The fiber was successfully extracted using manual, water-retting, and alkaline extraction methods. The mean value of the fiber length extracted by water retting was 482 mm, followed by the manual method (454 mm) and the alkaline method (434 mm). The tensile strength and elongation of fibers extracted using water retting were found to be higher (302.6 MPa) and $1.38 \pm 0.5\%$, followed by manual extraction methods, which are (254.2 MPa) and $(1.25 \pm 0.4\%)$, respectively. Whereas fiber extracted using alkaline extraction had the lowest tensile strength and elongation (183.4 MPa) and $(1.10 \pm 0.2\%)$, respectively. The moisture content values ranges from 8.4 to 10.8%, which is similar to other natural plant fibers. The FTIR analysis showed that cellulose, hemicellulose, and lignin functional groups were present in the extraction techniques used. Overall, the study's findings proved that the physical, mechanical, and chemical properties of *Schoenoplectus acutus* fiber are similar to those of other naturally occurring fibers. As a result, the fiber can be used in textile applications, particularly green composite reinforcement.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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References

[1] Y. G. Thyavihalli Girijappa, S. Mavinkere Rangappa, J. Parameswaranpillai, S. Siengchin, and S. Siengchin, "Natural fibers as sustainable and renewable resource for development of eco-friendly composites: a comprehensive review," *Frontiers in Materials*, vol. 6, p. 226, 2019.

[2] R. A. Kurien, M. M. Anil, S. L. S. Mohan, and J. A. Thomas, "Natural fiber composites as sustainable resources for emerging applications-a review," *Materials Today: Proceedings*, 2023.

[3] H. Ku, H. Wang, N. Pattarachaiyakoop, and M. Trada, "A review on the tensile properties of natural fiber reinforced polymer composites," *Composites Part B: Engineering*, vol. 42, no. 4, pp. 856–873, 2011.

[4] R. Guru, A. Kumar, and R. Kumar, "Basic functional application for natural fibers and types," in *Natural Fiber*, IntechOpen, 2022.

[5] A. K. Bhunia, D. Mondal, K. R. Sahu, and A. K. Mondal, "Characterization of new natural cellulosic fibers from Cyperus compactus Retz.(Cyperaceae) Plant," *Carbohydrate Polymer Technologies and Applications*, vol. 5, Article ID 100286, 2023.

[6] B. F. Adamu, "Extraction of Ethiopian Kusha fiber from Ethiopian Kusha Plant by different methods and characterization of its morphological and mechanical properties," *Results in Materials*, vol. 12, Article ID 100238, 2021.

[7] A. Karimah, M. R. Ridho, S. S. Munawar et al., "A review on natural fibers for development of eco-friendly bio-composite: characteristics, and utilizations," *Journal of Materials Research and Technology*, vol. 13, pp. 2442–2458, 2021.

[8] S. A. S. Goulart, T. A. Oliveira, A. Teixeira, P. C. Miléo, and D. R. Mulinari, "Mechanical behaviour of polypropylene reinforced palm fibers composites," *Procedia Engineering*, vol. 10, pp. 2034–2039, 2011.

[9] D. N. Saheb and J. P. Jog, "Natural fiber polymer composites: a review," *Advances in Polymer Technology*, vol. 18, no. 4, pp. 351–363, 1999.

[10] A. Ticoalu, T. Aravinthan, and F. Cardona, "A review of current development in natural fiber composites for structural and infrastructure applications," in *Proceedings of the 2010 Southern Region Engineering Conference (SREC 2010)*, 2010.

[11] V. Fiore, T. Scalici, and A. J. C. P. Valenza, "Characterization of a new natural fiber from Arundo donax L. as potential reinforcement of polymer composites," *Carbohydrate Polymers*, vol. 106, pp. 77–83, 2014.

[12] A. Porras, A. Maranon, and I. A. Ashcroft, "Characterization of a novel natural cellulose fabric from Manicaria saccifera palm as possible reinforcement of composite materials," *Composites Part B: Engineering*, vol. 74, pp. 66–73, 2015.

[13] N. Reddy and Y. Yang, "Biofibers from agricultural byproducts for industrial applications," *Trends in Biotechnology*, vol. 23, no. 1, pp. 22–27, 2005.

[14] D. Murdiyanto, "Potensi serat alam tanaman Indonesia sebagai bahan fiber reinforced composite kedokteran gigi," *Jurnal Material Kedokteran Gigi*, vol. 6, no. 1, pp. 14–22, 2017.

[15] A. Karimah, M. R. Ridho, S. S. Munawar et al., "A comprehensive review on natural fibers: technological and socio-economical aspects," *Polymers*, vol. 13, no. 24, p. 4280, 2021.

[16] T. P. Schlöesser, "Natural fiber reinforced automotive parts," in *Natural Fibers, Plastics and Composites*, pp. 275–285, Springer US, Boston, MA, 2004.

[17] M. R. Mansor, A. H. Nurfaizey, N. Tamaldin, and M. N. A. Nordin, "Natural fiber polymer composites: utilization in aerospace engineering," in *Biomass, Biopolymer-Based Materials, and Bioenergy*, pp. 203–224, Woodhead Publishing, 2019.

[18] N. S. Sadeq, Z. G. Mohammadsalih, and D. Ali, "Natural fibers and their applications: a review," *Jornual of AL-Farabi for Engineering Sciences*, vol. 1, no. 1, p. 13, 2022.

[19] P. Peças, H. Carvalho, H. Salman, and M. Leite, "Natural fibre composites and their applications: a review," *Journal of composites science*, vol. 2, no. 4, p. 66, 2018.

[20] N. S. Sadeq, Z. G. Mohammadsalih, and R. H. Mohammed, "Effect of grain size on the structure and properties of coir epoxy composites," *SN Applied Sciences*, vol. 2, no. 7, p. 1191, 2020.

[21] A. F. Jusoh, M. R. M. Rejab, J. P. Siregar, and D. Bachtiar, "Natural fiber reinforced composites: a review on potential for corrugated core of sandwich structures," *MATEC Web of conferences*, vol. 74, p. 00033, 2016.

[22] L. Mohammed, M. N. M. Ansari, G. Pua, M. Jawaid, and M. S. Islam, "A review on natural fiber reinforced polymer composite and its applications," *International journal of polymer science*, vol. 2015, no. 1, Article ID 243947, 15 pages, 2015.

[23] M. P. Staiger and N. Tucker, "Natural-fibre composites in structural applications," in *Properties and Performance of*

Natural-Fibre Composites, pp. 269–300, Woodhead Publishing, 2008.

[24] S. Leweyehu, G. K. Rotich, E. Hermela, and G. Yohannes, *Extraction and Characterization of Fiber from the Stem of Cyperus Papyrus Plant*, 2022.

[25] R. Blackburn, Ed., "Biodegradable and sustainable fibres," *A volume in Woodhead Publishing Series in Textiles*, vol. 47, 2005.

[26] C. Felgueiras, N. G. Azoia, C. Gonçalves, M. Gama, and F. Dourado, "Trends on the cellulose-based textiles: raw materials and technologies," *Frontiers in Bioengineering and Biotechnology*, vol. 9, Article ID 608826, 2021.

[27] N. Herlina Sari, I. Wardana, Y. S. Irawan, and E. Siswanto, "Characterization of the chemical, physical, and mechanical properties of NaOH-treated natural cellulosic fibers from corn husks," *Journal of Natural Fibers*, vol. 15, no. 4, pp. 545–558, 2018.

[28] S. Bhuyan and N. Gogoi, "Natural fibers: innovative sustainable and eco-friendly," *International Journal of Current Microbiology and Applied Sciences*, vol. 9, no. 7, pp. 1004–1011, 2020.

[29] I. P. Lokantara, N. P. G. Suardana, I. W. Surata, and I. N. S. Winaya, "A review on natural fibers: extraction process and properties of grass fibers," *International Journal of Mechanical Engineering & Technology*, vol. 11, no. 1, pp. 84–91, 2020.

[30] W. Konczewicz, M. Zimniewska, and M. A. Valera, "The selection of a retting method for the extraction of bast fibers as response to challenges in composite reinforcement," *Textile Research Journal*, vol. 88, no. 18, pp. 2104–2119, 2018.

[31] T. Getachew, "Wetland ecosystems of Ethiopia: definition, classification and distribution," in *Paper Presented on Proceedings of the "National Consultative Workshop on the Ramsar Convention and Ethiopia", March*, pp. 18-19, 2004.

[32] M. Teferi, *Geography of Ethiopia and the Horn*, 2019.

[33] E. Teferi, S. Uhlenbrook, W. Bewket, J. Wenninger, and B. Simane, "The use of remote sensing to quantify wetland loss in the Choke Mountain range, Upper Blue Nile basin, Ethiopia," *Hydrology and Earth System Sciences*, vol. 14, no. 12, pp. 2415–2428, 2010.

[34] E. Teferi, S. Uhlenbrook, W. Bewket, J. Wenninger, and B. Simane, "The use of remote sensing to quantify wetland loss in the Choke Mountain range, Upper Blue Nile basin, Ethiopia," *Hydrology and Earth System Sciences*, vol. 14, no. 12, pp. 2415–2428, 2010.

[35] L. Sheferaw, R. K. Gideon, H. Ejegu, and Y. Gatew, "Extraction and characterization of fiber from the stem of Cyperus papyrus plant," *Journal of Natural Fibers*, vol. 20, no. 1, Article ID 2149661, 2023.

[36] A. Azanaw, A. Haile, and R. K. Gideon, "Extraction and characterization of fibers from Yucca Elephantine plant," *Cellulose*, vol. 26, no. 2, pp. 795–804, 2019.

[37] I. Plazonić, Ž. Barbarić-Mikočević, and A. Antonović, "Chemical composition of straw as an alternative material to wood raw material in fibre isolation," *Drvna Industrija*, vol. 67, no. 2, pp. 119–125, 2016.

[38] G. N. Onyeagoro, "Effect of chemical treatment on the constituents and tensile properties of oil palm leaf fibre," *Academic Research International*, vol. 2, no. 3, p. 88, 2012.

[39] A. K. Rout, J. Kar, D. K. Jesti, and A. K. Sutar, "Effect of surface treatment on the physical, chemical, and mechanical properties of palm tree leaf stalk fibers," *Bioresources*, vol. 11, no. 2, pp. 4432–4445, 2016.

[40] C. Morvan, A. Jauneau, A. Flaman, J. Millet, and M. Demarty, "Degradation of flax polysaccharides with purified endopolygalacturonase," *Carbohydrate Polymers*, vol. 13, no. 2, pp. 149–163, 1990.

[41] M. Samanth and K. Subrahmanya Bhat, "Conventional and unconventional chemical treatment methods of natural fibres for sustainable biocomposites," *Sustainable Chemistry for Climate Action*, vol. 3, Article ID 100034, 2023.

[42] A. K. Mohanty, M. Misra, and G. I. Hinrichsen, "Biofibres, biodegradable polymers and biocomposites: an overview," *Macromolecular Materials and Engineering*, vol. 276-277, no. 1, pp. 1–24, 2000.

[43] R. Vijay, A. Vinod, D. Lenin Singaravelu, M. R. Sanjay, and S. Siengchin, "Characterization of chemical treated and untreated natural fibers from Pennisetum orientale grass-A potential reinforcement for lightweight polymeric applications," *International Journal of Lightweight Materials and Manufacture*, vol. 4, no. 1, pp. 43–49, 2021.

[44] F. I. Mahir, K. N. Keya, B. Sarker, K. M. Nahiun, and R. A. Khan, "A brief review on natural fiber used as a replacement of synthetic fiber in polymer composites," *Materials Engineering Research*, vol. 1, no. 2, pp. 88–99, 2019.

[45] D. Thapliyal, S. Verma, P. Sen et al., "Natural fibers composites: origin, importance, consumption pattern, and challenges," *Journal of Composites Science*, vol. 7, no. 12, p. 506, 2023.

[46] D. B. Shakyawar, A. S. M. Raja, A. Kumar, P. K. Pareek, and S. A. Wani, *Pashmina Fibre—Production, Characteristics and Utilization*, 2013.

[47] J. W. S. Hearle and W. E. Morton, *Physical Properties of Textile Fibres*, Elsevier, 2008.

[48] J. Wilson, "Fibres, yarns and fabrics: fundamental principles for the textile designer," in *Textile Design*, pp. 3–30, Woodhead Publishing, 2011.

[49] L. Y. Mwaikambo and M. P. Ansell, "Chemical modification of hemp, sisal, jute, and kapok fibers by alkalization," *Journal of Applied Polymer Science*, vol. 84, no. 12, pp. 2222–2234, 2002.

[50] B. Ding, X. Wang, and J. Yu, Eds., *Electrospinning: Nanofabrication and Applications*, William Andrew, 2018.

[51] S. Monga, S. Naithani, B. P. Thapliyal, S. Tyagi, and M. Bist, "Effect of morphological characteristics of indegeneous fibers (E. tereticornis and S. officinarum) and their impact on paper properties," *Ippta Journal*, vol. 29, no. 2, pp. 1–5, 2017.

[52] M. A. Bueno, A. P. Aneja, and M. Renner, "Influence of the shape of fiber cross section on fabric surface characteristics," *Journal of Materials Science*, vol. 39, no. 2, pp. 557–564, 2004.

[53] K. Raja, B. Prabu, P. Ganeshan, V. S. Chandra Sekar, and B. NagarajaGanesh, "Characterization studies of natural cellulosic fibers extracted from shwetark stem," *Journal of Natural Fibers*, vol. 18, no. 11, pp. 1934–1945, 2021.

[54] A. A. M. Moshi, D. Ravindran, S. S. Bharathi, S. Indran, S. S. Saravanakumar, and Y. Liu, "Characterization of a new cellulosic natural fiber extracted from the root of Ficus religiosa tree," *International Journal of Biological Macromolecules*, vol. 142, pp. 212–221, 2020.

[55] D. Chandramohan and K. Marimuthu, "A review on natural fibers," *International Journal of Research and Reviews in Applied Sciences*, vol. 8, no. 2, pp. 194–206, 2011.

[56] D. Atalie and R. K. Gideon, "Extraction and characterization of Ethiopian palm leaf fibers," *Research Journal of Textile and Apparel*, vol. 22, no. 1, pp. 15–25, 2018.

[57] R. Vijay, D. Lenin Singaravelu, A. Vinod et al., "Characterization of raw and alkali treated new natural cellulosic fibers

from Tridax procumbens," *International Journal of Biological Macromolecules*, vol. 125, pp. 99–108, 2019.

[58] H. A. Begum, T. R. Tanni, and Md A. Shahid, "Analysis of water absorption of different natural fibers," *Journal of Textile Science and Technology*, vol. 07, no. 04, pp. 152–160, 2021.

[59] P. Sahu and M. K. Gupta, "Water absorption behavior of cellulosic fibres polymer composites: a review on its effects and remedies," *Journal of Industrial Textiles*, vol. 51, no. 5_ suppl, pp. 7480S–7512S, 2022.

[60] O. Benaimeche, N. Toubal Seghir, Ł. Sadowski, and M. Mellas, *The Utilization of Vegetable Fibers in Cementitious Materials*, 2020.

[61] R. Wahab, M. T. Mustafa, N. Fauzi, and H. Samsi, "Thermal degradation analysis on 4-year-old culms of cultivated tropical bamboo bambusa vulgaris," *Journal of Agricultural Studies*, vol. 5, no. 2, p. 50, 2017.

[62] M. C. Paiva, I. Ammar, A. R. Campos, R. Cheikh, and A. M. Cunha, "Alfa fibres: mechanical, morphological and interfacial characterization," *Composites Science and Technology*, vol. 67, no. 6, pp. 1132–1138, 2007.

[63] S. K. Sharma, D. S. Verma, L. U. Khan, S. Kumar, and S. B. Khan, Eds., *Handbook of Materials Characterization*, Springer International Publishing, New York, NY, USA, 2018.