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ORIGINAL PAPER

Novel Cellulosic Natural Fibers from *Abelmoschus Ficulneus* Weed: Extraction and Characterization for Potential Application in Polymer Composites

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Abstract

Owing to the mounting environmental consciousness, natural fibers in composite materials have become inevitable, especially for lightweight semi-structural applications which includes the door panels, side body structures, stressed shell structure and hood components in automotive and aerospace industry. This study represents the properties of raw and NaOH treated novel cellulosic *Abelmoschus ficulneus* weed plant fibers. The extracted fibers were characterized by physicochemical analysis, fourier transform infrared spectroscopy, X-ray diffraction, thermogravimetric analysis, and Differential scanning calorimetry, single fiber tensile test, optical microscopy, and scanning electron microscopy. The physicochemical analysis found that the extracted fiber possessed higher cellulose content (80.86%). The extracted fiber was also chemically modified by NaOH treatment, which enhanced the tensile and thermal properties. The peak load at which the fiber failure occurred improved from 2.87 N for the untreated fiber to 3.57 N for the treated fiber while the modulus improved from128 MPa to 159 MPa for the untreated and treated fiber. Further, the inflection degradation increased from 349 °C to 352 °C. Hence, with better functional properties, the novel *Abelmoschus ficulneus* weed fibers can be a potential reinforcement material for the composites used in semi-structural applications.

Keywords *Abelmoschus ficulneus* · Physico-chemical analysis · Single fiber tensile and thermal properties

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Introduction

In recent years, there has been an increase in the use of natural fibers as reinforcing agents in polymer composites to address concerns about environmental contamination and degradation caused by petroleum-based synthetic materials [1–5]. Apart from the economic and environmental benefits, natural fibers also offer several other advantages: low density, better thermal insulation properties (e.g., automobiles and buildings), comparable mechanical properties, reduced wear, etc., when compared to their synthetic counterparts [6–12]. Hence, there is enormous scope for utilizing natural fibers as reinforcement in composites. Natural fibers are potentially used in automotive applications such as brakes, bumpers, doors, etc. [13–17]. They are also widely used in other applications like household and sports appliances, packaging, textile, construction, and aerospace industries [18–26].

Due to this, many researchers have attempted to extract and utilize novel plant fibers for this purpose. Novel fibers like *Grewia damine* [27], *Cortaderia selloana* Grass (Pampas) [28], *Cieba patendra* [29], *Citrullus lanatus* Climber [30], *Vachellia farnesiana* [31], *Albizia julibrissin* [32], *Epipremnum aureum* [33], *Pithecellobium dulce* [34] and *Parthenium hysterophorus* [35], etc.,. were extracted and their properties were reported. According to recent findings on plant-based fibers, these fibers have excellent tensile properties due to their ideal chemical composition and are the most suited and low-cost reinforcement material [8–13]. Natural fibers obtained from various parts of the plant are extracted through several techniques such as manual decortication, dew retting, water retting, chemical retting, etc., [36]. The performance of the natural fiber is mainly influenced by the part of the tree or plant from which the fiber has been extracted which can influence the crystalline and amorphous characteristics. It has been reported that fibers with fewer amorphous contents such as hemicellulose, lignin, pectin, and possess better mechanical properties [37]. Further, the physicochemical and mechanical properties of plant fibers can be enhanced by modifying the fiber surface through chemical treatments namely silane, alkali, HCl, etc. The composites reinforced with chemically treated fibers exhibited improved mechanical properties due to the enhanced interfacial adhesion between the surface-modified fiber and the polymer matrix [9, 35, 37, 38]. Among the various fiber treatment methods, NaOH treatment is the simplest, most effective, and commonly used chemical treatment. In this method, when the fiber is immersed in the NaOH aqueous solution, the ingredients of the fiber such as hemicellulose, lignin, pectin, and other impurities are removed from the surface of the fiber resulting in a rough fiber surface and fibrillation depending on the natural fiber. This in turn assists in the improved mechanical interlocking of the fiber with the matrix. The removal of fiber ingredients due to the reaction between the fiber and alkali solution can be given by the below Eq. (1) [39].

$$\text{Fiber–OH} + \text{NaOH} \rightarrow \text{Fiber–O–Na}^{+} + \text{H}_2\text{O} \tag{1}$$

As a result of the literature review, it is clear that there is increasing potential for the use of novel natural fibers in composite materials. This research attempts to extract fibers from the *Abelmoschus ficulneus* weed plant for their potential use as reinforcement in polymer composites. In this research, a novel natural fiber was extracted from the stem of the *Abelmoschus ficulneus*, a crop weed popularly known as '*Kaatu Vendi*' in Tamil. This plant is perennial with a woody stem and belongs to the *Malvaceae* family which is commonly found in Africa, Asia, and Australia. The average height of the plant is 2 m and can reach up to 4 m. These plants have edible parts such as the seeds which can be used as additives in sweets and coffee. The plant leaves can be used for treating *diarrhea*, and the stem can be used to treat calcium deficiency and snake bites. However, these plants often grow like a weed and hinders the growth of paddy crops, act as a host for the crop pests, and occupy the harvested crop area due to their rapid growth, thereby creating problems for the farmers, and their stem is usually discarded as waste.

Extraction of the fibers from this plant helps to develop a new reinforcement material as well as enables proper weed management creating value for the discarded weed. In this regard, *Abelmoschus ficulneus* fibers in raw form and chemically modified with NaOH treatment were characterized by physico-chemical analysis, Fourier Transform Infrared Spectroscopy (FTIR), X-ray diffraction technique (XRD), thermogravimetric analysis (TGA), Differential Scanning Calorimetry (DSC), Single fiber tensile test, optical microscopy (OM) and scanning electron microscopy (SEM).

Materials and Methods

Materials

Abelmoschus ficulneus weed plant was cut from the paddy fields in Kumbakonam, Tamil Nadu, India. Sodium Hydroxide (NaOH) and deionized water were obtained from Ganapathy Chemical Company, Srivilliputhur, India.

Extraction of the Fiber

The fibers were extracted from the stem of the plant by water retting and manual peeling process according to the steps in a published work [40]. The collected stem was initially cleaned with water to remove the impurities from the surface of the stem. Then the stem was immersed in fresh water for about 15 days for microbial degradation in the open air, dried, and combed using the metal comb to obtain the individual fibers. The extracted fibers were washed thoroughly using distilled water to remove any unwanted dust particles and dried under sunlight for about 72 h to remove the moisture. The process of fiber extraction is depicted in Fig. 1.

Chemical Treatment of Fibers

In this study, the fibers were modified using NaOH. The extracted fibers were immersed in 5% (w/v) of aqueous NaOH solution for about 1 h (Fig. 2a). The treated fibers were then washed thoroughly with deionized water (Fig. 2b). After washing, the fibers were dried in hot air and woven at about 60° Covernight. Finally, the fibers were stored in airtight bags before testing.

Physico-chemical Analysis

To determine the physical properties (diameter and density) and chemical composition (cellulose, hemicellulose, lignin, wax, ash, moisture, and pectin) of the fibers, a physical and chemical analysis was carried out. The fiber diameter was measured using an optical microscope (HUVITZ, HRM-300) in which the diameter from different parts of the fibers was measured, and the average value was reported. Density was determined by following the pycnometer procedures where distilled water was taken as an immersion liquid. The cellulose content in the fiber was determined by Kurshner and Hoffer's method. Hemicellulose was measured by treating the samples for 30 min with mineral acid at high temperatures. The leftover sample was then mixed in alkali solution at high temperature before being dried and weighed. The hemicelluloses were eliminated during the alkali treatment. The lignin content of each fraction was determined by the Klason method. Wax

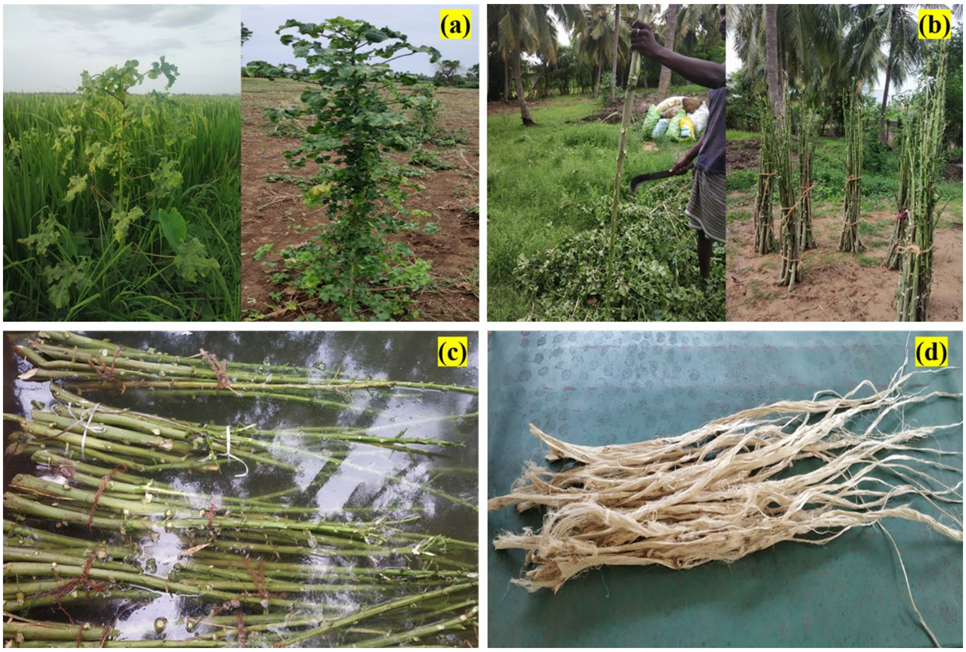

Fig. 1 Process of fiber extraction from *Abelmoschus ficulneus* plant. **a** *Abelmoschus ficulneus* plant; **b** Removal of leaves; **c** Water retting and **d** Extracted fiber

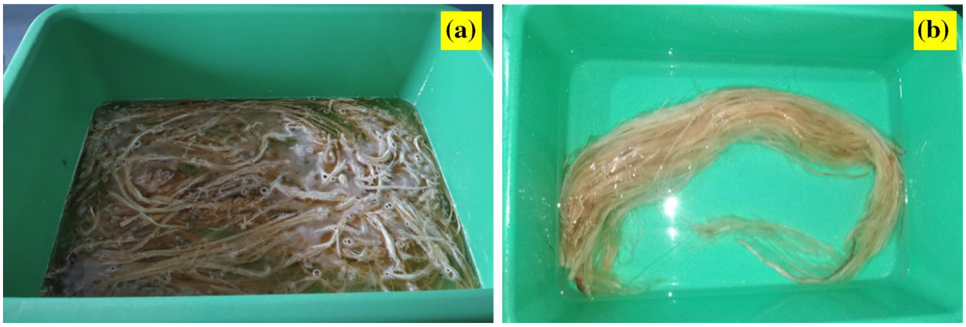

Fig. 2 Chemical treatment of *Abelmoschus ficulneus* fibers **a** fibers immersed in aqueous NaOH, **b** fibers washed with deionized water

content was determined by the hydrocarbon-based solvent extraction process mentioned in the Conrad method. Moisture and ash contents were determined as per the Indian Standard test method, IS 199:1989 (R2005).

Fourier Transform Infrared Spectroscopy

Bruker Invenio S Fourier transforms infrared (FTIR) Spectrophotometer was used to record the IR spectra of both the treated and untreated *Abelmoschus ficulneus* fiber. The spectrum was recorded in the range of 4000 to500 cm^{-1} in ATR mode at a scan rate of 32 scans per min with are solution of 4 cm^{-1}.

X-ray Diffraction

To determine the crystallinity index of the treated and untreated *Abelmoschus ficulneus* fiber, X-ray diffraction was performed. A Smart Lab X-ray diffractometer (Rigaku) with Cu radiation run at 20 kV and 2 mA was used to record the diffractograms of the fibers at $2\theta = 10°$ to 80° range at a scan rate of 4°/min. The crystallinity index (CI) of the fibers was calculated using the Eq. (2) [41]

$$CI = \left[\left(I_{Cr} - I_{am}\right)/I_{Cr}\right] \times 100 \qquad (2)$$

where I_{cr} is the maximum intensity of the crystalline materials, and I_{am} is the intensity of diffraction of the amorphous material [21]. The crystallite size (CS) of fibres was also determined using the XRD pattern and estimated using Scherrer's Eq. (3)

$$CS = \left[k\lambda/\beta \mathrm{Cos}\theta\right] \qquad (3)$$

where K is the Scherrer constant (0.89), k is the wavelength of the x-ray beam (0.154 nm), and β is the peak full width half maximum (FWHM).

Thermogravimetric Analysis (TGA)

In order to evaluate the thermal degradation behavior of both the treated and untreated *Abelmoschus ficulneus* fiber, TGA was performed. For this, a thermogravimetric analyzer TGA/DSC 3 + HT/1600 (Mettler Toledo) was used. The thermograms were recorded within a temperature range of 30 to 700 °C at a heating rate of 10 °C/min. The test was performed under a nitrogen atmosphere with a flow rate of 60 ml/min.

Differential Scanning Calorimetry (DSC)

The thermal analysis of the fiber was examined using a Mettler Toledo DSC 3 + Differential Scanning Calorimeter within a temperature range of 0–300 °C at a heating rate of 10 °C/min. The test was performed under a nitrogen atmosphere with a flow rate of 60 ml/min.

Single Fiber Tensile Test

In order to evaluate the tensile behavior of the fibers, a single fiber tensile test was performed using a Zwick/Roell universal testing machine. The test was performed as per the ASTM D3822-07 standard method at ambient conditions with a gauge length of 50 mm and a crosshead speed of 1 mm/min. Twenty fiber samples were taken for the test, and the average values were reported.

Morphological Analysis

The cross-section and the surface morphology of the fibers were analyzed by using a scanning electron microscope (FEI Quanta 450, FELMI-ZFE, Australia) with an accelerated voltage of 15 kV.

Results and Discussions

Physico-chemical Properties

The physiochemical properties can greatly influence the performance of the natural fibers. It is generally challenging to find the diameter of the fibers due to the uneven outer surface of the fibers. The diameter at various parts of the *Abelmoschus ficulneus* fiber was measured, and the average diameter was found to be 86.52 ± 5.71 µm. The diameter of the fiber measured with the help of an optical microscope is presented in Fig. 3. The density of the fiber influences the weight of the composites. The density of the fiber investigated in the current study was found to be 1.21 g/cm^3. The chemical composition also plays a significant part in defining the properties of the fiber.

Higher cellulose content results in enhanced thermal and mechanical properties, and on the other hand, higher hemicellulose contents can have negative effects on the mechanical properties. The higher the wax and moisture contents lower the bond ability of the fiber with the matrix during the fabrication of the composites [7]. The cellulose, hemicellulose, and lignin content in the *Abelmoschus ficulneus* fiber was 80.86%, 36.63%, and 5.12%, respectively. On the other hand, the fiber had 0.26% wax, 1.09% ash, and 10.85% moisture contents.

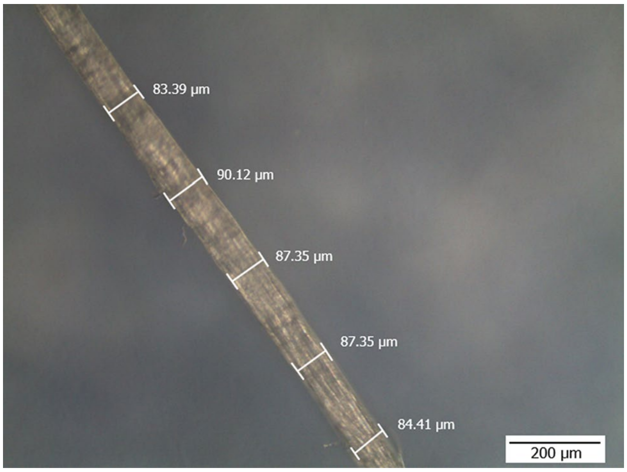

Fig. 3 Optical microscopic image showing the diameter of the *Abelmoschus ficulneus* fiber

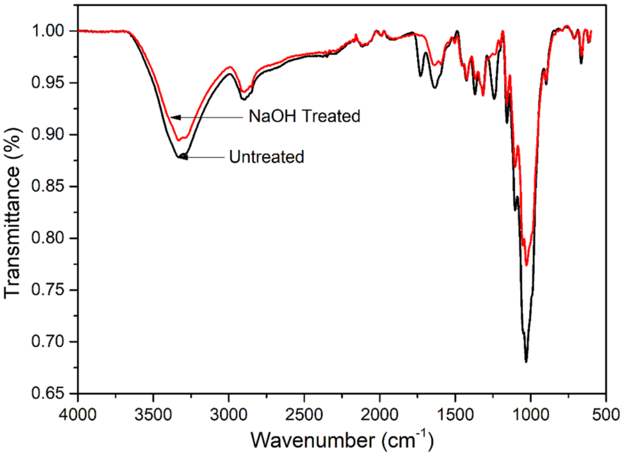

Fig. 4 FTIR spectra of untreated and NaOH treated *Abelmoschus ficulneus* fiber

A comparison of the physical and chemical properties of the *Abelmoschus ficulneus* fiber with other fibers is presented in Table 1.

It is evident from comparing the physical and chemical composition of the *Abelmoschus ficulneus* fiber with other natural fibers that it possesses equivalent or even better physicochemical properties over the recently investigated novel fibers by the other researchers. It has the highest cellulose content (80.86) among all the natural fibers taken for comparison. Furthermore, density was lower than most of the natural fibers taken for comparison.

FTIR Analysis

The FTIR spectra of *Abelmoschus ficulneus* weed fibers, as illustrated in Fig. 4, show the peaks corresponding to functional groups and the effect of NaOH treatment on the fiber surface.

The characteristic peaks observed from the FTIR spectra has been tabulated in Table 2 below. It can be noticed that charcteristic peaks observed in the wavelength 1265 cm^{-1}, 1730 cm^{-1} and 2130 cm^{-1} for the raw fiber did not appear for the treated fiber.

The broad peak observed in the wavelength range between 3050 and 3650 cm^{-1} corresponds to O–H stretching in free or weakly H–bonded hydroxyls. The peak at 3370 cm^{-1} is responsible for the presence of α-cellulose constituents [45, 46]. The following two peaks at 2950 cm^{-1} represent the stretching vibrations of –CH in the fiber [9]. The peak at 1730 cm^{-1} representing C=O stretching in carbonyl groups of alpha-keto carboxylic acid in lignin or the ester group in hemicellulose has completely vanished after alkaline treatment [8]. Besides, the peak at 1240 cm^{-1} corresponding to

Table 1 Comparison of physical and chemical properties of *Abelmoschus ficulneus* fiber with other natural fibers

Name of the fiber	Diameter (µm)	Density (g/cm^3)	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Wax (%)	Ash (%)	Moisture (%)	References
Abelmoschus ficulneus	86.52	1.21	80.86	36.63	5.12	0.26	1.09	10.85	Present work
Grewia damine	28.06	1.37	57.78	14.96	16.65	0.59	7.76	–	[7]
Cortaderia selloana Grass	372.6	1.26	53.70	14.43	10.32	3.10	4.20	7.60	[8]
Phoenix sp.	576.6	1.25	61.13	12.56	19.91	0.32	7.69	10.41	[38]
Citrullus lanatus Climber	210	1.22	53.70	12.50	10.10	3.20	2.17	14	[40]
Vachellia farnesiana	231	1.27	38.30	12.10	9.20	3.40	6.21	11	[41]
Albizia julibrissin	162.01	1.33	55.83	10.74	16.03	0.53	10.84	8.44	[42]
Epipremnum aureum	105–150	0.65	66.34	13.42	14.01	0.37	4.61	7.41	[33]
Coccinia grandis.L	27.33	1.24	62.35	13.42	15.61	0.79	4.388	5.60	[37]
Banana*Inflorescence bracts*	79.60	1.39	56.48	–	28.44	–	3.44	10.45	[43]
Nendran Banana*Peduncle fiber*	26.0	0.97	73.20	10.85	15.32	0.25	2.59	9.01	[44]

Table 2 Characteristic peaks from the FTIR spectra

Characteristic peaks from the FTIR spectra		Description
Raw fiber	NaOH treated fiber	
676	676	OH out-of-phase bending
1052	1037	C–O stretching
1265	-	C–O
1352	1370	–CH bending
1423	1472	–CH_2 symmetric bending
1670	1676	-
1730	–	C=O stretching
2130	–	–
2950	2964	CH stretching
3370	3370	OH stretching

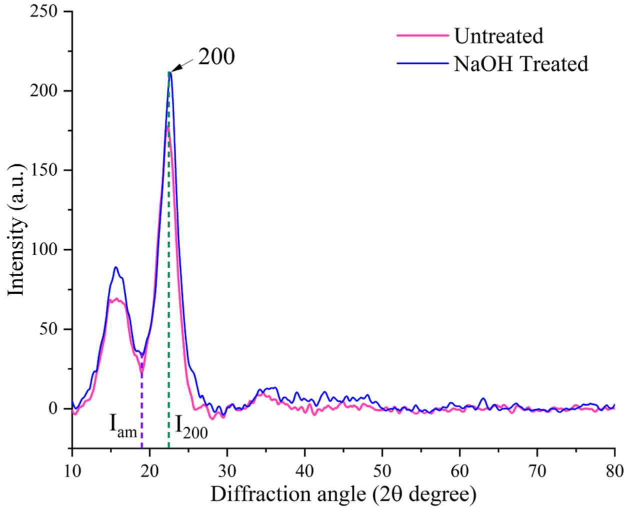

Fig. 5 XRD spectra of the untreated and NaOH treated *Abelmoschus ficulneus* fiber

the C–O bond of the acetyl group in xylan and hemicellulose also tend to disappear for the treated fiber. This means that the hemicellulose on the fiber surface has been removed after treatment with a 5% NaOH solution. The peaks at 1676 cm^{-1} corresponding to adsorbed water molecules in noncrystalline cellulose are found to diminish after alkaline treatment. Thus, the amount of moisture adsorbed on the fiber surface is reduced after treatment with NaOH solution.

XRD Analysis

The XRD spectrum of the untreated and alkali-treated *Abelmoschus ficulneus* fiber is illustrated in Fig. 5. It can be observed from the spectra that 5% NaOH treatment for 1 h has slightly improved the crystallinity of the fiber. The first peak intensity at the lattice plane (1 1 0), which correspond to the amorphous constituents occurred at 2θ = 18.15° for both untreated and treated fiber. Furthermore, the peak intensity corresponding to cellulose I in the lattice plane (2 0 0) occurred at 2θ = 22.54° and 22.4° for the untreated and treated fiber. CI and CS calculated based on the peak intensities of cellulose and amorphous constituents from the seagull method using Eq. (2) is presented in Table 3. CI of treated fiber was found to be more than untreated fiber. A similar kind of observation has been reported for other natural fibers under similar treatment conditions [47, 48].

Table 3 CI of the untreated fiber and NaOH treated *Abelmoschus ficulneus* fiber

Specimen	I_{cr}	I_{am}	CI (%)	CS (nm)
Untreated fiber	160	70	56.25%	4.17
NaOH treated fiber	215	85	60.46%	5.84

Thermogravimetric Analysis (TGA)

It is significant to explore the thermal behaviour of natural fibers for the production of natural fiber-based composites because the natural fiber is affected by the elevated temperature used during the fabrication of the composites of thermoplastics composites such as the extrusion and injection moulding technique while in case of the thermosetting composites, autoclave, hot press and the oven-curing technique [49, 50].

The primary and derivative thermograms of untreated and treated *Abelmoschus ficulneus* fiber are shown in Fig. 6a, b. The treated fiber exhibited higher thermal stability than the untreated fiber. The fiber displayed two major losses in the temperature range between 30 °C to 700 °C. The first loss was observed between 30 °C to 100°Ccorresponding to the evaporation of the moisture content in the fiber [51, 52]. The treated fiber exhibited a lesser weight loss of 2.87% over 3.37% for the untreated fiber (Fig. 6b). which could have been due to the reduction of free hydroxyl groups [53] and increasing order of cellulose content from the untreated to treated fiber [35, 53, 54]. Moreover, the degradation temperature of treated fiber at 5% weight loss was also 13% higher than the untreated fiber, as shown in Table 4.

After the initial loss due to moisture, further degradation occurred at ~ 220 °C due to the removal of hemicellulose and some fraction of lignin [55]. However, the derivative thermogram did not show any derivative peak in the case of the treated fiber as the treatment condition may not be sufficient to show major weight loss. Furthermore, the untreated and treated fibers showed a decomposition between 300 and 400 °C, which corresponds to the decomposition of cellulose content [56, 57]. The inflection degradation corresponding to

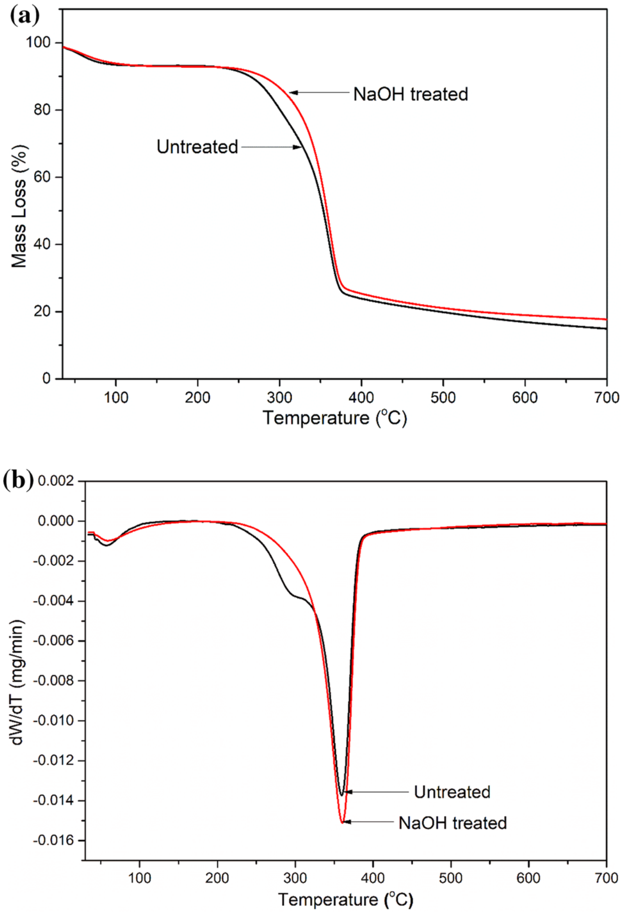

Fig. 6 **a** Primary thermograms of untreated and NaOH treated *Abelmoschus ficulneus* fiber. **b** Derivative thermograms of untreated and alkali-treated *Abelmoschus ficulneus* fiber

the maximum degradation was 349.83 and 352.33 °C for the untreated and treated fibers. Compared to other constituents, lignin is difficult to decompose. The decomposition would usually take place from 200 to 700 °C [55]. Table 3 shows the enhancement in thermal stability of the treated fiber evident from their higher degradation temperature between 5 and 80% weight loss. The treated fiber had a higher char residue (19.32%) than the untreated fiber (18.61%). Because the NaOH treatment would reduce the hemicellulose content, thereby exposing the lignin-cellulose contents. Thus, the treated fiber becomes more stable than the untreated fiber which is reflected by the increase in char value [56].

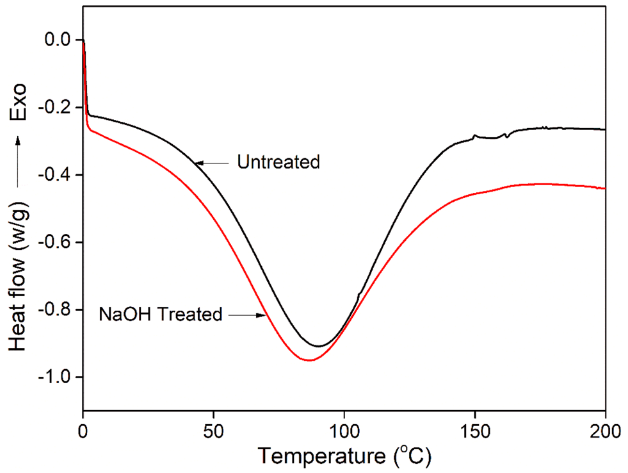

Fig. 7 DSC curves of the untreated and NaOH treated *Abelmoschus ficulneus* fiber

DSC Analysis

The DSC curves of the untreated and treated *Abelmoschus ficulneus* weed fibers are shown in Fig. 7. The single endothermic peak in the temperature ranging between 50 and 120 °C is due to the desorption of water from the fiber surface. However, there is an evident peak broadening after alkaline treatment due to moisture in the fibers. Furthermore, there areno evident exothermic reactions in the temperature range between 150 and 200 °C owing to the better stability of fibers upto 200 °C [58].

Tensile Properties

To find the tensile properties of the *Abelmoschus ficulneus* fiber, the single fiber tensile test was carried out. The load vs. elongation plot from the single fiber test is presented in Fig. 8. The test was conducted for 20 specimens. However, the load vs. elongation plots of 10 random specimens was only reported here. A significant difference in the tensile properties, such as Young's modulus (slope of the curve) and peak load, can be observed before and after the fiber treatment.

Figure 9a–c presents the tensile strength, Young's modulus, peak load, and % elongation at break for the single fiber. The "as extracted" or raw fiber displayed tensile strength and Young's modulus of 538 MPa and 0.128 GPa respectively,

Table 4 Thermal degradation behaviour of *Abelmoschus ficulneus* fiber

Specimen	$T_{5\%}$ (°C)	$T_{10\%}$ (°C)	$T_{20\%}$ (°C)	$T_{40\%}$ (°C)	$T_{50\%}$ (°C)	$T_{80\%}$ (°C)	Char residue (%)
Untreated fiber	69.32	263.91	300.80	343.44	353.64	495.43	18.61
NaOH treated fiber	78.48	279.61	322.66	350.48	357.80	541.82	19.32

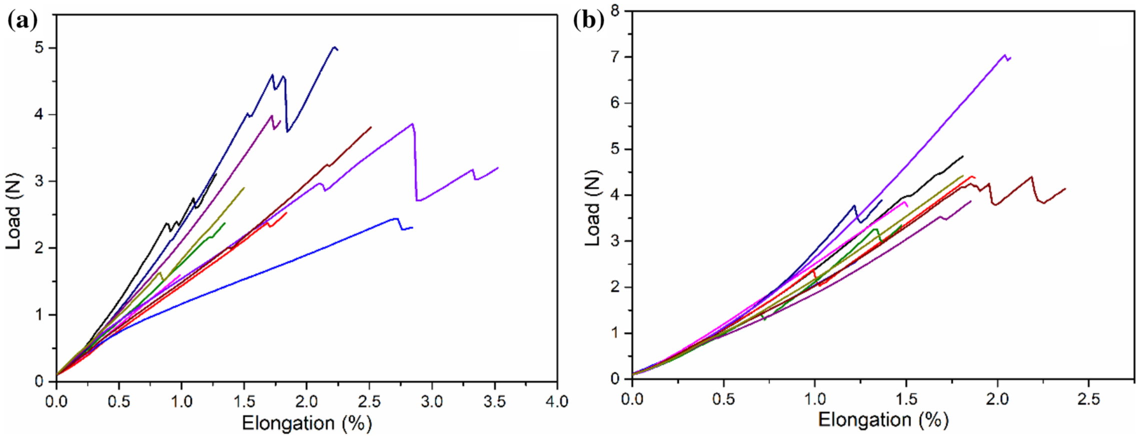

Fig. 8 Load vs. Elongation curves of **a** untreated and **b** NaOH treated *Abelmoschus ficulneus* fiber

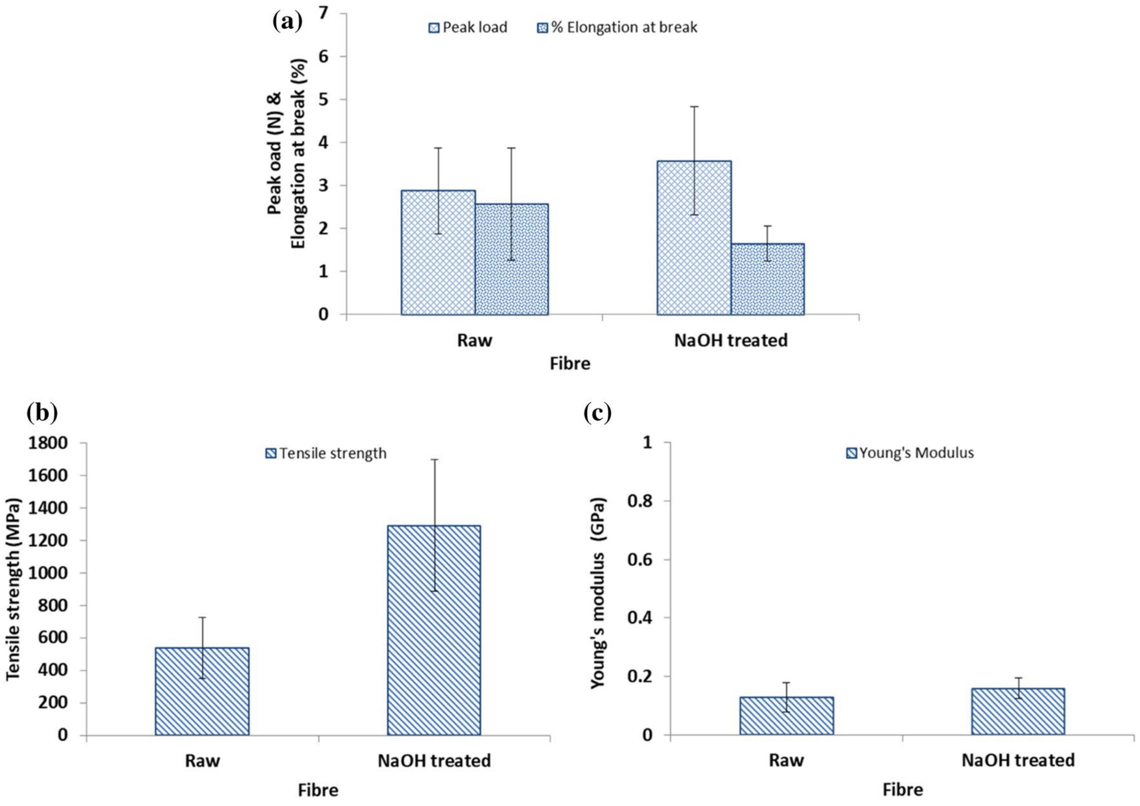

Fig. 9 Tensile properties of the untreated and NaOH treated *Abelmoschus ficulneus* fiber **a** Peak load and Elongation at break, **b** Tensile strength and **c** Young's Modulus

while the NaOH treated fiber showed a slightly superior tensile strength and stiffness of 1292 MPa and 0.159 GPa. The increasing trend concerning the fiber treatment was observed for peak load as well. The untreated fiber was able to withstand a peak load of 2.87 ± 0.99 N while the treated fiber exhibited 3.57 ± 1.26 N. Unlike Young's modulus and peak load, elongation at break was found to decline after the alkali treatment. Untreated fiber possessed a value of 2.57 ± 1.29%, which is around 36% higher than the value of the treated fiber (1.65 ± 0.40%). The increase in elasticity as well as peak load and decline in % elongation at break for the NaOH treated fiber was similar to that of the trend reported on a novel natural fiber extracted from the Phoenix sp. plant [38]. It is well known that the inherent characteristics of the natural fiber such as fiber constituents, fiber physical properties depending on the growth or maturity, and geographical location (where the fiber is extracted from) are the major factors that influence the tensile properties of the fiber. In addition to this, the improvement in tensile strength, load bearing ability and Young's modulus of the single fiber could be due to the morphological changes in the natural fiber that occur due to the removal of hemicellulose, other non-cellulosic constituents, and impurities from the NaOH treatment [59]. In the case of the *Abelmoschus ficulneus* fiber, the removal of fiber constituents was evident from the FTIR spectra (Fig. 4), while the morphological changes from the SEM image of the fiber (Fig. 10).

In summary, tensile strength of the extracted fiber from the *Abelmoschus ficulneus* weed possessed tensile strength comparable to that of the commercially available natural fibers such as hemp, kenaf and coir. However, their stiffness was far lower than the typical value for the commercial fibers. In this stusy, as extracted fiber was employed as opposed to fiber yarn which could have been the primary reason for inferior stiffness. Thus, the testing of fiber yarn can provide clarification on the poor stiffness of the fiber.

Microscopic Analysis

The *Abelmoschus ficulneus* fiber surface of both the untreated and treated samples is examined through SEM. as shown in Fig. 10a–d. Surface impurities were visible in Fig. 10a which can reduce fiber wetting with the polymer matrix. Figure 10b shows the fiber morphology after the NaOH treatment. It is observed that (i) the fiber surface became rough with pores appearing on the surface and (ii) the discontinuous fibrillation was apparent to some extent. Figure 10c–d shows the cross-section dimension of the untreated and treated fiber surfaces, respectively. Figure 10c shows the cross-section values were higher due to the deposition of the hemicellulose and other surface impurities. However, these impurities were removed by the NaOH treatment. This was supported by indicating lesser diameter values of the NaOH treated fiber as shown in Fig. 10d. Similar observations were also reported by Obi Reddy et al. [53].

Conclusion

In this research, novel cellulosic fiber was extracted from *Abelmoschus ficulneus* weed plant. The density of the extracted fiber was found to be 1.21 g/cm^3, which is comparatively lower than many novel natural fibers extracted

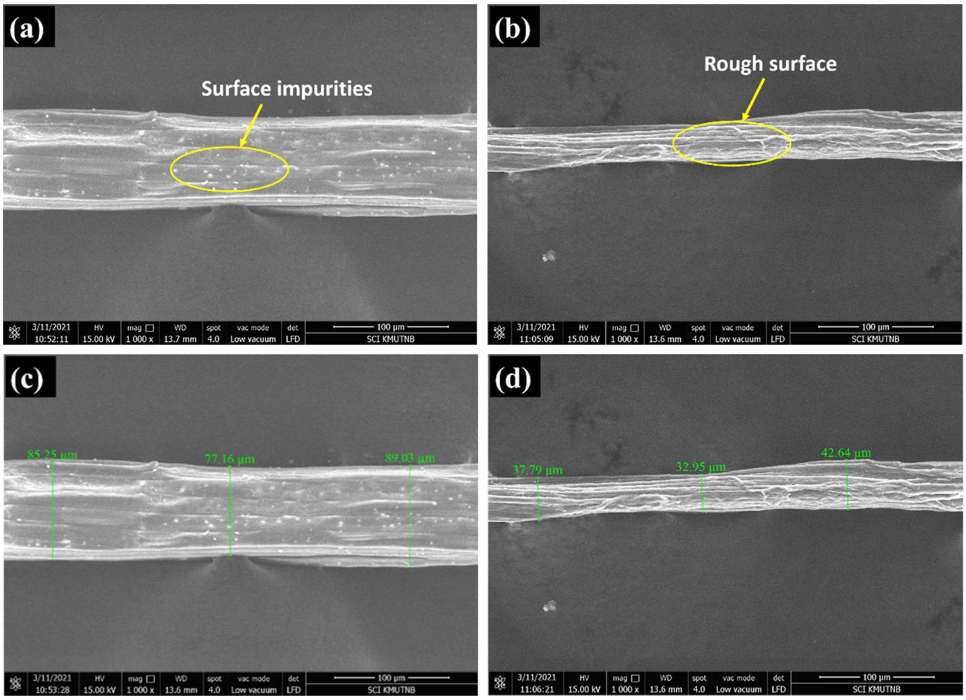

Fig. 10 Surface morphology of untreated and NaOH treated *Abelmoschus ficulneus* fiber **a** untreatedfiber, **b** alkali-treated fiber, **c** cross-section dimension of untreatedfiber, and **d** cross-section dimension of alkali-treated fiber

in recent years and an essential characteristic for the reinforcement in composite materials. Higher amounts of cellulose content (80.86%) in the extracted fiber can help fabricate high-strength composites. The inflection degradations corresponding to the maximum degradation were 349.83 and 352.33 °C for the treated and untreated fibers. Besides, the thermal stability of NaOH-treated fibers was increased by exhibiting the reside of 19.32% when compared to untreated fibers. Single fiber tensile test revealed that the untreated and NaOH treated fibers could withstand a peak load of 2.87 ± 0.99 Nand 3.57 ± 1.26 N, respectively. Tensile strength was nearly similar to that of the commercially available natural fibers such as kenaf, hemp and coir. Young's modulus of the raw and NaOH treated fiber was found to be 0.128 GPa and 0.159 ± 35 GPa respectively. The NaOH treatment removed the hemicellulose in the fiber displayed by the absence of characteristic peaks corresponding to the hemicellulose from FTIR spectra and the surface of the fiber became rough with discontinuous fibrils along the length of the fiber, as could be noted in the SEM micrographs. Based on the investigated properties, the novel *Abelmoschus ficulneus* could be a potential candidate for reinforcement in polymer composites.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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