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EFFECT OF TENSILE STRENGTH OF LIGNOCELLULOSIC HIMALAYAN NETTLE FIBERS BY CHEMICAL TREATMENT

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ABSTRACT

The physical and chemical properties of Himalayan nettle fibers treated with sodium hydroxide and sodium chlorite solutions have been studied in this research. Nettle fibers are naturally derived, high-strength nettle yarn for the preparation of home textiles, handicrafts, and ropes. It is a high fiber-yielding plant that grows naturally in the Himalayan areas. In this study, nettle fiber samples were soaked in 4% sodium hydroxide (NaOH) and 1% sodium chlorite ($NaClO_2$) solutions at a 100ºC temperature for 90 minutes. The untreated nettle fibers were soaked in a 4% sodium hydroxide water solution at a 100ºC for 60 minutes. The nettle fiber test samples were prepared and tested as stated in the ASTM standards. The average tensile strength of alkaline nettle fibers increases by upto 60% compared with untreated fiber. The mild alkali treatment increases tensile strength, cellulose content and decrease elongation break acts to be due to fiber extraction and separation of non-cellulosic materials such as hemicellulose, lignin, and pectin. Compared to untreated nettle fiber, the average young's modulus of sodium hydroxide-chlorite treated fiber was increased. Moisture sorption analysis, Fourier transform infrared spectroscopy (FTIR), single fiber tensile strength, and physical properties were used to evaluate the properties of untreated and treated nettle fibers.

KEYWORDS

Nettle, Tensile strength, Alkaline, Textile, Cellulose.

MATERIALS AND METHODS

Raw Materials

The Nagaland Hill invention lead origination provides a 2-3 metre dry nettle barks for use in this research. Commercially available sodium hydroxide (NaOH) pellets with a purity of 97% are available, and sodium chlorite ($NaClO_2$) was obtained from Sigma and other chemicals using acetic acid, distilled water, and neutralised nettle fiber [1–3].

Experimental methods

The nettle stem outer layer or bark is peeled using a crushing machine and sun-dried for 2-3 days. For example, 100 g of dry nettle bark was soaked in a small water reservoir tank for 24 hours to remove dirt and impurities. Afterwards, the nettle bark was dried in the sun light for 1 day [2].

Alkaline-Sodium chlorite treatment on nettle fibers

In this process, untreated nettle fibers were soaked in a 4% wt. sodium hydroxide (NaOH) chemical and water for 60 minutes at a 100ºC temperature. The treated nettle fibers were continuously washed with water and allowed to air dry for 24 hours. After that, pre-treated nettle fibers further soaked in a 1% wt.

sodium chlorite ($NaClO_2$) solution for 90 minutes at a boiling temperature of 100ºC with the pH maintained at 14. The ratio of nettle fibers to alkaline solution was maintained at 1:30 (by weight). After treatment, the nettle fibers were neutralized with a 2% wt. acetic acid solution and copiously washed with distilled water until neutral. The alkaline-treated samples were dried for 48 hours at room temperature. The dried nettle fibers are opened and the combing process converted into yarn by carding and spinning machines [1,3].

Fourier transform infrared spectroscopy analysis

An ABB Bomem MB3000 spectrometer was used to obtain FTIR spectra of chemical treated and untreated nettle fibres. The fibres were ground into a powder and combined with potassium bromide powder (1:10) before being shaped into a pellet for testing. Each sample received a total of 30 scans with a resolution of 4 cm^{-1} in the range of 600–4000 cm^{-1}. The goal of the FTIR test was to look for changes in functional groups, which could assist confirm that hemicellulose, lignin, and other elements had been removed [4–6].

Single fiber tensile strength measurement

The ASTM D3379-05 Standard Test Method for Tensile Strength, Elongation and Young's Modulus were used to determine the strength of single nettle fibres. The UniStretch 250 universal testing equipment was used to test untreated and processed nettle fibres (50 mm gauge length), and the results were recorded for statistical analysis at room temperature and humidity [1]. Specimens were made by manually separating fibre bundles and then using polyvinyl acetate glue to connect single fibres to cardboard mounting cards with 12 mm holes punched in them, resulting in a gauge length of 10 mm. The fibres were tensile tested using a 10 N load cell and a cross-head speed of 0.5 mm/min. This test will determine the maximum force (F) that a single nettle fibre can withstand. Finally, a total of 20 specimens were evaluated for each type of nettle fiber, the average fibre diameter (d_{avg}) was measured, and the average maximum force (f_{avg}) was used as a representative value [5–7]. Before each test, the mean diameter of the fiber was measured using a digital micrometre with an accuracy of 0.001 mm. The linear mass is used in the tex system to specify yarn thickness. Depending on the end users, thinner or thicker yarns might be chosen.

$$F_{ts} = \frac{4f_{avg}}{\pi d_{avg}^2} \quad [1]$$

where, F_{ts} - single nettle fiber tensile strength, d_{avg} - average fiber diameter, f_{avg} - average tensile force.

Moisture sorption test

The 1.0 gram nettle fibres specimens were initially dried in an oven at 100°C for 4 hours, cooled in the atmosphere, and their initial weight was measured (W0). The moisture sorption test was carried out in a humidity chamber with a relative humidity of 70% and a temperature of 30°C. The weight of wet nettle fibres was measured after the period and indicated as Wt. Finally, Eq. [2] was used to calculate the percentage of moisture sorption (Ms) in untreated and treated nettle fibers:

$$M_s = \frac{Wt\text{-}W0}{W0} 100 \quad [2]$$

where, Ms - percentage of moisture sorption in nettle fiber, W0 - initial weight of dried nettle fiber, Wt - nettle fiber weight after absorb water.

This technique was repeated until the weight of the nettle fibers reached a state of equilibrium [3–5]. The moisture sorption test was conducted as per ASTM D570. Wt and W0 were measured using an analytical digital balance with a precision of 0.0001 gram.

RESULTS AND DISCUSSION

FTIR spectra Analysis

The FTIR spectra of untreated and treated nettle fibre are shown in Figure 1, which clearly illustrates the functional group modification. The hydrogen bound and hydroxyl group (O-H) stretching vibrations ascribed to intramolecular or intermolecular hydrogen bonding and free OH hydroxyl have a high peak at 3472 cm^{-1}. In cellulose and hemicellulose, the peak at 2878 cm^{-1} is indicative of methyl and methylene C-H stretching vibration groups. The C-O stretching vibration of carbonyl groups and ester groups of hemicellulose removal in treated fibre has a peak between 1844 and 1740cm^{-1} [6–8]. The peak between 1636 and 1535 cm^{-1} is caused by water content in fibers. The CC=stretching of the aromatic ring of lignin causes the peak between 1535 and 1489 cm^{-1}. The peak in the range of 1489–1366 cm^{-1} is due to CH_2 bending in cellulose, hemicellulose, and lignin. The C-O groups of the aromatic ring in polysaccharides are responsible for the peak between 1366 and 1273cm^{-1}. The peak is between 1273 and 1196cm^{-1}, which removal to the acetyl groups -CO stretching vibration. C-O-C asymmetrical stretching in cellulose and hemicellulose is responsible for the peak at 1142–1040 cm^{-1}. The C–O stretching vibration, which belongs to the polysaccharide in cellulose, is responsible for the high peak at 1040–972 cm^{-1}. When compared to raw nettle fibres, the peaks at 1320 cm^{-1} decreased for all treated, which is primarily due to the removal of some hemicellulose after treatment [9,10].

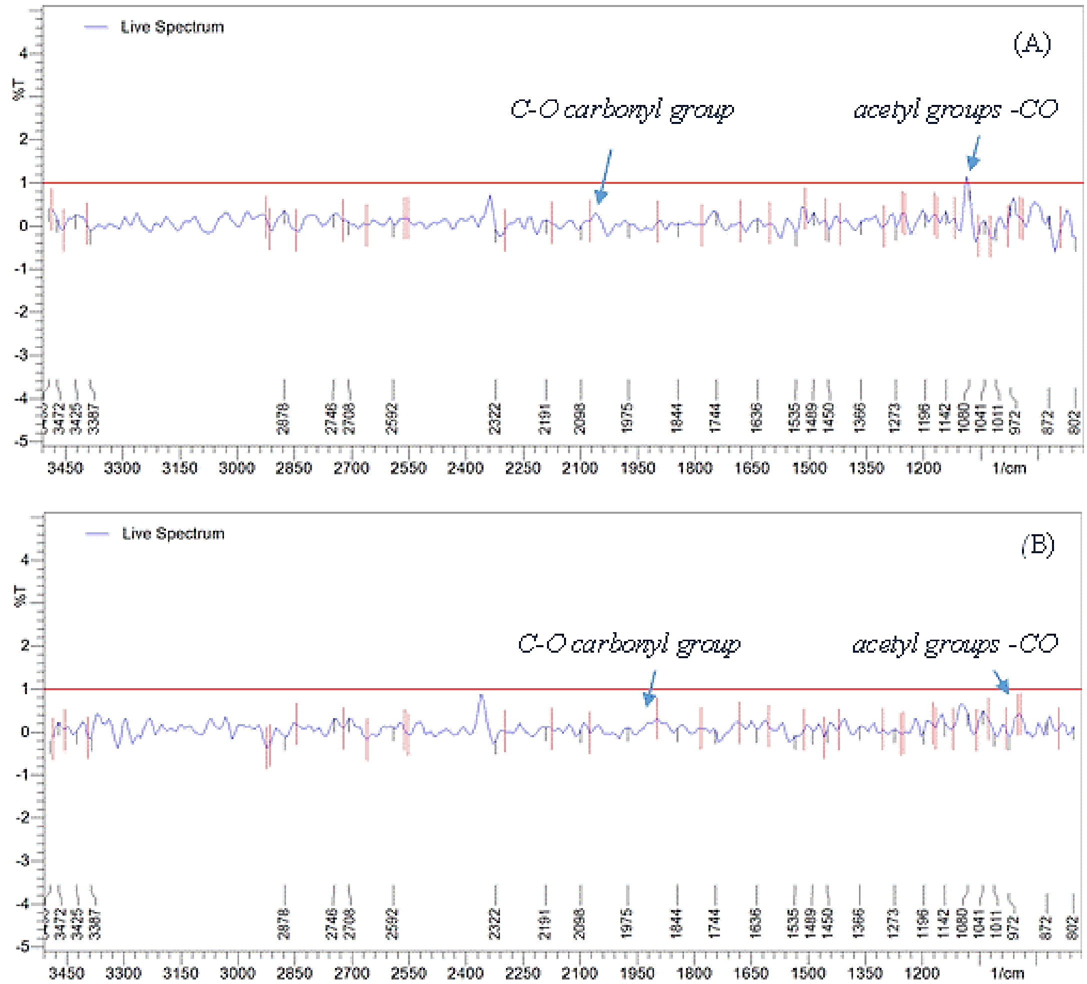

Figure 1. A) FTIR spectra of untreated nettle fiber, B) FTIR spectra of treated nettle fiber.

Moisture sorption analysis

In Table 1, the moisture sorption behaviour of chemically treated and untreated nettle fibers is represented. The weights of raw and treated nettle fibers were recorded at 60, 120, 240, 300, and

420 minutes after being placed in the moisture chamber. The weight of the nettle fibers increases with time up to 340 min, thereafter it becomes constant. It is shown that compared to raw nettle fibers, treated nettle fibers 4% sodium hydroxide and 1% sodium chlorite uptake low moisture absorption. This can be due to the chemical and physical changes that occur when cementing materials are removed. The presence of cellulose and hemicellulose in plant fibres is thought to be the fundamental reason for their hydrophilic nature. Hemicellulose is also more hydrophilic than cellulose and absorbs more water. Reduced moisture absorption may result from the elimination of hemicellulose, lignin, and other extractives. The moisture plays a significant role in influencing the nettle fiber mechanical properties. The treated fibers in the tensile testing, however the excess water was removed [3–5].

Table.1 Moisture sorption % of untreated and treated nettle fibers.

S.No	Time in Minutes	Raw nettle fiber	4% Sodium hydroxide treated (NaOH)	1% Sodium chlorite treated ($NaClO_2$)
1	60	9.1	8.85	8.72
2	120	9.95	9.73	9.35
3	240	10.8	10.60	9.86
4	300	11.6	11.38	10.80
5	420	12.5	11.66	11.12

Single fiber tensile test

The diameter (µm) of the treated nettle fibres is considered significant after the elimination of hemicellulose, lignin, and other impurities, indicating that the nettle fibres become considerably finer after the treatment. The diameter of the fiber varied widely, but much of the fibre might have been used in a circular elimante cross-section. Tensile testing was thus conducted using relative cross sectional shapes rather than the actual cross sectional area. The digital micrometer was used to approximate the diameter. The aspect ratio increased as the fibre diameter reduced, resulting in rough surface structure [11,12]. The average tensile strength of treated and untreated nettle fiber is illustrated in Figure 2.

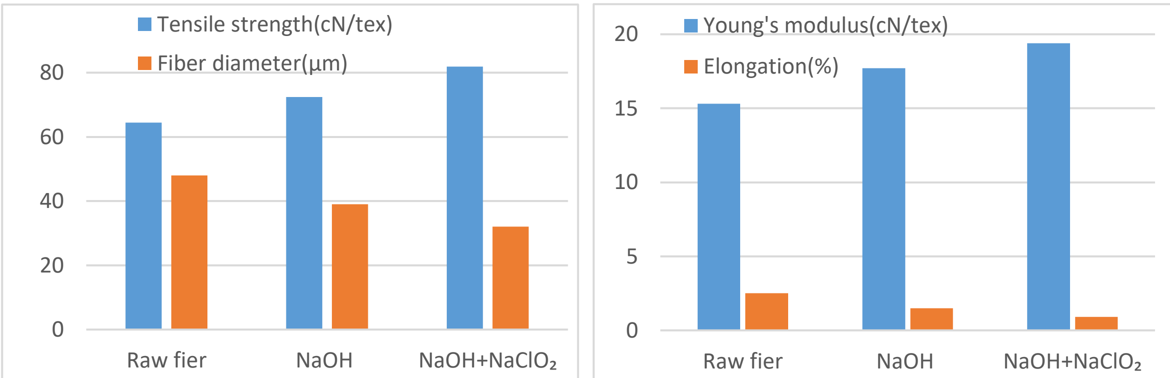

Figure 2. Physical and mechanical properties of nettle fiber.

The strengthening of the cellulose chain packing arrangement may be causing an improvement in tensile strength and young's modulus in nettle fibers. The diameter of the alkaline-sodium chloride fibre is lowered even more because more lignin is removed, resulting in the finest fibre [5–7]. The nettle fiber's average tensile strength is 79.9 cN/tex, which is quite steady. The tensile strength of nettle fibres was somewhat improved after a 4% alkaline treatment in this study. The removal of hemicellulose, lignin, and impurities may have resulted in an increase in cellulose content as well as a higher crystallinity index. According to these findings, after alkaline pretreatment, further sodium chlorite ($NaClO_2$) chemical treatment can improve tensile strength by 20%. When compared to untreated nettle fibres, the young's modulus of treated nettle fibres increased by 19.4 cN/tex.The cellular structure of of the fiber is clearly evident along with the variability in fiber size and shape. It appears in general that sodium hydroxide and chlorite decreases the deviation of failure stress from the untreated fibers [8,9].

CONCLUSION

The effects of alkaline chemical treatment on the features of Himalayan nettle fibers were investigated in this study, which used chemicals such as sodium hydroxide and sodium chlorite to treat nettle fibers. Moisture sorption tests, FTIR analyses, physical characteristics, and single fiber testing were used to investigate the tensile strength of chemically treated nettle fibers. As a result, it may be stated that the characterization of treated nettle fiber produces better results and strength. In a moisture sorption test, the ability of treated nettle fibers to absorb moisture was shown to be lower than that of raw nettle fibers. As compared to raw nettle fiber, the maximum tensile strength of chemically treated nettle fiber increased. The increase in tensile strength was attributed to the decrease in fiber diameter caused by the losses of non-cellulosic fiber materials in treated fiber. Nettle yarn is used to manufacture mats, ropes, bags, fabrics, and handicrafts due to its high strength.

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