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Research Article

Extraction and Characterization of Natural Cellulosic Fibers from 'Apple of Sodom' (*Solanum linnaeanum*) Plant Stems

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Abstract

Natural lignocellulose fibers are being utilized in various areas such as apparel manufacturing, automotive building and packaging application to replace conventional manmade fiber due to their environmentally friendly nature and especial properties. The possibility of discovering natural lignocellulose fiber from non-conventional sources is being explored. Plant fiber is one of the lignocellulose fibers that are used in textile industry. However, availability of natural fiber is not enough for any textile application and competes with manmade fiber. In this research, an attempt has been made to extract fiber from the trunk of 'Apple of Sodom' plant by water retting method. The extracted fiber was examined for its diameter, fineness, tensile strength and elongation in the laboratory by using the ASTM method. The diameter of the fiber was found to be 14.32 microns with a fineness of 0.262Tex. The tensile strength and elongation of the fiber were found to be 20.3 g/Tex and 5.3 %. Moisture content and moisture regain of fibers were 8.09 and 8.8 % respectively. It is observed that the fibers had properties like those of most natural cellulosic fibers such as jute, sisal and suitability for textile applications as an alternative source.

Keywords: Natural fibre; Cellulose fibres; Apple of Sodom Plant; Water Retting Extraction.

Introduction

Nowadays, the necessity of preserving environment and increased application of renewable natural recourse has led to the use of natural fibre in several textile industry sector including polymer composites, building materials, technical textiles and geotextiles [1], Environmentally friendly products are the most important research area in the last couple of decades, in order to the constantly study the practical solutions to environmental problems and to replace the conventional ones such as plant fibres in terms of advantages like renewable natural resource, biodegradable, cheap in cost, good specific mechanical properties [2,3,4]. Most of the natural reinforced composite textile materials focus on jute, flax and sisal fibres which are having their own disadvantage or drawback for example, for example, Kenaf fiber is brittle and difficult to process [5,6], extraction of ramie fibres are difficult to extract by water retting, even if a combined microbial and chemical treatment is used it is not very effective [7]. Jute, one of the Cheapest natural fibres, the most versatile, eco-friendly, natural, durable and antistatic fiber has low extension at break (1-2%) [8-10], flax fiber is more Crystalline and not easy to twist [11-14]. World market, for industrial applications uses the most predominantly synthetic fiber [15].

In the present work, the fiber was extracted from natural abundantly available plant 'Apple of Sodom' plant stems by using microbial retting and was successfully extracted. Once retting is completed, the non-fibrous matter are removed and washed, and subjected to mechanical processing to remove the soft tissues and then dried to obtain the fibers. It was found that non-cellulosic substances were completely removed or reduced after microbial (water) retting treatment in the extracted fibers. The final product indicated that the fibers have good properties; therefore can be alternative source for natural cellulosic fibers that can be used in the textile industry such as apparel, household fabrics and various non-woven fabrics. Textile fabrics, such as non-woven, knitted fabrics, may be made of cellulose alone or in combination

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with other synthetic fibres. These Cellulosic fiber-based textile products include feminine hygiene products, absorbent products, household wipes, babies' wipes and diapers, pillowcases, surgical dressings and shoe lining, composite application and other textile and paper making applications.

Materials and methods

Materials

The 'Apple of Sodom' plant was harvested from rural area of Ethiopia. The locations were selected as they had similar environmental conditions and had an abundance of the 'Apple of Sodom' plant Stem. The stems were collected in order to obtain trunk almost of the same age which was done by observing the color, size and position of the stem on the plant and then the outer skin of the stem was peeled from the stems by hand and used for fiber extraction. From the collected or harvested stem, the removal of non-fiber content from the skin surface was done by water retting method.

Methods

Fiber extraction

Research done on the 'Apple of Sodom' plant trunk by the microbial retting of the trunk in water was found to be the easiest and cheapest method of extraction of the fibres as presented in Fig.1. Microbial retting process breaks the chemical bonds that hold the trunk together to fibers and allows separation of the best fibres from the woody core. Moisture was a key requirement for microbial breakdown to occur. The chosen stem branches were peel the trunk by use of a sharp knife and then bundled together. The trunks were then subjected to the retting process, whereby the trunks were immersed in water in a tank at room temperature. The retting process took about 27-29 days to rot away the cellulosic matter that holds the fibres and trunk together. The fibres obtained were then washed in plenty of water to remove the non-fiber**.** Retting process was conducted by placing trunk in water at room temperature for 27-29 days in a coated metal container or plastic container.

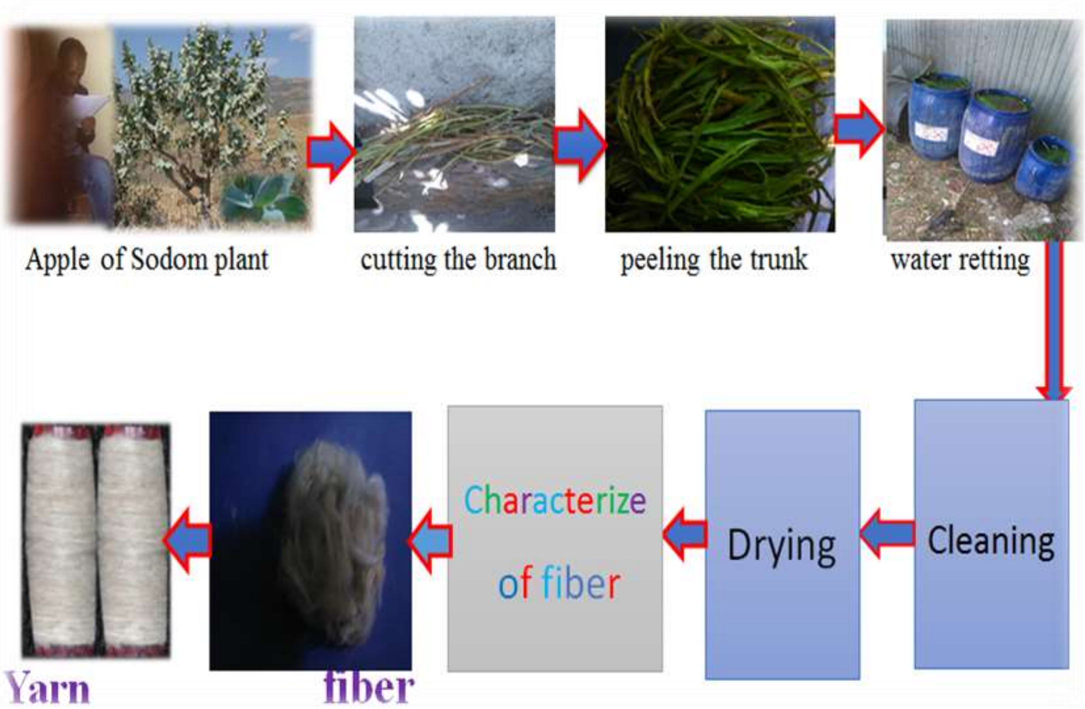

Fig. 1. Experimental procedure

Characterization

The properties of the fibers were tested in the laboratory by ASTM D-3822:07. Fibres samples each weighing 10gm were conditioned in a conditioning chamber to reach moisture equilibrium. The conditioned fibres were picked randomly and then used for the experimental testings. The tests were carried out with the standard textile testing conditions of relative humidity 65 ± 2% and temperature at 20 ± 2°C to ensure accuracy and reliability of results. The fibres were subjected to the following tests.

Fiber Diameter: By electron microscopic examination both the longitudinal and crosssectional views of the fibres were examined in order to calculate the diameter of the fiber.

*Fiber Fineness:*The fiber was tested for its fineness as indicated in ASTM D-1577:07 test method.

Tenacity and Elongation: Tenacity of the fibers was tested using ASTM D- 3822:07. After the rupture of the fibers the tenacity and elongation were noted.

Fiber length: After removing their crimp without stretching the fiber too much, 20 single fibres were drawn at random and each fiber was straightened out over a meter-ruler. The length was recorded in millimeters.

FTIR *characterization:* IR spectra of the samples were recorded using the Perkin Elmer FTIR instrument in the frequency range 4000 - 400 cm^{-1} using 20 scans and recorded in the transmittance mode as a function of wave number.

Results and Discussion

The test results of the extracted fibre for its important physical properties are presented in Table 1.

Table 1. Properties of the extracted fibres

S. No.	Parameters	Test results
1	Diameter(µm)	14.32
2	Fiber Fineness (Tex)	0.262
3	Strength (g/Tex)	20.30
4	Elongation%	5.3
5	Length (mm)	17.68
6	Moisture content (%)	8.09
7	Moisture Regain (%)	8.8
8	Uniformity (CV %)	2.103

Fiber diameter

The morphology of fibers obtained from the single cells was observed using a Projection Microscope as given in Fig. 2. The widths of the single cells were measured using a Projection microscope. The diameter or width of fiber is one of its most mandatory parameter of the fiber. Fiber diameter is usually measured with a Projection Microscope. The diameter of the fiber was found to be 14.32 µm and uniform from end to end.

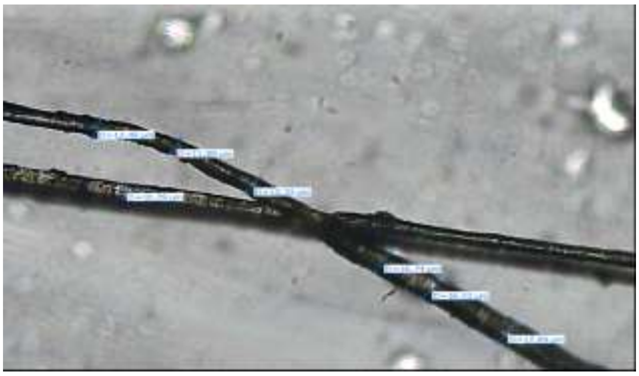

Fig. 2. Photograph of fibre taken in Projection microscope.

Fineness

Fineness or micronaire affects both the strength and irregularity of yarn. Fiber fineness also influences the twist for maximum strength, luster, the drape and hand value of fabrics. The fineness determines how many fibers are present in the cross-section of a yarn of given thickness. The linear density of the fiber was then calculated in Tex units which mean that it is a measurement equal to weight in grams of one kilometer of fiber or yarn. The extracted fibre was found to be having a fineness value of 0.262Tex.

Fiber Strength and Elongation

Strength and elongation are connected by cause and effect relationship and cannot be considered separately as the load in tension of the fiber is simultaneously stretched. These two properties are therefore often quoted in combination as stress and strain behavior. Tensile strength is the maximum stress caused by a pulling force that a material can withstand without failing. The 'Apple of Sodom' stem fibers were having strength of 20.30 g/tex and an elongation of 5.3%

Fiber length

The fiber length is one of the essential quality parameter of raw textile material .Fiber materials must have sufficient length so that they can be made into twisted yarns. In addition, the width of the fiber (the diameter of the cross section) must be much less than the overall length of the fiber, and usually the fiber diameter should be less than the length of the fiber because length to width ratio is the primary requirement of any textile fiber. The fiber length is usually suitable for producing for all count and was found to be 17.68 mm.

Moisture content and moisture regain

Most fibers tend to absorb moisture (water vapor) when in contact with the atmosphere. The amount of water absorbed by the textile fiber will depend on the chemical and physical structure and properties of the fiber, as well as the temperature and humidity of the surroundings. The percentage absorption of water vapor by a fiber is often expressed as its moisture regain. The regain is determined by weighing a dry fiber, then placing it in a room set to standard temperature and humidity (21 ± 2^0 C and 65% relative humidity [RH]. The moisture regain of the fibers was determined according to ASTM standard method 2654 and the fibre was found to be having 8% moisture content and a regain of 8.8%.

Uniformity

Uniformity is necessary to make high quality yarns; fibres should be similar in length, width and flexibility when spinning. Yarns that are composed of generally uniform fibres are preferred because they are regular, they appear smooth, and they accept dyestuffs more evenly to obtain good quality yarns. The 'Apple of Sodom' fibers are found to be very uniform that evident from the coefficient variation (CV) of 0.02103 or CV % 2.103.

Fourier Transform Infrared Spectroscopy (FTIR)

The Fourier transformation infrared attenuated total reflection (FTIR) spectra were recorded on Perkin Elmer GX spectrometer with an accessory diamond. One hundred acquisitions were performed in the range 400-4000 cm^{-1}. The band at 894cm^{-1} was used as internal standard band to determine the crystallinity index and the band intensity ratios. From the spectra, it is clear that it resembles cotton which also a cellulosic fibre. From Fig. 3, it is clear that the peak at 2850 cm^{-1} is the characteristic band for alkyl C-H symmetric and asymmetric stretching vibrations of α-cellulose. Additionally, the peak at 1735 cm^{-1} can be attributed to the carbonyl C=O stretching vibration mainly due to hemicellulose group, whilst the peak of C=C aromatic skeletal vibrations in lignin shows around 1550 cm^{-1}. The peak at 1450 cm^{-1} is associated with the CH_2 symmetric bending found in cellulose. The peaks at 1375 cm^{-1} and 1246 cm^{-1} correspond to the C-O stretching vibration of the acetyl group in lignin and hemicellulose component, respectively. Around 1050-1160 cm^{-1}, the absorptions can be attributed mainly to the carbohydrates (cellulose and lignin). On the whole, the FTIR peaks shows that these fibers compare well with other reported values for natural cellulosic fibres such as cotton, jute ramie, bamboo, sisal, flax and others.

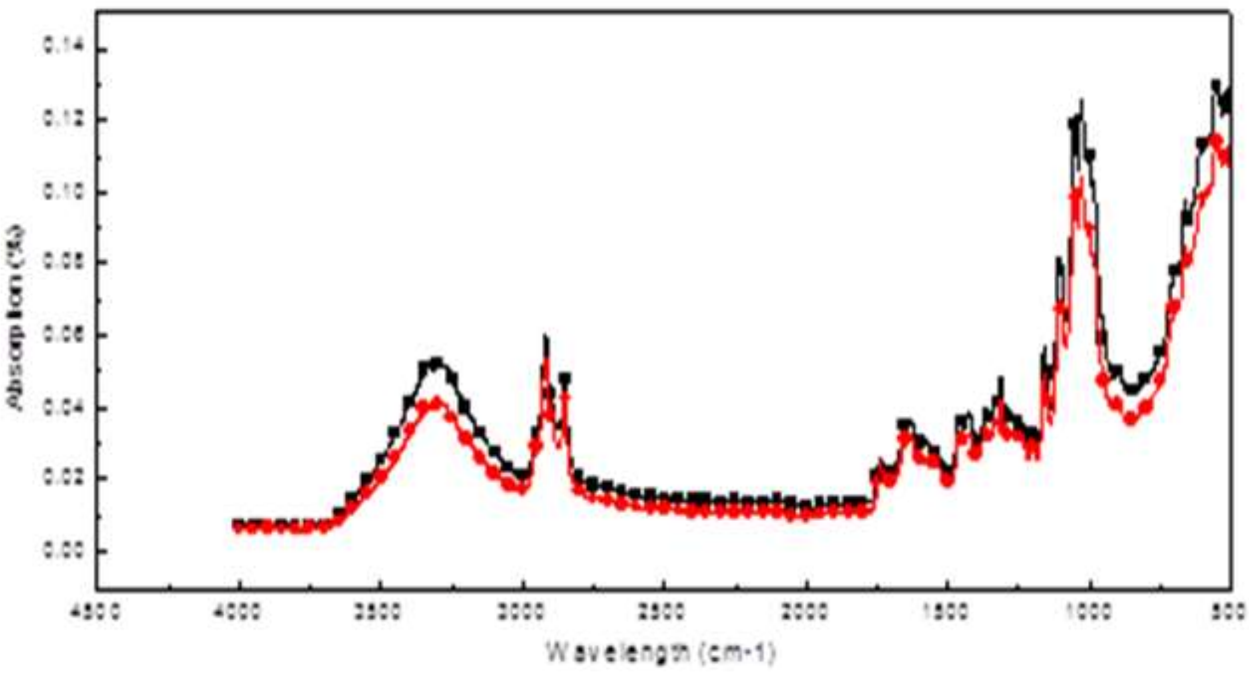

Fig. 3. FTIR spectra of fibre in comparison with cotton (red coloured: cotton, blackcoloured: the present fibre)

Conclusions

The 'Apple of Sodom' stems fibres extracted from its stems by water retting were comparable to other natural fiber such as cotton for most parameters required for clothing such as fineness, moisture high tenacity and elongation at break which makes that it could be considered as an alternative source for natural cellulosic fibres.

Acknowledgements

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Conflicts of Interest

Authors declare no conflict of interest

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