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Determination of Chemical Composition and Study on Physical Properties of *Sansevieria Roxburghiana Lignocellulosic* Fibre

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ABSTRACT

Lignocellulosic fibrous materials account for second largest biopolymers after cellulosic material. The presence of lignocellulose in fibres gives distinct characteristics such as improved strength, stiffness and reinforcement of the material. It also gives distinct identity as a textile fibres i.e., bast fibre. However, there are more than 1000 derivatives of lignocellulosic materials of which only a few are used as textile fibres. In the present study Sansevieria roxburghiana fibres was extracted from the leaf and was used for further studies. The fibre has been mechanically extracted from leaves of the plant using water retting extraction method. The chemical composition of the extracted fibres was determined using TAPPI method and it consisted of cellulose 54±0.2%, hemicellulose 30±0.2%, lignin 12±0.2% and ash content 2±0.2%. Structural analysis and physical properties were also studied by FTIR, SEM, TGA, XRD, tensile and moisture regain measurements, which showed that the fibres have functional groups and the structural features essential for its dyeability, good mechanical properties and ease of processing.

Keywords: Sansevieria roxburghiana fibre, retting, extraction, chemical composition, structural analysis

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INTRODUCTION

Natural fibres have been used to reinforce materials for over 3,000 years. More recently they have been employed in combination with plastics. Many types of natural fibres have been investigated like flax, jute, ramie, etc. but there are many more plants which possess usable fibres and which are yet to be investigated. Advantages of natural fibres over man-made fibres include their low cost, low density, recyclability and biodegradablility [1-3] and their CO_2 neutral life cycle [4]. The Plant fibres are mainly composed of cellulose, hemicellulose and lignin. Other components, usually regarded as surface impurities are pectin and wax substances [5].The most important of the chemical components of plant fibres, is the cellulose. The chemical structure of cellulose contains three hydroxyl groups, which in the macromolecular cellulose structure form hydrogen bonds [6]. Two of these hydroxyl groups form intermolecular bonds, while the third one forms intramolecular hydrogen bonds. Lignin is a complex three-dimensional polymer whose function is to connect elementary fibres in bundles, therefore the more is lignin content, the stiffer is the fibre structure. Hemicellulose which is thought to consist principally of xylan, polyuronide, and hexosan. The chemical composition of the plant fibres depends on the type, age, and origin of the fibre, as well as the extraction method and the final properties of natural fibres depend on their compositions [7].

Sansevieria roxburghiana (SR) Schult & Schult (Agavaceae), called Murva in Sanskrit and Hindi, and Indian bowstring hemp in English is a herbaceous perennial plant with short fleshy stem and stout rootstock, occurring in eastern coastal region of India, Sri Lanka, Indonesia and tropical Africa [9-10]. In India, this plant has been traditionally used for several medicinal purposes such as cardiotonic, expectorant, febrifuge, purgative, tonic in glandular enlargement and rheumatism [11-13].

In the present work, an attempt has been made to investigate the properties of SR fibres with an aim to explore its further potential to be used as textile and composite materials. Overall properties of SR fibre are studied and the characterization of the fibres by FTIR, XRD and TGA has been done along with analysis of chemical composition.

MATERIALS AND METHODS

Materials

The fibre was extracted from the leaves of the Sansevieria roxburghiana (SR) plant which was collected from (Mumbai, India). The SR fibres were used without any pre-treatment or purification. The chemical reagents of analytical grade such as sodium chlorite, glacial acetic acid, sodium hydroxide, sulphuric acid, ethanol, toluene and acetone were procured from SD Fine Chemicals Ltd., India.

Methods

Fibre Extraction

The fibres were extracted from the matured leaves of the Sansevieria roxburghiana plant. The leaves were directly subjected for water retting for 2 weeks. After this the leaves were removed from the water and beaten with a wooden hammer to loosen the fibres. These fibres were washed continuously under running tap water to get clean fibres. These fibres after washing were sun dried, combed and hand brushed to get uniform fibres and make them suitable for physical, chemical and morphological analysis.

Determination of Chemical Composition

The chemical composition of the SR fibres was determined by chopping the fibres into small pieces. These chopped fibres were weighed and Dewaxing was carried out in a mixture of toluene/ethanol (1:1 v/v) in a soxhlet apparatus for 6 h. The acid-insoluble lignin content was determined according to TAPPI T222 om-02 (2002). In this method of determination, lignin (also known as "Klasons lignin") is defined as constituents fibres insoluble in 72% sulphuric acid. The α-cellulose content was determined by TAPPI T203 cm-99 (2002). Ash content was determined by standard method of TAPPI T211 om-02 (2002) [12].

SEM Analysis

The scanning electron micrographs of the fibre surface were recorded on a JEOL JSM 820 microscope (Akishima, Japan), from Institute of Chemical Technology. The fibre samples were sputter coated with platinum before recording the micrographs.

FTIR Analysis

The IR spectra of raw fibre sample was recorded using FTIR spectrophotometer (Shimadzu 8400s, Japan) using ATR sampling technique by recording 45 scans in % transmittance mode in the range of 4000-600 cm^{-1}.

X-Ray Diffraction (XRD)

The crystallinity of raw SR fibre was studied using an X-ray diffractometer (Shimadzu 6100, Japan) equipped with CuK_α radiation ($\lambda = 1.54$ ºA) in the 2θ range 2-50º.The experiments were performed in the reflection mode at a scan speed of 2º/min in steps of 0.02º. The crystallinity index (CrI) of the fibre was calculated according to the Segal empirical method as shown in equation -1 [13].

$$CrI(\%) = \frac{(I_{002} - I_{am})}{I_{002}} \times 100 \quad (1)$$

where I_{002} and I_{am} are the peak intensities of crystalline and amorphous materials, respectively.

Thermogravimetric Analysis

A sample of SR fibres was cut into small pieces and thermo gravimetric analysis (TGA) was carried out. The thermograms were recorded on Shimadzu 60H DTG machine using aluminium pan between temperature range 30-500 ^{0}C under the inert atmosphere of nitrogen at a flow rate of 50ml/min.

Tensile Properties and Moisture Regain

The tensile properties of the SR fibres are measured in terms of the breaking load, percentage elongation at breaking using Tinius Olsen tensile testing machine. A gauge length of 20 mm with a speed of 5 mm/min were used for the testing. Approximately 15 fibres were tested for their tensile properties. To identify the moisture content and moisture regain values, the fibre sample was tested according to ASTM standard method 2495.

RESULTS AND DISSCUSSION

Determination of Chemical Composition

The chemical composition of SR fibre extracted by mechanical extraction method is studied. The results indicate that raw fibre was found to be composed of cellulose54±0.2%, hemicelluloses 30±0.2%, lignin 12±0.2%, ash 2±0.2% and extractives 2%±0.2%. Chemical compositions of existing natural fibres are also listed below in Table. 1, and are compared to the experimental found chemical composition of Sansevieria roxburghiana (SR) fibre. It was observed that the chemical composition of the SR fibre has been fairly compared with the chemical compositions of other lignocellulosic fibres and thus it does have great potential to be used as a textile material and also in composite materials, as other fibres.

SEM Analysis

Scanning electron micrograph (SEM) shown in Fig.1 (a & b) of Sansevieria roxburghiana (SR) fibres obtained by mechanical extraction process showed a thick layer of deposits on the fibre surface which may be composed of wax, lignin, pectin and hemicellulose, protecting the cellulosic fibres inside as reported in the literature in case of some lignocellulosic fibres. The diameter of the fibre was determined on scanning electron microscope and corresponding aspect ratio (L/D) value is presented in Table -2. Such a high L/D of about 957.9 indicates good fibre length properties of this fibre.

Table -1 Comparison of Chemical Compositions of Commonly Available Natural Fibres and Sansevieria Roxburghiana (SR) Fibre

Fibres	Cellulose %	Lignin %	Hemicellulose %	Ash %
Sansevieria roxburghiana	54	12	30	2
Cotton	92	-	6	1
Flax	72	13	13	5
Jute	65	13	22	0.8
Sisal	73	11	13	1
Hemp	74	4	18	0.8
Coir	43	45	1	3
Ramie	76	1	15	0.2
Kapok	13	-	-	-
Abaca	60	8	15	3
Henequen	77	13	6	2

Table -2 Physical Properties of the Fibres

Fibre	Average length L (cm)	Average diameter D (cm)	Aspect ratio L/D
Raw Sansevieria roxburghiana	10	0.01045	957.9

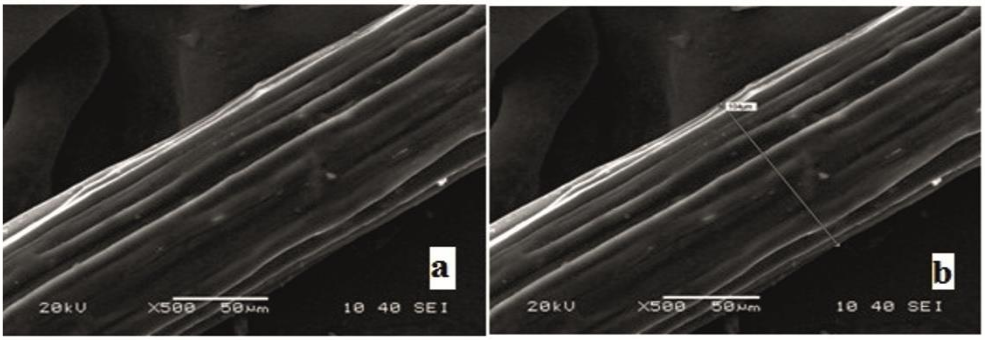

Fig. 1 (a-b) SEM images of SR Fibre

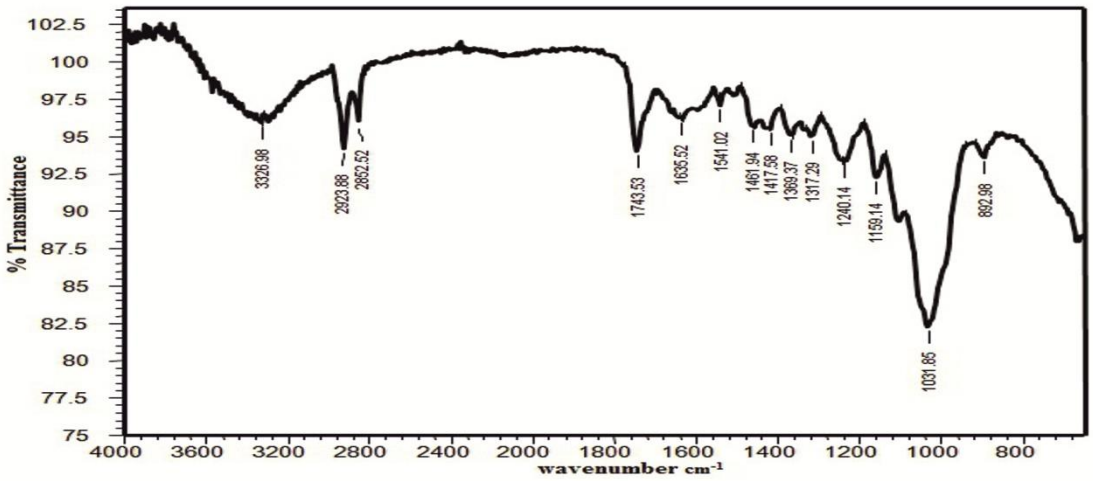

Fig. 2 FTIR spectra of SR Raw Fibre

FTIR Analysis

The FTIR spectrum of the raw SR fibres is presented in Fig. 2, which exhibited a broad band in the region of 3400 to 3300 cm^{-1}asssigned to the O-H stretching vibration of the OH group in cellulose molecules. A peak at 1743 cm^{-1} is attributed to the C=O stretching vibration of the acetyl and uronic ester groups, from pectin, hemicelluloses, or the ester linkage of the carboxylic group of ferulic and p-coumaric acids of lignin and/or hemicelluloses [14-15].The absorption peak was observed at 1635 cm^{-1} which reflects the stretching of the O-H group. The absorption peak at 1240 cm^{-1}in the raw fibre is attributed to the C-O out of plane stretching vibration of the acetyl group in the lignin [16].

The peak at 892 cm^{-1} attributes C-H rocking vibrations which is assigned to β-glucosidic linkage. Similarly, the peaks at 1417, 1369 and 1317 cm^{-1} present in raw fibre are associated with the bending vibrations of $–CH_2$, C-H, and C-O of cellulose. The peak at 1031 cm^{-1} assigned to aromatic C-H in plane deformation and a peak at 1159 cm^{-1} is due to C-O-C asymmetrical stretching in cellulose and hemicelluloses [12, 17]. Possible assignment of the functional groups is shown in Table 2.

XRD Analysis

The X-Ray diffraction pattern of raw fibre is shown in Fig. 3. The diffractogram showed two reflections, corresponding to 2θ values of around 16 º and 22.5º, respectively. Among these, the low angle reflection (16º) was of low intensity, representing $I_{(am)}$ of amorphous material and the other reflection (22.5º) had higher intensity, and it represented $I_{(002)}$ of crystalline material in cellulosic fibre. The degree of crystallinity (CrI%) was calculated using eq (1) described in experimental part of this paper and it was found to be 72%. This indicates that the crystallinity of the fibre was quite high and hence it is expected to exhibit good tensile strength. Crystallinity index of SR fibre is compared with the available natural fibres and is described below in Table. 3.

The crystallinity of the SR fibre was fair enough when compared to the crystallinity of other lignocellulosic fibres and thus it must have great potential to be used as a textile material and also as a reinforcement material in composites.

TGA Analysis

The thermogram of SR fibre is shown in Fig. 4, and it can be observed that the thermal degradation of SR fibre exhibited a three - step process. Yang et al. [18] attributed this behaviour to the differences in the chemical structures, of different components of wood fibres which decompose at different temperatures. SR fibre being lignocellulosic material is a composite structure of different types of components, and it will degrade below 400 ºC with wax, pectin, and hemicelluloses degraded at 180 ºC, cellulose at around 300 ºC, and lignin at 400 ºC. The first, second and third stages were found in the temperature ranges of 30–120 ºC, 200–270 ºC and 270 – 400ºC respectively [19]. The first decomposition temperature ranges of 30– 120 ºC corresponded to the evaporation of moisture and weight loss was 9.03 %. The second decomposition step of raw fibres in the temperature range of 200 – 270 ºC indicated the loss of hemicellulose and some part of the lignin taking the total weight loss 11.91%. The third decomposition step corresponding to the decomposition of cellulose was observed in the range of 270 –400 ºC causing maximum weight loss of 58.80 %. Similar observation was also made in the case of many other natural fibres. Since the fibre had very good thermal stability upto 270 ºC, it does have potential to be used as textile material and thus will have a large applicability in various sectors of technical or smart textiles [20, 21].

Tensile Properties and Moisture Regain

The fibres showed good tensile strength properties exhibiting 260.5 gf with elongation at break at 1.63% and moisture regain of 8.5-9%. In raw fibre, the strain remains intact in the cellulose chains because of presence of hemicellulose in the fibre structure which keeps the cellulose chains dissociated from each another. Hemicellulose acts as the barrier because of which the chains are in the state of strain [22].This is the reason why the fibres exhibited good tensile strength and elongation. Moisture regain capacity of the fibre was also good due to the abundant presence of hydroxyl groups.

Table -3 Possible Assignment of Frequencies (cm^{-1}) of Functional Group in Raw SR Fibre

Raw SR fibre (cm^{-1})	Possible assignment of functional groups
3326	O-H stretching of α-cellulose
2923	C-H stretching
2852	CH_2 Symmetric Stretching (cellulose & hemicellulose)
1743	C=O (stretching of carbonyl ester) (Hemicellulose)
1635	Adsorbed OH water
1541	Aromatic skeletal vibrations of benzene ring in lignin.
1417	CH_2 bending
1369	C-H symmetrical deformation
1317	O-H in plane bending
1240	C-O Stretching of acetyl (hemicellulose)
1159	C-O-C asymmetrical stretching (cellulose & hemicellulose)
1031	C-O stretch/C-C stretch
892	β - glucosidic linkage

Table-3 Crystallinity Index of Existing Natural Fibres and SR Fibre

Fibres	Crystallinity index %
Sansevieria roxburghiana	72
Cotton	65
Flax	86
Jute	58
Sisal	70
Hemp	87
Coir	44
Ramie	62
Kapok	35
Abaca	68
Henequen	60

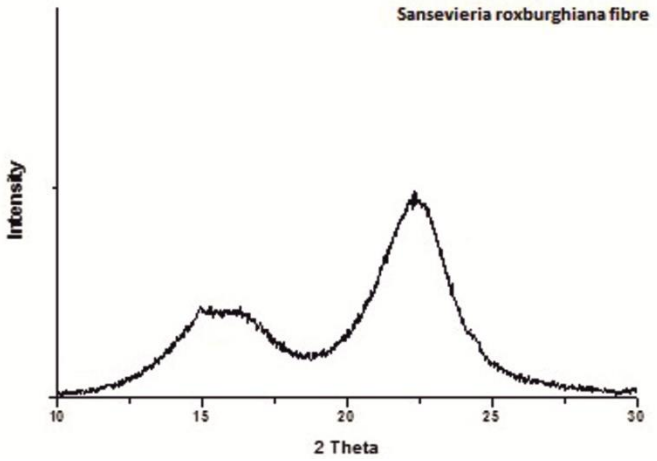

Fig. 3 XRD Diffraction Pattern of SR Fibre

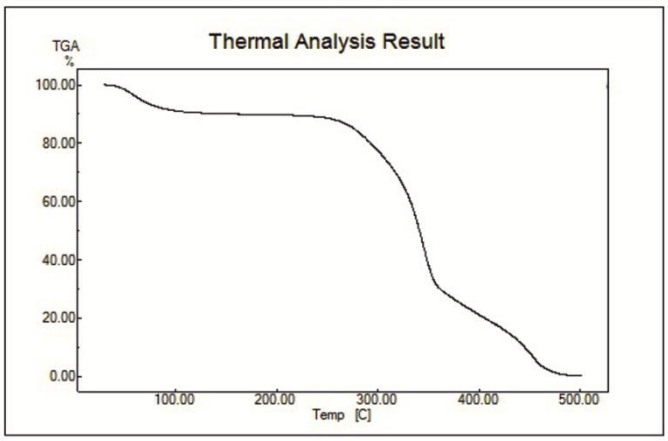

Fig. 4 Thermogram of Raw SR Fibre

CONCLUSION

The natural lignocellulosic fibre which was mechanically extracted from SR plant stem has cellulose content around 54% enabling it to be suitable for the textile applications. The XRD analysis showed that the fibres have a crystallinity of 72% which is similar to cotton. TGA analysis showed that the fibre had a very good thermal stability upto 270^{o} C. The tensile strength was also good with respect to other commonly available natural fibres. These properties show that, the fibre has a great potential to be used as a textile material. Although this plant is mostly grown in wild, if this fibre gets commercialized then there is likely hood that the farmers can also get a new source of income by growing this plant on a large scale, as it requires very less maintenance and it is easy to grow.

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