Characteristics of sugarcane fibres

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Sugarcane fibres have been extracted from bagasse by 0.1 N NaOH treatment and their characteristics are evaluated. The fibres show moderate crystallinity, with crystallinity index in the range 63–68%. The SEM photographs reveal that the fibre is composed of bundle of cells encrusted by cementing material, outside bundles are composed mainly of short thin walled parenchyma cells. The fineness of fibre varies between 25tex and 35tex. The moisture regain of fibre lies between 13% and 18%. The tenacity of the fibres lies between 12 g/tex and 18 g/tex and the percentage breaking elongation varies between 2.5% and 3.5%. The fibre possesses moderate amount of elastic recovery at 50% of breaking extension. The torsional rigidity of fibres is quiet high ranging between 95 dyne-cm² and 330dyne-cm², indicating that the fibre has high rigidity to twisting and is not suitable for making yarn. The flexural rigidity of fibres is quite low ranging from 0.015 g cm² to 0.032 g cm².

Keywords: Bagasse, Crystallinity index, Moisture regain, Sugarcane, Tenacity

1 Introduction

Sugarcane grass is a renewable, natural agricultural resource because it provides sugar, besides myriad of products/co-products with ecological sustainability.

The solid fibrous part (bagasse) is the major by-product of sugarcane industry1 Sugarcane bagasse, one of the largest cellulose based agro industrial by-products and fibrous residue left after the sugarcane, is crushed in the factories of the sugar and alcohol industry, and is widely available renewable source2. About 54 million tons of dry bagasse is produced annually throughout the world3. For a long time bagasse has been used as fuel for factory. Now a day it is used as a biofuel and as a renewable resource in the manufacture of pulp and paper products and building materials. Bagasse is also used as a source of renewable power generation and for the production of bio-based materials4.

In a study, the fibres are extracted from the bagasse. Bagasse is mainly composed of an outer rind and inner pith. Rind, which mainly consists of fibres, can be separated from lignin by alkali treatment. The removal of lignin depends upon the concentration of NaOH which ultimately decides the characteristics of fibre5. The fibres are used for many applications, such as nonwovens, composites as well as yarn6.

In this investigation, an attempt has been made to study the characteristics of sugarcane fibres produced from different varieties cultivated in western part of Maharashtra, India. The extraction of fibres is carried out in 0.1 N NaOH solution.

2 Materials and Methods

2.1 Materials

Four different sugarcane varieties, namely CO86032, COM265, COC671 and COVSI9805 were selected. For each variety three levels of growth period (12, 13 and 14 month) were chosen for monitoring the changes in the properties.

2.2 Methods

2.2.1 Extraction of Sugarcane Fibres

The samples were subjected to conventional miniature juice extractor wherein juice was separated from the sugarcane. The residue left after the extraction of juice called bagasse was collected for extraction of fibres. The soft-core part pith was removed from the bagasse manually to get outer hard rind. The rind was then cut across the length so that the cut portions are free from the nodes.

The samples were then subjected to hot water treatments (material:liquor ratio 1:50). In this process, the samples were kept in hot water at around 90°C for 1h for removal of coloring matters and sugar traces. The samples were then dried under the sunlight. Finally, samples were subjected to chemical
extraction. In this process, samples were treated with 0.1N NaOH solution, at boiling water temperature for 4 h under atmospheric pressure. The material: liquor ratio taken for this process was 1:100. During the tenure of this treatment, samples were subjected to vigorous stirring for effective separation of fibres. The well-separated fibres were then dried.

2.2.2 Testing

The fibres were then subjected to different tests for study of the characteristics.

Crystallinity

The crystallinity study was carried out using Xpert Pro Panlytical X-ray diffractometer with wavelength of 1.5405980Å (Cu-K-Alpha1). A sample of fibre was cut into small pieces by scissor and then ground into fine powder. Around 250 mg of powdered sample was placed in sample holder. Segal crystallinity index was calculated by the following equation:

\[
CI = \left( \frac{I_{002} - I_{18}}{I_{002}} \right) \times 100
\]

where \(I_{002}\) is the intensity corresponding to 002 peak; and \(I_{18}\) is the intensity corresponding to 20 value at 18°.

Morphology

The longitudinal and cross-sectional characteristics of fibres were studied by microscopic analysis. The fibres were observed under the scanning electron microscope (Specifications JEOL JSM6360).

Fibre Fineness

The fineness of sugarcane fibre was measured by gravimetric method. This test was carried out according to ASTM D1577-07 standards. A bundle of fibres was weighed and the total length of fibres in a bundle was measured.

Moisture Absorption

The moisture absorption in the sugarcane fibres was measured by the oven dry method. This test was carried out according to ASTM D 2495 standards. The moisture regain was calculated using the following formula:

Moisture regain (%) = (Weight of water present/Oven dry weight) \times 100

Tensile Properties

The tensile testing was carried out on the Instron 5565 tester. This test was conducted according to the ASTM D 3379 standard (specimen length 25cm, speed of testing 2mm/min, no. of observations 25).

Elastic Recovery

The given samples of fibres were subjected to the recovery properties. Elastic recovery test was carried out on Instron 5565 tester according to ASTM standard. The test was carried out at gauge length 25 mm and rate of loading 2mm/min. The specimen was extended to 50% of its breaking load.

Torsional Rigidity

The torsional rigidity values were measured dynamically by observing the oscillations of torsion pendulum which consists of a bar suspended by the fibre. The torsional rigidity (T.R.) was calculated using the following formula:

\[ T.R. = \frac{8\pi^3 IL}{T^2} \]

where \(I\) is the moment of inertia of rod about the fibre axis, as shown below:

\[ I = m \left( \frac{l^2}{12} + \frac{r^2}{4} \right) = 0.267 \text{ g cm}^2 \]

where \(m\) is the weight of rod; \(l\), the length of rod; \(r\), the radius of rod; \(L\), the length of a fibre; and \(T\), the period of oscillation.

The torsional rigidity values were calculated by subjecting the fibre to 4 torsional oscillations, corresponding to which the damping was negligible. The time for torsional oscillations was measured.

Flexural Rigidity

The method suggested by Peirce for studying the deformation of loops under the applied load was used for measuring the flexural rigidity of fibres. A circular ring of fibre was suspended and loaded by a rider. The deviation of ring from its circular shape in terms of increase in diameter along the direction of lower end of the ring was measured. The formula for calculating the flexural rigidity is given below:

\[
FR = 0.0047mg \left( 2\pi r \right)^2 \left( \frac{\cos\theta}{\tan\theta} \right)
\]

where \(mg\) is the weight of rider; \(r\), the radius of ring (0.8cm in this experiment); \(\theta = 493d/2\pi\); and \(d\), the deflection of lower end of the ring.

3 Results and Discussion

The results were analyzed by two-way ANOVA technique. The characteristic properties of sugarcane fibres are discussed hereunder.
3.1 Crystallinity
The statistical analysis reveals that there is no significant difference in crystallinity indices between varieties as well as maturity levels, indicating that crystallinity is independent of variety as well as maturity level. The crystallinity indices of samples are summarized in Fig. 1. The crystallinity values lie between 63% and 68%, indicating that the fibre has moderately high level of crystallinity.

3.2 Longitudinal and Cross-sectional Views
The SEM photographs of sugarcane are displayed in Fig. 2. It is observed that there is more encrusting material between the ultimate cells which is revealed in the cross-sectional view of the fibre. The longitudinal view shows that the outside bundle is composed mainly of short thin walled parenchyma cells.

3.3 Fibre Fineness
The fineness (tex) values of sugarcane fibre of different varieties are summarized in Fig. 3. The statistical analysis reveals that fineness of fibre varies significantly between varieties as well as maturity level. The tex value increases with maturity level for COM265 and COC671 varieties. It is observed that tex value of CO86032 is high compared to rest of varieties, and the value is found to decrease with the maturity period. Due to high tex value this fibre is more suitable in manufacturing of nonwovens; this can be used as reinforcing material in composites for various applications.

3.4 Moisture Absorption
The statistical analysis reveals that there is no significant difference in moisture regain between varieties as well as maturity levels. The moisture regain values of fibres are summarized in Fig. 3. For COVSI 9805, COC671, CO86032 varieties, the moisture regain marginally decreases with maturity level while in case of COM265 no trend is observed. In general, the moisture regain values for all cases lie between 13% and 18%.

3.5 Tensile Properties
The tensile testing was carried out on the Instron 5565 tester. The results are summarized in Fig. 4. The statistical analysis reveals that the tensile strength and elongation vary significantly between varieties and maturity levels, indicating that tensile properties are dependent on variety as well as maturity level. The tenacity decreases with increase in maturity period COVSI 9805 and COM265 varieties. The breaking extension of this fibre lies between 2.5% and 3.5%. The relatively high values of tenacity indicate that sugarcane fibre is strong cellulosic fibre in category of coir.
3.6 Elastic Recovery

The elastic recovery values are summarized in Fig. 5. The statistical analysis reveals that there is no significant difference in elastic recovery between the varieties but it varies significantly between the maturity levels. The elastic recovery varies between 50% and 60%, which means that the fibre shows moderate elastic recovery at given level of extension.

3.7 Torsional Rigidity

The experimental values of torsional rigidity are given in Fig. 5. The statistical analysis reveals that
torsional rigidity varies significantly between varieties as well as maturity level. The experimental results reveal that the torsional rigidity of this fibre at 0.1 N NaOH concentration is extremely high ranging from 95 dyne-cm$^2$ to 330 dyne-cm$^2$, indicating that the fibre is very rigid to spin.

3.8 Flexural Rigidity

The experimental values of flexural rigidity are summarized in Fig.5. The statistical analysis reveals that flexural rigidity varies significantly between varieties as well as maturity levels. The flexural rigidity values are quite low ranging from 0.015 g-cm$^2$ to 0.032 g-cm$^2$; this enables the applications such as manufacturing of nonwovens. The variety COC671 shows significantly high value compared to the rest.

4 Conclusion

4.1 The fibres are moderately highly crystalline with crystallinity values lying between 63% and 68%.
4.2 The SEM photographs reveal that the fibre is composed of bundle of cells encrusted by cementing material, outside bundles are composed mainly of short thin walled parenchyma cells.
4.3 The fineness of fibre varies between 25 tex and 35tex.
4.4 The moisture regain of fibre lies between 13% and 18%.
4.5 The tenacity of the fibres lies between 12 g/tex and 18 g/tex and the breaking elongation varies between 2.5% and 3.5%, which relates to the high crystallinity.
4.6 The fibre possesses moderate amount of elastic recovery at 50% of breaking extension.
4.7 The torsional rigidity of fibres is quiet high ranging between 95 dyne-cm$^2$ and 330dyne-cm$^2$, indicating that the fibre is very rigid to spin.
4.8 The flexural rigidity of fibres is quite low ranging between 0.015 g cm$^2$ and 0.032 g cm$^2$.

In general, there is difference in properties of fibres between varieties as well as between maturity levels and as such no specific trend observed. The properties of sugarcane fibres are closer to the properties of cellulosic coir fibres. Hence, this fibre can be used for making nonwoven mats. The nonwovens can be impregnated in resins for making composites for various applications.

References

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