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Nature Cellulose Fibre Extracted from Different Cotton Stalk Sections by Degumming

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Abstract
Bast fibres are important because they have biodegradable and eco-friendly characteristics. In this paper, natural cellulose fibre extracted from cotton stalk by degumming was investigated. On the basis on the chemical propertiess of cotton stalk bark, a cotton stalk was divided into three sections before fibres were extracted. Through an orthogonal experiment, the extracting conditions of fibres from different sections were obtained. The flexibility and linear density of the fibres extracted were then tested, and the morphology of the fibres was observed by SEM. It was shown that the flexibility and fineness of fibres from the different sections were various. The singular unit fibrel morphology of fibres from different sections had a visible difference.

Key words: *fibre extraction, cotton stalk, residue gum content, morphology.*

Introduction

Several agricultural by products such as wheat and rice straw, sugarcane stalks, pineapple leaves and sorghum stalks and leaves have been studied as a potential source for fibres in an effort to add value to the crops and, at the same time, find alternative sources for fibres [1 - 3]. Natural cellulose fibres obtained from these sources are reported to have properties similar to those of cellulose fibres in current use. Fibres obtained from agricultural byproducts have been processed into various products including textiles and also used as reinforcement in composites [4, 5]. The cotton plant residue left after harvesting is mostly comprised of stalks, and it has been estimated that nearly 2.5 - 3.5 tons of stalks are generated per acre of cotton grown depending on the type of harvester used to harvest cotton fibres [6]. Currently cotton stalks are mostly burnt on the ground since they harbour diseases that could affect future cotton crops. However, cotton stalks are rich in cellulose and some attempts have been made to study the potential of utilising cellulose in stalks as a source for paper, industrial fuel, and as regenerated cellulose for rayon [7 - 9]. The outer barks of cotton stalks were treated by various extraction conditions to get natural cellulose fibres [10, 11]. Earlier reports on the application of the alkali-H_2O_2 one-bath process in dyeing and finishing were made [12]. In this work, cotton stalks with bark were treated directly by alkali-H_2O_2 to obtain natural cellulose fibres.

Experimental

Material

The cotton stalk was from Baqiao County of Shaanxi Province, China. The cotton stalk was divided into three sections (see ***Figure 1***), of which the 1st section of the cotton stalk was under ground, the 2nd section - 25 cm long above the ground, and the 3rd section was more than 25 cm above the ground. The chemical properties of different cotton stalk bark sections were tested

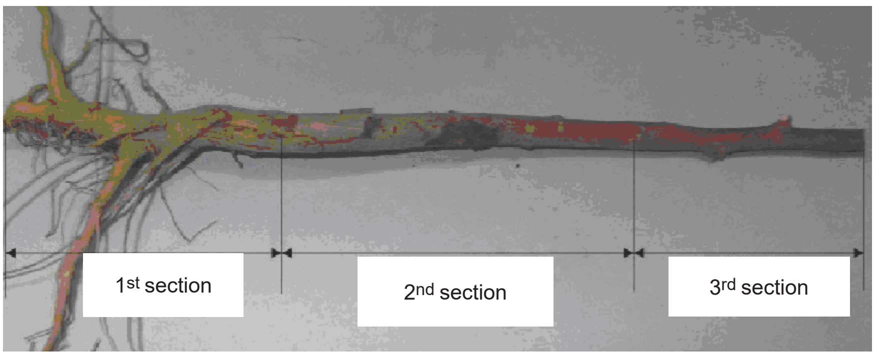

Figure 1. *Three sections of cotton stalk.*

Table1. Properties of different cotton stalk bark sections

	1st section	2nd section	3rd section
Wax, %	3.61	1.02	0.96
Water soluble, %	17.66	16.10	14.70
Pectin, %	4.67	3.84	2.86
Hemicellulose, %	26.99	24.22	23.34
Lignin, %	23.35	22.54	21.58
Cellulose, %	23.72	32.28	36.56

Table 2. Orthogonal experimental condition.

Level	NaOH content (A), g/l	Temperature (B), °C	Time (C), h	H_2O_2 content (D), g/l
1	25	80	1.5	8
2	30	90	2.0	10
3	35	100	2.5	12

according to Chinese Standard GB5888-86, the results of which are listed in ***Table 1***. It is shown that the 1st section of the cotton stalk has less cellulose and more gum compared with the 2nd and 3rd sections.

Sample preparations

Each cotton stalk section was treated by alkali solution under orthogonal conditions. The cotton stalks treated were washed by water thoroughly, and nature cellulose fibres were obtained.

The orthogonal experimental conditions are shown in ***Table 2***. Alkali treatment was carried out at M:L ratio 1:50.

Testing

The residue gum content of fibres (RG) in % was calculated using the following formula (1).

Table 3. Results of the fibres.

Experiment No.	Factor/level				Residue gum content,%		
	A	B	C	D	1st section	2nd section	3rd section
1	1	1	1	1	6.6	6.2	5.8
2	1	2	2	2	6.4	6.7	5.4
3	1	3	3	3	6.2	8.2	5.3
4	2	1	2	3	7	6.0	5.6
5	2	2	3	1	6.4	6.6	5.9
6	2	3	1	2	5.7	5.9	6.8
7	3	1	3	2	7.4	5.4	6.1
8	3	2	1	3	6.5	6.4	7.4
9	3	3	2	1	8.8	7.6	5.7

Table 4. Object analysis of fibre from different sections.

Factor	Residue gum content		
	Fibres from 1st section	Fibres from 2nd section	Fibres from 3rd section
A	k_{1A} = 6.400	k_{1A} = 7.033	k_{1A} = 5.5
	k_{2A} = 6.367	k_{2A} = 6.167	k_{2A} = 6.1
	k_{3A} = 7.567	k_{3A} = 6.467	k_{3A} = 6.4
	Max difference = 1.2	Max difference = 0.866	Max difference = 0.9
B	k_{1B} = 7.000	k_{1B} = 5.867	k_{1B} = 5.833
	k_{2B} = 6.433	k_{2B} = 6.567	k_{2B} = 6.233
	k_{3B} = 6.900	k_{3B} = 7.233	k_{3B} = 5.933
	Max difference = 0.567	Max difference = 1.366	Max difference = 0.4
C	k_{1C} = 6.267	k_{1C} = 6.167	k_{1C} = 6.667
	k_{2C} = 7.400	k_{2C} = 6.767	k_{2C} = 5.567
	k_{3C} = 6.667	k_{3C} = 6.733	k_{3C} = 5.767
	Max difference = 1.133	Max difference = 0.6	Max difference = 1.1
D	k_{1D} = 7.267	k_{1D} = 6.800	k_{1D} = 5.8
	k_{2D} = 6.500	k_{2D} = 6.000	k_{2D} = 6.1
	k_{3D} = 6.567	k_{3D} = 6.867	k_{3D} = 6.1
	Max difference = 0.767	Max difference = 0.867	Max difference = 0.3

$$RG = [(M_1 - M_2)/M_1]\times 100 \text{ in \%} \quad (1)$$

where, M_1 and M_2 are the gum content of the raw cotton stalk bark and that of degummed samples, respectively.

The flexibility of fibres (D) in t.p.m·tex was tested with a handle twister. Fibre bundles 40 mm in length were cut by a cutter, and then weighed, being about 3 mg for each test. The flexibility of fibres was calculated according to ***Equation 2*** [13].

$$D = \frac{n \times 40 \times 0.1}{L \times G} \quad (2)$$

where, n is the twist number of the fibre bundle broken, L the test length of the fibre bundle, mm, and G is the weight of the fibre bundle, mg.

The fibres were conditioned in a standard testing atmosphere of 21 °C and 65% relative humidity for at least 24 h before testing. The linear density of the fibres was measured in terms of tex by weighing a known length thereof. Tex is defined as the weight of the fibres in grams per 1000 m thereof.

The morphology of the natural cellulose fibre was observed with a JSM-6460LV scanning electronic microscope (JEOL Co., Ltd., Japan). The fibres were coated with gold, and then the testing was done.

Results and discussion

Results of orthogonal experiment

The residue gum content and flexibility of the natural cellulose fibres from each cotton stalk section under orthogonal conditions are shown in ***Table 3***.

Using mathematical statistic theory [14], an object analysis of the residue gum content of the fibres is shown in ***Table 4***. The factors influencing the residual gum content of fibres from the 1st section are in the following order: NaOH content > time > H_2O_2 content > temperature, and the optimum condition for fibres from the 1st section is NaOH content 30 g/l, temperature 90 °C time 1.5 h, and H_2O_2 content 10 ml/l.

The factors influencing the residual gum content of fibres from the 2nd section are in the following order: temperature > H_2O_2 content > NaOH content > time, and the optimum condition is NaOH content 30 g/l, temperature 80 °C, time 1.5 h, and H_2O_2 content 10 ml/l.

The factors influencing the residual gum content of fibres from the 3rd section are in the following order: time > NaOH content > temperature > H_2O_2 content. The optimum condition for fibres from the 3rd section is NaOH content 30 g/l, temperature 80 °C, time 2 h, and H_2O_2 content 8 ml/l.

For the fibres from different sections of the cotton stalk, those extracted from optimum conditions are various, because the properties of the different cotton stalk sections are not the same.

Property of fibres extracted

Under optimum conditions, the flexibility and linear density of the fibres extracted are listed in ***Table 5***. It is shown that the fibres extracted from the 1st section are coarser than those from the 2nd and 3rd. Moreover the fibres from the 1st section have low flexibility compared with those from the 2nd and 3rd sections. To simulate the use of the extracted fibres in various fields, the cotton stalk should be divided into sections before degumming. In general, the linear density of natural cellulose fibres from different sections is coarse, which leads to poor spinnability when the fibres are used directly for spinning processing.

Morphology of fibres extracted

Figure 2 shows the morphology of fibres from different sections. It is shown that the fibres are "technological", that is, singular unit fibres bonded together by a non-cellulose substance[1]). ***Figure 3*** shows the morphology of a singular unit fibre of the fibres. It is seen that the singular unit fibre surface of fibre from the 1st section is not regular compared with those from the 2nd and 3rd. The singular unit fibre of fibres from the 1st section has a groove, and that of fibres from the 2nd section has a distortion. Because the fibres are "technological", dugumming parameters influence the fibre properties, such as linear density and flexibility. For natural cellulose fibres from a cotton stalk obtained by degumming, the cotton stalk should be divided into at least two sections to attain the fibres, because of the distinct property difference between cotton stalk bark sections, of which the first section is the underground section, and the second is the above-ground section.

Conclusions

The cellulose content of the 1st section of cotton stalk bark is lower. For fibres from the different sections of the cotton stalk, those extracted optimum conditions are varied. Fibres from the 1st section have low flexibility compared with those from the 2nd and 3rd sections. The singular unit fibre of fibres from the 1st section has a groove, and that of fibres from the 2nd section has a distortion. Therefore the cotton stalk should be divided into two sections to obtain natural cellulose fibres by degumming. The first section is the underground, while the second is the above-ground one.

Table 5. *Properties of the fibres.*

Fibres from	Flexibility, t.p.m·tex	Linear density, tex
1st section	1.97	3.26
2nd section	2.07	2.89
3rd section	2.42	2.47

Editorial note

1. *"Technological fibre" is a singular unit fibre bonded together by non-cellulose substance, could be used for spinning only by blending with other fibres, such as cotton, polyester fibre. However, because of its poor flexibility resulting in poor spinning-ability, technological fibre is preferably soften to improve its flexibility and spinning-ability before blending(spinning).*

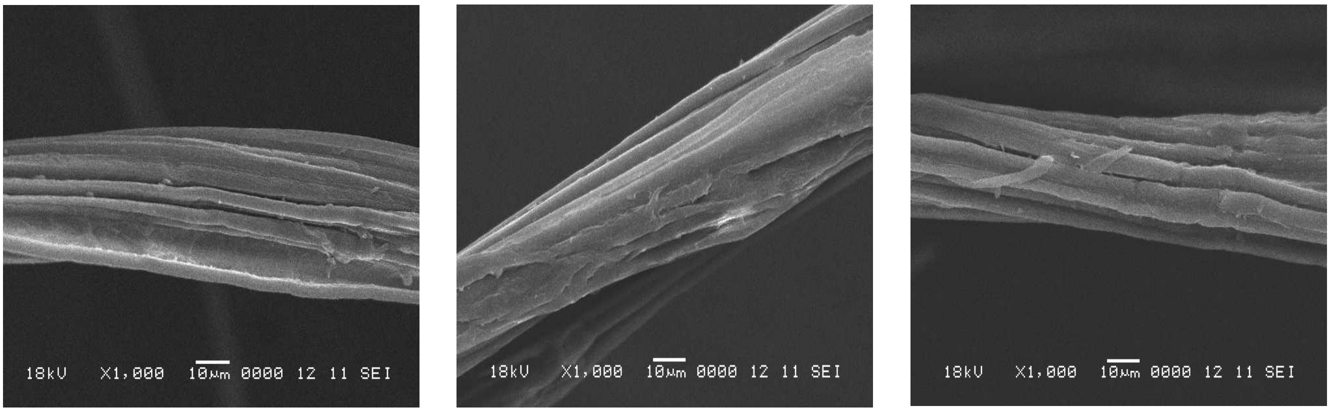

Figure 2. *Morphology of the fibres; a) fibres from 1st section, b) fibres from 2nd section, c) fibres from 3rd section.*

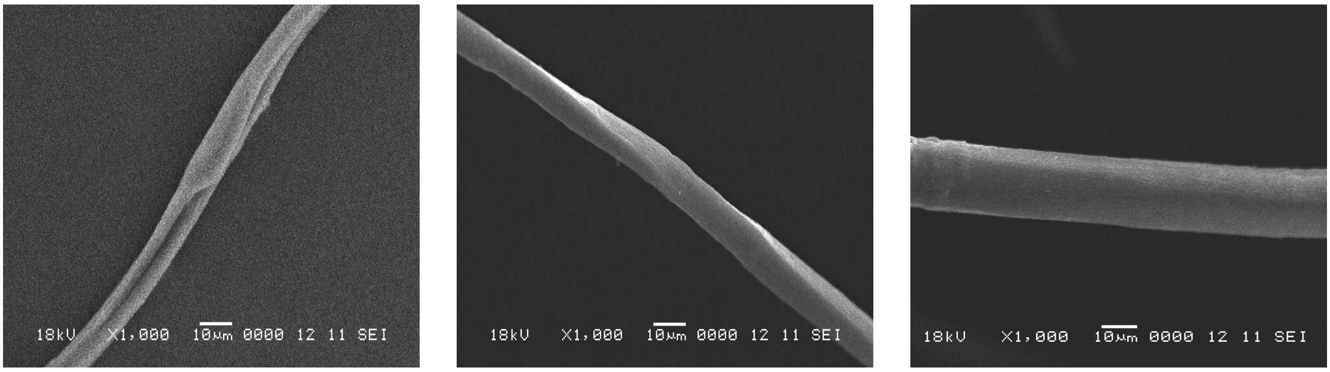

Figure 3. *Morphology of singular unit fibre; a) fibre from 1st section, b) fibre from 2nd section, c) fibre from 3rd section.*

Acknowledgements

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Regerences

1. Reddy N, Yang Y. Properties and potential applications of natural cellulose fibers from cornhusks. *Green Chem.* 2005; 7: 190-195.
2. Reddy N, Yang Y. Properties of high quality long natural cellulose fibers from rice straw. *J. Agric. Food Chem.* 2006; 54: 8077-8081.
3. Shyamal B, Debasis N, Sanjor D. Utilization of pineapple leaf agro-waste for extraction of fiber and the residual biomass for vermicomposting. *Indian Journal of Fibre & Textile Research* 2011, 36: 172-177.
4. Huda S, Yang Y. Chemically extracted fibers as reinforcement in light-weight poly(propylene) composites. *Macromol. Mater. Eng.* 2008**,** 293: 235-243.
5. Doraiswamy I, Chellamani P. Pineapple–leaf fibers. *Text. Prog.* 1993; 24**:** 1-25.
6. Gomes RS, Wilson PN, Coates WE, Fox RW. Cotton (*Gossypium*) plant residue for industrial fuel. An economic assessment. *Ind. Crop. Prod.* 1997; 7: 1-8.
7. Akdeniz CR, Acaroglu M, Hepbasli A. Cotton stalk as a potential energy source, *Energy Source* 2004; 26: 65-75.
8. Fahmy Y, Ibrahim H. Cotton stalks as a fibrous source for fine paper and rayon: Part I: Bleached pulp for fine paper. *Cell. Chem. Technol.* 1976; 10: 723-735.
9. Fahmy Y, Ibrahim H. Cotton stalks as a fibrous source for fine paper and rayon: Part II: Dissolving pulp for viscose rayon. *Cell. Chem. Technol.* 1979; 13: 385-390.
10. Reddy N., Yang Y., Properties and potential applications of natural cellulose fibers from the bark of cotton stalks. *Bioresource Technology*. 100(2009), pp. 3563-3569.
11. Li L, Sheng G, Zhang S, Sun J. Preparation and properties of cotton stalk bark fiber. *Journal of Materials Science and Engineering with Advanced Technology* 2011; 4: 57-68.
12. Hyung-Min C. One-Bath Dyeing and Nonformaldehyde Durable Press Finishing of Cotton Using Dialdehyde and a Monochlorotriazinyl Reactive Dye. *Textile Res. J.* 2002; 72: 469-473.
13. Xu PP. Study on the refining modifying and spinning properties of jute fiber. Master Thesis, Donghua University, Shanghai, 2007.
14. Wang RX. Mathematical Statistic, Xi'an Jiaotong University Press, Xi'an, 1987, pp. 148-151.

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