Evaluation of Properties of Natural Bamboo Fiber for Application in Summer Textiles

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Abstract: Properties of natural bamboo fibers produced by Neosinocalamus affinis were studied. The natural bamboo fiber was evaluated for its mechanical properties, moisture absorption and thermal properties using Optical Contact Angle Meter (OCA), Thermo-gravimetric Analyzer and Electronic Fiber Strength Tester. Flax and jute fibers were selected as control fibres. The results show that the bamboo fiber is high in tenacity, but low in elongation, similar to all bast fibers. By testing, it was found that the bamboo fiber is low in density with a small contact angle when water dropped, since it is constituted by cellulose along with lignin and hemicellulose. The bamboo fiber has advantages in terms of moisture absorption, drying rate and thermal property. Hence, we predict that the bamboo fiber is suitable for summer textiles, similar to flax and jute fibers.

Keywords: Natural bamboo fiber, mechanical property, moisture absorption, thermo-gravimetric analysis, contact angle, density.

1. Introduction

As there is scarcity of information on bamboo fibers, the Chinese bamboo fiber market is confused. In our previous studies, we learnt the structural characteristics of the fiber [1,2]. The research results show that the bamboo fiber is alike bast fibers in chemical composition, that is, cellulose constitutes the major portion, and lignin needs to be reduced further for usage in textiles. The cellulose of bamboo fiber has smaller molecular mass and degree of polymerization than other bast fibers. However, natural bamboo fiber belongs to cellulose I crystalline structure, like that of cotton and ramie. Cross section of bamboo single fiber is similar to that of small lumen. Generally the structural characteristics of bamboo fiber are different from other textile plant fibers, which are often used in textile industry. Being a new textile fiber, what about the properties of bamboo fiber?

2. Experimental

2.1 Materials

In order to learn the chemical and physical properties of natural bamboo fiber, jute fiber (provided by Zhejiang Linen CO. LTD.) and flax fiber (provided by Haerbing Linen Mill) were chosen as control fibers. We produced the natural bamboo fiber from the bamboo of Neosinocalamus affinis.

Since bamboo fiber and jute fiber were semi-finished goods, it was necessary to pre-treat them, however, flax was a finished good. The flax was extracted by carbon tetrachloride to remove oil. The bamboo fiber and the jute fiber were chlorine bleached under the condition of 3g/l available chlorine concentration for 60-min at room temperature. After treatment, parameters of the fibers are listed in Table 1.

Table 1 Parameters of the fibers

Index	Bamboo fiber*	Jute fiber*	Flax fiber**
Fineness /tex	2.58	3.01	0.30
Length /mm	70-90	60-100	10-25

Notes: *fiber bundle; **single fiber

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Table 2 Chemical components of the fibers [1]

Chemical component	Bamboo fiber	Jute fiber	Flax fiber
Aqueous extract content (%)	3.16	3.06	5.74
Pectin content (%)	0.37	1.72	1.81
Hemi-cellulose content (%)	12.49	13.53	11.62
Lignin content (%)	10.15	13.30	2.78
Cellulose content (%)	73.83	68.39	78.05

Notes: Grays were not included

In order to learn the relationships between the properties and the chemical composition of the bamboo fiber, chemical compositions of the bamboo fiber are listed in Table 2 [1]. It shows that natural bamboo fiber consists of more than 70% cellulose, while the contents of lignin and hemi-cellulose (especially lignin) are much more than that of the flax, and a little lower than that of the jute fiber.

We know that lignin is responsible for the stiffness and yellowness of natural bamboo fiber. However, it is impossible to remove the lignin clearly, as it is highly resistant to alkalis, resulting in great difficulties in delignification. Therefore, the properties of the bamboo fiber in this paper are obtained from the bamboo fiber with the chemical composition results listed in Table 2. Non-cellulose matters like pectin and hemi-cellulose will have significant effects on fiber properties, such as strength, flexibility, moisture, and even density.

2.2 Instruments and methods

2.2.1 Density

The experiment is conducted according to the Chinese standard FZ/T01057.9-1999 Identification of Textile Fiber is done by the Density Gradient Method. The density range of the standard balls is from 1.437g/cm^3 to 1.562g/cm^3. The n-heptane and carbon tetrachloride are mixed and poured slowly into the density gradient tube, which was immersed into a constant temperature trough at 25±0.5℃. The fiber balls are centrifuged in a centrifugal machine at a speed of 2000r/min, and then dried in a vacuum drying oven at 60℃.

2.2.2 Thermal properties

Thermal properties of the fibers are measured by Thermogravimetric Analyzer (TGA Q500) by Seiko Instruments Inc. The samples are tested under N_2 atmosphere, which flow at the rate of 60ml/min. The temperature is increased at a velocity of 10℃/min from 25-600℃.

2.2.3 Strength and elongation

The fibers are drawn according to Chinese standard GB5886-86 Determination of Breaking Strength of Ramie Single Fiber is done. Before which, the specimens are pre-conditioned at RH65±5%, 20±3℃ for 24h. Each fiber is pretensioned by 0.05cN/dtex. The clamping length between up clip and down clip is 20mm. And the down clip goes down at the speed of 20mm/min.

2.2.4 Moisture regain and water-retention rate

Moisture regain and water-retention rate are measured according to the Chinese standard GB/T9995 "The Determination of Water Absorption and Moisture Regain of the Textile Materials": Oven-Dry Method and DIN 53814 Methods separately.

When testing for water-retention rate of material, the specimens were immersed into distilled water for 30min. Then specimens were put into TDL-5 low-speed and high-capacity centrifugal machine which rotates at a speed of 3000r/min for 10min. After weighing, the specimens were dried at 105℃ for 1h. Results were calculated by the following equation:

$$R = (W - W_0)/ W_0 \times 100\%$$

Where R—water-retention rate, %;
W—wet weight after centrifuging, g;
W_0— dry weight, g。

2.2.5 Contact angle

By means of Optical Contact Angle Meter (OCA40) made in Germany, contact angles of the fibers were found. The experimental conditions are as follows: dropping method, the volume of water drop is 15pl; the contact angle of the fibers is measured by width and height of the drop.