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Analysis of Length and Fineness of Lotus Fiber Extracted by Physical Methods

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To investigate the characteristics of lotus fiber length and fineness to provide theoretical basis for developing lotus fiber products, 1500 fibers were extracted by physical method from tip part, middle part and bottom part of lotus stalks (500 fibers for each part) and measured. The analysis showed that the length range of lotus fiber was about 31-50 mm, generally, fibers from tip part are longer, fibers from bottom part are shorter, and fibers from middle part were average in normal distribution. The fineness range of single fiber was 3.963-4.516 μm (less than 5 μm, belongs to microfiber), and the finest fiber was from tip part, with smallest coefficient of variation. The ratio of lotus fiber length to fineness was about 10^4, which can meet the textile processing requirement.

1. Introduction

With the exhaustion of non-renewable resources such as coal, oil and natural gas, it has been a serious problem for people to look for alternative renewable resources. Cellulose materials are the cheapest and most abundant renewable resources in nature. In the view of environmental protection and sustainable development, the development and application of natural plant fiber and renewable fiber will be the inevitable trend.

Lotus plants spread across all over China, with planting area about 500,000 to 700,000 hectares, it is abundant (W D Ke et al., 2003). Each year, after the flowering season, most of the lotus leaves and stalks are degraded naturally, which result in a waste of resource. Natural cellulose fibers produce from renewable plant resources, especially from crop residues can help to mitigate energy and environmental issues. There are a lot of fibers between lotus leaves and stalks, be easily to be obtained. And it is renewable, biodegradable, abundant in resources, more comfortable and skin-friendly than synthetic fiber (J G Wang et al., 2009). The application of lotus fiber can not only avoiding resources waste but also diversify the raw materials of textile products and promote sustainable development of textile industry. (J He et al., 2010; J G Wang et al., 2012)

At present, there is little study done on the lotus fiber home or abroad, as it is a new kind of natural cellulose fiber. In China, there are mainly two research institutes researching in this field. One is Textiles and Clothing Technology Innovation Center led by Prof. D S Chen, and Prof. Y J Gan, they are concentrating on the research of fiber preparation, surface morphological structure, basic physical properties, basic chemical properties and its application (J G Wang et al., 2009; J G Wang et al., 2010; J He et al., 2010; J G Wang et al., 2012; D S Chen et al., 2008-04-23; Y J Gan et al., 2009; D S Chen et al., 2008; D S Chen et al., 2009; X H Yuan et al., 2012); another is Key Laboratory of Science & Technology of Eco·Textile led by Prof. Z P Mao, and doctor Y Pan, they are concentrate on the research of microstructure and main constitution of lotus fiber(Pan Y et al., 2011; Y Pan et al., 2011).

This research collected fibers from different part of lotus stalks, measured the length and fineness of each fiber, and analyzed the results to provide a basis for the development and application of lotus fibers.

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2. Materials and methods

2.1 Material Preparation

Lotus fibers grow in vascular bundle of lotus leaf, stalk, and root (Y J Gan et al., 2009). There are three ways to get lotus fibers: physical method, biological method and chemical method. The fibers obtained by physical method were milky white, soft, with a faint scent. The fibers obtained by the other two ways were brown, and stiffer. (Pan Y et al., 2011) And the morphology and structure of fibers which obtained by physical method with less change to the state in vascular bundle of lotus. (Y B Zhang et al., 2014)

Physical method is the common way to obtain lotus fibers, so we chose this method to prepare materials (D S Chen et al., 2008).

The materials we used were collected from the lotus pool in Minjiang University, Fuzhou Fujian Province. According to LOTUS FLOWER Cultivars in China, lotus can divide into three germ line, 50 group, and 23 types. The lotus stalks we used were belonging to the white bowl lotus, semi-double flower type, large and medium-sized flowers group, Chinese lotus (Wang Qichao. 2005).

The materials were collected respectively from the tip, middle and bottom parts of lotus stalks. They were prepared as follows: First, rinse the lotus stalks with clean water, dry and deburr them. Then, group 5-6 stalks into a bundle, break them off at an interval of 3-5 cm and pull out the fiber slowly and steadily from lotus stalks. Then, smooth and slub the fibers into bundles, and dried at a temperature of 20 - 25℃ without direct sunlight. Label the fibers samples as tip part, middle part and bottom part, with 500 fibers for each part (D S Chen et al., 2008-04-23).

2.2 Methods

2.2.1 Test of fiber length

All samples were measured with transparent glass-plate, clearer board, tweezers and steel ruler according GB/T16257-2008 (*Textile fibers-Test method for length and length distribution of staple fibers-Measurement of single fibers*).

Each fiber was pulled out from samples and put on a clear board with a tweezer. Then they were measured with a steel ruler (precision is 0.1mm) one by one until all samples were completed.

2.2.2 Test of fiber fineness

Lotus fiber exists in the vascular bundle in a spiral way. As shown in Fig. 1, the fiber bundle we extracted is composed of 3-10 single fibers (J He et al., 2010), and the fineness we measured was the fineness of single fiber shown in Fig. 2. The cross section of single lotus fiber is round or nearly round (Y J Gan et al., 2009), so we chose to measure the fineness of lotus fibers by electron microscopic method, and adopt diameter as an indicator to reflect the fineness. Compared with linear density, it is more accurate to reflect the fineness and the regularity of fineness.

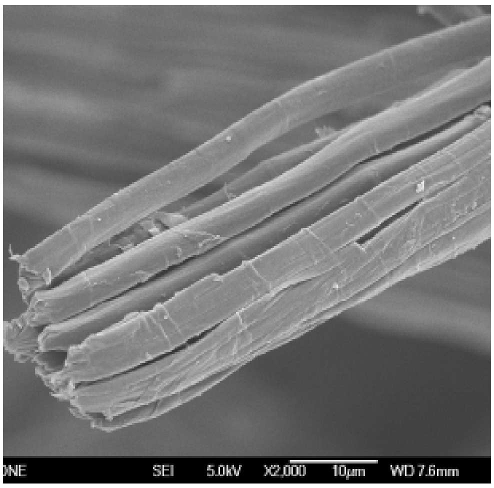


Figure 1: An electron micrograph of fiber bundle

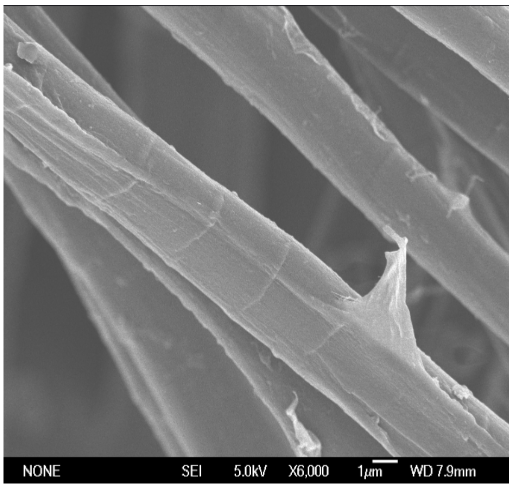


Figure 2: An electron micrograph of single fiber

The fiber diameter was measured by fiber projection method with JSM-6700 F field emission scanning electron microscope, micro-projector, Hardy fiber microtome, glycerin, slide glasses, cover glasses, tweezers and micrometer.

All the tests were operated under the standard environmental conditions at a temperature of 20+3℃ and a humidity of 65%+3%.

3. Results and discussion

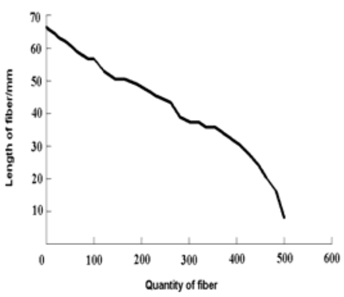
3.1 Distribution of fiber length

During the test, 1500 fibers were measured: 500 for tips, 500 for middles and 500 for bottoms. The results were sorted by the length of fibers. Lengths smaller than 10 mm were sorted as class 1, and the rest were upgraded every 5 mm (Liu Gui et al., 2013). As shown in Table-1, they were divided into 13 classes, with counted fibers quantity and percentage calculated for each class.

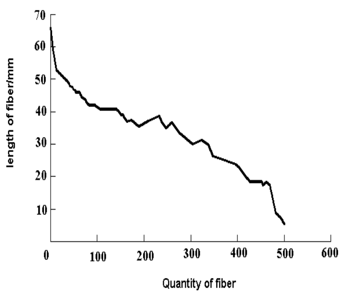
Table 1: Test data of fibers length

Class	Length (mm)	Class mid-value	Tip Parts		Middle Parts		Bottom Parts	
			Quantity of fibers	Percent -age	Quantity of fibers	Percen -tage	Quantity of fibers	Percen -tage
1	0-10	8	4	0.8%	29	5.8%	8	1.6%
2	11-15	12.5	7	1.4%	30	6.0%	32	6.4%
3	16-20	17.5	10	2.0%	38	7.6%	56	11.2%
4	21-25	22.5	15	3.0%	51	10.2%	56	11.2%
5	26-30	27.5	25	5.0%	62	12.2%	74	14.8%
6	31-35	32.5	36	7.2%	65	13%	92	18.4%
7	36-40	37.5	49	9.8%	64	12.8%	81	16.2%
8	41-45	42.5	77	15.4%	73	14.6%	43	8.6%
9	46-50	47.5	96	19.2%	53	10.6%	25	5.0%
10	51-55	52.5	79	15.8%	20	4%	19	3.8%
11	56-60	57.5	52	10.4%	11	2.2%	9	1.8%
12	61-65	62.5	38	7.6%	4	0.8%	5	1.0%
13	66-70	67.5	12	2.4%	0	0	0	0

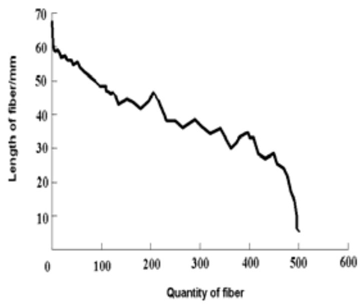
The bundles of lotus fibers were uneven in length, so if we arrange the fibers neatly in length order, the regularity of distribution will be obvious. According to the test data of Table-1, we arranged the fiber length and obtained the length-quantity distribution of lotus fibers by using computer software.



(a) length-quantity distribution of tip fibers



(b) length-quantity distribution of middle fibers



(c) length-quantity distribution of bottom fibers

Figure 3: Length-quantity distribution of lotus fibers

As can be seen from Fig. 3, most of the fiber lengths are 15-50 mm. Although the length arrangements of fibers from different parts of lotus stalk present some distinguishes, they are all in continuous distribution and similar to the length rule of cotton fiber, having the main features of the length distribution of natural fibers.

3.2 Distribution of fiber length-quantity

According to the test data of Table-1, we got the length-quantity distribution of lotus fibers. See Fig. 4.

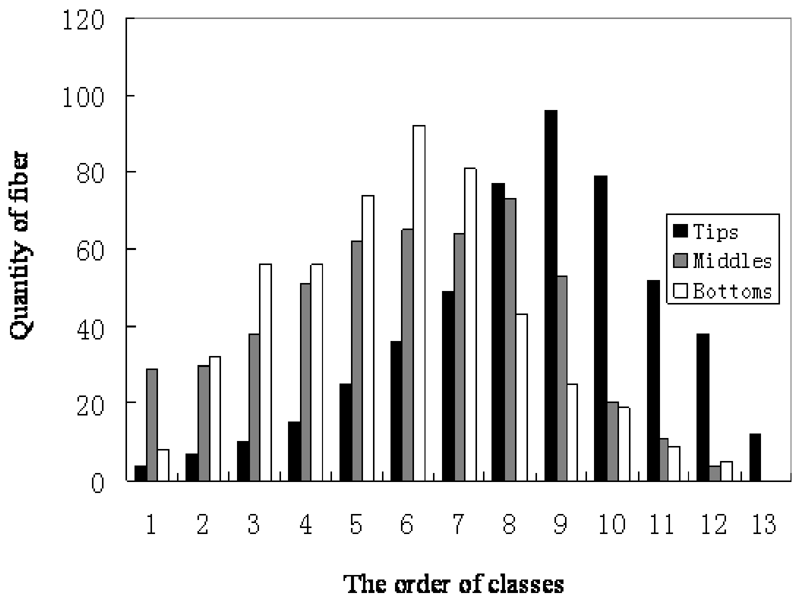


Figure 4: Length-quantity distribution of lotus fibers

As shown in Fig. 4, for the tip part, most fiber lengths are 36-60 mm, accounting for 70.8%, and lengths of 41-55 mm take up the largest number. For the middle part, most fiber lengths are 20-50 mm, accounting for 73.6%, and lengths of 24-45 mm take up the largest number. For the bottom part, most fiber lengths are 15-45 mm, accounting for 80.4%, and lengths of 25-40 mm take up the largest number.

Most of the fiber lengths are located between 31-50 mm, similar to Sea Island cotton fiber (Y Mu. 2013), see Table 2.

Table 2: Length of different natural fibers

Species	Length(mm)
Upland cotton	25-31
Sea Island cotton	33-46
Sheep wool	40-300
Mohair	45-70
Cashmere	22-36
Silk	60-1300
Flax	12-24
Ramie	20-200

Lengths of fibers from tip part are comparatively longer than those from other parts, and the quantity of lengths between 51-70 mm makings up to 34.6% of tip part. Lengths of fibers from bottom part are comparatively shorter than other parts, and the quantity of lengths less than 30 mm is up to 45.26% of bottom part. Lengths of fibers from middle part are in normal distribution.

Lotus fiber is primarily from vascular bundle of lotus. The bottom part is highly lignified and the fibers are stiffer and crisper meaning that the stalks are easy to break when preparing materials. Moreover, the adhesion between fiber and vascular bundle is strong, with the result that, the fiber lengths are shorter overall. On the opposite, the tip part is low lignified, meaning that the fibers are softer and tougher. Adhesion between fiber and vascular bundle is low, with the result that the fiber lengths are longer overall (Y Pan et al., 2011; Y Mu. 2013).

3.3 Distribution of fiber fineness

According to the test data of fiber fineness, we obtained the mean value, standard deviation and coefficient of variation, as shown in Table-3.

Table 3: Lotus fiber diameter profile

Parts	Mean value (μm)	Standard deviation	Coefficient of variation
Tip part	3.963	4.070	22.63%
Middle part	3.988	5.440	28.69%
Bottom part	4.516	5.518	25.65%

As shown in Table-3, the diameter of fibers from tip part is smaller, the diameter of fibers from bottom part is larger, and the diameter of fibers from middle part is average. Lotus fiber is primarily from vascular bundle, which acts as the transport system of plant water and nutrition, so the bottom part develops better than middle part and tip part (Y Pan et al., 2011). This might be one of the main factors affecting the diameters.

The coefficient of variation for tip part is small, the bottom one greater, and middle one greatest, which shows the uniformity of fiber fineness in tip part is the best.

As shown in Table-3, the diameter of a single lotus fiber is much smaller than any other plant fibers, it is less than 5 μm, belongs to the category of Microfiber. So each lotus fiber bundle we extracted directly from lotus stalks was super multifilament. Unlike synthetic superfine fiber, it is natural and easily obtained without special technology and complicated chemical process. Fiber fineness greatly influences the fabric luster, dyeing rate and hand feeling, etc. The microfiber textiles with soft hand feeling, large surface area, this means excellent moisture absorption and adsorption capacity (Y Mu. 2013).

4. Conclusions

The lengths of fibers from tip part, middle part and bottom part were in continuous distribution and consistent with the length rule of natural fibers. Most of the fiber lengths were between 31-50 mm, similar to that of Sea Island Cotton fiber. Generally, lengths of fibers from tip part were longer, lengths from bottom part were shorter, and lengths from middle part were in normal distribution.

The fineness range of fibers was 3.963-4.516 μm, and the fiber was slender, belong to the category of Microfiber. The order of fineness was: fineness of tip part < fineness of bottom part < fineness of middle part. The coefficient of variation of fiber fineness was: tip CV < bottom CV < middle CV. The uniformity of fiber fineness in tip part was the best.

The ratio of lotus fiber length to fineness was about 10^4, between 10^2 and 10^5, which can meet the textile processing requirement (Y Mu. 2013).

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