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Evaluation of the Fineness of Degummed Bast Fibers

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Abstract: Fiber fineness characteristics are important for yarn production and quality. In this paper, degummed bast fibers such as hemp, flax and ramie have been examined with the Optical Fiber Diameter Analyzer (OFDA100 and OFDA2000) systems for fiber fineness, in comparison with the conventional image analysis and the Wira airflow tester. The correlation between the results from these measurements was analysed. The results indicate that there is a significant linear co-relation between the fiber fineness measurement results obtained from those different systems. In addition, the mean fiber width and its coefficient of variation obtained from the OFDA100 system are smaller than those obtained from the OFDA2000 system, due to the difference in sample preparation methods. The OFDA2000 system can also measure the fiber fineness profile along the bast fiber plants, which can be useful for plant breeding.

Keywords: Bast fibers, Fiber fineness, Hemp, Flax, Ramie, OFDA systems

Introduction

The study of yarn quality has indicated that fiber fineness is very important for yarn evenness, because the limiting irregularity of a yarn is determined by the number of fibers in the yarn cross-section and the fiber fineness variation [1,2]. Based on the morphological features of fibers, different standard systems are available in the textile industry for the measurement of fiber fineness, such as the HVI system for cotton and the Optical Fiber Diameter Analyzer (OFDA) and Laserscan systems for wool. For bast fibers such as flax and hemp, the image analysis technique has been employed to evaluate the fiber fineness in terms of fiber cross sectional area [3]. The problem in practice for this method is that sample preparation is very complicated and also time consuming.

Compared with other natural fibers (wool and cotton), bast fibers must be degummed and separated into fine fibers before textile processing. The techniques of degumming bast fibers include enzymatic, chemical, or ultrasonic plus mechanical methods [4-9]. Some new processing strategies have also been proposed [10,11]. Nevertheless, some fiber bundles of different sizes usually remain in the degummed bast fibers, leading to variations in the measured fineness values. The present systems for evaluating fiber length, tensile properties and whiteness may be satisfactory for different applications [12-17]. However, the measurement of fiber fineness remains a concern in the bast fiber industry.

This paper will examine the fineness characteristics of degummed bast fibers and compare the results from the present fiber fineness measurement systems, including Wira airflow tester, conventional image analysis, and the OFDA100 and OFDA2000 systems. Although the OFDA systems have been used widely in the wool industry for fiber diameter measurements, further research is needed to examine their applicability for evaluation of bast fiber fineness. Statistical analysis has been conducted on the test data and a comparison between results obtained from the OFDA100 and OFDA2000 systems has also been made.

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Experimental

Materials

Three varieties of hemp, one ramie and flax were selected for this study. Two of the three hemp varieties were produced in Australia, the third one in China; the ramie and flax were from China. The hemp and ramie were all degummed by chemical processing followed by opening and carding for textile applications. The flax was retted by warm water and hackled into a long fiber ribbon.

Fineness Measurements

The Wira airflow fiber fineness tester was calibrated for bast fibers. Two two-gram samples were prepared and each sample was measured twice.

Conventional image analysis was conducted with an Olympus BX51 optical microscope and the ImagePro plus software (MediaCybernetics). The samples were embedded into the resin of Technovit 7100 and then cut into sections of 12 micron in thickness. The area of the fiber cross-sections can be calculated by the image processing program. The number of fiber observed was over 800 for each sample.

The commercial OFDA100 and OFDA2000 systems were used directly to measure the fiber fineness. Because of the special morphology of bast fibers after processing, their fineness has been expressed in terms of the fiber width as in previous studies [18,19]. Over 4000 fiber snippets were observed for each test. When the flax was measured for profile along length, the fibers were cut into several lengths along the ribbon and measured in the large-glass mode of the OFDA2000.

Results and Discussion

Image Analysis of the Separation of Degummed Bast Fibers

The cross-sectional morphology of bast fibers before and after processing can be observed from the optical microscopy. As shown in Figure 1, unretted hemp has fibers bundled together. After degumming, many fiber bundles are separated into single fibers but some bundles still remain. Figure 2 shows chemically degummed hemp and ramie.

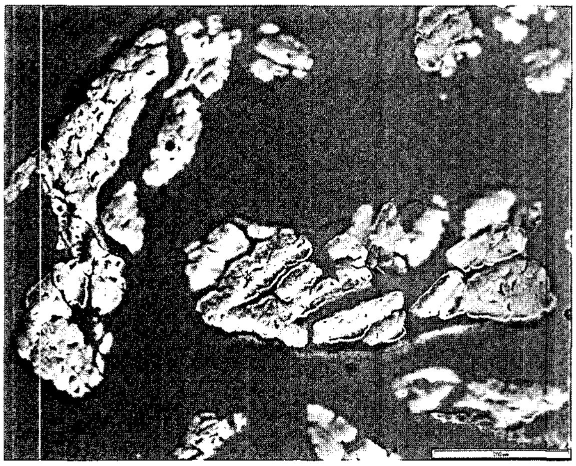


Figure 1. Cross-sectional observation of un-retted hemp fibers.

Statistic Analysis of the Fineness Distribution of Degummed Bast Fibers

In contrast to the fineness distributions of wool and cotton, the distribution of degummed bast fibers has a broad range with a long tail on the right-hand side, as shown in Figure 3. The distribution curves are largely skewed to the right,

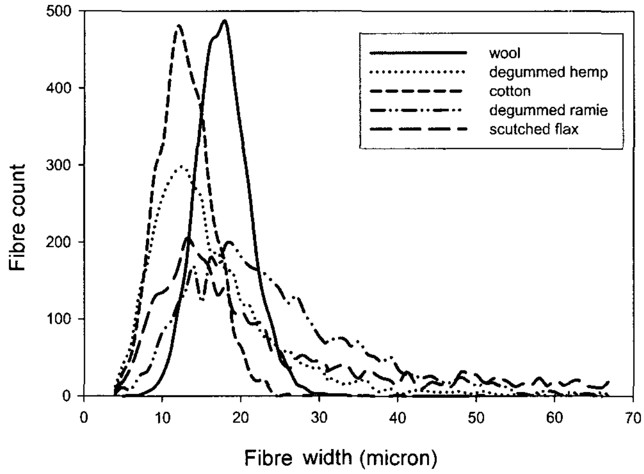


Figure 3. Distribution of wool, cotton and degummed bast fibers (OFDA100).

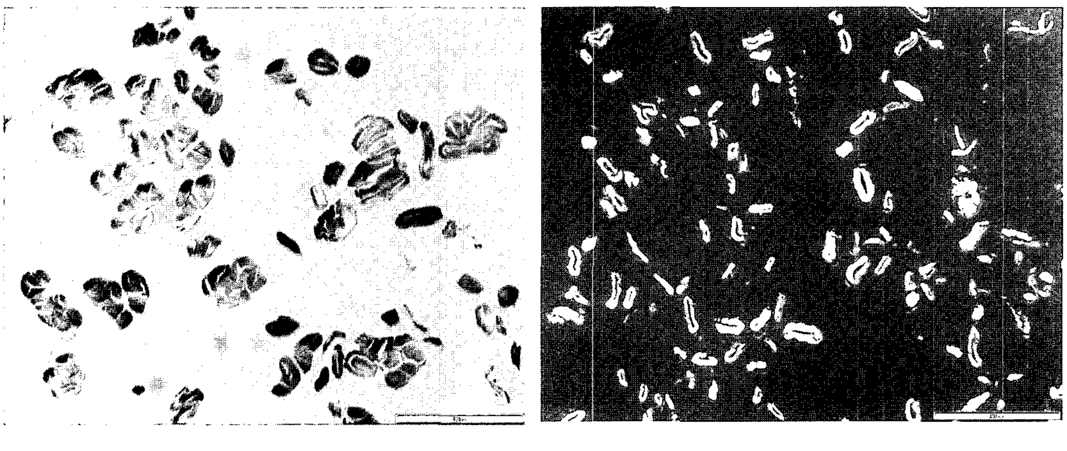


Figure 2. Cross-sectional observations of degummed hemp and ramie fibers.

Table 1. Characteristics of the fiber width distributions of fine wool, cotton and degummed bast fibers

Materials	Mean (μm)	Median (μm)	Std. dev. (μm)	Range (μm)	Skewness	Kurtosis
Wool (OFDA2000)	17.7	17.0	3.5	25	0.588	2.805
Cotton (OFDA2000)	13.0	13.0	3.4	21	0.322	0.079
Degummed hemp (OFDA2000)	16.9	15.0	8.9	66	2.063	6.182
Degummed ramie (OFDA2000)	27.8	26.0	11.4	66	0.791	0.466
Scutched flax (OFDA2000)	31.1	20.0	24.6	96	1.034	–0.045

Table 2. Characteristics of the fiber width distributions of degummed bast fibers after the log transformation

Materials	Mean	Median	Std. dev.	Range	Skewness	Kurtosis
Degummed hemp (OFDA2000)	2.7	2.7	0.5	2.9	0.292	0.302
Degummed ramie (OFDA2000)	3.2	3.2	0.4	2.9	−0.365	0.302
Scutched flax (OFDA2000)	3.1	3.0	0.8	3.2	0.130	−1.118

especially for the degummed ramie and scutched flax. This is due to incomplete fiber separation during degumming.

The characteristics of the fiber fineness distribution of the degummed bast fibers are listed in Table 1, compared with fine wool and cotton. The asymmetric distribution of the degummed hemp, ramie and flax can be further confirmed by the large positive skewness, which skews the mean to the right of the median. The large positive kurtosis for degummed hemp and ramie also indicates that the distribution of the fiber fineness is more peaked and has longer tails than the normal distribution. This distribution inflates the standard deviation to a point where it is no longer useful as a measure of the spread of data values.

Therefore, the test of normality of the data for degummed bast fibers is required. If the normality is violated, a transformation of the data may be needed to bring the distribution closer to normal in order to assess the spread of data. The log transformation is a sensible choice because the data obtained takes almost positive values and is right skewed. From the statistics shown in Table 2, the transformation has brought the distribution closer to normal, except for the scutched flax. The skewness and kurtosis are greatly reduced, and the mean and median are much closer together. In particular, the distribution curve for the degummed hemp is greatly improved, as shown in Figure 4.

Correlation Analysis Between the Measurements

The correlations between the measurements can be investigated based on the results for the degummed hemp. The significance level for the test of linear relationship is 5 %. As indicated in Table 3, the three measurements of the fineness for the degummed hemp are significantly correlated with each other. This also suggests that the OFDA system can be a better alternative than the other two measurement

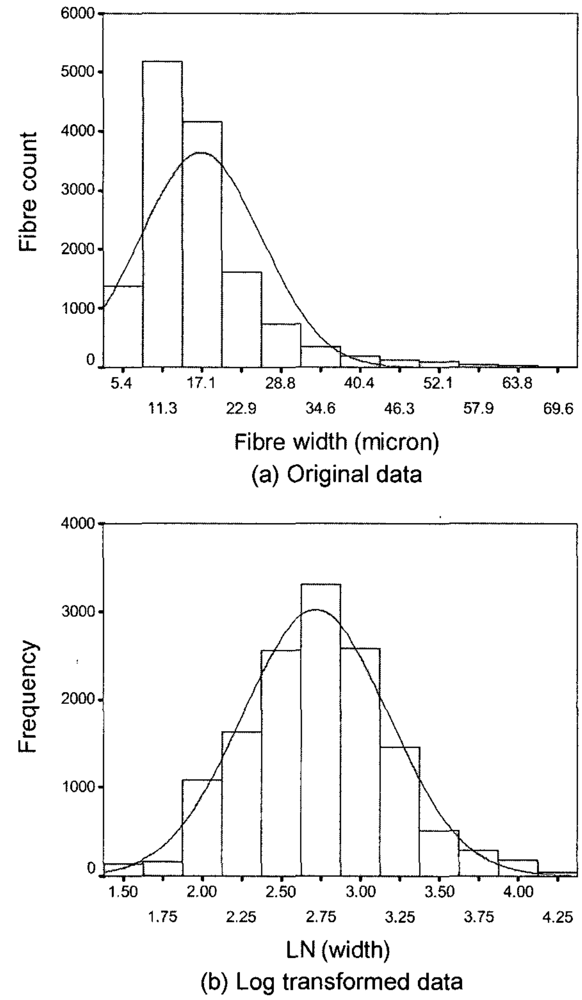


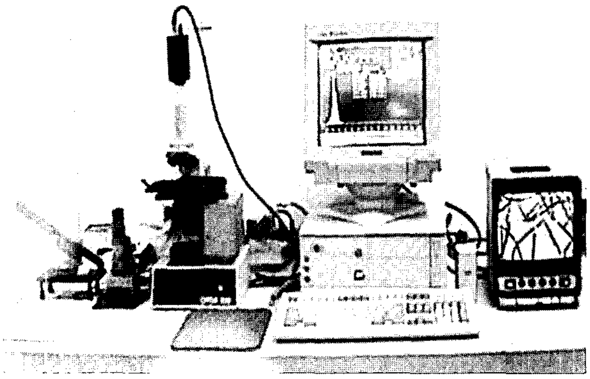
Figure 4. Distribution of the fiber width of degummed hemp (OFDA2000).

Table 3. Correlations between the measurements

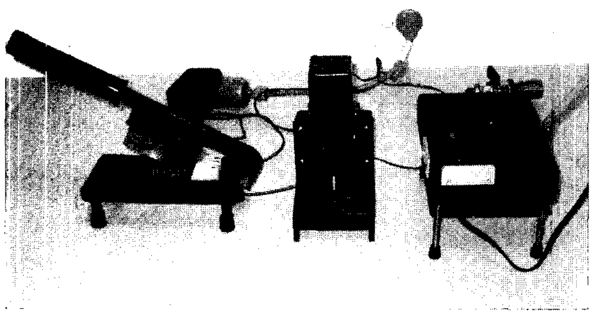
Items		Airflow value (Wira)	Cross-sectional area (image)	Width (OFDA 2000)
Airflow value (Wira)	Pearson Correlation	1	0.653[a]	0.701[a]
	Sig. level (2-tailed)	-	0.000	0.000
Cross-sectional area (image)	Pearson Correlation	0.653[a]	1	0.461[b]
	Sig. level (2-tailed)	0.000	-	0.014
Width (OFDA2000)	Pearson Correlation	0.701[a]	0.461[b]	1
	Sig. level (2-tailed)	0.000	0.014	-

[a]correlation significant at the 0.01 level (2-tailed), [b]correlation significant at the 0.05 level (2-tailed).

methods. The airflow method gives an average fineness result only, without any information on the variation of fiber fineness, while the conventional image analysis technique is time-consuming. Thus, the OFDA system is preferred in the present research.



(a) The whole system



(b) The guillontine and spreader

Figure 5. The OFDA100 system and the sample preparation accessories.

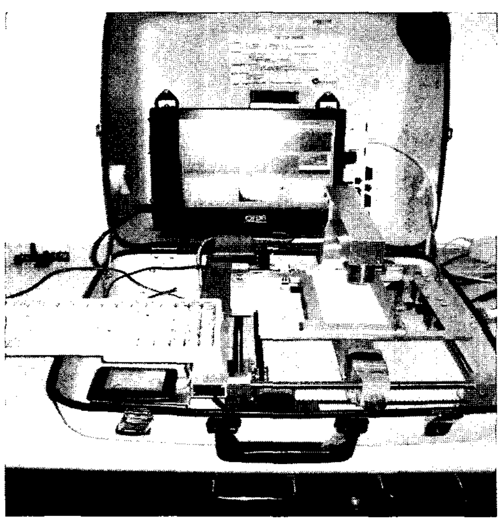
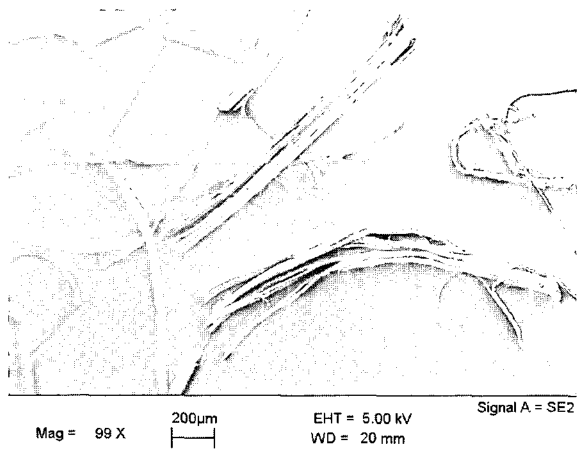


Figure 6. The OFDA2000 system.

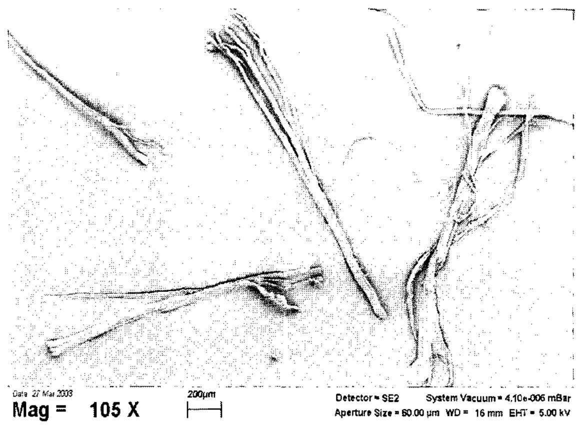
Comparison of OFDA100 and OFDA2000 for the Measurement of Bast Fibers

The OFDA100 and OFDA2000 employ the same principle for measuring fiber width, but the preparation of samples is a little different. The samples for OFDA100 system must be fiber snippets of 2 mm in length, which are obtained with the supplied guillotine (as shown in Figure 5). Before each measurement, the snippets are spread onto a hinged glass slide using an automatic spreader. For the OFDA2000 system, the whole fibers can be used instead of fiber snippets as shown in Figure 6.

When the OFDA100 is used, cutting the fibers into 2 mm snippets will facilitate further separation of the fiber bundles by the spreader. The snippets in the form of bundles will possibly be further split into fine fiber bundles or even single fibers during spreading, depending on the morphological structures of the fiber bundles (as shown in Figure 7). Therefore, the centre statistics such as mean fiber width will tend to be



(a)



(b)

Figure 7. Separation of the hemp fiber bundles by the spreader for the OFDA100 measurement.

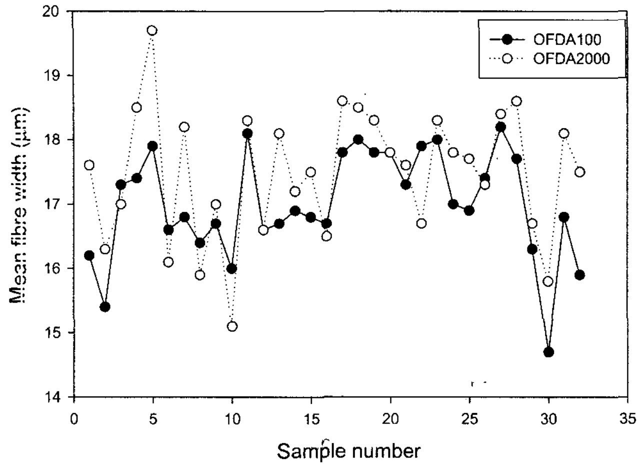


Figure 8. Mean fiber width for the degummed hemp obtained from OFDA100 and OFDA2000.

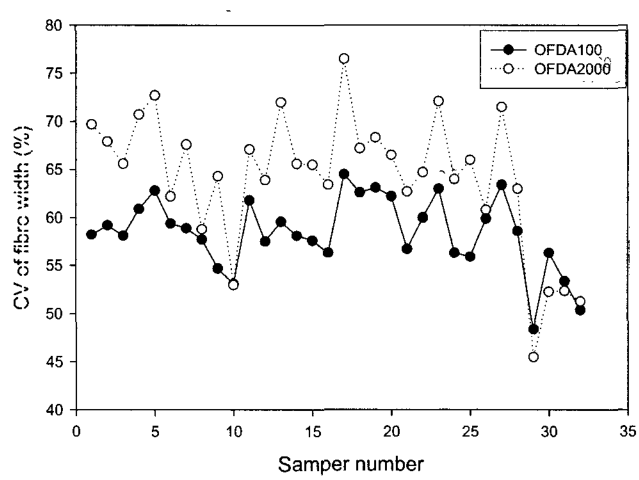


Figure 9. CV of fiber width for the degummed hemp obtained from OFDA100 and OFDA2000.

smaller than those from the OFDA2000, depending on the proportion of the fiber bundles in the samples. As a result, the OFDA100 system gave 75 % of the samples in the measurement pool a smaller mean fiber width than the OFDA2000 (as shown in Figure 8).

Furthermore, the split finer fiber bundles and single fibers will improve the fineness uniformity of fibers, because the proportion and the width of the fiber bundles are reduced in the specimen. As a result, the CV (coefficient of variation) of the fiber width will be decreased. As indicated in Figure 9, about 87.5 % of the samples in the measurement pool have a lower CV of fiber width when measured on the OFDA100 system.

Measurement of the Fineness Along-fiber Profile with the OFDA2000 System

Another advantage of the OFDA2000 system is that it is capable of measuring the along-fiber profile at 5 mm steps along fiber length. The results can provide information about the fiber fineness changes along the plant stalks for the genetic breeding research on bast fiber plants. As an example, a scutched flax ribbon was cut into 4 sections corresponding to the bottom to top regions of the flax plant. These sections were tested using the OFDA2000 in the large-glass model. The results are shown in Figure 10 for the fibers from the bottom to the top region (corresponding to the test 01 to test 04). The fine fibers in the top region are clearly shown.

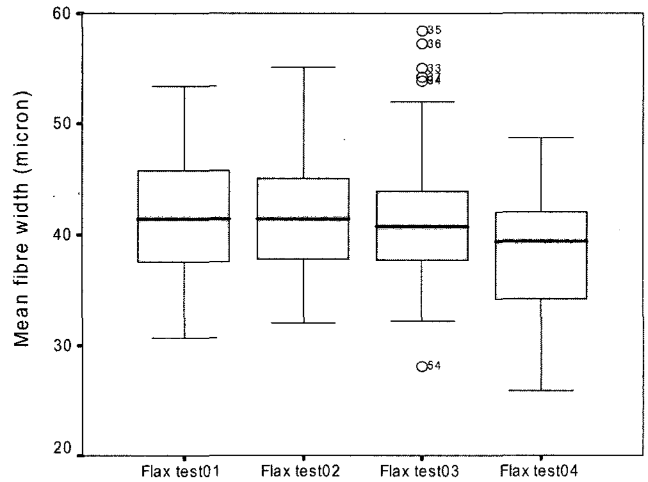


Figure 10. Mean fiber width along a flax fiber ribbon from four tests (OFDA2000).

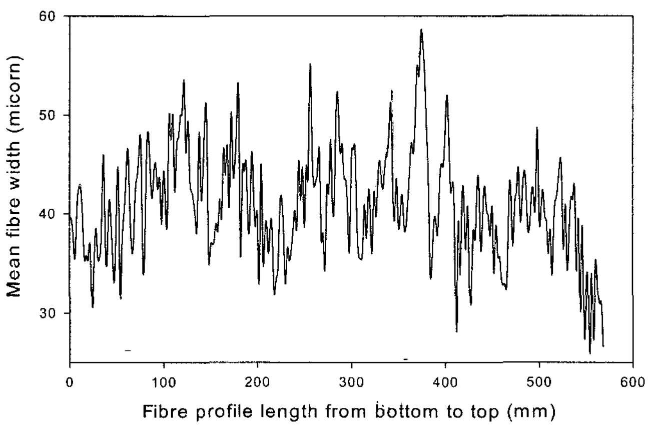


Figure 11. A fiber width profile along the whole fiber ribbon of scutched flax.

Furthermore, if the fiber width profiles of the four tests are combined together from the bottom to top region, the whole fiber profile can be obtained as shown in Figure 11.

Conclusion

Evaluation of the fineness of bast fibers is complicated by the presence of fiber bundles in degummed bast fibers and the non-circular cross section of the fibers. This paper has shown that modern fiber metrology instrument, such as the OFDA systems, can be used to quantify fiber fineness in terms of fiber width. There is a significant linear co-relation between the fiber fineness of the degummed bast fibers evaluated with the Wira airflow tester, conventional image analysis and the OFDA systems. The fiber width distribution curves of the degummed bast fibers are usually asymmetric about the mean value, with a long tail on the right hand side due to the existence of unseparated fiber bundles. Therefore, the test of normality of the data may be required. The log transformation can be employed to bring the distribution close to be normal for the data analysis, if the normality is violated.

Some discrepancies exist between the fiber width results obtained from the OFDA100 and OFDA2000 systems for the bast fibers examined. The mean fiber width as well as its coefficient of variation obtained from OFDA100 are smaller than those obtained from OFDA2000, due to different sample preparation methods. The OFDA2000 can also provide fiber fineness profile along the bast fiber plants.

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