A Study on the Production Method of Kenaf High Fiber Strength

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Abstract

Kenaf bast fiber from 58 varieties grown in Zhejiang province, China, was treated using three treatments. First treatment used ammonium oxalate, sodium hydroxide and acidic chlorite (AT3), second treatment used ammonium oxalate and sodium hydroxide (AT0) and the third one was retting treatment (RET). Some parameters such as diameter, height and weight of stalk, and also fiber strength were measured for screening method.

Treatment AT3 show much better strength than the other two. It means the single fiber which belongs to AT3 is stronger than the bundle fiber of AT0 and RET. Moreover the chemical treatment of AT0 has much stronger bundle fiber than RET. The best-8 varieties (kenaf sample number 8, 11, 12, 30, 32, 48, 52 and 58) were selected based on the fiber strength and kenaf sample number 12 and 32 reached the superior two if evaluated with other factors.

Keywords: production method, kenaf bast, single fiber, bundle fiber and fiber strength.

Introduction

With the growing interest in the protection of global environment and nature in recent years, the utilization of bio-resources such as wood is required to harmonize well with the preservation of global environment. Many studies have been done on the effective utilization of non-wood lignocellulosic materials such as oil palm, kenaf, bamboo, etc. due to a drastic fall in forest resources.

New applications of kenaf fiber have been developed not only in the pulp and paper industry, but also in other industries such as fiber board and nonwoven products (Watson *et al*. 1976). Kenaf fiber composites are increasingly used for making automotive interior trim parts because of their excellent strength and renewability. An application example is use of kenaf fiber in replacing glass fiber for making automotive headliner (Chen *et al*. 2003). The oriented kenaf fiberboard, made from designing highly-oriented long and strong bast fiber bundles by using a unique orientation technique, provides superior strength and dimensional stability, and the product is believed to be applicable to interior wall and flooring materials as well as construction materials (Ohnishi *et al*. 2003).

Preparation of the fiber before it is used for composite reinforcement is important. With bast fibers, such as hemp, flax and kenaf, the fiber needs to be removed from the plant core (decortication) and extracted from the natural plant polymer (retting) before it can be used for composite manufacture (Mazumder *et al*. 1998 and Ververis *et al*. 2003). Pre-treatments with some chemicals will increase the penetration and bonding efficiencies of the polymer matrix (Everaert *et al*. 2003). Kenaf bast pulps processed by modification of ammonium oxalate, sodium hydroxide and acidic sodium chlorite treatments gave the higher viscosity and paper strength properties. These treatments kept the kenaf fiber from severe damage as indicated by longer fiber length and higher viscosity (Suwinarti *et al*. 2005).

Kenaf (*Hibiscus cannabinus* L.) is an annual herbaceous crop of the Malvaceae family, of which cotton and okra are also members. Kenaf is believed to have its origin in ancient Africa (Western Sudan), occurring as early as 4000 B.C. (Dempsey 1975; Kobayashi 1991). Kenaf is mainly grown commercially in China, India and Southeast Asia, and its excellent compatibility to soil conditions and climate makes the cultivation possible in wide areas of the tropical and the temperate zones.

In the case of kenaf fiber, loss of viscosity, a measure of pulp damage under processing, has been found to be highly sensitive to the conditions under which the pulping process occurs (Chark *et al*. 1962 and Nezamoleslami *et al*. 1998). Therefore, this study sought to know the best method to produce the high fiber strength from 58 kenaf varieties.

Materials and Methods

Materials

Kenaf plants from 58 varieties grown in Zhejiang province (China), was harvested at 161 days after planting. The agronomic characteristics such as stalk height, diameter and weight of whole stalk were measured before cutting 10 cm in length prior to the bast and core separation.

Treatments

Kenaf bast fibers were treated by three treatments. The first treatment (AT3) used 15% ammonium oxalate (% in solution with liquor ratio 1:25), 1.5% sodium hydroxide (% in solution with liquor ratio 1:10) and acidic sodium chlorite (Suwinarti *et al*. 2004). This treatment gave the single fibers. The second treatment (AT0) used 15% ammonium oxalate (% in solution with liquor ratio 1:25), 1.5% sodium hydroxide (% in solution with liquor ratio 1:10). The third treatment (RET) was performed by traditional retting method. These two treatments (AT0 and RET) produced fiber bundles. Some characteristics of fiber such as viscosity, fiber length, fiber diameter and fiber strength were also measured.

Viscosity Treatment

The viscosity was measured according to the TAPPI test method TAPPI T 230 om-89 using cupriethylendiamine (CED) as a solvent and a capillary viscometer. The viscosity was calculated as:

$$V = CTD$$

Where V = viscosity of CED solution (centipoises/cP)
C = viscometer constant
T = average the efflux time (second)
D = density of the pulp solution (1.052 g/cm^3)

Fiber Length and Fiber Diameter Measurement

Kenaf bast fibers (10 mg) were disintegrated for 10 min in 1 L water prior to fiber length measurement. The fiber length was measured by Kajaani FS-200 fiber length analyzer.

The microscope (digital HF microscope, VH-8000) was used for fiber diameter measurement which was taken at 3 positions along fiber with using 0.01 μm in scale.

Fiber Strength Testing

The fiber strength of single and bundle fiber were measured by using Autograph Universal Testing Machine (AG-1000D) with fiber holder tools set. The tools were made from aluminum and using Span of 1 mm and epoxy glue. The fiber strength was calculated by formula below:

$$(\sigma) = P/A$$

where σ = fiber strength (MPa)
P = force
A = $[(\pi \times r^2)/4] \times 0.8$

Results and Discussion

Agronomic Characteristics

The agronomic characteristics of 58 kenaf varieties were determined. The result showed stalk height and stalk diameter range was 170~450 cm and 0.8~2.1 cm, while weight of whole stalk with and without leaf range was 105.3~924.2 g and 98.5~745.9 g (air dried). The average of stalk height, stalk diameter, weight of whole stalk with and without leaf was 349.8 cm, 1.7 cm, 507.3 g and 405.9 g, respectively. The relationship among stalk height, stalk diameter and weight of whole stalk is described in Figure 1.

The R-square values of 0.7178 and 0.6213 indicate there is a high relationship between stalk height and whole stalk weight, and between stalk diameter and whole stalk weight. It means all kenaf plants were growing well which showed by increasing characteristics value in all parameters. This result supported the previous investigation of Cheng *et al*. (2000) and Nishimura *et al*. (2002).

Fiber Characteristics

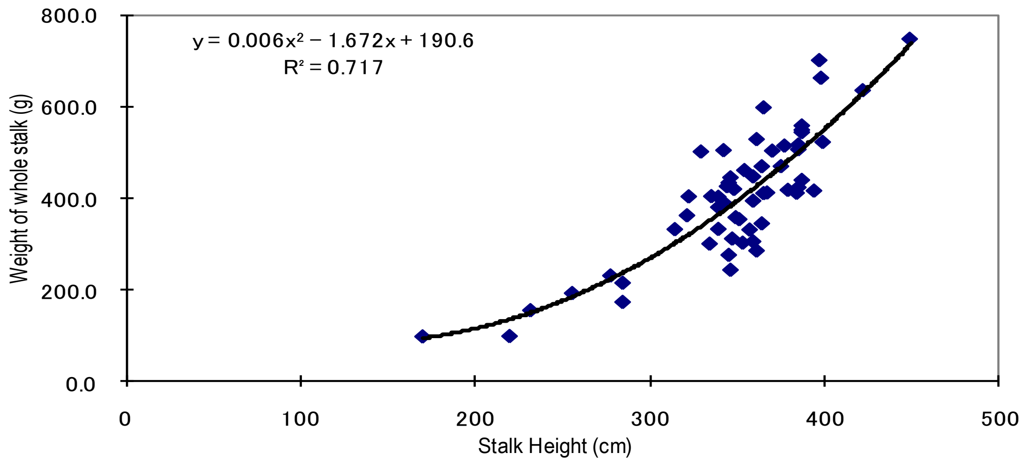
The fiber characteristics of 58 kenaf varieties were examined. The viscosity range was 73~137 cP with average of 104 cP. The average of fiber length of single fiber derived from AT3 treatment was 2.44 mm while the diameter average of single fiber, bundle fiber and retted bundle was 16.4, 71.3 and 76.6 μm, respectively. The single fiber had stronger fiber with average 736.2 MPa and followed by bundle fiber (651.4 MPa) and retted bundle (491.0 MPa) as shown in Figure 2. It indicates that the sequence treatment of ammonium oxalate and sodium hydroxide gave much stronger fiber strength than the conventional retting treatment, as also reported by Keshk *et al*. (2003) and Mazumder *et al*. (2000).

Relationship between Fiber Characteristics and Fiber Strength

In relationship between fiber length, diameter of single fiber and fiber strength, there is a little tendency that the longer and the wider fiber, the lower the fiber strength, even though the correlation coefficient is small as visualized in Figure 3. It means these fiber characteristics did not affect the fiber strength. Likewise, for both treatments in bundle fiber showed the fiber strength decreased when the fiber diameter increased.

The Best Eight Samples Selected

According to the agronomic and fiber characteristics, eight samples were selected as shown in Figure 4. The average of stalk height, diameter, whole stalk weight with leaf and whole stalk weight without leaf were 360.5 cm, 1.8 cm, 616.1 g, 478.4 g, respectively. On the other hand the average fiber strength of AT3 was 937.1 MPa, while AT0 and retted bundle were 719.7 and 549.2 MPa. These eight samples average showed much stronger fiber than those of 58 samples average. This might be explained why these eight samples were selected. The results of characteristic value evaluation indicated that plant number 12 and 32 were the best samples than those of others.



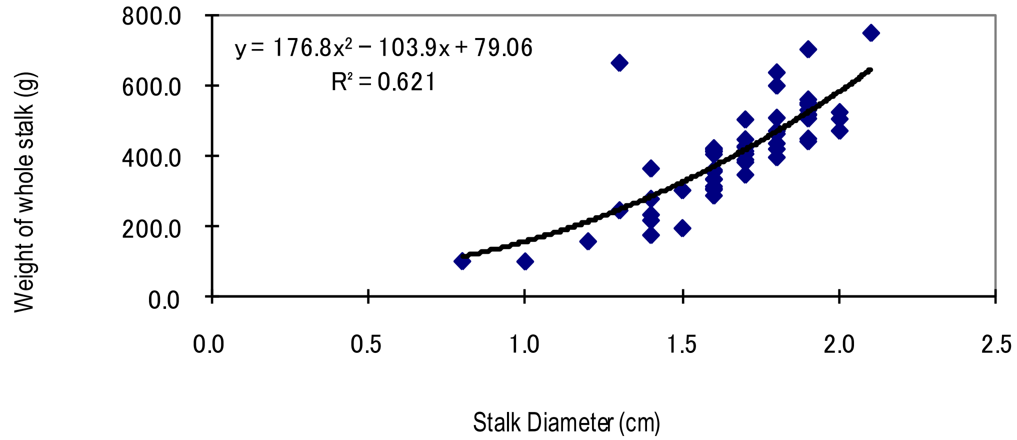


Figure.1. The relationship among stalk height, stalk diameter, and weight of whole stalk on 58 kenaf varieties.

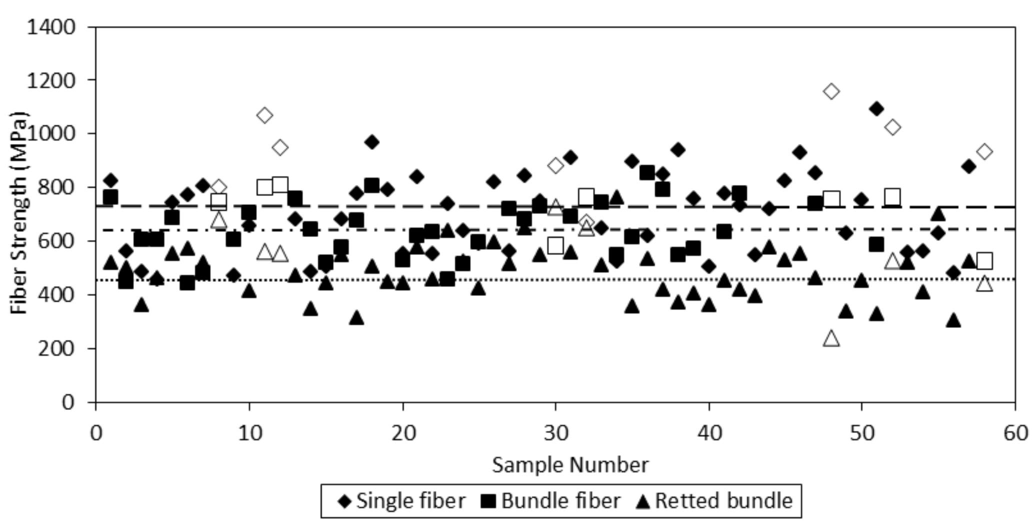


Figure.2. Fiber strength of 58 kenaf varieties.

* open symbol indicates the best eight samples ** avg. of – – – – Single fiber -·-·-·- Bundle fiber ——— Retted bundle

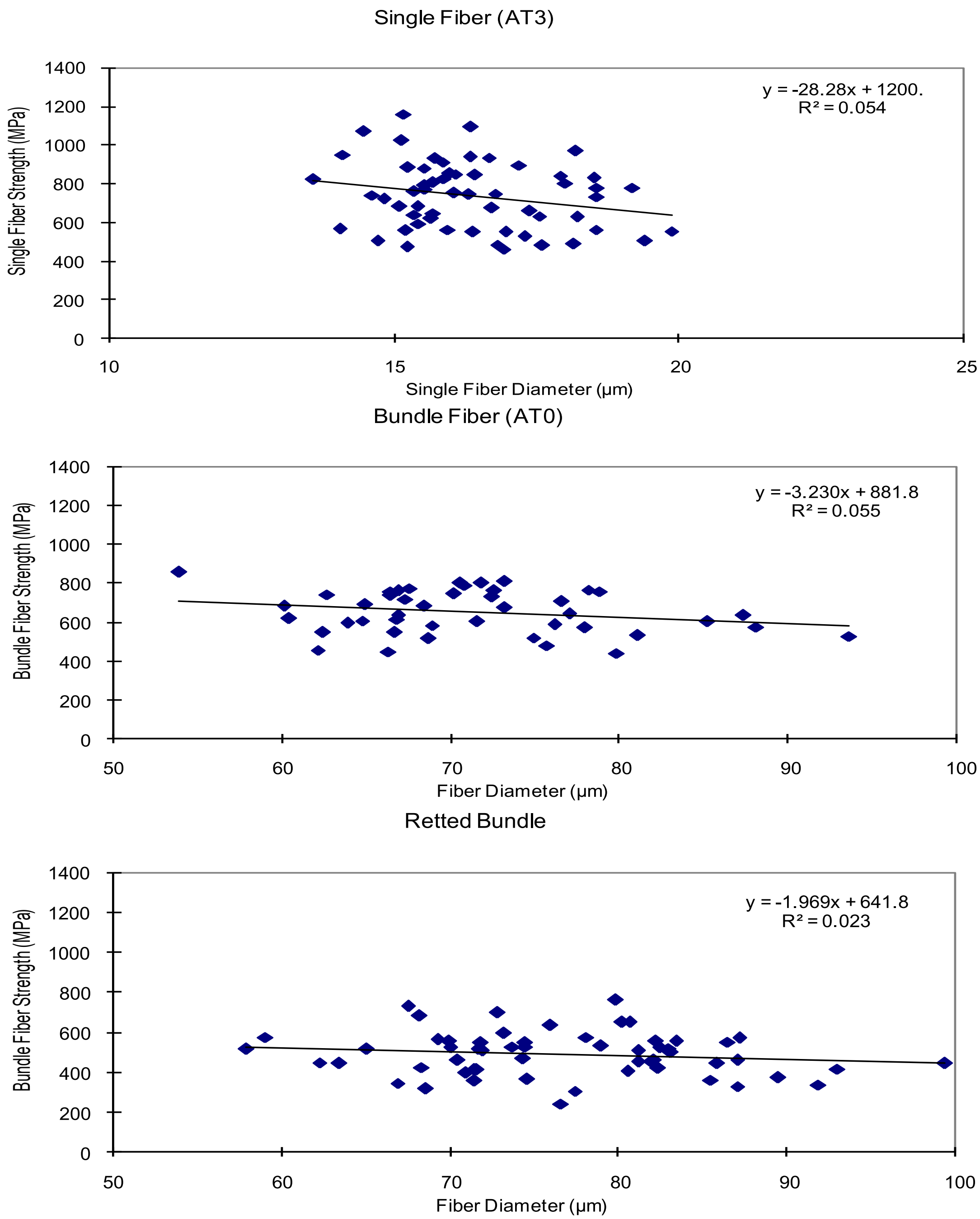


Figure.3. Relationship between fiber characteristics and fiber strength.

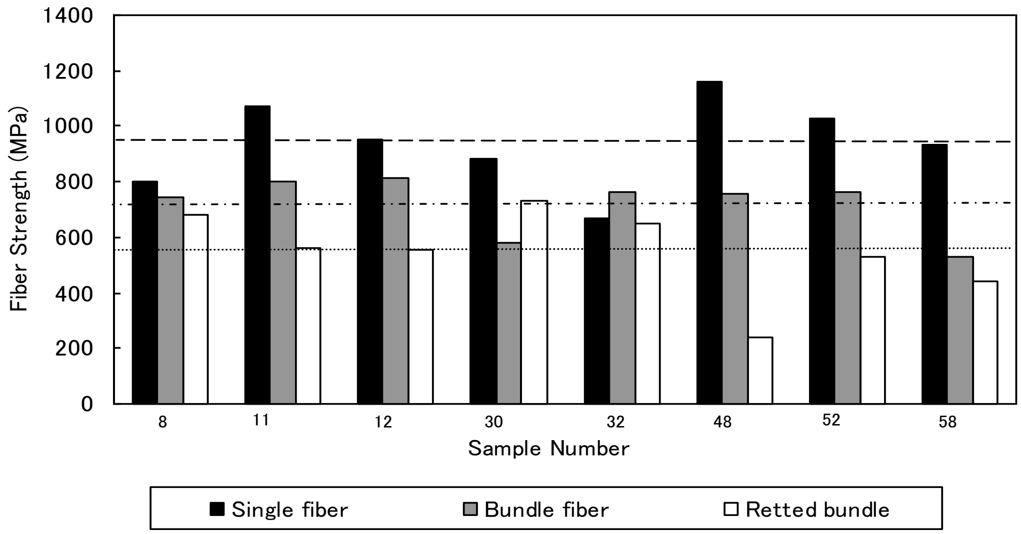


Figure 4. Fiber strength of the eight sample selected.
* avg. of the eight varieties — — — Single fiber -·-·-·- Bundle fiber .... Retted bundle

Conclusions

Treatment used ammonium oxalate, sodium hydroxide and acidic sodium chlorite (AT3) gave single fiber which showed much stronger than the other treatments which gave fiber bundles. On the other hand omparison between the two bundle fibers show the chemical treatment of bundle fiber (AT0) has much stronger fiber than retted one. Kenaf sample number 8, 11, 12, 30, 32, 48, 52 and 58 were the best eight for all parameters if compare to other samples and sample number 12 and 32 exceeded as the superior two if evaluated with other indicators.

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