Fibers and Polymers 2006, Vol.7, No.1, 26-29

Pulp and Paper from Kenaf Bast Fibers

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(Received September 24, 2005; Revised November 20, 2005; Accepted December 14, 2005)

Abstract: Samples of kenaf (*Hibiscus cannabinus*) grown in Malaysia were examined to determine the kraft pulp and papermaking properties of their bast (or bark) fibers. Using kraft pulping process showed that bast fibers were relatively easy to cook resulting good pulp yields in the range of 45-51 %. The bast pulp produced sheets with great density, tear index and dry zero-span breaking length. Kenaf bast fiber is considered promising for production of high-grade printing, writing and specialty papers.

Keywords: Kenaf, Bast fiber, Kraft pulp, Kappa number, Strength properties

Introduction

In recent years there has been a trend to the diversification of raw materials for pulp production as supplies of preferred softwood have diminished and cannot meet the current demand for pulp and paper products. Paavilainen [1] has predicted that the total global consumption of papermaking fibers will grow from about 300 million tonnes in 1996-97 to approximately 425 million tonnes by the year 2010, an increase of 125 million tonnes. Due to the global demand for fibrous material, worldwide shortage of trees in many areas, and environmental awareness, non-woods have become one of the important alternative sources of fibrous material for the 21st century. Non-woods are a critical fiber resource in regions with inadequate forest resources (in the developing countries in Africa, Asia and Latin America), and will continue to play an increasingly important role in these regions. There is a wide variety of non-wood plant fibers that can be used for papermaking [2]. Non-woods such as bagasse, wheat and rice straws, bamboo, and kenaf are being used in the manufacture of pulp and paper all over the world [3]. However, kenaf (*Hibiscus cannabinus*) is being explored as a useful raw material for papermaking in developing and developed countries [4]. Table 1 lists the physical and chemical properties of some non-woods in comparison to those of wood [5-11].

The objective of this study was to determine the kraft (sulfate) pulp and papermaking properties of the kenaf bast fibers cultivated in Malaysia. The kraft pulping process was used because it is an effective method of delignification. In Finland about 90 % of all the chemical pulp is made using the kraft process [1] and globally it is 80 % [12].

'Kenaf', a word of Persian origin that is used to describe the plant, *Hibiscus cannabinus L.* is a warm season, short-day, annual herbaceous plant which originated in west Africa. Kenaf grows quickly, rising to a height of 3.7-5.5 m, in as little as 4-5 months in suitable temperature, soil and rainfall conditions. The kenaf yield has ranged from 14-22 t/ha or more [13]. Kenaf yield is 5-10 times higher than the growth rate of Japanese cedar, one of the most popular plantation trees for papermaking in Japan [14].

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Experimental

Materials

Kenaf stalks were collected from the experimental fields at the Malaysian Agriculture Research and Development Institute (Figure 1). The raw material used in this study was separated kenaf bast. All the raw materials were taken from one harvest, to ensure that, as far as possible, variations in raw materials used were kept to a minimum (Table 2).

Methodology

Some samples of bast were pulverized to pass through BS 40 mesh (425 μm) but retained at BS 60 mesh (250 μm) sieve and were used for determining chemical components as in TAPPI Standard (T 257 cm-02). The ethanol-benzene (1:2 by volume) solubility was followed by TAPPI T 204 cm-97 for 6 hours. The solubility of kenaf bast fibers in hot water and 1 % sodium hydroxide were also determined by TAPPI T 207 cm-99 and TAPPI T 212 om-98, respectively. A flow chart of kenaf pulping by the kraft process is shown in Figure 2. Kenaf chips were placed in a laboratory M/K digester and pulped using kraft process according to the cooking conditions given in Table 3.

After cooking, the pulps were thoroughly washed with fresh water on a fine filter, and then disintegrated in a hydropulper at 30,000 revolutions and 0.5 % consistency for 5 min. Disintegrated pulps were screened with vibratory flat screen (with a bedplate of 0.15 mm slit openings) to determine the screened rejects (pulp shives) and screened yield. Residual material remaining on the screen after screening of the pulp slurry for 15 min was collected and oven-dried. The screen accepts were collected on a linen cloth in order to retain all the fines. The screened pulp suspension was spin-dried, fluffed and kept in the cold room (4 °C) for further analysis and processing. The Kappa number (T 236 om-99) of the pulp samples were all performed according to TAPPI Test Methods [15]. Pulp yields were based on the oven-dry weight

Table 1. Comparison of morphological and chemical properties of non-wood fibers with those of wood raw materials

Properties	Kenaf [5]	Straw [6,7]	Bagasse [7,8]	Bamboo [7]	Eucalyptus [9]	Birch [9]	Spruce [10,11]
Morphological							
Fiber length, mm	1.7	1.3	1.7	2.3	1.0	1.9	3.6
Fiber width, m	24	12.9	20	14.4	18	25	35
Felting factor†	105	102	85	161	51	58	101
Chemical							
Holocellulose, %	82.6	78.1	77.8	76.6	74	81	71
Hemicellulose, %	26.2	24.1	27.9	19.5	18	40	27
Lignin, %	17.7	18.4	20.8	23.4	26	19	29

†The ratio of fiber length to fiber width.

Figure 1. Kenaf plant as grown in field.

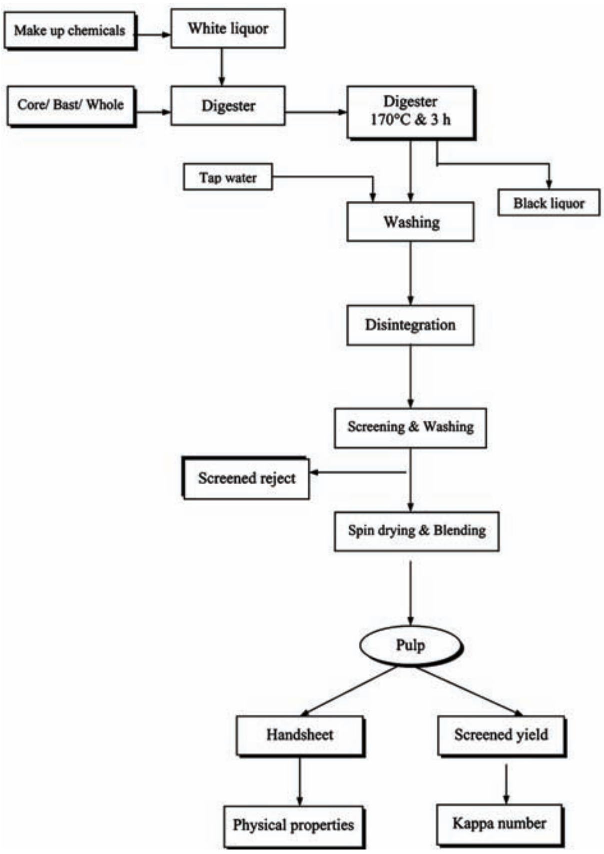

Figure 2. Flowchart of kenaf pulping by kraft process.

Table 2. Chemical composition of kenaf bast fibers grown in Malaysia

Soluble components	%
Ethanol-benzene	2.7
Hot water	3.4
Cold water	1.1
1% NaOH	14.5

Table 3. Pulping process conditions for kraft cooking

Sulfidity, %†	25
Active alkali, %†	15
Time to maximum temperature, min	60
Time at maximum temperature, min	120
Raw material to liquor ratio	1:7
Cooking temperature, °C	170
Raw material weight, g‡	300
Rate of heating, °C/h	170

†Calculated as Na_2O based on oven-dry fiber, ‡oven-dried (o.d.) weight.

of kenaf chips initially put in the digester.

For evaluation of various pulps, handsheets were made in a British handsheet former as per TAPPI Standard T 205 sp-02. The handsheets were conditioned at 50 ± 2 % relative humidity and 23 ± 1 °C temperature according to TAPPI T 402 sp-98 for at least 4 h. The handsheet were tested for:

1. Tensile index (T 494 om-01)
2. Tear index (T 414 om-98)
3. Burst index (T 403 om-97)
4. Dry zero-span breaking length (T 231 cm-96)
5. Canadian Standard Freeness (T 227 om-99)
6. Roughness (T 535 om-91)

Results and Discussion

Extractives in plants come in three main categories-those that are soluble in organic solvents (such as ethanol-benzene mixtures), those that are soluble in water (water solubles), and those that are soluble in aqueous alkali (alkali solubles). Extraneous materials in bast fibers are similar to values reported for most conventional pulp-wood [16]. Ohtani *et al.* [17]

Table 4. Pulp evaluation and paper properties of kenaf bast fiber

Properties	Active alkali		
	13 %	15 %	17 %
Density, g/cm^3	0.48	0.49	0.47
Freeness, m*l* CSF	668	656	652
Pulp yield (o.d.)	44.8	48.8	51.4
Kappa no.	19.8	16.9	13.5
Tear index, mN·m^2/g	29.00	29.05	28.73
Burst index, kPa·m^2/g	4.60	4.80	4.25
Dry zero-span, km	43.4	45.6	47.4
Tensile index, N·m/g	76.07	82.15	74.57
TEA†, J/m^2	68.48	68.57	63.09
Stretch, %	2.21	2.10	2.20

†Tensile energy absorption.

have noted that although the extractives consume alkali during cooking to a significant extent, they can act to protect hemicellulose and slight increases in pulp yields can be obtained if higher chemical consumption can be tolerated. As shown in Table 4, the average pulp yields of kenaf bast fibers were higher than *Pinus oocarpa* (44.0 %) or *Pinus caribaea* (43.1 %) at similar cooking condition [18].

The results of studies on pulping of kenaf conducted during this investigation are given in Table 4. The cooks at 12 % active alkali and less, gave pulps that had high Kappa number, and contained too much uncooked material that was difficult to disintegrate into fibers, so it was not possible to make handsheets from them. Hence, the minimum amount of active alkali (called as charge) was chosen 13 %. Analysis of pulps prepared using 13 % active alkali showed that either lignin precipitation had occurred, and/or lignin within the fiber walls had not been sufficiently removed, as indicated by the high Kappa number. To obtain bleachable-grade kenaf kraft pulps, the charge of active alkali used had to be increased. With increasing active alkali charges between 15-17 %, Kappa number decreased, screened yield increased and screened rejects reduced. An increase in the active alkali above 17 % generally led to limited improvements in screened pulp yield, the Kappa number. Kraft pulping with levels of 17 % active alkali and 25 % sulfidity was sufficient to ensure almost complete elimination of non-cellulosic matter. Therefore, any further increase in the chemicals concentration above this value was found to be unnecessary.

Using kraft pulping showed that bast fibers were relatively easy to cook resulting good pulp yields in the range of 44.8-51.4 %, at low Kappa number (13.5-19.8).

The bast kraft pulp made using 15 % active alkali has the strongest tear index (29.05 mN·m^2/g), of any of the kenaf pulps studied in this investigation although the variation in tear index with alkali charge during pulping is small in the range 13-17 %. This is probably due to the morphological (principally fiber length) differences in the kenaf bast fiber and soft- and hard-wood fibers (Table 1).

In overall, the strength properties of kenaf handsheet were better than those of *Eucalyptus species* [19] and *Quercus rubra* [20] but similar to those of *Pinus caribaea* and *Pinus oocarpa* [18]. Kenaf bast pulps elucidated high bonding ability and thus, high tensile strength. Kenaf bast pulp seems suitable raw material for blending with short-fibered raw materials to improve their physical properties, especially the tear resistance, it is obviously possible and attractive to use the kenaf bast pulp for the same purpose if the end properties that are needed commercially can be achieved.

Conclusions

The kraft pulping of Malaysian kenaf bast fiber produced pulps with good yield and strength properties using 15 % active alkali charge. In general, the use of higher active alkali charges increased the pulp yield. The good pulping characteristics and high strength properties of kenaf paper are indicative that kenaf bast pulp and paper are suitable for production of wide rage of specialty papers.

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