American-Eurasian J. Agric. & Environ. Sci., 12 (7): 886-889, 2012
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2012.12.07.831

Producing Paper from Iranian Kenaf by Soda and Soda-Anthraquinone Processes

Amir Hooman Hemmasi

Department of Wood and Paper Engineering, Science and Research Branch,
Islamic Azad University, P.O. Box 14515/775 Tehran, Iran

Abstract: Chemical composition and fiber characteristics of Iranian kenaf whole talk were determined. Then Soda and Soda-anthraquinone (Soda-AQ) cooking of kenaf core, bark and whole stalk from Iran was carried out under different conditions and pulps with good to very good yields and mechanical properties were obtained. The Soda-AQ process was particularly well suited for kenaf whole stalk with yield, rejects, kappa number, viscosity, brightness and strength properties superior to those of soda pulping. Thus, it seems possible to avoid the high cost of separation of bark and core, which would represent a problem for commercialization of this raw material. In general, soda pulping provided better results only in tensile and burst index with kenaf bark. The same method showed better results in tensile and burst index as well as viscosity, brightness and runnability only with kenaf core.

Key words: Kenaf · Papermaking · Chemical composition · Soda · Soda-anthraquinone

INTRODUCTION

Kenaf is an herbaceous annual plant grown in many parts of the tropics and in some sub-tropical and warm temperate areas for its bark fibers used as a substitute for jute in cordage and sacking. Kenaf *(Hibiscus Cannabinus L.)* is a native plant to hot and humid regions and has been cultivated in some countries such as India, Bangladesh, Pakistan, China, Sudan, Cuba, Brazil, Thailand, Argentina, Italy, Russia and Hungary for centuries. Kenaf research in Iran has undergone in its history over the years and highly influenced by its area cultivation. Cultivar, planting, date, plant height, stem diameter, plant density, cambial duration and harvest time are the most effective factors on fibers yielding [1]. Kenaf is sensitive to photoperiod and different cultivars. Accurate cultivation time benefits the spring rainfall for seeds to germinate quickly and early growth stage completes better, resulting increment of height and stem diameter which finally results on fiber yield.

In Iran kenaf is grown in Varamin (40 kilometers southeast Tehran Province-IRAN) with latitude 35°, 19′ north and longitude 51°, 39′ east, located at an elevation of 915 meters above sea level. According to Koppen climate division, Varamin climate is arid and semi desert. Seasonal temperature fluctuation and even day and night are high.

Annual rate of evaporation is higher than rainfall so the weather is dry. The maximum and minimum temperature is 42°C and-1°C respectively. The soil texture of the research site was loam-clay with a pH of 7.56 and the Electrical Capacity (EC) was 3.02 ds/m. The kenaf plant contains two distinct fiber components, bark and core. The bark (bast) fibers constitute 35-40% and the core (woody) fibers 60-65% by weight of the stalk [2, 3, 4, 5]. The separation of the bark and core by simple mechanical and screening treatments has made possible the use of bark alone to produce a high quality long fiber pulp. The yield and strength properties of soda and sulfate pulps from kenaf bark were approximately equivalent under identical cooking conditions. Soda pulp consumed higher bleaching chemical, but showed less degradation than sulfate pulp [6].

Cold soda and alkaline sulfite processes gave high-yield (72-88%) pulps with satisfactory strength properties, brightness and opacity. Blending of these pulps with commercial bleached bamboo pulps further improved the strength properties and brightness [7]. Kenaf bast fibers cooked by kraft, kraft-AQ, soda, soda-AQ processes gave pulp yields in the range of 51-60%. Kenaf core fibers

Corresponding Author: Amir Hooman Hemmasi, Department of Wood and Paper Engineering,
Science and Research Branch, Islamic Azad University, P.O. Box 14515/775 Tehran, Iran.

treated with the same chemical pulping processes gave pulp yields of 40-54% [8]. Kraft and soda pulping of kenaf gave similar yields and papermaking properties.

The purpose of the present work was to evaluate the suitability for papermaking of the Iranian varieties of kenaf by the soda and Soda-anthraquinone pulping methods with additives separately for the bark, core and the whole stalk.

MATERIALS ANS METHODS

Kenaf stalks were collected from the samples prepared from Varamin Agricultural Research Center. The 2-3 m high kenaf stalks were 3.5-6.0 cm in diameter at the center of the stalk. The stalks were chopped to 3-5 cm and the kenaf bark and core were manually separated. The soda-AQ pulp fibers were used for fiber measurement after dispersion in water and staining with 1% aqueous Safranine solution and mounted on slides [9]. Fiber measurements were microscopically carried out at ×300 and × 400 magnifications.

For chemical composition determination, agro-fibers were ground and 40-mesh fractions were selected. The procedures were performed according to TAPPI Method T 264 om-88. The samples were first submitted to Soxhelt extraction with ethanol/benzene [1:2 (v/v)] for 6 hours. The determination of alpha-cellulose, lignin and ash content were performed following the standard methods T 212 om-93, T 203 os-74 and T 211 om-93, respectively. Holocelluloses were determined according to a previous study.

The pulping trials with soda and soda-AQ methods against a reference soda cooking with different levels of alkali charge were carried out in a 7-L electrically heated rotary digester [10]. A Jokro mill was used for beating. Pulps characteristics and strength properties were determined according to Tappi and German Zellcheming standards.

RESULTS AND DISCUSSIONS

The kenaf bast fibers average length (2.9 mm) was in the range of softwoods and bamboo (1-7 mm), whilst the woody portion fiber length (0.9 mm) was similar to that of hardwoods (0.7-1.5 mm). The quite wide core fibers (30.1 µm) had medium thick walls (3.8 µm) in contrast to less wide (20 µm) but almost of the same thickness bast fiber. The ash contents of the bark (KB), core (KC) and whole kenaf stalk (KW) were rather high with 3.2-4.7% (Table 1), but typical for tropical non-woody plants.

Table 1: Chemical composition of kenaf core and bark from Iran compared with data from other locations (all values expressed as percent oven-dry soluble or components on oven-dry raw material).

Component of Kenaf	Iran		France (2)		
Origin, reference	bark	Core	Sudan (1)	Whole stalk	USA (3)
Ash	4.7	3.2	3.4	5.9	4.1
Silica	0.05	0.11	0.13	0.03	n/a
Soluble in:					
Hot water	7.4	5.2	9.5	9.3	10.2
1% NaOH	23.4	27.7	28.4	32.2	54.4
Alcohol-benzene (1/2)	1.8	3.1	2.9	5.6	3.1
Total extractives	10.1	6.9	n/a	n/a	54.4
Cellulose	55.1	46.5	49.1	47.6	n/a
Holocellulose	n/a	n/a	78.9	n/a	n/a
α-Cellulose	n/a	n/a	49.5	n/a	37.4
Pentosans	n/a	n/a	18.6	n/a	n/a
Lignin [a]	11.5	18.9	15.6	19.3	19.7
Acid-soluble lignin	5.0	3.8	n/a	n/a	n/a
Cellulose/lignin ratio	74.8	3.2	3.1	3.3	4.1

a Corrected for ash.
(1) Khristova *et al*. (1998)
(2) CTFT (1987)
(3) Touzinski *et al*. (1973)
n/a, Not available.

Table 2: Kenaf bark (KB): pulping conditions and Results

Cooking process	Soda	Soda-AQ
Pulping conditions		
Active alkali as Na2O (%)	17	1.5
Anthraquinone (%)	-	0.1
Liquor-to-bark ratio	4	4
Maximum temperature (C)	165	165
Time to maximum temperature (min)	60	60
Time at maximum temperature (min)	120	120
Pulping results		
Total yield (%)	52.8	57.1
Rejects (%)	1.7	0.6
Kappa number	25.5	16.1
CED viscosity (ml/g)	81.3	835
ISO brightness (%)	18.1	25.2
Hand sheet properties at 40 °*SR*		
Tear index ($mN/m^2/g$)	8.1	13.3
Tensile index (N/m/g)	73.8	64.5
Burst index ($kPa/m^2/g$)	5.8	4.1
Runnability factor	7.5	9.7

However, the silica contents were in the range of 0.05 to 0.11 for the bark and core respectively. The hot water extractives (5.2-7.4%), organic solvents extractives (1.8-3.1%) and the 1% NaOH soluble (23.4-27.7%) were rather high due to the presence of many soluble polysaccharides and phenolic compounds [11] The good Kurschner-Hoffer cellulose contents for kenaf bark and whole kenaf stalk implied good pulp yields to be expected. The total lignin content of kenaf bark (11.5%) was low and moderate compare to the kenaf core (18.9%).

Table 3: Kenaf core (KC): pulping conditions and results

Cooking process	Soda	Soda-AQ
Pulping conditions		
Active alkali as Na2O (%)	17	1.5
Anthraquinone (%)	-	0.1
Liquor-to-bark ratio	4	4
Maximum temperature (C)	168	165
Time to maximum temperature (min)	60	60
Time at maximum temperature (min)	120	120
Pulping results		
Total yield (%)	41.2	46.1
Rejects (%)	3.8	1.6
Kappa number	24.8	20.1
CED viscosity (ml/g)	780	734
ISO brightness (%)	31.4	23.1
Hand sheet properties at 40 °*SR*		
Tear index (mN/m^2/g)	6.3	9.6
Tensile index (N/m/g)	70.5	62.1
Burst index (kPa/m^2/g)	7.5	4.9
Runnability factor	8.7	5.0

Table 4: Whole kenaf stalk (KW): pulping conditions and results

Cooking process	Soda	Soda-AQ
Pulping conditions		
Active alkali as Na2O (%)	19	17
Anthraquinone (%)	-	0.1
Liquor-to-bark ratio	4	4
Maximum temperature (C)	165	165
Time to maximum temperature (min)	60	60
Time at maximum temperature (min)	120	120
Pulping results		
Total yield (%)	4.8	53.8
Rejects (%)	3.5	0.9
Kappa number	28.4	22.1
CED viscosity (ml/g)	827	875
ISO brightness (%)	24.6	29.1
Hand sheet properties at 40 °*SR*		
Tear index (mN/m^2/g)	8.1	13.1
Tensile index (N/m/g)	68.4	98.1
Burst index (kPa/m^2/g)	4.8	5.8
Runnability factor	7.8	11.9

Pulping of Kenaf Bark: In soda pulping of kenaf bark, carried out as reference cook with an active alkali level of 17% as Na2O, a kappa number of 25.2 was attained (Table 2). The addition of 0.1% anthraquinone to the cooking liquor at lower effective alkali charge (15%) gave a much higher degree of delignification (kappa number 13.5) and an increase in yield at lower reject content. Moreover, brightness and pulp viscosity were improved [12].

The strength properties of the unbleached kenaf bark pulps (Table 2) were quite high. The tensile and burst strengths of the soda-AQ were lower than for the soda reference, which might be attributed to some carbohydrate degradation associated with the more intense delignification [13].

Lower yields and brightness, more rejects and kappa number were obtained with the soda process compare to AQ addition. The viscosity was also significantly lower as for the Soda-AQ pulp. The soda pulps showed lower tear strength, but the tensile and burst index were slightly higher. From Tables 2 and 3 it is obvious that the kenaf bark and core behave very differently in cooking and the pulps differ considerably in their properties, particularly with regard to the burst-tensile relationship. Therefore, it was of interest to conduct pulping trials with whole kenaf stalk.

Pulping of Kenaf Core: The lignin content of kenaf core is more than the lignin content of kenaf bark. Due to its much higher lignin content, kenaf core is more difficult to pulp than kenaf bark and the relationship between kappa number and its yield is less favorable. Thus, a kappa number less than 20 was not achieved with the conditions chosen (Table 3).

Pulping of Whole Kenaf Stalk: Soda-anthraquinone pulping of whole kenaf stalk resulted in lower rejects and kappa number, higher screened yield, viscosity, brightness and strength properties compared to those for the soda process (Table 4). The soda cooks were carried out at higher alkali charge of 19%, nevertheless delignification was not sufficient and high reject contents were obtained. Comparison of kenaf bark, kenaf core and whole kenaf stalk as separate raw materials shows that kenaf bark was easy to cook and gave good yields of pulp with high tensile and burst resistance, while kenaf core was much more difficult to pulp and gave significantly lower yield at higher kappa number. Kenaf core pulps showed high bonding ability and thus, high tensile and burst strength.

For whole kenaf stalks intermediate results were obtained. Although kenaf bark pulp seems the most suitable raw material for blending with short fibered raw materials to improve their physical properties, it is obviously possible and attractive to use the whole kenaf stalk pulp for the same purpose. Low yields were obtained with the soda process without AQ addition. Comparison of the strength properties of the whole kenaf pulps indicated, in general, the superior strength properties of

the Soda-anthraquinone pulps. The high tensile strength, which is mainly based on the good bonding ability of the fibers, results from the high carbohydrate content of the Soda-anthraquinone pulps due to the high stability of xylan and cellulose in the outer cell wall layers.

CONCLUSIONS

The fiber dimensions are specific for each part of the kenaf stalk, with the bast fibers similar to softwoods and the woody core similar to hardwoods. The chemical composition is characterized by low to moderate lignin content and good carbohydrate content. The reference soda pulping of all raw materials yielded more than 40% of bleachable grade pulp with satisfactory strength characteristics. The addition of AQ in soda cooking accelerated the delignification, reduced alkali consumption, kappa number and brightness, increased yield and viscosity and gave pulps with properties superior to those of reference soda pulping. The S-AQ process was particularly well suited for pulping of kenaf bark, but not for kenaf core, which behaved like hardwood. With kenaf bark, tensile and burst indexes were superior in soda compare to soda-AQ pulps. The use of whole kenaf stalk without separation of core and bark gives pulps with very good quality a high yield, especially with the Soda-anthraquinone process. Thus, it seems possible to avoid the high cost of separation, which would represent a problem for commercialization of this raw material [8].

REFERENCES

1. Bahtoee, A., K. Zargari and E. Baniani, 2012. An Investigation on Fiber Production of Different Kenaf (*Hibiscus cannabinus L.*) Genotypes, World Applied Sciences Journal, 16(1): 63-66.
2. Kaldor, A.F., C. Karlgren and H. Verwest, 1990. Kenaf, a fast growing fiber source for papermaking, Tappi J., 72: 205-209.
3. Horn, R.A., 1978. Morphology of Pulp Fiber from Hardwoods and Influence on Paper Strength, Forest Products Lab Report 312, Madison.
4. Khristova, P., S. Bentchgeva and I. Karar, 1998. Soda-AQ pulping of four Acacias from Sudan, Cell. Chem. Technol., 32: 299-307.
5. Sharma, Y.K., R. Dhawan and B.G. Karira, 1984. High yield pulps from kenaf. Ind. Forest, 110: 401-406.
6. Khristova, P., O. Kordsachia, R. Patt, T. Khider and I. Karrar, 2002. Alkaline pulping with additives of kenaf from Sudan, Industrial Crops and Products, 15: 229-235.
7. James, K.R. and J. McCamley, 1981. Separation of core and bark from forage harvested kenaf, In: I.M. Wood and G.A. Stuart (Eds.), Proceedings of the Kenaf Conference (Kenaf as a Potential Source of Pulp in Australia), Brisbane, Queensland, pp: 69-72.
8. CTFT., 1987. Annual Report of Cellulose and Chemistry Division of CTFT, Nogent-sur-Marne, France.
9. Zhou, C., Y. Ohtani, K. Sameshima and M. Zhen, 1997. Selection of kenaf (*Hibiscus cannabinus L.*) varieties for papermaking on arid hillside land in China. Mok. Gakkais, 43(9): 770-777.
10. Watson, A.J. and B.G. Gartside, 1976. Using woody fibre from agricultural crops, Aus. For., 39(1): 16-22.
11. Hart, P.W., B.N. Brogdon and J.S. Hsieh, 1991. Anthraquinone pulping of non-wood species, Nonwood Plant Fibers. Progress Report, 21: 183-191.
12. Touzinski, G.F., T.F. Clark, W.H. Tallant and W.F. Knolek, 1973. Soda pulps from kenaf bark and from core. In: Non-wood Plant Fibre Pulping, CA Report No. 52. Tappi, Atlanta Holton, H.H., 1977. Soda additive softwood pulping a major new process, Pulp Paper Can, 78: T218-T223.
13. Holton, H.H., 1977. Soda additive softwood pulping a major new process. Pulp Paper Can., 78: T218-T223.