Kenaf—a fast growing fiber source for papermaking

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Kenaf, a fast growing annual crop with a high fiber yield per acre, has considerable potential as a versatile raw material for papermaking in tropical and temperate climates.

Extensive practical research by the U. S. Department of Agriculture (USDA), as reported in a number of USDA publications and TAPPI research reports (*1*, *2*), has identified kenaf as a promising alternative fibrous raw material for papermaking. The work by USDA included agricultural trials in a number of southern U.S. states, harvesting developments, and pulping and papermaking trials. During the course of these programs, whole stalk kenaf was pulped by the kraft, soda, and mechanical pulping processes, and bond and newsprint papermaking trials were carried out (*3*, *4*).

Recent agricultural trials in Australia, together with the harvesting and transporting techniques developed there, have added to the U.S. research findings (*5*). The Australian approach to pulping has concentrated on the separate chemical pulping of the two very distinct kenaf plant components—bark and core. These two fiber fractions have been pulped and assessed separately in laboratories in Australia, Japan, Scandinavia, and North America. The results of some of these bark and core pulping tests have been reported (*5*), but correlation of these tests and their implications for the papermaking properties of bark and core pulps have received little attention.

Kenaf cultivation

Kenaf is grown extensively in Asia and Central America as a cordage fiber. It is an annual plant that grows a straight stem to a height of up to six meters on a five- to seven-month growth cycle in suitable temperate and tropical climatic conditions. As a summer crop, the kenaf seed is planted during the spring, and the crop is harvested in early autumn. In tropical areas, kenaf can produce two crops per year. Yields from 6 to 8 a.d. metric tons per acre per year have been demonstrated in the southern United States.

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Sufficient rainfall or irrigation and the use of fertilizer are necessary for optimum yield. Disease and pest problems necessitating the use of pesticides and herbicides have been minimal. Ongoing research with plant breeding and seed selection can be expected to further improve yield and fiber quality as well as disease resistance.

It is preferable to harvest the kenaf crop when the fiber is air-dry (approximately 10% moisture content). This is achieved by leaving the crop standing in the field. Integrated harvesting, baling, and transporting techniques have been developed in Australia for the cost-effective harvesting of kenaf on a large scale. This system is capable of harvesting in excess of two acres per hour on a three-shift basis.

Kenaf fiber

The kenaf plant contains two distinct fiber components, bark and core. The bark fibers, which constitute 35% to 40% by weight, are 3 to 4 mm long and slender. The core fibers, 60–65% by weight, are short, from 0.5 mm to 0.7 mm.

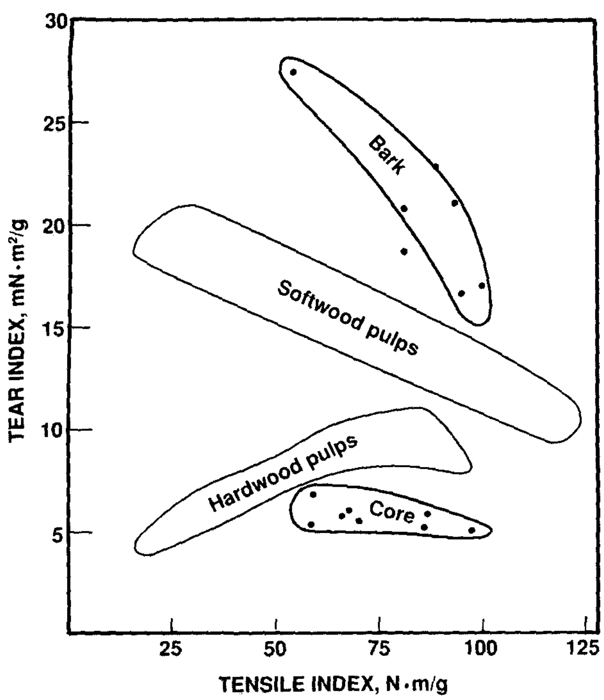
Kenaf is currently used on a limited scale in pulp and papermaking in Thailand and China by pulping the whole stalk, generally with other fibrous raw materials (*6*).

To attain optimum results in chemical pulping, the bark and core fractions have to be separated prior to pulping. An automated fiber separation process has been developed and patented by Ankal Pty. Ltd. in Australia (*5*). The Ankal equipment includes bale opening, fiber separation, and screening at a rate of 12–15 a.d. metric tons/h. It produces a bark fiber fraction of 94–99% purity by weight and core fiber with limited residual bark content.

Chemical pulping

Kenaf fiber can be processed into chemical pulp by the usual conventional pulping processes including sulfate, soda, and soda-anthraquinone (AQ) (*2*). Much of the laboratory testing has been based on soda-AQ pulping, which gives a bleached yield of 57% for bark and 41% for the core. The yield differential results in a finished pulp ratio of approximately 45% bark pulp and 55% core pulp.

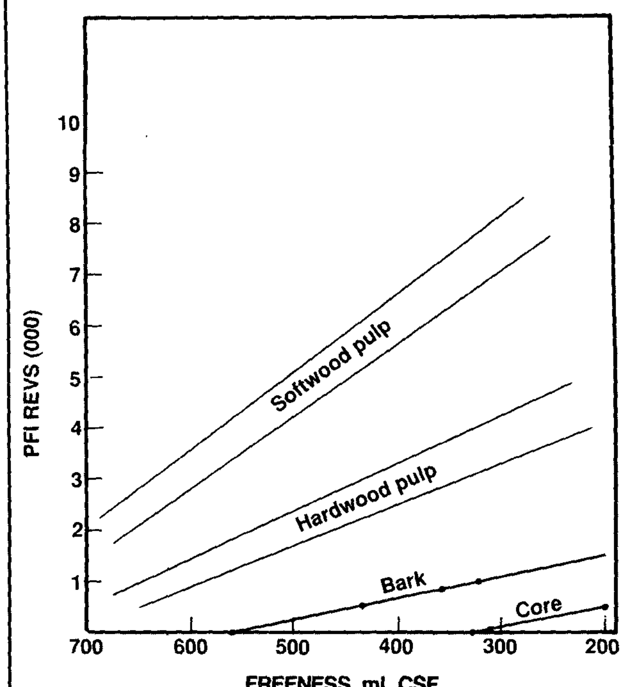
1. Tear versus tensile indices for kenaf bark and core pulp compared with softwood and hardwood pulps



Source for bark and core pulp properties:

Associated Pulp & Paper Mills, Australia
Australian Paper Manufacturers, Australia

2. Refining time/energy versus freeness for kenaf bark and core pulps compared to softwood and hardwood pulps.



Source for bark and core pulp properties:

Associated Pulp & Paper Mills, Australia

I. Basic properties of bark and core pulps, and some blends (all unbeaten)

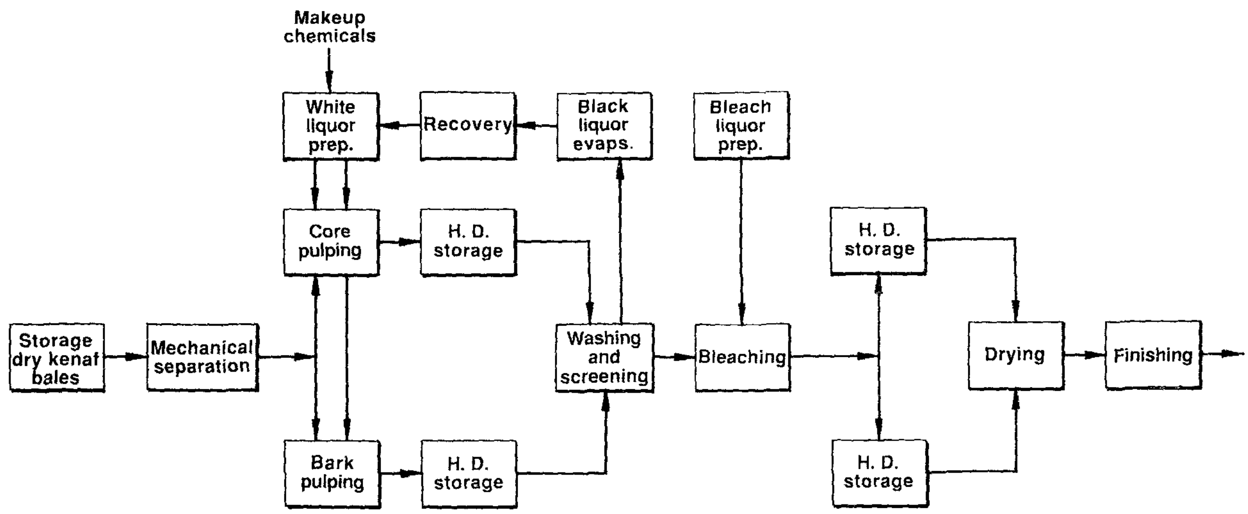
	Mixture				
Bark %	*100*	*80*	*65*	*50*	*—*
Core %	*—*	*20*	*35*	*50*	*100*
Freeness, mL CSF	625.0	600.0	530.0	425.0	225.0
Bulk, cm^3/g	2.1	2.0	1.9	1.7	1.1
Burst index, kPa·m^2/g	3.7	4.5	5.0	5.7	7.3
Tensile index, Nm/g	63.7	72.0	80.0	88.1	123.0
Tear index, mN·m^2/g	22.1	20.0	17.5	13.1	3.9
Z strength, kPa	276.0	350.0	420.0	556.0	>750.0
Scattering coeff., m^2/kg	25.2	28.5	28.5	27.5	18.7
Fiber coarseness, mg/100 m	18.8	17.5	20.5	21.1	33.1
Drainage time, s	3.4	4.0	5.0	8.6	20.4

Source: Associated Pulp & Paper Mills, Australia

II. Cost comparison of wood and kenaf in chemical pulping

	Southern pine	*Kenaf*
Growing cycle	15 - 20 years	5 - 6 months
Average yield of dry fibrous material	3 tons of wood/ acre/year	6 tons of kenaf/ acre/year (Range 2.5-12)
Bleached yield	43%	46% (average of core and bark)
Tons of pulp/acre	1.45 a.d. ton/acre/ year	3.05 a.d. ton/acre/ year
Delivered cost of fibrous raw material	US$ 120-180/ton of pulp	US$ 100-120/ton of pulp

3. Kenaf pulp mill basic flow diagram



Raw material and pulp proportions (by weight)

	Raw fiber	Bleached yield	Pulp
Bark	35% - 40%	57%	43% - 48%
Core	60% - 65%	41%	52% - 57%

Silica content, often a problem with annual fiber crops, has been found to be 1% or less (*6, 7*).

Papermaking characteristics

Bark pulp

The papermaking properties of chemical bark pulp compare favorably with those of softwood pulp. At comparable tensile strength, bark pulp has a considerably improved tear strength and higher bulk factor. **Figure 1** provides comparisons of kenaf bark and core pulps versus hardwood and softwood pulps, while **Table I** lists basic properties of kenaf bark and core pulps. Values such as opacity, porosity, and surface smoothness are very similar to wood pulps.

A special characteristic of bark pulp is that only a fraction of the softwood pulp refining energy is required to develop strength properties. This is illustrated in **Fig. 2.**

Chemical bark pulp can replace softwood chemical pulp in mechanical pulp grades such as newsprint, LWC, and SC, as well as in normally low-refined tissue grades and woodfree grades, with the added advantage of low refining energy requirements.

In addition, kenaf bark pulp can serve as a specialty pulp because of its favorable diameter-to-fiber-length ratio. The possibility of selling a portion of kenaf bark pulp at specialty pulp prices enhances the financial attractiveness of a kenaf pulp mill.

Core pulp

The short fiber core pulp has a relatively low tear strength but high tensile and burst strength when compared to hardwood pulps, as shown in Fig. 1 and Table I. In comparison with bleached kraft, hardwood pulp, opacity and bulk are slightly lower, porosity is higher, and surface smoothness is similar.

Core pulp leaves the pulping process at a comparatively low freeness of 350-450 mL CSF, and it should preferably be used in unrefined condition for papermaking. It is extremely sensitive to refining and can easily end up being overrefined, with a negative impact on drainage as suggested in Fig. 2.

With papermaking properties very similar to those of hardwood pulp, core pulp has potential end uses in printing and writing papers, coating base paper, board surface layers, and tissue grades.

Bark and core pulp mixtures

Mixtures of bark and core pulp combine the characteristics of both grades with minimum refining requirements. The addition of 20-25% core pulp as an extender in bark pulp for papermaking purposes does not appear to have a significant effect on physical properties and should be considered to optimize the saleable quantity of bark pulp.

Mill configuration

With the fundamental differences in fiber characteristics, pulping yield, and commercial application of chemical bark and core pulps, fiber separation prior to pulping in a nonintegrated market pulp mill is a logical concept in the evolution of kenaf pulping. Such a development is now under consideration in several locations. It would permit the production of a range of pulp grades, including specialty bark pulps, substitutes for long and short fiber wood pulps, and a range of intermediate pulp grades.

The need for covered kenaf storage between harvests is a disadvantage. This is offset, however, by low fiber cost and low manufacturing cost in pulping and bleaching, and mill capacity need therefore not be on the same scale as wood-based pulp mills.

A comparison of raw material costs between southern pine and kenaf in the southern United States, shown in **Table II**, indicates that the fiber cost per ton of pulp of kenaf will be 20–40% less than that for southern pine. This cost advantage originates in the high agricultural yield of kenaf and the high pulping yield of the bark fiber. Intensive kenaf cultivation could accentuate this cost advantage. The delivered cost of kenaf fiber of $45-50 per moisture-free ton, which is the basis for this comparison, would result in a farm revenue similar to cotton and well in excess of soybeans.

In common with other annual fibers, kenaf pulps readily with lower chemical consumption and a shorter cooking cycle and permits good strength development in soda or soda-AQ pulping, which in turn facilitates bleaching at reduced chemical consumption. With soda or soda-AQ pulping and less bleaching, the environmental impact of a kenaf pulp mill would be significantly less than that of a wood-based mill. Chemical recovery can be through conventional processes, as the silica content in black liquor is low. Heat and power consumption will be less than for a wood-based mill because of reduced pulping and bleaching requirements. In the absence of bark as a fuel for steam generation, auxiliary fuel will be a requirement.

The two fiber fractions could be cooked in parallel digester lines, followed by a common bleach plant and drying line with high-density storage before and after the bleach plant to permit alternating and blending of bark and core pulps, as illustrated schematically in **Fig. 3.**

Continuous digesters would lend themselves well for the pulping of kenaf, but effective feed mechanisms for the two fiber fractions would have to be developed first. Pending the design of these systems, batch digesters could be used.

A pulp brightness between 80 and 85 will be attainable without the use of chlorine. The selection of the bleaching sequence and bleaching chemicals is site specific and dependent on relative local chemical costs.

The chemical kenaf pulp potential

In addition to pulp characteristics and economic and environmental factors, local raw material conditions may give added impetus to a kenaf pulp mill development.

In the southern United States, the limits on the existing fiber supply and the desirability of introducing a new high-yielding farm crop are important incentives. The viability of growing kenaf has been demonstrated in a number of southern U. S. locations, and sample calculations indicate that a kenaf pulp mill with a capacity of 100,000 tons/year to 150,000 tons/year will be economically attractive. It will have to be supported by a kenaf growing area of 50,000–75,000 acres, which includes provisions for crop rotation.

In other locations, a deficit of papermaking raw materials and import substitution will be the rationale for kenaf pulping. The rapid increase in paper consumption in Asia cannot everywhere be supported by existing forest resources. Kenaf, which is widely grown in Asia, is a ready answer to such raw material deficits. Local labor costs may permit consideration of mills of smaller capacity in developing countries.

Current predictions of worldwide paper and board consumption indicate an anticipated increase from the current 220 million tons/year to close to 300 million tons in 2000. Part of the incremental raw material required will come from increased recycling. In addition, some 50–75 million acres of new forests and fast-growing plantations will have to be committed to the pulp and paper industry during the next 10 years if wood alone is to satisfy the increased demand.

In this perspective, kenaf is a strong contender to meet part of the additional fiber supply requirements. Kenaf represents a high-quality, high-yield option, particularly in areas where wood is in deficit and paper consumption increases at a high rate.

Summary

Chemical kenaf pulps are a promising alternative to other papermaking raw materials in many areas of the world. Existing experience and trials suggest that kenaf pulps can be used in most paper grades, alone or in combination with other fibers. Kenaf pulp can be produced in a spectrum of chemical pulp grades ranging from short fiber substitutes to specialty pulps. It has quality characteristics that will merit price equality with the corresponding wood-based pulp grades and a substantial price premium for the specialty pulp. The low specific refining power requirements are of particular interest.

Extensive experience with kenaf already exists in cultivation, harvesting, and fiber separation. Fiber costs are predictable and will generally be well below those of wood. Kenaf pulp mills can be built on a smaller scale than conventional wood-based mills because of lower fiber, pulping, and bleaching costs, and the environmental impact of kenaf pulping is substantially less than for wood-based mills.

In summary, kenaf possesses properties and economic merits that make it an outstanding supplementary fibrous raw material of the future.☐

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