Suitability of kenaf CTMP for linerboard

Gary C. Myers and Marvin O. Bagby

ABSTRACT: The authors studied using whole-stem kenaf for CTMP as an alternative to wood and determined the feasibility of substituting high-yield kenaf mechanical pulp for kraft softwood pulp in linerboard. Linerboard using kenaf CTMP alone was not comparable to linerboard prepared from 100% loblolly pine kraft. Blending 30–50% kenaf CTMP with loblolly pine kraft pulp appeared to produce pulp with acceptable strength for linerboard. Results showed that kenaf CTMP addition could enhance compressive strength, a critical factor.

KEYWORDS: Chemithermomechanical pulps, kenaf, linerboards, mechanical pulps, substitutes.

Kenaf (Hibiscus cannabinus L.) is an annual, nonwoody plant for possible use as a renewable fiber resource and an alternative agricultural crop for the southern United States. Most pulping processes familiar to the pulp and paper industry can handle kenaf (1, 2). Scientists from the U.S. Department of Agriculture, Agricultural Research Service (ARS), found that kenaf pulped with kraft, soda, or neutral sulfite chemicals was superior to commercial hardwood pulps. Excepting resistance to tear, it was comparable to softwood kraft pulps and superior to softwood sulfite pulps (1). Paper machine runs using various kenaf pulps have provided anywhere from a few kilograms up to several tons of specific grades of paper (3, 4). There has also been successful newsprint production on a commercial scale using a kenaf peroxide chemithermomechanical pulp (CTMP) (4). The U.S. Department of Agriculture Forest Service, Forest Products Laboratory (FPL) in collaboration with the ARS, the Cooperative States Research Service (CSRS), and an industrial newsprint recycling mill recently showed successful use of a pulp blend with 25% kenaf CTMP as a reinforcing pulp in recycling newsprint (5).

For this study, the FPL, CSRS, and ARS entered a cooperative agreement to determine how much high-yield kenaf mechanical pulp could substitute for kraft softwood pulp in linerboard. The mechanical pulps used in this study came from two locations. There was an initial, experimental pulping trial at the Andritz Sprout-Bauer (AS-B) Research and Development Laboratory using commercial-scale equipment. The FPL conducted the other experimental pulping trials using a 305-mm pressurized refiner. This paper will present and discuss the results from both locations.

Experimental

Raw material

All FPL pulping trials used kenaf grown in Louisiana. All Andritz Sprout-Bauer trials except one used the same kenaf. This exception used kenaf grown in Texas.

Particle size reduction and washing

The particles of chopped, whole-stem kenaf from Louisiana varied from dust to approximately 25-cm long strips of predominantly bark fibers. Attempts to use the as-received raw materials failed because the long particles quickly became entangled on any rotating shaft such as the stirrers and feed screws of pressurized refiners. Additional reduction in particle size was therefore necessary before processing. Hammer milling accomplished this. The hammer mill at Andritz Sprout-Bauer had a 25-mm grate opening, and the one at FPL had a 38-mm grate opening.

Both locations slurried the kenaf materials in a pulper at approxi-
Fiberizing and refining

The Andritz Sprout-Bauer location fiberized the kenaf in a pressurized double-disc refiner with a commercial plate pattern installed on both discs. The discs rotated in a counterclockwise (CCW) direction. The material was presteamed and fiberized at 207-kPa steam pressure. Dwell time varied between 1.5 min and 3.0 min. Raw material feed rate and clearance between the refiner plates varied. The fiberized material underwent refining in an atmospheric double-disc refiner with the same plate pattern installed on both discs rotating in a CCW direction. A series of constant speed belt conveyors delivered uniform volume of shredded pulp to the refiner inlet. Clearance between the refiner plates was variable. The dilution water entering with the shredded pulp was approximately 22% consistency in the refining zone. Two or three passes were necessary to reach desired pulp freeness. Measuring the motor load in brake kilowatts and actual feed rate of raw material to the refiner provided measurement of the energy consumed during fiberization and refining. These values gave energy consumption as kW·h o.d. metric ton.

The FPL location fiberized the kenaf in a laboratory-scale pressurized refiner with a commercial plate pattern installed in both stationary and rotating positions. The kenaf was presteamed and fiberized at 68.9-kPa steam pressure. Feed-screw rotation speed and clearance between the refiner plates varied. The fiberized material was refined in a laboratory scale atmospheric refiner with the same plate pattern installed in both stationary and rotating positions. A constant speed belt conveyor delivered a uniform volume of shredded pulp to the refiner inlet. Clearance between the refiner plates was variable. The dilution water entering with the shredded pulp was approximately 15% consistency in the refining zone. Three to five passes were necessary to reduce pulp CSF to 100 mL or less. An integrating watt-hour meter attached to the power supply side of the 44.8-kW electric motor measured the energy consumed during fiberization and refining. Energy consumption values for fiberizing and refining are in W·h o.d. kg with the idling energy subtracted. Latency was removed from the pulp after fiberizing and after each refining stage. Pulp was slurried with 88°C water in a large container and soaked for 30 min with stirring.

Kraft pulping

Two kraft pulps were prepared separately from loblolly pine chips at FPL in a 23-L batch digester equipped with heat exchanger and liquor cir-
Pulps produced at Andritz Sprout-Bauer were made into handsheets weighing 60 g/m² and were tested in the laboratory according to TAPPI test methods. A disc with 0.10-mm slot openings determined shive contents.

### Results and discussion

Commercial pulps intended for linerboard production are usually high freeness softwood kraft pulps. These produce linerboard of acceptable strength and product quality. An important characteristic of linerboard is sufficient bursting and edge compression strengths (3). Mechanical pulps must be refined to very low freeness values to reduce or eliminate shives and develop strength properties (9). Unfortunately, lowering freeness also shortens average fiber length, increases fines content, and increases pulp drainage time.

### Andritz Sprout-Bauer pulping trials

There were three series for the Andritz Sprout-Bauer trials. Sodium hydroxide applications of 4.4%, 7.2%, and 10.9% were added at the eye of the refiner and metered during the trials as the steamed kenaf materials were conveyed from the digester to the refiner.

Figure 1 shows that energy consumed to reach comparable freeness for each pulp decreased as the concentration of NaOH increased. Lowering pulp CSF to 100 mL consumed 1184, 1106, and 918 kW·h/ton for 4.4%, 7.2%, and 10.9% NaOH applications, respectively. Lowering pulp CSF also reduced shive content to below 4%. When the caustic addition increased from 4.4% to 7.2% to 10.9%, the long fiber fraction of 100 mL pulps were 11%, 16%, and 16% respectively, and the fines contents were 25%, 31%, and 29%, respectively.

Handsheet density for pulps refined to 100 mL CSF increased from 432 to 633 kg/m² when the NaOH application increased from 4.4% to 10.9%, respectively. Within each NaOH application, group handsheet density also increased in response to additional refining. The increasing handsheet density probably reflects a combination of reduced coarse fiber fraction, greater fines content, more flexible and conformable fibers, and better fiber-to-fiber bonding. Increasing NaOH application from 4.4% to 10.9% and refining to 100 mL CSF improved most handsheet strength properties. Tensile index increased from 43.2 to 63.6 N/m², burst index increased from 1.7 to 3.2 kPa·m²/g, and tear index increased from 6.2 to 6.8 mN·m²/g.
Kenaf

5. Tensile strength of loblolly pine kraft and kenaf CTMP blends

6. Compressive strength of loblolly pine kraft and kenaf CTMP blends

FPL pulping trials

FPL ran three series of pulping trials. There were NaOH applications of 4.4%, 7.2%, and 11.2% approximately 18 cm before the eye of the refiner. The addition point was in a screw conveyor that moved steamed kenaf materials from digester to refiner.

Figure 2 shows that the energy consumed to reach 100 mL freeness at FPL was almost twice the energy consumed at Andritz Sprout-Bauer. High energy consumption was anticipated, since laboratory-scale refiner equipment traditionally uses more electrical energy than commercial-scale equipment to process the same amount of pulp. Retention time is longer and more impacts per revolution occur in the commercial-scale equipment to yield a better developed fiber per pass through the refiner. More passes and more energy input are necessary with laboratory-scale refiners to reach the same degree of fiber development.

Figure 2 shows that the energy consumed at FPL in reaching comparable pulp freeness values decreased as the NaOH application increased. Lowering pulp freeness to 100-mL CSF of 3040, 2292, and 2081 W·h/o.d. kg for 4.4%, 7.2%, and 11.2% NaOH applications, respectively. These NaOH applications respectively reduced fiber length from 1.1 mm to 0.9 mm to 0.8 mm and increased fines content from 7.5% to 9.5% to 9.3%.

Drainage times increased dramatically as pulp freeness decreased. Shortened fiber length did not appear to cause reduction in drainage time because fiber length changed little as freeness decreased. The slower drainage times were probably due to reduced shive content and improved fiber swelling. These in turn should produce better paper strength properties.

Handsheet density for the pulps refined to 100-mL CSF increased from 649 to 757 kg/m³ when the NaOH application increased from 4.4% to 11.2%, respectively. These conditions exerted only minor effects on handsheet strength properties. Tensile index increased from 51.3 to 53.2 N/m², burst index increased from 2.5 to 3.0 kPa·m²/g, and tear index decreased from 6.1 to 5.2 mN·m²/g in response to the increased NaOH application.

Kenaf and loblolly pine pulp blends

Linerboard traditionally uses a high freeness softwood kraft pulp. Drainage during paper formation is rapid, and the paper has high strength properties. When refining the kenaf CTMP made at FPL to 100-mL CSF, there was an approximately 175-s drainage time in forming a 205-g/m² handsheet. Tear indexes of the 100% kenaf CTMP handsheets were low, but the other strength properties were reasonable. Because of the slow pulp drainage and low tear index, we decided to prepare a blend of kenaf CTMP with loblolly pine kraft pulp and to make 205-g/m² handsheets for testing. Blending mechanical and chemical pulps does not produce a linear relationship between blend ratio and paper properties (10).

FPL used loblolly pine chips to prepare two 57% yield kraft pulps. One kraft pulp was refined to 620-mL CSF and the other refined to 440-mL CSF. Physical properties of handsheets made using the 440-mL CSF loblolly pine kraft pulp suggest that the fibers might have been cut instead of developed during refining. The highest strength kenaf CTMPs made at Andritz Sprout-Bauer and FPL with 10.9% and 11.2% NaOH applied respectively were blended in several proportions with the loblolly pine kraft, made into handsheets, and tested. The Andritz Sprout-Bauer kenaf CTMP used in the blends had a 157-mL freeness,
and the FPL kenaf CTMP had two freeness levels of 345 mL and 142 mL. Figures 3 through 6 show the freeness values of the individual kraft pulps, kenaf CTMPs, and blends. In these figures, the lines represent CSF and the bars represent other properties.

As Kenaf content increased, handsheet densities increased from 661 to 743 kg/m³ for blends prepared with the 142-mL and 157-mL CSF kenaf CTMPs. Increasing handsheet density was probably the result of higher fines content rather than better fiber bonding and consolidation. Handsheet density decreased from 677 to 663 kg/m³ when the 345-mL CSF kenaf CTMP was blended with the 440-mL CSF loblolly pine kraft. Decreasing handsheet density was probably caused by the stiffer CTMP fibers with lower fines content. These form a much bulkier and less dense handsheet. Because most paper strength properties are density dependent, this relationship probably had an impact on the results.

Burst index depended upon the loblolly pine kraft pulp freeness. It was independent of either the percentage added or the freeness of the kenaf CTMP in the blends, as Fig. 3 shows. Handsheets prepared from the 620-mL CSF loblolly pine kraft had burst indexes that were greater than those of the 440-mL CSF loblolly pine kraft. The burst indexes remained high and constant as the 157-mL CSF kenaf CTMP blend reached equal parts. Handsheets prepared from 100% 157-mL CSF kenaf CTMP had much lower burst indexes. Handsheets prepared from the 440-mL CSF loblolly pine kraft had lower initial burst indexes. The burst indexes either remained constant or declined as the 345-mL and 142-mL CSF kenaf CTMPs blended with the 440-mL CSF kraft pulp. Tear index depended on the freeness of the loblolly pine kraft pulp. Figure 4 shows that it declined as the percentage of kenaf CTMP in the blends increased. Handsheets prepared from the 620-mL CSF loblolly pine kraft had tear indexes that were greater than those of the 440-mL CSF loblolly pine kraft. The tear indexes declined quickly as the 157-mL kenaf CTMP blended with the 620-mL kraft pulp. Handsheets prepared from the 440-mL CSF kraft pulp had lower initial tear indexes. These also declined when blended with the 345-mL and 142-mL CSF kenaf CTMPs. Handsheets made from 100% 142-mL CSF kenaf CTMP had the lowest tear indexes because of short fiber length (0.8 mm) and high fines content (8.9%).

Figure 5 indicates that handsheets prepared from the 620-mL CSF loblolly pine kraft pulps had tensile indexes that were greater than those of the handsheets prepared from the 440-mL CSF kraft pulp. When the 157-mL kenaf CTMP pulp blended with the 620-mL CSF kraft pulp, tensile index increased until it peaked with a 25% kenaf CTMP addition. Then it declined as the kenaf CTMP content increased. Tensile index was initially lower for the 440-mL CSF loblolly pine kraft pulp and showed little change in tensile index when blended with the 345-mL kenaf CTMP. When blending 440-mL CSF loblolly pine kraft with the 142-mL kenaf CTMP, tensile index dropped and then steadily increased as the kenaf content in the blend increased. Tensile index is most dependent upon the long fiber length of the high freeness loblolly pine kraft. Tensile index also benefits from the addition of kenaf CTMP. Blending the chemical and mechanical pulps appears to enhance bonding and the load bearing capability of the handsheets.

Compression strength is a critical factor in judging the suitability of linerboard for corrugated boxes. Figure 6 presents the effect of kenaf CTMP on vacuum compression strength of linerboard. Freeness of loblolly pine kraft appears to play a significant role in vacuum compression strength. The 620-mL CSF loblolly pine kraft pulp, as either 100% pine or blended with the 157-mL CSF kenaf CTMP, gave significantly lower compression strength than did the other pulps. Blending any amount of kenaf CTMP with the 620-mL CSF loblolly pine kraft pulp also reduced the compression strength. This is opposite to the tensile index behavior. These values fall well below the average for cross- and machine-direction compression strength (3.9–4.5 kN/m) of commercial 205-g/m² linerboard (11). When blending the 440-mL CSF loblolly pine kraft pulp with the 345-mL CSF kenaf CTMP, however, the compression strength increased as the amount of kenaf CTMP increased. The 142-mL CSF kenaf CTMP peaked in compression strength when blended equally with the 440-mL CSF loblolly pine kraft. There was a decline as the percentage increased to 100% kenaf CTMP. All handsheets made from the 440-mL CSF loblolly pine kraft, 345-mL CSF kenaf, and 142-mL CSF kenaf CTMPs equaled or exceeded the average for cross- and machine-direction compression strength of commercial 205-g/m² linerboard (11).

These results indicate that acceptable linerboard properties can result with 30–50% kenaf CTMP refined to 345-mL and 142-mL CSF and blended with loblolly pine kraft refined to 440-mL CSF. Adding 30–50% kenaf CTMP to the blends caused reductions in burst and tear indexes, no change or slight increase in tensile index, and either no change or increase in compression strength.

**Conclusions**

Increasing the amount of sodium hydroxide applied reduces the amount of energy required to pro-
Kenaf

duce CTMP and increases paper strength property values. Blends of 30–50% kenaf CTMP with 70–50% loblolly pine kraft pulp, respectively, produced handsheets with compression strength that equals or exceeds reported values for commercial linerboard. For best results of furnish blending, kenaf CTMP freeness should exceed 140-mL CSF and loblolly pine kraft pulp freeness should be 440 mL. The blend of 30% kenaf CTMP and 70% loblolly pine kraft is preferable because of better drainage properties. Kenaf CTMP alone is unsuitable for use in linerboard because of slow drainage times and low burst, tear, and tensile indexes.

Literature cited


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