Press drying: a way to use hardwood CTMP for high-strength paperboard

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ABSTRACT *Chemithermomechanical pulp (CTMP) is not presently used in linerboard or corrugating medium. Because of its high lignin content and stiff fibers, CTMP dried conventionally cannot achieve sufficient bonding for products requiring high strength. Results show that press-drying technology offers potential for using high-yield CTMP made from hardwoods for the manufacture of high-strength paperboard products.*

With the exception of tear strength, strength properties of press-dried CTMP paperboards were equivalent to or better than those of commercial paperboards. In particular, compressive strength of the CTMP paperboards was much higher. Combined board and containers made from press-dried CTMP paperboards met current expectations except in impact resistance. At high humidity, we noted high retention of short-column strength in the combined board and of top-to-bottom compressive strength in the containers.

KEYWORDS
Birch
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Corrugating medium
Furnish
Linerboard
Papermaking
Pulping

To our knowledge, chemithermomechanical pulp (CTMP) is not presently included in linerboard or corrugating medium furnishes. Rawlins (*1*) concluded that the production of kenaf CTMP for linerboard was an option but that the development of commercial interest should precede further study. Tilsley (*2*) stated that kenaf CTMP used for corrugating medium should be competitive in quality but that kenaf pulps are not presently accepted. The use of CTMP in multiply linerboard was reported by Jackson and Akerlund (*3*).

During the past decade, press drying has been studied at the Forest Products Laboratory (FPL) and elsewhere. Press drying may change the fiber furnish requirement for high-strength products such as linerboard because it improves interfiber bonding and leads to improvements in linerboard strength. Our research has shown that press-dried linerboard and corrugating medium of overall superior properties can be produced from various high-yield (up to 70%), high-freeness, hardwood kraft pulps (*4, 5*) and from recycled fiber (*6*). Also, when combined to make corrugated containers, the strength of containers made from these press-dried components is equal to or better than strengths demanded by today's shipping requirements (*5–7*). Furthermore, the properties of recycled multi-ply linerboard can be improved by press drying (*8*).

In press drying, a high degree of interfiber contact and restraint during drying is achieved by drying the fibrous web under heat and pressure. Heat and pressure not only increase fiber conformability but also increase bonding by promoting natural polymer flow on the fiber surface (*9, 10*).

The prospect of making linerboard and corrugating medium from a 100% hardwood CTMP furnish is attractive. In addition to the advantage of high yield, a major advantage of substituting an ultra-high-yield (80–90%) hardwood CTMP for either a softwood or hardwood kraft pulp would be its much lower cost per ton. No chemical recovery plant is needed. Assuming a CTMP plant was built alongside an existing chemical pulp mill, the dissolved organics could be disposed of either through waste treatment or through the use of effluent as wash water for brownstock washing.

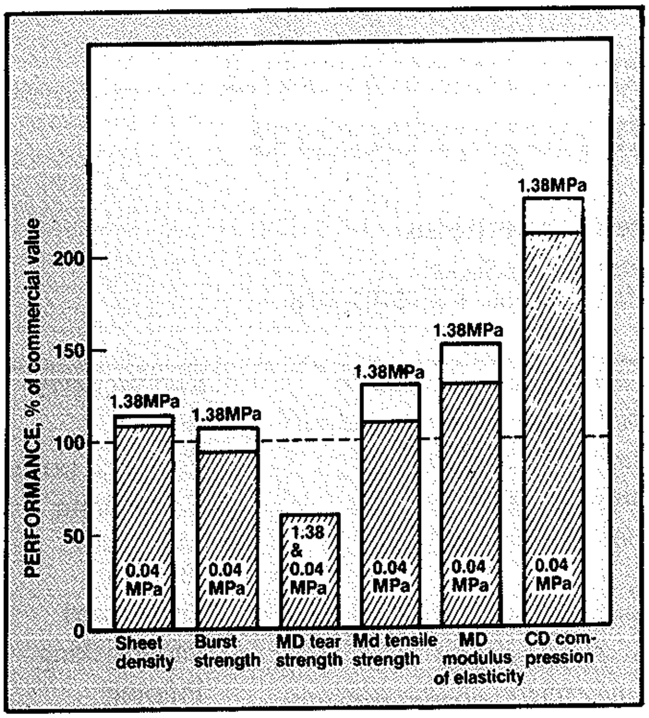
Successful application of the FPL press-drying concept to recycled old corrugated container pulp, to recycled multi-ply boxboard pulp, and to various high-yield pulps suggested that even higher yield pulps might be used in corrugated fiberboard containers. Therefore, the objective of our research was to: (a) determine the feasibility of making acceptable press-dried linerboard and corrugating medium from 100% birch CTMP furnish, (b) evaluate the strength of combined boards and corrugated fiberboard containers made from these components, and (c) identify problems encountered in the converting operation, particularly the corrugating of press-dried medium.

Discussion

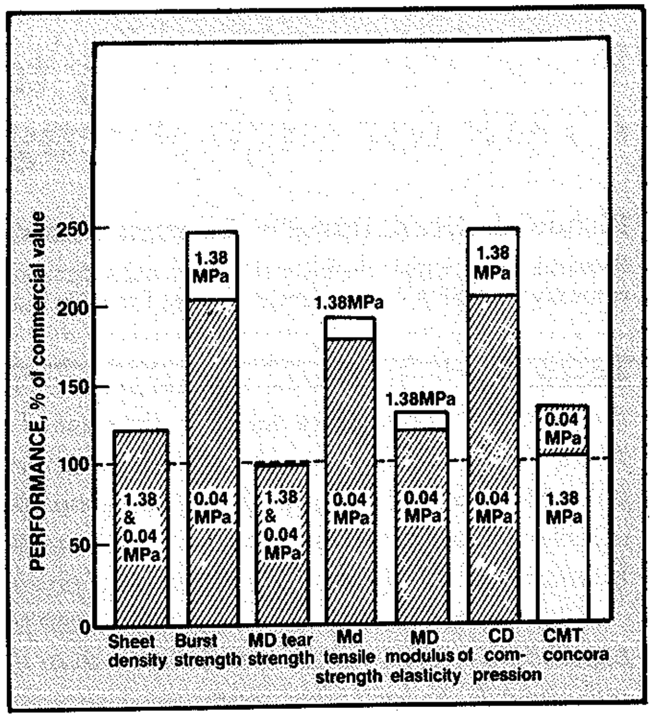
Linerboard

With the exception of tear strength, the strength properties of press-dried

1. Properties of press-dried linerboard (205-g/m²) made from CTMP expressed as percent of the performance of a commercial linerboard



2. Properties of press-dried corrugating medium (127 g/m²) made from CTMP expressed as a percent of performance of a commercial NSSC medium.



linerboard made from 100% CTMP at high press roll pressure (1.38 MPa) compare well to those of a commercial southern pine kraft linerboard (**Fig. 1**).

It was necessary to use a press roll pressure of 1.38 MPa to produce an acceptable press-dried linerboard. At a pressure of 0.04 MPa, the press-dried linerboard only marginally met the required bursting strength (689 kPa) of Rule 41.[1] Use of the higher pressure coupled with X-Y-Z restraint[2] produced a linerboard which was 5% greater in bursting strength, 30% greater in tensile strength, 7% greater in modulus of elasticity, and 128% greater in CD compressive strength than the conventionally dried commercial pine linerboard.

Press-dried linerboard made from the CTMP had lower tear strength than the commercial pine linerboard. This difference can be attributed to the shorter length of the birch fiber.

Data in **Table I**, comparing values for commercial and press-dried paperboard, summarize the percentage improvement in CD specific compressive strength of linerboard and corrugating medium resulting from increased pressure. (Specific compressive strength is the measured compressive strength divided by the basis weight.) A high specific compressive strength can be achieved by press drying even at a low press roll pressure. For instance, a compressive strength that is 90% higher than the commercial board can be achieved at the low pressure of 0.04 MPa. Increasing that pressure 34.5-fold only produces a 5.5% additional gain.

The high compressive strength can possibly be attributed both to the improved fiber bonding achieved through press drying and to the greater stiffness of the CTMP fiber at 84% yield. The CTMP fiber had a lignin content of 18.5%, and at such a high lignin content the fibers can be expected to be stiff. When these CTMP fibers are press dried, the combined effect of improved bonding and inherent fiber stiffness produces a sheet with greater compressive strength. We found a similar effect for press-dried birch kraft pulps, for which compressive strength increased when yield increased (*4*).

I. Effect of press-drying pressing pressure on specific compressive strength of CTMP paperboards

	Pressing pressure				
	Specific compressive strength, N·m/g		*Increase by press drying, %*		*Increase by increasing pressing pressure, %*
	0.04 MPa	*1.38 MPa*	*0.04 MPa*	*1.38 MPa*	
Linerboard	27.5	29.0	90.0[a]	100.0	5.5
Corrugating Medium	25.2	27.7	80.0[b]	97.9	9.9

[a]Based on commercial 205-g/m² pine kraft linerboard (control) 14.5 MPa.
[b]Based on commercial 127-g/m² hardwood NSSC (control) 14.0 MPa.

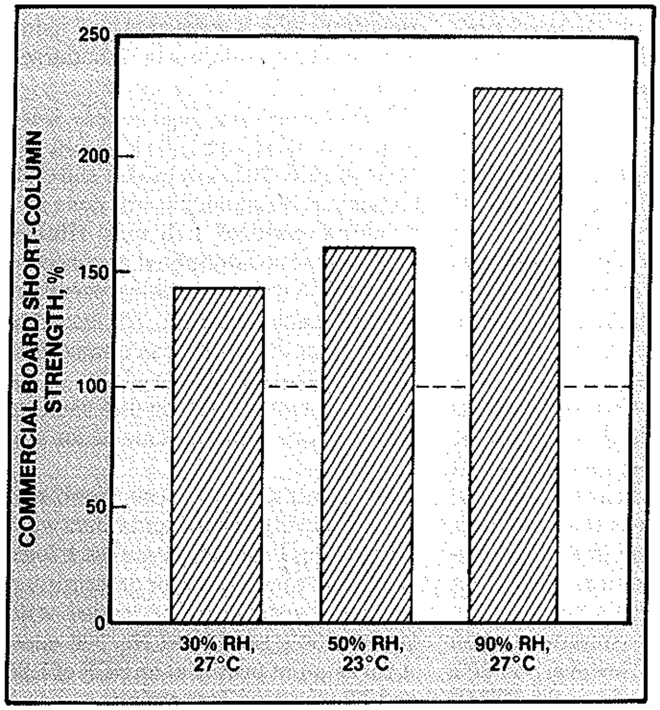
Corrugating medium

Compared to a commercial, hardwood, neutral sulfite semichemical (NSSC) corrugating medium, the press-dried corrugating medium exhibited overall high strength properties, except for tearing strength (**Fig. 2**). Although strength properties, except tear, were

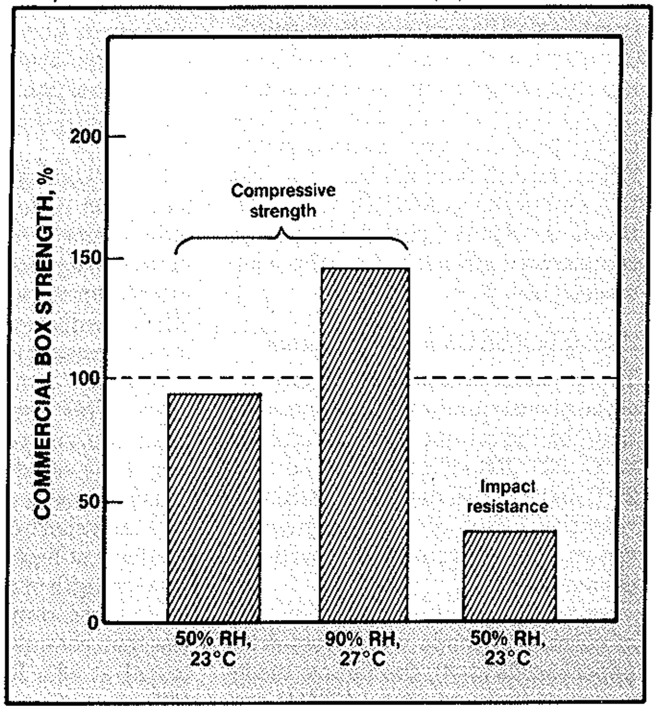
[1]Uniform freight classification of the U.S. Dept. of Commerce.

[2]Obtained by the tension drawn in the machine direction on twin wires of a press dryer unit. The wires deliver a z-directional force of 0.04 MPa.

3. Relative short-column strength of combined boards made from all press-dried components. The comparison is based on combined board made from commercial components.



4. Relative box top-to-bottom compressive strength (within a deformation of 25 mm) and impact resistance. Boxes made from press-dried CTMP linerboard and CTMP corrugated medium are compared to boxes made from commercial paperboards.



II. Short column specific compressive strength for combined boards made from CTMP components

Board description	Short-column compression (ECT), Nm/g 23° C, 50% RH	Short-column compression (ECT), Nm/g 27° C, 90% RH	Improvement, %[a] 23° C, 50% RH	Improvement, %[a] 27° C, 90% RH	Influence of press-dried medium, % 23° C, 50% RH	Influence of press-dried medium, % 27° C, 90% RH
		Control				
Commercial	12.9	5.5	...	...	...	...
		Press-dried				
CTMP linerboard and medium	21.0	12.7	62.8	130.9	7.1	30.9
CTMP linerboard and commercial NSSC medium	19.6	9.7	52.0	76.4	...	...

[a]Based on comparison to commercial sample.

substantially better with press drying at the lower press roll pressure of 0.04 MPa, increasing the pressure to 1.38 MPa further raised the burst, tensile, and compressive strengths of the corrugating medium.

Concora (CMT) values were higher for the press-dried corrugating medium.

Combined board

Bursting strength of the combined board containing all press-dried CTMP paperboards was equal to boards made from conventionally dried commercial paperboards. Combined boards made from press-dried components exhibited little variation in flat crush strength and outperformed those made with commercial components.

Compared to the commercial combined board, pin adhesion values for the combined boards containing all press-dried CTMP paperboards were 20% lower for the single-face side and 8% lower for the double-face side. Bonding of press-dried paperboard components presented similar problems in a previous study (*5*). However, in that study, enough material was available to optimize the corrugating process. Once those conditions were optimized, pin adhesion values typical of commercial boards were obtained. In the present study, we did not have enough material to optimize the conditions. Had we been able to conduct more extensive experimentation on these combined boards, we are confident that we would have attained pin adhesion strength equivalent to that of the commercial combined board.

Each combined board containing CTMP paperboard was evaluated in both flute and cross-flute directions for scoreline fracture resistance. Two clearances were used: Scorewheel clearance ratio (SCR)[3] 1.25 and SCR 1.50. No visible fracture occurred on any of the press-dried boards when scored at 27°C, 30% RH; 23°C, 50% RH; or 27°C, 90% RH; and folded after conditioning at 23°C, 50% RH.

Short-column compressive strength (edgewise compression test—ECT) of the combined boards containing all CTMP press-dried paperboards was greater than the short-column values of the commercial boards at all levels of humidity studied (**Fig. 3**). **Table II** shows the effect of press-dried CTMP medium on specific compressive strength (ECT divided by total basis weight) of the combined board. As can be seen in the comparison of the boards, press drying the corrugating medium adds to the combined board short-column compressive strength, particularly at 90% RH.

Comparing the commercial com-

[3]Defined as actual scorewheel clearance divided by the sum of the three paperboard TAPPI thicknesses (TAPPI Method 411OM-83).

bined board to the combined boards containing all press-dried CTMP paperboards, we see that the CTMP boards tested at 23°C, 50% RH have 62.8% greater specific compressive strength. Compared to the control, press drying is particularly beneficial in maintaining strength at 27°C, 90% RH. The CTMP board is nearly as strong at 90% RH as the commercial board is at 50% RH. Compared at 90% RH, the CTMP board is 130.9% greater in specific compressive strength than the commercial board.

Corrugated fiberboard containers

Top-to-bottom compressive strength is slightly lower for the CTMP containers than for the commercial container at 23°C, 50% RH (**Fig. 4**). At the high 27°C and 90% RH, the positive strength retention effect of press drying, as shown for the combined boards, is evident.

As with previous compression tests of containers made with press-dried paperboards (*4–6*), the failure mechanism of the press-dried CTMP containers in compression consisted of rolling of the flap edges rather than panel buckling. The high short-column strengths would lead us to expect higher container compressive strengths. It is not presently known why the high compressive strength of the components and combined boards is not carried through to the containers. A possible explanation is a need to improve the adhesive bond and support of the corrugating medium. Another possibility is that the present design of the corrugating medium is not sufficient to carry the higher compressive strength characteristic to press-dried paperboard.

Impact tests show that the CTMP press-dried containers were decidedly deficient in this property (Fig. 4). Shorter fiber length and increased stiffness associated with these high-yield pulps are thought to contribute to this deficiency. However, the addition of long fiber in the form of recycled old corrugated container fiber may improve impact resistance (*6*), where impact strength requires high priority.

Summary

Linerboard with strength equivalent to or better than that of a commercial pine kraft linerboard can be made from high-yield (84%) CTMP by press drying. With the exception of tear strength, press drying at the higher of two pressing pressures (1.38 MPa rather than 0.04 MPa) produced linerboard strength properties greater than those of a conventionally dried, commercial pine kraft linerboard. Of particular note is the large gain in compressive strength of the linerboard and combined board that resulted from press drying.

CTMP corrugating medium equivalent to or better than a commercial NSSC control can be made by the press-drying process. Significant gains in medium strength over a commercial NSSC medium were noted even at the lower pressing pressure of 0.04 MPa.

Overall, combined boards made from CTMP press-dried paperboards meet current requirements; that is, they have satisfactory burst and flat crush strength, excellent scoreability, and high short-column strength (particularly at high humidity). Compressive strength of containers made from press-dried components was slightly less than commercial containers when tested at 50% RH. However, at 90% RH, containers made from the CTMP press-dried paperboards retained a greater portion of their top-to-bottom compressive strength than did the container made from commercial paperboards. Impact resistance is low; however, we feel this could be improved by the addition of recycled old corrugated container fiber to the furnish.

Experimental procedures

A 100% birch, two-stage CTMP (*11*) was supplied by the Mead Corp. and was run on the FPL experimental pilot press dryer (*4*). The wood (a mixture of white and yellow birch) was debarked and pulped to 84% yield. The freeness of the CTMP furnish was 490 mL CSF.

Two types of press-dried paperboards were produced: 205-g/m^2 linerboard and 127-g/m^2 corrugating medium. These paperboards were produced on the FPL pilot press dryer (*4*) at 0.04- and 1.38-MPa press roll pressure. All press-dried paperboards used for converting were produced at a press roll pressure of 1.38 MPa. In addition, paperboards of equal basis weights and representative of commercial quality were obtained for comparison.

FPL machine-made press-dried and commercial-made paperboard samples were conditioned at 23°C and 50% RH prior to testing. All testing was done according to TAPPI test procedures, except for tensile properties, which are obtained by the use of a universal constant elongation rate-testing machine (*13*), and paperboard compression data, which were obtained using the method developed by Gunderson (*13*).

The corrugating fiberboards were prepared using the FPL 500-mm experimental C-flute singlefacer and doublebacker. Singlefacing was done at a machine speed of 1.78 m/s. Higher speeds were not attempted, to conserve material. No flute cracking occurred at this machine speed. All bonding was done at 180°C using an unmodified starch adhesive prepared by a no-carrier formula. The double-backing temperature was the same as for singlefacing.

All evaluations of the combined boards and fiberboard containers were made using TAPPI procedures. Fiberboard containers used for determining impact resistance were loaded with twelve 454-g sandfilled No. 303 cans. A three-point profile at an SCR of 1.25 or 1.50 was used for scoring.

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