Birch thermomechanical pulp for newsprint via the Opco treatment

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A second-grade birch wood can be transformed into high-quality pulp at high yield for use in newsprint.

We have devoted years of research into the possible transformation of low-grade hardwoods into high-yield pulps for use in newsprint furnishes. As part of our research, we replaced the 30% spruce/balsam-fir thermomechanical pulp (TMP) component of a newsprint furnish with an equal amount of white birch (*Betula papyrifera*) TMP. Both TMPs were produced in the same refiners operated under identical conditions during an industrial trial. The experimental newsprint met the quality requirements of a conventional newsprint. However, slight deterioration in certain properties discouraged the manufacturer from introducing white birch TMP into the regular newsprint furnish (*1*).

The slight deterioration in newsprint properties showed up as a major reduction in the properties of handsheets made from pure white birch TMP when compared with handsheets made from conventional spruce/balsam-fir TMP. At 100 mL CSF (Canadian standard freeness), the breaking length (BL) was reduced by 49%, from 3.9 km (spruce/balsam-fir) to 2.0 km (white birch). Similarly, the tear strength suffered a 56% decrease, from 10.1 mN · m²/g to 4.4 mN · m²/g (*1*).

In spite of these major reductions, it was surprising to find that the short-span BL of the birch TMP (7.2 km) was relatively close to that of the spruce/balsam-fir furnish (9.7 km). This small difference (2.5 km) prompted us to try to improve the properties of birch TMP by further treatment. The Opco reaction was chosen because it permitted a combination of chemical and mechanical treatments aimed to produce the desired level of yield and CSF for a variety of paper and tissue products. The Opco process typically involves an interstage chemical treatment of conventional TMP at 4–10% consistency in a sodium sulfite solution (7–10%) for a period ranging from 15 min to 2 h at 130–180°C, followed by second-stage refining (*2, 3*).

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Experimental

White birch TMP was produced in an industrial trial in a two-stage process. In the first stage, the chips were screened, washed, presteamed at 69 kPa (115°C) for 1.5 min, and subsequently refined under pressure (138 kPa; 126°C) at 25% feed consistency, at 40% discharge consistency, and 3.4 MJ/kg specific energy.

The second stage refining was carried out at 3.0 MJ/kg energy consumption. The resulting pulp was then submitted to a latency treatment at 3% consistency for 30 min at 85°C. This was followed by pressurized Centrisorter screening (1.5% consistency), producing about 25% rejects. The accepted pulp was then cleaned in a series of hydrocyclones, while the rejects were further refined at 3.4 MJ/kg energy input.

Samples of both the experimental birch TMP (B) and the standard spruce/balsam-fir TMP (S) were taken from the first-stage (B1, S1) and second-stage (B2, S2) refiners, which were then subsequently treated for 50 min at 10% consistency in a 10% solution of sodium sulfite using a pressurized (480 kPa) microdigester that was immersed in a thermostatically heated oil bath kept at 150°C. The treated pulp samples were then washed and refined at 10% consistency in a PFI mill to various levels of CSF, and the handsheet properties were evaluated according to TAPPI test methods.

Results and discussion

The data obtained in this study are summarized in **Table I**. For the sake of simplicity, the first- and second-stage white birch TMPs are designated by B1 and B2, respectively. The first- and second-stage spruce/balsam-fir pulps are designated by S1 and S2, respectively.

The Bauer-McNett fiber classification data for the four TMPs are summarized in **Fig. 1**. As expected, the first-stage spruce/balsam-fir and birch pulps possess high percentages of long-fiber fractions (63% and 34%, respectively) and low percentages of short-fiber fractions (19% and 11%, respectively). With respect to the species effect, the first-stage spruce/balsam-fir TMP (S1) possesses higher long-fiber content and short-fiber content than the corresponding birch TMP (B1). In contrast, the

I. Physical properties of the Opco-treated birch and spruce/balsam-fir thermomechanical pulps

	White birch (B)										
	First stage (B1)						*Second stage (B2)*				
	TMP	*Opco*	*PFI*				*TMP*	*Opco*	*PFI*		
	(■)	[■]	■	■	■	■	(▲)	[▲]	▲	▲	▲
CSF, mL	616	417	327	230	170	150	375	385	220	170	110
Bulk, cm³/g	4.8	2.9	2.3	2.0	2.1	2.0	3.8	2.7	2.3	2.2	2.0
Density, g/cm³	0.21	0.34	0.43	0.51	0.48	0.50	0.25	0.37	0.44	0.45	0.50
Porosity, mL/min	2825	5045	1070	378	164	100	2445	3180	467	310	127
Roughness, mL/min											
Felt	71	81	68	65	62	67	50	54	58	52	57
Wire	70	74	79	83	91	67	48	57	72	74	77
Brightness, %	46	49	48	48	46	45	49	48	47	48	46
Opacity, %	96	93	91	91	91	91	97	96	95	96	95
Scat. coeff., %	394	336	305	291	280	276	486	399	345	337	323
Tear, mN·m²/g	1.2	5.2	5.6	5.3	5.0	4.7	1.7	5.2	5.5	5.2	5.4
Burst, kPa·m²/g	0.03	0.7	1.9	2.2	2.7	2.9	0.1	1.1	2.1	2.1	2.7
Breaking length, km	0.2	2.4	4.2	5.4	5.9	6.3	0.5	3.2	5.1	5.0	5.9
Zero-span BL, km	6.1	8.0	8.7	9.1	10.8	9.7	6.2	9.1	9.6	10.1	10.1
Stretch, %	0.7	0.9	1.1	1.5	1.6	1.9	0.8	1.3	1.6	1.5	1.7
Elastic modulus, MPa	500	1164	2443	3404	3434	3767	304	1275	2649	2649	3139
Energy, g·cm	7.2	123	242	465	539	790	16	240	490	452	620

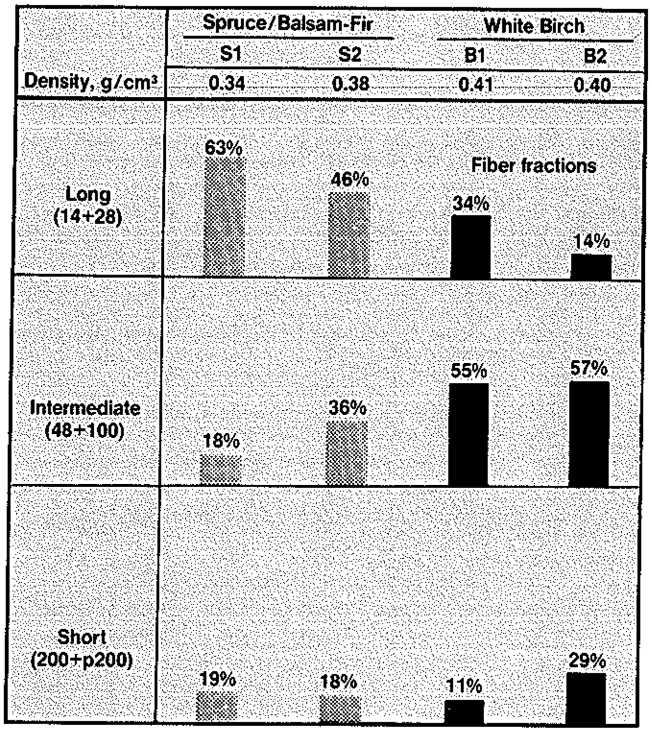
	Spruce/balsam-fir (S)									
	First stage (S1)					*Second stage (S2)*				
	TMP	*Opco*	*PFI*			*TMP*	*Opco*	*PFI*		
	(●)	[●]	●	●	●	(★)	[★]	★	★	★
CSF, mL	600	635	275	185	119	234	267	175	135	115
Bulk, cm³/g	4.8	3.6	2.7	2.4	2.2	3.3	2.8	2.5	2.3	2.3
Density, g/cm³	0.19	0.28	0.37	0.42	0.45	0.30	0.36	0.41	0.43	0.43
Porosity, mL/min	2595	429	278	128	100	1000	1090	195	105	100
Roughness, mL/min										
Felt	63	77	75	66	56	47	62	61	60	56
Wire	74	70	72	57	57	66	56	58	59	50
Brightness, %	49	41	41	41	39	52	47	48	46	43
Opacity, %	94	95	95	94	96	97	96	95	95	94
Scat. coeff., %	402	337	333	316	316	520	446	415	395	333
Tear, mN–m²/g	901	11.0	7.6	5.9	5.9	9.0	8.8	7.6	6.4	6.2
Burst, kPa–m²/g	0.2	1.2	2.5	3.1	3.5	1.4	2.0	3.3	3.5	3.5
Breaking length, km	1.2	2.8	5.0	6.4	7.0	3.0	3.9	5.8	6.3	6.5
Zero-span BL, km	7.5	7.9	8.8	10.4	10.7	9.0	9.0	9.9	9.7	10.8
Stretch, %	1.2	1.4	1.6	2.0	1.9	1.8	2.0	2.1	2.2	2.3
Elastic modulus, MPa	285	746	1913	2639	3159	981	1177	2256	2649	2649
Energy, g·cm	96	224	482	810	840	307	484	689	796	915

birch pulps are rich in intermediate-fiber content. In fact, more than half of the entire birch pulp is made up of the R48+ R100 fractions. These fiber classification data provide a useful explanation for many of the handsheet properties discussed later in this article.

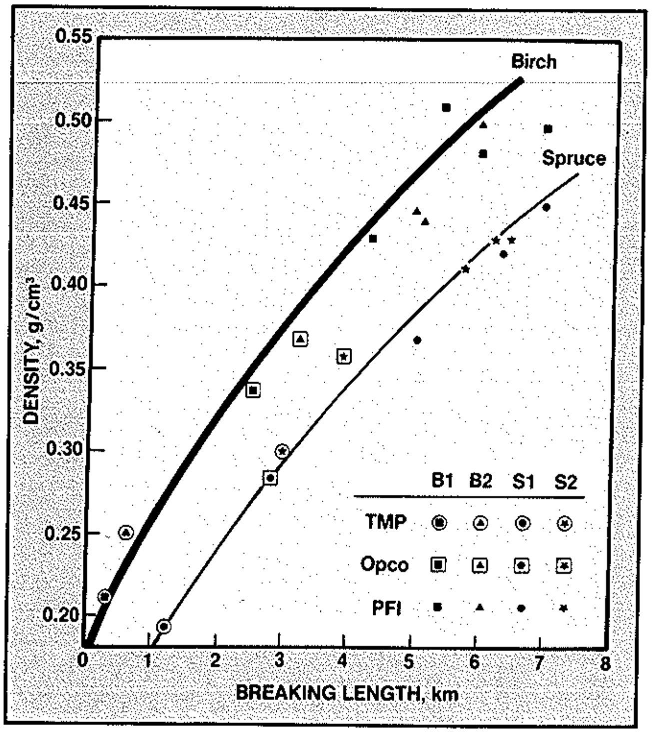
Figure 2 shows that both the Opco treatment alone and the subsequent refining produce a significant increase in density, which in turn produces a corresponding augmentation in BL. This is due to the increased conformability of the fibers and to the production of increased quantities of short fibers and fines.

Figure 2 also shows that, at a given density level, the spruce/balsam-fir furnish produces a higher BL than the corresponding birch TMP, even after refining in the PFI mill. On the other hand, at each level of BL, the birch handsheets possess higher densities than their corresponding spruce counterparts. Thus the birch pulps must be refined to higher densities to produce equivalent tensile strength to the spruce/balsam-fir pulps. This difference can be attributed to a reduced level of fiber-to-fiber bonding caused by the relatively rigid nature of the birch fiber, which in turn is due to its thick fiber wall (3.8μm) as compared with the relatively thin wall (1.2μm) of an average spruce fiber. The presence of vessels and a larger

1. Bauer-McNett fiber classifications for first- and second-stage TMP pulps produced from white birch and spruce/balsam-fir chips.



2. The effect of density on the breaking length of laboratory handsheets made from birch and spruce/balsam-fir pulps.



percentage of parenchyma cells in birch may also contribute to the reduction of the tensile properties of the birch handsheet.

Tensile properties

Figure 3 shows the relative tensile strengths developed by the untreated TMP (the control pulp), by the Opco-treated TMP, and by Opco-treated TMP refined in a PFI mill. It is evident that both the Opco treatment and the subsequent refining produced significant improvement in the tensile strength of each of the four pulps, with the birch pulps (B1, B2) closely approaching the tensile strengths of the spruce/balsam-fir pulps (S1, S2). These improvements can be attributed to improved fiber bonding as a result of increased density, as seen in Fig. 2.

In Fig. 3, the tensile strength of the handsheet is expressed in terms of the burst index and the breaking length. It is evident that both of these parameters provide a reasonably reliable measure of the tensile strength of the handsheet, as the data form a relatively narrow band of points across the graph. Indirectly, the scatter of the data points can be considered as a measure of the confidence that can be attributed to the data in Fig. 3. These data were taken from the experimental results in Table I.

One of the weak points of the birch pulp is its inferior stretch. **Figure 4** shows that at all levels of BL, the birch pulps possess consistently lower stretch than their spruce/balsam-fir counterparts. Even after the Opco treatment and subsequent refining, the birch pulps could not reach the stretch level of the control TMP (S2). However, the birch TMP showed the greatest improvement in stretch. Stretch for the B1 pulp increased from 0.7% to 1.9%, closely approaching the maximum stretch of 2.3% obtained for the refined control pulp (S2) and bypassing the stretch (1.8%) of the untreated conventional spruce/balsam-fir TMP (S2). This was a rather unexpected result, considering the rigid nature of the birch fibers.

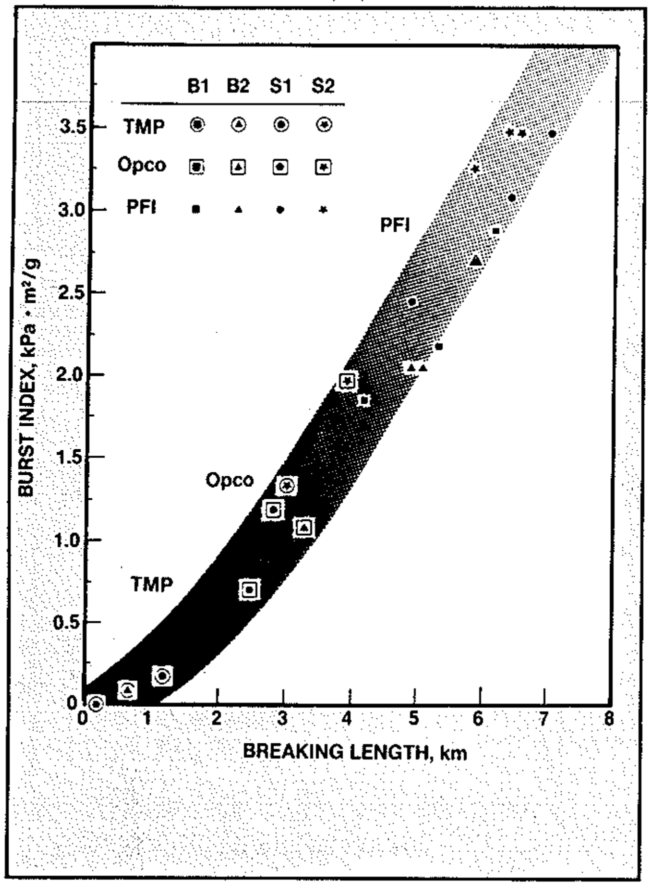
Figure 5 shows the predictable reduction in scattering coefficient for the four pulps following Opco treatment and subsequent refining. The relative slopes of the four curves show that the most serious reduction was produced in S2 (36%), less for B2 (33%) and B1 (30%), and the least for S1 (21%). There is relatively little difference in the scattering coefficients of the four pulps at the 8-km breaking length. All pulps display similarly low values.

In the case of B1, the 30% reduction in scattering coefficient translates itself into a 5-point reduction in opacity, as seen in Table I. This is a significant negative effect produced by the Opco treatment and the subsequent refining. However, the desired opacity of newsprint could be reestablished by the groundwood component of the newsprint furnish, and its relatively low brightness due to its high gum content (*4*) could be increased to the desired level by bleaching with H_2O_2 (*5*).

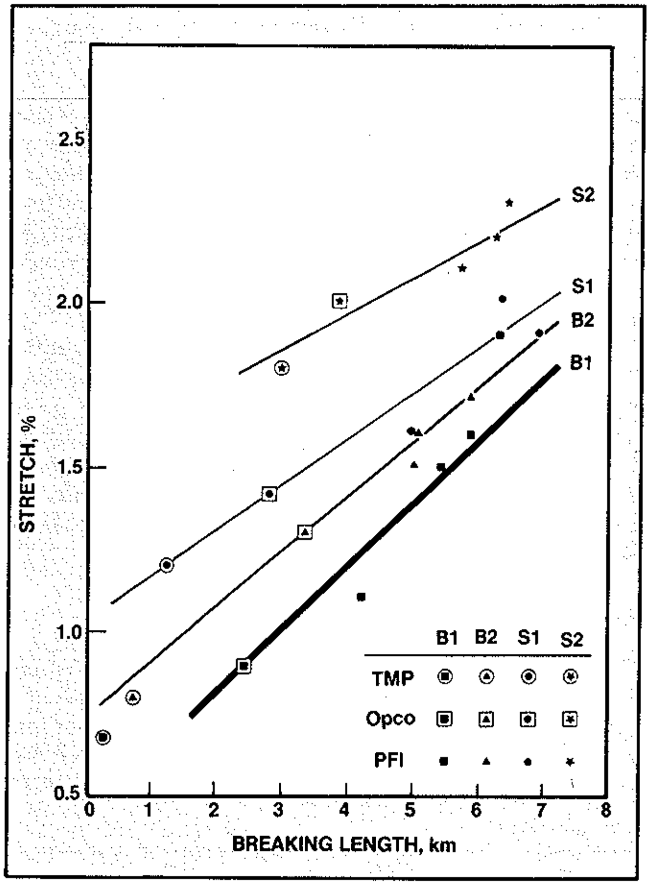
Tear vs. tensile strength

The conventional plot of tear vs. BL in **Fig. 6** provides an overall view of the evolution of the strength properties of the birch pulps in comparison with those of the spruce/balsam-fir furnish. It is evident that the situation is not favorable for the tear resistance of the spruce/balsam-fir furnish. In the case of the first-stage TMP (S1), the tèar strength was increased significantly as a result of the Opco reaction. However, this improvement was lost entirely after refining in the PFI mill. Tear strength for S1 fell

3. The relationship between the burst index and breaking length for white birch and spruce/balsam-fir pulps.



4. Stretch as a function of breaking length for white birch and spruce/balsam-fir pulps.



from 11 mN • m²/g to 5.9 mN • m²/g, which is much below its initial value of 9.01 mN • m²/g.

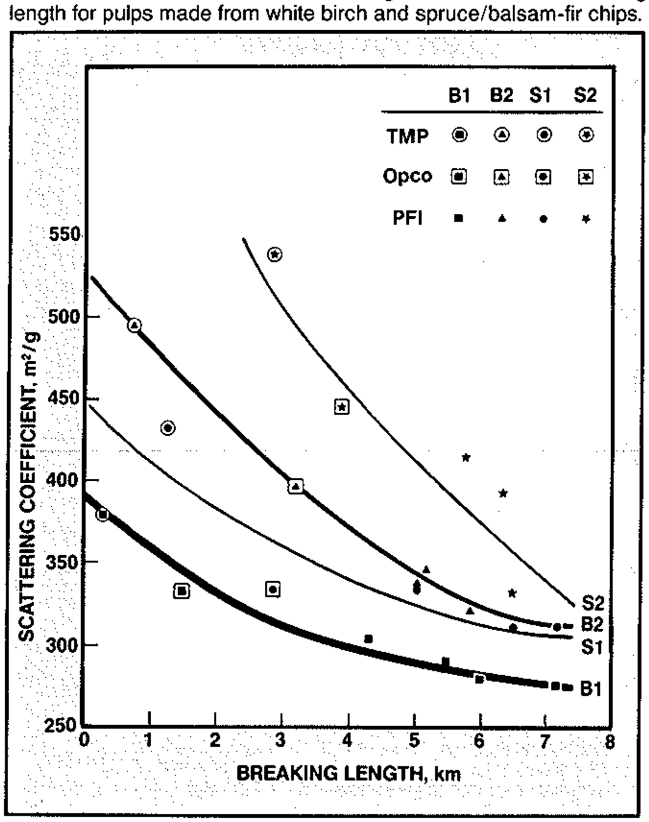
In the case of the conventional spruce/balsam-fir TMP (S2), both the Opco treatment and the subsequent refining produced significant improvement in BL, but at the cost of tear strength, which decreased 31%, from 9 mN • m²/g to 6.2 mN • m²/g.

For the birch pulps (B1, B2), the trend of the curve is different. Figure 6 shows that both the tear and BL increased significantly as a result of the Opco treatment alone. Since there is no change in fiber length, these improvements can be attributed entirely to improved fiber-to-fiber bonding, as discussed previously.

Refining of the Opco-treated birch pulp practically doubled its tensile strength while only slightly decreasing the tear resistance of the handsheet. This is a good sign, since the tear resistance of the handsheet was expected to decrease significantly as a result of refining. Thus, from the point of view of overall strength development, Opco treatment followed by refining seems to offer an attractive solution for white birch.

In comparison with the Opco treatment, the high-yield sulfite process (*6,7*), sulfite semichemical (NSSC), chemithermomechanical (CTMP), and cold soda processes are also capable of producing generally good quality pulp from hardwoods. In each case, the overall pulp strength depends on the final pulp yield. In the case of birch CTMP, for example, intermediate tensile (3.4 km) and tear (4.6 mN • m²/g) values were reported at 200 mL CSF. These

5. Correlations between the scattering coefficient and breaking length for pulps made from white birch and spruce/balsam-fir chips.



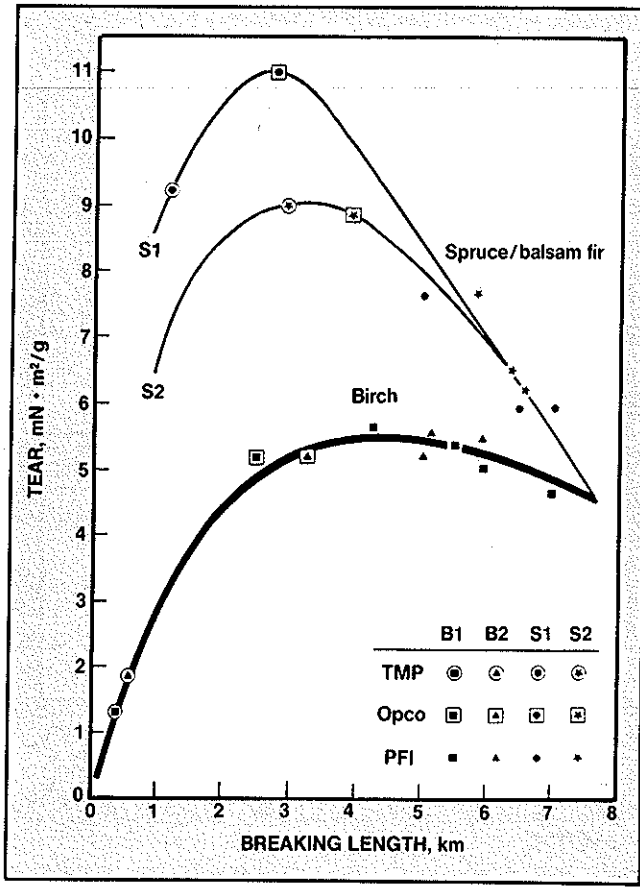
data are only slightly inferior to the values plotted in Fig. 6. In fact, Jackson (*9*) claims that on a commercial scale, a CTMP process yields strength values that are equal or superior to those shown in Fig. 6. This is quite possible, since in this study the second-stage refining was carried out in a PFI mill, which is known to produce inferior tear strength by significantly reducing fiber length. Based on the results of Shawn (*10*), an industrial second-stage refiner would be expected to produce 33% higher tear strength than could be achieved in a PFI mill. Thus at 4 km BL in Fig. 6, the tear strength of birch pulp would be expected to increase by 33%, from 5.6 $mN \cdot m^2/g$ to 7.2 $mN \cdot m^2/g$.

All three of the curves in Fig. 6 tend to intercept at 7.7 km BL and 4.5 $mN \cdot m^2/g$ tear strength. This means that, at this point, both the birch and spruce/balsam-fir pulps possess identical tear and tensile properties. Once again, it is rather unexpected to see that white birch could produce a furnish with tear and tensile strengths comparable with those of a standard spruce/balsam-fir furnish.

Summary

The interstage Opco treatment of white birch TMP offers an attractive alternative for upgrading the strength of a white birch furnish. This implies that under optimal operating conditions, the second-quality white birch can be transformed into a high-quality pulp at high yield (96%). This pulp is suitable for a variety of paper and possibly tissue products.

6. Tear as a function of breaking length for white birch and spruce/balsam-fir pulps.



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