Effects of liquor composition on the properties of hardwood ultra-high-yield pulps

Kwei N. Law and Jacques L. Valade

ABSTRACT: Ultra-high-yield pulps from aspen and white birch were produced using an alkaline pretreatment at low temperature (< 100° C) of chips followed by an atmospheric refining and an interstage peroxide bleaching prior to a secondary atmospheric refining. By using 3% NaOH charge in chip pretreatment, 5% hydrogen peroxide in interstage bleaching, and 5 mJ/kg refining energy (CSF 200 mL) one could produce hardwood pulps with excellent strength properties (tensile index 4.5–5 N·m²/g; tear index 6.5–7 mN·m²/g) and brightness (78–80% ISO). The use of Na_2CO_3 and Na_2SO_3 in chip pretreatment considerably improved pulp brightness, but had poor effect on strength improvement. Using Na_2CO_3 instead of NaOH in peroxide bleaching gave higher brightness for pulps produced from chips pretreated with Na_2CO_3, but this chemical formulation yielded poor mechanical properties.

KEYWORDS: Betula papyrifera, bleaching, brightness, chips, cooking liquors, high yield pulps, impregnation, Populus tremoloides.

Sodium sulfite or sodium bisulfite is the principal chemical used in conventional chemimechanical pulping (CMP) and chemithermomechanical pulping (CTMP). The purpose of the sulfite treatment in high-yield pulping is to soften the lignin without dissolving it by a chemical reaction called sulfonation that facilitates defibration and improves fiber bonding *(1–3)*.

However, using sulfite contributes to environmental pollution due to the risk of sulfur emission. To reduce the environmental impact of high-yield pulping, the pulp and paper industry is attempting to eliminate or minimize the use of sulfur containing agents. One such achievement is the development of alkaline peroxide mechanical pulping (APMP) [e.g., *(4–8)*], which has been successfully exploited on an industrial scale by Millar Western *(9)* and Malette Quebec *(10)*.

The practical application of APMP at the Millar Western mill *(9)* and the Malette Quebec mill *(10)* is based on a process *(7–8)* which consists of multiple press-impregnation-extraction stages employing a variety of chelating agents (DTPA, EDTA, HEEDTA, etc.), sodium silicate and bleach chemicals (e.g., hydrogen peroxide). This process, which produces high-quality pulps suitable for many grades of product requires, however, high capital investment.

On the basis of the concept of APMP, we tried to develop a simple process that requires only minor modifications to the existing CTMP system, and produces high strength and brightness mechanical pulps that can be used in printing and writing grades. The objective of this work is to evaluate the effectiveness of various liquor compositions for both chip impregnation and bleaching.

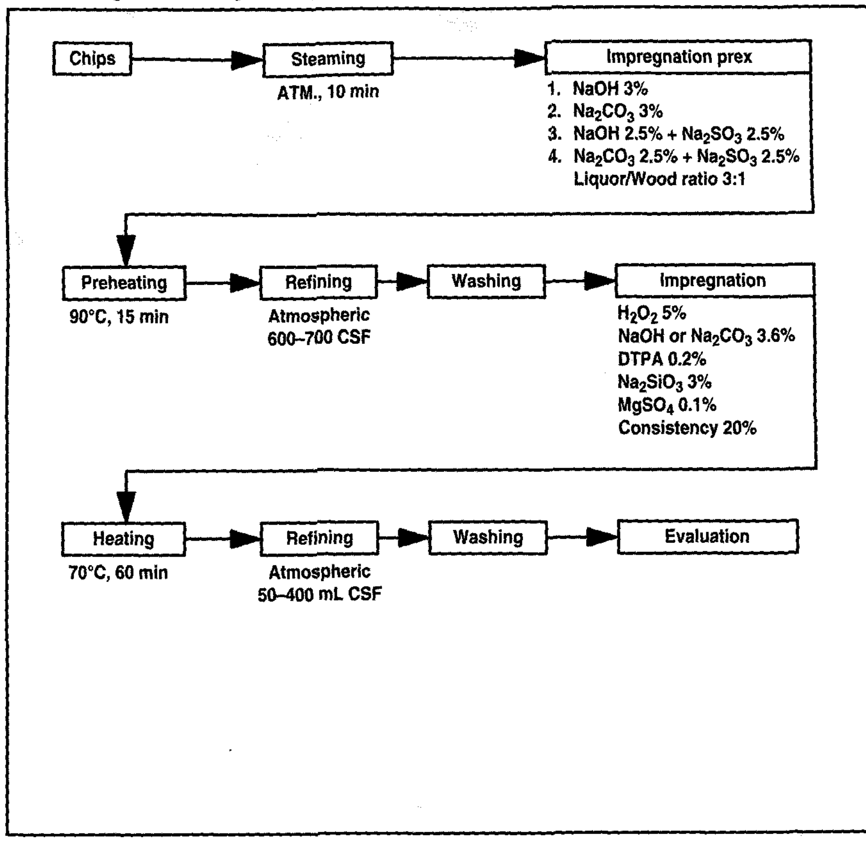
Law and Valade are research associate and professor, respectively, Centre de Recherche en Pâtes et Papiers, Université du Québec à Trois-Rivières, C.P. 500, Trois-Rivières, PQ, Canada G9A 5H7.

Experimental

Fresh chips of trembling aspen (*Populus tremuloides* Michix.) and white birch (*Betula papyrifera* Marsh.) were used in the study. The chips were screened with a laboratory Rader chip classifier to remove the chips thicker than 8 mm and the fines less than 2 mm large, and washed prior to chemical pretreatment and refining.

The pulping process used is basically a low temperature (< 100°C) with an interstage peroxide bleaching between the primary and secondary refining. The detailed conditions are presented in **Fig. 1.** In this work, three liquors of different chemical compositions were used to impregnate the chips by means of the PREX system of a Sunds Defibrator CD300 pilot unit, using a compression ratio of 2:1. An alkaline condition was used to soften the wood components of hardwood, facilitating defibration and improving pulp quality *(11)*.

1. Flow diagram showing the experimental procedures



Preheating was carried out at 90°C for 15 min and followed by a primary refining at the same temperature, at about 20% discharge consistency. A relatively low preheating temperature (90°C) was chosen to prevent severe alkaline darkening of pulp.

As shown in Fig. 1, an alkaline peroxide bleaching stage was applied between the primary and secondary atmospheric refining. By doing so one, first all, minimizes the bleaching cost by eliminating the expensive bleach plant facilities and, secondly, makes use of the influence of bleach chemicals to improve the fiber quality prior to the secondary refining, thus minimizing the possible mechanical damages caused to the fibers by the refiner plates.

Peroxide bleaching was conducted using a domestic microwave oven (1.5 kW, 2450 mHz) where the pulp (1 kg), mixed with bleach chemicals and sealed in a plastic bag, was irradiated at 70°C for 60 min. The temperature was controlled by a temperature probe.

A secondary atmospheric refining was performed immediately after the bleaching stage. The discharge consistency was approximately 15%. The resulting pulps were neutralized and washed using a centrifuge-extractor prior to their characterization in accordance with the CPPA standard methods.

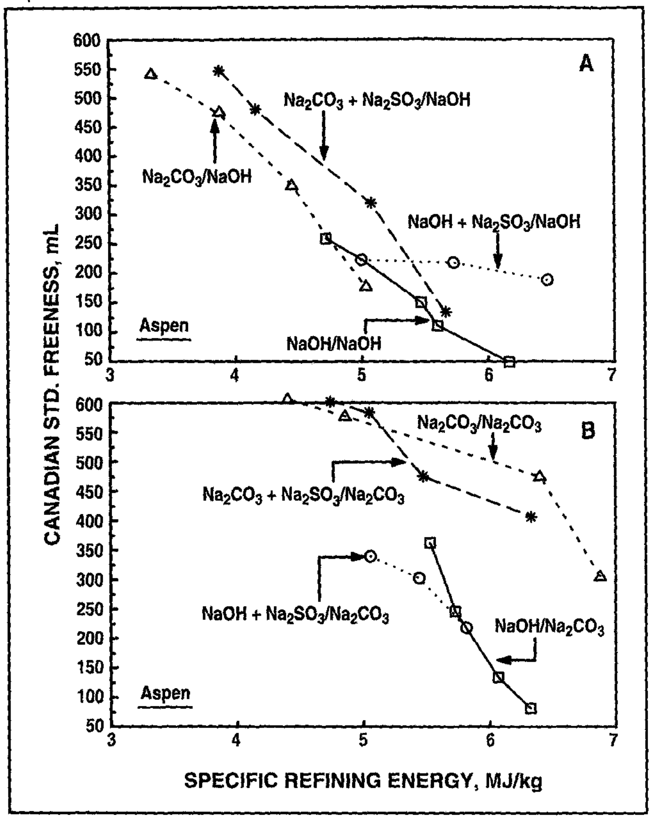
Results and discussion

Some of the more important experimental results obtained are presented in **Figs. 2–11**, in which the chemicals used are indicated for each property curve. The chemicals employed for chip impregnation are shown on the left side of the slash sign of the chemical formula, while the alkali medium used in the interstage peroxide bleaching (either NaOH or Na_2CO_3) is indicated on the right side. Part A of each figure (Figs. 2–11) represents the results obtained with peroxide bleaching using NaOH as the alkali medium, while part B shows the results obtained with Na_2CO_3 as the alkali medium in bleaching. Statistical analysis (F-test) was conducted to determine the difference between various chemical treatments.

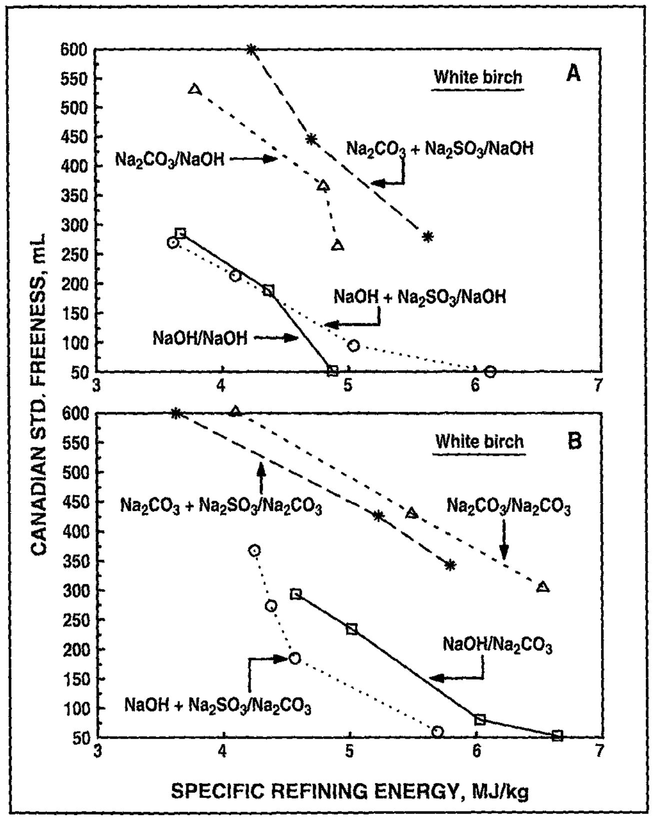
Effect on freeness

The use of NaOH alone or combined with Na_2SO_3 in chip impregnation significantly reduced the freeness for a given level of refining energy, except for aspen pulps bleached with NaOH as the alkali medium (Fig. 2A), when compared to Na_2CO_3, as shown in Figs. 2 and 3. Statistical analysis indicated that when NaOH was used in chip impregnation, the presence of Na_2SO_3 gave no significant influence (at 95% confidence level) on freeness, except when the aspen pulps were treated with a combination of NaOH and Na_2SO_3 and bleached with NaOH as the alkali medium (Fig. 2A). However, when

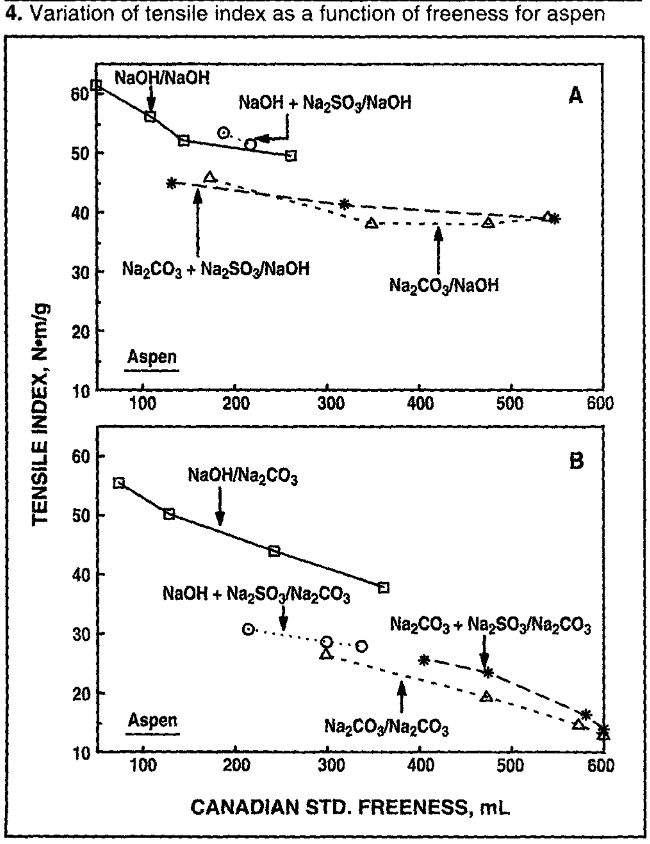
2. Variation of freeness as a function of specific refining energy for aspen



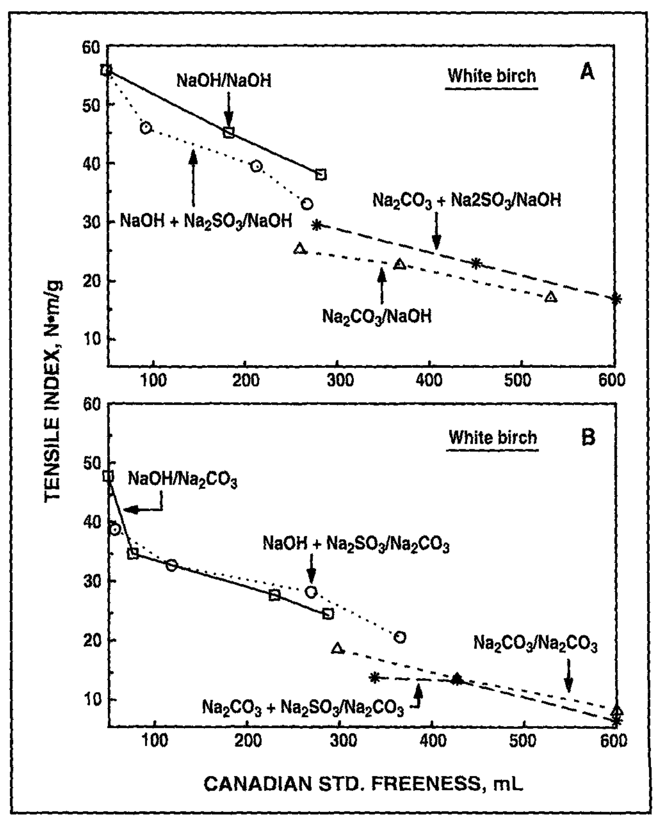
3. Variation of freeness as a function of specific refining energy for white birch



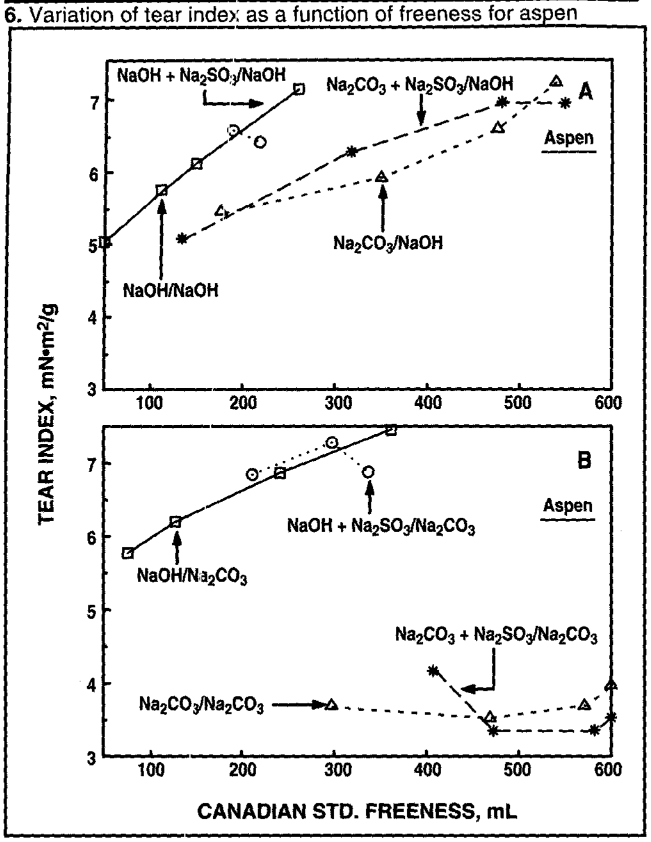
4. Variation of tensile index as a function of freeness for aspen



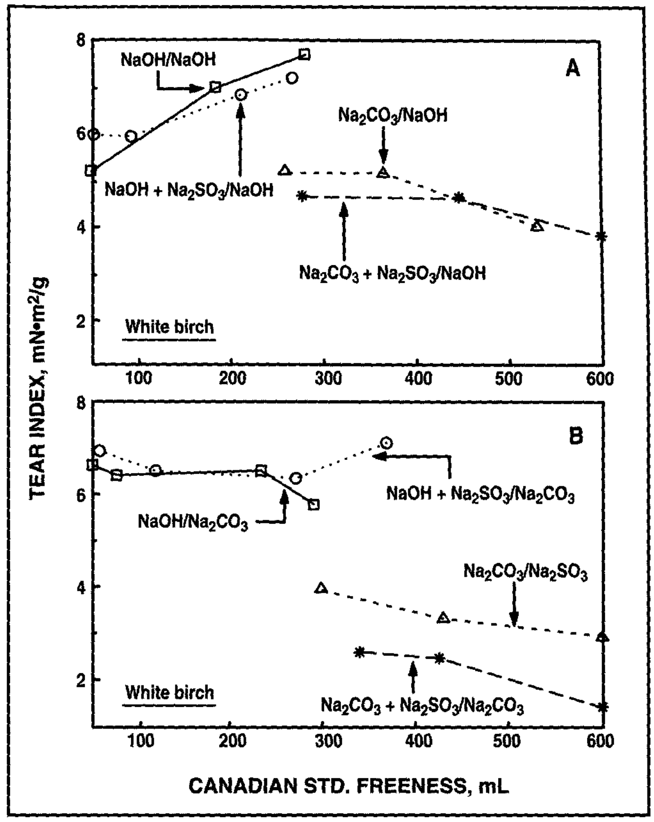
5. Variation of tensile index as a function of freeness for white birch



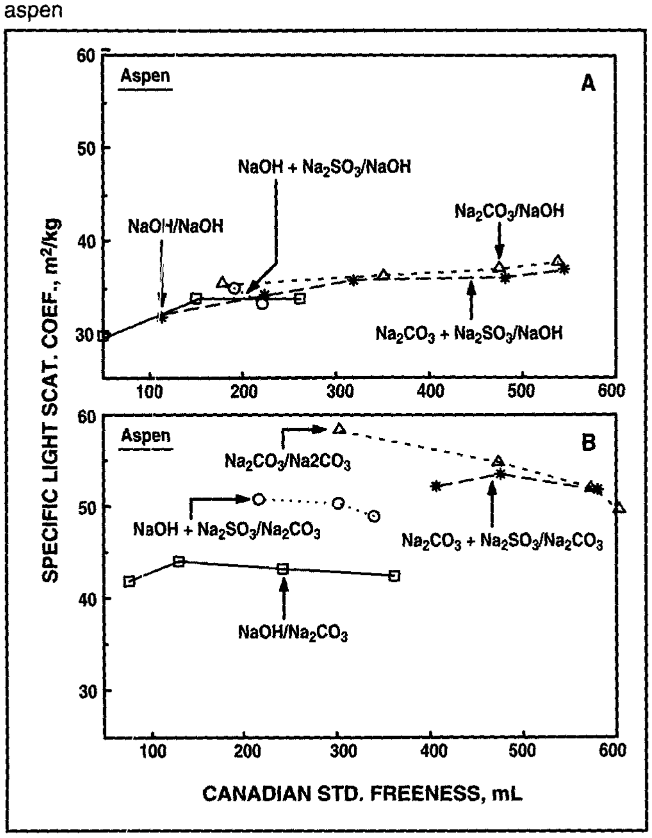
6. Variation of tear index as a function of freeness for aspen



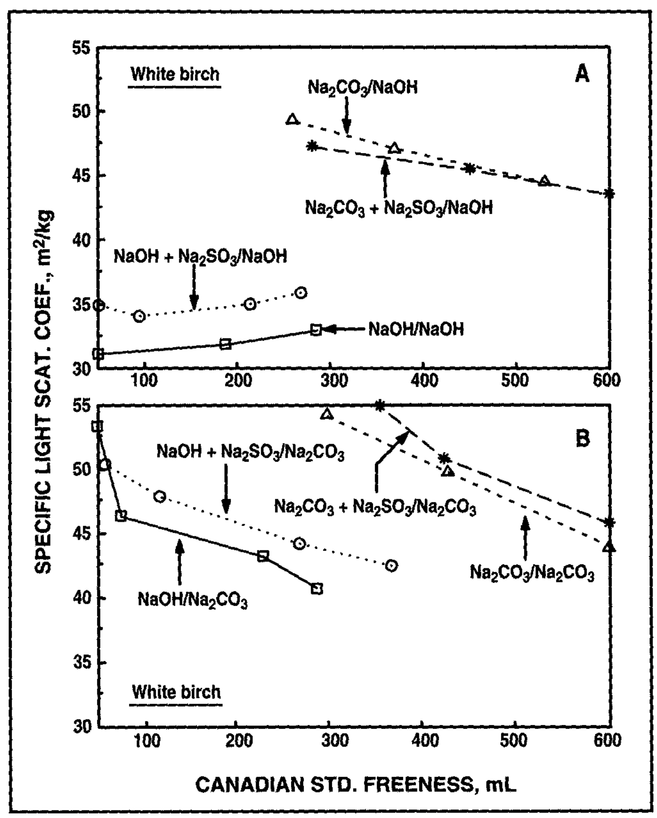
7. Variation of tear index as a function of freeness for white birch



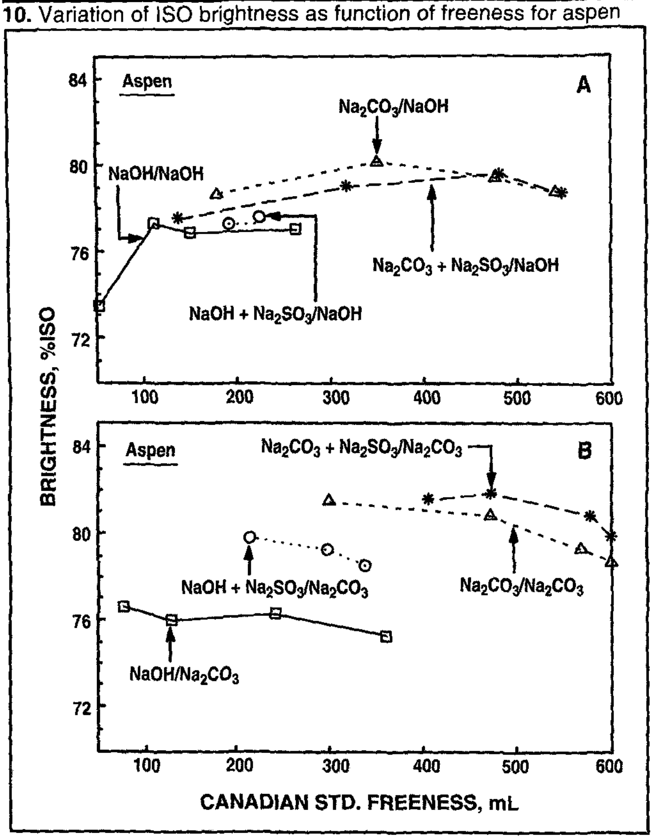
8. Variation of specific light scattering as a function of freeness for aspen



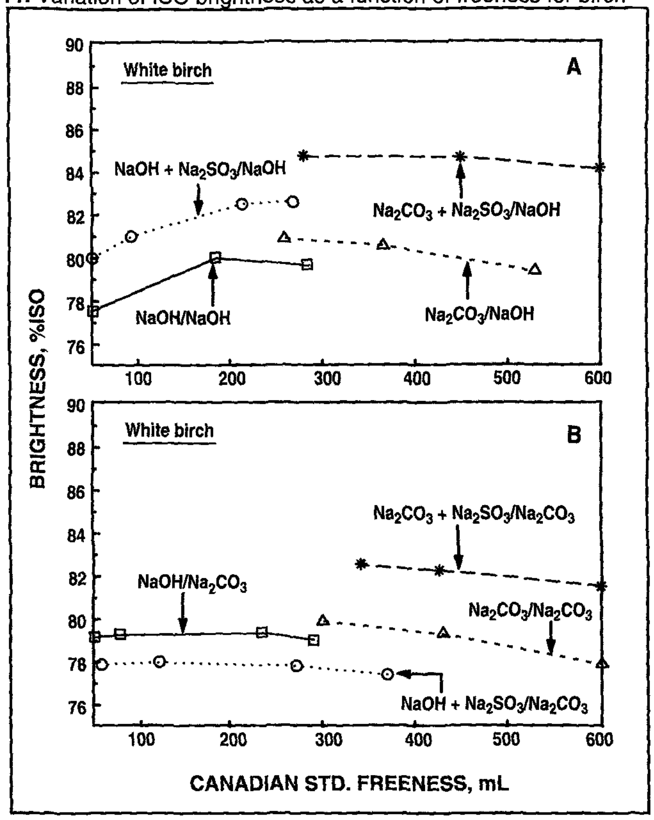
9. Variation of specific light scattering as a function of freeness for birch



10. Variation of ISO brightness as function of freeness for aspen



11. Variation of ISO brightness as a function of freeness for birch



I. Summary of results of chemical treatment for a freeness range of 50 to 200 mL

		Impregnation agent/bleach alkali	
Property		*Aspen*	*Birch*
Tensile index	40–50 N·m/g	NaOH/NaOH	NaOH/NaOH
	30–40 N·m/g	$NaOH/Na_2CO_3$	$NaOH/Na_2CO_3$
Tear index	5–7 mN·m²/g	NaOH/NaOH	NaOH/NaOH
		$Na_2CO_3/NaOH$	$Na_2CO_3/NaOH$
		$NaOH/Na_2CO_3$	$NaOH/Na_2CO_3$
	3–5 mN·m²/g	Na_2CO_3/Na_2CO_3	Na_2CO_3/Na_2CO_3
Light scat.	40–50 m²/kg	$NaOH/Na_2CO_3$	$NaOH/Na_2CO_3$
		Na_2CO_3/Na_2CO_3	Na_2CO_3/Na_2CO_3
	30–40 m²/kg	NaOH/NaOH	NaOH/NaOH
Brightness	>80% ISO	$Na_2CO_3/NaOH$	NaOH+S[a]/NaOH
		Na_2CO_3/Na_2CO_3	$Na_2CO_3/NaOH$
			Na_2CO_3/Na_2CO_3
	76–80% ISO	NaOH+S[a]/NaOH	NaOH/NaOH
		$NaOH/Na_2CO_3$	NaOH+S[a]/Na_2CO_3

[a]S = sodium sulfite

combined with Na_2CO_3, sodium sulfite produced statistically significant effect by increasing the freeness, for a given level of refining energy (Figs. 2 and 3), except for the aspen pulps bleached using Na_2CO_3 as the alkali medium (Fig. 2B).

Effect on tensile index

The use of NaOH alone or combined with Na_2SO_3 in chip impregnation yielded substantially stronger pulps, for a given level of freeness, when compared to Na_2CO_3 (Figs. 4, 5). Note that the addition of Na_2SO_3 to chip impregnation showed no significant effect on tensile strength of pulps of both aspen and white birch. The relatively poor influence of Na_2CO_3 and Na_2SO_3 on fiber bonding strength might be partly attributed to the relatively low reactivity, at low temperatures, of these chemicals with wood components *(10)*.

Effect on tear index

As shown in Figs. 6 and 7, the application of NaOH, whether in chip impregnation or in bleaching stage, is essential to promote tearing strength for both hardwoods. Using Na_2CO_3 produced poor tear resistance compared to NaOH. Statistical tests showed that the addition of Na_2SO_3 either to NaOH or to Na_2CO_3 had no significant effect on tear index.

Effect on light scattering

When compared to Na_2CO_3, the presence of NaOH whether in chip impregnation or pulp bleaching caused considerable reduction in light scattering, as seen in Figs. 8 and 9. On the other hand, the use of Na_2CO_3 in chip impregnation and/or pulp bleaching increased substantially the light scattering, except for aspen pulps treated and bleached with NaOH, as illustrated in Fig. 8A that shows no statistical difference between the various chemical treatments. The statistical analysis indicated that, in most cases, the addition of Na_2SO_3 did not improve the light scattering coefficient, as seen in Figs. 8 and 9.

Effect on brightness

When NaOH was used in both chip impregnation and bleaching of aspen pulps, all chemical treatments produced similar brightness, about 78%, as shown in Fig. 10A. In all other cases (Figs. 10B and 11), NaOH yielded significantly lower brightness as compared with Na_2CO_3 or Na_2CO_3 + Na_2SO_3. The F-test indicated that the use of Na_2SO_3 combined either with NaOH or Na_2CO_3, gave significantly higher brightness compared to NaOH or Na_2CO_3, except in the case where the aspen pulps were treated and bleached with NaOH (Fig. 10A).

Summary and conclusion

The influence of chemical composition used in chip impregnation and peroxide bleaching on four major paper properties for pulps produced from aspen and white birch can be summarized in **Table I**. In general, NaOH is much more effective in mechanical strength development compared to a similar charge of Na_2CO_3, which is particularly true in the chip impregnation stage. On the other hand, Na_2CO_3 is effective in promoting optical properties. As a result, depending on the product requirements, it is possible to produce, at low treatment temperature, a chemimech-anical pulp with acceptable quality by optimizing the application of NaOH and Na_2CO_3. Meanwhile, the use of Na_2SO_3 can be totally eliminated.

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The financial aid for this work granted by the Natural Sciences and Engineering Research Council of Canada is gratefully acknowledged.

Received for review April 19, 1993.

Accepted Feb. 20, 1994.