

Cost-effective brightening of thermomechanical pulp from mountain pine beetle-infested lodgepole pine

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ABSTRACT: We developed a cost-effective bleaching method for overcoming the brightness ceiling of thermomechanical pulp (TMP) made from mill chips containing predominantly mountain pine beetle-infested lodgepole pine. The method involves synergistic bleaching of the TMP in the refiner with hydrosulfite (Y) and diethylenetriaminepentaacetic acid (DTPA) as the chelating agent. The synergistic, in-refiner Y+DTPA bleaching, when followed by post-refiner Y or peroxide bleaching, can provide higher brightness gain or lower bleaching chemical cost for Y- or peroxide-bleached TMP from the mill chips. Estimated cost savings for Y bleaching to 60.0% ISO brightness and peroxide bleaching to 74.3% ISO brightness are USD 5.2/ton pulp and USD 5.2-6.2/ton pulp, respectively.

Application: TMP mills that use mountain pine beetle-infested, lodgepole pine chips can bleach pulps to target brightness at lower costs by adding sodium hydrosulfite and the chelating agent, DTPA, to the refiner, and by reducing the doses of chemicals added to their post-refiner bleach towers or storage tanks.

An infestation of mountain pine beetle in British Columbia (BC) has affected 80% of lodgepole pine (LPP) in the province [1]. In the first stage of a beetle attack (termed the green stage), adult beetles tunnel underneath the bark of a host tree to lay their eggs. The tree dies soon after, but the needles stay green for several months. In the red stage, the needles turn red. Finally, in the grey stage, the needles fall off the tree and only the bare branches remain [2]. Practically all of the beetle-infested LPP trees in BC, covering an estimated 14 million hectares, have been dead for two years or more and are now in the grey stage. They will comprise the major wood chip supply to pulp mills in BC for many years to come.

Pulp bleaching is an important and costly process in the production of high-quality, high-brightness mechanical pulps and papers. Almost all mechanical pulp mills in BC bleach their pulps with sodium hydrosulfite (Y) or alkaline hydrogen peroxide in bleach towers, which generally is more efficient than in-refiner bleaching. In-refiner Y bleaching of thermomechanical pulp (TMP), when combined with post-refiner Y bleaching, can sometimes provide higher ISO brightness gains than post-refiner Y bleaching alone [3,4]. However, all the in-refiner bleaching data reported in the literature are about TMP from uninfested wood.

As a result of widespread beetle infestations, mechanical pulp mills in BC have encountered the problem of low brightness and low bleaching response of TMP made from the beetle-infested wood. This problem is becoming more severe as more and more grey-stage LPP chips enter pulp mills. The blue stain in the sapwood of the infested LPP trees remains with

the TMP after pulping and lowers the brightness and Y bleaching response [5,6]. The brightness ceiling of Y-bleached TMP made from 25% blue-stained, red-stage LPP chips can be overcome by adding 0.2% sodium borohydride to post-refiner Y bleaching [6]. This paper describes a cost-effective, in-refiner bleaching method for overcoming the brightness ceiling of TMP made from mill chips containing predominantly beetle-infested LPP.

MATERIAL AND METHODS

Pilot-plant and mill chips, TMP pulping and bleaching chemicals

Pilot-plant green LPP chips and beetle-infested red-stage or grey-stage LPP chips were prepared from mature (>40 years old) sapwood sections of green and beetle-infested red-stage or grey-stage LPP trees harvested from within BC [6,7]. Two batches of mill chips weighing approximately 60 kg and 160 kg (oven-dried [o.d.] basis) were received from a BC mill in October 2007 and May 2008, respectively. Each of the pilot-plant or mill chips was screened on a two-deck laboratory chip classifier to remove oversize (>31 mm) and fine (<8 mm) materials.

A sample of the screened mill chips was analyzed by reflected darkfield microscopy [8] for species composition. Chips with visibly blue coloration (blue-stained chips) (about 630 g) and those without any blue coloration (unstained chips) (670 g) were hand-sorted from the screened October 2007 mill chips and air-dried from moisture contents of 31.0% and 40.5% to 4.2% and 6.2% (wet basis), respectively. The air-dried unstained chips, blue-stained chips, and 18 chip blends prepared

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from the air-dried chips, each sample weighing about 500 g, were placed on a laboratory rotating tray with a total area of about 300 cm². While the tray was rotating, 10 visible (VIS) and 10 near-infrared (NIR) spectra of each of the samples were recorded using a VIS-NIR spectrometer. Using a full spectrum calibration and a partial least square regression, a blue-stained chip content VIS- or NIR-predictive model was developed. The model was then applied to each of the 10 spectra of chip samples to give 10 blue-stained chip content values, from which the average was calculated. The accuracy of the model was validated by plotting the average values against the actual values. Three samples of unsorted, screened mill chips were placed on the rotating tray and two NIR spectra per sample were recorded. Six predicted blue-stained chip content values were obtained from the spectra and the NIR-predicted model, and used to calculate the average blue-stained chip content (and standard deviation) of the mill chips.

TMP pulping was performed in a 30.5 cm single-disc laboratory refiner and a 30.5 cm open-discharge laboratory secondary refiner [5,7] to give TMP with a CSF value of 110±15 mL. Unless otherwise specified, sodium hydrosulfite (Y) obtained in powder form was used for in- and post-refiner bleaching. The active concentration of Y was determined according to TAPPI T 622 cm-01 (“Analysis of sodium hydrosulfite”). DTPA is the pentasodium salt of diethylenetriamine-pentaacetic acid. All chemicals used for bleaching are reported in percent o.d. weight chips or pulps.

In-refiner bleaching, DTPA treatment, and post-refiner bleaching

In-refiner Y or Y+DTPA bleaching, and in-refiner DTPA treatment of TMP were performed by replacing the primary refiner dilution tap water in TMP pulping with 40 L of tap water containing 4.83 g/L Y, 4.83 g/L Y + 3.03 g/L DTPA, and 3.03 g/L DTPA, respectively, unless otherwise specified. The pHs of the tap water containing such concentrations of Y, Y+DTPA, and DTPA were 9.7, 10.6, and 11.3, respectively, unless otherwise specified. The chemical(s)-containing dilution tap water was added to the primary refiner via the eye of the refiner at a feed rate of 0.70 L/min. The pHs of the filtrates from the pri-

mary refiner pulps were, unless otherwise specified, 4.8-5.5. The average chip feed rate (0.366-0.439 kg/min), based on the total of the o.d. chips used and the total time needed for each pulping/refining run, was determined and used, together with the concentration(s) of the chemical(s) in the dilution tap water and its feed rate, to calculate the dose (o.d. chips) of Y and/or DTPA. Typical variation of chip feed rate from one run to another was ≤10%. Other refining and pulp processing conditions were identical to those used for the control TMP pulping to give in-refiner Y- or Y+DTPA-bleached TMP, or in-refiner DTPA-treated TMP with CSF of 110±15 mL.

Unless otherwise specified, post-refiner Y or Y+DTPA bleaching of TMP was performed at 5.0% consistency and 70°C for 15 min in tap or deionized water without adjustment of the pulp initial pH and with other procedures similar to those reported previously for Y bleaching [6]. Post-refiner peroxide bleaching of TMP was done at 25% consistency and 78°C for 3 h on unchelated TMP but with 0.3% DTPA added to the peroxide bleaching and with other procedures similar to those reported previously [6].

Samples (o.d. 12 g) of TMP were used to make three handsheets (200 g/m²) according to a PAPTAC C.5 (“Forming handsheets for optical tests of pulp [British sheet machine method]”). The ISO brightness values of the sheets were determined with a brightness, opacity, color and fluorescence tester according to PAPTAC E.1 (“Brightness of pulp, paper, and paperboard”), and their average value reported. No replicate pulping or bleaching experiments were performed.

RESULTS AND DISCUSSION

Effect of beetle-infestation stage on pulp brightness and post-refiner bleaching

We first evaluated the brightness and post-refiner bleaching of TMP made from pilot-plant, green, and beetle-infested LPP chips. These chips were from mature sapwoods of green and red-stage LPP trees [6] harvested from one site (site 1), and of green, early-grey (time since death = approximately 2 years) and late-grey (time since death = 6-7 years) LPP trees [7] from another site (site 2). The initial brightness and the post-refiner bleachability of TMP made from the infested

LPP chips	ISO Brightness (%) of TMP	ΔB ^a	ISO Brightness (%) of Y-bleached ^b TMP	ΔB ^a	ISO Brightness (%) of P-bleached ^c TMP	ΔB ^a
Green (site 1)	60.1		69.7		78.1	
Red-stage (site 1)	55.1	-5.0	61.9	-7.8	77.6	-0.5
Green (site 2)	58.8		65.1		76.4	
Early-grey (site 2)	51.5	-7.3	55.6	-9.5	71.2	-5.2
Late-grey (site 2)	51.0	-7.8	-		70.6	-5.8

^aΔB = ISO brightness difference between the infested and green TMP; ^bbleaching done in deionized water and a pH 6.0 buffer for 1 h with 1.0 and 1.5% Y (Virwite H541 from Chemtrade Logistics) for site 1 and site 2 TMP, respectively; ^con 0.5% DTPA-chelated TMP with 5.0% H₂O₂, 4.5% NaOH, 3.0% Na₂SiO₃ and 0.05% MgSO₄ at 20% consistency and 80°C for 2 h.

I. Effect of beetle-infestation stage on thermomechanical pulp (TMP) brightness and post-refiner bleaching.

In-refiner Y Dose (%)	Post-refiner ^b		ISO Brightness (%)
	Chemical	Dose (%)	
0.0	none	-	51.5
0.77	none	-	56.6
0.0	Y	0.80	54.2
0.77	Y	0.70	59.8
0.0	Y	1.50	55.4
0.77	H ₂ O ₂	5.0	74.6
0.0	H ₂ O ₂	5.0	71.2

^apH of the Y-containing dilution tap water was 9.5, chip feed rate = 0.439 kg o.d./min, and pH of the primary refiner pulp filtrate was 4.5; ^bconditions for Y bleaching, and conditions and doses of chemicals other than hydrogen peroxide for peroxide bleaching were the same as those detailed in Table I.

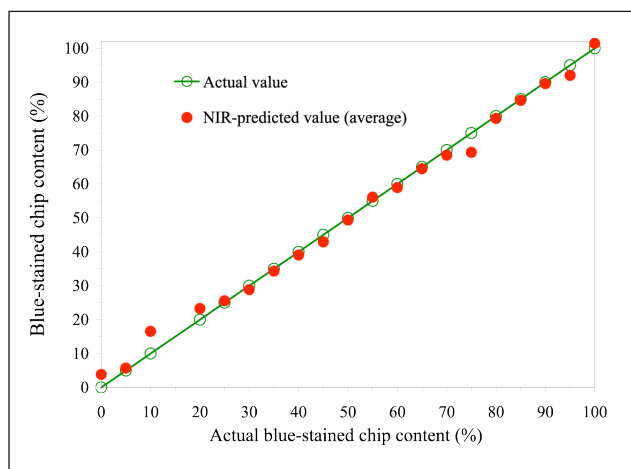
II. Efficiency and potential of in-refiner Y bleaching^a of TMP from the pilot-plant, early-grey lodgepole pine chips.

chips depended on the infestation stage (**Table I**). Grey-stage infestation reduced ISO brightness of the TMP by 7.3-7.8 points, more than the 5.0-point reduction from red-stage infestation. Red-stage and grey-stage infestations made the TMP more difficult to bleach with post-refiner Y. For example, the ISO brightness difference between the TMP from the early-grey and the green chips was 7.3 points before bleaching, but 9.5 points after Y bleaching. Although post-refiner peroxide bleaching brought the brightness of the red-stage TMP within 0.5 ISO point of the green TMP, it only narrowed the brightness difference between the grey-stage TMP and the green TMP slightly (ΔB from about -7.6 to about -5.4 points) (Table I). Bleaching of TMP from grey-stage LPP chips thus represents a more significant challenge than bleaching of TMP from red-stage chips. The early-grey chips, which contained about 80%-85% chips with visibly blue coloration, were selected for the initial in-refiner Y bleaching studies.

In-refiner Y bleaching of TMP from the pilot-plant, early-grey LPP chips

In-refiner Y bleaching of TMP from the pilot-plant, early-grey LPP chips showed a much higher bleaching efficiency than post-refiner Y bleaching. ISO brightness of the in-refiner Y-bleached pulp (56.6%) was 2.4 points higher than that of the post-refiner Y-bleached pulp (54.2%) at approximately 0.8% Y (**Table II**). When the in-refined Y-bleached pulp was subjected to post-refiner Y bleaching (0.7% Y post-refiner; total 1.44% Y for in- and post-refiner), ISO brightness of the pulp reached 59.8%, which was 4.4 points higher than the control TMP post-refiner bleached with 1.5% Y (Table II). When the in-refiner Y-bleached pulp was subjected to post-refiner peroxide bleaching (at 5.0% peroxide), ISO brightness of the pulp was 3.4 points higher than the control TMP post-refiner bleached with peroxide (Table II).

In separate experiments, we found that storage of the in-refiner Y-bleached primary refiner pulp at 70°C for 30 min did not increase the brightness of the pulp any further, indicating that all 0.77% Y added to the refiner was consumed inside the refiner. Addition of 0.18% sodium hydroxide to the Y-containing dilution tap water to raise its pH from 9.5 to



1. Near infrared-predicted, blue-stained chip contents vs. actual blue-stained chip contents from mill chips 1.

12.2, and the pH of the primary refiner pulp filtrate from 4.5 to 5.8 gave a lower ISO brightness (55.3%). The energy requirement to a given freeness was similar between the control and the in-refiner Y bleached pulps (data not shown).

Y+DTPA bleaching of TMP from mill chips

Encouraged by the above results, we studied species composition and blue-stained chip content of mill chips from a BC TMP mill and examined in-refiner Y bleaching of TMP from the mill chips. Reflected darkfield microscopy studies showed that the October 2007 mill chips (mill chips 1) and the May 2008 mill chips (mill chips 2) consisted of, on o.d. weight basis, 85% LPP/13% spruce/2% fir and 89.5% LPP/9.2% spruce/0.3% fir/1.0% aspen, respectively.

Figure 1 compares the NIR-predicted, blue-stained chip contents with the actual values for hand-sorted, visibly blue-stained (100% blue-stained) and unstained (0% blue-stained) chips (from mill chips 1) and chip blends from these two hand-sorted chips. The predicted values matched the actual values very well, particularly in the blue-stained chip content range of 25%-70%; the error of prediction = (difference in predicted and actual values / actual value) $\times$ 100% $\leq$ 4.7%.

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TMP	Y (%)	DTPA (%)	ISO Brightness (%)	ΔB (points) ^f
Control (1) ^a	0.0	0.0	55.1	-
In-refiner Y ^{a,b}	0.92	0.0	56.2	1.1
Control (2) ^c	0.0	0.0	54.4	-
In-refiner DTPA ^{c,d}	0.0	0.57	54.5	0.1
In-refiner "Y + DTPA" ^{c,e}	0.90	0.56	60.0	5.6

^amill-chips-1; ^bchip feed rate = 0.366 kg o.d./min; ^cmill-chips-2; ^dchip feed rate = 0.375 kg o.d./min; ^echip feed rate = 0.380 kg o.d./min; ^ffrom in-refiner bleaching/treatment.

III. Chemical dose and ISO brightness (%) of TMP from the mill chips, and brightness gain (ΔB).

TMP	In-refiner		Post-refiner		Total Chemicals		ISO Brightness (%)
	Y	DTPA	Y	DTPA	Y	DTPA	
Control			0.90	0.60	0.90	0.60	58.7 ^a
			1.50	0.60	1.50	0.60	60.0 ^a
In-refiner bleached	0.90	0.56	0.00	0.00	0.90	0.56	60.0 ^b
			0.60	0.00	1.50	0.56	61.5 ^c

^afrom post-refiner bleaching; ^bfrom in-refiner bleaching; ^cfrom in-refiner and post-refiner bleaching.

IV. Chemical doses and ISO brightness (%) of TMP made from mill chips 2.

Similar results were obtained with the VIS data. Measurement of three samples of the unsorted mill chips by NIR and application of the NIR-predictive model gave blue-stained chip contents of 39.8% and 40.0% for mill chips 1 and mill chips 2, respectively; the standard deviation = 3.0% for the measurements of both mill chips. The blue-stained chip content NIR-predictive model is being refined and used for the commercial installations of FPInnovations-Paprican's NIR-chip sensor to measure blue-stained chip content on-line, in addition to measuring chip moisture content and other chips properties.

In-refiner Y bleaching of TMP from mill chips 1 with 0.92% Y produced only an ISO brightness gain of 1.1 points (Table III), compared to 5.1 points for TMP from the pilot-plant, early-grey LPP chips (Table II). Mill chips 1 contained 0.77 ppm copper, 16.5 ppm iron, and 64.8 ppm manganese, and mill chips 2 contained 0.74 ppm copper, 14.6 ppm iron, and 66.3 ppm manganese, compared to 0.72 ppm copper, 3.75 ppm iron, and 61.3 ppm manganese for the pilot-plant, early-grey LPP chips. We hypothesized that the higher iron content of the mill chips was responsible for their poor in-refiner Y bleaching response and that adding DTPA together with Y to the refiner might improve the in-refiner bleaching response of the mill chips. We found that adding Y and DTPA together to the refiner gave a synergistic bleaching of TMP from the mill chips. The brightness gains using only Y or DTPA alone were 1.1 and 0.1 point, respectively, and the brightness gain using Y+DTPA was 5.6 points (Table III). This represented a synergy of $5.6 - 1.1 - 0.1 = 4.4$ points.

In-refiner Y+DTPA bleaching efficiency and potential

The synergistic, in-refiner Y+DTPA bleaching had a higher bleaching efficiency than post-refiner Y+DTPA bleaching (Table IV). To obtain 60.0% ISO brightness, 0.90% Y and 0.56% DTPA were needed for in-refiner bleaching, compared to 1.50% Y and 0.60% DTPA for post-refiner bleaching. This represented a reduced Y consumption by 6 kg/ton pulp. Even if the reduced use of Y was only 3 kg/ton pulp, the cost saving on reduced Y usage would be USD 5.20/ton pulp (at USD 1.74/kg Y [9]; $3 \text{ kg/ton pulp} \times \text{USD } 1.74/\text{kg} = \text{USD } 5.2/\text{ton pulp}$). This would give a cost saving of about USD 0.36 million/year for a mill with an annual production of 70,000 tons of Y-bleached TMP. In addition, the synergistic, in-refiner Y+DTPA bleaching allowed the TMP to be reductively bleached to 61.5% ISO brightness instead of the ceiling of 60.0% ISO brightness obtained from post-refiner Y+DTPA bleaching alone.

In-refiner and post-refiner bleaching of TMP from the mill chips

We have also investigated the potential of in-refiner Y+DTPA bleaching to overcome the brightness ceiling of post-refiner peroxide-bleached TMP from the mill chips and/or to obtain the same brightness at lower bleach chemical costs. We bleached the control TMP (54.4% ISO brightness) and the in-refiner Y+DTPA-bleached TMP (60.0% ISO brightness) with various doses of peroxide at different sodium hydroxide to peroxide ratios. The optimal sodium hydroxide/peroxide ra-

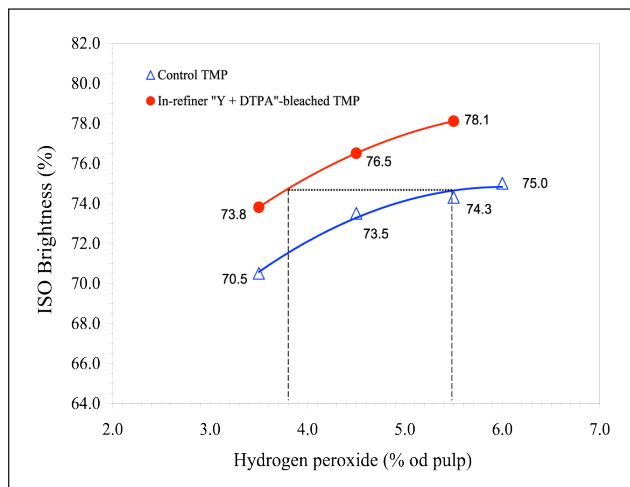
TMP	H ₂ O ₂ (%)	NaOH (%)	NaOH/H ₂ O ₂ Ratio	Residual H ₂ O ₂ (%)	End pH	ISO Brightness (%)
Control ^a	3.5	2.3	0.66	9.9	8.5	70.5
	4.5	2.55	0.57	13.1	8.4	72.2
		3.0	0.67	10.7	8.6	73.5
		3.4	0.75	5.6	8.5	72.6
	5.5	3.2	0.58	9.9	8.4	73.8
		3.7	0.67	4.4	8.5	74.3
In-refiner Y+DTPA bleached ^b	3.5	2.3	0.66	19.1	8.2	72.9
		2.7	0.77	16.6	8.5	73.5
		3.0	0.86	8.0	8.7	73.8
	4.5	3.4	0.76	17.0	8.6	76.5
		3.7	0.82	10.5	9.1	76.2
	5.5	3.7	0.67	18.0	8.7	78.1
		4.2	0.76	14.1	9.1	77.9
		4.7	0.85	10.1	9.6	77.9

^aISO brightness = 54.4%; ^bISO brightness = 60.0% (Y and DTPA doses for in-refiner bleaching were 0.90 and 0.56%, respectively).

V. Effect of peroxide and sodium hydroxide on post-refiner peroxide bleaching (25% consistency, 78°C for 3 h along with 3.0% Na₂SiO₃ and 0.3% DTPA) of the control and in-refiner Y+DTPA-bleached TMP.

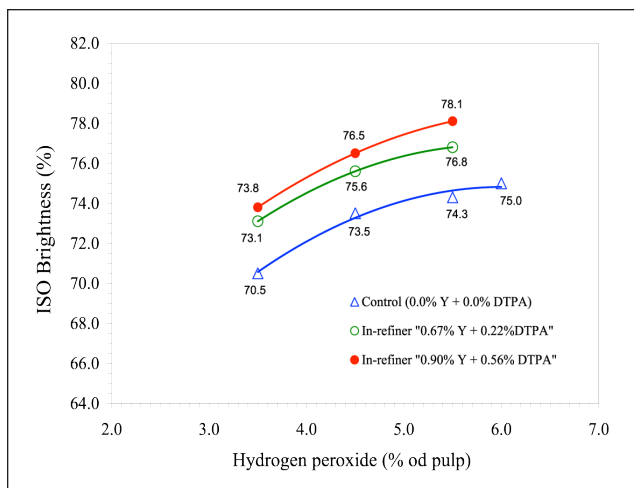
tios were approximately 0.67 and 0.67-0.86 for post-refiner peroxide bleaching of the control, and of the in-refiner Y+DTPA-bleached TMP, respectively (**Table V**). A significant portion (about 68%) of the brightness gain obtained from in-refiner Y+DTPA bleaching was retained after post-refiner peroxide bleaching over a wide range of peroxide doses. For example, the ISO brightness difference between the in-refiner Y+DTPA followed by 5.5% peroxide bleaching and the control post-refiner only with 5.5% peroxide bleaching was 3.8 points (78.1 - 74.3 = 3.8) (**Fig. 2**), as compared to 5.6 points (60.0 - 54.4 = 5.6) for the corresponding TMP with no peroxide bleaching.

The higher (average 3.4 ISO points) brightness gain obtained from in-refiner Y+DTPA bleaching, followed by post-refiner peroxide bleaching could potentially be used by the mill to obtain the same brightness at a lower bleach chemical cost or to achieve higher brightness for their pulp and paper. For example, to achieve a peroxide-bleached ISO brightness of 74.3%, the mill could use 0.9% Y and 0.56% DTPA (added to the primary refiner) to reduce peroxide by 17 kg/ton pulp (from 5.5% to 3.8% on o.d. pulp) (**Fig. 2**) and sodium hydroxide by 6 kg/ton pulp (from 3.7% to ~3.1% on o.d. pulp) (**Table V**) in their post-refiner peroxide bleaching. Such a reduction could give a cost saving of USD 6.2/ton pulp, based on the costs of USD 1.74, USD 1.33, USD 1.41, and USD 0.90 per kilogram of Y, DTPA, peroxide, and sodium hydroxide [9], respectively. (The cost of using 0.9%Y + 0.56% DTPA = 9 kg Y/ton pulp × USD 1.74/kg + 5.6 kg DTPA/ton pulp × USD 1.33/kg =



2. ISO brightness vs. water dose for post-refiner peroxide bleaching of TMP from mill chips 2.

USD 23.11/ton pulp, and cost of using 17 kg peroxide/ton pulp and 6 kg sodium hydroxide/ton pulp = 17 kg/ton pulp × USD 1.41/kg + 6 kg/ton pulp × USD 0.90/kg = USD 29.37/ton pulp. Thus, a cost saving of using 0.9%Y + 0.56% DTPA to allow the reduction of peroxide by 17 kg/ton pulp and sodium hydroxide by 6 kg/ton pulp = USD 29.37/ton pulp - USD 23.11/ton pulp = USD 6.26/ton pulp.) For a mill making 200,000 tons/year of peroxide-bleached TMP, this would result in a cost saving of USD 1.24 million/year.



3. ISO brightness vs. water dose for post-refiner peroxide bleaching of the control and in-refiner Y+DTPA-bleached TMP from mill chips 2 at different Y and DTPA doses.

Reducing Y and DTPA doses for in-refiner bleaching

To determine if higher cost savings could be achieved, we performed in-refiner Y+DTPA bleaching with 0.67% Y and 0.22% DTPA by using dilution tap water containing 3.62 g/L of Y and 1.21 g/L of DTPA for the primary refiner (at a chip feed rate of 0.380 kg o.d./min). An ISO brightness gain of 3.3 points (from 54.4% to 57.7%) was obtained. This compared to 5.6 points using 0.90% Y and 0.56% DTPA (Table III). Post-refiner peroxide bleaching on the in-refiner 0.67% Y + 0.22% DTPA-bleached TMP also gave significantly higher ISO brightness gain (by 2.1-2.6 points) (**Fig. 3**) than on the control TMP. Similar calculation on the possible cost saving for bleaching to 74.3% ISO brightness using this in-refiner Y+DTPA-bleached TMP, followed by post-refiner peroxide bleaching, gave a potential cost saving of USD 5.2/ton pulp (from the replacement of 1.4% peroxide with 0.67% Y and 0.22% DTPA) or USD 1.04 million/year for the mill.

CONCLUSIONS

TMP made from pilot-plant grey-stage LPP sapwood chips had an initial ISO brightness that was 7.3-7.8 points lower than that made from green chips. Post-refiner peroxide bleaching only slightly decreased the brightness gap between the grey-stage and green TMP, but post-refiner hydrosulfite (Y) bleaching actually increases the brightness gap.

In-refiner Y bleaching of TMP from the pilot-plant early-grey LPP chips had a much higher efficiency than post-refiner Y bleaching. However, when in-refiner Y bleaching was applied to TMP from mill chips containing predominantly beetle-infested LPP, a much smaller brightness gain was obtained. Addition of the chelating agent (DTPA) to the refiner synergistically increased the efficiency of in-refiner Y bleaching of TMP made from mill chips containing predominantly beetle-infested LPP.

Synergistic, in-refiner Y+DTPA bleaching, when followed by post-refiner Y or peroxide bleaching, can provide higher brightness gain or lower bleaching chemical cost for Y- or peroxide-bleached TMP from mill chips. Estimated cost savings for Y bleaching to 60.0% ISO brightness and peroxide bleaching to 74.3% ISO brightness are USD 5.6/ton pulp and USD 5.2-6.2/ton pulp, respectively. The higher brightness gain also could allow mills using beetle-infested LPP to achieve brightness targets and retain market shares for their pulp and paper products. **TJ**

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ABOUT THE AUTHORS

Mechanical pulp mills that use mountain pine beetle-infested lodgepole pine (LPP) chips in British Columbia and other regions of the Pacific Northwest have encountered the problem of low brightness and low bleaching response of thermomechanical (TMP) made from such chips.

This research complements our previous work on post-refiner bleaching of TMP made from beetle-infested LPP sapwood chips, and previous work done by others on in-refiner bleaching of TMP made from un-infested wood. It differs from previous research in that in-refiner bleaching was performed on beetle-infested LPP TMP.

The most difficult aspect of this research was to improve the in-refiner bleaching response of TMP made from the mill chips. We addressed this difficulty by identifying the cause for the different in-refiner bleaching responses of TMP pulps made from the mill chips and from the pilot-plant, beetle-infested LPP sapwood chips and then by adding the chelating agent, DTPA, along with sodium hydrosulfite, to the refiner.

We discovered that careful analyses of the data and design of further experiments to test thoroughly-thought-of hypothesis could lead us to the develop-

ment of practical solutions to difficult problems. The most interesting and commercially important finding we obtained was the synergistic in-refiner bleaching effect of sodium hydrosulfite (Y) and the chelating agent, diethylenetriaminepentaacetic acid (DTPA) for TMP made from the mill chips containing predominantly beetle-infested LPP.

TMP mills that use beetle-infested LPP chips can produce bleached pulps with target brightness at significantly lower costs by adding a small amount of sodium hydrosulfite and the chelating agent, DTPA, to their TMP refiners, and by reducing the doses of chemicals added to their post-refiner bleach towers or storage tanks.

The next step is to perform mill trials of in-refiner Y+DTPA bleaching of TMP made from beetle-infested LPP chips, quantify the cost benefits, and implement such a bleaching process.

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