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Contents

Comparing chips made in a woodroom to chips made by a portable system

Abstract

FERIC undertook a study in central Alberta to compare debarking and chipping of small-diameter logs at a woodroom chipping operation and at a portable in-woods chipping operation. FERIC evaluated whether chip recovery and quality, and chipping productivity, are affected by changes in stem size, log condition (unfrozen versus frozen), and debarking and chipping method. Net operational costs were also examined.

Keywords

Chips, Chipping, Woodroom, Portable chipper, Debarking, Chip quality, Chip recovery, Chipping productivity, Chipping costs, Alberta.

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Introduction

In Alberta, due to the recent construction of new sawmills and pulp mills, and the upgrading of existing sawmills, new sources of wood chips to supply the pulp mills are being developed. In the past, the main means of producing pulp chips was by whole-log debarking and chipping in pulp mill woodrooms. Now pulp mills obtain the majority of their softwood chip requirements from sawmills through fibre-exchange and/or purchase agreements. Some pulp mills are processing small-diameter stems in their woodrooms and/or having them processed by portable in-woods delimber/debarker/chipping systems. However, chips produced from small-diameter logs can contain higher bark content, and more fines and pins, than chips produced from large-diameter logs (Araki 1996). And, it is known that pulp quality is affected by bark content and the percentage of fines and pin chips.

In light of the changes in how and from where pulp mills obtain chips, and in keeping with FERIC's ongoing commitment to investigate opportunities to produce higher quality and lower cost chips, FERIC undertook a study to compare debarking and chipping of small-diameter logs at a woodroom operation and at an in-woods chipping operation. With the cooperation of the Hinton Division of Weldwood of Canada Limited in central Alberta, FERIC evaluated whether chip recovery and quality, and chipping productivity, are affected by changes in stem size, log condition (unfrozen versus frozen), and debarking and chipping method.

Objectives

FERIC conducted a series of log debarking and chipping trials to:

- Determine and compare chip recovery, chip quality, and chipping productivity, when logs of different butt-diameters, lengths, and conditions (unfrozen versus frozen) are processed through a portable, in-woods Peterson DDC5200 delimber/chain-flail debarker/chipper system, and a drum debarker/chipper in a pulp mill woodroom.
- Determine net costs associated with these operations.

Equipment description

Woodroom operation

Weldwood's kraft pulp mill and sawmill in Hinton, Alberta are located on adjacent properties and share a common gravel-surfaced logyard. Mobile equipment includes two Wagner stackers, plus two Caterpillar 980 and two Caterpillar 966 front-end loaders to unload logging trucks, place logs in storage, and forward logs to the infeed decks of the mills. The main woodroom equipment includes a FMP-Rauma drum debarker and a Carthage disc chipper.

At the pulp mill woodroom, the Wagner stacker places tree-length logs on the infeed deck. The logs move up the infeed deck (Figure 1) and fall into a large pocket slasher (1.8 × 2.1 × 25 m) with a conveyor beneath it. Two vertically mounted circular saws drop down through the pocket and cut the logs to desired lengths. Because of the infeed configuration, the maximum length of log that can be placed in the drum debarker is 4.2 m. After the saw is retracted, bucked logs advance into a de-icing chamber (2.4 × 3 × 45 m) where frozen logs are sprayed with hot water for approximately 15 min. This thaws the logs sufficiently (but not completely) before they fall into the drum debarker. Unfrozen logs also spend a short time in the de-icing chamber. The water is used to clean and lubricate the logs, and to help control dust in the woodroom.

The FMP-Rauma drum debarker is 5.4 m in diameter and 29 m long. Inside, a series of baffles assists the tumbling of the logs. The bark and waste fall through 6-cm-wide slots situated along the horizontal length of the drum, and are conveyed to a hog mill. The hog fuel is burned in a boiler. A gate at the end of the debarker is used to control the dwell time of the logs. Through visual inspection, the operator determines the amount of bark removed and opens and closes the gate accordingly to allow debarked logs to exit. New logs entering the drum push out the debarked logs. The debarked logs are then conveyed to the 12-knife Carthage 2.8-m disc chipper which is powered by two 750-kW electric motors. The chips fall onto a conveyor and are mixed with those produced at the sawmill. The mixed chips are conveyed to the chip silos or the chip pile to be stored until needed.

Figure 1. Pocket slasher infeed deck to drum debarker at Weldwood's pulp mill.

Portable in-woods operation

The Peterson DDC5200 is a portable single unit delimber/debarker/chipper that processes whole stems into pulp-quality chips (Figure 2) (Araki 1994, 1996). Delimbing and debarking are accomplished by passing stems through chain flails attached to three rotating drums. The chain flails remove the small limbs and bark from the stems before the stem enters the 3-knife Precision disc chipper. From the chipper, the chips are blown up a chute and then into waiting chip vans for hauling to the pulp mill.

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The latest model of the Peterson DDC5200 features separate speed controls for the flail drums, infeed rolls, and chipper rotation. These new adaptations have helped operators to minimize bark content, and improve production of acceptable chips.

Study methods

For both the woodroom and in-woods components of the study, the logs were obtained from the same or similar sources. The logs consisted mainly of lodgepole pine, but included some black spruce and a small amount of white spruce.

Woodroom operation

Delivered truckloads of frozen and unfrozen small-diameter, *tree-length logs* were set aside and then separated into three butt-diameter classes (<15, 15–20, and >20 cm), plus a class of mixed butt diameters. There were a minimum of two loads of logs in each butt-diameter class. The total number of logs in each of the first three diameter classes were counted, a representative sample was manually scaled to determine the average log volume, and then the total volume in the diameter class was calculated. Logs in the mixed-diameter class were counted by diameter class and these totals were multiplied by the corresponding average volume to determine the overall volume. All the logs in each diameter class were weighed to determine the total log weight. A piece of welding rod was inserted into the first of the logs to be fed into the system. This log could then be detected by the system's metal sensor and thus signal the end of processing one diameter class and the beginning of processing the next diameter class. Unfortunately, this method did not always work, and in some cases FERIC grouped the results for two log classes because it was not possible to distinguish the exact entry and exit times of the classes.

Delivered truckloads of frozen and unfrozen, small-diameter, *cut-to-length logs* (mostly tops from lodgepole pine and spruce sawlogs) were also counted and volumes determined, in a manner similar to that described above for the tree-length logs.

Figure 2. Peterson Pacific DDC 5200 chipping logs near Hinton Alberta.

During the chipping trials the chip conveyor from the sawmill was temporarily shut off so the chips that normally come from the sawmill would not mix with the woodroom chips. The woodroom chips were dropped onto the chip pad and then weighed using a load cell installed on a Caterpillar 988 front-end loader. Chip samples for analysis (50-L each) were taken during the processing of each diameter class.

Portable in-woods operation

At the harvesting site, frozen and unfrozen pre-marked, small-diameter, *tree-length logs* were sorted into two classes as they were loaded onto a self-loading logging truck: smaller diameter logs (<20 cm, mostly tops) and larger diameter logs (>20 cm). On-board weigh scales were used to determine the total weight of logs. The logs were transported a short distance from the harvesting site to the Peterson DDC5200 delimber/chain-flail debarker/chipper system. The class of <20-cm-diameter logs were fed into the system first, followed by the >20-cm-diameter logs.

Samples of chips were analyzed for bark content, acceptable chips, fines, and pins using a BM&M chip classifier and a Domtar chip-thickness analyzer.

Results

Tables 1 and 2 summarize the volumes of frozen and unfrozen logs processed by both the woodroom and in-woods operations.

Log density ratios. The log density ratios for the unfrozen logs were generally lower

Table 1. Volumes processed: frozen logs

Chipping location and log class	Average log volume (m³/log)	Total logs (no.)	Estimated total log volume (m³)	Total log weight (×1000 kg)	Log density [b] (kg/m³)
Woodroom					
<15-cm tree-length	0.08	1 744	134	118.3	881
15–20-cm tree-length	0.16	734	116	94.8	819
>20-cm tree-length	0.34	210	71	59.6	835
Mixed-diameter tree-length	0.24	875	211	173.3	821
Smaller-diameter cut-to-length [a]	0.04	2 592	102	78.6	770
Larger-diameter cut-to-length	0.06	1 632	101	78.4	772
In-woods					
Smaller-diameter tree-length	0.12	316	39	30.0	777
Larger-diameter tree-length	0.26	152	40	31.9	798

[a] Mostly tops.
[b] May have slight differences due to rounding.

Table 2. Volumes processed: unfrozen logs

Chipping location and log class	Average log volume (m³/log)	Total logs (no.)	Estimated total log volume (m³)	Total log weight (×1000 kg)	Log density [a] (kg/m³)
Woodroom					
<15-cm tree-length	0.11	1 291	136	103.9	765
15–20-cm plus mixed-diameter tree-length	0.21	2 133	453	274.0	605
Mixed-diameter cut-to-length	0.05	7 956	377	320.4	850
In-woods					
Smaller-diameter tree-length	0.12	530	61	42.0	685
Larger-diameter tree-length	0.24	278	67	38.5	576

[a] May have slight differences due to rounding.

than for the frozen logs. This was because, in many cases, the logs that were processed in the summer trial had been cut in the late winter and had dried for three months prior to delivery. However, the frozen logs had been harvested less than a month before being delivered to the mill.

In the in-woods operation, the log density ratio for the unfrozen logs was lower for the larger diameter logs than the smaller diameter logs. Again, the larger diameter logs had been left at roadside from the previous winter and were likely drier, while the smaller-diameter logs had been harvested less than a week prior to the trials.

Tables 3 and 4 give productivity and chip recovery results.

Delays. For both operations, the debarking time and summaries of productivities did not include any long delays.

Chip recovery and system productivity. In the trials of frozen logs in the woodroom operation (Table 3), FERIC suspects that the system productivity for the tree-length logs in the <15-cm diameter class is overstated because the dwell time in the debarker was too short.

After the trials of frozen logs in February 2000, FERIC suggested that the minimum small-end diameter of logs going to the woodroom be increased from 6 cm to 8 cm to reduce the incidence of small ends passing through the debarker's 6-cm-wide slots. As a result, chip recovery from unfrozen cut-to-

Table 3. Chip recovery and system productivity: summary for frozen logs

Chipping location and log class	Total log weight (t)	Total chip weight (t)	Total debarking and chipping time (h)	Chip recovery (%)	Moisture content of chips (%)	System productivity (BDt/h)
Woodroom						
<15-cm tree-length	118.3	98.9	1.5	84	42	38
15–20-cm tree-length	94.8	85.9	2.3	91	44	21
>20-cm tree-length	59.6	54.0	0.7	91	45	42
Mixed-diameter tree-length	173.3	134.5	3.0	78	40	27
Smaller-diameter cut-to-length [a]	78.6	39.7 [b]	1.2 [b]	51 [b]	46	18 [b]
Larger-diameter cut-to-length	78.4	67.6 [b]	1.3 [b]	86 [b]	40	31 [b]
In-woods						
Smaller-diameter tree-length	30.0	24.6	0.6	82	41	24
Larger-diameter tree-length	31.9	28.2	0.4	88	41	42

[a] Mostly tops.
[b] Chip recovery, debarking and chipping time, and system productivity are estimated because FERIC had difficulty determining the exact entry and exit times as these log classes were put through the system.

length logs was higher (89%, Table 4) than from cut-to-length frozen logs (51 and 86%, Table 3). While some of this improvement in recovery can be attributed to the log condition (frozen versus unfrozen), it occurred mainly because fewer chunks passed through the debarker's slots.

Bark content and chip size. As expected, chips produced in the woodroom from frozen logs were higher in bark content than chips produced from unfrozen logs (Tables 5 and 6). The problem of debarking frozen logs was partially mitigated by conditioning the logs in the de-icing chamber for approximately 15 min prior to their entering the drum debarker. The percentage of accept chips was higher for frozen logs than unfrozen logs even though the chips made from the frozen logs were slightly smaller because the wood was only partially thawed by the de-icer. The trial of unfrozen logs resulted in more over-thick and over-size chips than the trial of frozen logs.[1]

In the woodroom, the cut-to-length logs, both frozen and unfrozen, generally produced a higher percentage of over-thick chips. This is probably due to the fact that many short chunks were produced by the pocket slasher when cutting the 5-m logs. These short chunks would often not be properly aligned when the chipper knife hit them. Therefore, chip "cards" (long slab-like pieces) and long strands of fibre resulted, leading to excessive amounts of over-thick chips.

As expected, in the woodroom operation, chips produced from frozen logs were smaller and thinner than chips produced from unfrozen logs. FERIC was unable to explain the differences in percentages for the over-thick and over-size chips made from unfrozen logs in the <15-cm, mixed-diameter, and cut-to-length classes (Table 6). The difference in moisture content may have contributed to the difference in chip thickness, but usually drier logs produce smaller chips. It is possible that the pocket slasher was set to cut shorter logs than in the earlier trials. The relatively large percentage of over-thick and over-size chips produced from unfrozen logs (Table 6) indicate that an adjustment to the chipper should have been made. The chipper disc

[1] Although Weldwood's Chip Quality Index program penalizes the production of over-size and over-thick chips, pulp mill personnel were not too concerned about these chips because the chip conditioner in the pulp mill would break them down.

Table 4. Chip recovery and system productivity: summary for unfrozen logs

Chipping location and log class	Total log weight (t)	Total chip weight (t)	Total debarking and chipping time (h)	Chip recovery (%)	Moisture content of chips (%)	System productivity (BDt/h)
Woodroom						
<15-cm tree-length	103.9	86.8	1.0	84	32	59
15–20-cm plus mixed-diameter tree-length [a]	274.0	217.1	1.9	79	33	77
Mixed-diameter cut-to-length [a]	320.4	285.8	3.2	89	35	58
In-woods						
Smaller-diameter tree-length	42.0	30.5	0.5	73	39	37
Larger-diameter tree-length	38.5	30.4	0.4	79	40	46

[a] Classes could not be separated during debarking and chipping and are therefore combined.

Table 5. Chip analysis: summary of frozen logs

Chipping location and log class	Unacceptable chips: Over-thick >10 mm [a] (%)	Unacceptable chips: Over–size 45 mm pp [b] (%)	Acceptable chips: 32 mm pp [b] (%)	Acceptable chips: 13 mm/ >4 mm [c] (%)	Acceptable chips: 13 mm/ <4 mm (%)	Acceptable chips: 7 mm ww [d] (%)	Acceptable chips: 3 mm pp [b] (%)	Fines (%)	Bark (%)	Total (%)
Woodroom										
<15-cm tree-length	13.8	2.6	9.6	47.3	17.5	4.4	3.1	0.3	1.4	100
15–20-cm tree-length	11.2	2.1	7.9	50.9	17.3	5.1	4.4	0.4	0.7	100
>20-cm tree-length	13.6	1.0	7.5	54.0	15.8	4.4	3.1	0.2	0.4	100
Mixed-diameter tree-length	12.8	2.2	8.3	49.6	17.7	5.0	3.6	0.3	0.6	100
Smaller-diameter cut-to-length [e]	20.2	2.1	7.9	48.6	13.2	4.3	3.2	0.2	0.4	100
Larger-diameter cut-to-length	17.8	1.7	7.9	45.8	15.0	5.6	5.2	0.6	0.4	100
In-woods										
Smaller-diameter tree-length	11.2	1.3	8.6	44.2	16.5	5.5	7.1	0.8	4.9	100
Larger-diameter tree-length	8.3	1.9	12.0	45.8	17.1	5.1	5.4	0.6	3.9	100

[a] Over-thick chips are those >10 mm in thickness from all the size classifications. [b] pp = punched plate screen. [c] Using punched plate screen chips 13 mm in size and >4 mm in thickness. [d] ww = woven wire screen. [e] Mostly tops.

speed, anvil and knife settings, and infeed speed all affect chip quality. More attention should be devoted to the chipper setup by woodroom personnel in order to produce fewer unacceptable chips.

The analysis of the chips from the in-woods chipping operation (Tables 5 and 6) showed the bark content of chips produced from frozen logs (average 4.4%) was twice as much as the bark content of chips produced from unfrozen logs (average 2%). In both cases it was too high for the pulp mill standard (1.5% for frozen logs, and 1% for unfrozen logs). Usually the percentage of bark decreases as stem diameter increases (Araki 1996). But when the diameters are too large, the chain flails of the Peterson cannot wrap around the sides of the log as completely and therefore bark removal will be poorer. The in-woods operation produced smaller chips when processing frozen logs than unfrozen ones.

Productivity. Debarker productivity in the woodroom operation was lower when it handled frozen logs because they dwelled longer in the de-icer and debarker than did unfrozen logs (Tables 3 and 4).

Table 6. Chip analysis: summary of unfrozen logs

Chipping location and log class	Unacceptable chips: Over-thick >10 mm [a] (%)	Unacceptable chips: Over-size 45 mm pp [b] (%)	Acceptable chips: 32 mm pp [b] (%)	13 mm/ >4 mm [c] (%)	13 mm/ <4 mm (%)	7 mm ww [d] (%)	3 mm pp [b] (%)	Fines (%)	Bark (%)	Total (%)
Woodroom										
<15-cm tree-length	21.5	3.0	12.5	50.3	7.9	2.2	2.1	0.2	0.4	100
15–20-cm tree-length	16.1	4.1	14.7	46.5	11.9	2.5	3.4	0.7	0.3	100
Mixed-diameter tree-length	26.2	3.1	12.8	46.5	7.5	1.8	1.7	0.2	0.2	100
Small-diameter cut-to-length [e]	22.3	2.7	12.4	50.0	8.4	1.8	1.9	0.4	0.3	100
Large-diameter cut-to-length	23.2	4.4	14.4	47.1	7.4	1.6	1.5	0.2	0.2	100
In-woods										
Small-diameter tree-length	4.9	0.6	5.8	42.1	24.3	12.6	7.4	1.0	1.4	100
Large-diameter tree-length	7.7	0.8	10.8	45.0	19.9	6.8	5.5	0.9	2.6	100

[a] Over-thick chips are those >10 mm in thickness from all the size classifications. [b] pp = punched plate screen. [c] Using punched plate screen chips 13 mm in size and >4 mm in thickness. [d] ww = woven wire screen. [e] Mostly tops.

Costs[2]

Woodroom operation

Appendix I illustrates the operating and owning costs of the woodroom, the millyard equipment, and the Peterson DDC 5200. The woodroom processes approximately 850 000 m^3 of logs annually, at an hourly cost of $1146/h (Table 7). The total annual operating cost is estimated to be $8 251 000.

The detailed calculation of the net chip cost is illustrated in Table 8. FERIC's cost analysis focuses on the net cost of placing chips on the chip pad. Not included in the analysis are the cost of processing the wood waste generated in the yard from log handling and the cost of disposing of the excess hog fuel (estimated to be $1 million/year or $1.20/m^3).

In determining the net cost of placing chips on the chip pad, the cubic-metres-to-BDt conversion ratio for each of the diameter classes was calculated from the volume: weight ratio, the chip recoveries achieved, and the chip moisture contents. The conversion ratio was multiplied by the harvesting cost and added to the adjusted chipping cost (Appendix II). The cost to harvest and deliver tree-length logs to the pulp mill has been estimated[3] at $34/m^3, while cut-to-length logs were delivered for $35/m^3. These costs also include all road access, silvicultural obligations, administration, and stumpage.

The net cost of placing chips made from frozen, mixed-diameter, tree-length logs on the woodroom chip pad was relatively high at $130.84/BDt. The net cost of placing chips made from unfrozen, mixed-diameter, tree-length logs on the pad was somewhat lower at $121.30/BDt (Table 8). The cost of processing frozen, cut-to-length, smaller-diameter logs, at $228.87/BDt, was the highest of all classes. The cost of processing

[2] All costs stated in this section are estimates.

[3] Based on discussions with Weldwood personnel.

Table 7. Annual cost of operating the millyard and the woodroom

Description	Rate ($/h)	Annual operating time (h)	Total cost ($ × MM)
Woodroom	896	7 200	6.451
Millyard			
Wagner stacker	130	7 200	0.936
Caterpillar 980 loader	82	7 200	0.590
Caterpillar 966 loader [a]	38	7 200	0.274
Average cost	1 146		8.251

[a] The rate for the Caterpillar 966 loader is half the actual because use of the loader was split between the chip pad and the millyard.

Table 8. Net cost of chips

Log condition, chipping location, and log class	Log density (kg/m³)	Chip recovery (%)	Moisture content of chips (%)	System productivity (BDt/h)	Conversion (m³/BDt)	Adjusted log cost ($/BDt)	Debarking and chipping cost ($/BDt)	Net chip cost ($/BDt)
Frozen								
Woodroom								
<15-cm tree-length	881	84	42	38	2.33	79.22	30.16	109.38
15–20-cm tree-length	819	91	44	21	2.40	81.60	54.57	136.17
>20-cm tree-length	835	91	45	42	2.39	82.26	27.29	108.55
Mixed-diameter tree-length	821	78	40	27	2.60	88.40	42.44	130.84
Smaller-diameter cut-to-length [a]	770	51 [b]	46	18 [b]	4.72 [b]	165.20 [b]	63.67 [b]	228.87 [b]
Larger-diameter cut-to-length	772	86 [b]	40	31 [b]	2.51 [b]	87.85 [b]	36.97 [b]	124.82 [b]
In-woods								
Smaller-diameter tree-length	777	82	41	24	2.66	58.52	25.08 [c]	83.60
Larger-diameter tree-length	798	88	41	42	2.41	53.02	20.76 [c]	73.78
Unfrozen								
Woodroom								
<15-cm tree-length	765	84	32	59	2.29	77.86	19.42	97.28
15–20-cm plus mixed-diameter tree-length	605	79	33	77	3.13	106.42	14.88	121.30
Mixed-diameter cut-to-length	850	89	35	58	2.03	71.05	19.76	90.81
In-woods								
Smaller-diameter tree-length	685	73	39	37	3.28	72.16	21.54 [c]	93.70
Larger-diameter tree-length	576	79	40	46	3.66	80.52	20.26 [c]	100.78

[a] Mostly tops. [b] Chip recovery, debarking and chipping time, and system productivity are estimated because FERIC had difficulty determining the exact entry and exit times as these log classes were put through the system. [c] Includes chip-hauling cost of $15/BDt.

unfrozen, cut-to-length logs was among the lowest, at $90.81/BDt.

By comparison, when processing frozen, tree-length, smaller-diameter logs, the in-woods operation produced and delivered chips to the pulp mill for $83.60/BDt, which was the second lowest of all the net chip costs. The harvesting cost of stems at the in-woods chipping operation was reduced from $34.00 to $22.00/m³ because the loading and hauling phases were eliminated. The chip-hauling cost was estimated to be $15.00/BDt, and was added to the net chipping cost. When chipping unfrozen, tree-length, mixed-diameter logs, the cost was calculated to be $90.81/BDt. While these costs appear attractive relative to the woodroom costs, the chips were not acceptable by pulp mill standards because the bark content of the chips produced at the in-woods chipping operation was too high, and the chips contained too many fines and pins. Weldwood is aware of these issues and was working with the contractor to reduce the percentages of bark, fines, and pins to acceptable levels.

FERIC did not determine the chip recovery associated with chipping full-tree stems because they were not weighed before chipping. The harvesting cost should be lower for full-tree stems relative to tree-length because the delimbing and topping phases are eliminated and the incremental increase in chip volume from the tops would reduce per-unit costs.

The waste-disposal costs associated with the in-woods chipping operation are not included in the analysis. While hog fuel is in surplus at Weldwood, there is nevertheless an opportunity to recover hog fuel from the debris produced by the in-woods chipping operation if it is needed in the future.

Discussion

Woodroom operation

If the woodroom is to continue to debark and chip cut-to-length logs, it is advisable to change the log length to 4.2 m from 4.8 m. The logs could then be fed directly into the conditioning chamber without being bucked in the pocket slasher, resulting in fewer short chunks. The longer logs or pieces would not tumble end over end in the debarker as much as shorter pieces, and more would be properly aligned for the chipper after exiting the debarker. The pocket slasher was rarely set to cut the longest log possible (4.2 m) because the operators had to watch that the logs did not plug the infeed conveyor of drum debarker. Instead, the slasher was set to cut shorter lengths (3.6 m) which minimized the possibilities of plugging the conveyor. However, this makes it possible for the cut-to-length logs to be bucked twice, the result being two short chunks and one 3.6 m log. Because the cut-to-length logs comprised approximately 10% of the total volume processed through the drum debarker, and Weldwood's plan was to increase the cut-to-length program significantly over the next few years, Weldwood should consider re-designing the debarker infeed to be able to accept longer logs.

As mentioned earlier in this report, the minimum small-end diameter should be increased to 7.5 cm (3 inches) so the logs will not fall through the slots of the drum debarker. While the utilization in the woods associated with manufacturing logs to a small-end diameter of 6-cm was high, the corresponding low recoveries in the debarker was also a result. Again, a re-designed debarker infeed might increase chip recovery and quality if small-diameter logs are longer (4.2 m) because longer logs would not tumble end over end in the debarker and break up less.

Portable in-woods operation

While all of the bark contents associated with the in-woods chipping operation were unacceptable in this study, Weldwood has been happy with the net chip costs. The in-woods operation has been working in stands where stems are small and uneconomic for conventional roadside harvesting, log hauling, and processing into chips at the pulp mill woodroom. If the in-woods chipping operation can produce acceptable chips, it is an attractive alternative because costs are reduced, and little waste is hauled to the pulp mill. The in-woods chipping operation should be examined more closely to improve chip quality.

Conclusions

FERIC conducted a study to compare chip recovery, chip quality, and chipping productivity in the woodroom of Weldwood of Canada's pulp mill in Hinton, Alberta, with that of a portable in-woods processing and chipping operation, where both systems were handling similar types of logs. Trials of both frozen and unfrozen logs were undertaken.

On average, the woodroom's productivity in frozen conditions (range from 21 to 43 BDt/h) was lower than the productivity achieved in unfrozen conditions (range from 59 and 78 BDt/h). The in-woods chipping operation experienced similar productivity reductions between frozen and unfrozen conditions (range from 24 to 42 BDt/h when handling frozen logs, and 37 to 46 BDt/h when handling unfrozen logs).

The woodroom's chip recoveries were similar in both trials (range from 68 to 91% in frozen conditions, and from 79 to 84% in unfrozen conditions) because the conditioning chamber partially thawed the frozen logs. When debarking and chipping tree-length logs, the in-woods operation had better recoveries in frozen conditions (from 82 to 88% for frozen logs, and from 73 to 79% for unfrozen logs) but the bark contents were higher than those produced in unfrozen conditions. In the woodroom, when the minimum small-end diameter of the cut-to-length logs was increased from 6 to 8 cm, chip recovery increased from 68 to 89% and fewer tops fall through the slots of the drum debarker.

FERIC's analysis of the chips indicated that the woodroom at the pulp mill was producing 82% accept chips from frozen logs, and 74% from unfrozen logs. The trial of unfrozen logs produced 8.5% more over-size and over-thick chips than the trial of frozen logs.

The net cost to produce chips from mixed-diameter frozen and unfrozen logs in the woodroom was estimated at $131.70 and $117.11/BDt, respectively. The cost of producing and delivering chips made from frozen and unfrozen logs in the in-woods operation ($83.82 and $93.81/BDt, respectively) was better than those produced in the woodroom. However, the chips produced at the in-woods operation did not meet pulp mill standards due to excessive bark, fines, and pins contents.

If the in-woods operation continues to have problems producing acceptable chips, the operation should be evaluated in more detail to determine how the recovery and chip quality can be improved. There is a significant cost advantage when producing chips in the woods.

The processing of cut-to-length logs through the woodroom operation in frozen conditions had lower recoveries. The operation should be evaluated in more detail to improve recovery.

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Appendix I

Machine costs[a] ($/scheduled machine hour (SMH))

	Woodroom infrastructure	Woodroom drum debarker chipper	Wagner stacker	Caterpillar 980 front-end loader	Caterpillar 966 front-end loader	Peterson DDC5200
OWNERSHIP COSTS						
Total purchase price (P) $	20 000 000	5 000 000	1 200 000	450 000	400 000	691 000
Expected life (Y) y	20	7	5	5	5	5
Expected life (H) h	144 000	50 400	36 000	36 000	36 000	12 000
Scheduled hours/year (h) = (H/Y) h	7 200	7 200	7 200	7 200	7 200	2 400
Salvage value as % of P (s) %	25	25	25	25	25	25
Interest rate (Int) %	6.0	6.0	6.0	6.0	6.0	6.0
Insurance rate (Ins) %	3.0	3.0	3.0	3.0	3.0	3.0
Salvage value (S) = ((P • s)/100) $	5 000 000	1 250 000	300 000	112 500	100 000	172 750
Average investment (AVI) = ((P + S)/2) $	12 500 000	3 125 000	750 000	281 250	250 000	431 875
Loss in resale value ((P-S)/H) $/h	104.17	74.40	25.00	9.38	8.33	43.19
Interest ((Int • AVI)/h) $/h	104.17	26.04	6.25	2.34	2.08	10.80
Insurance ((Ins • AVI)/h) $/h	52.08	13.02	3.12	1.17	1.04	5.40
Total ownership costs (OW) $/h	260.42	113.47	34.37	12.89	11.45	59.38
OPERATING COSTS						
Fuel consumption (F) L/h	-	-	70	45	40	60
Fuel (fc) $/L	-	-	0.45	0.45	0.45	0.45
Power consumption (PC) kW/h	-	1 050	-	-	-	-
Power cost (pc) $/kW	-	0.065	-	-	-	-
Lube & oil as % of fuel (fp) %	-	15	15	15	15	15
Annual repair & maintenance (Rp) %	5	10	14	16	16	20
Chipper knives and/or flail chains $/y	-	90 000				140 000
Total wages (W) $/h	-	150.00	24.00	24.00	24.00	24.00
Wage benefit loading (WBL) %	-	35	35	35	35	35
Shift length (sl) h	-	10	10	10	10	10
Fuel (F • fc) $/h	-	-	31.50	20.25	18.00	27.00
Power cost (PC • pc) $/h	-	68.25	-	-	-	-
Lube & oil ((fp/100) • (F • fc)) $/h	-	10.24	4.73	3.04	2.70	4.05
Repair & maintenance (Rp • P/h) $/h	138.89	69.44	23.33	10.00	8.89	57.58
Chipper knives $/h	-	12.50				58.33
Wages & benefits (W • (1 + WBL/100)) $/h	-	202.50	32.40	32.40	32.40	32.40
Prorated overtime (((1.5 • W-W) • (sl-8) • (1 + WBL/100))/sl) $/h	-	20.25	3.24	3.24	3.24	3.24
Total operating costs (OP) $/SMH	138.89	383.18	95.20	68.93	65.23	182.60
TOTAL OWNERSHIP AND OPERATING COSTS (OW + OP) $/SMH	399.31	496.64	129.57	81.82	76.68	241.99

[a] These costs are estimated using FERIC's standard costing methodology for determining machine ownership and operating costs for new machines. The costs shown here do not include supervision, profit and overhead, and are not the actual costs for the contractor or the company studied.

Appendix II

Example of net cost calculation: frozen mixed-diameter logs

Harvesting cost, from stump to pulp mill log yard	$34.00/m^3
Log density	821 kg/m^3
Chip recovery	78%
Moisture content of chips (total basis)	40%
Woodroom chipping productivity	27 t/h
Woodroom cost	$1146/h

Chip equivalent of 1 m^3 of solid wood = 821 kg × 0 .78 (recovery) = 640 kg green chips

Dry chip equivalent = 640 kg green chips × 0.60 (solid wood) [1.00-0.40] = 384 kg of dry chips/m^3

1 BDt of chips = 1000 kg /384 kg/m^3 = 2.60 m^3

Cost of logs ($34/m^3 × 2.60 m^3) =	$88.40/BDt
Chipping cost (($1146/h)/(27 BDt/h)) =	$42.44/BDt
Net chip cost	$130.84/BDt