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Vol. 4 No. 5 March 2003

Contents

Chip recovery and productivity of frozen and unfrozen hardwood and softwood at a Saskatchewan pulp mill

Abstract

The Forest Engineering Research Institute of Canada (FERIC) evaluated wood chip recovery and productivity at Weyerhaeuser Company Limited's pulp mill in Prince Albert, Saskatchewan. Frozen and unfrozen hardwood and softwood logs were debarked and chipped over a range of butt diameters and lengths. This report summarizes the chip recovery, quality, and productivity, and provides recommendations on how the operation and chip recovery can be improved.

Keywords

Chips, Chipping, Woodroom, Debarking, Chip quality, Chip recovery, Chipping productivity, Drum debarker, Disc chipper, Saskatchewan.

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Introduction

Saskatchewan, like other western provinces, faces the challenge of providing fibre for the many competing forest companies and processing plants. It is important that any fibre delivered to the mills is useable and can be economically converted into a marketable product. In the past, pulp mill woodrooms in Saskatchewan had a ready supply of large, good quality logs from which to produce chips. However, the demand for fibre by competing sawmills has resulted in the pulp mills having to harvest smaller and poorer quality stands in addition to using the small tops and logs that were not suitable for lumber. While the woodroom at Weyerhaeuser Company Limited's Prince Albert pulp mill can utilize this material, the actual quality and cost of producing chips from this material were not well known. FERIC was asked by Weyerhaeuser's Saskatchewan Timberlands operation to evaluate the productivity of its Prince Albert pulp mill woodroom, analyze the chips being produced, quantify the amount of fibre being lost, and make recommendations to improve the operation and chip recovery of the woodroom.

Objectives

The objectives of the study were to:

- Determine and compare chip recovery, chip quality, and chipping productivity when frozen and unfrozen pulp logs of different species, butt diameters, lengths, and levels of dryness are processed by a drum debarker and disc chipper.
- Determine the net cost of chips associated with this operation.
- Investigate other debarking technologies, and/or changes to existing millyard and woodroom practices to improve fibre recovery and reduce costs.
- Review the harvesting practices and log specifications of wood delivered to the woodroom to determine if changes to them can improve fibre recovery.

Woodroom and logyard description

The majority of the volume delivered to the pulp mill is tree length (maximum 18 m). The provincial utilization standard dictates that all stems to an 8 cm top be utilized. Approximately 850 000 m^3 of hardwood logs and 150 000 m^3 of softwood logs are delivered annually (50% in winter and 50% in summer). Two Kranco portal cranes (Figure 1) unload the logging trucks in two grapple loads and place the logs on the bucking station infeed deck or into storage under the craneway. The shortwood pulp (2.4 and 5-m logs) is unloaded into a log storage area beside the woodroom by a rubber-tired loader with a large clam grapple. Since the shortwood is already processed, a bypass conveyor feeds these logs directly into the infeed conveyor of the drum debarker.

Figure 1. Portal crane in Weyerhaeuser's Prince Albert pulp mill.

The tree-length logs are placed on the slashing deck by the Kranco cranes and are slashed into lengths up to 5 m. The logs are separated by a drum-type log singulator and processed into 2.4-m logs by seven retractable cutoff saws. They are then conveyed to the infeed conveyor of a Kone Wood 5.4-m-diameter, 41-m-long drum debarker which rotates at approximately 40 rpm. During the winter, steam is blown into the debarking chamber to help clean and partially thaw the logs. In warmer weather conditions, water is added for dust control and log lubrication. The logs tumble in the drum for 15–20 minutes depending on the species and log condition. The bark and waste fall through slots in the drum onto a waste conveyor to the hog mill. A gate at the end of the debarker opens and closes to control the dwell time of the logs in the debarker. Debarked logs are pushed out of the drum by the force of the unbarked logs entering the drum.

The debarked logs move across widely spaced scalping rolls partially submerged in water. Any material that has a density greater than water, e.g., rocks, falls through the scalping rolls, while the wood moves across the water onto the infeed conveyor to the chipper. A metal detector is located on the chipper infeed conveyor as a final check before chipping with a Kone Wood Model HQ900 disc chipper. The chipper is 3.35 m in diameter and has 16 knives on the disc. The chipper is powered by four electric motors totalling 1200 kW. Chips are discharged onto a 1.2-m-wide conveyor that moves them away from the chipper and onto a narrower 1-m conveyor to the chip piles, where they are stored in separate hardwood and softwood piles. The hardwood chips are "conditioned" for a minimum of two months prior to pulping.

Study method

The study included hardwood and softwood logs processed in both unfrozen and frozen conditions. Truckloads of hardwood and softwood were directed to Wapawekka Lumber Ltd.'s sawmill where a butt-n-top loader unloaded and spread the logs for scaling and sorting. The hardwood logs were not sorted by species (predominantly aspen with a minor component of

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ISSN 1493-3381

balsam poplar), but were sorted into four butt-diameter classes. The softwood logs were sorted into either three or four butt-diameter classes, and were also separated by species (jack pine and spruce). Some hardwood and softwood logs remained unsorted and were left as tree-length or 5-m lengths. The logs in the unsorted classes were unloaded and stored outside the craneway. Log counts by butt diameter were done on the unsorted loads prior to processing.

FERIC measured the length and the butt and top diameters inside bark for every log, and used Smalian's formula to determine the average gross log volume in each class. The logs in each class were loaded onto log trucks, weighed on the weigh scales at the pulp mill, and then placed in separate piles near the infeed deck to the woodroom. As each diameter class was processed, the logs were counted and the total debarking and chipping time was recorded. The weight of the chips produced in each class was determined from the weightometer on the chipper's outfeed conveyor belt. In the unfrozen log trial, the weightometer was calibrated by diverting chips into chip vans and comparing its readings to the weights measured on the weigh scale. In the frozen log trial, the weightometer reading was compared to the net chip weight, which was calculated by subtracting the weight of the collected hog fuel of one log class from the log weight of that class.

During the chipping of each log class, a minimum of three 50-L chip samples were taken from the chip transfer point on the chipper conveyor. When the chipping of each log class was at the midpoint, a small 2-L chip bucket was placed into the middle of the chip flow as the chips fell onto the conveyor to the chip pad. The samples were sent to Vancouver for analysis.

In Vancouver, the chip samples were analyzed for proportions of accept chips, fines, pins, and bark content. Each 50-L bag was thoroughly mixed, and three 10-L samples were taken and individually placed on a BM&M chip analyzer. The bark in each of the chip classes was weighed separately. Small samples of chips of approximately 500 g were also weighed, dried in an oven, and re-weighed to calculate the moisture content of each log class.

Results and discussion

Table 1 summarizes the estimated volumes and weights of the butt-diameter classes that were processed through the woodroom. During the trial under unfrozen conditions, dry logs and logs with butt rot were processed. This may have contributed to some of the variation in log densities that were recorded. FERIC was unable to determine the reason for the high log density of the <14.9-cm aspen log class in both unfrozen and frozen trials, and the unfrozen 15–24.9-cm aspen log class. Also, FERIC was unable to determine the reason for the higher log density of the frozen jack pine than of the unfrozen jack pine.

During log sorting and measuring of unfrozen logs, butt rot was noted mostly on the large-diameter jack pine and in some of the larger diameter aspen and balsam poplar. When logs with large amounts of butt rot (>50%) are bucked and debarked, the logs usually break apart in the drum debarker and slabs are produced. While this may be desirable to reduce the rot, the chips that are produced usually are of poorer quality. FERIC suggested that Weyerhaeuser review the log quality specifications with respect to rot content. In the frozen log trial, only a few dry logs and logs with butt rott appeared to have been delivered.

FERIC's trial of processing small-diameter aspen (<14.9 cm) in unfrozen conditions was not very successful (Table 2). Firstly, FERIC was unable to get a large sample (only 39.8 t). Secondly, it was a mistake to run the small-diameter logs after the largest butt-diameter class was processed. The small-diameter logs could not push the larger ones through the drum, and because the sample was small, other logs had to be

Table 1. Volumes processed: unfrozen and frozen logs

Log class	Unfrozen logs					Frozen logs				
	Logs (no.)	Avg log volume (m^3)	Estimated volume (m^3)	Log weight (× 1000 kg)	Log density [b] (kg/m^3)	Logs (no.)	Avg log volume (m^3)	Estimated volume (m^3)	Log weight (× 1000 kg)	Log density [b] (kg/m^3)
Aspen										
<14.9 cm	445	0.09	41	39.8	961	1 606	0.09	149	134.6	900
15–24.9 cm	794	0.23	179	171.5	960	2 004	0.23	455	378.9	833
25–34.9 cm	558	0.47	260	215.7	829	605	0.50	301	239.2	795
>35 cm	153	0.92	140	99.8	710	202	0.96	193	131.9	682
Unsorted	212	0.43	92	74.8	813	548	0.29	159	133.8	840
Unsorted 5 m	635	0.27	174	139.5	802	-	-	-	-	-
Jack pine										
<14.9 cm	1 410	0.08	116	62.0	536	1 952	0.09	166	162.6	980
15–19.9 cm	1 501	0.18	267	162.1	607	987	0.16	156	154.8	993
20–24.9 cm						199	0.27	54	43.1	800
>25 cm [a]	307	0.42	130	83.8	646	182	0.50	90	60.5	670
Spruce										
<14.9 cm	2 196	0.07	147	106.7	725	3 473	0.07	233	131.3	564
15–19.9 cm	767	0.16	123	75.4	614	977	0.12	114	71.8	628
20–24.9 cm						333	0.26	86	56.3	653
Unsorted 5 m	355	0.16	56	38.8	692	-	-	-	-	-
Mixed softwood										
Unsorted	915	0.14	127	76.2	598	1 310	0.09	121	60.5	498
Wapawekka [c]	-	-	-	56.7	-	-	-	-	-	-

[a] The >25 cm log class included both jack pine and spruce logs.
[b] May show slight differences due to rounding.
[c] The logs within this class were not scaled because they were very small and too numerous.

placed into the drum to drive the material out. As a result, three log classes were in the drum at the same time and it was difficult to determine the start and end points of the log classes. The large-diameter logs likely smashed many of the small-diameter logs into pieces that fell through the slots of the drum. Therefore, the results for aspen in Table 2 are questionable. That is, the recovery and productivity for the <14.9-cm butt-diameter class are higher than they ought to be, and are lower than they ought to be for the largest butt-diameter class.

During the trial of frozen logs, FERIC was able to obtain a larger log sample for the aspen <14.9-cm butt-diameter class (Table 3). The recovery and productivity for the largest log class were lower than the other aspen log classes because there were many balsam poplar logs observed in the log class. Balsam poplar has thicker bark and is more difficult to debark than aspen.

In the unfrozen log trial, the jack pine and spruce log classes were sorted in 10-cm butt-diameter increments. In the frozen log trial, FERIC was able to sort logs into 5-cm butt-diameter classes because a lot of softwood pulp logs were being delivered to the pulp mill.

The average debarking and chipping productivity under frozen conditions was higher than under unfrozen conditions. Previous studies have shown that debarking in frozen conditions is less productive, has lower recovery, and results in higher bark content than debarking in unfrozen conditions. The reason for the higher productivity results in this study is that the frozen log trial was done on a weekend shift. No log hauling was taking place and the Kranco crane operator could focus his time on keeping the slashing deck full. This ensured that the slasher operator could keep the drum debarker full and the logs were moved through the

Table 2. Chip recovery and system productivity summary for unfrozen logs

Log class	Log weight (t)	Adjusted chip weight [a] (t)	Chipping time (h)	Chip recovery (%)	Moisture content (%)	System productivity (BDt/h)
Aspen						
<14.9 cm	39.8	35.7	0.30	89	46	64
15–24.9 cm	171.5	121.2	1.25	71	46	52
25–34.9 cm	215.7	155.2	1.90	72	46	44
>35 cm	99.8	77.2	1.20	77	45	35
Unsorted	74.8	45.7	0.80	61	50	29
Unsorted 5 m	139.5	118.9	0.83	85	48	74
Jack pine						
<14.9 cm	62.0	45.7	0.90	74	31	35
15–24.9 cm	162.1	106.2	1.20	66	30	62
>25 cm	83.8	49.0	0.75	58	35	42
Spruce						
<14.9 cm	106.7	70.5	1.30	66	34	36
15–24.9 cm	75.4	54.0	0.75	72	35	47
Unsorted 5 m	38.8	24.1	0.50	62	31	33
Mixed softwood						
Unsorted	76.2	54.0	1.20	71	36	29
Wapawekka	56.7	35.7	0.40	63	30	62

[a] Adjusted weight calculated from weightometer and chip van weight comparison.

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

Log class	Log weight (t)	Adjusted chip weight [a] (t)	Chipping time (h)	Chip recovery (%)	Moisture content (%)	System productivity (BDt/h)
Aspen						
<14.9 cm	134.6	85.5	0.66	64	50	65
15–24.9 cm	378.9	250.0	1.92	66	55	59
25–34.9 cm	239.2	168.0	0.97	70	50	87
>35 cm	131.9	79.0	0.67	60	51	57
Unsorted	133.8	96.8	0.42	72	46	124
Jack pine						
<14.9 cm	162.6	127.4	0.67	78	42	110
15–19.9 cm	154.8	117.4	1.16	76	39	62
20–24.9 cm	43.1	32.8	0.45	76	47	39
>25 cm [a]	60.5	43.7	0.53	72	44	46
Spruce						
<14.9 cm	131.3	113.8	0.75	87	42	88
15–19.9 cm	71.8	63.7	0.83	89	47	41
20–24.9 cm	56.3	41.9	0.58	74	48	38
Mixed softwood						
Unsorted [b]	60.5	62.8	0.28	71	43	128

[a] Adjusted weight calculated from weightometer and chip weight based on log weight less weight of hog fuel.

debarker in a timely manner. On the other hand, the unfrozen log trial had work stoppages while waiting for logs to be placed on the slashing deck, and although the waiting times were not included in the timing summaries, the debarking time was probably extended. During both trials, one of the Kranco cranes was not operating and it appeared that the second crane was used primarily as a backup. It may be prudent to operate both cranes to keep the slashing deck full of logs, which is the first priority, and still unload trucks in a timely manner.

With frozen logs, debarking the softwood was much easier than debarking the hardwood. Because jack pine and spruce logs have thinner bark than aspen and balsam poplar, steam conditioning thawed the softwood bark more and led to easier bark removal. The thicker bark of the aspen and balsam poplar logs prevented complete thawing of the bark–inner wood interface. The productivity when debarking frozen hardwood logs was reduced (Table 2) because of the longer dwell time required in the debarker. In other woodrooms observed by FERIC, the logs were "pre-conditioned" in a separate heating chamber prior to being placed in the drum debarker. The heating chambers applied more steam directly onto the logs and thawed them more effectively than by adding steam and heat into a revolving drum debarker.

Although FERIC did not sort the log classes by different top diameters, a similar drum debarker recovery study done by FERIC showed that the recovery was better when the minimum top diameter was increased (Araki 2002). In that study, changing the minimum top diameter from 6 cm (2.5 in.) to 8 cm (3.5 in.) had a positive effect by improving chip recovery from 68% to 89%. In this study, 31% of the softwood logs had tops less than or equal to 8 cm and an additional 43% had tops less than 10 cm. Twenty-three percent of the aspen logs had tops less than or equal to 8 cm and an additional 21% had tops less than 10 cm.

Recovery of aspen chips in unfrozen conditions may be improved by sorting the logs into different butt-diameter classes (Table 2). The unsorted aspen logs had between 10% and 28% less recovery than the sorted log classes. This indicates that some of the smaller diameter logs were crushed by the large logs and ended up as hog fuel. Sorting the logs into two log classes (<25 cm and >25 cm) at the stump should improve recovery. The experience gained from other pulp mill recovery studies suggests that sorting small-diameter logs during the harvesting phase but processing them during non-frozen conditions will improve recovery (Araki 2001). In warm weather conditions, the small-diameter logs should go directly onto the slashing deck and the large-diameter logs should go into storage. In frozen conditions, the small-diameter logs should go into storage and the large-diameter logs should go directly onto the slashing deck along with those stored from summer logging.

The moisture contents for the aspen, jack pine, and spruce appear to be lower in unfrozen conditions than frozen conditions (Tables 2 and 3). Even though the logs used in the trial were delivered from the forest, FERIC was unable to determine the length of time the trees had been decked at roadside before they were hauled to the pulp mill. In unfrozen conditions, some moisture loss from stems is expected, especially in late August when the trial was done. In frozen conditions, the stems would unlikely experience any drying.

The higher recovery and productivity experienced when processing 5-m-long aspen logs in unfrozen conditions indicate that the woodroom should consider slashing logs into lengths greater than the current 2.4 m. During the two trials, 2.4-m logs from private log purchases were being delivered. The farmers and private wood contractors should be encouraged to change to a 5-m minimum log length. Unfortunately, the 5-m log class in frozen conditions was not studied because no aspen logs of this length were delivered during the trial. When the 5-m spruce class was tested, they were still slashed into shorter log lengths so comparisons could not be made. FERIC suggests that the slashing saw closest to the butt end of the logs be deactivated to reduce the number of short logs being produced and improve accept chip recovery.

Tables 4 and 5 summarize the chip analysis results for each butt-diameter class when processed in unfrozen conditions and frozen conditions, respectively. Generally, the

Table 4. Chip analysis: summary of unfrozen logs

Butt-diameter class	Oversized >45 mm (%)	Overthick >8 mm (%)	Accepts >13 mm (%)	Accepts >7 mm (%)	Pins >2 mm (%)	Fines (%)	Bark (%)
Aspen							
<14.9 cm	6.6	15.6	61.5	11.0	1.5	2.4	1.4
15–24.9 cm	8.4	13.4	65.4	8.4	1.1	1.0	2.3
25–34.9 cm	6.3	11.9	69.8	8.4	0.9	1.3	1.2
>35 cm	7.3	13.0	66.2	10.2	1.1	1.9	0.3
Unsorted	8.8	15.1	60.0	12.0	2.0	1.0	1.0
Unsorted 5 m	5.3	15.5	64.8	11.0	1.3	1.7	0.4
Jack pine							
<14.9 cm	5.1	16.1	67.6	8.5	0.6	1.5	0.6
15–24.9 cm	10.0	16.7	64.5	6.4	0.6	0.9	1.0
>25 cm	8.1	12.3	71.3	6.3	0.6	0.7	0.6
Spruce							
<14.9 cm	5.6	13.7	60.6	14.5	0.8	3.7	1.1
15–24.9 cm	6.3	13.2	65.5	9.9	0.9	1.7	2.4
Unsorted 5 m	10.0	11.4	68.0	8.0	0.5	1.3	0.9
Mixed softwood							
Unsorted	8.3	13.8	67.2	8.5	0.6	1.2	0.3
Wapawekka	8.1	15.2	68.5	6.3	0.6	0.6	0.7

Table 5. Chip analysis: summary of frozen logs

Butt-diameter class	Oversized >45 mm (%)	Overthick >8 mm (%)	Accepts >13 mm (%)	Accepts >7 mm (%)	Pins >2 mm (%)	Fines (%)	Bark (%)
Aspen							
<14.9 cm	3.5	8.7	63.0	16.7	1.4	4.5	2.2
15–24.9 cm	2.9	7.6	64.1	17.3	1.4	4.9	1.8
25–34.9 cm	2.3	6.9	66.3	14.7	1.5	5.7	2.6
>35 cm	3.3	8.1	65.8	16.0	1.5	5.2	0.1
Unsorted	2.5	6.5	66.7	17.7	0.8	4.3	1.5
Jack pine							
<14.9 cm	1.9	6.5	69.7	18.5	0.4	2.6	0.4
15–19.9 cm	0.7	5.4	65.5	19.8	0.9	6.4	1.3
20–24.9 cm	1.2	7.4	65.1	20.3	0.7	4.1	1.2
>25 cm	4.5	9.3	65.5	16.3	0.5	3.1	0.8
Spruce							
<14.9 cm	1.7	6.7	70.8	17.8	0.4	2.2	0.4
15–19.9 cm	2.5	7.8	69.4	17.5	0.5	2.2	0.1
20–24.9 cm	1.0	6.7	64.3	22.6	0.5	4.2	0.7
Mixed softwood							
Unsorted	1.2	5.5	66.6	22.9	0.6	2.9	0.4

chips produced in frozen conditions contained more fines than those produced in unfrozen conditions. In unfrozen conditions, the 15–24.9 cm butt-diameter classes for all three species had the highest bark content (2.3, 1.0, and 2.4% for aspen, jack pine, and spruce, respectively). When the system productivity for these three classes were compared to the rest (Table 2), they were also the highest (52, 62, and 47 bone dry tonnes per hour [BDt/h] for aspen, jack pine, and spruce, respectively). These results indicate that the dwell time in the debarker should have been longer to remove more bark. Similarly, in frozen conditions the majority of the aspen and jack pine butt-diameter classes would have benefitted from a longer dwell time in the drum, and thereby reduce bark contents to more acceptable levels.

The unfrozen mixed butt-diameter aspen logs produced the lowest percentage of acceptable chips. This result, coupled with low recovery, further indicates that sorting and processing similar diameter classes might be beneficial. The short chunks and broken pieces from small-diameter logs frequently are not properly aligned for chipping. Since the size and design of the chipper is for larger and longer logs, chip quality is reduced.

The bark content for the majority of the butt-diameter classes did not meet the minimum standard that the company has set (Appendix I). Only three of the fourteen classes met the bark content standard in unfrozen conditions, and only five of thirteen classes met the minimum standard in frozen conditions. Trying to remove all the bark results in excessive fibre loss. In all the log classes, the percentages of pins were within acceptable limits in both unfrozen and frozen conditions. The percentages of fines were acceptable in seven of the log classes in unfrozen conditions but none were acceptable in frozen conditions.

None of the diameter classes in unfrozen conditions had acceptable percentages of overthick and oversized chips. The sum of the lowest oversized and overthick percentages was over 18%, and the highest was approximately 26% (Table 4). In frozen conditions, eight of the log classes had acceptable levels of oversized and overthick chips. The chipper needs to be constantly monitored and adjusted to minimize the production of unacceptable chips. All the chips are screened before they go into the digester. The oversized and overthick chips are sent through a chip slicer and re-enter the conveyor to the digester without further screening. The fines and pins are sent to the hog boiler.

As a result of the study, FERIC suggests that the woodroom review its chip quality standards because the majority of the minimum chip standard criteria were not met. If the chip standards are to remain unchanged, then the woodroom should focus on making adjustments to the drum debarker and chipper operations to improve the acceptable chip quality.

Costs

FERIC estimated that the operating cost for the woodroom was $1 876/h or $45 100/day. The cost includes all of the rolling stock and the operation of the craneway. Appendix II illustrates a detailed breakdown of the machine cost analysis. The shift length is based on a 44-h work week and an average wage of $22/h for the slasher, debarker/chipper operators, two crane operators, and three utility workers. Two Caterpillar D8 crawler-tractors were used to move chips on the chip piles. No supervision costs were included in the analysis.

Table 6 summarizes the estimated cost to chip the different butt-diameter classes in unfrozen and frozen conditions. As pulp mill personnel prefer costs to be reported in terms of bone dry tonnes of chips, this study reports costs in this way.

Again, the estimated chipping cost for the small-diameter aspen in unfrozen conditions is probably understated and should be greater than estimated for the 15–25 cm diameter class. The productivity and cost of the aspen <15 cm is probably similar to that of the small-diameter jack pine. Chipping

Table 6. Estimated debarking and chipping cost

Butt-diameter class	Unfrozen logs: Productivity (BDt/h)	Unfrozen logs: Debarking and chipping cost ($/BDt)	Frozen logs: Productivity (BDt/h)	Frozen logs: Debarking and chipping cost ($/BDt)
Aspen				
<14.9 cm	64	29.31	65	28.86
15–24.9 cm	52	36.08	59	31.80
25–34.9 cm	44	42.64	87	21.56
>35 cm	35	53.60	57	32.91
Unsorted	29	64.69	124	15.13
Unsorted 5 m	74	25.35	-	-
Jack pine				
<14.9 cm	35	53.60	110	17.05
15–19.9 cm	62	30.26	62	30.26
20–24.9cm			39	48.10
>25 cm	42	44.67	46	40.78
Spruce				
<14.9 cm	36	52.11	88	21.32
15–19.9 cm	47	39.91	41	45.76
20–24.9 cm			38	49.37
Unsorted 5 m	33	56.85	-	-
Mixed softwood				
Unsorted	29	64.69	128	14.66
Wapawekka	62	30.26	-	-

costs ranged from $25.35 to $64.69/BDt in unfrozen conditions and from $15.13 to $49.37/BDt in frozen conditions.

Tables 7 and 8 summarize the net cost of producing chips in the woodroom in unfrozen and frozen conditions, respectively. The cost of harvesting and transporting logs to the pulp mill was estimated to be $35/m^3.[1] This cost included road construction, silvicultural obligation, stumpage, and administration. Chip recovery, weight ratio, and moisture content were used to determine the number of cubic metres of logs to produce one bone dry tonne. In unfrozen conditions, the net chip costs ranged from $104.91 to $205.74/BDt . In frozen conditions, the net chip costs ranged from $96.15 to $207.21/BDt.

For the net cost analysis of Wapawekka pulp logs, the volume equivalent was assumed to be similar to the <14.9-cm butt-diameter jack pine in the Prince Albert study. The Wapawekka fibre cost was also increased to include the extra cost of processing ($4/m^3) and loading and hauling to the pulp mill ($5/m^3).[2]

Conclusions and implementation

During the summer of 2001 and winter of 2002, FERIC undertook trials to determine the productivity and chip recovery at Weyerhaeuser's Prince Albert pulp mill woodroom. The study included the processing of unfrozen and frozen aspen, jack pine, and spruce logs of different diameters and lengths through a drum debarker and disc chipper.

The recoveries that were achieved ranged from 58 to 89% in unfrozen conditions and from 60 to 89% in frozen conditions. The productivities ranged from 29 to 74 BDt/h

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1 Dave Harman, Harvest Systems, Weyerhaeuser Company Limited, personal communication, June 2001.

2 Norm Riopel, Business Manager, Wapawekka Lumber Ltd., personal communication, June 2001.

Table 7. Estimated net cost of chips: unfrozen logs

Butt-diameter class	Log density (kg/m³)	Chip recovery (%)	Moisture content (%)	System productivity (BDt/h)	Conversion (m³/BDt)	Adjusted log cost ($/BDt)	Debarking and chipping cost ($/BDt)	Net chip cost ($/BDt)
Aspen								
<14.9 cm	961	89	46	64	2.16	75.60	29.31	104.91
15–24.9 cm	960	71	46	52	2.72	95.20	36.08	131.28
25–34.9 cm	829	72	46	44	3.11	108.85	42.64	151.49
>35 cm	710	77	45	35	3.32	116.20	53.60	169.80
Unsorted	813	61	50	29	4.03	141.05	64.69	205.74
Unsorted 5 m	802	85	48	74	2.82	98.70	25.35	124.05
Jack pine								
<14.9 cm	536	74	31	35	3.65	127.75	53.60	181.35
15–24.9 cm	607	66	30	62	3.57	124.95	30.26	155.21
>25 cm	646	58	35	42	4.10	143.50	44.67	188.17
Spruce								
<14.9 cm	725	66	34	36	3.16	110.60	52.11	162.71
15–24.9 cm	614	72	35	47	3.48	121.80	39.91	161.71
Unsorted 5 m	692	62	31	33	3.38	118.30	56.85	175.15
Mixed softwood								
Unsorted	598	71	36	29	3.68	128.80	64.69	193.49
Wapawekka [a]	-	63	30	62	4.24	186.56	30.26	216.82

[a] Used the same log density as jack pine <14.9 cm butt diameter and delivered log cost of $44/m³.

Table 8. Estimated net cost of chips: frozen logs

Butt-diameter class	Log density (kg/m³)	Chip recovery (%)	Moisture content (%)	System productivity (BDt/h)	Conversion (m³/BDt)	Adjusted log cost ($/BDt)	Debarking and chipping cost ($/BDt)	Net chip cost ($/BDt)
Aspen								
<14.9 cm	900	64	50	65	3.47	121.45	28.86	150.31
15–24.9 cm	833	66	55	59	4.05	141.75	31.80	173.55
25–34.9 cm	795	70	50	87	3.60	126.00	21.56	147.56
>35 cm	682	60	51	57	4.98	174.30	32.91	207.21
Unsorted	840	72	46	124	3.06	107.10	15.13	122.23
Jack pine								
<14.9 cm	980	78	42	110	2.26	79.10	17.05	96.15
15–19.9 cm	993	76	39	62	2.17	75.95	30.26	106.21
20–24.9 cm	800	76	47	39	3.11	108.85	48.10	156.95
>25 cm	670	72	44	46	3.70	129.50	40.78	170.28
Spruce								
<14.9 cm	564	87	42	88	3.51	122.85	21.32	144.17
15–19.9 cm	628	89	47	41	3.38	118.30	45.76	164.06
20–24.9 cm	653	74	48	38	3.98	139.30	49.37	188.67
Mixed softwood								
Unsorted	498	71	43	128	4.95	173.25	14.66	187.91

in unfrozen conditions and from 38 to 128 BDt/h in frozen conditions. To improve recovery the company should review and set rot content guidelines for delivered logs. It should also consider sorting the logs into a minimum of two butt-diameter classes to prevent larger butt-diameter logs from crushing the smaller ones while in the debarker. The drum debarker should be full of logs at all times to optimize productivity. This can be best achieved by keeping the slashing deck full.

The woodroom should consider changing bucking standards for aspen to process 5-m logs through the woodroom instead of 2.4-m logs. The recovery and productivity were better, and more accept chips are produced when chipping longer logs.

The analysis of the chips produced in unfrozen conditions showed that only three of the log classes had acceptable bark content levels. In frozen conditions, only five of thirteen log classes had acceptable bark content levels. Similarly, the level of fines was acceptable in seven of fourteen log classes in unfrozen conditions, and no log classes had acceptable fines levels in frozen conditions.

The net cost to produce chips through the woodroom ranged from $104.91 to $205.74/BDt in unfrozen conditions, and from $96.15 to $207.21/BDt in frozen conditions depending on log class and species.

References

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Acknowledgements

The author would like to thank the woodroom personnel of Weyerhaeuser's Prince Albert pulp mill and the Saskatchewan Timberlands operation for assistance in carrying out this study. Special thanks go to Angela Arnold, Ken Landry, and Dave Harman.

Appendix I

Chip quality targets at Weyerhaeuser's Prince Albert mill

Season	Chip description	Hardwood (%)	Softwood (%)
Unfrozen	Overs [a]	11.0	13.0
	Pins	3.1	3.6
	Fines	1.2	1.3
	Bark	0.5	0.5
Frozen	Overs [a]	9.2	9.7
	Pins	2.9	4.2
	Fines	1.4	1.5
	Bark	0.75	0.5

[a] Overs includes both oversized and overthick chips.

Appendix II

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

	Woodroom building & infeed	Woodroom debarker & chipper	Kranco portal cranes	Caterpillar 980 loader	Ore truck	Caterpillar D8 crawler-tractor	Caterpillar 966 loader
OWNERSHIP COSTS							
Total purchase price (P) $	18 000 000	7 000 000	7 000 000	480 000	300 000	550 000	450 000
Expected life (Y) y	15	7	10	3	5	3	3
Expected life (H) h	108 000	50 400	72 000	21 600	36 000	21 600	21 600
Scheduled hours/year (h) = (H/Y) h	7 200	7 200	7 200	7 200	7 200	7 200	7 200
Salvage value as % of P (s) %	25	25	25	25	25	25	25
Interest rate (Int) %	6.0	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	3.0
Salvage value (S) = ((P • s)/100) $	4 500 000	1 750 000	1 750 000	120 000	75 000	137 500	112 500
Average investment (AVI) = ((P + S)/2) $	11 250 000	4 375 000	4 375 000	300 000	187 500	343 750	281 250
Loss in resale value ((P-S)/H) $/h	125.00	104.17	72.92	16.67	6.25	19.10	15.63
Interest ((Int • AVI)/h) $/h	93.75	36.46	36.46	2.50	1.56	2.86	2.34
Insurance ((Ins • AVI)/h) $/h	46.87	18.23	18.23	1.25	0.78	1.43	1.17
Total ownership costs (OW) $/h	265.62	158.86	127.61	20.42	8.59	23.39	19.14
OPERATING COSTS							
Power consumption (Pw) kW/h	-	1 500	500	-	-	-	-
Fuel consumption (F) L/h	-	-	-	45.0	20.0	45.0	45.0
Power cost (Pwc) $/kW	-	0.065	0.065	-	-	-	-
Fuel cost (fc) $/L	-	-	-	0.45	0.45	0.45	0.45
Lube & oil as % of fuel (fp) %	-	15	15	15	15	15	15
Annual repair & maintenance (Rp) %	5	20	20	20	20	20	20
Shift length (sl) h	-	8.8	8.8	8.8	8.8	8.8	8.8
Chipper knives (Ck) $/year	-	75 000	-	-	-	-	-
Wages (W) $/h	-	110.00	48.00	24.00	20.00	24.00	24.00
Wage benefit loading (WBL) %	-	35	35	35	35	35	35
Power cost (Pw • Pwc)	-	97.50	-	-	-	-	-
Fuel (F • fc) $/h	-	-	32.50	20.25	9.00	20.25	20.25
Lube & oil ((fp/100) • (F • fc)) $/h	-	14.63	4.88	3.04	1.35	3.04	3.04
Repair & maintenance (((Pp/100) • P)/h) $/h	125.00	194.44	194.44	13.33	8.33	15.28	12.50
Chipper knives (Ck/h) $/h	-	10.42	-	-	-	-	-
Wages & benefits (W • (1 + WBL/100)) $/h	-	148.50	64.80	32.40	27.00	32.40	32.40
Prorated overtime (((1.5 • W-W) • (sl-8) • (1 + WBL/100))/sl) $/h	-	6.75	2.95	1.47	1.23	1.47	1.47
Total operating costs (OP) $/SMH	125.00	472.24	299.57	70.49	46.91	72.44	69.66
TOTAL OWNERSHIP AND OPERATING COSTS (OW + OP) $/SMH	390.62	631.10	427.18	90.91	55.50	95.83	88.80
Machines in system (no.)	1	1	1	1	1	2	1
Total cost ($/SMH)	390.62	631.10	427.18	90.91	55.50	191.66	88.80

[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.