Comparison of rough mill yield for white birch lumber between a conventional and a short-log sawmill

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Abstract

This study explored the potential use of white birch lumber manufactured at sawmills processing short logs (no more than 8 ft. long). A database of random width and length white birch boards obtained from a conventional and a short-log sawmill was developed. To analyze the effects of lumber source, grade, cutting bill, and processing method on yield, 5,576 board feet (13.16 m^3) of Selects, No.1 Common, and No.2A Common lumber were used. ROMI-RIP and ROMI-CROSS simulation software were used to model two processing methods, rip-first and crosscut-first, respectively. Four cutting orders, Furniture, Panel, USDA Easy, and USDA Tough were processed in the simulation. Processing of lumber from the conventional sawmill resulted in significantly higher furniture part yields: 8.8 percent for Selects and 10.3 percent for No 2A Common as compared to the yields derived from lumber manufactured at the short-log sawmill. These differences were explained by: 1) a shorter average length (i.e., the longer conventional-length lumber offers a greater number of part combinations); and 2) the increased presence of wane and void. However, there was little difference in yield, when comparing the No.1 Common part yields obtained from lumber from the short-log and conventional sawmills, with appropriate cutting bills. Results also indicate that crosscut-first rough milling generates, on average, a 4.2 percent higher yield than rip-first rough milling. This analysis is of interest to a value-added industry faced with resource scarcity and increasing lumber costs.

The objective of this study was to evaluate the effect of sawing smaller white birch logs on yield in manufacturing furniture components. This evaluation was made using three grades (Selects, No. 1 Common, No. 2A Common) of white birch (*Betula papyrifera*, Marsh.) with two processing methods (rip-first, crosscut-first) and four industry-based cutting orders.

Inventory data indicate that white birch is the only underutilized commercial species, relative to growth, that is available for industry expansion in Québec, Canada. There are over 5,300,000 m^3 available per year on a sustainable basis (16,22), yet large quantities of this species are left standing because the stems are of small diameter and considered too small to be an economically viable source for conventional hardwood sawmills. In general, the log diameter is either too small or the length is too short for traditional sawmilling (4,23). In recent years, a new concept of hardwood sawmilling was developed to process these small birch trees. While the wood supply of conventional sawmills consists only of sawlogs, non-conventional sawmills get their supply in whole-tree

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Table 1. — White birch database characteristics.

Grade	Volume	No. of boards	Avg. width	Avg. length	Avg. max. crook	Clear wood
	(BF/m^3)		- - - - - - - - - (m)	- - - - - - - - -	(mm)	(%)
Conventional-length						
Selects	1157/2.73	183	0.165 (0.040)[a]	3.560 (0.258)	7.9 (5.2)	92.7 (4.3)
No. 1C	911/2.15	241	0.141 (0.032)	2.475 (0.415)	6.6 (3.8)	90.9 (7.6)
No. 2AC	873/2.06	235	0.140 (0.027)	2.456 (0.368)	7.2 (4.5)	89.3 (9.6)
Short-length						
Selects	962/2.27	312	0.134 (0.030)	2.120 (0.246)	5.5 (3.8)	91.1 (7.6)
No. 1C	970/2.29	292	0.152 (0.032)	2.030 (0.405)	5.2 (3.3)	91.3 (9.8)
No. 2AC	703/1.66	350	0.124 (0.027)	1.490 (0.347)	4.5 (2.6)	90.9 (8.2)

[a]Values in parentheses are standard deviations.

lengths. The trees are bucked at the mill yard and one-third of the volume is cross-cut and chipped; two-thirds of the volume enters the sawmill. Some of the logs being processed at the non-conventional sawmill are of sawlog grade according to Petro and Calvert (24), but many of them are pulp grade. This study analyzed one each of these two types of sawmills. While the conventional sawmill is the one traditionally found in Québec, the non-traditional sawmill shows potential for processing the underutilized white birch resource that is available in small-diameter trees, across the northernmost regions of Québec and Canada.

Because of the increased industrial demand for hardwoods in Canada over recent years, traditional hardwoods are becoming scarce (16,19). This shortage has increased prices to the point that previously non-profitable merchantable timber operations are now being considered (16), and sawyers are fitting their production to the needs of furniture and other secondary manufacturers. Since most of the component parts needed in furniture production are of small dimension or panel parts (3), a number of hardwood sawmills are tailoring their production to meet customer-specific needs instead of sticking to a standard. Increasing numbers among them produce "custom grade" lumber or components to match end user requirements (6,28). Many manufacturers of hardwood end-products are now considering the use of more of the smaller white birch but the question arises as to the economic sustainability of such an option.

In the past, questions about yield, processing methods, parts distribution, etc. were answered by computer modeling tools that utilized databases of digitized lumber (1,2,5,11,12,14,17,18,25,26,27, 28,29,31,32). These techniques and tools can help answer similar questions about white birch. To do this, a computer database was built on a sample consisting of 5,576 board feet (BF) (13.16 m^3) contained in 1,613 boards of digitized random width and random length white birch. The data acquisition was based on the methodology applied by Gazo et al. (15) and Harding (17).

Traditionally, lumber is graded on the poor face; however, some manufacturers use only the best face for their products (e.g., tabletops or flooring); therefore, information on what grade they purchase does not tell the whole story with regard to yield or cost per part. Using the database in combination with a rough mill simulation software such as ROMI-RIP (30) and ROMI-CROSS (29) provides a better fit between the lumber grade mix and the manufacturers' needs.

Methodology

Sample material

The boards selected for this study were required to show a range of qualities representing the traditional approach as well as recent developments in the sawing of white birch in Québec. Two sawmills were selected. The first sawmill, the one referred to as the conventional sawmill, processes conventional logs into National Hardwood Lumber Association (NHLA) grade lumber (23). Petro and Calvert (24) define conventional sawlogs as being of such a size and quality that they can provide a good yield in NHLA lumber. The conventional sawmill utilized logs ranging from 175 mm to 915 mm in small-end diameter (SED), with an average of 225 mm; log length ranged from 2.4 m to 4.8 m. The conventional sawmill consisted of a carriage bandsaw headrig, a horizontal resaw, an edger, and a two-end trimmer. The main product of the conventional sawmill was NHLA lumber but it also produced pallet stock as a by-product.

The second sawmill, the one referred to as the short-log sawmill, processed logs ranging in SED from 100 mm to 700 mm, with an average of 185 mm; log lengths ranged from 1.2 m to 2.4 m. This second sawmill consisted of a carriage bandsaw headrig, a cant gang resaw, a board edger, and a two-end trimmer. The use of a gang resaw tended to result in the production of more wany lumber. The product mix of the short-log sawmill is primarily pallet stock that is turned into pallet components, with some house-grade lumber produced for specific customers requiring short lumber for components, and a smaller amount of NHLA lumber. For the purpose of this study, only the NHLA lumber from the two sawmills was compared. This provides insight into the furniture component potential of the lumber originating from those two types of sawmills.

Table 1 tallies the number of boards analyzed per grade for each of the two sawmills included in the study. The conventional sawmill, located at Senneterre, Abitibi, provided 2,941 BF (6.94 m^3) of sawn white birch. The short-log sawmill, located at Ste-Monique, Lake St.-Jean, provided 2,635 BF (6.22 m^3) of short-length white birch lumber for a total of 5,576 BF (13.16 m^3) of random width and length NHLA boards. The lumber from both sawmills came from comparably mixed hardwood-softwood boreal forest stands distinctive of the Laurentian shield. The boards were dried together in the same commercial kiln using high temperature schedule No. 23 from Cech and Pfaff (7) and surfaced on both faces at Forintek Canada Corp., Québec Laboratory, to allow easier defect identification for digitizing. The digitizing took place at Purdue University, West Lafayette, Indiana.

Board grading

A large volume of random width and standard length hardwood factory lumber produced in Québec is used in the furniture, cabinetry, and flooring industries. This lumber is graded using the NHLA lumber grading rules (23). Under these rules, the lumber is graded according to the potential recovery of clear

Table 2. — List of digitized defects and correspondence in ROMI-RIP and ROMI-CROSS.

Defect type	Corresponding ROMI defect type	Status[a]
Bark pocket	All bark pockets	x
Burl	Burl	a
Compression failure	Callus wood	a
Crook	Void	x
Decay	Decay	x
Heartwood	Bud trace with bark/check	a
Hole	All grub holes/holes	x
Loose knot	All unsound knots	x
Mineral streak	Sapstain/mineral streak	a
Open knot	All unsound knots	x
Pin knot	Pin worm hole (1/16-in.)	a
Pith	Pith	x
Shake	Shake	x
Sound knot	All sound knots	p
Spike knot	All unsound knots	x
Split knot	All unsound knots	x
Split	Split	x
Stain	Incipient decay	p
Void	Void	x
Wane	Void	x
Twisted grain	Burl	a
Drying check	Surface check	a
Pressure roller stain	Sticker stain	a
Conveyor mark	Mechanical damage	a
Machine burn	Sticker stain	a
Machine gouge	Mechanical damage	a
Spike mark	Machine snipe/tearout	a

[a]Status: x = unacceptable on either side; a = acceptable on both sides; p = acceptable on poor side.

cuttings that can be obtained. In order to determine the lumber grade, areas of potential clear cuttings are considered. The size of cuttings, number of cuts allowed, percentage of clear cutting area on the entire board, and size of board define the NHLA standard grading rules for factory lumber. As the boards are intended for subsequent remanufacturing into flooring, furniture and cabinetry, individual cuttings must satisfy both size and quality criteria.

Under the NHLA rules, the lumber is graded into eight grades: FAS, F1F, Selects, No. 1 Common, No. 2A Common, No. 2B Common, No. 3A Common, and No. 3B Common. FAS, F1F, No. 2B Common, No. 3A Common, and No. 3B Common were not considered for this analysis because they are not used in the furniture-parts market segment under study. There are four basic grading requirements, one of which is percentage of clear cutting area available in grading cuttings. Selects grade boards require at least 83 percent clear area on the better face of the board; whereas No. 1 Common boards require 66.7 percent and No. 2A Common boards require 50 percent clear area in grading cuttings on the poor face of the board. A detailed account of the grading rules is given in the NHLA grading rule book (23).

Prior to digitizing, all the boards were manually graded by an experienced grader both before and after surfacing in order to insure that the grade quality was accurate. The short-log sawmill also produced house-grade lumber but these grades were not sampled for this study.

Database

A database of 5,576 BF (13.16 m^3) random width and length boards containing information on all grade defects was developed. For this study, 1,157 BF of Selects, 911 BF of No. 1 Common, 871 BF of No. 2A Common from the conventional sawmill, and 962 BF of Selects, 970 BF of No. 1 Common, and 703 BF of No. 2A Common from the short-log sawmill were used. **Table 1** lists the quantity, average width, length, and average maximum crook per board, for each of these samples.

Table 2 lists the defects that were digitized, the ROMI-RIP and ROMI-CROSS defect types used to represent these defects, and their status in the simulations. Certain types of defects were filtered out of the database because they were acceptable on both sides of the component or because they did not have to do with the species characteristics but rather with processing (i.e., man-made defects). All sound knots and stain were considered acceptable, on the back side of the cuttings only, and were defined accordingly in the rough mill simulation software.

Cutting bills

Four different cutting bills were used to best estimate the effect of lumber length and grade on yield: the USDA Easy (**Table 3**) and USDA Tough (**Table 4**) cutting bills were adapted from Steele et al. (27). The Furniture Cutting Bill (**Table 5**) and Panel Cutting Bill (described below) were created by the authors, and were based on local industry practice. Cutting bill characteristics important for interpreting the results included the total number of parts, the length and width of the parts, and the board footage of parts required by the cutting bill. The Easy Cutting Bill (**Table 3**) has an average length of 545 mm and width of 56.5 mm, and, in general, contains parts that are shorter and narrower than the Tough Cutting Bill (987 mm long and 76.5 mm wide) (**Table 4**).

The Furniture (**Table 5**) and Panel Cutting Bills were adapted from actual Canadian furniture manufacturers using white birch lumber in their operations. The Furniture Cutting Bill was obtained from a rough mill producing pre-cut components and panel parts for several furniture plants. With an average length of 803 mm and width of 36.2 mm, this cutting bill has more narrow parts than both the Easy and Tough Cutting Bills. The Furniture Cutting Bill is representative of the production of buffet and hutch types of dining room furniture.

The Panel Cutting Bill came from a plant that produces solid wood panels of specific lengths. To overcome the inability of ROMI-RIP Version 2 to produce solely panel parts under the metric parameters settings, it was decided to divide the 25- to 89-mm width range in 6.5-mm increments (approximately

Table 3. — USDA Easy Cutting Bill showing number of required parts (adapted from Steele et al. [27]).

	Width						
Length	44 mm	51 mm	57 mm	95 mm	114 mm	127 mm	133 mm
(mm)							
254	2						
311	1						4
330			4				
343				1			
368			2			1	
381	11	20					2
476	8	4	8				
521	2	1	9				
533					3		
572			8				
629	23	13	23				
705	10						
718			14	4			
800		2					

Table 4. — USDA Tough Cutting Bill showing number of required parts (adapted from Steele et al. [27]).

	Width			
Length	51 mm	70 mm	89 mm	108 mm
(mm)				
381	7	4	5	
457	2			
635	5	5		
737				8
838	6			
965			5	
1143		12		
1270	8		12	4
1524			2	
1829		3		6

Table 5. — Furniture Cutting Bill showing number of required parts.

	Width								
Length	25 mm	32 mm	38 mm	44 mm	51 mm	57 mm	64 mm	70 mm	76 mm
(mm)									
362					5			7	
387	36	8	3	2	1	1	1	5	
451	42	10	4	2	1	1	1		
514	57	13	5	3	2	1	1	10	
584	9	2	1	1				20	
768	29	7	3	2	1	1			
914	49	11	5	3	2	1	1	5	
1073	51	12	5	3	2	1	1	8	35
1175	8	4	1						
1245	24	6	2	1	1	1		4	
1295	13	3	1	1					
1346	19	4	2	1	1				

1/4-in.) and request an infinite number of each component. For the Panel Cutting Bill, an infinite demand of all combinations of the following widths and lengths was used: widths of 25, 32, 38, 44, 51, 57, 64, 70, 76, 83, 89, 95, 102, and 114 mm and lengths of 445[1], 546[1] 749[1], 940, 991, 1041, 1092, 1143, 1245, 1372, and 1549 mm. This approach was justified since there was no difference in demand by length. This Panel Cutting Bill was expected to generate the highest yields because it offered the greatest number of part-size options. Although it had some very long components, the absence of limitations on the number of parts required made it more likely to achieve higher yields. It represented a different production scheme than the other three cutting bills since it was designed to produce a continuous stream of panel components while the others were required to produce a fixed number of components in order to complete a finite number of furniture parts.

Simulation

The cutting bills were scaled to produce approximately 190 BF of components. Considering the board size distribution (the smallest boards were 2 BF), it was decided to create board data sets of 190 boards per simulation. The board files were constructed by randomly selecting 190 boards, after randomizing the order of appearance of the boards for each board file. The board data sets were created using the same procedure for the crosscut-first and rip-first simulations within each lumber grade cell. The same board data sets were used for each cutting bill.

The following parameters were used for the rip-first and crosscut-first simulations. These settings were designed to obtain the highest possible yield and are based on the best available rough mill technology.

ROMI-RIP simulation parameters. — Arbor type: all-blades movable arbor with 6 spacings; Kerf: 4 mm (0.157 in.); Prioritization strategy: complex dynamic exponent (CDE); Part prioritization: updated constantly for all cutting orders except for the Panel Cutting Bill, which was never updated; Salvage cuts: made to primary part dimensions, except in the Panel Cutting Bill, where three lengths were salvage-specific.

[1] Salvage specific length.

Table 6. — Defect frequency (number of defects per m²) and t-test results for difference between conventional and short lumber occurrence rates by grade.[a]

	Bark pocket	Sound knot	Unsound knot
	- - - - - - - - - - - - (no./m²) - - - - - - - - - - - -		
Selects			
Conventional	1.9 (5.6)	0.0 (0.2)	0.4 (1.1)
Short	1.8 (4.5)	0.7 (2.2)	0.5 (1.8)
p-value	0.42	0.00**	0.20
No. 1C			
Conventional	5.4 (10.1)	0.2 (0.9)	1.4 (2.8)
Short	3.8 (6.2)	1.0 (2.4)	2.0 (3.3)
p-value	0.01**	0.00**	0.01**
No. 2AC			
Conventional	7.9 (15.3)	0.2 (1.0)	2.2 (3.4)
Short	7.4 (15.8)	0.8 (2.8)	6.8 (6.8)
p-value	0.36	0.00**	0.00**

[a]Values in parentheses are standard deviations; ** = highly significant difference ($\zeta < 0.01$).

ROMI-CROSS simulation parameters. — Primary yield maximization method: crosscuts optimized for best length fitting to board features; Kerf: 4 mm (0.157-in.); Prioritization strategy: complex dynamic exponent (CDE); Part prioritization: updated constantly for all cutting orders except for Panel Cutting Bill, which was never updated; Salvage cuts: Made to primary part dimensions, except in Panel Cutting Bill, where three lengths were salvage-specific.

Statistical analysis

A three-factor analysis of variance (ANOVA) was performed, within each grade category, to identify the effect of the following factors: lumber source (conventional vs. short-log sawmills), processing method (crosscut-first vs. rip-first), and cutting bill. No interaction factor was considered. Since the study was exploratory in nature, a fixed effect modeling approach was adopted (Type I model ANOVA). This allows for the positive identification of differences between the two situations observed but it does not allow inference on broader populations of similar sawmills. The generation of data files of randomly mixed and picked boards from each category allowed us to assume independence of experimental errors, which in turn allowed us to perform the ANOVAs and paired comparisons. Where main factor effects have been established, paired t-test comparisons were made to allow for the interpretation of the respective effects.

The number of simulation replications (n) was established based on the estimate of the standard deviation for yield (S), determined by preliminary simulation, using the following equation:

$$n | \frac{(t_{\zeta/2,n41} \; 2\, t_{\eta,n41})^2 \, \Delta S^2}{\iota^2}$$

where:

α = significance level, set at 0.05

β = 1-power of the test, set at 0.10

δ = minimum detectable difference, set at 1 percent yield

Based on standard deviation estimates of initial yield, simulations were replicated 20 times in order to obtain significance in detecting 1 percent yield differences. However, due to the high variability in yield for the USDA Cutting Bills, additional simulations had to be performed in order to be able to achieve the desired test power (detection of 1% differences). For the USDA Tough Cutting Bill using Selects grade conventional- and short-length lumber, 65 and 80 simulations were required, respectively. For the No. 1 Common grade, 150 simulations were necessary for the USDA Easy Cutting Bill with short-length lumber and the USDA Tough Cutting Bill with both conventional- and short-length lumber.

Results

Defect distribution

Tables 6 and **7** list the defect frequency and defect area, respectively. Overall, bark pocket is the most frequently occurring defect. However, based on area, the wane/void defect is most important, followed in decreasing order of importance by stain, bark pocket, split, decay, and unsound knots. As expected, the results in **Table 7** establish that the better grades have more clear wood. However, this table does not show defect location, which is of primary importance when determining grade and potential component yield. The clear wood area (%) is defined as the ratio of board clear area (board area minus total defect area) to board surface area. **Table 6** shows that there is an increase in the frequency of occurrence of bark pockets, sound knots (except when comparing No. 1 Common and No. 2 Common), and unsound knots with a decrease in grade quality. **Table 7** indicates that these same defects and decay occupy increasing surface area as quality diminishes. It also appears that short lumber has more knots, in general, than conventional-length lumber. This is due to the characteristics of the logs from which this short lumber was sawn; the short-length lumber came from small-diameter trees, which have not had time to overgrow lost branches with clear wood. Our short-length lumber also had more wane and void than the conventional-length lumber, due to the use of a gang resaw and lighter edging in the short-log sawmill (intended to allow for a higher component recovery which would partly compensate for smaller lumber dimension).

Yield

The ANOVA analysis on yield showed significant effects for all three factors: lumber sorts (from conventional vs. short-log sawmills), processing method (crosscut-first vs. rip-first), and cutting bill. **Table 8** shows yield results from the simulations, within each grade, for the two lumber sorts, four cutting bills, and two processing methods. The USDA Easy Cutting Bill resulted in a higher yield than the USDA Tough Cutting Bill for all lumber grades. This result is explained by the greater selection of short and narrow components in this cutting bill (27). The higher yield obtained by the Panel Cutting Bill versus

Table 7. — Defect area (cm^2/m^2) and t-test results for difference between conventional and short lumber defect area by grade.[a]

	Clear wood	Bark pocket	Decay	Pith	Shake	Split	Stain	Wane/void	Sound knot	Unsound knot
	(%)	(cm^2/m^2)								
Selects										
Conv.	92.7 (4.3)	3.5 (17.2)	2.7 (19.8)	0.3 (4.6)	0.0 (0.0)	4.2 (19.6)	9.6 (118.4)	44.7 (87.2)	0.0 (0.0)	2.5 (9.3)
Short	91.10 (7.6)	9.1 (108.1)	6.7 (96.8)	1.8 (31.5)	0.0 (0.0)	2.1 (16.1)	28.5 (499.9)	213.9 (276.5)	0.4 (1.9)	1.7 (12.4)
p-value	0.42	0.19	0.24	0.21	0.50	0.11	0.26	0.00**	0.00**	0.23
No. 1C										
Conv.	90.9 (7.6)	20.9 (94.15)	7.1 (76.1)	0.0 (0.0)	0.3 (4.2)	16.6 (103.5)	69.9 (993.9)	159.4 (230.2)	0.3 (1.8)	9.6 (31.8)
Short	91.3 (9.8)	10.8 (48.2)	13.6 (111.8)	0.0 (0.0)	0.1 (1.3)	8.3 (69.6)	126.9 (1093.3)	191.6 (256.0)	0.9 (4.0)	16.6 (61.1)
p-value	0.89	0.06	0.21	0.50	0.27	0.15	0.26	0.06	0.01**	0.04*
No. 2AC										
Conv.	89.3 (9.6)	32.7 (100.4)	73.7 (466.5)	0.5 (5.4)	0.4 (4.5)	12.8 (64.1)	70.3 (704.8)	177.7 (263.4)	0.4 (3.4)	16.9 (35.2)
Short	90.9 (8.2)	17.7 (49.4)	43.8 (350.0)	0.8 (13.4)	0.9 (9.4)	10.4 (62.0)	11.6 (73.9)	258.9 (450.4)	1.5 (9.8)	47.5 (73.9)
p-value	0.58	0.02	0.20	0.35	0.20	0.33	0.10	0.00**	0.03*	0.00**

[a]Values in parentheses are standard deviations; * = significant difference ($\zeta < 0.05$); ** = highly significant difference ($\zeta < 0.01$).

the Furniture Cutting Bill is also explained by the greater selection of short components as shown in the cutting bill descriptions. However, this yield trend was not always consistent, rip-first processing of the Furniture Cutting Bill produced higher component yield than the Panel Cutting Bill in two instances.

Conventional- vs. short-log sawmill. — The primary objective of this study was to compare the yield obtained from the conventional sawmill to the yield from the short-log sawmill. In previous studies (31,32), significantly higher yield results were observed when components were produced from conventional-length lumber compared to short-length red oak lumber. The same observation holds true for white birch, although in the present study differences in lumber widths between samples also influenced yields. In this study, the general configuration of lumber coming from a conventional sawmill was compared to that from a non-conventional sawmill. The dimensions of the lumber from the conventional mill were, in general, both longer and wider than those from the non-conventional sawmill.

When the component yield derived from lumber produced at the short-log and conventional sawmills was compared, the lumber from the conventional sawmill always produced a significantly higher (ζ Ω0.01) yield than the lumber from the short-log sawmill for Selects and No. 2A Common grades. The yield differences ranged from 4.9 percent, when a rip-first rough mill processed Selects grade lumber using the Furniture Cutting Bill, to 16.2 percent when the same rough mill using the same grade lumber was processed using the USDA Tough Cutting Bill. On average, conventional-sawmill lumber had a 9.8 percent higher yield when ripped-first and 9.2 percent when crosscut-first. There was greater variability in rip-first processing yields as demonstrated by a standard deviation of 3.5 vs. 2.4 for crosscut-first.

Results for No. 1 Common grade lumber were surprising. **Figure 1** shows that in a rip-first rough mill no significant difference was observed in yield between conventional-length and short-length No. 1 Common lumber, when cutting the Furniture and USDA Tough Cutting Bills. Lumber from the short-log sawmill had significantly higher yield by 7.9 percent when processed with the USDA Easy Cutting Bill. Only when processing the Panel Cutting Bill did conventional-sawmill lumber have significantly (α Ω0.01) higher yield, but the difference was small, only 0.5 percent. For the crosscut-first rough mill

Table 8. — Yield (%) results for rip-first and crosscut-first rough mills according to grade and cutting bill as a function of lumber length.[a]

	Cutting bill											
	USDA Easy			USDA Tough			Panel			Furniture		
	Rip-first	Crosscut-first	*p*-value[b]	Rip-first	Crosscut-first	*p*-value[b]	Rip-first	Crosscut-first	*p*-value[b]	Rip-first	Crosscut-first	*p*-value[b]
Selects												
Conv.	64.4	67.7		61.4	64.0		71.8	78.3		70.3	71.7	
	(4.7)	(2.3)	0.008**	(4.0)	(2.3)	0.000**	(0.3)	(0.3)	0.000**	(0.7)	(1.2)	0.000**
Short	55.3	59.4		45.2	53.6		63.0	71.6		65.5	65.5	
	(4.7)	(5.3)	0.012*	(5.7)	(4.5)	0.000**	(0.5)	(0.5)	0.000**	(1.0)	(1.0)	1.000
p-value[c]	0.000**	0.000**		0.000**	0.000**		0.000**	0.000**		0.000**	0.000**	
No. 1C												
Conv.	48.8	60.0		34.4	39.7		62.6	70.2		64.1	64.3	
	(6.1)	(3.7)	0.000**	(8.7)	(8.1)	0.000**	(0.5)	(0.6)	0.000**	(1.1)	(1.3)	0.558
Short	56.8	59.5		33.9	33.4		62.1	66.6		63.9	61.7	
	(4.4)	(2.8)	0.000**	(11.5)	(8.3)	0.674	(0.5)	(0.8)	0.000**	(1.0)	(1.2)	0.000**
p-value[c]	0.590	0.000**		0.002**	0.000**		0.000**	0.553		0.700	0.000**	
No. 2AC												
Conv.	44.4	54.4		20.5	24.7		57.5	64.0		56.3	59.6	
	(3.7)	(3.6)	0.000**	(7.0)	(8.3)	0.937	(0.3)	(0.5)	0.000**	(2.2)	(1.2)	0.000**
Short	35.9	42.5					49.4	54.5		47.2	47.0	
	(4.2)	(3.2)	0.000**	--[d]	--[d]	n/a	(0.6)	(0.6)	0.000**	(0.8)	(0.7)	0.464
p-value[c]	0.000**	0.000**		n/a	n/a		0.000**	0.000**		0.000**	0.000**	

[a]Values in parentheses are standard deviations; * = significant (ζ Ω0.05); ** = highly significant (ζ Ω0.01).
[b]*p*-value for comparison between rip-first and crosscut-first.
[c]*p*-value for comparison between conventional- and short-length lumber.
[d]Cutting order not filled.

cutting No. 1 Common lumber, **Figure 2** illustrates that lumber from the conventional sawmill had a significantly ($\alpha \leq 0.01$) higher yield of 4.1 percent, with a standard deviation of 1.9, for all cutting bills except the USDA Easy Cutting Bill processing No. 1 Common lumber, where no significant difference was observed.

Two factors help explain the decrease in yield for lumber from the short-log sawmill compared to conventional-sawmill lumber. The first is the shorter average length and narrower width; both contribute to a reduction in the number of component combinations that can be sawn out of a single board, limiting the maximum use of available lumber. The second is wane or void. As shown by **Table 7**, when wane/void occupy a much greater surface there is a larger difference in yield between the two types of lumber. This increased amount of wane/void comes from a different edging policy practiced in the short-log sawmill. The short-log sawmill must extract lumber from smaller diameter timber and in so doing it is subject to a greater amount of wane. The short-log sawmill edging practices tend to allow more wane on boards in order to be able to recover more components from the resulting lumber. The increase in wane/void areas allows increased absolute volume of components produced but effectively reduces the relative yield because it generates a larger overall board surface. This policy allows for higher volume recovery, on a tree level, but it is bound to have a detrimental effect on throughput and productivity at the rough mill. It also negatively impacts the drying capacity.

The high standard deviation between simulations in the USDA Cutting Bills indicates that they are probably not suitable for white birch. In some cases, the cutting bills could not be filled completely. The average width and length of white birch lumber in our database are smaller than those of the red oak database (13). The red oak database was built in the southeastern U.S. where it is the resource of choice to the hardwood furniture, cabinetry, and casket industries. The survey upon which the USDA Cutting Bills were based (3) was also made in this region. This suggests that those cutting bills are probably better suited to the red oak

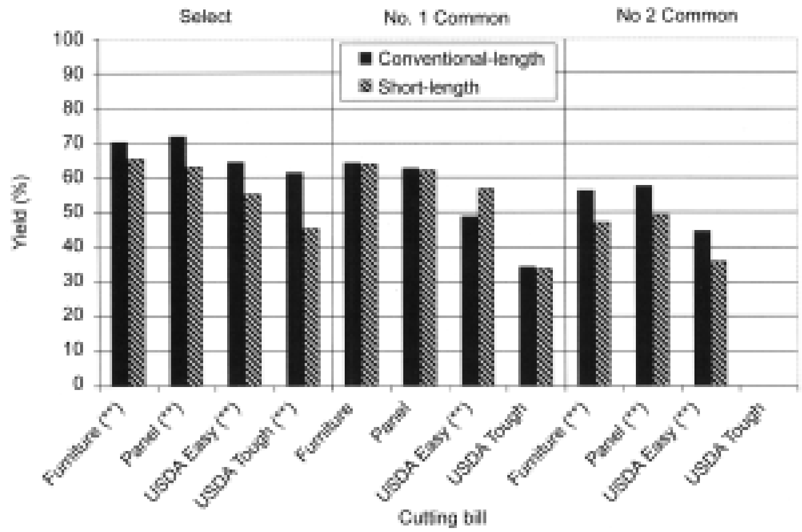

*Figure 1. — Rip-first yield: conventional-length vs. short-length lumber; ** = highly significant (ζ Ω0.01).*

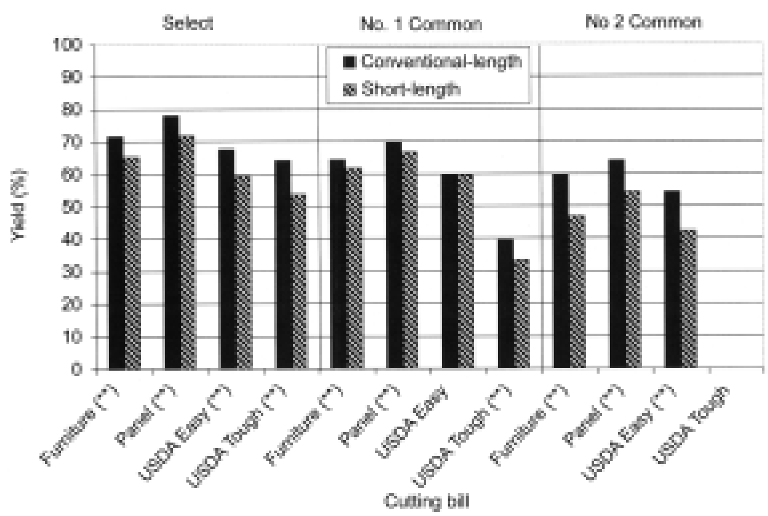

*Figure 2. — Crosscut-first yield: conventional-length vs. short-length lumber; ** = highly significant (ζ Ω0.01).*

resource. The Furniture and Panel Cutting Bills, derived from Eastern Canada industries include, on average, narrower parts that are more appropriate for shorter and narrower white birch boards. This might explain why we obtained less variability with the Furniture and Panel Cutting Bills than with the USDA Easy and Tough Cutting Bills. One factor differentiating the USDA Cutting Bills and the Furniture and Panel Cutting Bills is the presence of panel parts with a positive impact on yield.

Although the present study allows us to conclude that lower component part yields are to be expected from lumber produced at the short-log sawmill when compared to the conventional mill, several issues remain to be dealt with. In a context where conventional lumber is increasingly scarce and significant volumes of short-length lumber could be generated, the question arises as to what is the limit of economic utilization of short-length lumber. Short-length lumber should be expected to be cheaper than conventional lumber, which offsets, to a point, the yield decrease. Further studies should be devised to define the thresholds of economic feasibility of short-length white birch lumber. The sampling among the two hardwood sawmill systems should be expanded to allow for inference of the conclusions derived from comparing these two specific sawmills to the broader population of such sawmills.

Also, since short-length lumber has not been produced for long, it is likely that there is room for optimization both in sawing strategies, including edging and trimming policies, and in grading. Future studies should look at the yield issue not only in the rough mill context but rather in the framework of integrated processes, taking into account primary and secondary log breakdown into components. Recent research suggests that there would be an overall optimum to be reached when looking at both operations in an integrated process, that would be higher than when looking at them in isolation (9,20,21).

This study used a database of NHLA-graded white birch lumber from conventional and short-log sawmills. Other in-house grading systems are being defined and refined, based on industrial-user specifications and agreements between sawmills and industrial users. Increased yields might be expected from such specific grades defined to meet the narrower needs of specific users. The scope of further studies should be expanded to include the whole product mix, including, not only the NHLA grade lumber, but also house grades and pallet stock. With this approach, it appears possible (based on the experiences of a small number of companies) to find economical ways of using white birch of lesser dimensions in the various hardwood-using industries.

Rip-first vs. crosscut-first. — **Table 8** compares yield between rip-first and crosscut-first processing of lumber from the conventional and the short-log sawmills. It should be noted that comparisons involving the USDA Tough Cutting Bill with No. 2A Common short-length lumber were excluded because the cutting bill requirements could not be met after reasonably reducing the size of the cutting bill.

The results show that for white birch, crosscut-first rough milling generally produces a significantly higher ($\alpha \leq 0.01$) yield than does rip-first. An exception to this is that no significant difference in yield was found when processing lumber from the conventional sawmill using the Furniture Cutting Bill with No. 1 Common lumber, and when processing short-length lumber using the USDA Tough (No. 1 Common) and Furniture Cutting Bills (Selects, No. 2A Common).

According to the cutting bills used in this study, crosscut-first generates on average 4.7 percent higher yield, with the highest difference (11.2%) occurring when using the USDA Easy Cutting Bill with No. 1 Common lumber. These differences in yield can be explained by the characteristics of white birch. As shown in **Table 1**, the lumber is narrow and contains crook. According to Wiedenbeck (33) and Gatchell (10), these two properties favor crosscut-first rough milling.

Conclusion

The lumber from the short-log sawmill was in general smaller in length and width than that from the conventional sawmill. This, combined with the fact that it contains more of the void and wane defects, negatively affects lumber yield. Thus, lumber from the conventional sawmill generally produced a higher yield than the lumber from the short-log sawmill. Selects grade conventional-length lumber resulted in an 8.8 percent higher yield (average difference for four cutting bills), and No. 2A Common grade conventional-length lumber had an average 9.9 percent higher yield than the lumber from the short-log sawmill. No. 1 Common lumber had comparable yield results for the two groups, however, in one case the lumber from the short-log sawmill produced a higher yield. This indicates that, with minor exceptions (where results were not significantly different), No. 1 Common lumber from the small-log sawmill can produce a similar or better yield than that from the conventional sawmill using all four cutting bills for both rip-first and crosscut-first processing. This is a result of some importance. It indicates that in some cases, when used with the appropriate cutting bill, the lumber from small-log sawmills can yield satisfactory results

It was also noted that crosscut-first achieved, on average, a 4.2 percent better yield than rip-first rough milling. This difference is attributed to the characteristics of northeastern white birch, which is in general small and produces narrow boards. These characteristics reduce the rip-first process flexibility in producing long clear components and therefore tends to have a negative impact on rip-first yield compared to crosscut-first.

The present study was exploratory in nature. Further studies are required to be able to validate that these findings can be broadly applied to conventional and non-conventional white birch sawmill systems. Further studies are also needed to define the economic limits when processing smaller and smaller white birch trees into components. Research should be devised to look at integrated optimization of primary and secondary breakdown of the white birch resource of lesser dimension and quality for the production of components. Research should also look at the benefits of creating in-house grades, and of using multiple grading systems simultaneously, to better serve specific end-uses.

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