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Short communication. Lumber yield and production time in sawmilling of pallets in Durango, Mexico

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Abstract

Aim of study: Evaluate times and yields in the transformation of pine logs to pieces of pallets.

Area of study: Four sawmills of the forest region of El Salto, Durango, Mexico.

Material and methods: The sample size was 388 logs with 32.91 m^3 as volume without bark grouped in four diameter classes and five taper classes. The transformation time was estimated using the "Snap-back timing" method, and yield was defined as the ratio between pallets and log volume.

Main results: The time required to obtain 1,000 bft of pallets is approximately 5.8 hours and the mean yield is 56%. This means that for each cubic meter of logs without bark, it is possible to obtain 240 board feet of pallets (bft). In addition, 4.16 m^3 of logs without bark are required to obtain 1000 board feet of pallets. The estimated mean productivity was 0.54 m^3/h.

Research highlights: As the log diameter increases, yield also increases. The taper of the logs was not significant in the transformation yield.

Key words: indicators of productivity; pallets; diameter logs; taper; sawmilling process; lumber yield; raw material; Mexico.

Introduction

The rational use of forest resources plays an important role in the economic and social development of Mexico. To reduce loss of raw material, improve the quality of the products and optimize the use of labor and equipment are pending tasks in the continuous development of the productive sector (Aguilera *et al.*, 2005). Wood sawing, consisting of the transformation of the piece (log) (approximately cylindrical) to a product with specific dimensions in width, length and thickness, for the purpose of being used in a later process such as the production of furniture, homes, pallets, among others (Meza and Simón, 2007). To know the yield, productivity and profitability of the sawing process are indicators that help to have better control and planning of the activities carried out in the sawmill. The studies of times and yields are a powerful tool making it possible to know the situation of the use of the human resources and materials in the sawmills. The yield or transformation time is expressed as the volume of lumber obtained from the logs. The factors that have a positive or negative effect on the wood transformation process are: characteristics of the machinery and equipment, the performance of the operators, as well as the form, dimensions and properties of the raw material. Some elements of the equipment such as tooth angle, depth of gullet, hook angle, pitch or tooth spacing, saw tension and the feed speed, can be controlled or manipulated to obtain better performance. However, there are factors inherent to the raw material that cannot be modified, especially those related to the form of the log (taper, dimensions and class) (Rocha, 2002; Vital, 2008). Therefore, it is convenient to evaluate methods for increasing efficiency in the sawing process to obtain better quality of finished products and of sale prices (García *et al.*, 2001). The pallets for packing are an option for using tips and branches derived from forest management; they are used as support and cargo surface in the transport and storage of a great variety of products.

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There is little information in Mexico with respect to the level of utilization of the raw material destined for pallet production. The objective of the present study was to evaluate the times and yields in our sawmills dedicated to the elaboration of components of this product in Durango, Mexico, generating information that makes it possible to know the degree of transformation of the logs into lumber and the time necessary for this purpose.

Materials and methods

The study was carried out in the forest region of El Salto, Durango, Mexico, which is located in the Sierra Madre Occidental (SMO) mountain system. Four privately operated sawmills were selected from the study area dedicated to the elaboration of pallets and their components. The sawmills subject to this analysis have similar equipment, team of human labor and machinery.

Methods

In order to carry out the present study, 388 pine logs of 152.4 cm (5 feet) of long were used distributed into four diametric classes (9 cm each one), and five of taper (2 cm each one) (Table 1), with the purpose of analyzing the influence of diameter and taper of the logs on lumber yield and productivity. In evaluation studies of sawmills, 100 logs have been randomly used (SFF, 1978; cited by Zavala and Hernández, 2000). However, to estimate the number of logs necessary to achieve a sampling error of 5% and a reliability of 95%, the expression of Dobie (1975); cited by Zavala (1996) was used.

Table 1. Distribution of the logs per diametric and taper category in four sawmills in Durango, Mexico

Diametric category (cm)	Logs by category (n)	Taper category (cm/m^{-1})	Logs by category (n)
11-20	103	0-2	256
21-30	95	2.1-4	85
31-40	99	4.1-6	23
>41	91	6.1-8	12
		8.1-10	12
Total	388		388

The selected logs were marked and identified, immediately proceeding to measure them to determine their volume with and without bark, employing the formula of Smallian (Husch *et al.,* 2003).

The "snap-back timing" method was used, described by Villagómez and García (1986), which pertains to the random sampling methods. The time of the process was carried out by quantifying each activity from start to finish, employing a precision of 1/100 seconds, later converting it to hours. The sawing process was classified in productive and unproductive time.

Based on the information generated from the sawing of the logs, the time required for sawing 1000 board feet (bft) was determined according to Nájera *et al.* (2011).

The pieces resulting from the sawing were measured and related to the log of origin with the purpose of quantifying the lumber volume according to what was suggested by Romahn *et al.* (1987).

With the volume calculated from the sawed pieces and the volume of the raw material used, lumber yield was determined using the relationship of Quirós *et al.* (2005).

The taper of the log is the difference between the diameter of the base and the diameter of the tip with the distance that separates them (Scanavaca and García, 2003; Vignote and Martínez, 2005).

Sawing productivity was estimated by relating the volume of lumber between the times required to saw this volume, using the formula of García *et al.* (2001).

To identify significant differences in the indicators of productivity: total time to saw 1000 bft, yield with bark, without bark and productivity (m^3/h), considering as factors: diametric category and of log taper, an analysis of variance was made (95%) as well as a comparison of means, using tests of multiple ranks of Duncan at a significance level of 0.05. The analysis of data was carried out using the statistical package SAS/STAT® (SAS Institute Inc., 2004).

Results and discussion

The average yield in the production of pallet pieces was 56% without bark (Table 2); this indicates that for each processed m^{3}r, 240 bft are obtained, and to obtain 1000 bft of lumber, 4.16 m^{3}r are necessary, requiring a time of 5.78 hours on the average, of which 5.30 hours correspond to productive time. The results showed significant differences (p < 0.0001) in the productivity indicators among diametric categories showed values of 0.38 to 0.69 m^3/h of labor, averaging

Table 2. Times and yield per diametric category, in four sawmills in Durango, Mexico

Variable	Diameter category (cm)			
	11-20	21-30	31-40	>41
Characteristics of sawlogs				
DM with bark (m)	0.18	0.26	0.36	0.47
DM without bark (m)	0.17	0.25	0.35	0.45
Dm with bark (m)	0.16	0.24	0.34	0.43
Dm without bark (m)	0.16	0.23	0.32	0.43
l (m)	1.14	1.16	1.20	1.11
Vcc (m^3r)	2.87	5.64	11.78	16.32
Vsc (m^3r)	2.57	5.10	10.56	14.68
Products obtained by milling				
Pieces of lumber (n)	486	1051	2468	3067
Pieces by log (n)	5	11	25	34
Vol (m^3)	1.34	2.94	6.27	8.68
Sawing time of 1,000 board feet				
Tde (min)	20.83	10.96	8.01	7.04
Tar (min)	89.98	38.24	27.26	25.59
Tas (min)	113.90	94.36	65.62	65.30
Tra (min)	145.58	124.63	111.33	86.42
Ttr (min)	88.90	55.47	52.82	41.53
Tin (min)	29.17	12.94	12.08	14.10
Tnn (min)	29.17	14.04	8.26	7.52
Indicators of productivity in the sawmill operation*				
T (min)	505.84 a	350.63 b	285.40 bc	247.50 c
Rcc (%)	45.91 b	52.34 a	53.66 a	53.26 a
Rsc (%)	51.02 b	57.58 a	59.60 a	59.08 a
P (m^3/h)	0.38 c	0.53 b	0.57 b	0.69 a

* Means with the same letter among diametric categories are not significantly different. Duncan $\alpha = 0.05$. Where: n = number of logs; DM = greatest diameter; Dm = smallest diameter; l = length; Vcc = volume with bark; Vsc = volume without bark; Vol = Volume; Tde = displacement time; Tar = placement time; Tas = sawing time; Tra = re-sawing time; Ttr = sectioning time; Tin = necessary unproductive time; Tnn = unnecessary unproductive time, T = Total time for sawing 1,000 bft (min); Rcc = Yield with bark (%); Rsc = Yield without bark (%); P = Productivity (m^3/h).

0.54 m^3 h, equivalent to sawing 229 bft/h of labor, observing a yield increment (productivity), as the diameter of the logs increases, while 8.3 hours are required to obtain 1,000 bft of logs with diameters of 11-20 cm, the time is reduced by as much as 4.12 hours when logs > 41 cm of diameter are sawed; that is, 1000 bft produced in the first case and 2014.5 bft for the second (Table 2). Log taper had no direct effect on the productivity indicators, given that no significant differences were observed ($p < 0.0001$) (Table 3), as the average length of the selected logs (1.15 m) did not permit an accentuation of the taper, and 88% of the logs tested did not present a marked taper. Nájera *et al.* (2011) mention that as the log taper increases, yield and productivity decrease, and the sawing time for 1000 bft remains constant, coinciding with our study, given that the time was established at 5.8 hours for any taper category.

Studying the yields of sawed wood for the elaboration of pallets of *Pinus pinaster* from logs of 18.3 to 34.6 cm diameter and 2.3 m length in the Portugese Villa of Mação, Knapic *et al.* (2003) found a yield without bark of 47.2%. The above was 9.5% less than what was estimated in the present study, the dimensional factor of the logs being the difference between the two. According to Steele (1984) and Fahey

Table 3. Times and yields per log taper, in four sawmills in Durango, Mexico

Variable	Taper category (cm/m^{-1})				
	0-2	**2.1-4**	**4.1-6**	**6.1-8**	**8.1-10**
Characteristics of sawlogs					
DM with bark (m)	0.52	0.33	0.41	0.44	0.46
DM without bark (m)	0.50	0.31	0.39	0.42	0.44
Dm with bark (m)	0.50	0.30	0.33	0.38	0.37
Dm without bark (m)	0.49	0.28	0.33	0.35	0.37
l (m)	1.81	1.13	1.08	1.13	1.07
Vcc (m^{3}r)	21.52	8.26	3.12	1.93	1.79
Vsc (m^{3}r)	19.54	7.37	2.69	1.68	1.63
Products obtained by milling					
Pieces of lumber (n)	4539	1477	479	292	285
Pieces by log (n)	18	17	21	24	24
Vol (m^3)	11.68	4.25	1.46	0.91	0.94
Sawing time of 1,000 board feet					
Tde (min)	12.29	12.97	8.00	7.51	8.15
Tar (min)	45.66	50.21	42.57	42.51	40.11
Tas (min)	82.61	93.96	83.14	88.57	85.45
Tra (min)	117.58	131.16	103.41	106.73	67.78
Ttr (min)	59.56	60.29	57.21	59.31	86.14
Tin (min)	17.56	15.45	8.81	25.43	33.05
Tnn (min)	14.15	6.67	11.35	2.22	13.29
Indicators of productivity in the sawmill operation*					
T (min)	394.41 a	370.71 a	314.48 a	332.28 a	333.97 a
Rcc (%)	52.49 a	49.36 a	46.16 a	48.38 a	48.79 a
Rsc (%)	57.77 a	55.23 a	52.84 a	55.25 a	53.49 a
P (m^3/h)	0.54 a	0.54 a	0.52 a	0.57 a	0.55 a

* Means with the same letter among taper categories are not significantly different Duncan $\alpha = 0.05$. Where: n = number of logs; DM = greatest diameter; Dm = smallest diameter; l = length; Vcc = volume with bark; Vsc = volume without bark; Vol = volume; Tde = displacement time; Tar = placement time, Tas = sawing time; Tra = re-sawing time, Ttr = sectioning time; Tin = necessary unproductive time; Tnn = unnecessary unproductive time; T = total time for sawing 1000 bft (min); Rcc = Yield with bark (%); Rsc = Yield without bark (%); P = Productivity (m^3/h).

and Sachet (1993), yield decreases with the increase in length of the log; this makes it possible for the log to curve and lose straightness, causing problems for finding the adequate geometry of the sawing.

Prades *et al.* (2001), in logs of 15 cm diameter of *Pinus pinaster* (province of Granada, Spain), report a yield of 31.25%, which suggests that to obtain 1m^3 of lumber, it is necessary to process 3.2 m^{3}r, also indicating that to obtain this amount (1 m^3) in *Pinus sylvestris*, 2.80 m^{3}r are required, and 3.00 m^{3}r in *Pinus nigra.* In this study, 1.76 m^3 roll is required, which leads to the assumption of a direct effect of log diameter, these being thicker (14 cm) than those of the reference study.

Similarly, Fahey and Sachet (1993) indicate that log diameter is the factor of highest incidence in the yield of the sawing process, given that the processing of logs of small dimensions implies low levels of use and lower profit in the sawmills. It is common that logs of small diameters provide lower yields because these pieces (from the high parts of the tree) present knots, generating twisting and curvature that affect the geometry of the pieces and consequently the yield (Rocha, 2000).

Murara *et al.* (2005) evaluated the yield of wood in plantations of *Pinus tadea*, using two sawing systems, conventional and optimized, the logs were divided into five diametric classes: 18-24, 24.1-28, 28.1-34, 34.1-

38 and 38.1-44 cm, finding that in both systems, the yield increases in proportion to the diameter of the logs, which agrees with what was found in the present study. However, the yields per category are lower than ours, except those estimated in the optimized sawmill (categories 38.1-44 cm).

Conclusions

The average yield in the sawmills dedicated to the elaboration of pine wood pallets, of the region of El Salto, Durango, Mexico is of 56%, without bark, obtaining 240 bft per each cubic meter of wood roll; that is, to obtain 1 m^3 of lumber, 1.76 m^3 roll is required. The time required to saw 1,000 bft was estimated at 5.8 hours, whose productivity is of 0.54 m^3h, equivalent to sawing 229 bft per hour. The yield and productivity increase as the log diameter increases, reducing the time necessary to saw 1,000 board feet. The taper of the logs of small dimensions does not have direct influence on yield, thus it is considered irrelevant in the productivity indicators.

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