



AGRARIAN SCIENCES

Production costs in the log processing of *Eucalyptus* spp. wood

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Abstract: The objective of this study was to evaluate the production costs of processing logs from *Eucalyptus grandis* Hill ex Maiden and *Eucalyptus saligna* Sm, using two sawing patterns in a medium-sized sawmill. Alternating tangential sawing pattern was used for logs with a mean diameter of 33.0 cm and the radial sawing pattern for logs with a mean diameter of 47.0 cm. Based on the data obtained in the different sawing patterns, the fixed, variable and total costs were calculated and, subsequently, the average value for each of these costs. For the alternating tangential sawing pattern, the fixed cost represented 19.32% and the variable cost 80.68%. For the radial sawing pattern, the fixed cost represented 18.92% and the variable cost 81.08%. The radial sawing pattern presented lower average production costs, with a difference of 22.89 R\$/m³, however there is no significant difference between the sawing patterns.

Key words: Average production costs, diametric class, lumber, sawing pattern.

INTRODUCTION

In the Brazilian wood market, the use of *Eucalyptus* wood is in constant expansion, demonstrated by the eucalyptus area growth of 2.4% a.a. in the last five years, according to data from the most recent survey of the Brazilian industry of trees - IBÁ (2017). This is due to the multiple uses of *eucalyptus*, such as paper, firewood, lumber, charcoal, energy generated with sawdust, wood chips and forest tailings. Consequently, the research support seeking new technologies and which aim to improve the final product derived from *eucalyptus* persists. This technology support allows to minimize the negative impacts of the use of this resource, accelerate and increase the productive systems (Bracelpe 2014).

A large part of the sawmills in Brazil use machinery and equipment considered obsolete,

with an increasing need for maintenance, which results in high production costs, reduction in the quality of products and consequent loss of competitiveness in the sector. For Vital (2008), the equipment conservation status makes some sawmills more productive, while others are inefficient and anti-economic and generate a large number of by-products.

The complexity that covers the sawmills industry, since the disparity of logs supply to the mix of products, makes the conversion of logs to lumber consist of a determinant factor for the venture success associated with the log cost factor and the lumber price. That is, the log appropriate use reflects on economic issues, which is the determining factor for the company to keep active in the market.

Manhiça et al. (2013) mentions that some mills use new technical procedures in the sawing of wood, which aims to reduce the production

costs and add value to the final product, thereby keeping competitive in the sawn sector. For this reason, knowledge about the information related to the undertakings production costs are required for the managerial strategies definition.

Thus, sawmills managers must search for new methods, technologies and tools that will assist in the decision-making moment, to provide acceptable solutions regarding the diametric class ideal for each product, the sectional model applied to the log and the innovations in this whole process, aiming at the costs reduction to make their businesses more competitive and active in this type of market.

Within this context, the objective of this work was to evaluate the production costs of processing logs of *Eucalyptus grandis* Hill ex Maiden and *Eucalyptus saligna* Sm., in two logs cutting templates models in a medium-sized sawmill.

MATERIALS AND METHODS

Study site and species used

The data obtained for the study were supplied by a sawmill located in the municipality of Campina Grande do Sul, Paraná state, metropolitan region of Curitiba. The company operates in the Brazilian

domestic market supplying the furniture sector and especially the civil construction sector.

The species used were *Eucalyptus grandis* Hill ex Maiden and *Eucalyptus saligna* Sm., with logs coming from plantations in the states of Paraná, São Paulo and Santa Catarina. The production process used in the company, does not classify the logs as to species and diameter, but for the study, the diametric classification was performed, using the same amount of logs for two classes, one with an average diameter of 33.0 cm and another with an average diameter of 47.0 cm.

Logs sawing patterns

For the main logs sawing the sawmill offers a simple vertical band saw with wheel of 1350 mm diameter and a simple vertical tape with a wheel of 1100 mm of diameter. For the wood resawing the sawmill has a simple vertical saw with wheel of 800 mm in diameter, a circular multiple saw with one shaft, a circular dual saw and three circular edge saws. The average diameter logs of 33.0 cm were subjected to alternating tangential sawing pattern (Figure 1a), and the average diameter logs of 47.0 cm were subjected to the radial sawing pattern (Figure 1b).

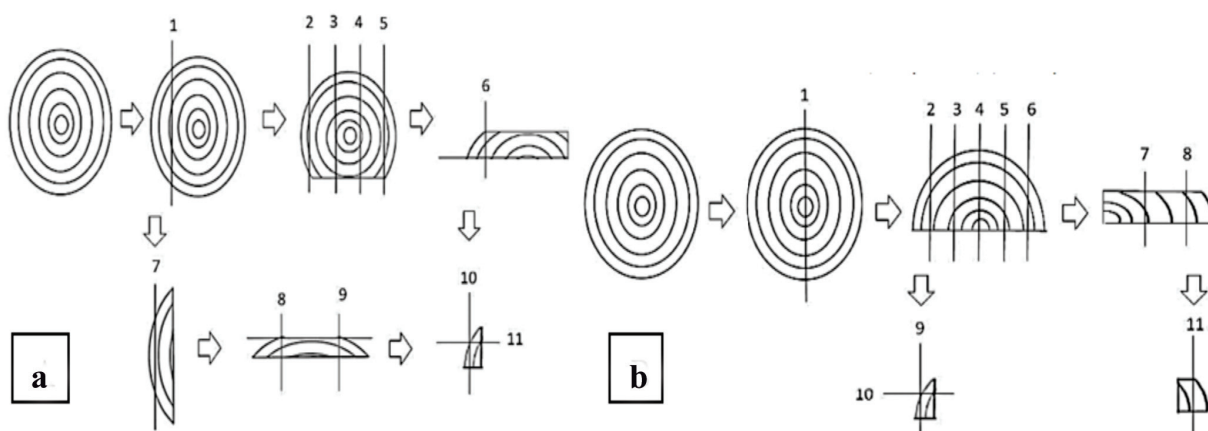


Figure 1. Alternating tangential model sawing (a) and radial sawing model (b).

Production costs

The data for the production costs analysis was used for the fixed costs calculations, variable costs and total costs and, subsequently, the mean fixed costs, variable mean costs and total mean costs for each sawing pattern.

Fixed costs

For the fixed costs analysis expenses were related to direct labor, Social Security (INSS and FGTS), the administrative costs (office material, accountant, tools, remuneration on own capital, depreciation of machinery and equipment, taxes and license (permit, SERFLOR, DAS, IPTU, IPVA).

Because of the difference between the values of machinery and equipment used and due to the same, many times, are already obsolete and outdated and do not have a fixed marketing value, it was chosen to use values used in the market, supplied by a specialized company in machinery and equipment for the sawmill.

Among the models used by the bibliography for calculating depreciation the calculation process for linear depreciation was used, described by Equation 1, as mentioned by Timofeiczuk Junior (2004).

$$D = (V_a - V_r) / V_u \quad (1)$$

Where:

D = Depreciation (R\$/year);

V_a = the value of acquisition (R\$);

V_r = residual value (R\$);

V_u = Useful Life in years.

Equity remuneration

The rate of interest used was 10% a year, as indicated by the company, as well as all other values for the calculation of remuneration, which was calculated using Equation 2.

$$RC = VA * ((1+i)^n * i) / ((1+i)^n - 1) - D \quad (2)$$

Where:

RC = Capital remuneration (R\$);

VA = Present Value of investment or acquisition (R\$);

I = Annual discount rate (%);

D = annual depreciation (R\$).

Variable costs

For the variable costs those which fluctuate according to the sawn wood production was considered, such as: employee feeding, fuels and lubricants, electrical energy, toll, raw material (logs), maintenance of machines and equipment and variable tax (ICMS). The costs calculation regarding the raw material acquisition (wood) was calculated based on Equation 3:

$$MP = ((Pr + Fr) * V_t) + Desc \quad (3)$$

Where:

MP = Raw material cost (logs) in R\$;

Pr = Price per m³ of logs (R\$/m³);

Fr = Price of freight per m³ (R\$/m³);

V_t = Volume of purchased logs (m³);

Desc = Unloading (R\$).

Total production cost

To calculate the total cost the sum of fixed and variable costs were used according to Equation 4:

$$CT = \sum CFT + \sum CVT \quad (4)$$

Where:

CT = Total cost (R\$);

CFT = Sum of fixed costs (R\$);

CVT = Sum of variable costs (R\$);

Mean production costs

The mean costs correspond to the costs per unit of product, which the mean fixed cost, mean variable cost and total mean cost. The mean fixed cost is the result of dividing the fixed cost by the production volume, as well as the

mean variable cost is a quotient of the variable cost divided by the production volume and the total mean cost was obtained by dividing the total cost by the production volume (Pyndyck & Rubinfeld 2009), all calculated from Equation 5:

$$C_m = C / V.m.s. \quad (5)$$

Where:

C_m = Fixed cost, variable cost or total mean cost (R\$/m³);

C = Fixed cost, variable cost or total cost (R\$);

$V.m.s.$ = Total volume of sawn timber produced in the period (m³).

For calculations of production costs, the volume of logwood used by the sawmill in the month was considered to be the same for the two sawing patterns. The monthly volume of lumber was estimated from the yield obtained in each used sawing patterns, whereas the logs production and consumption in a month of normal work. The data of percentages of fixed and variable costs and production mean costs were statistically analyzed and compared with the multivariate test T2 of Hotelling and the F test with significant differences at 1% probability, using the software FreeMat version 4.2

RESULTS AND DISCUSSION

Production total costs

The total fixed cost presented lower representativeness in comparison to the total

variable cost in the two analyzed sawing patterns analyzed (Table I).

The alternating tangential sawing pattern presented lower total cost about the radial sawing pattern, mainly due to the cost of raw material (logs) used in this model. The supply, labor and social security costs have contributed to this difference in total costs, but at a lower representativeness.

Fixed costs

In Table II the percentage of factors of fixed costs for the alternating tangential sawing pattern and radial sawing pattern are represented, which totaled R\$ 58,973.74 and R\$61,757.74, respectively.

Despite perceiving the difference between the percentages of the factors of fixed costs the null hypothesis is accepted that the averages for factors of response are equal, because the value of the T2 statistic of Hotelling (T2 = 10.32) is smaller than the value of F (F = 31.85), so there is no significant difference between the sawing patterns.

Among the factors, labor presented the highest cost in both models. This value is assigned to the number of employees involved in the sawing pattern process, being the most representative factor for the company's fixed costs, which is expected in the small to medium-sized sawmills because they do not have a fully automated system, requiring a greater quantity of labor.

Table I. Total fix costs, total variable cost and total cost for the alternating sawing pattern and radial sawing pattern.

Sawing pattern	Alternating tangential		Radial	
	R\$/month	Total cost	R\$/month	Total cost
Total fix	R\$ 58,973.74	19.32 %	R\$ 61,757.74	18.92 %
Total variable	R\$ 246,231.45	80.68 %	R\$ 264,711.45	81.08 %
Total	R\$ 305,205.19	100.00 %	R\$ 326,469.19	100.00 %

The results were similar between the models, but this was upper for the labor in the radial sawing pattern, due to the use of two employees in the productive process, which reflects an increase in wages and social charges in relation to the alternating tangential sawing pattern. Among the other factors, the percentages were similar between the models, but upper for the tangential sawing pattern, generating a greater percentage of the total cost for this type of sawing pattern.

Variable costs

In Table III the percentage of factors of variable costs and the relevance of each in the total cost

are presented. The total value in the alternating tangential sawing pattern and radial sawing pattern were R\$ 246,231.45 and R\$ 264,711.45, respectively.

As observed for fixed costs, the null hypothesis is accepted that the means of the response factors of the variable costs are equal between the sawing patterns, because of the value of the T2 statistic of Hotelling ($T_2 = 8.55$) is smaller than the value of F ($F = 31.85$).

Among these factors of variable costs, raw material presented greater representativeness in the models, being also the most influential among the total costs, with a rate of 70.28% for the alternating tangential sawing pattern and

Table II. Percentage of total fix costs for the alternating sawing pattern and radial sawing pattern.

Sawing pattern	Alternating tangential		Radial	
	Fixed cost	Total cost	Fixed cost	Total cost
D.M.E.	17.44 %	3.37 %	16.65 %	3.15 %
Administrative expenses	2.50 %	0.48 %	2.39 %	0.45 %
Social taxes (INSS/FGTS)	4.56 %	0.88 %	4.97 %	0.94 %
Tools	4.24 %	0.82 %	4.05 %	0.77 %
Taxes	7.40 %	1.44 %	7.09 %	1.34 %
Labor	33.15 %	6.41 %	35.54 %	6.72 %
R.C.P.	30.68 %	5.93 %	29.30 %	5.54 %
Total	100.00 %	19.32 %	100.00 %	18.92 %

Where: D.M.E. = Depreciation of machinery and equipment; R.C.P. = Equity Remuneration.

Table III. Percentage of total variable costs for the alternating sawing pattern and radial sawing pattern.

Sawing pattern	Alternating tangential		Radial	
	Variable cost	Total cost	Variable cost	Total cost
Supply	1.36 %	1.10 %	1.45 %	1.18 %
Fuel	3.75 %	3.02 %	3.49 %	2.83 %
Electrical energy	3.44 %	2.77 %	3.20 %	2.59 %
ICMS	0.74 %	0.60 %	0.69 %	0.56 %
Maintenance	3.32 %	2.68 %	3.08 %	2.50 %
Toll	0.28 %	0.23 %	0.26 %	0.21 %
Raw material (logs)	87.11 %	70.28 %	87.83 %	71.21 %
Total	100.00 %	80.68 %	100.00 %	81.08 %

71.21% for the radial sawing pattern. Despite the percentage values being close to each other, the total variable cost was higher for the radial sawing pattern, which is attributed mainly to the raw material factor, because the used logs used had greater diameter, being also the cost higher, in addition to the supply cost due to involving two more employees in this model.

These high figures demonstrate the raw material importance for the company's costs, since its quality is crucial to achieve high yields. Berger et al. (2002) found that the raw material purchase for sawmills is the factor with the greatest impact within the variable costs, corresponding to 72.50% of the variable cost, similar to the result of this research.

In terms of the total cost, Berger et al. (2002) mention that raw material corresponds to 62.60%, value also below the one obtained in the present study with logs of two diameter classes. This disparity of values can be attributed to the time of the study and the type of wood used since the cited authors analyzed tropical timber and in the past considered period.

Whereas in more recent studies Murara Jr. et al. (2010) obtained in their work, the media

cost of *Pinus taeda* logs ranging from 18 to 40 cm, 74.46% of the total production cost, and Manhiça et al. (2013) also in the study of *Pinus* spp. Sawmill found a value of 93.31% for the raw material cost, representing 78.67% of the total production cost. These values are above the results obtained in the present study, which can be explained by the factor species, availability of logs and also by values practiced in the market, which vary according to the supply and demand of the logs diameter classes.

The fuel expenses are attributed to the displacement of the raw material to the unit of production, i.e., from the forest to the sawmill. This variable could have lower values with a reduction of distances between the forest and the production unit and proper harvest planning.

Maintenance costs are considered high, due to machinery and equipment already have significant wear, requiring greater care for conservation and maintenance. The importance of maintenance and periodic reviews are required to minimize the expenses with repairs and purchase of parts to keep the sawmill's machines and equipment, according to Murara Jr. et al. (2010) who mention the constant need

Table IV. Percentage of mean fixed costs for the alternating sawing pattern and radial sawing pattern.

Factor	Mean fixed cost		Difference R\$/m ³
	Alternating tangential	Radial	
D.M.E.	R\$ 17.93	R\$ 16.04	-R\$ 1.89
Administrative expenses	R\$ 2.57	R\$ 2.30	-R\$ 0.27
Social taxes (INSS/FGTS)	R\$ 4.69	R\$ 4.79	R\$ 0.11
Tools	R\$ 4.36	R\$ 3.90	-R\$ 0.46
Taxes	R\$ 7.64	R\$ 6.83	-R\$ 0.80
Labor	R\$ 34.08	R\$ 34.24	R\$ 0.15
R.C.P.	R\$ 31.55	R\$ 28.22	-R\$ 3.32
TOTAL	R\$ 102.81	R\$ 96.32	-R\$ 6.49

Where: D.M.E. = Depreciation of machinery and equipment; R.C.P. = Equity Remuneration.

for assessments in the machinery due to high usage.

In the face of these high costs, the importance of proper utilization of raw materials stands out, which can reduce the average production cost and add value to the final product, and as stated by Murara Jr. et al. (2010) there may be significant advances in the economy and the sawmill operational performance.

Mean production costs

Table IV presents a comparison of the mean fixed costs between the alternating tangential sawing pattern and radial sawing pattern and the difference in values between the models.

Only for the labor and social taxes the tangential alternating sawing pattern presented lower average costs, due to the smaller number of employees involved in the production process in relation to the radial sawing pattern.

It is noted that the mean fixed cost of production for the radial pattern was R\$ 6.49 bottom than the mean fixed cost of alternating tangential sawing pattern. The greatest influence was the equity remuneration, which despite being equal for the two models, the production of estimated sawn timber or the radial sawing

pattern was higher than the production in the alternating tangential sawing pattern in reason of the yield (53.43% and 47.08%, respectively). Among other factors, the difference of the mean fixed costs ranged from R\$ 0.11 to R\$ 1.89 between the sawing patterns.

Table V exhibits the comparison of mean variable costs between the models and the difference between them. The mean variable costs were lower for the radial sawing pattern, only being higher for the supply factor, which is explained by the increase of employees necessary needed for this production *lay-out*.

Despite the radial sawing pattern having higher value in the logs purchase, the mean variable costs for this factor showed a reduction of R\$ 11.32 in relation to the alternating tangential sawing pattern. The highest yield in sawn wood of this model reduces the average cost of raw material, being this the most representative value of the variable between the models.

Although the difference between the average costs, the null hypothesis is accepted that the averages for all variable and fixed cost factors of response are equal (Tables IV and V), since the value of the T2 statistic of Hotelling ($T2 = 3.77$) is smaller than the value of F ($F = 31.85$),

Table V. Percentage of mean variable costs for the alternating sawing pattern and radial sawing pattern.

Factor	Mean variable cost		Difference R\$/m ³
	Alternating tangential	Radial	
Supply	R\$ 5.86	R\$ 5.99	R\$ 0.13
Fuel/Lubricant	R\$ 16.09	R\$ 14.39	-R\$ 1.69
Electrical energy	R\$ 14.76	R\$ 13.20	-R\$ 1.55
ICMS	R\$ 3.20	R\$ 2.86	-R\$ 0.34
Maintenance	R\$ 14.23	R\$ 12.73	-R\$ 1.50
Toll	R\$ 1.21	R\$ 1.08	-R\$ 0.13
Raw material (logs)	R\$ 373.93	R\$ 362.61	-R\$ 11.32
TOTAL	R\$ 429.26	R\$ 412.87	-R\$ 16.40

Table VI. Mean costs of sawn wood production of *Eucalyptus* for the alternating tangential sawing pattern and radial sawing pattern.

Cost	Mean cost		Difference R\$/m ³
	Alternating tangential	Radial	
Mean fixed cost	R\$ 102.81	R\$ 96.32	-R\$ 6.49
Mean variable cost	R\$ 429.26	R\$ 412.87	-R\$ 16.40
Total mean cost	R\$ 532.07	R\$ 509.19	-R\$ 22.89

so there is no significant difference between the sawing patterns.

The mean costs for the radial sawing pattern were lower than the mean costs for the alternating tangential sawing pattern (Table VI), resulting in the total difference of R\$ 22.89 per m³/month, superior to that obtained by Manhiça et al. (2013) where the mean difference between scheduled and random sawing was R\$ 15.80 per m³/month with logs of *Pinus* spp. with diameters ranging from 24 to 33 cm.

Whereas the total mean cost was R\$532.07 and R\$509.19 for the alternating tangential sawing pattern and radial sawing pattern, respectively, is higher than the mean cost obtained by Manhiça et al. (2013) with logs of *Pinus* spp., equivalent to R\$ 263.26 for the random sawing pattern and R\$ 247.46 for the scheduled sawing pattern.

It is worth mentioning that besides the mean cost for the radial sawing pattern being lower, the dimensional stability of the parts obtained for this model is greater, because they are parts with radial orientation and, consequently, these parts have advantages about parts with tangential orientation, regarding the stability in width and less likelihood of drying defects, which results in better quality parts for the market.

Regarding the mean cost less there is the likelihood of profit margin to be greater, however,

this is not a rule, because the profit is paired with the products selling price and according to Santana (2003) this is determined according to the market rules and the strategies used by competitors.

Wipieski et al. (2002) mention that economic-financial analysis, definitions of engineering, and investments are crucial for venture competitiveness and success. In the sawmill branch simulations with cutting models, types of product, quality, and values are fundamental for the evolution of this branch.

The obtained results are paramount to the decision-making process regarding the type of logs to be used along with the sawing pattern to be used to each diametric class. Murara Jr. et al. (2010) corroborate with the assertion, emphasizing that the logs distribution by diameter classes linked to correct choice of cutting diagram are fundamental factors for gains in yield of the desired product.

With this analysis it is noted that the work optimization through appropriate sawing models to each type of log, the yield of the sawn wood and its production cost bring in results of paramount importance for the company's administration, providing support for the pursuit of technological innovations, which is fundamental to the sawmills sector's evolution in Brazil.

CONCLUSION

Logs purchase is the most representative factor within the variable costs. Labor is the factor that encumbered the most on the fixed cost.

The radial sawing pattern using logs of the diametric class applied in this model presented the lowest mean production cost.

The study of the type of model applied to each diametric class not presented significant differences of the percentage of fixed and variable cost and mean production costs.

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