YIELD IN EUCALYPTUS SLAB FOR USE IN THE OBTAINMENT OF BATTENS

Cláudio Gumane Francisco Juizo[1*], Douglas Edson Carvalho[1], Pedro Lício Loiola[1], Márcio Pereira da Rocha[2], Ricardo Jorge Klitzke[2], Jose Guilherme Prata[2]

[1] Federal University of Paraná, Graduate Program of Forestry, Curitiba, Paraná, Brazil - c.gumane@gmail.com*; douglasedsoncarvalho@gmail.com; pedrlicio@hotmail.com.
[2] Federal University of Paraná, Graduate Program of Forestry, Curitiba, Paraná, Brazil - mprocha01@gmail.com; rjkklitzke@gmail.com; jgprata@gmail.com

Received for publication: 20/06/2016 - Accepted for publication: 15/11/2017

Abstract

The present study aimed to assess the yield in eucalyptus slabs for the obtainment of battens to be used in the production of higher value-added products. For this purpose, 15 logs of *E. grandis* and 15 logs of *E. saligna*, which were separated into three diametric classes of five logs for each species, were used: diameter class 1 (25 - 32 cm); diametric class 2 (33 - 39 cm); and diametric class 3 (> 40 cm). Then, they were cubed and assessed regarding the taper and breakdowns in the band saw. The slabs were removed for assessment of quality, yield and yield in battens obtained for each studied species. The results indicated average classification for basic density, and good dimensional stability for *E. grandis* and *E. saligna* wood. The logs taper and the yields observed were not significant for either species. However, the yields in slabs and yields in battens slightly decreased as the diameter of the logs increased. Thus, logs with greater yields in slabs had lower yields in battens. Therefore, it is possible to use slabs for the production of battens, mainly in industries that process high amounts of logs.
Keywords: Taper, breakdown, wood quality, untrimmed wood, sawdust.

Resumo

Rendimento em costaneira de eucalipto para aproveitamento na obtenção de sarrafos. O presente trabalho teve o objetivo de avaliar o rendimento em costaneira de eucalipto para aproveitamento na obtenção de sarrafos a serem utilizados na produção de produtos de maior valor agregado. Para isso, foram utilizadas 15 toras de *E. grandis* e 15 toras de *E. saligna*, as quais foram separadas em três classes diamétricas de cinco toras para cada espécie: classe diamétrica um (25 – 32 cm); classe diamétrica dois (33 – 39 cm); e classe diamétrica três (> 40 cm). Em seguida, as mesmas foram cubadas e avaliadas com relação à conicidade e desdobras em serra fita. As costaneiras foram retiradas para avaliação de qualidade, rendimento e rendimento em sarrafos obtidos para cada espécie estudada. Os resultados obtidos indicaram classificação média da massa especifica obtida, com boa estabilidade dimensional da madeira de *E. grandis* e *E. saligna*. A conicidade das toras e os rendimentos observados não foram significativos nas duas espécies, porém os rendimentos em costaneiras e os rendimentos em sarrafos tiveram um ligeiro decréscimo com o aumento do diâmetro das toras. Toras com maior rendimento em costaneiras tiveram menor rendimento em sarrafos. Assim sendo, o aproveitamento de costaneiras para produção de sarrafos pode ser feito principalmente nas indústrias que processam elevadas quantidades de toras.
Palavras-chaves: Conicidade, desdobro, qualidade da madeira, madeira sem refilo, serragem.

INTRODUCTION

Eucalyptus wood stands out for its potential in supplying market demand. In the last decade, eucalyptus has been competing with other traditional woods, which have been more studied from the technological point of view and have wide commercial acceptance. This situation occurs due to its wide use as an industrious source of raw material, since, in addition to the versatility of the wood of this genre in the obtainment of various products, the industry can also benefit from the use of the eucalyptus' processed waste for the production of energy and higher value-added products.

According to Valério *et al.* (2007), generation of larger waste (slabs, chips and trimmings) and smaller waste (sawdust and shaving) is inevitable during industrial processing as it is a natural consequence of the wood transformation process. For Biasi and Rocha (2007), the waste generated must be properly managed, since, even if it is biologically degraded, its concentration in certain places may cause environmental damages. However, waste can be reused and incorporated in the production process to obtain new products.

In the last decade, a great demand to use waste from the timber industry in the obtainment of energy has been verified. However, some types of waste generated, such as slabs, may be available in other forms of use. One of the main forms is the production of battens, which can be used to obtain higher added value products, such as decorative floors and panels. Besides its lower cos, slab wood has the advantage of being obtained from an area of the log made up of mature wood. Therefore, it has the best technological properties, especially regarding dimensional stability and mechanical strength.

To encourage the establishment of production lines that aim to use slabs in the industry, Melo *et al.* (2012) argue that it is important for the industrial manufacturing sector the knowledge and dissemination of the qualities of slab wood. Thus, slabs can be used to obtain appropriate products, without compromising the productive process, and gaining from the consolidation of products of used wood on the market.

Other aspects to be considered to promote the use and exploitation of slabs are the technologies used and the qualification of the workforce employed in the logs breakdown. In addition to minimizing the losses in the yields, these factors may favor an appropriate breakdown and establish cut models that allow not only a greater use of the log, but also the production of useful slabs that can be successfully employed in the obtainment of battens or other smaller wooden products.

Murara Junior *et al.* (2005) argue that, during the wood breakdown, operators are continuously making decisions for the proper functioning of the machines and the obtainment of yield and better product quality. The authors emphasize that choosing the way in which logs will be processed to obtain satisfactory yield in conventional sawmills depends on the experience and common sense of the operators. However, in practice and in most cases, such decision is random, which causes the wood to be processed at the primary level, resulting in high losses of lumber and waste. These losses include the slabs obtained in a higher percentage.

Besides the technologies and the workforce experience, log flaws also influence the yields of lumber and the yield of waste produced by breakdown. In the slabs' case, the presence of knots, hollows and taper of logs is a flaw that influences the percentage variation of sawn wood and waste for use. However, taper is the main flaw for eucalyptus wood, since it is a dendrometric variable influenced by the species, planting density and age of the trees, according to Gonçalves *et al.* (2010). Therefore, taper contributes to modify the wood characteristics and influences in the quantification of the wood diameter and volume, and consequently in the yields obtained in the breakdown.

In this context, despite the high volume of waste generated by logs taper, the low use of wood in sawmill is one of the major problems for the industry. It limits the progress of this sector, especially in developing countries, since it represents a loss of opportunity for the private sector due to the lack of destination for the waste produced. This waste could be used in other production lines to obtain different products within the industry instead of being incinerated for the purpose of vacating the yards.

For slabs, it is possible to adapt a better destination and make the production of battens viable. With this action, it would be possible to convert serious environmental problems into solutions. Monteiro *et al.* (2013) argued that studies regarding wood quality and yields obtained in the log breakdown are important. In this context, we developed this research with the objective of assessing the yield in slabs obtained from eucalyptus logs for possible use in the obtainment of battens to be used to produce higher value-added products. Thus, pieces that may serve to create whole products of greater value-added and high commercial value for low costs could be obtained.

MATERIAL AND METHODS

To accomplish the present study, trees of *Eucalyptus grandis* and *Eucalyptus saligna* older than 20 years were used. Fifteen logs were used for each species, and their lengths and circumferences of the thin and the thick points were measured. Then, they were grouped into three diametric classes of five logs each: diameter class 1 (25 - 32 cm), diameter class 2 (33 - 39 cm) and diameter class 3 (> 40 cm).

Wood quality

The slab wood quality was assessed by means of physical properties, which were determined by using samples taken from the slabs. Thus, two slabs of each diametric class were randomly selected, totaling six slabs per species. Then, they were trimmed on a multi-blade circular saw. We attained oriented pieces that enabled the obtainment of 60 specimens per species and a total of 120 specimens of nominal dimensions of 100 x 25 x 25 mm (length x width x thickness) for the determination of the basic density, radial and tangential shrinkage, and anisotropy coefficient, according to the recommendations of COPANT (1972).

Taper and breakdown yield

Logs taper

FLORESTA, Curitiba, PR, v. 48, n. 1, p. 19-26, jan./mar.2108.
Juízo. C. G. F. *et al.*
ISSN eletrônico 1982-4688
DOI: 10.5380/rf.v48i1.47286

As a parameter of log quality, taper was assessed. It was defined as the diameter variation rate along the length that may influence the percentage of useful slab removed from each log. For this purpose, the length and diameter data of the thin and the thick points of each log were used for each diametric class, according to the methodology of Hornburg *et al.* (2012). Thus, three taper lots were obtained for each species of eucalyptus assessed.

Yield in slabs

After assessing the logs taper, the yield in slabs taken from the breakdown of eucalyptus logs in band saw was also measured. The volume of slabs is difficult to quantify directly since they do not have a regular form. First, the yield in untrimmed wood was defined, followed by the determination of the yield in sawdust. Finally, the material balance was assessed to determine the yield in slab:

The pieces obtained immediately after the breakdown were considered as untrimmed wood. They were immediately cubed to determine their respective volumes. This technique was adapted to facilitate the quantification of the material lost in the obtainment of sawn wood, and thereby to include the trimmings, which are difficult to cube since they are products that do not have a defined shape in the material balance.

After cubing the pieces obtained from the breakdown of each log of each diametric class, we used equation 1 to estimate the yield in untrimmed wood.

$$R\% = \frac{Vm}{Vt}$$

In which: R%: untrimmed wood yield per log (%); Vm: untrimmed wood volume per log (m^3); Vt: log volume (m^3).

Concomitantly, the volume of sawdust obtained from each log was determined. In order to do so, the number of cuts made in the breakdown of each log was multiplied by the height of cutting, thickness of the jig saw blade and the respective log length for each diametric class of each species. Based on the sawdust volume, the respective yield was estimated with the aid of equation 2.

$$Rs\% = \frac{Vs}{Vt}$$

In which: Rs%: yield in sawdust per log (%); Vs: sawdust volume per log (m^3).

After obtaining these values, the yield in slabs was estimated through the material balance, which is the difference between the total yield of the log before breakdown by the yield in untrimmed wood and yield in sawdust, as observed in equation 3.

$$Rc\% = 100\% - R\% - Rs\%$$

In which: Rc%: yield in slab per log; R%: yield in wood before trimming per log (%); Rs%: yield in sawdust per log (%).

Yield in battens

The slab of each diametric class of each species was submitted to the trimming in Multi-blade Circular Saw, and topped in a topping saw separately. Thus, boards with dimensions ranging from 25 to 30 mm of thickness, 50 to 60 mm of width and 600 to 2500 mm of length, were obtained.

The respective yield per log was estimated for each diametric class, with the aid of equation 4, through the volumes of batten obtained.

$$Rsa\% = \frac{Vsa}{Vt}$$

In which: Rsa% = yield in battens per log; Vsa = volume of battens per log.

For the analysis of the results, the normality of the data was verified by means of Bartlett's test.The Student's t-test was then applied to compare the means obtained in the physical properties, which were evaluated in the two species, considering them as a source of variation for the treatment.

An analysis of variance (ANOVA) was used for the yield in wood with no trimming, yield in slab, yield in sawdust and yield in battens, using a factorial arrangement of 2 x 3 type (two species x three diametric classes).

For each one of the variables evaluated, the Tukey test was used at 95% probability when a significant difference was detected in the treatments.

In addition, *Pearson* correlation analysis and regression analysis were performed in order to verify the trend of yield variation in the slabs obtained. This was done in function of the logs' taper of each diametric class of the two eucalyptus species represented by the adjusted coefficients of determination.

RESULTS

Wood quality

The results of the physical properties of slab wood from *E. grandis* and *E. saligna* are presented in (Table 1). It was observed that the basic specific mass was relatively higher for *E. saligna* by means comparison.

Although mean shrinkage of the two species studied is very influenced by the variation of the specific mass, this characteristic (Table 1) was considered statistically equal by Student's t-test. Moreover, in the individual analysis, the retraction of the wood in the tangential direction was twice as large in the radial plane, thus influencing the volumetric shrinkage and the anisotropy coefficient of the two species.

Table 1. Values of basic density, radial shrinkage, tangential shrinkage, volumetric shrinkage and anisotropy coefficient of wood slabs of *E. grandis* and *E. saligna*.

Tabela 1. Valores de massa específica básica, retratibilidade radial, retratibilidade tangencial, retratibilidade volumétrica e coeficiente de anisotropia da madeira de costaneira de *E. grandis* e *E. saligna*.

	Eucalyptus grandis	***Eucalyptus saligna***
Basic density ($g.cm^{-3}$)	0,58a	0,67b
Radial shrinkage (%)	6,37a	6,54a
Tangential shrinkage (%)	11,43a	11,75a
Volumetric shrinkage (%)	18,10a	18,63a
Anistropy coefficient	1,80a	1,80a

Means followed by the same lowercase letter are statistically equal by the Student's t test.

Taper and yield on the breakdown

It can be observed in Table 2 that the species, the diameter classes and their respective interactions did not have a significant effect on taper, yield in wood without trimming and yield in by-products evaluated to obtain battens.

Table 2. Summary of variance analysis for log taper, yield in untrimmed wood, yield in sawdust, yield in slabs and yield in battens for *E. grandis* and *E. saligna* per diametric class.

Tabela 2. Resumo da análise de variância para a conicidade das toras, rendimento em madeira sem refilo, rendimento em serragem, rendimento em costaneiras e rendimento em sarrafos de *E. grandis* e *E. saligna*, por classe diamétrica.

Source of variation	**Significance**				
	C (cm/m)	**R (%)**	**Rs (%)**	**Rc (%)**	**Rsa (%)**
Species (A)	ns	ns	ns	ns	ns
Diametric class (B)	ns	ns	ns	ns	ns
AxB	ns	ns	ns	ns	ns

C: taper; R: yield in untrimmed wood; Rs: yield in sawdust; Rc: yield in slabs; Rsa: yield in battens; ns: not significant (p >= .05).

In order to understand the possible utilization of slab wood in eucalyptus sawmill, the mean values obtained for each one of the variables evaluated were observed in the three diameter classes for the two species in Table 3.

The taper of logs and the yield on slabs are variables very associated with the diameter of logs and, even though no significant differences were observed between them, both presented a slight increase and decrease with the raise of the diameter class, respectively.

Table 3. Mean values of yield in untrimmed wood, sawdust, slabs and battens observed for *E. grandis* and *E. saligna* by diametric class.

Tabela 3. Valores médios de rendimento em madeira sem refilo, serragem, costaneiras e sarrafos observados para *E. grandis* e *E. saligna*, por classe diamétrica.

Species	**Diametric class**	**Taper (cm/m)**	**Yield (%)**

FLORESTA, Curitiba, PR, v. 48, n. 1, p. 19-26, jan./mar.2108.
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ISSN eletrônico 1982-4688
DOI: 10.5380/rf.v48i1.47286

			R	Rs	Rc	Rsa
E. grandis	25 - 32	0,81	67,98	2,53	29,49	0,034
	33 - 39	0,97	67,90	1,71	30,39	0,025
	> 40	1,28	67,29	2,60	30,10	0,021
E. saligna	25 - 32	0,77	71,69	2,91	25,41	0,041
	33 - 39	0,89	76,21	2,59	25,21	0,044
	> 40	0,95	69,98	2,36	27,66	0,026

R: yield in untrimmed wood; Rs: yield in sawdust; Rc: yield in slabs; Rsa: yield in battens. The comparison of means test was not applied since F was not significant.

Thus, the trend of the yield values in battens, in function of the logs' taper evaluated, is illustrated in Figure 1. An inverse relation was verified, indicating that it is necessary to use logs of smaller diameters and less taper in order to establish exploitation lines of slab to obtain battens in the industry.

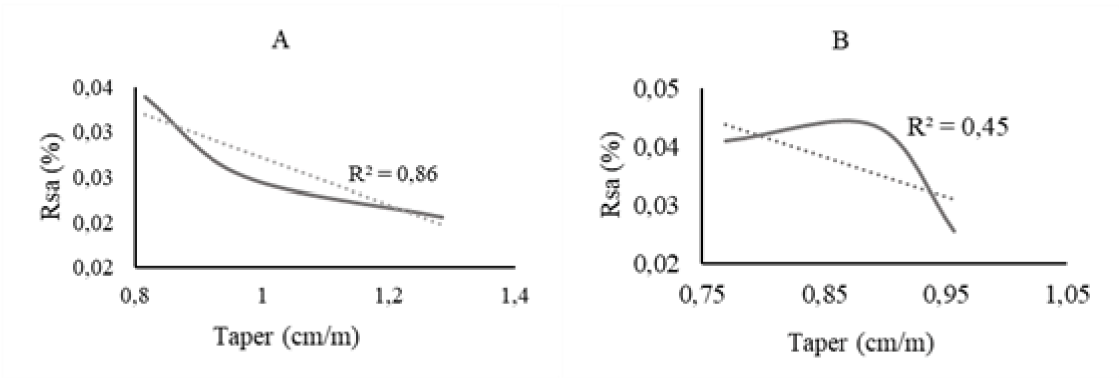

Figure 1. Variation of the yield in battens due to logs' taper. A: *E. grandis*; B: *E. saligna*.
Figura 1. Variação do rendimento em sarrafos em função da conicidade das toras. A: *E. grandis*; B: *E. saligna*.

DISCUSSION

Physical properties

In Table 1, it can be observed that the two species had average basic density for wood classification. On the one hand, the values found are relatively high in relation to the observations of Eleotério *et al.*(2015), which determined the value of 0.46 g.cm^{-3}. On the other hand, they were similar to the results of Bellon *et al.*(2015), who found 0.52 g.cm^{-3} for basic density.

Despite the use of slab wood obtained from adult trees, in which the cells are more developed and have longer fibers and thicker cell walls, the basic density values were relatively low in relation to the observations made by Serpa *et al.*(2003), mainly for *E. grandi.* The authors obtained 0.70 g.cm^{-3} from a distance of 10 cm from the pith.

It is worth remembering that the basic density obtained in the wood of most species is an important characteristic for wood utilization purposes. Thus, it can be said that, generally, woods with higher basic density present greater resistance, which provides multiple uses to them. The values of basic density obtained for the two species indicate characteristics of greater dimensional variation. This may be observed by the percentage of shrinkage in the radial and tangential directions, and the respective retraction coefficient (Table 1).

As previously reported by Glass and Zelinka (2010), woods with a high basic density have a larger fiber size, and a greater thickness of the cell wall with or without decrease in the proportion of vessels. As a result, these species contract more because they contain a higher quantity of water impregnated in the cell wall. Thus, the mean shrinkage found in the radial plane from *E. grandis* was similar to the one found by Acosta (1999), who obtained 5.80%. In the tangential shrinkage, Paes *et al*. (2015) obtained 10.16%. In contrast, the mean radial shrinkage from *E. saligna* resembles the results obtained by Oliveira and Silva (2003) in 16-year-old trees (6.17%), and the mean shrinkage values are similar to the ones found by Trugilho *et al.* (2003) in the tangential plane.

It can be observed that the relationship between tangential shrinkage and radial shrinkage is close to two times, probably due to the anatomical differences observed in the two planes. However, according to Oliveira *et al*. (2010), this difference can exceed three times, being attributed to the number of cells, width and height, which contributes to its restriction in radial dimensional variation. This makes both species of eucalyptus unstable. As a result of these variations in their characteristics, they present tendencies to crack and warp, which limits their use. However, it can be observed in Table 1 that the slab wood of the two species used was relatively stable, since their coefficients of anisotropy were considered normal, ranging from 1.5 to 2.0 in the classification by Durlo and Marchiori (1992); similar to the anisotropy coefficients of more stable woods such as Cupiuba (*Goupia glabra* Aubl) and Angelim (*Vatairea sp*.).

Taper and yield on the breakdown

It can be observed in the analysis of variance in Table 2 that the species, the diametric class and the respective interactions did not have a significant effect in the taper variation, wood yield without trimming, sawdust yield, and battens yield. Although the species affect the taper, the similarity observed in the two species studied can be attributed to the same genus. However, this similarity can also be attributed to the origin of these two species, since they were obtained from the same planted forest, in which similar silvicultural operations were applied. Thus, both have the same development and are individuals with similar dendrometric characteristics.

Different diametric classes were evaluated in logs obtained from the same planting and with the same age, due to the positions in which the logs were obtained along the shaft of the tree. However, this difference did not result in their taper variation, probably due to the age of the specimens used, since older trees tend to present slow growth, favoring diametric development along the stem. According to Scolforo and Figueiredo Filho (1993 apud. Gonçalves *et al.,* 2010), the development of these characteristics reduces the difference of the relationship between the log diameter and its respective length.

In Table 2, it is also possible to observe that the yield in untrimmed wood did not present a significant difference because it obtained the same products for the two species during the breakdown. The use of tangential breakdown may also have influenced the obtainment of untrimmed wood, especially when associated with the breakdown method. Such method was applied to obtain the pieces with a relatively low diametrical amplitude to control the variation of yield in untrimmed wood in the studied diametric classes of the two species.

The similarity observed in the sawdust yield (Table 2) is associated with the type and geometry of the jig saw blade used. Due to the fact that they are species with the same technological characteristics and use blades with the same thickness and geometry during the process, the same sawing volumes were obtained in the three diametric grades for the two eucalyptus species, thus confirming the observations of Vidaurre *et al.* (2008).

Yields in slabs and in battens are associated with the quality of the logs. Much of the variation occurs due to their taper, since conical logs generate shorter slabs in relation to cylindrical logs that generate longer slabs. As observed by Valério *et al.* (2007), this situation directly influences the yield in slabs and in battens, as shown in Table 2.

In absolute terms, it is observed in Table 3 that the taper had an amplitude from 0.81 $cm.m^{-1}$ to 1.28 $cm.m^{-1}$ for *E. grandis*, and from 0.77 $cm.m^{-1}$ to 0.95 $cm.m^{-1}$ for *E. saligna*, with an increasing tendency going from the smaller to the larger diameter logs. The taper of the present study is similar to that described by Valério *et al.* (2007), in which the values observed are not sufficient to influence the yield of untrimmed wood, as shown by the mean values presented in Table 3.

Additionally, in Table 3, the highest percentage of yield in untrimmed wood was that of *E. saligna* in diametric class 2 (33-39cm). In this way, the increase of the diametric class resulted in the reduction in yield in the two species evaluated. It is uncommon to observe yield reduction with an increase of the diametric class. This situation may occur due to the small variation observed in the larger taper of the logs with larger diameters, resulting in high losses per yield in these diametric classes.

The mean yields of untrimmed wood obtained were similar to those observed by Cunha *et al*. (2015). They determined 66.40% in yield of flawless wood using tangential breakdown with *Eucalyptus benthamii* and *E. grandis*. In absolute terms, the sawdust yield demonstrated a slight decrease in diametric class 2 (33-39cm), increasing again in the larger diametric class of *E. grandis,* as seen in Table 3. In contrast, for *E. saligna,* there was a gradual decrease in sawdust yield in logs with larger diameters. The sawdust losses observed were relatively low compared to the losses verified by Biasi and Rocha (2007), who found a variation from 5.74% to 7.53% when evaluating the generation of subproducts in tropical wood using a band saw.

The two species studied presented the highest absolute value of yield in slabs in the larger diameter classes because their logs allowed better visualization and breakdown options during the first cut for the removal of the slab by the operator. This result directly influences the highest yield in slabs in relation to logs with smaller diameters.

It is worth noting that the logs with larger diameters, despite having higher yields, presented a lower percentage of useful slabs because they were conical logs. In practice, this makes them produce shorter slabs in relation to the smaller diameter logs. These logs are more cylindrical in shape and have a higher percentage of useful slabs to obtain battens, as shown in Table 3.

Due to the yields in battens obtained from the slabs, the use of these residues can become a viable alternative for industries, since there is a good production of battens to obtain higher value-added products to high amounts of breakdown logs.

Variation of yield in battens

The variation of yield in battens of *E. gandis* and *E. saligna,* shown in Figure 1, can be explained by the difference in the quality of the logs since the larger taper of the logs caused a smaller percentage of battens. It is worth mentioning that waste generation is unavoidable, regardless of the log characteristics, and although the logs with larger diametric class produce a higher absolute percentage of slabs, the use of this material is efficient in the cylindrical logs only. The effect of this characteristic is represented in Figures 1A and 1B. It can be observed that, for both species, the increase of the taper of the logs caused a reduction in the yield in battens, with relatively high determination coefficients of 86% and 45% for *E. grandis* and *E. saligna* respectively.

Thus, in *E.grandis*, 86% of the reduction in the yield in battens in the wood of the slab is explained by the increase of the taper of the logs. In *E. saligna*, in turn, this variation explains only 45% of the reduction in the taper of the logs. Therefore, regarding *E. grandis,* the taper can be used as a variable to estimate the yield in battens for the purpose of their use. Regarding *E. saligna,* it is necessary to observe the possible influence of the breakdown equipment utilized.

In this context, both the diameters and the taper are good tools for management decision to purchase the unprocessed material, as observed by Murara Junior *et al.* (2013). In addition, they can also be used to establish lines of use of unprocessed material at sawmills. When the mean taper of the log is reached, it is possible to estimate the mean yield in battens used for the production of higher value-added products.

CONCLUSIONS

Through the evaluations carried out for quality and yield in eucalyptus slabs for the production of battens, it is concluded that:

- Due to the specific mass and dimensional stability, the wood obtained from the slabs holds quality to be used in order to obtain higher value-added products.
- The two species of eucalyptus neither significantly influenced the taper of the logs, the yield in slabs nor the yield in battens obtained in the three diametric classes.
- The increase in the diameter of the logs increases their taper, reducing the percentage of battens to be used.
- According to the obtained yields, the establishment of lines for the use of battens to industries that process large volumes of wood proved to be viable.

ACKNOWLEDGMENTS

To the Coordination for the Improvement of Higher Level Personnel - Capes, and to Mademape Madeiras Ltda.

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ISSN eletrônico 1982-4688
DOI: 10.5380/rf.v48i1.47286