Analysis of Surface Finishing and Pressing Time in Wooden Pieces for the Use of Wood Waste in the Furniture Industry

Carlos Mario Gutiérrez Beatriz Elena Ángel Julia Silva
Asher Kiperstok Rita Cunha Sandro Fábio César

Abstract

This article analyzes the behavior of surface finish and pressing time in glued pieces of eucalyptus wood. The importance of the study lies in verifying the influence of two variables (surface finish and pressing time) on the gluing of wood pieces for the furniture industry over time. For this purpose, the quality of adhesion of *Eucalyptus urograndis* wood pieces with polyvinyl acetate adhesive and the behavior of the wood to shear in the glue line are evaluated. It was necessary to produce test specimens according to the ABNT-NBR 7190 standard; three different surface finishes were evaluated on the faces to be adhered and three different cold pressing times, a variable that has not been analyzed in previous studies. It was possible to determine the shear resistance in the glue line and also to observe the percentage of wood failure when performing the destructive test on the test specimen 1 year after being glued. The highest shear strength was obtained for test specimens without surface finish and with a pressing time of 24 hours. With the results obtained in this study, the optimal surface finish and pressing time to be used in the furniture industry is evidenced.

In order to reduce the exploitation of wood from native forests, Brazil has been increasing forest plantations in recent years, with species such as pine and especially eucalyptus (Brazilian Tree Industry 2015). The Brazilian tree industry (Brazilian Tree Industry 2017) claimed that 7.84 million hectares of trees are planted, of which 5.7 million hectares are eucalyptus plantations.

The Brazilian planted-trees sector is responsible for 91 percent of the wood produced for industrial purposes and is the world leader in the production of wood from forest plantations. The Brazilian Tree Industry (2017) stated that eucalyptus plantations in Brazil are located mainly in the states of Minas Gerais (24%), São Paulo (17%), Mato Grosso do Sul (15%), and Bahia (11%). This production of planted forests has been growing and has become an alternative for supplying various industrial sectors, including the furniture industry. This national scenario of increasing production of forests planted since the beginning of the 2010s led to different studies that sought to produce superior-quality wood at lower prices to be used for civil construction and furniture production (Albino et al. 2012).

The advances obtained in the eucalyptus industry demonstrated the quality of this wood due to its mechanical characteristics, short cultivation time, low cost, and great abundance, leaving it in an outstanding position when compared to other native woods of Brazil (Ferreira et al. 2008). New trends in the subject led to the development of several technical and scientific studies on various eucalyptus species and the use of their wood (Teixeira et al. 2009, Acosta 2012, Müller 2013, Silva et al. 2015). Although the main contributions of research in this area are aimed at making the material easier to work with, it is important to note that eucalyptus wood also contributes to the aesthetic and visual aspects, making new applications in the furniture industry possible (Galinari et al. 2012, Dias Júnior et al. 2013, Movergs 2015). However, the correct processing of

The authors are, respectively, Assistant Professor, Design Dept., Arts and Humanities Faculty, Metropolitan Technol. Inst., Medellin, Colombia (carlosgutierrez@itm.edu.co [corresponding author]); Professor, Pontifical Bolivarian Univ., Medellin, Colombia (beatriz.angel@upb.edu.co); Master's Student, Wood Lab., Federal Univ. of Bahia, Salvador, Brazil (jsjuliaria@gmail.com); Professor, Clean Technol. Network, Federal Univ. of Bahia, Salvador, Brazil (asherkiperstok@gmail.com); and Professor and Professor, Wood Lab., Federal Univ. of Bahia, Salvador, Brazil (ritadi@uol.com.br, sfcesarpaz@uol.com.br). This paper was received for publication in September 2018. Article no. 18-00038.

Forest Prod. J. 69(3):239–244.
doi:10.13073/FPJ-D-18-00038

the raw material is a determining factor in the final quality of the products (Motta et al. 2014).

In spite of the advantages mentioned in relation to eucalyptus wood, one of the biggest problems encountered during the manufacturing cycle of wood products is the waste generated by raw materials partially used in the manufacturing process; when this waste is discarded, it generates labor, infrastructure, transportation, and storage costs that do not contribute any value to the company (Koch 2012, Nolasco et al. 2013). These high levels of waste created the need to develop mechanisms for greater use of wood, as well as the recovery and use of waste, not only because of its impact on production costs but also because of the environmental impact it generates (Boa et al. 2014). Taking this into account, some studies show different ways of minimizing the generation of waste in the production processes in the eucalyptus wood industry and especially in the furniture industry without negatively affecting the quality of the products (Gutierrez et al. 2017).

Different concepts address this issue. Cleaner production seeks the reduction of waste and therefore a decrease in the amount generated in the process (Centro Nacional de Tecnologias Limpas 2003), but sometimes it is not possible to take this waste to zero, as is the case with the manufacture of wooden furniture; for these cases, concepts such as Industrial Ecology consider that the waste generated must be treated by the company as by-products and given a later use (Cervantes 2012).

In the wood industry, it is important to qualify the waste as a derivate that can be used for other productive processes, adding value to a percentage of the unused wood that would be discarded. In the case of eucalyptus, the appropriate use of waste (derivate) has led to the development of different research projects focused especially on the production of glued laminated wood and agglomerates (Schneider et al. 2003, Teixeira and César 2006, Pereira et al. 2010, Boa et al. 2014). In all cases, we are looking for the best use of this raw material, considering that its dimensions and characteristics are no longer the same as the original parts. It is necessary to analyze the derivate—waste from the wood industry—to adapt it to the manufacture of products made from eucalyptus wood, especially for furniture.

According to de Souza et al. (2009) and Pereira et al. (2010), several investigations have been carried out on the use of eucalyptus wood waste in the furniture industry, some of them focused on the production of glued wood sheets, joining small pieces in different positions, thus generating varied aesthetic results and ensuring resistance and functionality. Other studies have tested the resistance of the glue sheet with different types of adhesives (Cressoni 2011, Alves 2012, Silva 2013) and provide information to be used in eucalyptus wood derivates.

The use of glued wood gains relevance when its transformation turns it into a product of greater added value, achieving a greater use of the raw material. The adoption of appropriate processing technologies for the gluing of wood makes it possible to obtain a homogeneous material with good dimensional stability (Motta et al. 2012). It also allows the reconstitution of wood with larger dimensions and better distribution of mechanical strength, with gains in quality and a better cost–benefit ratio, by reducing limitations related to anisotropy, size, and natural defects to which solid wood products are subject (Iwakiri 2005).

Some factors can influence the gluing of wood, such as the type of adhesive, curing time, and pressing pressure (do Nascimento et al. 2013). Much of the success of glued products is related to the type of adhesive used, as it is responsible for providing strength, stability, and durability (Bianche et al. 2017). However, in addition to analyzing the type of adhesive, studies have been conducted that relate it to other variables, such as adhesives and part layout (Iwakiri et al. 2000); adhesive and pressure (Luz et al. 2011); wood types, adhesives, and humidity (Motta et al. 2012); the quantity of extractive agents and the position of the wood in the trunk (Albino et al. 2012); adhesives and the forest management system (Plaster et al. 2012); the density and quantity of adhesive applied (Boa et al. 2014); and types of wood and the quantity of adhesive applied (Bila 2014). In all cases, shear strength and failure rate of the wood were considered, taking into account the recommendations of international standards for such studies. Follrich et al. (2007) indicated that the mechanical balance of glued joints is also influenced by the surface of the wood, especially by surface roughness, after machining, to receive the adhesive. According to the Alves (2012) study, it was found that for wood surfaces with less roughness, higher shear strength values were obtained.

Other studies conducted by Iwakiri et al. (2013, 2015), Boa et al. (2014), Motta et al. (2014), Segundinho et al. (2015), Gonçalves et al. (2016), and Bianche et al. (2017) to test the shear strength of glue sheeting, using native and planted forest woods, with various types of adhesives, show a range of mechanical shear strength between 4.09 and 13.66 MPa. These studies are presented to demonstrate that the resistance values found for the *Eucalyptus urograndis* clone are of the same order, although there are specificities in each particular study as well as different variables considered.

What these studies do not show is the time elapsed between the manufacture and the rupture of the test bodies; in the case of this study, a year was allowed to elapse to observe the behavior of the glue as it would happen with the use in furniture.

Taking into account the use of eucalyptus wood, the objective of this work was to analyze the behavior of the surface finish and pressing time of glued wood for the production of furniture to make use of the waste treated as a by-product.

Materials and Methods

This research used wood from clonal hybrid *Eucalyptus urophylla* × *Eucalyptus grandis* with 12 percent moisture content from crops in southern Bahia state, supplied by a distributor in the metropolitan region of Salvador. The test specimen was manufactured following the recommendations of the Brazilian standard ABNT-NBR 7190 (Associação Brasileira de Normas Técnicas [ABNT] 1997). The test specimen was made to test three types of wood surface finish and three pressing times. The types of finishes listed in this study refer to surfaces that are only sawn (unfinished), sanded with 60- and 200-grit sandpaper. For each type of finish of the bonded surfaces, parts were pressed at a pressure of 9 MPa for 12-, 18-, and 24-hour periods.

To obtain the test specimen, pieces of wood boards were randomly selected, as in the production process of wooden furniture, from a batch of approximately 12 m^3, some of which were cut 20 mm thick, 50 mm wide, and 50 mm high and others 30 mm thick, 50 mm wide, and 64 mm high. These pieces were glued to produce the test specimen for shear test on the glue sheet, according to the specifications of the ABNT-NBR 7190 standard (ABNT 1997), according to the model in Figure 1.

Keeping in mind that the selection of the pieces for the elaboration of the test specimen was random, the density of the wood can vary as it occurs in the production process of the furniture. Twelve test specimens were made for each type of surface finish and pressing time, obtaining a total of 108 test specimens, according to Table 1.

Precatalyzed polyvinyl acetate emulsion mono component (PVA) cross-linking adhesive, called Multibond EZ-1, has been used as a recommended adhesive for bonding wood on high-frequency hot and cold presses, allowing moisture-resistant adhesion according to the product manufacturer's technical bulletin (Franklin Adhesives and Polimers, S/D). This adhesive, according to the same bulletin, is fast drying, has a light-colored glue line, and has a high percentage of solids (47% to 50%), stable viscosity (3,000 to 4,000 cps) and a pH between 2.0 and 3.0.

The test specimen was pressed the same day to ensure the same room temperature and relative humidity. Later, they were left in the lumberyard for 1 year without any control of ambient temperature and relative humidity in order to simulate the behavior of wooden furniture during its use.

Other variables, such as the number of extractives, the position of the wood in the trunk, the density of the wood, and other types of adhesives, were not the focus of this study due to the characteristics of the furniture manufacturing companies.

The performance of the test specimen was evaluated by the analysis of the shear strength of the glue sheeting parallel to the wood fibers according to ABNT-NBR 7190 (ABNT 1997), with increasing monotonic charge at a rate of

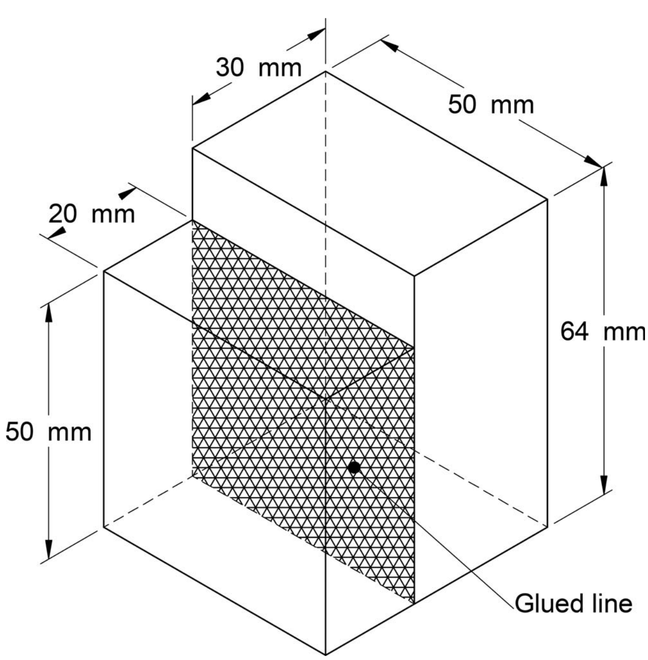

Figure 1.—Dimension of test specimen according to standard NBR 7190 (Associação Brasileira de Normas Técnicas 1997).

Table 1.—Number of test specimens per type of finish and pressing time.

Number of test specimens	Type of finish (grit)	Pressing time (h)
12	Barely sawn (without sanding)	12
12	Barely sawn (without sanding)	18
12	Barely sawn (without sanding)	24
12	Sandpaper (60)	12
12	Sandpaper (60)	18
12	Sandpaper (60)	24
12	Sandpaper (200)	12
12	Sandpaper (200)	18
12	Sandpaper (200)	24

2.5 MPa/min, as shown in Figure 2. Figure 2a presents a general view of the test specimen on the testing machine. Figure 2b presents details of the test specimen positioned before the test. Figure 2c presents details of the destroyed test specimen after the test. The equipment used in the tests was the universal testing machine INSTRON model 1000HDX-C4-G7C with a 1,000-KN capacity.

In addition to the glue shear test and to complement the analysis, a visual observation of the failure rates of the wood was made in accordance with D5266-99—Standard practice for estimating the percentage of wood failure in adhesive bonded joints (American Society for Testing and Materials 2000). This standard describes the technique of measuring areas of wood failure, which, according to Abrahão et al. (2003), consists of a subjective assessment. The failure rates in the wood are measured with the help of transparent square films with a percentage-delimited area. In this study, the failure rate of the wood was obtained visually through transparent square films divided into 25 spaces of 10 by 10 mm, each space corresponding to 4 percent of the surface of the adhered area.

To determine the shear strength and average failure rate of the wood, each data set was collected and then subjected to statistical analysis. The statistical delineation was entirely randomized in the factorial scheme (3 by 3), having the surface finish of the glued surfaces with three levels (without sandpaper, 60-grit sandpaper, and 200-grit sandpaper) and the pressing time with three levels (12, 18, and 24 hours), totaling nine treatments with 12 repetitions each. The results were subjected to analysis of variance for identification of significant difference between the proposed variables and the Tukey test for comparison of averages. All evaluations were performed with the statistical software Action stat3 at 95 percent probability.

Results and Discussion

At this point, the shear strength values of the glue sheet and the failure rates obtained in the tested test bodies 1 year after its production are presented in order to compare with results presented by other authors. Table 2 shows the average shear strength values parallel to the compression fibers in the glue sheeting and the failure rates in the wood for glued joints made of *E. urograndis* wood.

According to the Tukey test, there is a significant difference between the treatment with 200-grit sandpaper with 12 hours of pressing time and the other treatments. There is also a significant difference between treatments 0-24, 60-24, and 200-12, while between treatments 0-12, 0-18,

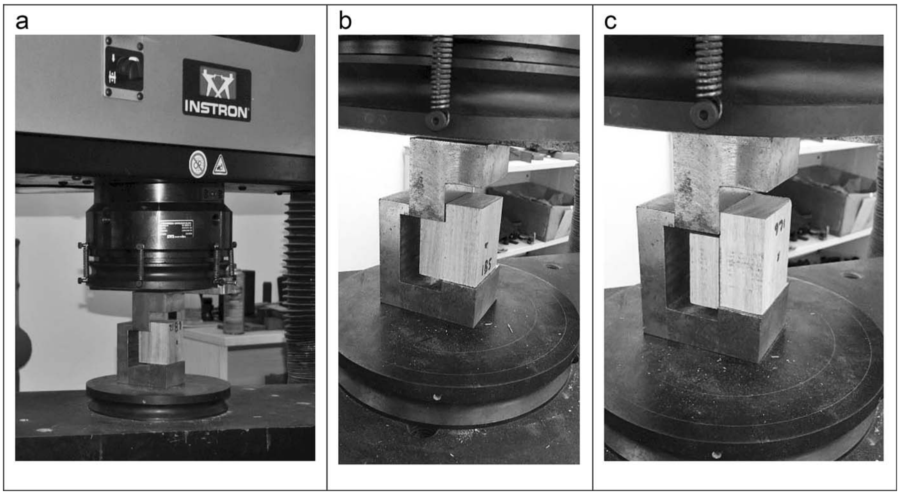

Figure 2.—Test specimen in the test press: (a) general view of the test specimen on the testing machine, (b) detail of the test specimen positioned before the test, and (c) detail of the destroyed test specimen after the test.

Table 2.—Results of shear tests.[a]

Treatment (grit)	Pressing time (h)	Shear strength (MPa)	Coefficient of variation	Standard deviation	Wood failure (%)
Sandpaper (200)	12	5.15 C	42.77	2.20	10.17
Sandpaper (200)	18	9.91 AB	44.27	4.39	14.33
Sandpaper (200)	24	9.92 AB	37.18	3.69	6.58
Sandpaper (60)	12	8.80 B	13.55	1.19	7.50
Sandpaper (60)	18	9.98 AB	15.31	1.53	17.08
Sandpaper (60)	24	11.47 AB	24.66	2.83	7.58
No sandpaper	12	12.34 AB	17.98	2.22	14.17
No sandpaper	18	11.29 AB	29.97	3.38	21.75
No sandpaper	24	13.36 A	13.85	1.85	9.58

[a] Averages followed by the same letter are statistically the same by the Tukey test at 95 percent probability.

60-12, 60-18, 60-24, 200-18, and 200-24, there is no significant difference. This means that, taking into account production costs, the best alternative is 0-12, without sanding and the shortest pressing time (12 hours).

In the results found in Table 2, it is evident that the lowest average value of shear strength was in the test specimen with 200 sandpaper, in contrast to the results presented by Alves (2012), which obtained the highest resistance value shear using 220-grit sandpaper. In addition, for the group of test specimens with 200-grit sandpaper, the highest coefficients of variation and the highest standard deviation were also found, which means that this group had the worst performance. This can be attributed to the fact that the less rough the surface, the less glue penetrates into the fibers of the wood.

Figure 3 shows the results of shear strength in the glue sheeting for the different factors studied.

The test bodies whose faces were only sawn without sanding and with the longest pressing time (24 hours) have the best shear strength behavior (13.36 MPa), and the lowest average value (5.15 MPa) was obtained for joints glued with surface finish with 200-grit sandpaper and a pressing time of 12 hours, showing that greater roughness in the wood and high pressing time improve the quality of the adhesion.

The test bodies without sanding, although they broke in the glue sheet, had higher mechanical strength than the

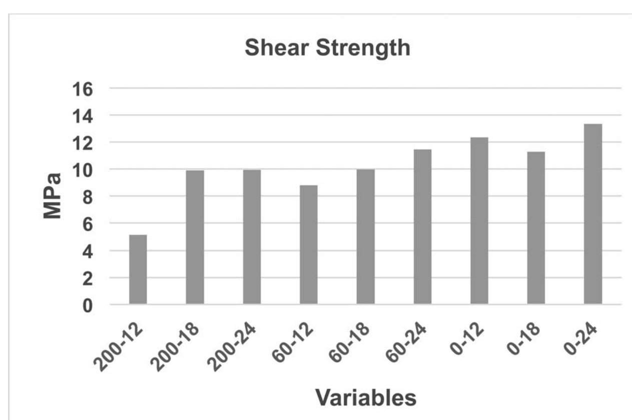

Figure 3.—Shearing in the glue line of the specimens with three surface finishes and three pressing times. 200-12: 200-grit sandpaper with 12 hours pressing time; 200-18: 200-grit sandpaper with 18 hours pressing time; 200-24: 200-grit sandpaper with 24 hours pressing time; 60-12: 60-grit sandpaper with 12 hours pressing time; 60-18: 60-grit sandpaper with 18 hours pressing time; 60-24: 60-grit sandpaper with 24 hours pressing time; 0-12: barely sawn (without sanding) with 12 hours pressing time; 0-18: barely sawn (without sanding) with 18 hours pressing time; 0-24: barely sawn (without sanding) with 24 hours pressing time.

values found in the literature regarding shear tests in the glue sheet. The studies that used eucalyptus wood and PVA adhesive obtained lower shear strength results, as presented in Lima et al. (2008). In the latter study, the best average shear rupture in the tail plate for these clones, using PVA, was 7.94 MPa. Iwakiri et al. (2013) presents a maximum of 9.44 MPa, and Bianche et al. (2017) found 7.23 MPa.

Figure 4 shows the failure rate values in the wood. Test bodies with a pressing time of 18 hours had the highest percentage of wood failure. On the other hand, test bodies with a 24-hour pressing time had the lowest failure rate values for wood.

The failure rate for all three types of finish is higher for the press time of 18 hours; however, the more polished the bonding surface, the lower the failure rate for the press time of 18 and 24 hours.

Both the shear strength and the average failure rate of the wood present the best results without the application of sandpaper on the faces to be glued. However, the highest percentage of failure in the wood was given for the pressing time of 18 hours.

Another finding of this work is that there is no direct relationship between surface finish and failure rate in wood.

The higher shear strength of the glue sheet was verified with a pressing time of 24 hours for parts with a sawn-only surface without sanding application.

Although shear strength results for glue shear strength vary in the range of 5.15 to 13.36 MPa, these are within the line of values accepted by the furniture industry for glued joint strength. This means that, in the production process in the manufacture of glued pieces for furniture, it is recommended to use the most economical gluing given by finishing without sandpaper and 12 hours of pressing with resistance to shearing of 12.34 MPa so as not to incur unnecessary production costs due to manufacturing times and material costs.

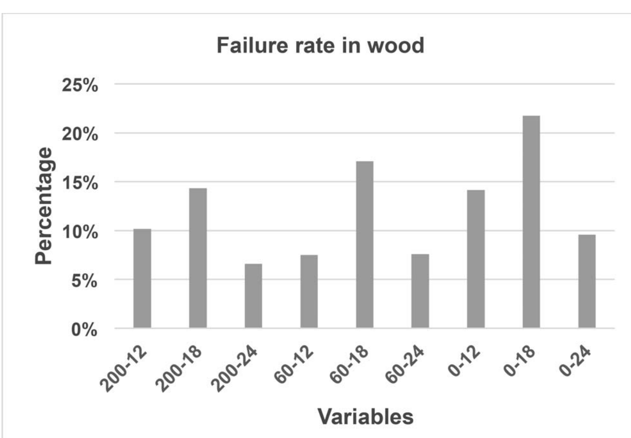

Figure 4.—Failure rates of wood test pieces with three surface finishes and three pressing times. 200-12: 200-grit sandpaper with 12 hours pressing time; 200-18: 200-grit sandpaper with 18 hours pressing time; 200-24: 200-grit sandpaper with 24 hours pressing time; 60-12: 60-grit sandpaper with 12 hours pressing time; 60-18: 60-grit sandpaper with 18 hours pressing time; 60-24: 60-grit sandpaper with 24 hours pressing time; 0-12: barely sawn (without sanding) with 12 hours pressing time; 0-18: barely sawn (without sanding) with 18 hours pressing time; 0-24: barely sawn (without sanding) with 24 hours pressing time.

Conclusions

When observing the results of the tests carried out in this work, it is found that the shear strength of the test specimen and the quality of the adhesion are in accordance with the literature, being in the same range obtained in previous studies but with better performance. In this investigation, it was also possible to evaluate the variables in the rupture of the test specimen 1 year after being manufactured, allowing one to determine that they are within the limits allowed for the production of wood furniture.

The highest averages of shear strength were presented by test bodies without surface finish.

The high superficial roughness allows a greater penetration by the adhesive, creating a greater adherence and, in the case of the productive process of wood furniture, does not add costs for the sanding of the surfaces before being glued.

The use of *E. urograndis* clone residues is shown as a suitable material for the manufacture of products in the furniture industry since the shear strength and adhesion quality were satisfactory.

The treatment with 60- and 200-grit sandpaper on the surfaces to be adhered with PVA does not contribute to the increase of mechanical resistance in the glue sheet when compared with unfinished surfaces.

The highest values for wood failure percentages were given by the test bodies with pressing times of 18 hours.

The results presented in this article can be used in the wood industry to manufacture products made from wood waste treated as by-products.

Literature Cited

Abrahão, C. P., C. A. Varella, F. D. Pinto, and J. K. Khoury, Jr. 2003. Quantification of wood failure in bonded joints using artificial vision techniques. *Rev. Árvore* 27(1):71–78. (In Portuguese.) http://doi.org/10.1590/S0100-67622003000100010

Acosta, M. M. S. 2012. Characterization of the wood of the new hybrid *Eucalyptus grandis*, Hill ex Maiden × *Eucalyptus tereticornis*, Smith, its aptitude for uses in Argentina. PhD thesis. University of Valladolid, Spain. (In Spanish.)

Albino, V. C., S. Do, F. A. Mori, and L. M. Mendes. 2012. Influence of anatomical characteristics and total extractive content of eucalyptus wood Grandis W. Hill ex maiden on bonding quality. *Cienc. Florestal* 22(4):803–811. (In Portuguese.)

Alves, P. R. G. 2012. Strength of the glue line on sanded surfaces of eucalyptus wood. Master's thesis. Universidade Estadual Paulista, Guaratinguetá, Brazil. (In Portuguese.)

American Society for Testing and Materials (ASTM). 2000. Standard practice for estimating the percentage of wood failure in adhesive bonded joints. ASTM D5266-99. *In:* Annual Book of ASTM Standards. ASTM, Philadelphia. http://doi.org/10.1520/C1530_C1530M-04R10E01

Associação Brasileira de Normas Técnicas (ABNT). 1997. NBR 7190. Design of wooden structures. ABNT, Rio de Janeiro. (In Portuguese.)

Bianche, J. J., A. P. M. Teixeira, J. P. S. Ladeira, A. D. C. O. Carneiro, R. V. O. Castro, and R. M. D. Lucia. 2017. Shearing in the cola line of *Eucalyptus* sp glued with different adhesives and different weights. *Floresta Ambiente* 24:e00077114:1–9. (In Portuguese.)

Bila, N. F. 2014. Evaluation of the quality of bonded joints of six species of tropical timber from the Amazon. Master's thesis. Universidade Federal do Paraná, Curitiba, Brazil. (In Portuguese.)

Boa, A. C., F. G. Gonçalves, J. T. Da Silva Oliveira, J. B. Paes, and M. D. C. Arantes. 2014. Eucalypt wood residues bonded with urea formaldehyde resin at room temperature. *Sci. Forestalis* 42(102):279–288. (In Portuguese.)

Brazilian Tree Industry. 2015. IBÁ Statistical Yearbook: Base Year 2014. Brazilian Tree Industry, Brasilia. (In Portuguese.)
Brazilian Tree Industry. 2017. IBÁ Statistical Yearbook: Base Year 2016. Brazilian Tree Industry, Brasilia. (In Portuguese.)
Centro Nacional de Tecnologias Limpas. 2003. Implementation of Cleaner Production Programs. Centro Nacional de Tecnologias Limpas, Porto Alegre, Brazil. (In Portuguese.)
Cervantes, G. 2012. Industrial ecology: Innovation and sustainable development in industrial systems. *Sostenibilidad Tecnol. Hum*. 58–78. (In Spanish.)
Cressoni, A. 2011. Mechanical resistance of bonded joints in *Eucalyptus* sp. PhD thesis. Universidade Estadual Paulista, Guaratinguetá, Brazil. (In Portuguese.)
de Souza, M. O. A., J. D. C. Silva, R. M. D. Lucia, and W. V. Evangelista. 2009. Evaluation of wood of *Eucalyptus camaldulensis* Dehnh e *Eucalyptus urophylla* S.T. Blake in machining tests, aiming the furniture production. *Rev. Arvore* 33(4):751–758. (In Portuguese.)
Dias Júnior, A. F., P. V. Santos, J. H. C. Pace, A. M. Carvalho, and J. V. F. Latorraca. 2013. Characterization of the wood of four forest species for use in furniture. *Rev. Cienc. Madeira* 4(1):93–107. (In Portuguese.) http://doi.org/10.12953/2177-6830.v04n01a08
do Nascimento, A. M., R. A. Garcia, and R. M. Della Lucia. 2013. Adhesion quality of bonded joints of different commercial wood species. *Cerne* 19(4):593–601. (In Portuguese.)
Ferreira, A. R., D. D. M. Joao, and L. P. Godoy. 2008. The use of the raw material eucalyptus in the furniture industry as a strategy for sustainable development. *In:* IV National Congress of Management Excellence; Federal University of Rio de Janeiro, Brazil. (In Portuguese.)
Follrich, J., Teischinger, A., Gindl, W., and Müller, U. 2007. Effect of grain angle on shear strength of glued end grain to flat grain joints of defect-free softwood timber. *Wood Sci. Technol*. 41(6):501–509. http://doi.org/10.1007/s00226-007-0136-7
Galinari, R., J. R. T. Junior, and R. R. Morgado. 2012. The competitiveness of the Brazilian furniture industry: Current situation and perspectives. *BNDES Sectorial* 37:227–272. (In Portuguese.)
Gonçalves, F. G., P. G. A. Segundinho, L. F. Schayder, V. P. Tinti, and S. B. Santiago. 2016. Evaluation of the shear strength of *Pinus* sp. glued to ambient temperature. *Rev. Cienc. Madeira* 7(1):42–50. (In Portuguese.) http://doi.org/10.12953/2177-6830/rcm.v7n1p42-50
Gutierrez, C. M., R. Panameño, A. P. Velazquez, B. E. A. Alvarez, A. Kiperstok, and S. F. César. 2017. Cleaner production applied in a small furniture industry in Brazil: Addressing focused changes in design to reduce waste. *Sustainability* 9(10):17. http://doi.org/10.3390/su9101867
Iwakiri, S. 2005. Wood Panels. Paraná Forest Research Foundation (FUPEF), Curitiba, Paraná, Brazil. (In Portuguese.)
Iwakiri, S., C. R. Da Cruz, D. Olandoski, and M. Brand. 2000. Use of sawmill waste in the production of agglomerated wood panels of *Eucalyptus saligna*, *Eucalyptus citriadora* and *Eucalyptus pilularis*. *Floresta Ambiente* 7(1):251–256. (In Portuguese.)
Iwakiri, S., R. Trianoski, A. B. Da Cunha, J. G. Prata, M. Hara, N. F. Bila, and B. T. V. Bôas. 2013. Evaluation of bond strength of *Eucalyptus benthamii* wood with different adhesives and bonding faces. *Sci. Forestalis* 41(99):411–416. (In Portuguese.)
Iwakiri, S., R. Trianoski, R. F. França, T. A. Pereira Gonçalves, P. L. Loiola, S. R. Campelo, and S. M. De Araújo Pontes Farias. 2015. Evaluation of bond strength of the wood of *Cryptomeria japonica* and *Sequoia sempervirens* with different adhesives. *Sci. Forestalis* 43(105):19–26. (In Portuguese.)
Koch, M. R. 2012. Solid waste management of a lumber and furniture industry—A look at sustainability. Master's thesis. Univates, Lajeado, Brazil. (In Portuguese.)
Lima, C. K. P., F. A. Mori, L. M. Mendes, P. F. Trugilho, and C. L. S. De Oliveira Mori. 2008. Collage of wood from Eucalyptus clones with three commercial adhesives. *Sci. Forestalis* 36(77):73–77. (In Portuguese.)
Luz, S., P. P. Barbosa, H. Borges, F. Cesarr, and C. H. Martins. 2011. Wood industry residues. *In:* VII International Meeting of Scientific Production, CESUMAR (Ed.), October 25–28, 2011, Maringá, Paraná, Brazil; Directorate of Research of the University Center of Maringá, Brazil. pp. 1–5. (In Portuguese.)
Motta, J. P., J. T. S. Oliveira, and R. C. Alves. 2012. Influence of moisture content on the adhesion properties of eucalyptus wood. *Construindo* 4(2):9. (In Portuguese.) http://doi.org/10.13140/RG.2.1.1567.6967
Motta, J. P., J. T. D. S. Oliveira, J. B. Paes, R. C. Alves, and G. B. Vidaurre. 2014. Evaluation of the shear strength of joints glued with teak wood (*Tectona grandis*). *Sci. Forestalis* 42(104):615–621. (In Portuguese.)
Movergs. 2015. Sector Report 2015 Furniture Cluster of Rio Grande do Sul. Movergs, Porto Alegre, Brazil. (In Portuguese.)
Müller, B. V. 2013. Effect of deforestation systems on the quality and yield of sawn wood of *Eucalyptus benthamii* Maiden et Cambage. Master's thesis. Universidade Federal do Paraná, Brazil. (In Portuguese.)
Nolasco, A., L. Rodrigues, and M. Cerca. 2013. Waste management in wood flooring industries. Technical Course. International Tropical Timber Organization, Piracicaba, São Paulo, Brazil. (In Portuguese.)
Pereira, A. F., L. D. S. C. Carvalho, and A. C. D. O. Pinto. 2010. Residual wood: Limits and possibilities of its use as an alternative raw material. *In:* 9th Brazilian Congress of Research and Development in Design, October 13–16, 2010, São Paulo, Brazil; University Anhembi Morumbi, São Paulo, Brazil. pp. 1–11. (In Portuguese.)
Plaster, O. B., J. T. D. S. Oliveira, F. G. Gonçalves, and J. P. Motta. 2012. Behavior of wood adhesion of a clonal hybrid of *Eucalyptus urophylla* × *Eucalyptus grandis* from three management conditions. *Cienc. Florestal* 22(2):323–330. (In Portuguese.)
Schneider, V. E., É. Hillig, E. T. Pavoni, M. R. Rizzon, and L. A. Bertotto. 2003. Environmental management in the furniture industry—A case study in the municipality of Bento Gonçalves. *In:* XXIII National Meeting of Production Engineering (ENEGEP), October 21–24, 2003, Ouro Preto, Brazil; Brazilian Association of Production Engineering, Rio de Janeiro. pp. 1–7. (In Portuguese.)
Segundinho, P. G. D. A., C. C. Neto, F. G. Gonçalves, A. J. Regazzi, and C. C. Junior. 2015. Strength of glue lines for reforestation woods. *Semina Ciênc. Exatas Tecnol*. 36(1):107–116. (In Portuguese.) http://doi.org/10.5433/1679-0375.2015v36n1p107
Silva, J. D. C., V. R. De Castro, and W. V. Evangelista. 2015. Influence of age on wood machinability of *Eucalyptus grandis* Hill ex. Maiden, for use in the furniture industry. *Sci. Forestalis* 43(105):1–8. (In Portuguese.)
Silva, R. S. 2013. Mechanical resistance of eucalyptus saligna wood joined by polyurethane adhesive for different surface finishes. Master's thesis. Universidade Estadual Paulista, Guaratinguetá, Brazil. (In Portuguese.)
Teixeira, M. and S. F. César. 2006. Production of composite with wood waste in the context of industrial ecology. *In:* 10th Brazilian Meeting on Timber and Structures – EBRAMEM, July 30–August 2, 2006, São Pedro, São Paulo, Brazil; Ibramem, São Carlos, São Paulo, Brazil. pp. 1–15. (In Portuguese.)
Teixeira, T. D. O. B., M. L. Da Silva, L. A. G. Jacovine, S. R. Valverde, J. D. C. Silva, and V. A. V. Pires. 2009. The perception on the use of eucalyptus wood by manufacturers of the Ubá-Mg furniture cluster. *Rev. Árvore* 33(5). (In Portuguese.) http://doi.org/10.1590/S0100-67622009000500019