EVALUATIOM OF PHYSICAL AND MECHANICAL PROPERTIES OF PARTICLEBOARD PRODUCED FROM WOOD OF *Cupressus torulosa* IN MIXTURE WITH *Pinus taeda*

Setsuo Iwakiri[1*], Rosilani Trianoski[1], Amanda Leite da Silva[2], Angela Maria Stüpp[2], Bruna Mulinari Cabral[2], Helena Cristina Vieira[2]

[1*]Federal University of Paraná, Department of Forest Engineering and Technology, Curitiba, Paraná, Brazil – e-mail: setsuo.ufpr@gmail.com, rosillani@gmail.com
[2]Federal University of Paraná, Graduate Program in Forest Engineering, Curitiba, Paraná, Brazil – e-mail: eng.amandaleite@gmail.com; angela.stupp@hotmail.com; brunacabral@florestal.eng.br; lenacristin@hotmail.com

Received for publication: 02/10/2018 – Accepted for publication: 24/04/2020

Resumo

Avaliação das propriedades físicas e mecânicas de painéis aglomerados produzidos com madeira de Cupressus torulosa em mistura com Pinus taeda. O objetivo deste trabalho foi avaliar as propriedades físicas e mecânicas de painéis aglomerados produzidos com 100% de madeira de *Cupressus torulosa* D. Don., e diferentes proporções de mistura com *Pinus taeda* L. Os painéis experimentais foram produzidos com partículas de madeiras de *Cupressus torulosa/Pinus taeda*, nas proporções de 100/0%, 80/20%, 60/40%, 40/60%, 20/80% e 0/100%, totalizando seis tratamentos. Os painéis foram produzidos com densidade nominal de 0,75 g/cm³, 8% de resina ureia-formaldeído e 1% de emulsão de parafina. Foram realizados os ensaios de absorção de água e inchamento em espessura 2 e 24 horas, flexão estática (MOE e MOR), tração perpendicular (ligação interna) e arrancamento de parafuso. As avaliações comparativas dos resultados desta pesquisa com o *Pinus taeda*, outras espécies referenciadas na literatura, e requisitos normativos da EN 312-2003 para painéis comerciais, indicaram grande potencial da madeira de *Cupressus torulosa* para produção de painéis aglomerados.
Palavras-chave: espécies de rápido crescimento; prensagem de painéis; resina ureia-formaldeído.

Abstract

The objective of this work was to evaluate the quality of particleboard produced with 100% of wood of *Cupressus torulosa* and in different mixing proportions with *Pinus taeda*. The experimental panels were produced with wood particles of *Cupressus torulosa/Pinus taeda*, in proportions of 100/0%, 80/20%, 60/40%, 40/60%, 20/80% and 0/100%, totaling six treatments. The panels were produced with nominal density of 0.75g/cm³, 8% urea-formaldehyde resin and 1% paraffin emulsion. The quality of the panels was evaluated by water absorption and swelling thickness 2 and 24 hours, static bending (MOE and MOR), perpendicular tension (internal bonding) and screw withdrawal. The comparative evaluations of the results of this research, with the *Pinus taeda*, others species referenced in the literature, and normative requirements of EN 312-2003 for commercial panels, indicated great potential of the wood of *Cupressus torulosa* for the particleboard production.
Keywords: fast growing species; board pressing; urea-formaldehyde resin.

INTRODUCTION

The main source of raw material for the particleboard industries in Brazil comes from the planted forests of *Pinus* and *Eucalyptus*. Due to the high demand for wood from the pulp and paper industries, wood panels and sawmills, there is a need for studies on fast-growing alternative species for the formation of production forests for the supply of industrial raw materials.

In the last decades, studies have been conducted by several researchers on technological evaluations of wood of alternative species of fast growth aiming its use for the production of wood panels, such as *Acrocarpus fraxinifolius* Wight & Arn., *Toona ciliata* M. Roem. and *Melia azedarach* L. (TRIANOSKI *et al*., 2011); *Schizolobium amazonicum* e *Sida* sp. (BIANCHE *et al*., 2012) *Cryptomeria japonica* (L) Don. (TRIANOSKI *et al*., 2013); *Eucalyptus urophylla* (NAUMANN *et al*., 2008); *Sequoia sempervirens* (D. Don) Endl. (IWAKIRI, *et al*., 2014); *Cecropia pachystachya* (MARTINS *et al*., 2014) ; *Grevillea robusta* A. Cunn (TRIANOSKI *et al*., 2016); *Schizolobium amazonicum* and *Cecropia* sp. (ZELLER *et al.*, 2013). The results obtained by these researchers indicated the feasibility of using 100% of these species or in a mixture with *Pinus* woods for the production of particleboards.

The genus *Cupressus* is classified as a conifer, being known as Himalayan cypress trees, naturally occurring in southwest China, northeast India and Nepal. Its wood, extracted from some small-scale or experimental plantations, is used in Kenya; as a fuel source in Guatemala; for pulp production in Venezuela (OKINO *et al.,* 2005). Experimental plantations in Brazil have shown good growth rates and, due to their low density wood, from 0.40 to 0.57 g/cm^3 (OKINO *et al.,* 2010), it has great potential as a raw material for the paper and cellulose, laminated and plywood industries, in addition to particle and fiber boards (MALONEY, 1993). Specifically in the reconstituted panel industry, the application of species of this genus has shown technical feasibility in the production of OSB panels (OKINO *et al.*, 2008) and side bonding panels (ALMEIDA, 2017).

The selection of wood species for the production of particleboard must be based on some parameters such as density, pH and extractives (MOSLEMI, 1974; MALONEY, 1993).

The density of wood is one of the basic requirements when choosing species for the production of particleboard, due to its influence on the compaction ratio, which is the relationship between the density of the panel and the density of the wood. According to Moslemi (1974) and Maloney (1993), the compaction ratio must be at least 1.3 to ensure an adequate contact area between the particles and sufficient densification for the formation of the panel.

Moslemi (1974) states that, for panels of the same nominal density, produced with low-density wood particles, their mechanical properties will be superior; however, their dimensional stability will be inferior in comparison to panels produced with high-density wood. According to the author, in panels with a higher compaction ratio, there is a greater amount of wood particles, resulting in a greater water absorption surface and less adhesive in the interfaces between the particles for bonding, contributing to greater swelling in the thickness of the panels. Another important factor is related to the higher densification and compacting of the panel, resulting in the release of higher compression stresses generated during the high temperature pressing process. Guimarães Junior *et al.* (2016) corroborate these statements, reporting that as there was inclusion of material of lower density in particleboard of *Eucalyptus urophylla*, increased water absorption and reduced mechanical properties were observed, facts attributed mainly to the lower availability of resin in the particles.

Regarding chemical properties, Maloney (1993) states that pH and extractives can directly influence the curing of the resin and, consequently, the quality of the panels produced, with values ranging from 3.0 to 5.5. According to the same author, wood with a very acidic pH can cause the urea-formaldehyde resin to pre-cure during the press closure phase, impairing the degree of adhesion between the particles and reducing the values of the mechanical properties of the panels. On the other hand, wood with a low acid pH requires a slightly higher amount of catalyst to accelerate the curing of urea-formaldehyde resin. As for the influence of extractives on the polymerization and curing of the adhesive, Moslemi (1974) states that wood with high levels of extracts presents difficulties in bonding resulting in low resistance of the adhesive bond between the particles. Rios *et al.* (2016) also report that a high amount of extractives interferes with the adhesive's curing time, in addition to increasing the propensity of the particleboards to occur bubbles.

In view of the above, this research was conducted with the objective of evaluating the potential use of *Cupressus torulosa* wood, in different proportions of mixture with *Pinus taeda*, for the production of particleboards.

MATERIALS AND METHODS

The wood of *Cupressus torulosa* D. Don was obtained from an experimental plantation at UFPR located in the city of Rio Negro – PR, with 23 years old. Five trees were collected, which were cut into 2.0 m logs and transported to the study site. *Pinus taeda* wood was purchased in the form of planks from local businesses. The resin used was urea-formaldehyde, supplied by a manufacturer in the metropolitan region of Curitiba-PR, viscosity of 430, solids content of 65.5% and pH of 7.8. The catalyst employed was ammonium sulfate.

The logs were processed on boards of 25 x 200 x 2,000 mm (thickness x width x length), for generating particles in a disc chipper, with the nominal dimensions of 25 mm in length, 0.7 mm in thickness and variable width. From the boards, samples were obtained to determine the basic specific masses of the wood of the species under study and the control, in addition to the compaction ratio. The average wood densities of two species in different mixing proportions were calculated based on the methodology proposed by Moslemi (1977).

After drying at an average moisture content of 3%, the particles were reprocessed in the hammer mill to reduce the dimensions and classified in a 0.6 mesh sieve to remove "fines". Next, the particles were glued with 8% urea-formaldehyde resin, 1% paraffin emulsion and pressed at temperature of 140ºC, specific pressure of 4 MPa and pressing time of 8 minutes. The panels were produced with a nominal density of 0.75 g/cm^3 and nominal dimensions of 500 mm (length), 380 mm (width) and 13 mm (thickness).

Particleboards were produced with the wood of *Cupressus torulosa* and *Pinus taeda* (control), in different mixing proportions, according to the experimental design presented in table 1. Three panels were produced per treatment, making 18 panels.

Table 1. Experimental chart.
Tabela 1. Delineamento experimental.

Treatment	**Panel composition – mix of species**
T1 – Cu100	100% *Cupressus torulosa*
T2 – Cu80/Pi20	80% *Cupressus torulosa* x 20% *Pinus taeda*
T3 – Cu60/Pi40	60% *Cupressus torulosa* x 40% *Pinus taeda*
T4 – Cu40/Pi60	40% *Cupressus torulosa* x 60% *Pinus taeda*
T5 – Cu20/Pi/80	20% *Cupressus torulosa* x 80% *Pinus taeda*
T6 – Pi100	100% *Pinus taeda*

After pressing, the panels were square and placed in a climatic chamber with a temperature of 20 ± 2ºC and a relative humidity of 65 ± 3%, until their stabilization at an average moisture content of 12%.

To assess the physical-mechanical properties, five specimens were removed from each panel for each of the following tests: apparent specific mass, thickness swelling and water absorption after 2 and 24 hours of immersion, static bending, perpendicular traction, screw withdrawal resistance on the face and top. The tests were based on the procedures described in the standards EN 323 (1993), EN 317 (1993), EN 310 (1993), EN 319 (1993), EN 317 (1993) and NBR 14810-2 (2018), respectively.

The statistical analysis was performed based on a completely randomized design, and the results were evaluated using the Grubbs test for outliers, Shapiro Wilk test for normality, Bartlett test for homogeneity of variances and analysis of variance. As a statistically significant difference was found between specific masses, covariance analysis was applied to eliminate the effect of this variable on the other panel properties. Tukey's test at 95% significance was used to compare means, and all analyzes were performed using the Statgraphics statistical package.

RESULTS

Physical properties of the panels

The average values of basic density of wood varied from 0.440 g/cm^3 for *Pinus taeda* and 0.459 g/cm^3 for *Cupressus torulosa* (Table 2). The average values of density of the panels were all lower than the established nominal value of 0.75 g/cm^3 and the panels produced with 100% *Cupressus torulosa* wood were statistically lighter than the other types of panels. The compression ratio of all types of panels was between 1.501 and 1.666, and increased with the increase in the proportion of *Pinus taeda* in the panel.

Table 2. Average values of the densities and compaction ratio.
Tabela 2. Valores médios de massas específicas aparentes da madeira, painel e razão de compactação.

Treatment	**BD wood (g/cm³)**	**D panel (g/cm³)**	**Compaction ratio**
T1 – Cu100	0.459	0.689 (5.13) b	1.501 (5.13) d
T2 – Cu80/Pi20	0.455	0.713 (4.83) a	1.566 (4.82) c
T3 – Cu60/Pi40	0.451	0.716 (5.24) a	1.588 (5.23) bc
T4 – Cu40/Pi60	0.448	0.715 (5.74) a	1.595 (5.74) bc
T5 – Cu20/Pi/80	0.444	0.721 (6.91) a	1.624 (6.88) ab
T6 – Pi100	0.440	0.733 (5.82) a	1.666 (5.82) a

BD: basic density of wood; D: density; Averages followed by the same letter do not differ statistically at the level of probability of 95% by Tukey's test; values in parentheses correspond to the variation coefficient (%).

The average values of water absorption after 2 hours of immersion ranged from 9.87% to 12.82%, with the means being statistically different between treatments (Table 3). The panels produced with mixtures of cupressus and pine in the proportions of 20%/80%, 40%/60% and 80%/20% showed less water absorption, and statistically equivalent means in relation to the control panels produced with *Pinus* wood.

Table 3. Average values of the physical properties of the particleboard estimated by the ANCOVA.
Tabela 3. Valores médios estimados pela ANCOVA das propriedades físicas dos painéis aglomerados.

Treatment	**WA 2h (%)**	**WA 24h (%)**	**TS 2h (%)**	**TS 24h (%)**
T1 – Cu100	12.82 a (22.89)	33.01 a (14.66)	7.17 a (22.92)	13.06 a (16.95)
T2 – Cu80/Pi20	11.14 c (16.04)	31.11 ab (11.60)	6.02 a (19.74)	12.19 ab (12.99)
T3 – Cu60/Pi40	11.39 ab (12.38)	32.61 a (8.03)	5.83 ab (17.58)	12.72 a (13.22)
T4 – Cu40/Pi60	9.87 c (17.84)	23.34 c (13.99)	4.58 bc (22.15)	10.73 bc (13.49)
T5 – Cu20/Pi/80	10.39 bc (24.92)	30.98 abc (21.61)	5.96 a (30.11)	12.24 ab (13.12)
T6 – Pi100	10.78 bc (26.39)	29.66 bc (18.20)	4.12 c (36.59)	9.96 c (19.40)

WA: water absorption; TS: thickness swelling; averages followed by the same letter in the same column do not differ statistically at the 95% probability level by the Tukey test; Values adjusted by covariance analysis for an apparent specific mass of 0.72 g/cm^3; values in parentheses correspond to the variation coefficient (%).

For water absorption after 24 hours of immersion, the average values ranged from 23.34% to 33.01%, the means being statistically different between treatments for panels with 100% *Cupressus* (T1), with the averages being statistically different from each other. The panels produced with mixtures of cupressus and pine in the proportions of 20%/80% and 40%/60% showed less water absorption, and averages statistically equivalent in relation to the panels produced with 100% *Pinus* wood.

The average values of thickness swelling after 2 hours of immersion ranged from 4.12% to 7.17%, with the means being statistically different between treatments. For thickness swelling after 24 hours of immersion, the mean values ranged from 9.96% to 13.06%, with the means being statistically different between treatments. Both for 2 hours and for 24 hours of immersion, the panels produced with mixtures of cupressus and pine in the proportions of 40%/60% showed less swelling in thickness, and statistically equivalent means in relation to the control panels, produced with *Pinus* wood.

Mechanical properties of panels

The mean values of modulus of rupture ranged from 14.41 MPa to 17.16 MPa, with the means being statistically different between treatments (Table 4). All panels produced with 100% *Cupressus* and different proportions of mixtures with *Pinus* showed statistically equivalent means in relation to the control panels, produced with *Pinus* wood.

Table 4. Average values of the mechanical properties of the particleboard estimated by the ANCOVA.
Tabela 4. Valores médios estimados pela ANCOVA das propriedades mecânicas dos painéis aglomerados.

Treatment	**MOR (MPa)**	**MOE (MPa)**	**TP (MPa)**	**SWR face (N)**	**SWR topo (N)**
T1 – Cu100	16.07 ab (13.64)	2.521 ab (17.27)	0.76 a (16.49)	1.177 a (9.94)	1.279 a (6.53)
T2 – Cu80/Pi20	17.16 a (7.54)	2.583 a (7.68)	0.70 a (21.33)	1.123 a (15.81)	1.128 ab (13.18)
T3 – Cu60/Pi40	15.88 ab (16.36)	2.500 ab (11.55)	0.71 a (16.77)	1.227 a (14.59)	853 b (12.37)
T4 – Cu40/Pi60	14.60 b (9.15)	2.142 cd (8.38)	0.77 a (19.79)	1.109 a (9.88)	1.062 b (10.85)
T5 – Cu20/Pi/80	14.41 b (9.60)	2.134d (10.66)	0.77 a (22.20)	1.168 a (17.87)	1.155 ab (23.00)
T6 – Pi100	15.57 ab (14.58)	2.344 bc (12.88)	0.81 a (21.33)	1.121 a (27.17)	1.135 ab (20.99)

MOR: modulus of rupture; MOE: modulus of elasticity; TP: traction perpendicular to the surface; SWR: screw withdrawal resistance; averages followed by the same letter in the same column do not differ statistically at the 95% probability level by the Tukey test; Values adjusted by covariance analysis for an apparent specific mass of 0.72 g/cm3; values in parentheses correspond to the variation coefficient (%).

The mean values of modulus of elasticity ranged from 2,134 MPa to 2,583 MPa, the means being statistically different between treatments. The panels produced with 100% *Cupressus* showed a statistically equivalent average in relation to the panels produced with mixtures with *Pinus* of 80%/20% and 60%/40%, and higher in comparison to the control panels, produced with *Pinus* wood.

The average values of perpendicular traction ranged from 0.70 MPa to 0.81 MPa, the averages being statistically equivalent among all treatments.

The average values of screw withdrawal resistance on the surface ranged from 1,109 N to 1,227 N. There were no statistically significant differences between all treatments evaluated.

For the screw withdrawal at the top, the average values ranged from 853 N to 1,279 N, the averages being statistically different between treatments. The panels produced with 100% *Cupressus* showed a statistically equivalent average in relation to the control panels, produced with 100% *Pinus*, with mixtures of 80%/20% and 20%/80%, and higher compared to the other treatments.

DISCUSSION

The results of the basic density of the wood of *Cupressus* and *Pinus*, in addition to the mixture of these in different proportions, meet the recommendations by Moslemi (1974) for the production of particleboard up to 0.55 g/cm^3.

The density values of the panels were slightly lower than the nominal specific mass calculated at 0.750 g/cm^3. The differences observed between treatments can be attributed to the loss of material during the formation of the panels and an increase in volume due to the return in thickness after hot pressing followed by conditioning. The low coefficients of variation indicate that there were no significant variations in the formation of the panels.

The results of the compaction ratio of panels produced with *Cupressus* wood, pure or in different proportions of mixture with *Pinus*, were higher than the minimum value of 1.3 (MOSLEMI, 1974), recommended for the production of particleboards.

Significant differences were found for water absorption and thickness swelling of the panels of different treatments. However, the variations in the basic density of the wood of the two species and their mixture were small, and it is not possible to conclude about the influence of the lower density of the wood and the higher compaction ratio of the panels in reducing water absorption, contrary to the concepts reported by Moslemi (1974). All treatments showed average values of swelling in thickness 24 hours below 15%, as established by standard EN 312 (1993), for structural panels with use in dry conditions (P4) and below 14% for non-structural panels with application in wet conditions (P3), with thickness between 13 and 20 mm. For panels used in dry environments, including furniture, this standard has no minimum requirement.

The results of water absorption 24 hours were satisfactory when compared to some references presented in the literature on experimental particleboards produced with species from forest plantations. Rosa *et al.* (2017) found for particleboards produced with five species of *Eucalyptus* (*E. benthamii, E. dunnii, E. grandis, E. saligna, E. urograndis*) 24-hour water absorption values in the range of 22.28% to 29.82%. Trianoski *et al*. (2011) found for panels of *Acrocarpus fraxinifolius, Melia azedarach, Grevillea robusta, Schizolobium parahyba* (Vell), Blake and *Toona ciliata*, values in the range of 32.06% to 68.70%. Trianoski *et al.* (2013) and Iwakiri *et al*. (2014) obtained for 24-hour water absorption values of 17.39% and 55.40% for *Cryptomeria japonica* and *Sequoia sempervirens*, respectively.

Regarding the 24-hour thick swelling, the results are compatible with some values presented in the literature. Rosa *et al.* (2017) found for particleboards produced with five species of *Eucalyptus* (*E. benthamii, E. dunnii, E. grandis, E. saligna, E. urograndis*) 24-hour thick swelling values in the range of 10.74% to 11.76%. Trianoski *et al.* (2011) found for *Acrocarpus fraxinifolius, Melia azedarach, Grevillea robusta, Schizolobium parahyba* and *Toona ciliata*, values in the range of 16.78% to 29.76%.

All the panels produced with 100% *Cupressus* wood, or in different proportions of mixture with *Pinus*, presented average values of MOR, statistically equal in comparison to the control panels, produced with 100% of *Pinus*. Likewise, all treatments met the requirement of standard EN 312 (1993), which specifies a minimum value of 13 MPa and 14 MPa for MOR, respectively for classes P2 and P3 (13 to 20 mm). The influence of the compaction ratio of the panels on the MOR was not found.

The average values of MOR were satisfactory when compared to the results presented by some researchers for particleboards produced with species from forest plantations. Rosa *et al.* (2017) found particleboards produced with five species of *Eucalyptus* (*E. benthamii* Maiden et Cambage, *E. dunnii* Maiden, *E. grandis* Hill, *E. saligna* (Sm.), *E. urograndis*) values of MOR ranging from 15.82 MPa to 20.82 MPa. Trianoski *et al*. (2011) found for panels of *Acrocarpus fraxinifolius, Melia azedarach, Grevillea robusta, Schizolobium parahyba* and *Toona ciliata,* values ranging from 7.04 MPa to 19.83 MPa.

As for the MOE, with the exception of panels produced with a mixture of 20% *Cupressus* and 80% *Pinus,* all other treatments showed an average greater than or equal to the control panel with 100% *Pinus* wood. All treatments met the requirement of standard EN 312 (1993) which specifies for MOE, a minimum value of 1,600 MPa and 1950 MPa, for classes P2 and P3 (13 to 20 mm). The influence of the compaction ratio on the panel's MOE was not found.

The average values of MOE were satisfactory compared to the results presented by some researchers for particleboards produced with species from forest plantations. Rosa *et al*. (2017) found for particleboards produced with five species of *Eucalyptus* (*E. benthamii, E. dunnii, E. grandis, E. saligna, E. urograndis*) MOR values ranging from 2,111 MPa to 2,589 MPa. Trianoski *et al*. (2011) found for panels of *Acrocarpus fraxinifolius, Melia azedarach, Grevillea robusta, Schizolobium parahyba* and *Toona ciliata,* values ranging from 1,475 MPa to 2,427 MPa.

All panels produced with 100% *Cupressus* and different proportions of mixture with *Pinus* showed statistically equivalent mean values of perpendicular tension in comparison to the control panels, produced with 100% *Pinus* wood. All treatments met the requirement of standard EN 312 (1993), which specifies a minimum value of 0.35 and 0.45 MPa for perpendicular traction, for use classes P2 and P3 (13 to 20 mm), respectively. The influence of the compaction ratio of the panels on the perpendicular traction was not verified.

The results of perpendicular traction are in accordance with the results presented by Rosa *et al.* (2017) or particleboards produced with five species of *Eucalyptus* (*E. benthamii, E. dunnii, E. grandis, E. saligna, E. urograndis*), ranging from 0.64 MPa 0.91 MPa. Trianoski *et al.* (2013) and Iwakiri *et al*. (2014), found for panels of *Cryptomeria japonica* and *Sequoia sempervirens,* perpendicular tensile values of 0.99 MPa and 0.70, respectively. Colli, *et al.* (2010) found an average value of 0.22 MPa for *Schizolobium amazonicum*.

With respect to the screw withdrawal resistance, both for the surface and for the top, all panels produced with 100% *Cupressus* and different proportions of mixture with *Pinus,* showed statistically equal results in comparison to the control panels, produced with 100% of *Pinus* wood. All treatments met the minimum requirements of standard NBR 14810-2 (2018) class M1N.S, of 1,020 N for the surface and 800 N for the top of the panels. The compaction ratio of the panels did not influence the results of screw withdrawal resistance.

The results of screw withdrawal to the surface and top of the panels are in accordance with some values presented in the literature. Trianoski *et al.* (2016) found average values of 990 N for the surface and 824 N for the top for *Grevillea robusta* panels. Cunha *et al.* (2014) ound, for panels produced with *Eucalyptus benthamii, Eucalyptus dunnii* and *Eucalyptus grandis,* average values of screw withdrawal resistance on the surface and top, in the range of 1,042 N to 1,472 N.

CONCLUSIONS

Based on the results obtained, the following conclusions can be presented:

- The compaction ratio of the panels produced with 100% of the species, and, in different proportions of mixtures, did not significantly influence the results of the properties of the particleboards.
- For all evaluated treatments, the average values of swelling in thickness 24 hours, modulus of rupture, modulus of elasticity and perpendicular traction met the minimum requirements established by standard EN 312 (2010) for panels in use in dry environments including furniture (P2) and non-structural panels for use in wet conditions (P3), and screw withdrawal resistance in relation to the requirements of NBR 14810-2 (2018) M1N.S.
- The comparative evaluations of the results of this research, with *Pinus taeda*, which is the species most used commercially in Brazil, in addition to the normative requirements of EN 312 (2003) for commercial panels, demonstrated that the species *Cupressus torulosa* has great potential for the production of particleboards.

REFERÊNCIAS

ALMEIDA, C. C. F.; CUNHA, A. B.; RIOS, P. Avaliação da qualidade da colagem de topo da madeira de *Cupressus lusitânica* para a produção de painéis colados lateralmente. **Scientia Forestalis,** Piracicaba, v. 43, n. 13, p. 1-19, 2017.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS - ABNT. **NBR 14810 – 2.** Painéis de partículas de média densidade. Parte 2: Requisitos e métodos de ensaio. Rio de Janeiro, 71p., 2018.

BIANCHE, J. J.; CARNEIRO, A. C. O.; VITAL, B. R.; PEREIRA, F. A.; SANTOS, R. C.; SORATTO, D. N. Propriedades de painéis aglomerados fabricados com partículas de eucalipto (*Eucalyptus urophylla*), paricá (*Schizolobium amazonicum*) e vassoura (*Sida spp*.). **Cerne**, Lavras, v. 18, n. 4, p. 623-630, 2012.

COLLI, A.; VITAL, B. R.; CARNEIRO, A. C. O.; SILVA, J. C.; CARVALHO, A. N. M. L.; DELLA LUCIA, R. M. Properties of panels manufactured with wood particles of paricá (*Schizolobium* Huber ex. Ducke) and coconut fibers. **Revista Árvore,** Viçosa, v. 34, p. 333 – 338, 2010.

CUNHA, A. B.; LONGO, B. L.; RODRIGUES, A. A.; BREHMER, D. R. Produção de painéis de madeira aglomerada de *Eucalyptus benthamii, Eucalyptus dunnii* e *Eucalyptus grandis.* **Scientia Forestalis,** Piracicaba, v. 42, n. 102, p. 259 – 267, 2014.

EUROPEAN COMMITTEE FOR STANDARDIZATION - CEN. **EN 310.** Wood-based panels - Determination of modulus of elasticity in bending and of bending strength. Brussels, 1993.

EUROPEAN COMMITTEE FOR STANDARDIZATION- CEN. **EN 312.** Particleboards – Specifications. Brussels, 2010.

EUROPEAN COMMITTEE FOR STANDARDIZATION - CEN. **EN 317.** Particleboards and fibreboards - Determination of swelling in thickness after immersion in water. Brussels, 1993.

EUROPEAN COMMITTEE FOR STANDARDIZATION - CEN. **EN 319.** Particleboards and fibreboards - Determination of tensile strength perpendicular to the plane of the board. Brussels, 1993.

EUROPEAN COMMITTEE FOR STANDARDIZATION – CEN**. EN 323.** Wood-based panels - Determination of board density**.** Brussels, 1993.

GUIMARÃES, J. B.; XAVIER, M. M.; SANTOS, T. S.; PROTÁSIO, T. S.; MENDES, R. F.; MENDES, L.M. Inclusão de resíduo da cultura de sorgo em painéis aglomerados de eucalipto. **Pesquisa Florestal Brasileira**, Colombo, v. 36, n. 88, p. 435-442, 2016.

IWAKIRI, S.; TRIANOSKI, R.; CUNHA, A. B.; CASTRO, V. G.; BRAZ, R. L.; VILLAS BOAS, B. T.; SANCHES, F. L.; BELLON, K. R. R. Evaluation of the quality of particleboard manufactured with wood from *Sequoia sempervirens* and *Pinus taeda.* **Cerne**, Lavras, v. 20, p. 209 - 216. 2014.

MALONEY, T. M. **Modern particleboard & dry-process fiberboard manufacturing**. San Francisco: Miller Freeman Inc., 1993. 689 p.

MARTINS, E. H.; GUIMARÃES, J. B.; PROTÁSIO, T. P.; MENDES, R. F.; MENDES, L. M. Painéis aglomerados convencionais produzidos com madeira de *Cecropia pachystachya.* **Enciclopédia Biosfera**, v. 10, n.19; p. 2014.

MOSLEMI, A. A. **Particleboard**. London: Southern Illinois University Press, 1974. 245 p.

NAUMANN, R. B.; VITAL, B. R.; CARNEIRO, A. C. O.; DELLA LUCIA, R. M.; SILVA, J. C.; CARVALHO, A. M. M. L.; COLLI, A. Properties of particleboard manufactured from *Eucalyptus urophylla* S. T. Blake and *Schizolobium amazonicum* Huber ex. Ducke. **Revista Árvore,** Viçosa, v. 32, p. 1143 – 1150, 2008.

OKINO, E. Y. A.; SOUZA, M. R.; SANTANA, M. A. E.; ALVES, M. V. S.; SOUSA, M. E.; TEIXEIRA, D. E. Physico-mechanical properties and decay resistance of *Cupressus* spp. Cement-bonded particleboards. **Cement & Concrete Composites,** Hong Kong, v. 27, p. 333 – 338, 2005.

OKINO, E. Y. A.; TEIXEIRA, D. E.; SOUZA, M. R.; SANTANA, M. A. E.; SOUSA M. E. Propriedades de chapas OSB de *Eucalyptus grandis* e de *Cupressus glauca*. **Scientia Forestalis**, Piracicaba, v. 36, n. 78, p. 123-131, 2008.

OKINO, E. Y. A.; SANTANA, M. A. E.; ALVES, V. S. A.; MELO, J. E.; CORADIN, V. T.; SOUZA, M. R.; TEIXEIRA, D.; SOUSA, M. E. Technological characterization of *Cupressus spp*. wood. **Floresta e Ambiente**, Seropédica, v. 17, n. 1, p. 1-11, 2010.

RIOS, P. A.; PEREIRA, G. F.; VIEIRA, H.; GRUBERT, W.; CUNHA, A. C.; BRAND, M. A. Avaliação do potencial da madeira de *Pinus patula* Schltdl. & Cham para a produção de painéis de madeira aglomerada. **Scientia Forestalis**, Piracicaba, v. 44, n. 110, p. 497-508, 2016.

ROSA, T. S.; TRIANOSKI, R.; IWAKIRI, S.; BONDUELLE, G. M. Use of five *Eucalyptus* species for particleboard manufacture. **Revista Árvore,** Viçosa, v. 41, n. 2, p. 1 – 8, 2017.

TRIANOSKI, R.; IWAKIRI, S.; MATOS, J. L. M. Potential use of planted fast-growing species for production of particleboard. **Journal of Tropical Forest Science,** Kepong, v. 23, p. 311 – 317, 2011.

TRIANOSKI, R.; IWAKIRI, S; MATOS, J. L. M.; CHIES, D. Utilização da madeira de *Cryptomeria japonica* para produção de painéis aglomerados. **Scientia Forestalis,** Piracicaba, v. 41, n. 97, p. 57 - 64, 2013.

TRIANOSKI, R.; PICCARDI, A. B. R.; IWAKIRI, S.; MATOS, J. L. M.; BONDUELLE, G. M. Incorporação de *Grevillea robusta* na produção de painéis aglomerados de *Pinus* spp. **Floresta & Ambiente,** Seropédica, v. 23, p. 278 – 285, 2016.

ZELLER, F.; BARBU, M. C.; IWAKIRI, S. Paricá (*Schizolobium amazonicum*) and embaúba (*Cecropia* sp.) as new materials for particleboards. **European Journal of Wood Products,** Berlin, v. 71, p. 823 – 825, 2013.