CERNE
ISSN: 0104-7760
cerne@dcf.ufla.br
Universidade Federal de Lavras
Brasil

Longui, Eduardo Luiz; de Lima, Israel Luiz; Romeu Lombardi, Daniel; Nivaldo Garcia, José; Segala Alves, Edenise
WOODS WITH PHYSICAL, MECHANICAL AND ACOUSTIC PROPERTIES SIMILAR TO THOSE OF *Caesalpinia echinata* HAVE HIGH POTENTIAL AS ALTERNATIVE WOODS FOR BOW MAKERS
CERNE, vol. 20, núm. 3, 2014, pp. 369-376
Universidade Federal de Lavras
Lavras, Brasil

DOI: http://dx.doi.org/10.1590/01047760.201420021524

EVALUATION OF THE QUALITY OF PARTICLEBOARD PANELS MANUFACTURED WITH WOOD FROM *Sequoia sempervirens* AND *Pinus taeda*

Setsuo Iwakiri[1]*, Rosilani Trianoski[1], Alexsandro Bayestorff da Cunha[2], Vinicus Gomes de Castro[1], Rafael Leite Braz[1], Bárbara Talamini Villas-Bôas[1], Felipe Luis Sanches[1], Karine Ramos da Rosa Bellon[1], Edson Pinheiro[1]

*Autor para correspondência: setsuo@ufpr.br

ABSTRACT: *This work aimed to evaluate the physical and mechanical properties of particleboard panels manufactured with wood particles from Sequoia sempervirens and Pinus taeda and urea-formaldehyde resin (UF), using different mixing ratios of the two species, namely 100%, 0%, 75%, 50% and 25% of sequoia particles. Properties evaluated included panel density and compaction ratio, water absorption and thickness swelling after 24 hours of immersion, internal bond and static bending (MOE and MOR). The low density of sequoia wood raised the compaction ratio of the panels and helped improve their mechanical properties and dimensional stability. Panels manufactured at the ratios of 100%, 75%, 50% and 25% sequoia to pine provided better results compared to panels manufactured with 100% pine. Results of MOE and MOR under static bending and of internal bond met the minimum requirements of standard EN 312:2003 in all treatments. Results revealed that Sequoia sempervirens has great potential for production of particleboard.*

Keywords: wood particles, urea-formaldehyde resin, species mixing ratio.

AVALIAÇÃO DA QUALIDADE DE PAINÉIS AGLOMERADOS PRODUZIDOS COM MADEIRA DE *Sequoia sempervirens* E *Pinus taeda*

RESUMO: O objetivo do presente trabalho foi avaliar as propriedades físicas e mecânicas de painéis aglomerados produzidos a partir de partículas de madeira de *Sequoia sempervirens* e *Pinus taeda* com resina uréia-formaldeido (UF) em diferentes proporções de mistura das duas espécies, sendo 100%, 0%, 75%, 50% e 25% de partículas de sequoia, respectivamente. Foram avaliadas as propriedades de massa específica e razão de compactação dos painéis, absorção de água e inchamento em espessura após 24 horas de imersão, ligação interna e flexão estática (MOE e MOR). A baixa massa específica da madeira de sequoia elevou a razão de compactação dos painéis e contribuiu para melhorar as suas propriedades mecânicas e estabilidade dimensional. Os painéis produzidos com sequoia nas proporções de 100%, 75%, 50% e 25% em mistura com pinus, apresentaram melhores resultados de propriedades em relação aos painéis produzidos com 100% de pinus. Os resultados de MOE e MOR em flexão estática e ligação interna de todos os tratamentos avaliados atenderam aos requisitos mínimos da norma EN 312:2003. Os resultados demonstram que a *Sequoia sempervirens* apresenta grande potencial para produção de painéis aglomerados.

Palavras-chave: partículas de madeira, resina ureia-formaldeído, mistura de espécies.

1 INTRODUCTION

Use of new, fast-growing wood species obtained in forest stands for particleboard production has been the focus of several studies in Brazil in recent decades. That is justified, given that Brazil's MDF and particleboard companies rely on pine and eucalyptus as the main sources of raw material, and there is a need to increase the supply of wood available with alternative species.

From the 1990s, the Brazilian sector of reconstituted wood panels has expanded considerably and has shown a significant increase in its production capacity, with introduction of new particleboard and MDF industrial units. The increase in panel production has boosted the demand for raw material, and so the forest sector has been looking for future alternatives capable of responding to limited supplies of pine and eucalyptus woods, quantitatively and qualitatively. With the technological innovations introduced particularly in the past decade, a significant improvement has been noted in the quality of particleboard panels, also known commercially as medium density particleboard - MDP (ASSOCIAÇÃO BRASILEIRA DA INDÚSTRIA DE PAINÉIS DE MADEIRA - ABIPA, 2012).

Several researchers have engaged in studies about alternative species to pine and eucalyptus woods for the manufacture of particleboard panels. Trianoski et al. (2011b) evaluated the potential of species *Acrocarpus*

1 Universidade Federal do Paraná - Curitiba, Paraná, Brazil
2 Universidade do Estado de Santa Catarina - Lajes, Santa Catarina, Brazil

fraxinifolius, *Melia azedarach*, *Gravile arobusta*, *Schizolobium parahyba* and *Toona ciliata*. Iwakiri et al. (2010) studied the behavior of *Schizolobium amazonicum*, a tropical species grown in forest stands of the Amazon region, for laboratory production of particleboards. All species studied by the above researchers showed great potential for production of particleboards. Iwakiri et al. (2010) evaluated the quality of wood in five species of tropical pine, namely *Pinus oocarpa*, *Pinus caribaea*, *Pinus chiapensis*, *Pinus maximinoi* and *Pinus tecunumannii* for production of particleboard panels, and the results of physico-mechanical properties did substantiate their potential, with *Pinus moximinoi* standing out from other species. Protásio et al. (2012) studied the effects of compaction ratio and bulk density in three eucalyptus species, namely *Eucalyptus grandis*, *Eucalyptus saligna* and *Eucalyptus cloeziana*, and found a direct correlation between these variables and the bending properties, but an inverse correlation with the thickness swelling of the resulting particleboard panels.

Sequoia sempervirens is a species native to the United States whose characteristics include low-density wood (about 310 kg.m^{-3}), good dimensional stability and resistance to decay, besides having excellent attributes for production of panels and cellulose pulp (MARCHIORI, 1996 cited by DIEL; FRIZZO, 2002; SLOAN; BOE, 1974). Spichiger (2004) points to several characteristics that make sequoia wood attractive for panel production and furniture making, including good workability, good adhesion for paints and varnishes and absence of resins that are typical of softwoods. Depending on surface quality, number of knots and sapwood, sequoia wood is an excellent choice for obtaining high value-added products, on account of its color and price. In Brazil, experimental sequoia stands are currently being tried in Santa Catarina state.

Maloney (1993) and Moslemi (1974) cited wood density, pH and extractives as critical parameters when selecting wood species to produce particleboard panels. Measuring wood density is a basic requirement when selecting species intended for particleboards, given that it influences the compaction ratio of the resulting panel. According to Moslemi (1974), compaction ratio is the ratio of panel density to wood density, noting that it should be at least 1.3 in order to ensure enough densification for panel formation to occur. Kelly (1977) states that, for panels with the same density, those made with low-density wood will have superior mechanical properties but inferior dimensional stability compared to panels made with high-density wood. The author attributes this behavior to the larger quantity of wood particles and resulting increase in hygroscopic swelling, and greater compressive stress being released during the hot-press process.

According to Iwakiri et al. (1996), mixing different species in the manufacture of particleboards is highly desirable in that it expands the offer of raw material to manufacturers that in turn require large volumes of wood. The differing physicochemical characteristics of the species involved can be offset by uniformly blending the wood particles so as to facilitate bonding and panel formation.

Fully or partially using new species to produce particleboards is a viable and sustainable alternative while contributing to improve the quality and the properties of the resulting panels. Experimental stands of species *Sequoia sempervirens* have been showing great potential for silviculture, as the characteristic low-density, light-colored wood of the species are important technological requirements for production of particulate wood panels. Given the above, this work aimed to evaluate the quality of particleboard panels manufactured with wood from *Sequoia sempervirens* combined with wood from *Pinus taeda* at different ratios.

2 MATERIALS AND METHODS

Wood particles from *Sequoia sempervirens* and *Pinus taeda* were used to proceed with the experiment. The sequoia particles were obtained from six logs removed from three 18-year-old trees from stands located in EPAGRI Experimental Station, São Joaquim (SC). The pine particles, used in the outer layers of industrial panels, were obtained from the production line of Berneck S.A., a company located in Araucária (PR).

The sequoia particles were obtained in a disc chipper, to a length of 50 mm, a thickness of 0.7 mm and variable width of 50 mm. Once dried to a moisture content of 3%, the particles were reprocessed in a hammer mill and then graded using a 0.8 mm mesh sieve to remove fine particles. The particles retained in the sieve were used to manufacture the panels.

Fifteen panels were made measuring 500 mm in width and in length and 15 mm in thickness. The amount of material required to form a mat was determined, considering a panel density of 800 kg.m^{-3}. The resin used was urea-formaldehyde (UF) at a rate of 10%, on dry particle weight basis, using ammonium sulfate as a catalyst at a rate of 2% on resin solids. The catalyzed resin and the wax (1% on resin solids) were applied to the particles in a rotary tumbler using an integrated spray nozzle.

The particles were sorted and divided into five different mixing ratios of the two species, according to the treatments provided in Table 1.

Table 1 *- Experimental design.*

Tabela 1 - Delineamento experimental.

Treatment	Mixing ratios (%)	
	Sequoia sempervirens	*Pinus taeda*
T1-s100p0	100	0
T2-s0p100	0	100
T3-s75p25	75	25
T4-s50p50	50	50
T5-s25p75	25	75

After applying wax and resin, the mat of particles was shaped into form inside a molding box and pre-pressed prior to being hot pressed. The panels were then pressed at a temperature of 160ºC, specific pressure of 40 kgf/cm^3, for 8 minutes. Three panels were made per treatment, to a total of 15 panels.

After being pressed, the panels were trimmed to size and kept in a temperature-controlled room at 20 ± 3ºC with relative humidity of 65 ± 5%.

To establish the physico-mechanical properties, nine specimens were taken from each panel to determine density and compaction ratio; nine specimens were taken to determine water absorption and thickness swelling after 24 hours of immersion in water; six specimens were subjected to bending tests to determine the modulus of elasticity (MOE) and modulus of rupture (MOR), static by using a universal testing machine and dynamic by applying stress waves; and nine specimens were subjected to internal bond testing. The tests were conducted according to procedures described in Standards EN 323, EN 317, EN 310 and EN 319 (CEN, 1993a, 1993b, 1993c, 1993d) respectively.

The experiment was laid out in a completely randomized design, and the statistical analysis was based on analysis of variance and the Tukey test at the 95% probability level.

3 RESULTS AND DISCUSSION

3.1 Density and compaction ratio of panels

Results of wood and panel bulk density and also compaction ratio are illustrated in Table 2. Bulk wood density, as calculated for different mixing ratios of *Sequoia sempervirens* and *Pinus taeda*, ranged between 321 $kg.m^{-3}$ and 496 $kg.m^{-3}$ respectively. Due to the low density which is characteristic of sequoia wood (321 $kg.m^{-3}$) compared to the density of pine wood (496 $kg.m^{-3}$), increasing the proportion of pine in the mixture by 25% (T3), 50% (T4) and 75% (T5) resulted in higher values of density in the material.

Table 2 *- Results of density and compaction ratio.*

Tabela 2 - Resultados de massa específica e razão de compactação dos painéis.

Treatment	MEm ($kg.m^{-3}$)	MEp ($kg.m^{-3}$)		RC
		Mean	CV (%)	
T1	321	732a	4.0	2.279a
T2	496	719a	3.6	1.449b
T3	365	727a	3.3	1.993c
T4	409	734a	4.2	1.797d
T5	452	736a	4.9	1.628e

MEm: wood bulk density (species in pure state and at different mixing ratios); MEp: panel bulk density; RC: compaction ratio; CV: coefficient of variation; s: sequoia; p: pine. Means followed by the same letter in a column do not differ statistically, at the 95% probability level.

Panel bulk density ranged between 719 $kg.m^{-3}$ and 736 $kg.m^{-3}$ respectively for panels made with 100% pine and for the mixture of 25% sequoia and 75% pine. However, no statistically significant differences were found between treatments. The lower values found for panel density relative to the nominal density of 800 $kg.m^{-3}$, as established for calculating the materials, could be attributed to loss of material during the panel forming process and to thickness recovery after the pressing stage.

Compaction ratio ranged between 1.449 (T2) and 2.279 (T1). It was noted that increasing ratios of sequoia wood (T5, T4, T3) in relation to pine wood resulted in higher values of compaction ratio. This variation occurs because sequoia wood has lower density.

High values of compaction ratio were also found in other studies using low-density wood to make particleboards. Trianoski et al. (2011b) found values above 2 for particleboards made with *Schizolobium parahyba* (264 kg.m^{-3}) and *Toona ciliata* (373 kg.m^{-3}). Iwakiri et al. (2010) found values above 2 for particleboards made with *Schizolobium amazonicum* (320 kg.m^{-3}) and *Cecropia hololeuca* (270 kg.m^{-3}).

3.2 Water absorption and thickness swelling

Mean results of water absorption and thickness swelling after 24 hours of immersion in water are illustrated in Table 3. Panels made with 100% sequoia (T1) and with sequoia in a mixture with pine at 75% (T3), 50% (T4) and 25% (T5) had mean values of water absorption statistically lower than panels made with 100% pine (T2). Panels made with 50% and 25% sequoia in the mixture had the lowest values of water absorption.

Table 3 *– Results of water absorption and thickness swelling.*

Tabela 3 – Resultados de absorção de água e inchamento em espessura.

Treatment	Water absorption		Thickness swelling	
	Mean (%)	CV (%)	Mean (%)	CV (%)
T1	42.9 b	11.5	16.3 b	27.7
T2	55.4 a	12.8	22.2 a	16.3
T3	45.4 b	11.2	13.9 c	24.4
T4	26.3 d	13.3	8.3 d	11.3
T5	34.2 c	8.1	10.6 d	11.8

Means followed by the same letter do not differ statistically at the 95% probability level. CV: Coefficient of variation.

Results of thickness swelling after 24 hours revealed the same trend as water absorption. Panels made with 100% pine (T2) had a mean value of thickness swelling statistically higher than panels made with 100% sequoia (T1) or with three different mixing ratios of pine. Panels made with 50% and 25 % sequoia had lower values of thickness swelling.

Compaction ratio was found to influence the physical properties of the panels but only in results of water absorption, in accordance with which the panels with higher compaction ratio had lower values of water absorption. According to Moslemi (1974), panels with a higher compaction ratio have a more closed structure which contributes to obstruct the entry of water. As for thickness swelling, compaction ratio was found not to influence results.

Mean results of water absorption and thickness swelling for panels made with 100% sequoia and with a mixture of sequoia and pine at different ratios were lower compared to some results in literature. Iwakiri et al. (2010) found, for panels made with paricá and embaúba woods at the ratios 0%, 25%, 50%, 75% and 100%, mean values of water absorption and thickness swelling in the range of 80.57% to 79.22% and 28.42% to 26.19% respectively. In another study, Iwakiri et al. (1996) found, for panels made with a mixture of Pinus taeda and *Eucalyptus dunnii* at the ratios 0%, 25%, 50%, 75% and 100%, values of water absorption in the range of 75.04% to 80.05% and thickness swelling in the range of 30.19% to 35.09% respectively. The panels made with mixed sequoia and pine at the ratios 25%, 50% and 75% were found to meet the requirement of standard EN 312 (EUROPEAN COMMITTEE FOR STANDARDIZATION - CEN, 2003) concerning thickness swelling after 24 hours of immersion in water, whose maximum value is 15%.

3.3 Static bending

Results of modulus of elasticity (MOE) and modulus of rupture (MOR) are given in Table 4. Panels made with 100% sequoia had a mean MOE statistically similar to panels made with 100% pine or with a mixture of the two species at three different ratios (T3, T4, T5). Panels made with a mixture of sequoia and pine at three

Table 4 *– Results of modulus of elasticity and modulus of rupture in static bending.*

Tabela 4 - Resultados de módulo de elasticidade e de ruptura em flexão estática.

Treatment	MOE (MPa)		MOR (MPa)	
	Mean	CV (%)	Mean	CV (%)
T1	2,126 ab	24.4	17.76 a	18.78
T2	1,847 b	14.93	12.78 b	15.90
T3	2,319 a	17.66	17.93 a	15.91
T4	2,481 a	18.05	18.96 a	15.29
T5	2,351 a	16.38	18.13 a	16.59

MOE: modulus of elasticity; MOR: modulus of rupture; CV: coefficient of variation; s: sequoia; p: pine. Means followed by the same letter in a column do not differ statistically at the 95% probability level.

different ratios resulted in statistically higher values of MOE compared to panels made with 100% pine.

As regards MOR, panels made with 100% pine had statistically lower mean values than panels made with 100% sequoia or with a mixture of the two species at three different ratios (T3, T4, T5).

Increased values of MOE and MOR in panels made with 100% sequoia or with a mixture of sequoia and pine may be associated with the increase in the compaction ratio of the panels by including sequoia wood, whose density is lower than that of pine wood. A direct correlation between the compaction ratio and the mechanical properties of particleboard panels is also reported by Maloney (1993) and Moslemi (1974).

Comparatively, Trianoski et al. (2011b) found 2,247 and 16.36 MPa, 2,405 and 16.93 MPa, 1,878 and 10.87 MPa, 2,137 and 16.38 MPa, 2,529 and 18.73 MPa as mean values of MOE and MOR respectively for three-ply particleboard panels manufactured using *Acrocarpus fraxinifolius*, *Melia azedarach*, *Gravilea robusta*, *Schizolobium parahyba* and *Toona ciliata* in the outer layers and *Pinus taeda* in the inner layer. In another study, Trianoski et al. (2011a) found 1,948 and 12.88 MPa, 1,861 and 13.09 MPa, 2,312 and 16.64 MPa, 1,917 and 13.63 MPa, 1,742 and 11.82 MPa as mean values of MOE and MOR respectively for panels made with a mixture of *Pinus taeda* and *Acrocarpus fraxinifolius* at the ratios 100% pine, 100% acrocarpus, and 75%, 50% and 25% acrocarpus to pine. Therefore, the results of MOE and MOR obtained in this study are consistent with values reported in literature. The results of MOE and MOR for all treatments were found to be above the minimum requirements of standard EN 312 (CEN, 2003), which are respectively 1,600 MPa and 13 MPa.

Table 5 and Figure 1 provide mean values of static MOE and dynamic MOE and their correlations.

No significant differences were found between the mean values of dynamic MOE for all treatments. The correlations between static MOE and dynamic MOE were less than 1, except for T2, indicating that the mean values of dynamic MOE were below those found for static MOE.

The graphs drawn reveal a high correlation between static MOE and dynamic MOE for all treatments. The correlation coefficient (R2) ranged between 77% and 87%, and the highest correlation was found for treatment T1. Ross and Pellerin (1988) reported a high correlation between static MOE and dynamic MOE properties for particleboard panels.

3.4 Internal bond

Table 6 provides results of internal bond. Panels made with a mixture of pine and sequoia particles at three different ratios (T3, T4, T5) had statistically higher mean values of internal bond compared to panels made with 100% pine or 100% sequoia. These results are of great importance as indicative of the feasibility of using mixed sequoia and pine to manufacture superior quality particleboards. The results also point to the possibility of mixing up to 75% sequoia with pine wood to manufacture particleboards. As observed for MOE and MOR, the higher compaction ratio found in panels made with sequoia at different ratios did contribute to increase the values of internal bond.

The mean results of internal bond between 0.702 and 0.894 MPa, as obtained for panels made with 100% sequoia and with different mixing ratios, did meet the minimum requirement established by European Standard EN 312 (CEN, 2003), which is 0.35 MPa.

Comparatively to values reported in literature, Iwakiri et al. (2010) found 0.76 and 0.68 MPa of internal bond when studying particleboards made with *Schizolobium amazonicum* (paricá) and *Cecropia hololeuca* (embaúba) respectively. Therefore, the results found for panels made

Table 5 *– Mean values of MOE static and MOE dynamic.*

Tabela 5 - Valores médios de MOE estático e MOE dinâmico.

Treatment	MOE_{est} (MPa)	MOE_{din} (MPa)	MOE_{din}/MOE_{est}
T1-s100p0	2,126 ab	1,847 b	0.869
T2-s0p100	1,847 b	2,066 ab	1.118
T3-s75p25	2,319 a	2,121 ab	0.915
T4-s50p50	2,481 a	2,119 ab	0.854
T5-s25p75	2,351 a	2,027 ab	0.862

Means followed by the same letter in a column do not differ statistically at the 95% probability level.

Table 6 *– Results of internal Bond.*

Tabela 6 – Resultados de ligação interna.

Treatment	Internal bond (MPa)	
	Mean	CV(%)
T1	0.702 a	26.5
T2	0.583 a	17.9
T3	0.875 b	23.7
T4	0.894 b	18.7
T5	0.859 b	26.2

CV: Coefficient of variation; Means followed by the same letter in a column do not differ statistically at the 95% probability level.

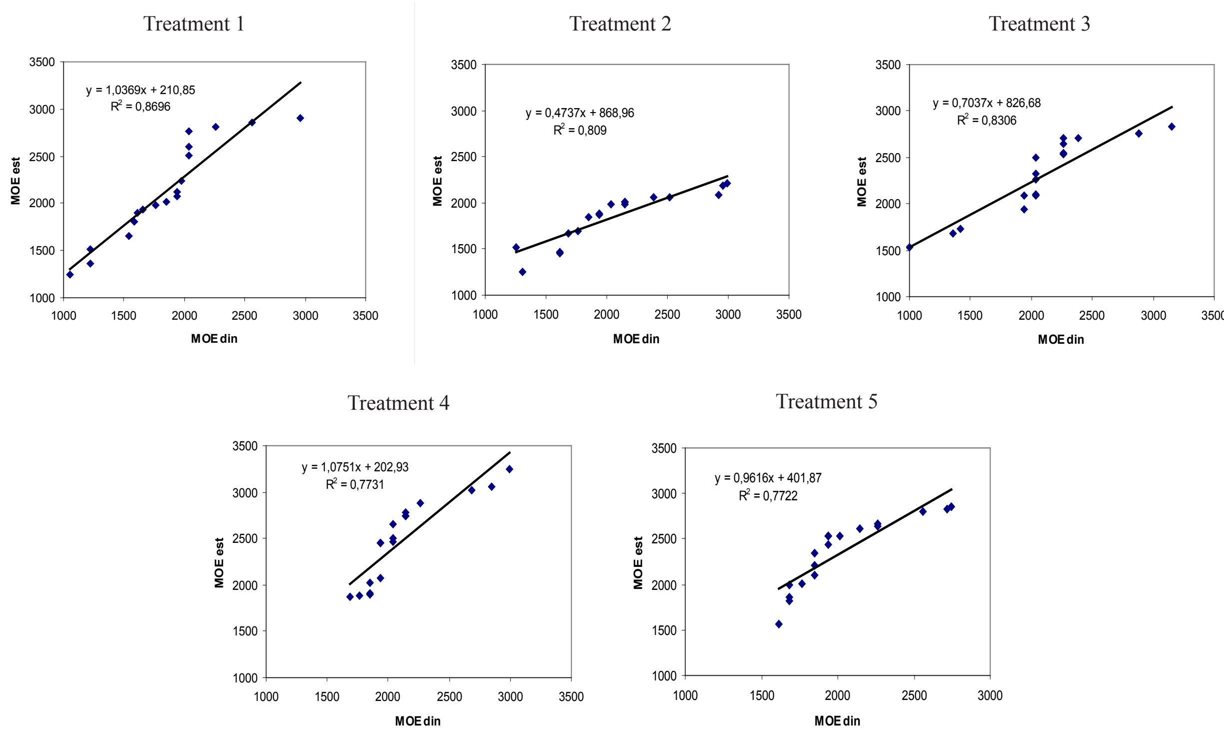

***Figure 1** – Graphic of linear correlation between static and dynamic MOE.*

Figura 1 - Gráfico de correlação linear entre o MOE estático e dinâmico.

4 CONCLUSION

Based on the results found in this study, the following conclusions can be drawn:

• The low density of sequoia wood and the consequent increase in compaction ratio were found to influence the increase in the mechanical properties and the reduction in the physical properties of the resulting panels.

• Panels made with *Sequoia sempervirens* provided better results of physical and mechanical properties compared to panels made with *Pinus taeda,* which is a species traditionally used by manufacturers of particleboard panels.

• Results of static bending, internal bond, water absorption and thickness swelling tests were satisfactory in relation to reference values reported in literature for fast-growing wood species cultivated in forest stands.

• Results of MOE and MOR under static bending and internal bond of panels were found to meet the minimum requirements of standard EN 312 (CEN, 2003) in all treatments. With respect to thickness swelling after 24 hours, only the panels made with a mixture of the two species at the ratios 25%, 50% and 75% were found to meet the requirements of said standard.

5 REFERENCES

ASSOCIAÇÃO BRASILEIRA DA INDÚSTRIA DE PAINÉIS DE MADEIRA. **ABIPA: [home page]**. Disponível em: <http:// www.abipa.org.br/>. Acesso em: 25 mar. 2012.

EUROPEAN COMMITTEE FOR STANDARDIZATION (CEN). **EN 310**. Wood-based panels – Determination of modulus of elasticity and modulus of rupture in static bending. 1993.

EUROPEAN COMMITTEE FOR STANDARDIZATION (CEN). **EN 312**. Particleboards – Specifications. 2003

EUROPEAN COMMITTEE FOR STANDARDIZATION (CEN). **EN 317**. Aglomerado de partículas de madeira e aglomerado de fibras de madeira – Determinação da absorção de água e inchamento em espessura após imersão em água. 1993.

EUROPEAN COMMITTEE FOR STANDARDIZATION (CEN). **EN 319**. Aglomerado de partículas de madeira e aglomerado de fibras de madeira – determinação da força da tensão perpendicular sobre a superfície plana da placa. 1993.

EUROPEAN COMMITTEE FOR STANDARDIZATION (CEN). **EN 323**. Wood-based panels – Determination of density. 1993.

IWAKIRI, S.; LATORRACA, J.V.F.; SILVA, D.A.; GABARDO, J.L.; KLITZKE, R.J.; FOFANO, A.; FABROWSKI, F.; INTERANMENSE, M.T. Produção de painéis aglomerados de *Pinus elliottii* e *Eucalyptus dunnii*. **Agrárias**, Curitiba, v. 15, n. 1, p. 33-41, 1996.

IWAKIRI, S.; ZELLER, F. PINTO, J. A.; RAMIREZ, M. G. L.; SOUZA, M. M.; SEIXAS, R. Avaliação do potencial de utilização da madeira de *Schizolobium amazonicum* "Paricá" e *Cecropia hololeuca* "Embaúba" para produção de painéis aglomerados. **Acta Amazonica**, Manaus, v. 40, n. 2, p. 303-308, 2010.

IWAKIRI, S.; SILVA, J.R.M.; MATOSKI, S.L.S.; LEONHARDT, G.; CARON, J. Produção de chapas de madeira aglomerada de cnco espécies de pinus tropicais. **Floresta e Ambiente**, Seropédica, v. 8, n. 1, p. 137-142, 2012.

KELLY, M. W. **A critical literature review of relationship between processing parameters and physical properties of particlebard**. Madison: U.S. For. Prod. Lab. General Technical Report, 1977. 66p.

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

MARCHIORI, J.N.C. Dendrologia das Gimnospermas. Ed. UFSM, 1996 citado por DIEL J. e FIZZO, S. Estudos de caracterização da *Sequoia sempervirens* para produção de celulose Kraft. In: 35o Congresso e exposição anual de celulose e papel. **Anais...** São Paulo, 2002.

MOSLEMI, A. A. **Particleboard Vol. 1: Materials**. Londres: Southerns Illinois University Press, 1974. 244p.

PROTÁSIO, T.P.; GUIMARÃES Jr, J.B.; MENDES, R.F.; MENDES, L.M.; GUIMARÃES, B.M.R. Correlações entre as propriedades físicas e mecânicas de painéis aglomerados de diferentes espécies de Eucalyptus. **Floresta e Ambiente**, Seropédica, v. 19, n. 2, p. 123-132, 2012.

ROSS, R. J; PELLERIN, R. F. NDE of wood-based composites with longitudinal stress waves. **Forest Products Journal**, Washington, v. 38, n. 5. P. 39 – 45, 1988.

SLOAN, J.; BOE, K. ***Sequoia sempervirens* (Lamb. Ex D. Don) Endl. Seeds of Woody plants in the United States**. Schopmeyer: USDA, 1974.

SPICHINGER, O. A. **Aprovechamiento en el aserrado de sequoia (*Sequoia sempervirens* (D.DON) Endl.) y clasificación de La madera obtenida**. 2004. 61 p. Dissertação (Mestrado em Ingeniería de La madeira) - Universidad de Chile, Santiago.

TRIANOSKI, R.; IWAKIR, S.; MATOS, J.L.M.; PRATA, J.G. Avaliação de espécies alternativas de rápido crescimento para produção de painéis de madeira aglomerada de três camadas. **Scientia Forestalis**, Piracicaba, v. 39, n. 89, p. 097-104, 2011a.

TRIANOSKI, R.; IWAKIR, S.; MATOS, J.L.M.; PRATA, J.G. Viabilidade da utilização de *Acrocarpus fraxinifolius* em diferentes proporções com *Pinus* spp. para produção de painéis aglomerados. **Scientia Forestalis**, Piracicaba, v. 39, n. 91, p. 343-350, 2011b.

Received: May 02, 2012; accepted: August 23, 2013.