Universidade Federal do Paraná
Setor de Ciências Agrárias
Pós-graduação em Engenharia Florestal
Revista Floresta

FEASIBILITY OF VENEER AND PLYWOOD PRODUCTION OF *Hevea brasiliensis* – CLONE RRIM600

Renan Zunta Raia[1*], Setsuo Iwakiri[2], Rosilani Trianoski[3], Alan Sulato de Andrade[4]

[1*]Universidade Federal do Paraná, Departamento de Engenharia e Tecnologia Florestal, Curitiba, Paraná, Brasil – renanraia@gmailcom
[2] Universidade Federal do Paraná, Departamento de Engenharia e Tecnologia Florestal, Curitiba, Paraná, Brasil – setsuo.ufpr@gmail.com
[3] Universidade Federal do Paraná, Departamento de Engenharia e Tecnologia Florestal, Curitiba, Paraná, Brasil – rosollani@gmail.com
[4]Universidade Federal do Paraná, Departamento de Engenharia e Tecnologia Florestal, Curitiba, Paraná, Brasil – alansulato@gmail.com

Received for publication: 10/10/2019 – Accepted for publication: 04/04/2022

Resumo

Viabilidade de produção de lâminas e painéis compensados de Hevea brasiliensis – Clone RRIM600. *Hevea brasiliensis* é uma espécie de grande destaque no Brasil, mas sua madeira é subutilizada em produtos de alto valor agregado. Baseado nisto, o objetivo deste trabalho foi avaliar a viabilidade técnica da produção de lâminas e painéis compensados de *Hevea brasiliensis*, variando a gramatura e teor de sólidos de batida de cola nas propriedades mecânicas dos painéis. Árvores randomizadas foram abatidas, e lâminas de 2mm de espessura foram obtidas destas para produção de painéis compensados fenólicos em laboratório, com dois diferentes teores de sólidos de batida de cola: 35 e 40%, e três diferentes gramaturas: 140, 160 e 180 g/m². Os painéis foram prensados por 10 minutos a 140 ºC com pressão de 10 kgf/cm². Foram avaliados o rendimento do laminado, a densidade básica e a resistência da linha de cola ao cisalhamento e flexão estática. O rendimento de laminação apresentou resultados satisfatórios O rendimento de laminação apresentou resultados satisfatórios apresentando 44,35%. O painel de menor peso não atendeu aos requisitos mínimos da EN 314-2 e os demais apresentaram médias estatisticamente iguais. Desta forma, recomenda-se o uso de 160 g / m² de peso. O teor de sólidos da mistura de cola influenciou nas propriedades mecânicas, mas os resultados ainda são superiores aos obtidos para *Pinus taeda*. A qualidade das lâminas e o rendimento da laminação apontam para a madeira de *Hevea brasiliensis* Clone RRIM 600 um espécie potencial, e os resultados das propriedades físico-mecânicas dos painéis demonstram potencial da espécie na produção de painéis compensados.
Palavras-chave: seringueira; painéis compensados; propriedades mecânicas; espécies alternativas.

Abstract

Hevea brasiliensis is a very prominent species in Brazil, but its wood is underused in high added value products. Based on this, the aim of this work was to evaluate the technical feasibility of veneer and plywood production of *Hevea brasiliensis* – Clone RRIM600 varying the weight and glue mixture solid content and the effects on its mechanical properties. Randomized trees were felled, and 2.0 mm thick veneers were obtained from these to produce phenolic plywood in the laboratory, with two different solid contents of the glue mixture: 35 and 40%, and three different glue weights: 140, 160 and 180 g/m^2. The panels were pressed for 10 minutes at 140°C on 10 kg/cm^{2}pressure . The laminate yield, basic density, and resistance of the glue line to shearing and static bending were evaluated. The lamination yield showed satisfactory results presenting 44.35%. The lower weight panels do not meet the minimum requirement of EN 314-2 and the others presented statistically similarl means. Thus, the use of 160 g/m² weight is recommended. The solid content of the glue mix influenced the mechanical properties, but the results were still higher than those obtained for *Pinus taeda*. The quality of the veneers and the yield of the lamination point to *Hevea brasiliensis* wood Clone RRIM 600 as having the potential to produce veneers, and the results of the physical-mechanical properties of the panels demonstrate the potential of the species in the plywood production.
Keywords: Rubber tree; Plywood; Mechanical properties; Alternative species.

INTRODUCTION

Plywood production has a great importance in the Brazilian trade balance, surpassing $500 million in exports per year. These values, according to the National Forest Information System - SNIF, exceeded the 2019 values of exported particle and fiberboards, the European continent being the main destination for plywood.

According to Ibá annual report, wood panels were responsible for the exportation of 331 thousand m³ of panels in 2020, which represents an increase of almost 23% compared to 2019. This shows the strength that panel manufacturing has on the Brazilian trade balance regarding forest product exportation .

There is strong environmental pressure for the use of wood coming from verified origin, certified and legally extracted in the production of plywood panels in Brazil. Currently, *Pinus* stands out as the main source of raw material in this production. However, studies of non-conventional species, coming from plantations, have great importance, since they tend to increase the supply of raw material to the forest-based industries, as well as to contribute to minimize the environmental pressures on the use of native wood.

Besides *Eucalyptus* and *Pinus*, studies of alternative species for veneer and plywood panels have been performed by several researchers. For example, Iwakiri *et al.* (2013) evaluated the potential of *Sequoia sempervirens* in plywood production; Pinto and Iwakiri (2013) evaluated the yield and quality of laminating veneer of *Cryptomeria japonica*, and Palma *et al.* (2012) evaluated the influence of veneer quality on the static bending of *Hevea brasiliensis* plywood panels. The researchers found satisfactory results, indicating the potential of low- and medium-density species for plywood production.

Hevea brasiliensis (rubber tree) is native to the Amazon region, but clonal plantations have been successfully established in several Brazilian regions, such as the Midwest, Southeast and more recently in northern Paraná, exceeding the 200 thousand hectares around the country. Its wood is classified by Rungwattana *et al.* (2018) as medium density, with mean values between 450 and 660 kg/cm^3, showing white coloration and low natural durability. The *Hevea brasiliensis* wood is classified as good workability (sawing, drilling, turning, gluing and nailing) (PALMA *et al.*, 2012). These characteristics make *Hevea brasiliensis* wood attractive for producing plywood panels and for the furniture industry.

In plywood production, some variables should be considered, including the wood physical and chemical properties, the type and amount of adhesive and pressing parameters. These can be controlled with the aim of obtaining a final product with desirable characteristics that meet the minimum values imposed by the reference standards under which a product is evaluated (TRIANOSKI *et al.*, 2015).

Knowing that the penetration of the adhesive in wood occurs in micrometer scale in the lumen and nanometer scale in the cell wall, it is confirmed that the density is the most important factor that influences the quality of the bonding (COOL; HERNANDÉZ, 2011).

The glue line quality can be affected for many other factors, such as physical, mechanical and chemical properties of the wood (Gonçalves *et al.*, 2016). Regarding the extractives, they can cause a significant reduction in adhesion capacity and contribute to the contamination of the wood surface. Extractives may change the pH of the wood, resulting in pre-cure of the adhesive or inhibiting its wetting, flow and penetration (CAMPELO *et al.*, 2018). In the bonding process and interaction between the wood-adhesive-wood system, one of the most important factors to consider, is the pH of the adhesive as well as the wood, because a little change in pH (adhesive or wood) may influence the solidification of the glue line (DAMÁSIO *et al.*, 2017). Although the ashes content in the wood does not directly affect the performance of the adhesive bonding it does present correlation with the wood acidification and can influence the bonding quality (BOA *et al*., 2014).

Regarding bonding quality, the quantity and the formulation of the resin must be controlled, because it is a factor that may influence the quality of the panels (BIANCHE *et al.*, 2017). The formulation is defined according to the resin type and the quality level required of the plywood, and even the weight of the adhesive varies, depending on the type of resin, the thickness of the veneer and the formulation. The appropriate choice of weight should consider that adhesives are expensive and interfere in the resistance and bonding quality (SANTOS; DEL MENEZZI, 2010).

The influence of the amount of glue in the manufacturing of plywood in general, is an important factor, and is related to the moisture content, decisively influencing the resistance of the joint and the stability of the glued product (SELBO, 1975).

Depending on the viscosity of the adhesive, woods that have large pores absorb more glue for better adhesion. However, the weight must be compensated whenever there is a change in thickness, since badly turned (corrugated) sheets need higher weight glue (IWAKIRI, 1999).

Thus, with the aim of increasing the diversity and availability of raw material for the plywood industry, as well as the valorization of the rubber tree, this research had as its objective to evaluate the potential of the use of *Hevea brasiliensis* – Clone RRIM600 to produce veneers and plywood, as well as the effect of the weight and glue mixture solid content on the mechanical properties.

MATERIALS AND METHODS

The research used 27 years old *Hevea brasiliensis* wood, from a commercial plantation for rubber production, located in Paranapoema, Parana, Brazil. For the lamination, eight short logs, without bark, were used with a length of 0.65 m, obtained from four trees which were randomly collected at the plantation . Logs were subjected to the lamination process without heating. The veneers were obtained with a thickness of 2.0 mm from a rolling mill and were subsequently sectioned into a pneumatic guillotine in the dimensions of 60 x 60 cm.

The lamination yield was determined by the ratio between logs volume, without bark, and total volume of whole veneers, using the CONAMA Resolution 474/2016. The wood basic density was determined using wedges by hydrostatic balance method, following recommendations of the Standard 461/72 COPANT.

For plywood production, the veneers were oven dried until they reached an average moisture content of 8%, and were screened in final dimensions of 50 x 50 cm.

The plywood panels were produced with five veneers, using phenol-formaldehyde resin (double line) with a solid content of 54.50%. The adhesives were formulated with a solid content of 35% – 100 parts of resin, 30% of wheat flour and 25% of water and with solid content of 40% – 100 parts of resin, 20% of wheat flour and 25% of water. The resin used presents pH around 12 and viscosity around 400-800cP. The weights adopted were 140, 160 and 180 g m², as shown in Table 1.

Table 1. Experimental design
Tabela 1. Plano experimental

Treatment	solid contents (%)	Weight (g m²)
T1 (35% – 140 g/m^2)	35	140
T2 (35% – 160 g/m^2)		160
T3 (35% – 180 g/m^2)		180
T4 (40% – 140 g/m^2)	40	140
T5 (40% – 160 g/m^2)		160
T6 (40% – 180 g/m^2)		180

The adhesive and their composition was based on the industry commonly used standards, considering that the industry uses around 35 % to solid content and 160 g/m^2 to weight. This research tested the same specification and a greater solid content varying the weight to test the formulation and its effect on the plywood quality.

The panels were pressed for 10 minutes at a temperature of 140°C and a specific pressure of 10 Kgf/cm^2, and three panels were produced per treatment, totaling 18 experimental panels. This parameter was used based on the veneer quality and the adhesive used and time was programmed in the ratio 1 min/mm of the plywood.

After pressing, the panels were squared and conditioned in a climatic chamber at a temperature of 20 ± 3 °C and relative humidity of 65 ± 5 % until reaching equilibrium moisture content of approximately 12%. Subsequently, test specimens were prepared in order to evaluate the mechanical properties of the panels.

For each panel, six specimens were used for static bending tests, three for each position, parallel and perpendicular.

For the glue line shear strength, five specimens were tested for the dry pre-treatment and five for the pre-treatment boiling cycle. The static bending, parallel and perpendicular, and the glue line shear strength were evaluated according to EN 310 and EN 314-1, respectively.

The chemical and some physical characterization of *Hevea brasiliensis*, used in this research, can be seen in picture 1.

Table 2. Chemical and Anisotropy characteristics of the wood *Hevea brasiliensis* – Clone RRIM600.
Tabela 2. Características químicas e anisotropia da madeira de *Hevea brasiliensis* – Clone RRIM600.

Specie	E.T.* (%)	Klason (%)	Soluble (%)	Total (%)	Holo (%)	Ashes (%)	Anisotropy
Hevea brasiliensis - Clone RRIM600	5,05	18,67	3,82	22,49	72,46	0,09	2,18

* E.T. – Total extractives.
FONT: Raia (2018).

The statistical design was factorial, in a 3x2 arrangement. The homogeneity and normality tests were performed. The results were analyzed using the analysis of variance and Tukey Test at 95% probability level.

RESULTS

Basic density and lamination yield

The average wood basic density, determined by the wedges test, was 572 kg/cm^3 ±7,3% and, based on this value, the species *Hevea brasiliensis* may be classified as medium density according to the recommendations of (LORENZI 2000). The average lamination yield obtained in this study is 44.35%, and, based on this value, this species may be classified as having a satisfactory lamination yield. This yield needs a technical study based on the CONAMA Resolution 474/2016, as it is superior to 35%.

Resistance of the glue line to shearing

Table 2 shows the average values of the resistance of the glue line to shearing of *Hevea brasiliensis* plywood , produced with different weights and glue mixture solid content.

From the analysis of the interaction between weight and glue mixture solid content, no statistically significant differences were found for the resistance of the glue line to shearing in the dry pre-treatment, and it

was noted that the treatments satisfied the minimum requirement of standard EN 314-2, and 1.0 MPa, being approved according to the respective standard.

Table 2. Average results of resistance of the glue line to shearing in *Hevea brasiliensis* – Clone RRIM600 plywood.
Tabela 2. Resultados médios de resistência da linha de cola ao cisalhamento em painéis compensados de *Hevea brasiliensis* – Clone RRIM600.

Treatment	Dry (MPa)	Wood failure (%)	Boiling cycle (MPa)	Wood failure (%)
T1 (35% – 140 g/m^2)	1.10 a (46.56%)	44	0.96 b (40.85%)	18
T2 (35% – 160 g/m^2)	2.00 a (15.92%)	67	1.10 ab (33.34%)	29
T3 (35% – 180 g/m^2)	1.89 a (9.69%)	58	1.15 ab (18.42%)	40
T4 (40% – 140 g/m^2)	1.19 a (55.56%)	41	0.51 c (69.70%)	29
T5 (40% – 160 g/m^2)	1.79 a (12.54%)	69	1.35 a (25.39%)	46
T6 (40% – 180 g/m^2)	1.99 a (28.82%)	72	1.22 ab (23.67%)	40

Averages followed by the same letter in the same column do not differ statistically by the Tukey test at 5% probability level.
Values in parentheses refer to the coefficient of variation in percentage.

For the boiling cycle pre-treatment, statistically significant differences between the treatments were detected, where the panels produced with a weight of 160 g/m^2 and solid content of 40% (T5) presented the best results for the resistance of the glue line to shearing.

Weight effect

Table 3 shows the effect of weight on the resistance of the glue line to shearing.

Table 3. Effect of weight on the resistance of the glue line to shearing in *Hevea brasiliensis* – Clone RRIM600 plywood.
Tabela 3. Efeito da gramatura na resistência da linha de cola ao cisalhamento em painéis compensado de *Hevea brasiliensis* – Clone RRIM600.

Weight (g/m^2)	Dry (MPa)	Wood failure (%)	Boiling cycle (MPa)	Wood failure (%)
140	1.41 b (50.05%)	43	0.65 b (67.64%)	33
160	1.89 a (15.40%)	68	1.22 a (36.68%)	60
180	1.93 a (21.79%)	65	1.19 a (16.00%)	42

Averages followed by the same letter in the same column do not differ statistically by the Tukey test at the 5% probability level.
Values in parentheses refer to the coefficient of variation in percentage.

It was noted that in the dry pre-treatment and boiling cycle, the mean values obtained for the weight of 140 g/m^2 showed statistically significant differences as compared to the others, but the panels evaluated after dry pre-treatment showed minimum values lower to the requirement of EN 314-2.

The average values found for panels produced with weights of 160 g/m^2 and 180 g/m^2 had no statistically significant differences. From an economic point of view, this represents an important aspect and allows the usage of the 160 g/m^2 weight in order to reduce costs and maintain the glue line quality, because the glue is the most expensive item in the plywood production, so the reduction in the glue weight used makes the process less expensive.

Solid content effect

Table 4 shows the effect of the glue mixture solid content on the resistance of the glue line to shearing.

Table 4. Effect of glue mixture solid content on the resistance of the glue line to shearing
Tabela 4. Efeito do teor de sólidos da batida de cola na resistência da linha cola ao cisalhamento.

Solid content of the glue line (%)	Dry (MPa)	Wood failure (%)	Boiling cycle (MPa)	Wood failure (%)
35	1.66 a (32.28%)	57	1.05 a (29.97%)	29
40	1.65 a (37.21%)	61	1.08 a (46.22%)	39

Averages followed by the same letter in the same column do not differ statistically by the Tukey test at 5% probability level.
Values in parentheses refer to the coefficient of variation in percentage.

There are no statistically significant differences between the average values of resistance of the glue line to shearing for the panels produced with glue mixture solid content of 35 and 40%.

In comparative evaluations with European Standard EN 314-2, all the treatments presented average values greater than the minimum value of 1.0 MPa, regardles the percentage of wood failure, meaning that they could be approved according to EN 314-2.

Static bending

Table 5 shows the average values of the modulus of elasticity (MOE) and modulus of rupture (MOR) in parallel and perpendicular static bending for the six treatments. No statistically significant differences between the treatments for parallel and perpendicular MOR were observed.

Table 5. Average values of static bending tests in *Hevea brasiliensis* – Clone RRIM600 plywood.
Tabela 5. Valores médios para o teste de flexão estática em painéis compensados de *Hevea brasiliensis* – Clone RRIM600.

Treatment	Parallel		Perpendicular	
	MOR (MPa)	MOE (MPa)	MOR (MPa)	MOE (MPa)
T1 (35% – 140 g/m^2)	45.14 a (31.86%)	7968 a (9.57%)	32.40 a (15.61%)	2326 ab (12.60%)
T2 (35% – 160 g/m^2)	53.70 a (30.76%)	7351 ab (6.67%)	33.87 a (10.45%)	2437 a (8.67%)
T3 (35% – 180 g/m^2)	58.93 a (13.21%)	6991 ab (9.81%)	33.87 a (10.45%)	2224 ab (6.68%)
T4 (40% – 140 g/m^2)	47.41 a (48.35%)	6107 b (29.73%)	32.53 a (20.85%)	2144 ab (22.43%)
T5 (40% – 160 g/m^2)	50.20 a (30.02%)	6351 ab (24.43%)	31.29 a (30.75%)	1848 b (31.43%)
T6 (40% – 180 g/m^2)	50.47 a (29.14%)	6267 b (20.87%)	35.82 a (12.12%)	1961 ab (13.02%)

Averages followed by the same letter in the same column do not differ statistically by the Tukey test at 5% probability level.
Values in parentheses refer to the coefficient of variation in percentage.

Parallel MOE presented statistically significant differences, where the T1 (35% - 140 g/m^2) presented better results. This may be explained by the fact that the veneers had not been previously classified , thus having a number of less dense sheets in this treatment, which causes greater elasticity in the plywood.

For perpendicular MOE, the mean values obtained presented statistically significant differences, where T2 (35% - 160 g/m^2) presented better results.

Weight effect

Table 6 shows the effect of weight on the MOR and MOE in the parallel and perpendicular directions.

Table 6. Effect of weight on the modulus of elasticity and rupture in static bending in *Hevea brasiliensis* – Clone RRIM600 plywood.
Tabela 6. Efeito da gramatura no modulo de elasticidade e ruptura em flexão estática em painéis compensados de *Hevea brasiliensis* – Clone RRIM600.

Weight (g/m^2)	Parallel		Perpendicular	
	MOR (MPa)	MOE (MPa)	MOR (MPa)	MOE (MPa)
140	46.21 a	7038 a	32.46 a	2235 a
	(39.59%)	(23.57%)	(17.68%)	(17.78%)
160	51.95 a	6851 a	32.57 a	2142 a
	(29.73%)	(17.94%)	(21.96%)	(24.32%)
180	54.70 a	6629 a	34.84 a	2092 a
	(22.33%)	(16.29%)	(11.40%)	(11.63%)

Averages followed by the same letter in the same column do not differ statistically by the Tukey test at 5% probability level.
Values in parentheses refer to the coefficient of variation in percentage.

No statistically significant differences were found, proving that the weight increment did not result in an increase in MOE and MOR values in static bending. This finding is important from an economic point of view, due to the possibility of lower resin consumption, considering that resin is the most expensive input in plywood production.

Solid content effect

Table 7 shows the effect of the glue mixture solid content on the MOR and MOE, both parallel and perpendicular.

Table 7. Effect of glue mixture solid content on the modulus of elasticity and rupture in static bending in *Hevea brasiliensis* – Clone RRIM600 plywood.
Tabela 7. Efeito do teor de sólidos da batida de cola no modulo de elasticidade e ruptura em flexão estática em painéis compensador de *Hevea brasiliensis* – Clone RRIM600.

Solid content of the glue mixture (%)	Parallel		Perpendicular	
	MOR (MPa)	MOE (MPa)	MOR (MPa)	MOE (MPa)
35	52.59 a	7437 a	33.38 a	2329 a
	(26.88%)	(10.18%)	(12.01%)	(10.05%)
40	49.44 a	6242 b	33.24 a	1984 b
	(34.50%)	(24.25%)	(21.79%)	(23.12%)

Averages followed by the same letter in the same column do not differ statistically by the Tukey test at 5% probability level.
Values in parentheses refer to the coefficient of variation in percentage.

The values of parallel and perpendicular MOR did not present statistically significant differences, however, for the parallel and perpendicular MOE values, statistically significant differences between the treatments were detected, where 35% presented the highest values.

DISCUSSION

Basic Density and lamination yield

The basic density values obtained in this study proved to be consistent with the results found by Rungwattana *et al.* (2018) who found *Hevea brasiliensis* values ranging between 450 and 660 Kg/cm^3 for basic density.

The porosity in the higher basic density species can influence the veneer bonding, but with good anchoring the mechanical properties can be increased.

The results obtained for lamination yield were superior to the one found by Palma (2012) for the same species, whose value was 36.60%. However, these values were inferior when compared to the average values found by Tavares *et al.* (2018) for *Pinus patula*, which obtained an average yield of 45%.

The results can be explained by the purpose of pine plantations to be shallow cut and that of *Hevea brasiliensis* being just a usage possibility, where there was no adequate management or shedding.

Resistance of the glue line to shearing

The results on this research were close to those found by Kazmierczak *et al.* (2017), for phenolic plywood produced with *Eucalyptus dunnii*, *Eucalyptus saligna* e *Eucalyptus urograndis*, where the mean values found were close to 1.41 MPa in dry pre-treatment of 36% solid content.

Moreover, Iwakiri *et al.* (2013), *Sequoia sempervirens* panels, found values ranging from 0.66 MPa to 0.94 MPa in the boiling cycle pre-treatment, which were inferior results to those found in this research.

It was also noted that the panels produced with a weight of 140 g/m^2, for both solid contents, did not meet the minimum requirements of EN 314-2, this result is probably due to the fact that the lower content of weight was not sufficient to bond the veneers one to another, or the glue line weakened with the boiling treatment.

About weight, the results obtained in this research were similar to those obtained by Pinto and Iwakiri (2013) for plywood of *Cryptomeria japonica*, that presented basic density similar to *Hevea brasiliensis*, wherein the variation of the weight of 270 g/m^2 and 300 g/m^2 did not influence the resistance of the glue line to shearing.

Considering the solid content of the glue mixture, the results obtained in this research were similar to those found by Iwakiri *et al.* (2018) when evaluating plywood made of a combination of *Pinus* and *Crupessus*, concluding that different solid contents of the glue mixture did not significantly influence the resistance of the glue line to shearing.

Static bending

In this research, parallel MOR and MOE obtained, presented higher results than those found by Cunha *et al.* (2016) for *Pinus* plywood, whose values ranged from 40.04 MPa to 57.11 MPa and 3657 MPa to 4450 MPa, respectively.

On the same way, perpendicular MOR and MOE presented the same behavior compared to the result of the same authors, who found average values ranged from 14.84 MPa to 25.03 MPa and 1404 MPa to 1838 MPa, respectively.

Regarding commercial panels of *Pinus taeda*, the values obtained in this research were higher than those found for *Pinus* taeda, being 6890 MPa and 38.1 MPa, respectively, for MOE and parallel MOR. This fact can be attributed to the apparent difference in density of *Hevea brasiliensis* panels in comparison to *Pinus taeda* panels.

For these panel samples, the mean values of panel density varied from 631 to 708 kg/cm^3 surpassing commercial values for *Pinus taeda* of 530 kg/cm^3. This difference in density may imply an increase in resistance values for panels produced from *Hevea brasiliensis* compared to commercial panels of *Pinus taeda*.

The results obtained in this research were similar to those found by Iwakiri *et al.* (2018) for plywood made of a combination of *Pinus* and *Cupressus*, whose values indicated that the variation of the glue mixture solid content did not influence the MOR results .

The average values found for parallel and perpendicular MOE for panels produced with a solid content of 35% were statistically higher than the average values found for panels produced with a solid content of 40%. This difference can be attributed to the higher apparent density found in panels produced with a solid content of 35%, rather than to the variation of the glue mixture solid content.

CONCLUSIONS

- The basic density of *Hevea brasiliensis* – Clone RRIM600 wood was classified as medium density and is suitable for lamination.
- The yield of the wood lamination process of *Hevea brasiliensis* was considered satisfactory.
- The panels produced with the weights of 160 g/m^2 and 180 g/m^2 were approved, according to the standard EN 314-2, and shown to be statistically similar. Therefore, it is recommended to use the lower weight, aiming at the rationalization of resources.
- The variation of the glue mixture solid content did not significantly affect the resistance of the glue line to shearing. However, it exerted an effect on parallel and perpendicular MOE.
- The quality of the veneers and the yield of the lamination point to *Hevea brasiliensis* wood Clone RRIM 600 as having the potential to produce veneers, and the results of the mechanical properties of the panels demonstrate that the species presents the potential to produce plywood for external use.

ACKNOWLEDGEMENTS

The authors wish to thank Fazenda Guanabara for the material granted and CAPES for funding the research.

REFERENCES

BIANCHE J. J.; TEXEIRA A. P. M.; LADEIRA J. P. S.; CARNEIRO A. C. O.; CASTRO R. V. O.; LUCIA R. M. D. Cisalhamento na linha de cola de *Eucalyptus* sp. colados com diferentes adesivos e diferentes gramaturas. **Floresta e Ambiente**, Seropédica, v. 24, n. e00077114, 2017

BOA A. C.; GONÇALVES F. G.; OLVEIRA J. T. S.; PAES J. B.; ARANTES M. D. C. Resíduos madeireiros de eucaliptos colados com resina ureia formaldeído à temperatura ambiente. **Scientia Forestalis**, Piracicaba, v. 42, n. 102, p. 279-288, 2014.

CAMPELO S.; IWAKIRI S.; TRIANOSKI R.; AGUIAR O. R. Utilização da madeira de *Genipa americana* para produção de painéis de colagem lateral – EGP. **Floresta**, Curitiba, v. 47, n. 1, p. 129-135, jan-mar. 2018.

COMISSÃO PANAMERICANA DE NORMAS TÉCNICAS. **COPANT 461**: Determinación del peso especifico aparente. Buenos Aires, 1972.

COOL J.; HENANDÉZ R. E. Evaluation of four surfacing methods on black spruce wood in relation to poly (vinyl acetate) gluing performance. **Wood and Fiber Science**, Monona, v. 43, n. 2, p. 194-205, 2011.

CUNHA A. B.; RIOS P.D.; STUPP A. M.; ANTUNES R.; BRAND M. A. Produção de painéis compensados com resina fenólica e melamínica sem formaldeído. **Floresta**, Curitiba, v. 46, n. 4, p. 553-559, out-dez. 2016.

DAMÁSIO R. A. P.; CARVALHO A. G.; GOMES F. J. B.; CARNEIRO A. C. O.; FERREIRA J. C.; COLODETTE J. L. Interação de nanocristais de celulose com adesivo ureia-formaldeído em juntas coladas de *Eucalyptus* sp. **Scientia Forestalis**, Piracicaba, v. 45, n. 113, p. 169-176, 2017.

EUROPEAN COMMITTEE FOR STANDARDIZATION. **EN 310**: determination of modulus of elasticity in bending and of bending strength. Lisboa, 2004.

EUROPEAN COMMITTEE FOR STANDARDIZATION. **EN 314-1**: plywood – Bonding Quality. Part 1: Test methods. Londres, 2004.

EUROPEAN COMMITTEE FOR STANDARDIZATION. **EN 314-2**: contraplacados – Qualidade da colagem. Parte 2: Requisitos. Lisboa, 2002a..

GONÇALVES F. G.; SEGUNDINHO P. G. A.; SHAYDER L. F.; TINTI V. P.; SANTIAGO S. B. 2016. Avaliação da resistência ao cisalhamento da madeira de *Pinus* sp. Coladas em temperatura ambiente. **Ciência da Madeira**, Pelotas, v. 7, n. 1, p. 42-50, 2016.

INDÚSTRIA BRASILEIRA DE ÁRVORES. **Anuário estatístico 2016**: Indicadores do setor brasileiro de árvores plantadas. Brasília: GWA, 2016.

IWAKIRI, S.; COSTA, A. F.; KLITZKE, R. J.; NIELSEN, I. R.; ALBERTI, R. A. R.; NIEFE, I. Produção de chapas de madeira aglomerada de *Pinus elliottii* Engelm. Com inclusão laminar. **Cerne**, Viçosa, v. 5, n. 2, 1999.

IWAKIRI S.; CUNHA A. B.; TRIANOSKI R.; BRAZ R. L.; CASTRO V. G.; KAZMIERCZAK S.; PINHEIRO E.; RANCATTI H.; SANCHES F. L. Produção de compensados fenólicos com lâminas de madeira de *Sequoia sempervirens*. **Floresta e Ambiente**, Seropédica, v. 20, n. 2, p. 264-270, 2013.

IWAKIRI S.; TRIANOSKI R.; VIEIRA H. C.; ANDRADE R.; ROCHA T. M. S.; FERREIRA V. R. S. Viabilidade de uso de madeira de *Cupressus torulosa* para produção de painéis compensados. **Scientia Forestalis**, Piracicaba, v. 46, n. 120, p. 638-645, 2018.

KAZMIERCZAK S.; HILLING E.; IWAKIRI S. 2017. Painéis compensados fabricados com lâminas de três espécies de eucaliptos. **Floresta e Ambiente**, Seropédica, v. 24, n. e00111614, 2017.

LORENZI, H. **Árvores brasileiras**: Manual de identificação e cultivo de plantas arbóreas nativas do Brasil. Nova Odessa: Plantarum, 2000.

PALMA, H. A. L.; ESCOBAR, J. F.; BALLARIN, A. W.; LEONELLO, E. C. Influência da qualidade das lâminas no desempenho mecânico de painéis compensados de *Hevea brasiliensis*. **Floresta e Ambiente**, Rio de Janeiro, n, 19, v. 2, p. 133-140, 2012.

PINTO J. A.; IWAKIRI S. Estudo sobre a viabilidade do uso da madeira de *Cryptomeria japonica* para produção de painéis compensados. **Scientia Forestalis**, Piracicaba, v. 41, n. 97, p. 29-37, 2013.

RAIA, R. Z.; IWAKIRI, S.; TRIANOSKI, R; ANDRADE, A. S. de; JUNIOR, E. A. B. Influência da extração de látex nas propriedades físicas e químicas da madeira de *Hevea brasiliensis*. **Ciência da Madeira**, Pelotas, v. 9, n. 3, p. 152-159, 2018.

RUNGWATTANA K.; KASEMSAP P.; PHUMICHAI T.; KANPANON N.; RATTANAWONG R.; HIETZ P. Trait Evolution in tropical rubber (*Hevea brasiliensis*) trees is related to dry season intensity. **Functional ecology**, Londres, v. 32, p. 2638-2651, 2018.

SANTOS C. M. T.; DEL MENEZZI C. H. S. Efeito da gramatura sobre a resistência ao cisalhamento da linha de cola de duas madeiras tropicais: Seru (*Allantoma lineata*) e Marupá (*Simarouba amara*). **Floresta**, Curitiba, v. 40, n. 2, p. 345-354, 2010.

SELBO, M. L. **Adhesive Bonding of wood. Technical Bulletin.** Washington, FOREST SERVICE, n 1512, 1975.

TAVARES E. L.; HILLIG E.; BEDNARCZUK E.; MACHADO J. F.; MUSTEFAGA E. Massa específica da madeira, rendimento da laminação e qualidade de lâminas de *Pinus patula* Schltdl & Cham. **Ciência da Madeira**, Pelotas, v. 9, n. 2, p. 103-112, 2018.

TRIANOSKI R.; IWAKIRI S.; MATOS J. L. M.; HIGA A. R.; BRAZ R. L. Avalição das propriedades de painéis compensados de *Melia azedarach* L. produzidos com diferentes gramaturas e tempos de prensagem. **Árvore**, Viçosa, v. 39, n. 4, p. 759-768, 2015.