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TECHNICAL PAPER

PARTICLEBOARD PRODUCED WITH CHROMATED COPPER ARSENATE- AND BORATE-TREATED CAIXETA WOOD: A TECHNICAL FEASIBILITY STUDY

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KEYWORDS

Simarouba amara wood, CCA/CCB treatment, particleboard, waste management.

ABSTRACT

Brazilian flora has more than 12 thousand tropical wood species, which can be the raw material for the construction industry. Chromated copper borate (CCB) and chromated copper arsenate (CCA) are wood preservative chemicals, which can generate toxic waste. Particleboards are usually produced from *Pinus* sp. and *Eucalyptus* sp. wood particles and a polymeric matrix (often formaldehyde-based), and they are used as raw material mainly for the furniture industry. This study aimed to investigate the technical feasibility of particleboard production using caixeta wood (*Simarouba amara* Aubl.) particles and bicomponent castor oil-based polyurethane resin for tropical wood waste management, as well as study the impact of CCA/CCB treatments on the performance of these panels according to NBR 14810 standards. Analysis of variance (ANOVA) tests was performed to compare ten physical and mechanical properties of the panels produced with CCA, CCB, and non-treated caixeta wood particles. The performance of caixeta wood panels was similar to the usually produced boards (using *Pinus* sp. and *Eucalyptus* sp. wood). Furthermore, preservative treatments did not change significantly the mechanical performance of panels. However, water absorption increased and thickness swelling decreased in CCA/CCB treated samples.

INTRODUCTION

Tropical Brazilian wood species are important raw materials in the building sector and are used as structural and non-structural wood components (doors, floors, and windows) (Calil Junior et al., 2003; Ferreira et al., 2013; Lukacs et al., 2016; Fueyo et al., 2017). Ter Steege et al. (2016) pointed out that Brazil has about 12 thousand tropical wood species, but only a few of them are already physically and mechanically characterized, leading to the misuse of such resources (Almeida et al. 2014). The Brazilian Code ABNT NBR 7190: Design of Timber Structures (ABNT, 1997) provides the procedures for calculating wood structures and characterizing wood properties for structural masonry designs.

Caixeta (*Simarouba amara* Aubl.) is a tropical Brazilian wood widely used because of its physical and mechanical properties, as well as its good appearance and coloration (Marques et al., 2006; Azevedo et al., 2010). This wood species is a raw material for timber structures and is usually classified into the C20 strength class of the Brazilian code (Gonçalez et al., 2014), with a characteristic value of 5-percentile compression strength parallel to grain of up to 20 MPa. The Brazilian furniture industry demands lots of caixeta wood, mainly for bespoke production, due to its coloration, low density (about 0.5 g/cm^3), and low incidence of defects (Azevedo et al., 2010; Gonçalez et al., 2014).

As tropical woods are widely used as raw material for several Brazilian industry sectors, lots of wastes are

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generated. Therefore, the way these wastes are handled in these activities should be investigated and find new alternatives to add value to them (Alves et al., 2014; Ogunwusi, 2014; Almeida et al., 2017).

Wood-based panels, such as medium-density particleboards (MDP), can be used to recover tropical wood residues as they are wood particle composites (usually *Eucalyptus* sp. and *Pinus* sp. from reforestation areas to large-scale production) and formaldehyde-based polymeric ligands (Iwakiri et al., 2005; Alves et al., 2014; Nascimento et al., 2016). These adhesives are the major component of the final costs of MDP panel production (Mendes et al., 2010). Wood panels are mainly used in furniture and building sectors, and about a half of the production is MDP. This, in turn, is mostly used in furniture manufacturing and as wood floors (Vidal & Hora, 2014).

Today, synthetic resins are more commonly used due to their better adhesion properties compared to natural ones. But now a worldwide trend to use biodegradable, non-polluting, and renewable products has brought more investments to search for a free-formaldehyde adhesive with similar adhesion efficiency (Nascimento et al., 2016). Castor oil-based polyurethane resin has been an alternative to formaldehyde-based adhesives, as it is a bicomponent resin composed of a polyol and a prepolymer (Ferro et al., 2014). Castor oil is extracted from *Ricinus communis* seed, which is found in tropical and subtropical regions and is very abundant in Brazil. Furthermore, this alternative resin does not require a paraffin emulsion, which is a positive point for its use as an adhesive (Bertolini et al., 2014).

To increase the service life of wood materials and structures, chemical treatments against biological decomposition are needed mainly for low-density wood species. In this context, water-soluble preservatives are mostly used since they increase wood resistance to xylophagous organisms (Boschetti et al. 2016). In Brazil, the most common chemical preservatives are chromated copper borate (CCB) and arsenate (CCA) (Bertolini et al., 2014). For this reason, CCA- and CCB-treated wood residues deserve more attention due to the toxicity of these chemicals (Vidal et al., 2015). In short, Brazilian wood particleboards must be evaluated for technical feasibility, as well as for physical and mechanical properties due to protective chemicals against biological attacks.

Particleboard performance evaluation is based on NBR 14810 (ABNT, 2018), which prescribes physical and mechanical tests for the following properties: Density, Modulus of Elasticity and Modulus of Rupture in Static bending test, Internal Adhesion – Perpendicular tension stress, Thickness Swelling in 2 and 24 hours Water absorption in 2 and 24 hours, Edge Screw Pullout and Face Screw Pullout, and establishes the reference performance values.

This study aimed to investigate the technical feasibility of particleboards of CCA- and CCB-treated caixeta wood and castor oil-based bicomponent polyurethane resin based on their physical and mechanical properties determined according to the NBR 14810 (ABNT 2018) code, besides comparing them (CCA, CCB, and untreated) to evaluate the impact of preservative treatment on panel performances.

MATERIAL AND METHODS

Caixeta wood lumbers were treated against biological attack with CCA and CCB preservatives. Both treatments were performed using the vacuum-pressure method at pressures between 1.21 and 1.41 MPa, with preservative retention of 9.6 kg per cubic meter of treated wood.

CCA/CCB treated and non-treated wood lumbers (the three treatments considered) were processed in a knife mill for the production of particles. Castor oil-based polyurethane resin was used to glue wood particles in a ratio of 12% adhesive/wood particles, as it is an alternative to formaldehyde-based adhesives.

Three particleboards were made for each treatment, totaling 9 panels. Figure 1 illustrates the manufacturing of particleboards, wherein Figure 1a shows the press equipment and Figure 1b the final panel produced.

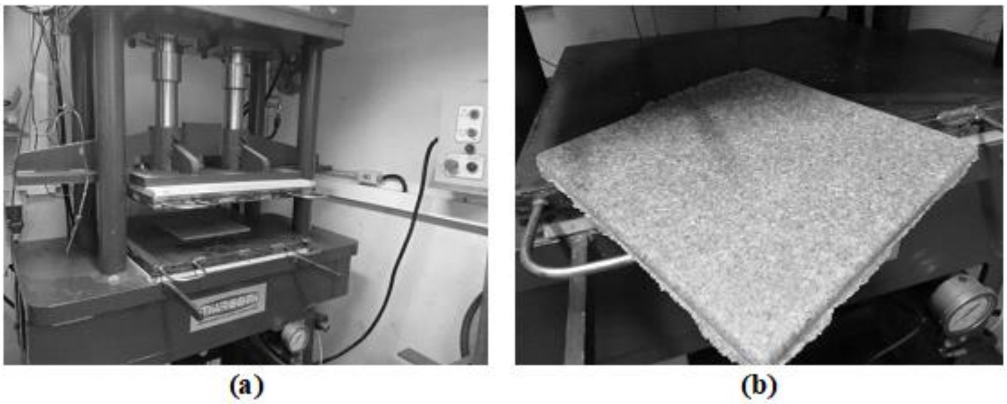
(a) (b)

FIGURE 1. (a) Panel press equipment. (b) Finished panel.

Dimensions of the final panels were 300 mm x 300 mm x 10 mm (length x width x thickness). After production, they were tested for physical and mechanical performances according to the NBR 14810 standards (ABNT, 2018). The polyol/pre-polymer considered mass proportion equal to 1:1, one part of polyol for one part of pre-polymer. Panels were pressed at 100ºC and 4 MPa for 10 minutes

The following panel properties were determined: Density (g/cm^3), Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) in Static bending test (MPa), Internal Adhesion (MPa), Thickness Swelling in 2 and 24 hours (%), Water absorption in 2 and 24 hours (%), Edge Screw Pullout (N), and Face Screw Pullout (N).

Each panel provided five specimens for static bending tests, three for Internal Adhesion tests, three for Thickness Swelling tests in 2 and 24 hours, three for Water absorption tests in 2 and 24 hours, two for Edge Screw Pullout tests, and two for Face Screw Pullout tests. The entire physical and mechanical characterization of particleboards provided 306 determinations.

Statistical analysis was performed using the R software version 3.5.2. Analysis of variance (ANOVA) tests was performed at a 5% significance level for evaluation of the equivalence among groups (three treatments considered). For ANOVA validation, variance normality and homogeneity were tested by Shapiro-Wilk and Bartlett's tests at the same significance level of 5%. The means of physical and mechanical properties were compared by Tukey's test considering a significant p-value of 5%.

RESULTS AND DISCUSSION

The performance of each panel could be determined by the physical and mechanical tests. Tables 1 to 5 show the summary of the results for Modulus of Elasticity (MOE), Modulus of Rupture (MOR), Density, Thickness Swelling in 2h, Thickness Swelling in 24h, Water Absorption in 2h, Water Absorption in 24h, Internal Adhesion, Edge Screw Pullout, and Face Screw Pullout.

TABLE 1. Summary of the results for Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) in Static bending test (MPa).

Statistics	MOE (MPa)			MOR (MPa)		
	CT	CCA	CCB	CT	CCA	CCB
Average value	2291.86	2378.69	2170.32	21.16	23.03	18.55
CV (%)	17.63	16.86	16.32	24.40	19.73	22.04
Minimum	1590.80	1788.13	1622.52	13.71	15.94	12.30
Maximum	2956.55	3033.94	2832.04	31.48	30.93	27.50
Count	15	15	15	15	15	15

CV: coefficient of variation (%); CT control panels (caixeta wood without CCA/ CCB treatments)

TABLE 2. Summary of the results for Density and Thickness Swelling in 2h.

Statistics	Density (g/cm^3)			Thickness Swelling - 2h (%)		
	CT	CCA	CT	CCA	CT	CCA
Average value	0.82	0.82	0.82	0.82	0.82	0.82
CV (%)	5.54	5.81	5.54	5.81	5.54	5.81
Minimum	0.74	0.73	0.74	0.73	0.74	0.73
Maximum	0.88	0.90	0.88	0.90	0.88	0.90
Count	15	15	15	15	15	15

CV: coefficient of variation (%); CT control panels (caixeta wood without CCA/ CCB treatments)

TABLE 3. Summary of the results for Thickness Swelling in 24h and Water Absorption in 2h.

Statistics	Thickness Swelling - 24h (%)			Water Absorption - 2h (%)		
	CT	CCA	CCB	CT	CCA	CCB
Average value	12.25	10.83	9.13	5.40	6.14	7.91
CV (%)	6.06	7.87	11.07	26.06	18.80	15.80
Minimum	11.04	9.91	7.25	3.68	4.17	6.07
Maximum	13.23	12.07	10.55	7.94	7.80	9.80
Count	9	9	9	9	9	9

CV: coefficient of variation (%); CT control panels (caixeta wood without CCA/ CCB treatments)

TABLE 4. Summary of the results for Water Absorption in 24h and Internal Adhesion.

Statistics	**Water Absorption - 24h (%)**			**Adhesion (MPa) (%)**		
	CT	**CCA**	**CCB**	**CT**	**CCA**	**CCB**
Average value	19.35	24.42	26.72	2.87	3.20	3.23
CV (%)	24.14	13.87	12.28	42.14	32.00	19.73
Minimum	13.32	19.13	22.35	0.79	1.59	2.63
Maximum	27.71	29.42	31.91	4.50	4.37	4.34
Count	9	9	9	9	9	9

CV: coefficient of variation (%); CT control panels (caixeta wood without CCA/ CCB treatments)

TABLE 5. Summary of the results for Edge Screw Pullout and Face Screw Pullout.

Statistics	**Edge Screw Pullout (N)**			**Face Screw Pullout (N)**		
	CT	**CCA**	**CCB**	**CT**	**CCA**	**CCB**
Average value	2141.82	2051.96	1594.13	1226.25	1357.02	1667.70
CV (%)	25.57	33.31	24.83	33.85	14.76	21.21
Minimum	1422.45	1373.4	1128.15	833.85	1128.15	1128.15
Maximum	2648.7	2992.05	2256.3	1912.95	1618.65	2109.15
Count	6	6	6	6	6	6

CV: coefficient of variation (%); CT control panels (caixeta wood without CCA/ CCB treatments)

Particleboards of CCA-treated caixeta wood lumber showed the highest MOE and MOR values (2378.69 and 23.03 MPa, respectively). The minimum MOE and MOR values for panel P4 (for use in dry conditions) are 16 and 2300 MPa, respectively (ABNT, 2018). The highest CV was 24.40% (MOR) for control samples, while the lowest was 16.32% (MOE) for CCB-treated samples. The coefficient of variations among the specimens of treatment (panel). Lower coefficients of variation indicate stability in the values of particleboard properties, while higher ones point to greater variations among specimens.

All treatments had the same density average, with CV values below 6%. The highest Thickness Swelling in 2h was 5.75% for control samples (below the maximum 8% preconized by ABNT, 2018), while the lowest was 4.56% for CCB-treated samples. The CVs for Thickness Swelling in 2h ranged between 14.89% and 18.97% for CCA-treated and control samples, respectively.

The smallest Thickness Swelling in 24h was observed in CCB-treated samples (9.13%), while the widest was 12.25% for control samples, with CVs of 11.07 and 6.06%, respectively. For this property, the Brazilian standard NBR 14810 (ABNT, 2018) establishes a maximum of 19%. Water Absorption in 2h reached the greatest value (7.91%) for CCB-treated samples and the lowest (5.40%) for control samples, with CVs between 15.80 and 26.06%, respectively. The greatest Water Absorption in 24h was 26.72% for CCB-treated samples, and the smallest (19.35%) for control samples, with CVs between 12.28 and 24.14%, respectively.

In terms of Internal Adhesion, the highest value was 3.23 MPa for CCB-treated samples (CV = 19.73%). This value is above the minimum 0.4 MPa preconized by ABNT (2018) for P4 panels (structural panels for dry conditions). The lowest value of this mechanical property was 2.87% for control samples (CV = 42.14%)..

The highest Edge Screw Pullout value was 2141.82 N for control samples, and the lowest 1594.13 N for CCB-treated samples, with CVs of 25.57 and 24.83%, respectively. Regarding Face Screw Pullout values, the largest was 1667.70 N and the lowest 1226.25 N, with CVs between 14.76 and 33.85% for CCA-treated and control samples, respectively.

According to the summary of results, CCA-treated samples showed intermediate values for physical properties and the best MOR and MOE performances. Our panel performance findings were compared to those of Bertolini et al. (2014). Given the similarity in results, we may state that caixeta wood can be used for particleboard production.

The particleboard panels produced with CCA-, CCB-treated, and untreated caixeta wood samples (three treatments) were compared by ANOVA at a 5% significance level for the ten properties investigated here. For p-values greater than 5%, we accept the hypothesis of group equivalence, refuting it otherwise. Table 6 displays the ANOVA tests.

TABLE 6. ANOVA tests comparing the three treatments on MDP particleboards for the ten properties analyzed.

ANOVA	DF	SS	MS	F	p
MOE treatment	2	328626	164313	1.096	0.3430
Residuals	42	6295023	149881		
MOR treatment	2	151.600	75.780	3.552	0.0376
Residuals	42	896.200	21.340		
Density treatment	2	0.00010	0.00005	0.023	0.9770
Residuals	42	0.08882	0.00211		
Thickness Swelling - 2h treatment	2	6.355	3.177	3.991	0.0319
Residuals	24	19.109	0.796		
Thickness Swelling - 24h treatment	2	44.040	22.022	28.750	0.0000
Residuals	24	18.390	0.766		
Water Absorption - 2h treatment	2	29.820	14.910	9.176	0.0011
Residuals	24	39.000	1.625		
Water Absorption - 24h treatment	2	255.800	127.900	8.708	0.0014
Residuals	24	352.500	14.690		
Internal Adhesion treatment	2	0.747	0.373	0.384	0.6850
Residuals	24	23.306	0.971		
Edge Screw Pullout treatment	2	10758	5379	1.681	0.2190
Residuals	15	47992	3199		
Face Screw Pullout treatment	2	6411	3206	2.742	0.0966
Residuals	15	17533	1169		

Table 6 demonstrates that only MOR, Thickness Swelling in 2h, Thickness Swelling in 24h, Water Absorption in 2h, and Water Absorption in 24h had significant differences among treatments (underlined p-values). ANOVA tests for each physical and mechanical property were validated by the Shapiro-Wilk normality test [SW] and Bartlett's homogeneity test [Bt]. Figures 2 to 6 show the ANOVA validation tests, as well as quantile graphs for the ten investigated properties.

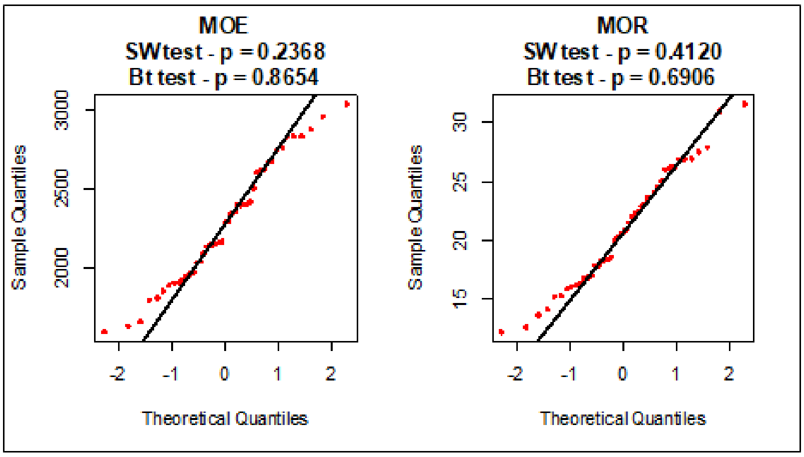

FIGURE 2. ANOVA validation tests for MOE and MOR.

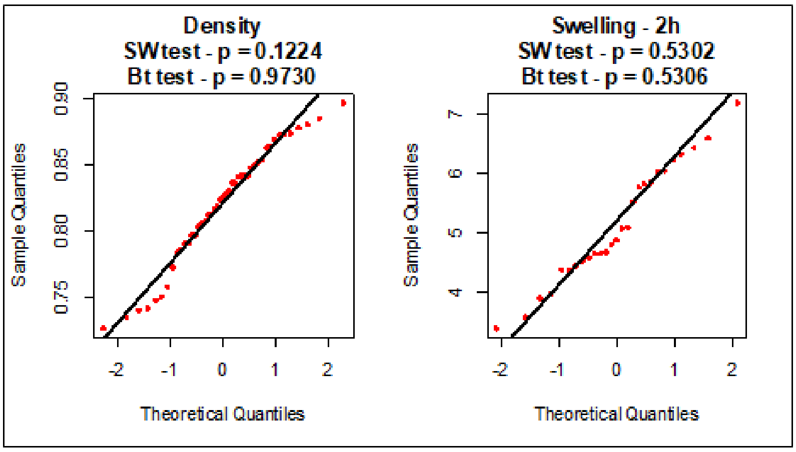

FIGURE 3. ANOVA validation tests for Density and Thickness Swelling in 2h.

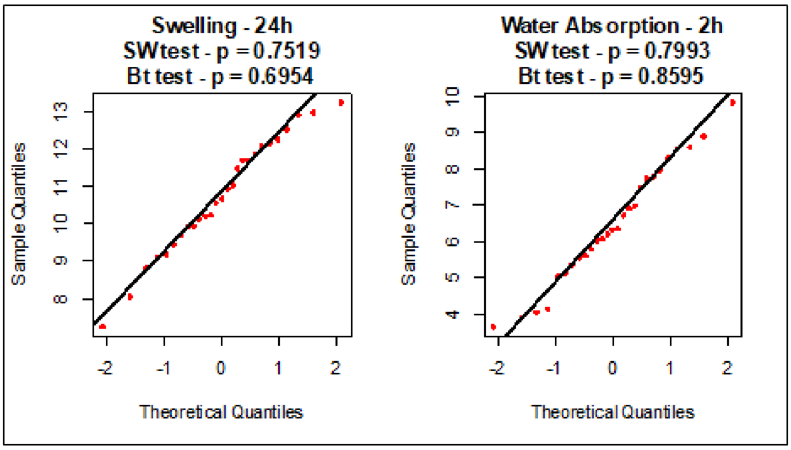

FIGURE 4. ANOVA validation tests for Thickness Swelling in 24h and Water absorption in 2h.

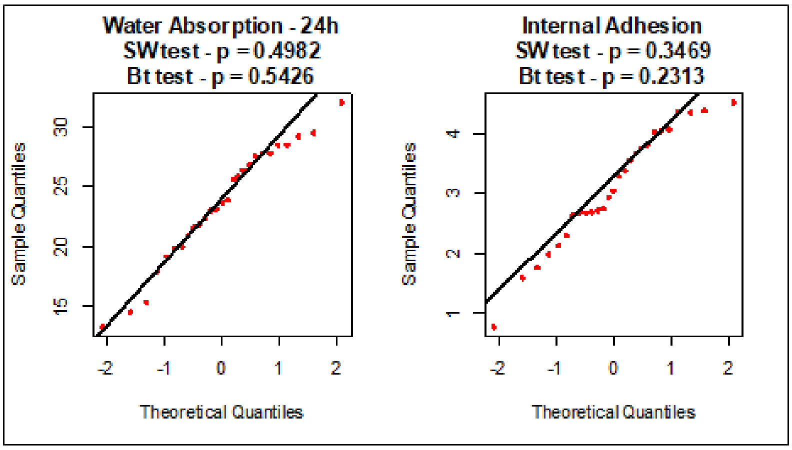

FIGURE 5. ANOVA validation tests for Water absorption in 24h and internal Adhesion.

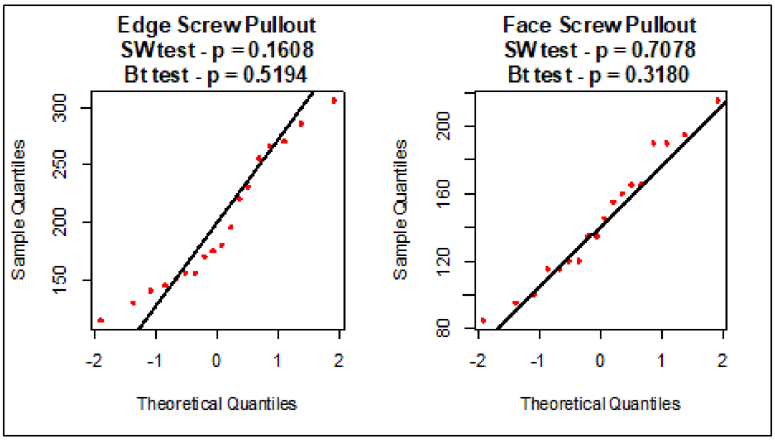

FIGURE 6. ANOVA validation tests for Edge Screw Pullout and Face Screw Pullout.

According to Figures 2 to 6, all parameters showed homogeneity in variances among the three treatments, and results had a clear normal distribution, thus validating the ANOVA tests.

When ANOVA p-values were significant, parameter means were evaluated by Tukey's contrast test. Figures 7 to 11 show the boxplots of the three groups for all investigated mechanical and physical properties, as well as contrast test results. In the contrast tests, equal letters mean equivalent groups, wherein "a" is greater than "b," which is greater than “c.”

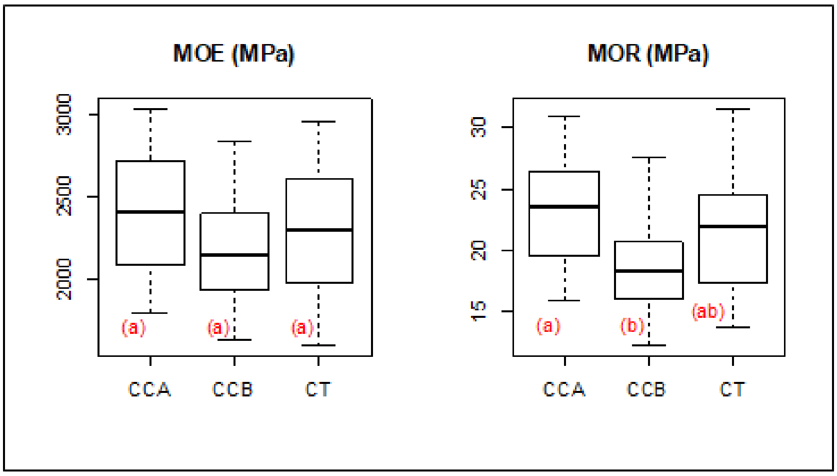

FIGURE 7. Boxplots and contrast tests for MOE and MOR.

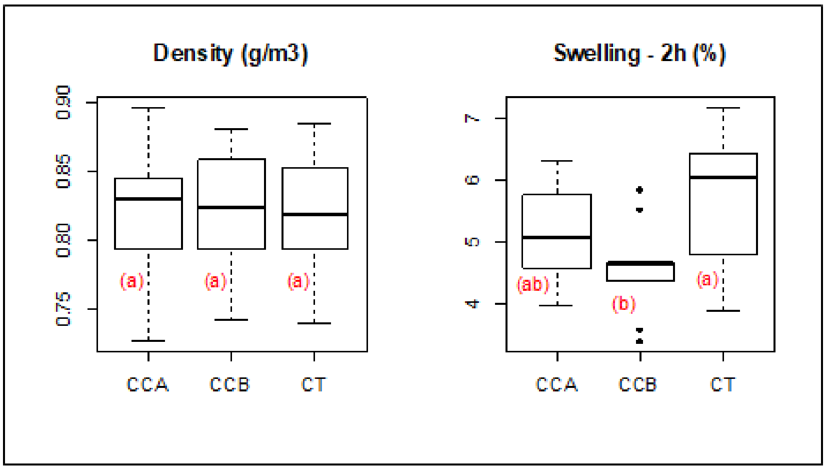

FIGURE 8. Boxplots and contrast tests for Density and Thickness Swelling in 2h.

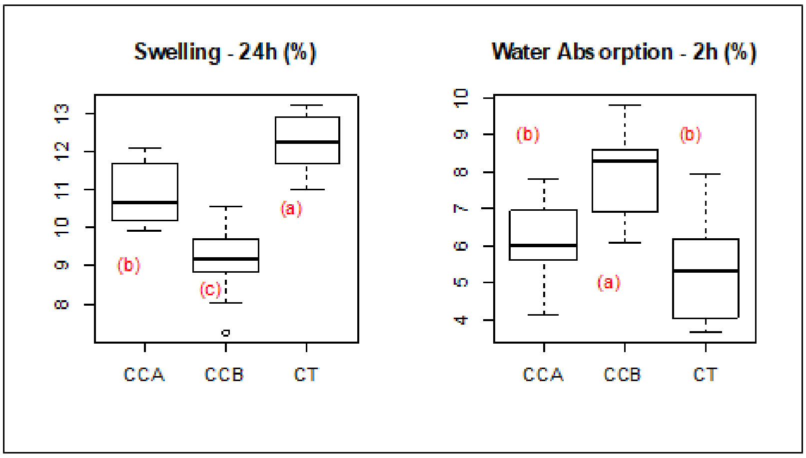

FIGURE 9. Boxplots and contrast tests for Thickness Swelling in 24h and Water Absorption in 2h.

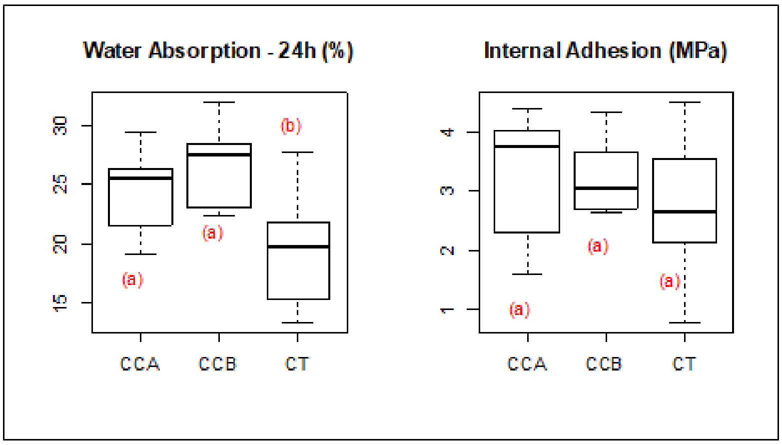

FIGURE 10. Boxplots and contrast tests for Water Absorption in 24h and Internal Adhesion.

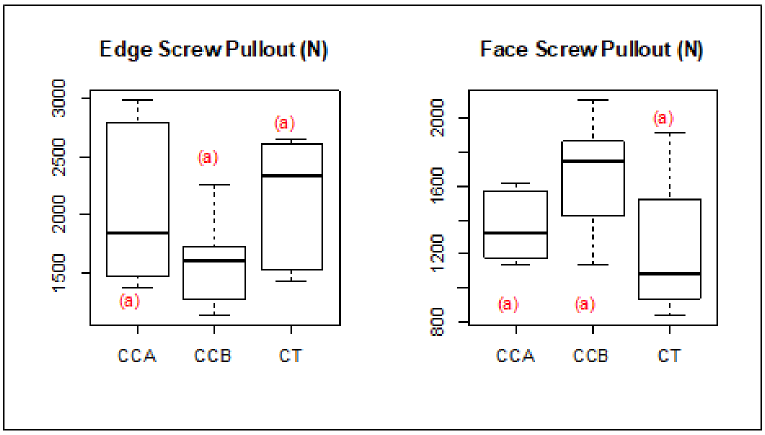

FIGURE 11. Boxplots and contrast tests for Edge Screw Pullout and Face Screw Pullout.

As shown by the boxplots and contrast tests, most of the physical and mechanical properties remained equivalent in terms of panel performance (control vs. without treatment). Summarizing the results into three treatment comparisons, CCA and CCB treatments increased Water Absorption and decreased Thickness Swelling in panels. Therefore, preservatives seem to facilitate Thickness Swelling in panels, with less water impregnation in wood microstructures (cell wall). This can be due to the hysteresis effect and chemical components in wood cavities (Amaral, 2012). Moreover, CCA- and CCB-treated wood samples seem to be more susceptible to free water retention instead of water impregnation, leading to decreased wood-particle swelling and increased water absorption.

CONCLUSIONS

Based on our results, we can conclude that caixeta wood can be used as raw material in particleboard production and provide to them a physical-mechanical performance similar to that often observed in panels made of *Pinus* sp. and *Eucalyptus* sp. woods. Moreover, castor oil-based polyurethane resin yielded good adhesion for the panels produced in this study, as confirmed by comparing our results with the Brazilian code reference values and with the findings of Bertolini et al. (2014), who used the same adhesive with conventional wood particles.

Also importantly, preservative treatments (CCA and CCB) against biological attacks made on caixeta wood seem to facilitate free water penetration into the cell lumen, thus increasing water absorption. However, these samples showed a low thickness swelling percentage, probably due to a decrease in impregnation water penetration (due to preservative chemical components), in addition to hysteresis effect (due to swelling and shrinking cycles of preservation method).

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REFERENCES

ABNT (1997) Projeto de estruturas de madeira ABNT-Técnicas NBR 7190. Associação Brasileira de Normas Técnicas.

ABNT (2018) Chapas de madeira aglomerada - NBR 14810. Associação Brasileira de Normas Técnicas

Almeida DH, Scaliante RM, Christoforo AL, Varanda LD, Lahr FAR, Dias AA, Calil Junior C (2014) Tenacidade da madeira como função da densidade aparente. Revista Árvore 38(1): 203–207.

Almeida TH de, Almeida DH de, De Araujo VA, Silva SAM, Christoforo AL, Lahr FAR (2017) Density as Estimator of Dimensional Stability Quantities of Brazilian Tropical Woods. BioResources 12:6579–6590. DOI: https://doi.org/10.15376/biores.12.3.6579-6590

Alves LS, Silva SAM, Azambuja M dos S, Varanda LD, Christoforo AL, Lahr FAR (2014) Particleboard produced with sawmill waste of different wood species. Advanced Materials Research 884–885:689–693. https://doi.org/10.4028/www.scientific.net/AMR.884-885.689

Amaral LS (2012) Penetração e retenção do preservante em eucalyptus com diferentes diâmetros. Lavras, Universidade Federal de Lavras.

Azevedo IMG de, Alencar RM de, Barbosa AP, Almeida NO de (2010) Estudo do crescimento e qualidade de mudas de marupá (Simarouba amara Aubl.) em viveiro. Acta Amazonica 40:157–164. DOI: https://doi.org/10.1590/s0044-59672010000100020

Bertolini MS, Nascimento MF, Christoforo AL, Lahr FAR (2014) Painéis de partículas provenientes de rejeitos de Pinus sp. tratado com preservante cca e resina derivada de biomassa. Revista Árvore 38:339–346. DOI: https://doi.org/10.1590/S0100-67622014000200014

Boschetti WTN, Vieira DM, Moulin JC, Lopes DJV, Paes JB, Carvalho AMML (2016) Preservative treatment of fence posts evaluation through photocolorimetry segmentation performance. Revista Árvore 40:731–739. DOI: https://doi.org/10.1590/0100-67622016000400017

Calil Junior C, Lahr FAR, Dias AA (2003) Dimensionamento de elementos estruturais de madeira. Barueri, Manole.

Ferreira CF, D'Ayala D, Fernandez Cabo JL, Díez R (2013) Numerical modelling of historic vaulted timber structures. Advanced Materials Research 778:517–525. DOI: https://doi.org/10.4028/www.scientific.net/AMR.778.517

Ferro FS, Icimoto FH, Almeida DH, et al (2014) Mechanical Properties of Particleboards Manufactured with Schilozobium amazonicum and Castor oil Based Polyurethane Resin: Influence of Proportion Polyol/Pre-Polymer. International Journal of Composite Materials 4:52–55. DOI: https://doi.org/10.5923/j.cmaterials.20140402.02

Fueyo JG, Domínguez M, Cabezas JA (2017) Contact shear stresses in dowel-type joints with expansive kits of timber structures. Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science 231:140–149. DOI: https://doi.org/10.1177/0954406216656215

Gonçalez JC, Marques MHB, Karas MCS, Janin G, Ribeiro PG (2014) Effect of drying process on Marupá wood color. Maderas: Ciencia y Tecnologia 16:337–342. DOI: https://doi.org/10.4067/S0718-221X2014005000026

Iwakiri S, Caprara AC, Saks DCO, Guisantes FP, Franzoni JA, Krambeck LBP, Rigatto PA (2005) Produção de painéis de madeira aglomerada de alta densificação com diferentes tipos de resinas. Scientia Forestalis/Forest Sciences 39–43

Lukacs I, Bjornfot A, Tsalkatidis T, Tomasi R (2016) Structural redundancy in cross-laminated timber buildings. In: World Conference on Timber Engineering. Vienna, University of Technology, Proceedings…

Marques MHB, Martins VA, Souza MR de, Alves MV da S (2006) Efeito da secagem nas propriedades acústicas da madeira de marupá (Simarouba amara Aubl.). Floresta & Ambiente 12:57–64

Mendes RF, Mendes LM, Abranches RAS, Santos RC, Guimarães Junior JB (2010) Painéis aglomerados produzidos com bagaço de cana em associação com madeira de eucalipto. Scientia Forestalis/Forest Sciences 285–295

Nascimento MF, Lahr FAR, Christoforo AL, Bertolini MS, Fiorelli J, Silva MR (2016) Painéis de partículas homogêneas fabricados com resíduos lignoceluósicos e resina alternativa para aplicação em pisos. Scientia Forestalis 44:1001–1007. DOI: https://doi.org/10.18671/scifor.v44n112.21

Ogunwusi AA (2014) Wood Waste Generation in the Forest Industry in Nigeria and Prospects for Its Industrial Utilization. Civil and Environmental Research 6:62–69

Steege H Ter, Vaessen RW, Cárdenas-López D, et al (2016) The discovery of the Amazonian tree flora with an updated checklist of all known tree taxa. Scientific Reports 6:1–15. DOI: https://doi.org/10.1038/srep29549

Vidal ACF, Hora AB da (2014) BNDES Panorama de mercado: painéis de madeira. Rio de Janeiro.

Vidal JM, Evangelista WV, Silva JC, Jankowsky IP (2015) Preservação de madeiras no brasil: Histórico, cenário atual e tendências. Ciencia Florestal 25:257–270. DOI: https://doi.org/http://dx.doi.org/10.1590/1980-509820152505257