<u>Format project technical report</u>

Project 433/06 R3 (I)

"Sustainable Model for the Brazilian Wood Flooring Production Chain"

Subproject:

<u>Manufacture of Wood Panels with Residues</u>

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Summary

The purpose of this research was to evaluate the potential use of residues of processing mechanical of *Caryocar villosum*, *Hymenolobium excelsum*, *Mezilaurus lindaviana*, *Erisma uncinatum*, *Tachigali myrmecophylae* and *Qualea paraensis* wood in the particleboard production.The experimental design consisted of seven treatments, in which were analyzed the performance of each individual species and a mixing ratio of all of them equally. Specimens from the particleboards will be prepared and conditioned to then to evaluate their physical (specific gravity, moisture content, water absorption and thickness swelling) and mechanical (static bending – modulus of elasticity and modulus of rupture, internal bond, direct screw withdrawal) properties. Through the analysis of the test results it was concluded that the panels manufactured with residues of the *Caryocar villosum*, *Hymenolobium excelsum* and *Tachigali myrmecophyla*woods (Treatment T1, Treatment T2 e Treatment T5, respectively), showed the highest potential for use in the production of particleboard.

Keywords: Tropical wood; Particleboards; Physical and mechanical properties.

1 Introduction

The best recovery of residues generated by industries that process wood made the reconstituted wood panels industry increase, annually, the investment in production quality, equipment and processes (BIAZUS et al., 2010).

The particleboards are particularly suitable for the furniture and joinery industry, in the production of residential and commercial furniture straight lines. Its main applications are: straight doors, side furniture, shelves, partitions, upright slabs, post-formed worktops and drawers (ABIPA, 2014). They can be used also as substrates in the flooring industry and construction, for example, in manufactured homes, since they are used moisture resistant adhesives (STARK et al., 2010).

According to ABRAF (2013), the prospects for this market are very favorable as the technological modernization of the industrial park (offering new products and improving quality), the performance of civil / construction real estate (due to a reduction of interest and income improvement) and the call for sustainable use of alternatives to solid wood sources assert themselves as crucial for the development of industry factors.

Accordingly, the purpose of this research was to evaluate the potential use of residues of processing mechanical of *Caryocar villosum* (Aubl.) Pers., *Hymenolobium excelsum* Ducke, *Mezilaurus lindaviana* Schwacke & Mez, *Erisma uncinatum* Warm., *Tachigali myrmecophyla* (Ducke) Ducke and *Qualea paraensis* Ducke wood in the particleboard production.

2 Applied methodology

2.1 Panel Manufacture

Eighteen particleboards were produced from the residues generated in the mechanical processing of wood of the species:

- *Caryocar villosum* (Aubl.) Pers. (pequiá);
- *Hymenolobium excelsum* Ducke (angelim-da-mata);
- *Mezilaurus lindaviana* Schwacke&Mez (itaúba-amarela);
- *Erisma uncinatum* Warm. (cedrinho);
- *Tachigali myrmecophyla* (Ducke) Ducke (tachi-preto);
- *Qualea paraensis* Ducke (mandioqueira-escamosa).

Three particleboards were produced with the mixture of particles of all species.

With a chipper type D3P, model 250, from the Demuth Industrial Machinery Ltda., belonging to the Laboratory of Chemistry, Pulp and Energy (LQCF) of the Department of Forest Sciences (LCF) in ESALQ/USP were generated chips from the tropical species.

The wood particles were generated from the processing chip and obtained a knife mill type Wiley, model n.3, Arthur H. Thomas Co., using a 4 mm sieve opening.

Phenol formaldehyde adhesive was applied at 8% (based on dry mass of the particles) for the production of the panels. The adhesive presented 50.9% of solids content. Adhesive and wax emulsion were sprayed by a compressed air gunin a rotatory blender.

The particles have been glued and posted manually on a wood box, forming the mat, with dimensions of 400 mm inner edge and 200 mm high. The nominal density of the panels was 0.85 g/cm³ and its nominal size 400 x 400 x 15.7 mm.

After formation, the mat was taken to a manual hydraulic press for cold pressing with the purpose of providing it with better shape and to avoid particle loss. Later, the mat was put between the hot plates of a motorized hydraulic press with automatic temperature, pressure and time controls. The hot pressing cycle of the particle mat was the following: temperature of 453.15 K, specific pressure of 3.51 MPa and time of 8 min.

After pressing, the panels were put in acclimatized room at the Wood and Derivatives Mechanical Assay Laboratory of LFC, piled and separated by wood studs, at a temperature of 295.15 ± 8 K and 65 ± 5 % relative moisture.

2.2 Evaluation of physical and mechanical properties of the panels

The dimensions of the test-bodies and the test procedures used to evaluate the properties specific gravity, moisture content, water absorption after two (WA2h) and twenty-four hours (WA24h) immersion, thickness swelling after two (TS2h) and twenty-four hours (TS24h) immersion, direct screw with drawal from the face (DSf) and from the edge (DSe) of the panel, static bending (Modulus of rupture – MOR and Modulus of elasticity – MOE) and internal bond (IB), were defined based on the Brazilian Norm ABNT NBR 14810-3 (2006).

2.3 Statistical analyzes and experimental design of the panels

Statistical analyzes were carried out in a completely randomized design with 7 treatments (Table 1). For each treatment three replications were produced, totaling 21 panels. To verify the effect of the factors, analyses of variance were conducted and subsequently Tukey tests at a level of 95% probability.

Table 1. Experimental design for thepanels production

Treatment	Species	Proportion of particles	Adhesive	Wax emulsion
		%	%	%
T1	CV	100	8	1
T2	HE	100	8	1
T3	ML	100	8	1
T4	EU	100	8	1
T5	TM	100	8	1
T6	QP	100	8	1
T7	MixtureT1 - T6	16.7	8	1

3 Presentation of the data

The Table 2 presents the basic density of the species as well as the values of the nominal and effective compression ratios of the particle boards.

Table 2. Average values of basic density of the species and compression ratio of particleboards

Species	Basic density ($kg.m^{-3}$)	Nominal compression ratio	Effective compression ratio
Cv	659.73	1.3	1.3
He	576.12	1.5	1.4
Ml	680.71	1.2	1.2
Eu	503.75	1.7	1.6
Tm	556.94	1.5	1.5
Qp	759.53	1.1	1.0
Mix	504.97	1.7	1.6

The average values for the physical properties for each treatment, are shown in Table 3.

Table 3. Average values of the physical properties of particleboards

Treatment	Specific gravity	Moisture content	WA2h	WA24h	TS2h	TS24h
	($kg.m^{-3}$)			(%)		
T1	832.13 a	9.5 bc	16.51 c	36.87 d	4.84 a	10.80 bc
T2	808.46 a	8.5 a	34.31 d	50.27 e	8.00 b	12.94 de
T3	817.07 a	8.7 a	15.83 c	32.18 c	4.45 a	9.32 a
T4	795.99 a	10.2 d	11.59 ab	26.84 b	5.32 a	13.48 e
T5	812.28 a	9.6 bc	37.80 e	53.79 f	11.54 c	15.78 f
T6	796.52 a	10.0cd	8.24 a	20.26 a	4.84 a	9.99 ab
T7	808.96 a	9.3 b	14.12 bc	32.74 c	5.24 a	11.76 cd
Overall average	810.20	9.4	19.77	36.13	6.32	12.01
CVe (%)	4.77	4.77	22.59	10.54	18.73	14.46

Averages followed by the same letter do not differ statistically by the Tukey test (α = 0.5)

The average values for the mechanical properties for each treatment, are shown in Table 4.

Tabela 4. Average values of the mechanical properties of particleboards

Treatment	MOR (MPa)	MOE (MPa)	IB (MPa)	DSf (N)	DSe (N)
T1	9.10 b	1634.15 d	0.87 c	1276.50 bc	1371.29 bc
T2	8.76 b	1223.64 bc	1.41 d	2007.09 d	1791.35 cd
T3	4.86 a	1281.93 c	0.45 a	730.59 a	791.07 a
T4	5.22 a	966.15 ab	0.63 ab	959.42 ab	965.96 ab
T5	10.04 b	1290.17 c	1.18 d	1624.63 c	1850.19 d
T6	4.59 a	887.63 a	0.57 ab	1077.10 ab	1080.36 ab
T7	6.33 a	1124.05 abc	0.71 bc	1247.07 b	1278.13 b
Overall average	6.96	1195.89	0.83	1274.63	1304.05
CVe (%)	21.08	21.15	23.15	16.18	19.47

Averages followed by the same letter do not differ statistically by the Tukey test (α = 0.5)

4 Analysis and interpretation of the data and results

According Iwakiri (2005), the basic requirement of a specie for the manufacture of particleboard is to be low density, so that the compression ratio, which is the ratio of the density of the panel and the density of the wood is at least 1.3, condition in which you can ensure that there is sufficient contact area between particles during the pressing operation in order to obtain a good bond. In this sense, according to Table 2, except *Mezilaurus lindaviana* and *Qualea paraensis* woods, with higher basic densities, all others showed the minimum required for adequate compression ratio of particleboard.

In the analysis of the average specific gravity of the panels (Table 3) a significant difference was not observedamong treatments, demonstrating that manufacturing step has been well conducted.

The analysis of variance performed for the moisture content of particleboard (Table 3) showed a significant difference between treatments. The average moisture content of the panels correspond to the same equilibrium moisture when placed in air-conditioned environment, in this sense, the changes observed may be related to the anatomical and chemical characteristics of each species used as raw material for manufacture of panels. The average moisture content of the panels (Table 3) ranged from 8.5 to 10.2% and the overall average was 9.4%, whose values can be considered compatible with the literature. Varanda (2012) studied the performance evaluation of particle made of *Eucalyptus grandis* with added oat hulls panels and found average moisture contents ranging between 8.3 and 10.0%. Weber (2011) studied about the viability of residues of wood for particleboard manufacturing panels, got moisture contents in the range 7.34 to 8.96%.

According to analysis of variance performed for the water absorption after two and twenty-four hours of immersion (Table 3), there was statistically significant difference between treatments. The average values of WA2h and WA24h varied, respectively, in the range from 8.24% to 37.80% and 20.26 % to 53.79%. The panels produced with residues of *Qualea paraensis* (T6) and *Erisma uncinatum* (T4) woods, with the extreme values of compression ratio (Table 2), were those who had lower water absorption for two and twenty-four hours of immersion (Table 3). The results of water absorption obtained in the present study were lower than those obtained by some researchers. With the exception of the panels produced with residues of *Hymenolobium excelsum* (T2) and *Tachigali myrmecophyla* (T5) woods, the other panels showed consistent results with those obtained by Iwakiri et al. (2012) for water absortion in particleboards with a density of 750 $kg.m^{-3}$, produced from Amazonian species.

Through the analysis of variance for thickness swelling after two and twenty-four hours of immersion of the particle boards (Table 3), it was found that there was statistically significant difference between treatments. The highest values for both properties were observed for the panels of *Tachigali myrmecophyla* (T5). Values obtained by Lima (2011) for thickness swelling ranged from 10.9% to 21.2% and from 20.4% to 28.9% for two and twenty-four hours of immersion, respectively, in particleboards produced from the woods freijó and *Pinus* sp., being higher than those found in the present study. The American standard commercial CS 236-66 (1968) states that the thickness swelling after twenty-four hours of immersion is a maximum of 55% for the high density panels made with phenolic resin. Thus, it appears that all the treatments had values below the defendant may meet the standard in reference.

From the results obtained for the MOR (Table 4), it is observed that the panels of *Caryocar villosum*, *Hymenolobium excelsum* and *Tachigali myrmecophyla* (T1, T2 and T5, respectively) showed average values statistically equivalent to each other and higher than the average values the other treatments (T3, T4, T6, T7), which, in turn, were statistically equivalent to each other. Considering the MOE (Table 4), verified that the T1 treatment, produced with *Caryocar villosum*, differed statistically from all others, revealing higher average value. The panels produced with residues of *Qualea paraensis* wood (T6) showed the lowest values for both properties (MOR and MOE), indicating that the compression ratio may had a significant effect on them. Kelly (1977), Moslemi (1974) and Maloney (1993) reported that the panels with same nominal density when produced with higher basic density material usually have lower resistance on static bending, especially because they have lower compression ratio.

The commercial standard CS 236-66 (1968) stipulates as minimum values of MOR 16.47 MPa and 23.34 MPa for classes 1 and 2, respectively. For the MOE, the required minimum values are 2402.63 MPa and 3432.33 MPa for classes 1 and 2, respectively. Thus, the results obtained for the MOR and MOE of all treatments were below the stipulated for both classes of standard.

According to the data in Table 4, the T3 treatment, consisting of residues of *Mezilaurus lindaviana* showed the lowest value of internal bond. The commercial standard CS 236-66 (1968) sets the minimum values of 0.85 and 2.75 MPa for classes 1 and 2, respectively, for the internal bond. It was observed that the T1, T2 and T5 treatments composts of *Caryocar villosum*, *Hymenolobium excelsum and Tachigali myrmecophyla* residues, attended the class 1, less demanding in the standard in reference.

Through the analysis of variance for direct screw with drawal from the face and from the edge of the particleboards (Table 4), it was found that there was statistically significant difference between treatments. The lowest values for both properties were observed for the panels of *Mezilaurus lindaviana* (T3).

5 Conclusions

Except *Mezilaurus lindaviana* and *Qualea paraensis* woods, with higher basic densities, all others showed the minimum required for adequate compression ratio of particleboard.

The dimensional stability varied according to the different species, were observed highest values for the properties of water absorption and thickness swelling for the panels of *Tachigali myrmecophyla* (Treatment T5). However, considering the commercial standard CS 236-66 (1968), all proposed treatments showed values below the required for property in thickness swelling after 24 hours of immersion and can meet the standard in reference.

Panels manufactured with residues of the *Caryocar villosum*, *Hymenolobium excelsum* and *Tachigali myrmecophyla* woods (Treatment T1, Treatment T2 and Treatment T5, respectively), showed the highest potential for use in the production of particleboard, since they met the minimum requirements specified by the standard CS 236-66 (1968) for the evaluated properties with the exception of MOR and MOE static bending.

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