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Mechanical Properties of Particleboards Manufactured with *Schizolobium amazonicum* and Castor oil Based Polyurethane Resin: Influence of Proportion Polyol/Pre-Polymer

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Abstract With a worldwide trend looking for biodegradable materials, non-polluting and biomass products, the Castor oil based polyurethane resin is an alternative to formaldehyde based resins. The Castor oil based polyurethane resin is bicomponent type, formed from a polyol component derived from the castor beans (*Ricinus comunalis*) and a pre-polymer resin. The aim of this research was to evaluate the influence of castor-oil based polyurethane resin formulation (particularly proportion of pre-polymer/polyol) in static bending properties (modulus of elasticity and modulus of rupture) of particleboards produced with Paricá (*Schizolobium amazonicum*) wood specie. Four proportions of components (polyol/pre-polymer) were evaluated: 0.75:1; 1:1; 1:1.25 and 1:1.5. Results showed significant improvements in the modulus of elasticity with increasing the pre-polymer component. Modulus of rupture property was not affected significantly by the different proportions of the components of the resin, providing equivalent results. The proportion of 1:1 (polyol/pre-polymer) could be considered the best solution for delivering better mechanical performance and use the least amount of the derivative component of the petroleum.

Keywords *Schizolobium amazonicum*, Particleboards, Castor oil based polyurethane resin

1. Introduction

The technological process of the wood sector, coupled with availability of planted forests has enabled a number of alternatives to the use of forest wood refuse, among them, the production of panels [1]. The particleboards are produced with wooden elements, with the addition of adhesives and consolidated by hot pressing by applying temperature and pressure [2].

In relation to the quality and properties of the panels, there are many factors that contribute to the characteristics of the final product. The adhesive is one of the factors that should be considered in the production process of panels, it is directly related to the conditions of product, use and costs. Setting the correct type and amount of resin to be used is very important to optimize the cost benefit, because the adhesive is the major cost component [3-4].

The synthetic origin adhesive are the most currently used, due to its better adhesion properties and resistance to attack by micro-organisms, when compared to adhesives from natural sources. The main adhesives employed in panel industries have formaldehyde in the composition, which when released may come to cause problems to the environment and human health. In addition, these adhesives require high temperature pressing (above 160℃), which causes a high power consumption [5-6].

With a worldwide trend to use of biodegradable products, non-polluting and sourced from renewable inputs, many investments are being made in order to get a free formaldehyde adhesive, but presenting the same efficiency. The castor oil based polyurethane resin is an alternative to formaldehyde-based adhesives [7-8].

The castor oil based polyurethane resin is the bicomponent type, composed by a polyol and a prepolymer. Castor-oil, extracted of *Ricinus communis* seed found in tropical and subtropical regions, is very abundant in Brazil. The prepolymer is obtained from petroleum. Mixture of these

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components origin the polyuretane resin, which viscosity is defined by ratio polyol/pre-polymer [9].

The Castor oil based polyurethane resin had its technical potential shown in several studies of wood based panels, like: Bertolini [10], Ferro [11], Nascimento e Morales [12], Souza [13] e Varanda [14].

Despite the promising market, the use of castor oil based polyurethane, developed by the Institute of Chemistry of São Carlos, University of São Paulo [15], is not used commercially by the industry of particleboard yet. The competitiveness of polyurethane adhesive in relation to other existing polymers implies in the fact that it originates from natural raw materials and renewable, in reasonable prices of diisocyanates available in Brazil, and for not being aggressive to humans and the environment [16].

For the purpose of using higher amount of resin component derived from renewable sources (polyol), the aim of this research is to evaluate the influence of castor-oil based polyurethane resin formulation, particularly proportion pre-polymer/polyol, in static bending properties of particleboards produced with *Schizolobium amazonicum*.

2. Material and Methods

Tests were carried out in Wood and Timber Structures Laboratory (LaMEM), Structural Engineering Department (SET), São Carlos Engineering School (EESC), São Paulo University (USP).

For this research, *Schizolobium amazonicum* residues obtained in LaMEM were used. After, they were processed in mill to obtain particles (Fig. 1a).

Particles were bonded with castor-oil based polyurethane resin, with 100% solids content (Fig. 1b). (A) component is the polyol (castor oil derivate), density 1.20g/cm³; (B) component is the petroleum-derivate diisocyanates, density 1.24 g/cm³ (Fig. 1c).

Four proportions between polyol and pre-polymer were evaluated, and are presented in Table 1. Two panels with nominal dimensions 28×28×1cm, density 0.80g/cm^3, were fabricated for each experimental conditions. Adhesive content used were 12% based on dry weight of particles [12].

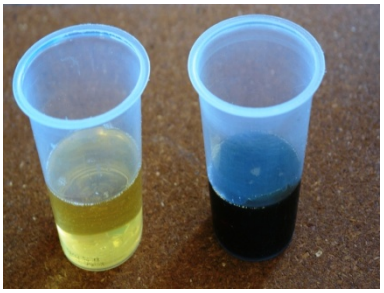
Table 1. Experimental program

Experimental Conditions	Polyol/pre-polymer proportion
C1	0,75:1
C2	1:1
C3	1:1,25
C4	1:1,5

The mattress particles (Fig. 1d) were pressed at 100ºC, for 10 minutes and specific pressure 4 MPa [11, 13], as showed in Fig. 1e. For stabilization and complete adhesive cure, panels were conditioneds during 48 hours (Fig. 1f). After this period, specimens were cut to correspondent tests.

From each panels, five specimens were obtained to determine the modulus of elasticity (MOE) and rupture modulus (MOR) in static bending, performing ten specimens for each experimental conditions. Tests were carried out according Brazilian standard ABNT NBR 14810 [17] recommendations.

(a)



(b)

(c)

(d)

(e)

(f)

Figure 1. Particleboards production process

In statistical analysis of results, effect of ratio polyol/pre-polymer in particleboard mechanical properties (MOR and MOE) was searched. Variance analysis and Tukey tests, conducted at 5% confidence level, were applied to identify different mean values. Results were compared with other researchs and normative standards: ABNT NBR 14810-2 [18], ANSI A208.1 [19], CS 236:66 [20] and EN 312 [21].

3. Results and Discussions

Table 2 presents the results of the mean values and coefficient of variation (CV) obtained for MOE and MOR in static bending for the panels produced.

Table 2. Results of MOE and MOR (MPa) from the particleboards produced

Experimental conditions	MOE (MPa)	CV (%)
C1	1882,40	16,68
	1599,85	6,84
C2	1938,40	14,24
	2064,15	5,48
C3	2096,45	10,38
	2089,88	4,02
C4	2324,48	11,12
	2312,26	8,89
Experimental conditions	**MOR (MPa)**	**CV (%)**
C1	21,86	13,45
	19,00	12,58
C2	18,77	14,70
	20,61	8,48
C3	20,49	13,96
	19,96	19,90
C4	23,39	15,15
	23,40	12,93

It is observed in Table 2 that the highest values of MOE and MOR were obtained for panels of experimental condition C3.

For the MOE property, only the experimental condition C3 showed mean values that reached the minimum value of 2300MPa required by standard EN 312 [21]. The requirements defined by ANSI A208.1 [19] and CS236-66 [20] standards, which requires minimum values of 2400 and 2450MPa, respectively, were not achieved by the particleboards produced. Brazilian standard ABNT NBR 14810 [13] do not mention these properties.

For the MOR, all experimental conditions met the minimum requirements of 18, 16.5, 16.8 and 16MPa required by ABNT NBR 14810-2 [18], ANSI A208.1 [19] CS236-66 [20] 312 and EN [21], respectively.

Similar results were obtained in others researchs with particleboards manufactured with *Pinus* sp. wastes treated with CCB and castor oil based polyurethane resin in ratio 2:1 (polyol: pre-polymer). Results obtained showed mean values for modulus of elasticityto of 1834 MPa [10].

Iwakiri et al. [22] manufactured particleboard with *Schizolobium amazonicum* wood species and urea formaldehyde resin, found mean values of 15.59 MPa for MOE. In this case, it is important to emphasize the superiority of the results obtained in this study to such property, a fact that should be related to the resin used.

Table 3 shows the Tukey test performed to check the influence of the proportion of polyol pre-polymer on the modulus of elasticity (MOE) and modulus of rupture (MOR). Same letters imply treatments with equivalent medium.

Table 3. Tukey test results

Properties	Experimental conditions			
	C1	C2	C3	C4
MOE (MPa)	1741,1	2001,3	2093,0	2268,3
	A	AB	AB	B
MOR (MPa)	20,4	19,7	20,3	23,4
	A	A	A	A

It is observed in Table 3 that only the MOE was influenced by the ratio of the components of the castor oil based polyurethane resin, in order to increase the pre-polymer led to the highest MOE. Through the Tukey test results (Table 3), it was found that the MOE from the experimental condition C1 differ from condition C4.

The modulus of rupture was not influenced by the proportions of the components, presenting mean values statistically equivalent.

Similar behavior where the increase of the prepolymer component provided to increase the performance of materials as observed by Pereira [23], and is related to the fact that the rigid reinforcing phase (diisocyanates) has on the properties of the material.

4. Conclusions

It is possible to conclude that ratio polyol/prepolymer, components castor-oil based polyurethane resin, significantly influenced the modulus of elasticity in static bending of the particleboard evaluated in this research. The increase in cited ratio resulted in higher mean values for the investigated properties. For the modulus of rupture, mean values were statistically equivalent.

Ratio 1:1 (polyol/pre-polymer) can be considered the best solution, considering the mechanical performance and the use of the least amount of petroleum-derivate component.

REFERENCES

[1] Bertolini, M. S.; Nascimento, M. F.; Rocco Lahr, F. A.; Chahud, E. Emprego de resíduos de *Pinus* sp. tratado com CCB e resina PU de mamona na produção de chapas de partículas. In: Rocco Lahr, F. A and Christoforo, A. L. Painéis de partículas. São Carlos: EESC/USP, 2013. p.57-91.

[2] Iwakiri, S. Painéis de madeira reconstituída. Curitiba: FUPEF. 2005.

[3] Maloney, T. M. Modern particleboard & dry-process fiberboard manufacturing. San Francisco: Miller Freeman, 1977.

[4] Mendes, R. F.; Mendes L. M.; Abranches, R. A. S.; Santos, R. C.; Guimarães Júnior J. B. Particleboards produced with sugar cane bagasse and Eucalyptus wood, Scientia Forestalis, v. 38, n. 86, p. 285-295, 2010.

[5] Dias, F. M.; Rocco Lahr, F. A. Alternative castor oil-based polyurethane adhesive used in the production of plywood. Materials Research, São Carlos, v.7, n.3, p.413-420, 2004.

[6] Dias, F. M. Aplicação de resina poliuretana à base de mamona na fabricação de painéis de madeira aglomerada. In: Lahr, F. A. R. Produtos derivados da madeira. São Carlos: EESC/USP, 2008. p. 37-160.

[7] Fiorelli, J.; Rocco Lahr, F. A.; Nascimento, M. F.; Savastano Junior, H.; Rossignolo, J. A. Particleboards of sugar cane bagasse and castor oil resin- production and properties. Acta Scientiarum. Technology, Maringá, v. 33, n. 4, p. 401-406, 2011.

[8] Paes, J. B.; Nunes, S. T.; Rocco Lahr, F. A.; Nascimento, M. F.; Lacerda, R. M. A. Quality of Pinus elliottii particle boards boned with polyurethane adhesive under various combinations of temperature and pressure, Ciência Florestal, v. 21, n. 3, p. 551-558, 2011.

[9] Nascimento, M. F.; Rocco Lahr, F. A.; Bertolini, M. S.; Souza, A. M. Viabilidade do emprego de Eucalyptus tratado com CCA e CCB na produção de painéis particulados de alta densidade. In: Rocco Lahr, F. A and Christoforo, A. L. Painéis de partículas. São Carlos: EESC/USP, 2013. p.57-91.

[10] Bertolini, M. S. Use of CCB treated Pinus sp residues in particleboard production employing polyurethane resin based on castor oil. São Carlos, 2011, 128 p. (Master´s Dissertation, School Engineering of São Carlos, USP).

[11] Ferro, F. S. OSB wood panel of *Schizolobium amazonicum* with polyurethane resin based-castor oil: the technical feasibility of production. São Carlos, 2013, 101 p. (Master´s Dissertation, School Engineering of São Carlos, USP).

[12] Nascimento, M. F.; Morales, E. A. M. Fabricação de painéis OSB com madeira proveniente de espécies de madeira da caatinga do nordeste brasileiro. In: Lahr, F. A.R. São Carlos: EESC/USP, 2008. p. . 119 - 136.

[13] A. M. Souza. Production and performance evaluation of Pinus sp oriented strandboard (OSB) with metallic gauze inclusion. São Carlos, 2012, 116 p. (Master´s Dissertation, School Engineering of São Carlos, USP).

[14] Varanda, L. D. (2012). Produção e avaliação do desempenho de painéis de partículas de Eucalyptus grandis confeccionados com adição de casca de aveia. 2012. 157 f. (Master´s Dissertation, School Engineering of São Carlos, USP).

[15] Silva, S. A. M. Chapa de média densidade (MDF) fabricada com poliuretana mono-componente derivada de óleo de mamona: caracterização por método destrutivo e ultrasom. 2003. 234 f. (Doutorado em Engenharia Agrícola)-Faculdade de Engenharia Agrícola, Universidade Estadual de Campinas, Campinas, 2003.

[16] Dias, F. M. et al. Relation between the compaction rate and physical and mechanical properties of particleboards. Materials Research, São Carlos, v. 8, n. 3, p. 329-333, 2005.

[17] Associação Brasileira de Normas Técnicas. NBR 14810: Chapas de madeira aglomerada. Parte 2: Requisitos. Rio de Janeiro. 2006.

[18] Associação Brasileira de Normas Técnicas. NBR 14810: Chapas de madeira aglomerada. Parte 3: Métodos de ensaio. Rio de Janeiro. 2006.

[19] American National Standard. A208.1: Particleboard. Gaithersburg. 1999.

[20] Comercial Standard. CS 236-66: Mat formed wood particleboard. [S.I]. 1968.

[21] European Standard. EN 312: Particleboards- Specification. British Standard. Bruxelas. 2006.

[22] Iwakiri, S.; Zelleri F.; Pinto J. A., Ramirezi 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. Amaz, Manaus, vol.40, n. 2, p. 303-308, 2010.

[23] Pereira, P. H. L. Estudo das propriedades físico-químicas da poliuretana derivada do óleo de mamona com potencial aplicação na área médica. São Carlos, 2010, 75 p. (Master´s Dissertation, School Engineering of São Carlos, USP).