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Production and Characterization of MDF Using Eucalyptus Fibers and Castor Oil-based Polyurethane Resin

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The growing popularity of wooden panels renders this market segment increasingly competitive. MDF (Medium Density Fiberboard), in particular, is widely employed for a variety of applications, including civil construction, furniture, and packaging. This paper discusses a study of MDF produced from alternative raw materials, i.e., Eucalyptus fibers and castor-oil-based polyurethane resin. Physical and mechanical tests were performed to determine the MDF's modulus of elasticity and modulus of rupture in static bending tests, its swelling, water absorption, moisture and density. The results of the physical and mechanical characterization of this laboratory-produced MDF are discussed and compared with the Euro MDF Board standard. MDF produced with eucalyptus fiber and castor-oil-based polyurethane resin presents results very satisfactory.

Keywords: *MDF, wooden panels, derived products*

1. Introduction

Wood-based products offer an interesting alternative to expand the range of materials for use in civil construction, cabinetmaking and other industries. Brazil is a potentially important worldwide producer/supplier of general purpose boards and possesses state-of-the-art technology to produce reconstituted wood products.

The total production of wood-based products shows a steady annual growth, and new types of panels which, until recently, had been produced only in Europe and the U.S. are now beginning to be manufactured in Brazil. This growing production is attributed to the increasing use of boards in some industrial sectors, e.g., cabinetmaking, civil construction, packaging, etc.

Although Brazil's share in the production and consumption of wooden panels was not significant in the past, this situation has been changing in recent years owing to new investments in board production units, especially particleboards and MDF. Both domestically and internationally, the production and use of general purpose boards will continue to grow at higher rates than other wood products. Panel production will continue to belong to the current major producers for some time to come, but the growth of panel production in developing countries will ensue from several factors, among them the availability of raw material in suitable quantities and quality, the competitiveness resulting from lower operational costs, and the opening up of new markets.

Brazil's prospects for becoming a major manufacturer of particleboard are excellent, with reconstituted wood panels, today represented by MDF and more recently by OSB, promising to change the profile of internal consumption.

Holokiz[1] successfully proved, in the laboratory, that eucalyptus fibers used in the composition of MDF confer greater modulus of rupture (MOR) on boards, and slightly lower values of water absorption and swelling in thickness properties.

Pranda[2], however, produced MDF with eucalyptus fibers that required a larger percentage of adhesive to attain the same mechanical properties as those of the MDF produced with Pinus fibers. Nevertheless, from the standpoint of swelling and absorption, MDF made of Eucalyptus fibers with the same adhesive content as pine fiber MDF showed superior values.

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Some authors argue that the use of Eucalyptus in the manufacture of reconstituted wood boards involves difficulties in terms of gluing, because the density of eucalyptus is higher than that of conifers, resulting in boards with low perpendicular tensile strength. However, other authors have demonstrated excellent mechanical properties for boards made of certain Eucalyptus species. Those studies indicate that there is still no consensus about the properties of boards produced from different species of Eucalyptus and the percentage of adhesive employed. Therefore, this study aims to help clarify the use of eucalyptus species in the production of boards, specifically in the manufacture of MDF, by varying the resin content.

MDF is normally produced using urea formaldehyde-based adhesive. However, in our search for new adhesives and resins for the manufacture of boards, we have employed an alternative, castor-oil-based polyurethane resin to produce MDF in the laboratory.

Using a natural and renewable resource, it is possible to synthesize polyols and prepolymers having different characteristics originating from the castor-oil plant which, when mixed, produce a polyurethane. Castor-oil-based polyurethane is competitive in comparison to other polymers because, in addition to its main mechanical properties, it derives from a low-cost natural and renewable raw material. Furthermore, it is flexible, rigid, and possesses molecular interchains and intercross strength conferred by the balancing of the chemical characteristics of the polyol in combination with the prepolymer.

Mixing polyol and castor-oil-based prepolymer causes the mixture to become polymerized. This polymerization reaction leads to the formation of polyurethane, in which the percentage of polyol may vary to produce greater or lesser hardness, and the use of a catalyzer can accelerate curing of the reaction. The adhesive used here was donated by KHEL Indústria Química, located in São Carlos, SP, Brazil, which pledged to provide further details about the adhesive and its advantages in working with wood and its by-products.

2. Methodology

The industrial dry process was used to produce the MDF in the laboratory. The eucalyptus fiber for the MDF was supplied by DURATEX Madeira Industrializada S.A. and, in collaboration with this research, KHEL Indústria Química donated the castor-oil-based polyurethane resin. 1500 g lots of fiber with 3% moisture content were used for the laboratory scale production of MDF. After being weighed, the fiber was placed in the upper part of a motor-driven gluer machine with a rotation rate of up to 120 rpm. The machine was closed, the motor activated and, with the blades rotating, the glue was added under high pressure to pulverize the resin for optimal distribution. After the fiber and glue were properly mixed, the mixture was transferred to another container to smooth out the lumps.

The material was then placed in a molding box. After deposition of the fibers, the material (air mattress) was compacted in a pre-press under a load of approximately 800 N, which corresponds to the pre-pressing stage without heat transfer. The purpose of pre-pressing is to reduce the volume of the mattress to be placed in the press.

The pre-pressing procedure was following by pressing in a hydraulic press heated electrically to a temperature of about 160 °C. The pressure applied was adapted to the pressing cycle proposed by Neves[3].

Table 1 indicates the cycle, in which the pressure varies from 0 to 3 MPa. In this work, the pressure on the sheet was determined by 1 cm thick limiters.

Starting from the fiber, the sheets were produced in the following sequence: drying of the fibers; preparation of the adhesive; mixing of the adhesive with the fibers in the mixer; dissolution of the lumps; preparation and formation of the mattress; cold pre-pressing; hot pressing; cutting and acclimatization of the sheets.

Figure 1 illustrates the MDF manufacturing sequence in the laboratory: a) fibers ready to be placed in the mixer; b) material from the mixer, composed of wood fibers, resin, catalyzer and water; c) dissolution of lumps in the mixture of the panel's constituents; d) placement of the mattress in the thermo-mechanical press; e) sheet removed from the press immediately following pressing; and f) sheet ready for use.

Following the manufacturing process, the sheets were acclimatized at a temperature of about 25 °C for 48 h, after which test specimens were prepared for physical and mechanical tests performed according to the EUROCODE (EC), whose results are listed below:

- Density (EC 323)[4];
- Moisture (EC 322)[5];
- Swelling in thickness (EC 317)[6];
- Absorption (EC 317)[6];
- Flexural strength (EC 310)[7].

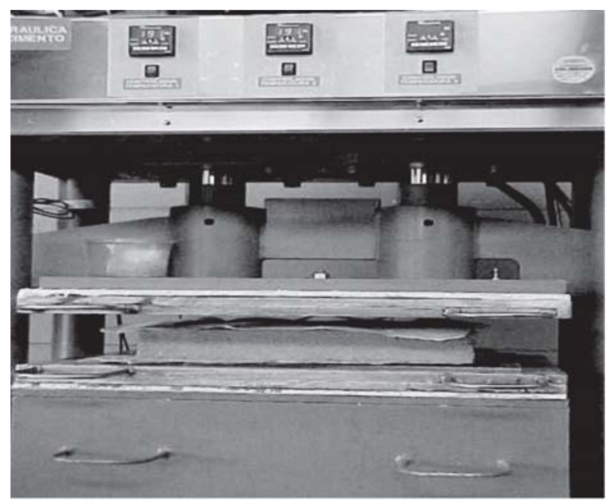
Table 1. Pressing cycle in MDF production.

Pressing time (s)	Pressure applied (MPa)
0	0.00
5	2.96
25	2.96
30	1.10
35	1.10
105	0.44
110	0.44
115	0.69
125	0.29
242	0.00

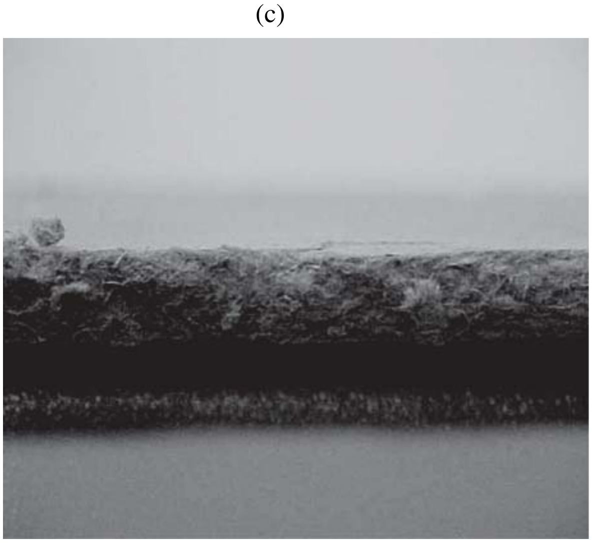
(a)

(b)

(c)



(d)



(e)

(f)

Figure 1. Sequence of the MDF production process in the laboratory.

3. Results

Shown below are the results of the density, moisture, swelling in thickness, absorption and static flexure tests obtained for the panels produced with polyurethane resin and *Eucalyptus grandis* fibers. The results of the density test are shown in Table 2, moisture in Table 3, swelling in thickness in Table 4, absorption in Table 5, static flexure to determine the MOE in Table 6, and static bending to determine the MOR in Table 7.

3.1. Results of the test to determine density

Table 2. Values of density for the eucalyptus sheets produced with polyurethane resin.

Type of resin	% Adhesive		
Polyurethane resin	8%	10%	12%
CP 1	698 g/cm^3	724 g/cm^3	761 g/cm^3
CP 2	702 g/cm^3	726 g/cm^3	764 g/cm^3
CP 3	700 g/cm^3	729 g/cm^3	767 g/cm^3
CP 4	705 g/cm^3	730 g/cm^3	769 g/cm^3
CP 5	703 g/cm^3	731 g/cm^3	770 g/cm^3
CP 6	698 g/cm^3	722 g/cm^3	765 g/cm^3
Average	701 g/cm^3	727 g/cm^3	766 g/cm^3

3.2. Results of the test to determine moisture

Table 3. Values of moisture for the eucalyptus sheets produced with polyurethane resin.

Type of resin	% Adhesive		
Polyurethane resin	8%	10%	12%
CP 1	5.0%	5.0%	4.3%
CP 2	5.4%	4.9%	4.2%
CP 3	5.6%	5.1%	5.3%
CP 4	5.9%	5.4%	4.7%
CP 5	6.1%	5.3%	4.9%
CP 6	5.0%	5.5%	4.8%
Average	5.5%	5.2%	4.7%

3.3. Results of the test to determine swelling in thickness

Table 4. Values of swelling in thickness for the eucalyptus sheets produced with polyurethane resin.

Type of resin	% Adhesive		
Polyurethane resin	8%	10%	12%
CP 1	14%	10%	7%
CP 2	14%	12%	9%
CP 3	18%	10%	10%
CP 4	17%	14%	11%
CP 5	15%	16%	13%
CP 6	18%	16%	10%
Average	16%	13%	10%

3.4. Results of the absorption test

Table 5. Values of absorption for the eucalyptus sheets produced with polyurethane resin.

Type of resin	% Adhesive		
Polyurethane resin	8%	10%	12%
CP 1	35.4%	32.1%	27.4%
CP 2	35.1%	32.0%	27.7%
CP 3	35.7%	32.4%	28.1%
CP 4	35.9%	32.6%	28.0%
CP 5	35.8%	32.3%	27.7%
CP 6	35.1%	32.4%	28.5%
Average	35.5%	32.3%	27.9%

3.5. Results of the static bending test

Table 6. Values of MOE for the eucalyptus sheets produced with polyurethane resin.

Type of resin	Adhesive %		
Polyurethane resin	8%	10%	12%
CP 1	24.136 MPa	26.971 MPa	28.974 MPa
CP 2	24.297 MPa	27.025 MPa	29.235 MPa
CP 3	24.511 MPa	27.196 MPa	29.176 MPa
CP 4	24.607 MPa	27.254 MPa	29.297 MPa
CP 5	24.823 MPa	27.339 MPa	29.314 MPa
CP 6	24.800 MPa	27.163 MPa	29.588 MPa
Average	24.529 MPa	27.158 MPa	29.264 MPa

Table 7. Values of MOR for the eucalyptus sheets produced with polyurethane resin.

Type of resin	Adhesive %		
Polyurethane resin	8%	10%	12%
CP 1	231 MPa	260 MPa	278 MPa
CP 2	230 MPa	263 MPa	280 MPa
CP 3	234 MPa	262 MPa	284 MPa
CP 4	235 MPa	265 MPa	285 MPa
CP 5	232 MPa	267 MPa	283 MPa
CP 6	230 MPa	261 MPa	276 MPa
Average	232 MPa	263 MPa	281 MPa

4. Conclusion

A comparison was made of the results of the tests of the laboratory-produced MDF made of eucalyptus fibers and three different contents of castor-oil-based polyurethane resin and the specifications of the Euro MDF Board – Part II[8] of December 1995.

Table 8 shows the average value of the results of the tests performed in the laboratory, while Table 9 gives the values of the Euro MDF Board.

The results obtained by using *Eucaliptus saligna* and castor oil-based polyurethane resin in the production of MDF were quite satisfactory, indicating the possibility of varying both the wood species and the resin used in its fabrication. This would allow for new materials to be proposed for future use by the wood panel manufacturing sector, and especially of MDF such as that proposed herein, aiming particularly at making use of wood processing residues and resin from natural renewable sources, and incentive to realized research news relationship to subject.

Table 8. Average values of MDF from eucalyptus and polyurethane resin, varying the adhesive content.

MDF with eucalyptus and polyurethane resin	8%	10%	12 %
Density	701 g/cm^3	727 g/cm^3	766 g/cm^3
Moisture	5.52%	5.21%	4.73%
Swelling in thickness	16%	13%	10%
Absorption	35.54%	32.32%	27.96%
MOE	24.529 MPa	27.158 MPa	29.264 MPa
MOR	232 MPa	263 MPa	281 MPa

Table 9. Values specified by the Euro MDF Board

Properties	EN standard	Unit	Thickness 9-12 mm
Conditions for use without contact with water			
Swelling	EN 317	%	12
MOE	EN 310	MPa	22000
MOR	EN 310	MPa	220
Conditions for use in contact with water			
Swelling	EN 317	%	10
MOE	EN 310	MPa	25000
MOR	EN 310	MPa	260
Conditions for external use			
Swelling	EN 317	%	10
MOE	EN 310	MPa	28000
MOR	EN 310	MPa	320

Source: EuroMDFBoard – Part II: Requirements for general purpose boards (1995).

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