MEDIUM DENSITY FIBERBOARD MADE FROM *EUCALYPTUS SALIGNA*

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ABSTRACT

The production of industrial wood from natural forests is predicted to decline in the future. Factors that will contribute to this decline include changes in land use patterns, depletion of resources in some parts of the world, and the withdrawal of forest areas from industrial production in order to provide for environmental, recreational, and other social needs. There is a shortage of information on the suitability of fiber from many plantation-grown species for alternative composite products. This research was conducted to determine the suitability of plantation-grown *Eucalyptus saligna* from Brazil as a raw material for medium density fiberboard (MDF). Test panels of varying thickness (6,13, and 19 mm) were made with 10 percent urea resin and 1.5 percent wax. Mechanical, water resistance, and dimensional stability properties were tested according to American Society for Testing and Materials standards (ASTM). The results showed that nearly all mechanical properties of the panels at all thickness levels were above minimum requirements for MDF as specified in the ANSI-AHA and Euro MDF standards. These results indicate that MDF-type panels can be made from wood fiber derived from *Eucalyptus saligna.* Additional work is needed to ascertain the performance of MDF panels from this species through pilot- and production-scale trials.

The Food and Agricultural Organization (FAO) of the United Nations estimates that the production of industrial wood from plantations will be an increasingly important source of industrial fiber worldwide (6). At present, countries like South Africa and New Zealand derive 100 percent of their industrial wood from forest plantations. Other countries that derive a high proportion of industrial wood from plantations include Chile (95%), Spain (81%), Brazil and Argentina (60%), and Japan (55%). In 1987, Sedjo (12) predicted that by the year 2000, half the industrial wood produced in Latin American countries would come from forest plantations.

Brazil is the largest plantation grower of various species of eucalyptus, with 2.7 million hectares. Other countries that grow this species include South Africa, Congo, India, and Burundi. Most of the eucalyptus fiber from Brazil is used for pulp and paper production, although some is currently diverted to the production of hardboards. Other fiber-based composite products, like medium density fiberboard (MDF), appear to be an attractive alternative for this fiber.

MDF is a nonstructural wood-based panel that is composed of wood fibers bonded together with resin under heat and pressure. In recent years, great changes have taken place in the MDF industry. Production of this product has increased dramatically and new plants are planned worldwide. In 1996, MDF shipments from U.S. plants set another annual record in an unbroken series, totaling 2.1 million m^3, an 8.5 percent increase from 1995. U.S. production for 1997 was forecasted to be 3 million m^3. Canadian plant capacity was predicted to increase 19 percent, to 1.2 million m^3. In 1996, European production of MDF jumped 18 percent to 4.5 million m^3, continuing an unbroken upward trend in Europe.

The popularity of this relatively new panel product is due to its ability to be produced in molded form, as well as in straight-edged flat panels, for a host of industrial markets. MDF is used extensively in factory-assembled and ready-

to-assemble furniture, as well as in cabinets, underlayment, drawer fronts, molding, and countertops. Finishes and overlays can be used to provide a grain pattern typical of lumber, and many wood finishing components such as door edgings, decorative trim, frames, and cornices are being made from MDF. Moreover, MDF is replacing thin plywood and wet-process hardboard in the production of molded and flush doorskins.

New MDF products include generic and proprietary panels. One example is a super-refined board in which fine fibers are distributed throughout the board to facilitate deep routing and machining. In some countries, panels are being made from many different hardwood and softwood species as well as from nonwood-based lignocellulosics from raw materials such as bagasse and cotton stalks. In South America and Australia, hardboard panels have been successfully produced from a variety of wood species including *Eucalyptus grandis* and *E. saligna* (3,7). In the United States, some panels are being produced from recycled fibers from postconsumer wood waste.

Continuing concerns for panel manufacturers are regional shortages in softwood fiber, the need to find suitable, low-cost hardwood fibers for the manufacture of various fiber-based products, and the need to determine if various fast-growing plantation species are suitable for MDF and hardboard panels. The objective of the research reported here was to develop the material and process for fabricating MDF composite panels from wood fibers of *E. saligna.*

SELECTED LITERATURE REVIEW

Literature pertaining to the manufacture of various fiberboards from different species of eucalyptus was reviewed and is briefly discussed here.

Products of hydrolysis can affect the properties of hardboard, but they can be removed from the stock by washing. In laboratory experiments, washing the eucalyptus fibrous stock produced in the defibrator process increased modulus of rupture (MOR) and internal bond strength and decreased linear hygro-expansivity of the resulting hardboard. There was also a slight adverse effect on the properties of water absorption, thickness swell, and machinability, but the magnitude of change was too small to be of concern in end-use applications (8).

The drainage time test method could be used as an efficient tool for the evaluation of eucalyptus hardboard pulps. The dimensional stability of hardboard made from high-density *Eucalyptus maculata* improved as the drainage time increased, while the opposite effect was found for boards made from low-density *Eucalyptus obliqua* (9).

In Australia, use of eucalyptus fiber in reconstituted wood products is concentrated primarily in the hardboard industry, with smaller amounts used in plywood and particleboard. Hardboards made from eucalyptus fiber have major advantages compared with those made from other species. No supplementary bonding resins are needed to provide a high level of strength, in contrast to the resins required for softwoods. Because eucalyptus fibers are short, they do not flocculate as readily as long fibers. Consequently, boards made with eucalyptus fiber have better surface properties and are preferred worldwide as the substrate for prefinished hardboard products (7).

Chauhan and Bist (4) concluded that unbarked eucalyptus hybrid (mainly *E. tereticornis*), including tops, twigs, and branches, is a suitable raw material for hardboard manufacture. Oil-tempered boards do not require the addition of sizing agents to the pulp suspension in the semichemical wet process.

Pranda (11) reported that MDF made from *Eucalyptus globulus* required higher amounts of adhesive to reach the same mechanical properties as those of MDF made from *Pinus pinaster.* However, water absorption and thickness swell values of MDF from *E. globulus* were higher than those of similar panels made from *Pinus pinaster.* A possible explanation for higher resin consumption may be the higher content of fine particles and relatively high specific surface area in eucalyptus fibers after defibration of the chips.

EXPERIMENTAL DESIGN

Fibers of *E. saligna* were used to make MDF with a specific gravity (SG) of 0.77 in three selected thicknesses: 6, 13, and 19 mm. The fiberboards had 10 percent resin content and 1.5 percent wax content (percentage based on solids content and ovendry fiber weight). Each panel thickness was considered a replicated set that consisted of five individual panels. In total, 15 panels were made for this experiment.

Wood chips of *E. saligna* were obtained from Votorantim-Siderugica Barra Mansa SA (Forest Business Unit) of Brazil. Initial moisture content (MC) was 25 percent (percentage based on ovendry weight). The chips were converted into fibers for fabricating the MDF panels. The physical characteristics of the fiber were controlled or modified by varying the chip retention time within the digester, varying the gap between the refiner plates, and selecting refiner plate patterns.

The chips were defibrated in a Sprout-Bauer Model 12-1CP (Andritz, Inc., Muncy, Pennsylvania) 305-mm thermal mechanical single-disk refiner. Defibration was done in a batch process, with each batch limited to a maximum of 4 kg (ovendry basis) by the capacity of the receiver tank. Before refining, the chips were placed into a digester, ahead of the refiner, to soften them for obtaining a higher quality fiber. The chips going into the digester were held for 20 minutes under 586 kPa of saturated steam pressure. Defibration occurred as the chips passed between the rotating and stationary plates of the refiner. Sprout-Bauer refiner plates (D2B503 type) with surface dams and closed periphery were used for the refining process; the plate gap was 0.36 mm. Refining each batch took approximately 4 minutes (from 3 min. and 45 sec. to 4 min. and 10 sec.).

The adhesive (a water-soluble, liquid urea-formaldehyde resin) was obtained from Neste Resins Corporation (North Bay, Ontario, Canada). The resin, Ba-255, had a solids content of 65 percent, viscosity of 0.19 Pa·s at 25°C pH of 7.62, and SG of 1.281. The wax, Cascowax EW-3100P (a paraffin wax emulsion), was obtained from Borden, Inc. (Columbus, Ohio). This material had a solids content of 58 percent and pH of 8.3.

PROCESSING

FIBERS

After defibration, fibers had an approximate MC of 125 percent. Before further processing, the fibers were dried to a final MC of 3 to 4 percent in a steam-heated tray dryer at 94°C for 24 hours. The drying process caused the fibers to clump together as a result of hydrogen bonding. Therefore, further processing was needed to make the fibers suitable for blending with resin and wax.

The ovendried fibers were processed through a hammermill using a 19-mm screen opening. The purpose of the hammermilling process was to separate clumps of fibers, not to shorten fiber length. This procedure resulted in a high-quality fiber furnish with few noticeable fines.

WAX AND ADHESIVE

The wax emulsion and urea-formaldehyde resin were mixed together using a high-speed laboratory mixer. The resin-wax mixture was sprayed onto the wood fiber at 25°C as it rotated in a drum-type blender. The mixture was applied with a single pneumatic spray gun applicator. All the blended furnish was then hammermilled again. In this case, the purpose of the hammermilling process was to break up any balls of fiber formed in blending with wax and resin. The same 19-mm screen opening used to separate the ovendried fiber clumps was used here.

BOARD MANUFACTURE

Mats were hand-formed in a 508- by 508-mm deckle box attached to a vacuum. The fiber was manually forced, using a brushing motion, through a 6-mm screen on the top of the box. This allowed individual fibers and fiber bundles to pass through the top screen and collect at the bottom of the box. When all the fiber had been put into the deckle box, the mats were manually precompressed. Depending on the target thickness of the board, the average height of the mat was 203 to 356 mm. To reduce the mat height and to densify the mat, the mat was cold-pressed. This procedure reduced the mat height to about 127

to 152 mm, which allowed for easy insertion of the mat into the hot-press.

All panels were consolidated using a manually controlled, steam-heated press. The press temperature was approximately 180°C. Maximum panel pressure during closing ranged from 3.05 to 6.10 MPa and was lowered to 0.11 MPa after the target thickness was reached.

In the manufacture of all panels, a thermocouple was inserted in the center of the formed mat to determine the core temperature. Press cycles were controlled by the core temperature.

TESTING

Mechanical and physical property tests were conducted on specimens cut from the selected experimental panels. All panels were weighed and measured and the SG was calculated. The panels were selected on the basis of the target SG (0.77 ± 0.05) and target thickness. This method of panel selection allowed us to narrow the variability in SG between individual experimental panels.

Prior to mechanical and physical property testing, the specimens were conditioned at 65 percent relative humidity and 20°C. Three-point static bending MOR and modulus of elasticity (MOE) and internal bond strength tests were performed in conformance with ASTM D 1037 standards (2) and ANSI A208.2 standards (10) using an Instron Model TTCLM1 (Instron Corp., Canton, Massachusetts) testing machine. Thickness swell and water absorption measurements were made by immersing specimens in water in a horizontal position for 24 hours at ambient temperature.

This test was performed in conformance with ASTM D 1037. Linear expansion tests were conducted on length measurements made at equilibrium conditions of 50 and 90 percent relative humidity and 27°C. The linear expansion test was done in conformance with ASTM D 1037. Mechanical and physical property data for the three panel thicknesses are presented in **Table 1.** Each value is an average of 10 tests for static bending MOR and MOE, 25 tests for internal bond strength, 10 tests for thickness swell and water absorption, and 10 tests for linear expansion.

For reference purposes, the minimum property standard requirements for MDF panels as specified in ANSI A208.2 and in the Euro MDF standard are included in **Table 1.** The results in **Table 1** were statistically analyzed and are reported as the mean and the coefficient of variation. Each stage of the research is presented separately.

RESULTS AND DISCUSSION

Bending strength (MOR) values increased as panel thickness increased, and values exceeded the Interior ANSI A208.2 MDF standard (10) for all three thicknesses. For the Euro standard (5), strength of the 6-mm panels was below the specified minimum bending strength value of 40 N/mm^2. The 12- and 19-mm panels met the minimum Euro standard requirements. Bending stiffness (MOE) values for all panel thicknesses exceeded both the ANSI and Euro MDF minimum property requirements. Internal bond strength decreased as panel thickness increased; nevertheless, internal bond strength exceeded the ANSI

TABLE 1. — *Mechanical and physical properties of panels made from Eucalyptus saligna fiber compared with minimum standards of ANSI and Euro MDF.*[a]

	Static bending MOR	Static bending MOE	Internal bond	Thickness swell, 24-hr.	Water absorption, 24-hr.	Linear expansion
	----------------- (N / m m ^{2}) -----------------			-------------------- (%) --------------------		
Formulation (88.5% fiber/10% resin/1.5% wax)						
6-mm panel	37.4 (14)	3140 (18)	1.12 (14)	11 (4)	24 (4)	0.30 (9)[b]
12-mm panel	39.8 (13)	4010 (10)	0.87 (14)	6 (8)	15 (12)	0.25 (17)[b]
19-mm panel	42.2 (12)	4420 (11)	0.66 (13)	3 (22)	8 (26)	0.24 (15)[b]
ANSI MDF standard (10)	24.0	2400	0.60	NA[c]	NA	NA
Euro MDF standard (5)						
6-mm panel	40	2600	0.70	22	NA	0.50[d]
12-mm panel	35	2500	0.65	15	NA	0.40[d]
19-mm panel	30	2500	0.60	10	NA	0.40[d]

[a] Values in parentheses are coefficients of variation (%).
[b] Panels conditioned at 50 to 90 percent relative humidity.
[c] NA = not specified in test requirements.
[d] Panels conditioned at 35 to 85 percent relative humidity.

and ᴇᴜʀᴏ MDF standard requirements for each panel thickness.

The ANSI A208.2 MDF standard does not specify performance requirements for thickness swell, water absorption, and linear expansion. These water sensitivity tests were conducted on the experimental MDF panels to provide a basis of reference for others doing work in this area. Maximum thickness swell and water absorption properties are specified by ANSI for other fiber-based products like basic hardboard (1) as 25 and 35 percent, respectively. The Euro standard specifies maximum 24-hour thickness swell values for 6-, 12- and 19-mm MDF panels as 22, 15, and 10 percent, respectively. The thickness swell and water absorption values of all the MDF panels in our experiment were well below these maximum specified levels.

CONCLUDING REMARKS

The results from this experiment indicate that laboratory MDF panels made from plantation-grown *E. saligna* can be fabricated with panel properties that ex-ceed levels specified in the appropriate existing standards. Further experimentation with other plantation-grown eucalyptus species must be conducted to confirm our findings with *E. saligna* and allow comparisons. Additionally, pilot-scale and full production trials must be conducted to confirm our laboratory results. These research results are promising and indicate that plantation-grown *E. saligna* can be successfully used for the production of MDF, a value-added panel product.

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