Dry Chips Versus Green Chips as Furnish For Medium-Density Fiberboard

Paul H. Short
George E. Woodson
Duane E. Lyon

Abstract

The fiber characteristics and the physical and mechanical properties of medium-density fiberboard (MDF), manufactured with pressure-refined fiber from green and partially dried raw material, were analyzed to determine if dry wood chips made a better furnish than green wood chips. Pressure-refining dry material produced coarser fiber than those obtained from green material at the same refiner conditions. This was true for both loblolly pine and mixed hardwood material. Several important properties were shown to be affected by the MC of the chips prior to pressure-refining. For the mixed hardwood furnish, partially drying chips significantly improved IB strength of the fabricated panels. MOR, MOE, and dimensional properties were independent of initial chip MC. Partially drying softwood chips significantly improved MOR, IB, water absorption and thickness swelling of the fabricated panels, however MOE and linear expansion were adversely affected. It was concluded that partially drying loblolly pine chips prior to pressure-refining improves the overall quality of the MDF panels.

MEDIUM-DENSITY FIBERBOARD (MDF) is a relatively new reconstituted wood product capable of competing with particleboard and lumber for interior

The authors are, respectively, Assistant Professor and Technologist, Forest Prod. Util. Lab., Mississippi State Univ., Mississippi State, Miss.; Wood Scientist, So. Forest Expt. Sta., USDA Forest Serv., Pineville, La.; and Assistant Professor and Technologist, Forest Prod. Util. Lab., Mississippi State Univ., Mississippi State, Miss. This paper was received for publication in March 1977.

products. The major advantages of MDF are: 1) it can be manufactured from a broad range of raw materials, and 2) its uniformity and machinability are superior to competitive products. In the manufacture of MDF, a pressurized refiner is used to reduce raw material to low-bulk density fibers. The low-bulk density enables a high-quality, industrial-grade product to be produced from high specific gravity (SG) hardwoods and wood residues.

Traditionally, no attempt has been made to condition raw materials to a constant moisture content (MC) prior to pressurized refining in MDF manufacture. After refining, the MDF fiber is dried to an MC of less than 6 percent. Brooks[1] has suggested that a superior fiberboard furnish could be produced from raw materials refined at MCs less than 18 percent. Brooks stated that partial drying improved internal bond (IB), screw pull, and linear expansion. An additional advantage is gained by reducing the open-flame drying time of the refined fiber. Thus, the potential hazard of fire in open-flame dryers is reduced.

The purpose of this study was to analyze the fiber characteristics and the physical and mechanical properties of panels manufactured with pressure-refined fiber from green and partially dried raw material to determine if dry wood chips made a better furnish than green wood chips for MDF.

Design and Procedure

MDF panels were made in the laboratory at three target SG levels (0.61, 0.71, 0.80) from two furnish types (mixed hardwoods (Table 1), and loblolly pine (*Pinus taeda* L.)) refined at two levels of MC (green and partially dried). Four panels (replications) were made for each combination of SG and MC for both species mixes; hence, a total of 48 panels was required for this study.

Raw Materials

All trees selected for this study were in the 15- to 20-cm class and were cut on the Noxubee National Wildlife Refuge located in north central Mississippi. The two furnish types evaluated were debarked loblolly pine boles cut to a 7.6-cm top, and a mixture consisting of the five major hardwood species groups growing on pine sites in the Midsouth. The hardwood mixture was made up in proportion to the volume of each species growing on these sites as determined by the Southern Forest Experiment Station.[2] The hardwood material consisted of the bole, limbs, and bark, but excluded the root system. All boles were chipped in a Carthage, 99-cm chipper. Half of the chipped material was dried in a kiln to 20 percent MC. The partially dried hardwood chips were then mixed in the proportions shown in Table 1.

The green and partially dried chips were refined in a Bauer 418 pressurized refiner with a steam pressure of 689 kPag[3] and a retention time of 5 minutes. Plate clearance was held at 0.064 cm for the pine and 0.127 cm for the hardwood mixture. Refining was done by the Bauer Bros. Co. of Springfield, Ohio.

After refining, all fiber types were dried to a uniform MC of 5 percent in a dry kiln. Ten-g (ovendry weight basis) samples of each fiber type were run through a Bauer-McNett classifier to determine percentages of fiber for 6 Tyler screen fractions: +8, −8/+14 (passing 8 mesh, retained on 14 mesh), −14/+28, −28/+48, −48/+100, and −100.

MDF Fabrication

Eight percent liquid urea-melamine-formaldehyde resin mixture (Allied Chemical Fiberbond binder) and 1 percent wax (Hercules, Inc. Paracol 404N) were sprayed onto the dried fibers in a rotating drum. After blending, the furnish was fluffed in a laboratory refiner with spike teeth and felted into 50- by 41-cm mats using a specially built former with engaging fingers to separate the fibers and deposit them on a caul plate. Mat thickness varied depending on the final panel SG desired. Mat MC was 12 percent.

The formed mats were prepressed at room temperature at 2068 kPa for 30 seconds and then consolidated into 9.5-mm-thick panels in an oil-heated hot press (168°C) for 6 minutes at 3448 kPa. Thickness stops were used to control board thickness.

After pressing, the panels were trimmed to 44.4- by 34.3-cm and conditioned to constant weight in an atmosphere of 50 percent relative humidity (RH) and 22°C.

Testing

Bending strength (MOR) and stiffness (MOE), internal bond (IB), linear expansion (LE), water absorption (WA), and thickness swelling (TS) were determined according to ASTM Standard D1037-72a.[4] From each trimmed and conditioned panel, two specimens were machined for MOR and MOE evaluation, four for IB, two for LE and one 15.2- by 15.2-cm specimen for WA and TS evaluation. Linear expansion was evaluated from 50 to 90 percent RH. Water absorption and TS were evaluated after 24 hours of submersion in water.

Table 1. — SPECIES INCLUDED IN HARDWOOD MIXTURE AS FURNISH FOR MDF.

Species	Percent of furnish by ovendry weight
Eastern red oak (*Quercus spp.*)	30
White oak (*Quercus spp.*)	24
Sweetgum (*Liquidambar styraciflua*)	22
Hickory, true (*Carya spp.*)	15
Blackgum (*Nyssa sylvatica*)	9

[1] Brooks, S. H. W. 1970. Utilization of hardwood and pine residue in manufacture of medium-density hardboard. Paper presented at Annual Meeting, Mid-South Section, Forest Products Research Society.

[2] Southern Forest Expt. Sta. 1974. Hardwood species and their volumes on pine sites: Alabama, Louisiana, Texas, Oklahoma, 1963-65. Forest Resources Research Work Unit.

[3] Standard International Units were used throughout this study: 6.895 kilopascals (kPa) equals 1 psi; 6.895 megapascals (MPa) equals 1,000 psi.

[4] American Society for Testing and Materials. 1975. Part 22. Standard methods of evaluating the properties of wood-base fiber and particle panel materials. D1037-72a.

Table 2. — BAUER-MCNETT SCREEN CLASSIFICATION OF PRESSURE-REFINED FIBERS FROM GREEN AND DRY SOFTWOOD AND HARDWOOD CHIPS.

	Tyler mesh designation					
	+8	-8/+14[1]	-14/+28	-28/+48	-48/+100	-100
Pine						
Dry	32.6[2]	21.5	24.3	9.0	2.3	10.3
Green	20.9	26.1	29.0	9.6	1.9	12.5
Hardwood						
Dry	22.7	13.5	15.4	16.9	8.0	23.5
Green	9.3	14.6	18.2	21.7	9.6	26.6

[1]Minus indicates fiber passing through screen; plus indicates fiber retained by screen.
[2]Weight percentages of fiber passing screens.

Average panel SG was approximately 6 percent less than the target level in all cases. Some variation occurred in average SG for the four furnish types, but the differences were not statistically significant. Therefore, comparison of properties will be based on the uncorrected experimental values shown in Table 3. As previously indicated, all panels were made using the same press cycle. Precured surfaces were detected by surface failures in the IB test samples for the high SG panels. Without precure, these specific panel types would have somewhat higher MOR and MOE values than those values recorded in Table 3.

Table 3. — PROPERTIES OF MDF PANELS FABRICATED FROM PRESSURE-REFINED DRY AND GREEN SOFTWOOD AND HARDWOOD CHIPS WITH 8 PERCENT RESIN AND 1 PERCENT WAX.

Panel property	Dry			Green			Dry			Green		
SG[1]	.59	.66	.75	.57	.67	.77	.57	.67	.75	.58		.75
MOR (kPa)[2]	17 170	25 180	23 870	11 510	20 030	23 020	15 750	22 650	29 250	16 510		27 180
MOE (MPa)[2]	1960	2690	2650	1840	3030	3420	1930	2410	2910	1730		2710
IB (kPa)[2]	326	454	456	147	261	249	340	589	872	308		669
LE (%)	0.165	0.162	0.147	0.109	0.105	0.144	0.131	0.094	0.093	0.085		0.128
WA[3] (%)	27.9	21.1	22.1	50.2	33.2	22.9	54.0	36.8	32.5	47.7		34.5
TS[3] (%)	9.4	8.0	10.7	18.7	14.6	12.1	14.6	12.5	12.6	14.5		13.3

Variations in panel properties due to differences in chip MC and panel SG were evaluated by analysis of variance, 5 percent significance level, and Duncan's New Multiple Range Test using a fixed-effects model. Due to different refiner plate settings, a comparison could not be made between the hardwood and softwood furnish types.

Results and Discussion

Fiber Classification

The fiber classification results are presented in Table 2. Chip MC had a definite effect on fiber distribution. Dry chips produced coarse fiber types with 32.6 percent of the weight of pine fibers and 22.7 percent of the hardwood fibers retained on the 8-mesh screen. Corresponding values for green pine and hardwood fibers were 20.9 and 9.3 percent, respectively. Green material consistently yielded greater percentages of fiber weights on screens smaller than 8 mesh. Green hardwood chips generated the finest fiber type, with approximately 58 percent passing a 28-mesh screen. The smallest variation in weight distribution over the six fiber classifications was provided by dry hardwood chips.

These results indicate that there was a difference in fiber morphology between furnishes refined from green and dry chips. Further research needs to be done to determine the nature of these differences and their effects on final panel properties.

Static Bending

Average experimental properties of MDF made from the four furnish types are shown in Table 3. The mean values for MOR versus SG are plotted in Figure 1. Analysis of variance indicated that there were no statistical differences, at the 99 percent level, between MOR values of panels made from dry or green hardwood chips at the three SG levels. Brooks reported an MOR for panels made from dry hardwood furnish of 24,270 kPa at an SG of 0.63, which is 3.2 percent greater than for the green hardwood furnish he tested. The difference in this study at an average SG of 0.66 was less than 1.0 percent.

The dry softwood furnish produced panels with significantly higher MOR values at the low and

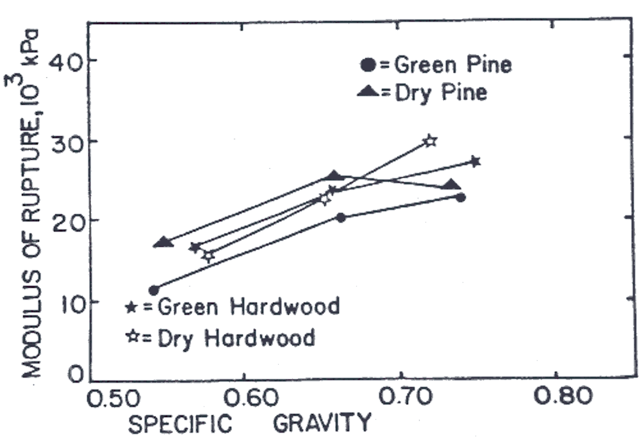

Figure 1. — MOR versus SG for MDF panels processed from dry and green chips.

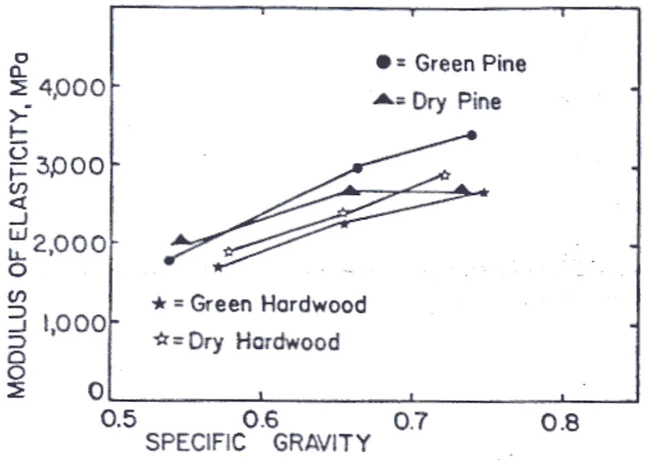

Figure 2. — MOE versus SG for MDF panels processed from dry and green chips.

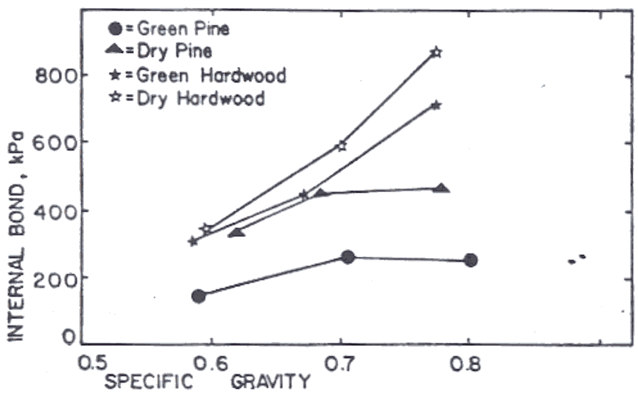

Figure 3. — IB strength versus SG for MDF panels processed from dry and green chips.

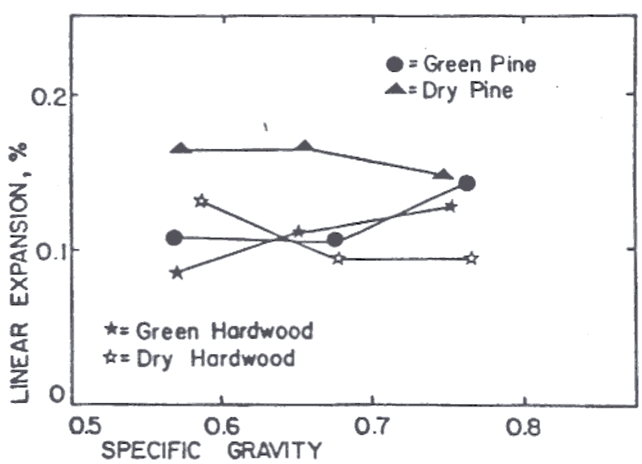

Figure 4. — LE (50% to 90% RH) versus SG for MDF panels processed from dry and green chips.

intermediate SG compared to panels produced from green softwood furnish. There was no significant difference in MOR at the high SG level. This could have been due to precure which occurred to a greater extent in the high SG panels made from dry pine chips. At an SG of 0.66, dry softwood furnish had an MOR of 25,180 kPa which is 26 percent greater than that for panels made with green softwood furnish.

Average values of MOE versus SG for all furnish types are presented in Figure 2. MOE values for panels made from the hardwoods were consistently higher for the green than for the dry refined furnish although the differences were not significant. Brooks' data also indicated very little difference between the two hardwood furnish types used in his work. In this work, boards made from green furnish had a slightly higher MOE (2455 MPa) than those made from dry furnish (2406 MPa).

Generally, the highest MOE values were obtained from panels made with the green softwood furnish. For the experimental values shown in Table 3, a statistical difference was found at the higher SG levels. At least part of this difference may be attributed to precure, which was more pronounced in the panels made with the dry softwood furnish. For the intermediate SG (0.67), the dry softwood furnish produced panels with an MOE 11 percent less than for panels from the green furnish.

IB Strength

As evidenced by Figure 3, at all SG levels both softwood and hardwood dry furnish produced panels with higher IB strength than panels processed from green chips. The differences were statistically significant except for the low SG hardwood panels. At an SG of 0.66, the dry hardwood furnish produced IB strengths of 589 kPa as compared with 438 kPa for the green furnish, thus a 34 percent difference was observed. At an SG of 0.63, Brooks found a 133 percent improvement in IB strength for panels made from the dry hardwood furnish (883 kPa) compared with the green furnish (379 kPa). Although Brooks found a much greater improvement in IB strength for panels made from dry refined hardwood furnish, the improvement found in this study was still significant. A large improvement (93%) in IB strength was also observed for the panels made from the dry refined softwood furnish (Table 3). These differences in IB values are attributed to differences in fiber coarseness and morphology between the two furnish types.

Dimensional Stability

As shown in Figure 4, LE values were higher at all three SG levels for panels processed from the dry refined softwood furnish than for panels made from green refined furnish. At the intermediate SG level (0.67), experimental LE values were 0.162 percent for dry refined softwood furnish and 0.105 percent for green refined softwood furnish, representing a difference of 54 percent (Table 3). However, the difference was not significant at the highest SG level. LE values for panels made from the refined hardwood furnish were generally independent of chip MC.

The LE values obtained in this study are lower than normally obtained for MDF. The reason for this is not

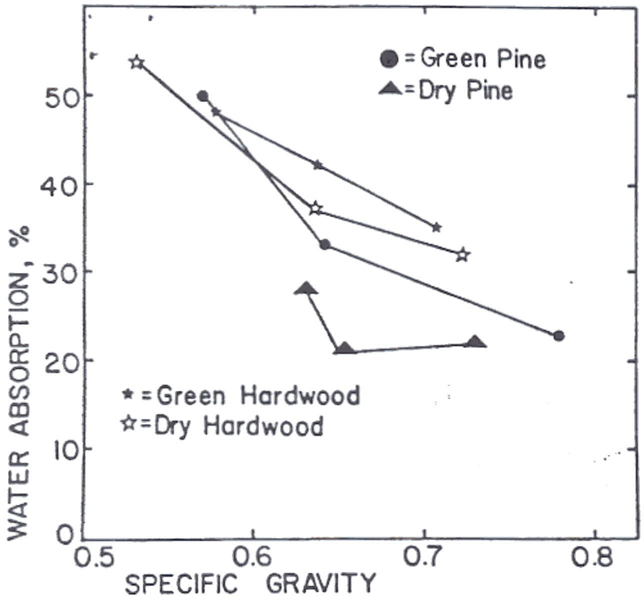

Figure 5. — WA (24-hr. immersion) versus SG for MDF panels processed from dry and green chips.

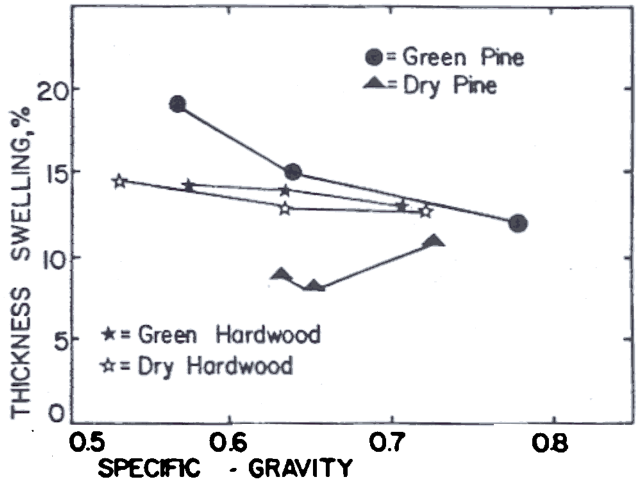

Figure 6. — TS (24-hr. immersion) versus SG for MDF panels processed from dry and green chips.

understood, but the specimens may not have been equilibrated at exactly 90 percent RH. However, for purposes of comparing the effects of chip MC on LE in this study, the LE test results are still valid.

Generally, WA values are lower for panels processed from dry chips compared to values for panels processed from green chips (Fig. 5). Although there were no significant differences in WA for the hardwood panels, the dry refined furnish produced panels with as much as 13 percent less WA than panels produced from the green refined furnish (Table 3). Brooks found a 63 percent improvement in WA for his mixed hardwood MDF panels made from the dry furnish, compared to panels made from the green furnish. In this study, softwood MDF panels had a significant difference for WA values at the low and intermediate SG levels (36% at SG of 0.67).

Generally, TS values, shown in Figure 6, were lower for panels processed from dry than from green refined furnish for both species types. The differences were only significant for the low and intermediate SG softwood panels. There was a 45 percent difference in TS between panels made from green and dry refined furnish at an SG of 0.67. By comparison, Brooks reported 25 percent less TS for panels made from the hardwood dry furnish compared to panels made from the green refined furnish.

Conclusions

Several important properties of MDF panels are affected by the MC of the chips prior to pressure-refining. Partially drying hardwood chips significantly improved IB strength of the fabricated MDF panels. MOR, MOE, LE, WA, and TS values were independent of initial chip MC. Partially drying softwood chips significantly improved MOR, IB, WA, and TS of the fabricated MDF panels; however, MOE and LE were adversely affected. Therefore, it is concluded that partially drying loblolly pine chips prior to pressure-refining improves the overall quality of the MDF panels. This is not the situation with partially dried hardwood chips where only the IB strength is significantly improved.

Analysis of weight distribution of fiber fractions indicated that the percentage of fibers on the 8-mesh screen was substantially greater for dry refining than for green refining. Conversely, the percentage of fibers on screens smaller than 8 mesh was consistently greater for green refining. However, the differences were of less magnitude than those found on the 8-mesh screen. It is concluded that pressure-refining dry material produces coarser particles than those obtained from green material at identical refiner conditions. This is not to say, however, that refiner conditions need to be the same. It is quite possible that green material could be refined at other conditions and produce superior board properties. It is probable that fiber size and shape is the controlling factor in explaining the resultant board properties between dry and green refining.

In addition to the technical aspects of panel quality the total energy requirements for manufacturing MDF from both the green and partially dried chips would have to be considered.