PARTICLEBOARD MADE WITH CROP RESIDUES MIXED WITH WOOD FROM *PINUS RADIATA*

Rose Marie Garay,*[a] Francisco MacDonald,[a] María Luisa Acevedo,[b] Beatriz Calderón,[b] and Jaime E. Araya [c]

The incorporation of crop residues was studied in particleboard panels (agrifibers, AG) in mixture with wood from *Pinus radiata* D. Don. Four crop residue stubble types were used, wheat, corn, rice plants, and rice husk. Their densities were compared. A wide array of mixtures varying from 9:1 = wood:AG to 1:9 = AG:wood were used to make the boards, from which the fundamental physical and mechanical properties were determined, to select one with the best properties and use potential. All AG were suited for board panels, although wheat and corn stubble gave better results, and their low fibre content was easily incorporated in low proportions without major modifications of processes and products.

Keywords: Agrifibers; Agricultural residues; Particleboard; Radiata pine; Corn; Rice husk; Wheat

*Contact information: a: University of Chile, Forest Science Faculty, Department Wood Engineering, Box 9206, Santiago, Chile. b: University Autonomy of Chapingo, Forest Science Division, Industrial Forest Engineering, México. c: University of Chile, Sciences Agricultural Faculty, Department of Healthy Vegetable, Box 1004, Santiago, Chile. * Corresponding author: rgaray@uchile.cl*

INTRODUCTION

In Chile, as throughout the world, the panel industry has grown continuously in recent years, using mainly wood produced on plantations. The most important Chilean company producing particleboards (over 90% of national production) has adopted the ISO 14001 certification, to produce boards only from industry byproducts such as radiata pine sawdust, shavings, and chips, instead of logged trees (MASISA 2008). So, this industry currently uses byproducts derived from other industrial processes, and competes to an increasing degree to access these resources at competitive prices. Such practices allow them to achieve good profitabilities in their business (Garay 2006).

In agriculture there is interest in the use of agrifibres (AGs), and in substantially increasing the land area under production. Actually some AGs and residues from production process are being used in cattle food, such as rice husk, and residues of wheat and corn plants. This scenario represents a use opportunity for logging, as represented by products such as sawdust, shavings, and chips, among others that surely will be incorporated. These prime products are in demand also by the cellulose industry, and their importance will increase gradually as an energy resource for the same industries, and for developing biofuels (Wood 2002; Garay 2006; Martinez 2006).

Alternative AGs are a poorly used resource to make products having aggregated value. This happens because there is little knowledge on their industrial use. The fabrication of boards with AG makes it possible to incorporate carbon capture and storage in these products, instead of liberating this carbon to the environment when burning these residues. The emissions of CO_2 to the atmosphere that are produced to obtain biomass, as they proceed from a carbon withdrawn from the atmosphere in the same biological cycle, do not affect the equilibrium of the atmospheric carbon, and thus they do not increase the greenhouse effect. And in cases where they substitute for fossil fuels, the use of AGs contributes to reduced net emissions of CO_2 to the air (Martinez 2006).

AG boards must compete in the market with traditional boards of wood materials. The physical and mechanical parameters of a standard board made in Chile, which are specified at various thicknesses, are presented in Table 1.

Table 1. Chilean Particle Board Properties

Thickness (mm)	Flexural strength (N/mm^2)	Internal bond strength (N/mm^2)	Thickness swelling 24 h (%)	Density (Kg/m^3)
9	16	0.50	Max. 25	700
12	16	0.50	Max. 25	660
15	15	0.50	Max. 25	640
18	15	0.50	Max. 25	630
24	15	0.45	Max. 25	600
32	13	0.40	Max. 25	570

Source: REGISTER CDT (2007).

Growers throughout the world are often challenged annually to eliminate harvest residues from their farms, and they strive to do so without creating environmental problems or unnecessary costs. To burn stubble is a questionable practice in many areas, as it often damages the soil and the environment, and it may have an adverse effect on health (Manterola *et al*. 1999).

Although typically the residues from wheat and barley crops, rice husk, and others have little or no value, they may become prime raw materials for the board industry, with the comparative advantage of a lesser cost than that of wooden fibres (Pease 1998). Today, logging volumes are reduced, and there is a decreasing availability of wood (FAO 2001), but crop residues are renewed each year, often in sustainable volumes sufficient to provide for the production of boards (INE 2006). The area of land cultivated in the Bio-Bio region in Chile, which concentrates most of the Chilean forestry industries, is presented in Table 2.

Table 2. Surface Cultivated (ha) with Agricultural Crops in the VIII Region of Chile

Agricultural year	Wheat	Corn	Rice	Total
2000/2001	111,600	3,730	4,460	184,290
2001/2002	113,330	4,350	4,340	183,640
2002/2003	108,250	5,180	4,560	176,790
2003/2004	114,100	6,600	3,800	189,430
2004/2005	115,200	7,100	3,790	187,360
2005/2006	90,070	5,440	4,580	166,160

Source: INE (2006)

Most residues from thinning and pruning in forestry, including unused wood blocks from other industrial processes, stumps, and even roots may be used, depending mainly of their availability and associated costs. Excluded are only those residues that do not generate quality fibres, such as sanding and fine dusts, as well as some barks (Poblete 2001).

The main considerations when fabricating boards with crop residues are price fluctuations, extraction methods, and difficulties associated with storage, transportation, and handling, in addition to contaminants such as soil, pebbles, sand, etc. (Kollmann *et al*. 1975). The plant material to be added must be sufficient to meet the desired content goals over the long term (Poblete 2001).

The relationship between the supply of raw materials and processes has occurred naturally over time by increases in efficiency, lower environmental impact, resource availability, among other reasons. Figure 1 illustrates a relative position or product's life cycle of each process in the wood industry, particularly boards, and it highlights the growing status of strawboard.

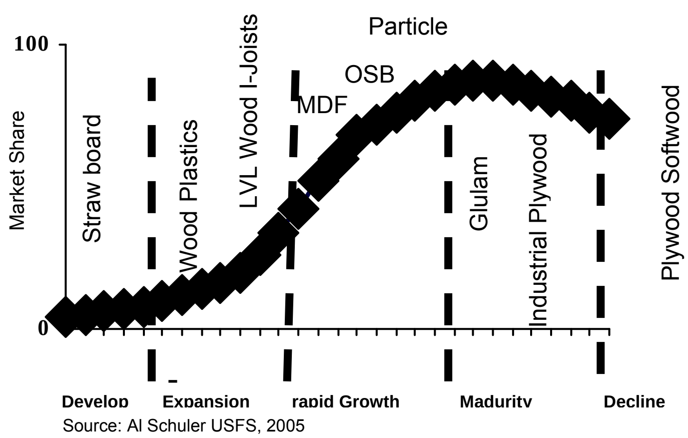

Figure 1. Products life Cycle in Canada

As stated Rowell in (1995), "The use of renewable biomass (agro-fibers) as a raw material in composites production was one approach, and the use of renewable biomass may result in several benefits such as environmental and socioeconomic."

Three-layer particleboards were produced from mixtures of sunflower stalks (*Helianthus annuus* L.) and Calabrian pine (*Pinus brutia* Ten.) particles at various ratios by Guler *et al*. (2006). It was observed that the properties of the panels were the best with the 50:50 mixtures of calabrian pine and sunflower stalk particles in the boards. The properties of all the panels manufactured met the minimum requirements for general grade particleboards. This study showed that the renewable sunflower stalks and calabrian pine particles can be used at different ratios in the production of particleboards, and the resulting panels can be utilized for general purposes as well as furniture for interior environments. In other research Guler (2008) investigated about the suitability of peanut hull to produce general purpose particleboards and the main observation was that increase in peanut hull in the mixture resulted in a decrease in mechanical and physical properties of produced panels and panel including 25% hull in the mixture solely met the standard required by TS-EN 312 standard. Conclusively, a valuable renewable natural resource, peanut hull could be utilized in panel production while it has been mixed to the wood chips.

Straw particleboard is nearly 90 percent straw and 3 percent MDI, a resin that is five times more expensive that urea formaldehyde. Urea formaldehyde is the most common resin used in wood-based particleboard. Although straw particleboard is formaldehyde-free, the petroleum-derived MDI resin is classified as a hazardous pollutant in the air. There are a few main advantages that explain why straw is even worth using. The first advantage of straw particleboard is its moisture resistance. The straw fibers and bonding resin produce a moisture-resistant product when mixed. A greater moisture resistance decreases swelling and warping and also provides more stability. Another critical advantage is the screw holding capacity of straw particleboard. A third advantage to using straw particleboard is its density and weight. The density and weight of straw particleboard can be regulated in the manufacturing process that will also be discussed later. It can have the same density and weight as wood-based particleboard or it can be 15 to 20 percent lighter while still meeting premium particleboard standards, which makes for easier handling and less expensive shipping costs (Wood 2002).

Rice straw can be used as a fiber source for the manufacture of particleboards. Polymeric methylene diphenyl diisocyanate (PMDI) is widely used as an adhesive for manufacturing such products. PMDI has the ability to bind rice straw despite the wax present on the surface of the straw (Pan 2006).

As expressed by Xu *et al.* (2004) many different kinds of materials are being emphasized. Agribased composites are a particular interest and are cause for optimism due to the significant quantities of raw materials. These materials are interconnected with the agricultural sectors, and they are perceived as having positive environmental characteristics.

Lee *et al.* (2004) investigated various adhesive systems and determined the best composite formulation for selected mechanical and physical properties of medium density fiberboard (MDF) made from wood and bagasse fibers. This study investigated opportunities of biomass utilization for natural fiber-based composites from agricultural (bagasse) and Chinese tallow tree (*Sapium sebiferum*) fibers. The mixing ratios were 100:0, 75:25, 50:50, 25:75, and 0:100 of bagasse and tallow tree fiber, and the furnish moisture content (MC) was 4 percent. The resin systems used were 8 percent urea formaldehyde (UF), 2.5 percent MDI (4,4'-diphenylmethane diisocyanate), and a mixed resin system of 1 percent MDI and 4 percent UF. Panels containing 100 percent bagasse furnish were also prepared with either 3.5 percent or 4.5 percent MDI at a furnish MC of 0 percent, 4 percent, and 8 percent. Two mixing combinations (50:50 and 25:75) of bagasse/tallow tree fibers yielded mechanical and physical properties which were not statistically different from higher proportions of Sapium fibers and provided the maximum utilization of bagasse fibers into the panels. The MC of the furnish and additional moisture from the resin applications were significant factors influencing the mechanical properties of the composites. MDF made from 8 percent MC bagasse fibers obtained a 63 percent increase in modulus of rupture (MOR) and a 30 percent in modulus of elasticity (MOE) compared to composites manufactured with 0 percent MC furnish. Panels at all fiber combination ratios with the mixed resin system performed superior to all furnish mixes with 4.5 percent MDI for MOR and MOE. Internal bond (IB) test results showed that the mixed resin system yielded slightly lower IB mean values than panels produced with 4.5 percent MDI.

The objectives of this research were to evaluate the physical and mechanical properties of board panels fabricated with variable proportions of AG from wheat, corn and rice, in addition to rice husk, with the objective of their possible use in this industry in Chile.

EXPERIMENTAL

Materials

The wood from radiata pine came from a board company, Río Itata in the 8th region. Formaldehyde urea adhesive, used commonly in the Río Itata Plant, was also used.

The used agricultural plant residues corresponded to what is left after harvest. The residues used were rice plant (PA) and rice husk (CA) obtained in San Javier, Maule Region, Chile; wheat plant residues (PT) from the South Campus of the University of Chile, Commune of La Pintana, Santiago, and residues of corn plants (PM) from the town of Llallauquen, Bernardo O'Higgins Region, Chile. Radiata pine shavings (MA) were used as a control. More information about the initial fibers is indicated in the Table 3.

Table 3. Length of the Fibers (mm), and Diameters of Fibers, Lumens, and Cell Walls (μm)

Crop residues	Length	Fiber diameters	Lumen diameters	Cell wall diameters
Corn plants	1.525	8.4	4.4	2.0
Rice plants	0.663	4.9	1.9	1.5
Rice husk	0.594	6.7	2.4	2.2
Wheat plants	0.851	9.9	6.8	1.6

Source Garay et al, 2009. Chilean Agricultural Research. Vol. 69, Nº 3

Methods

The study was done in two phases. In phase 1, the AG boards were fabricated using the same variables as in industrial processes, and phase 2 was done from optimized conditions obtained in phase 1, modifying the variables of adhesive percentage and board density. In phase 1, the variables for elaboration of 12 x 12 x 1.5 cm boards were: density 600 Kg/m^3; 10% adhesive, and 1% of wax on the dry weight of fiber. Percentages in mixtures of AG and wood were: 90/10; 70/30; 50/50; 30/70; and 10/90. Moisture (%) of the AG:corm (PM) was 7.46, rice plants (PA) 8.07; rice husk (CA) 7.05; wheat (PT) 8.51, and radiata pinewood (M) 5. Particle size (Table 4) of the stubbles were decreased to a size according with the usual particles in industrial processes in a Hombak machine. The size of radiata pine fine particles (mm) was: length 1 - 3, thickness 0.1 – 0.3, width

0.5 - 1 and the size of radiata pine core layer particles (mm): length 10 a 20, thickness 0.3 to 0.5, width 3 to 6. The pressing was done at 140ºC and 5000 psi during 11 min.

Table 4. Size of Particles of Corn (a) and Wheat (b) Residues

Particle grains	Width (mm)	Corn (%)	Wheat (%)
Oversize	>4	14	25
Coarse	1.4<x<4	45	54
Fine	1.4<x<0.3	46	37
Dust	<0.3	8	6

To fabricate the boards and for the mechanical tests the presses and study machines presented in Fig. 2 were used.

Figure 2. Fifty-ton Mega prepress (left); heating 4 ton Carver monoplate press (center); Amsler machine for mechanical tests (right)

The European standard was used for the number of samples of each board (EN 326), so sixteen 50 x 50 mm ± 0.1 mm test pieces of each different AGs proportion were obtained. Figure 3 shows the scheme used in cutting the samples. From these samples, the following properties were determined: (1) density, (2) moisture content, (3) absorption of water, (4) thickness swelling, and (5) internal bond. For these tests the standards for internal bond EN 319 (1993), density EN 323 (1993), moisture content EN 322 (1993), moisture absorption, and thickness swelling EN 317 (1993) were used.

2	3	4	1	4	3	2	1
1	5	3	5	5	5	4	1
1	3	2	5	4	2	5	1
2	4	3	1	3	5	5	1
1	3	4	1	4	5	4	2
1	2	3	1	2	3	5	1
2	3	5	1	5	4	5	1
2	4	3	5	3	4	2	4

Figure 3. Cut scheme of samples for physical and mechanical properties test

The apparent density (D) is the quotient of the mass (M) and volume (V) of the piece. It is measured in Kg /m^3. The calculation formula is $D=M/V$.

The moisture content (MC) corresponds to the difference between the humid piece mass (M_u) and the dried piece mass (M_o) at 105°C, divided by the dried mass (M_o). The calculation formulas is $MC = 100*(M_u-M_o)/M_o$. It is expressed in %.

The thickness swelling (S) is the difference between the thickness of the piece after the water immersion (T) and before the water immersion (T_o), all divided by the thickness before the water immersion (T_o). The calculation formula, expressed in %, is $S = 100 \text{ x } (T-T_o)/T_o$.

To determine the moisture absorption (A), each piece was weighed before immersion in water (W_o), and after each period (W). The calculation formula is $A = 100 \text{ x } (W-W_o)/W_o$. It is expressed as the percentage of increment with respect to its weight before immersion, under the conditions described for the swelling of thickness.

In this study, the pieces were immersed in water at 20°C for 2 and 24 h, after which the thickness of the humidified piece was measured, and the calculations were carried out to obtain the thickness swelling and moisture absorption.

The resistance to the internal bond failure perpendicular to the plane (T) of the board is the quotient of the maximum weight supported (W_{max}) and the surface area of the piece (S). The calculation formula is $T = W_{max}/S$. The UNE-EN 319 standard was used for this test.

In the second phase the same methodology and physic-chemical tests were used as in phase 1, but the density was increased to 650 kg/m^3, and the proportion of adhesive to 15%. The complete treatment was repeated for the combinations of 90% wheat AG with 10% wood, and 70% of this AG with 30% wood, which in phase 1 presented lamination problems between particles after pressing, an effect known as blowing. The complete treatment was repeated with rice husk, but the contact surface was activated by a mechanical desfibrator to facilitate adherence of particles with the adhesive, to decrease the volume of the board, and to achieve better compaction.

RESULTS AND DISCUSSION

Availability of Annual Cultures of Wheat, Corn, and Rice in Chile

In Table 5, the quantities that turn out to be more significant in different regions are emphasized. For the wheat, the production of metric hundredweight is important in the regions B. O'Higgins, Maule, Bio Bio, Araucania, and Los Lagos, including the major availability in Araucania. In this case, it might project an industry in this region; the quantity of residues exceeds 300 thousand tons/year. For the employment of corn, the advisable thing would be to employ this resource in B O'Higgins region, where the availability of residues of has been estimated to be 477 thousand tons. In turn, the availability of plantations of rice in Chile are not so significant, though a strong increase of these crop practices can be anticipated in view of the rise of the international price of this cereal; it is possible to consider an industrial focus of increase located in the Maule region.

Table 5. Availability of Annual Crops and Residues: Wheat, Corn, and Rice in Chile (Period 2004/2005)

Annual cultures	Total	Coquimbo	Valparaiso	Libertador B. O'Higgins	Maulel
Wheat					
Surface(ha)	419,660	3,560	7,230	**28,760**	**62,450**
Production(qqm)	18,519,400	150,588	310,167	**1,265,440**	**2,604,165**
Performance (qqm/ha)	44.1	42.3	42.9	44.0	41.7
Availability residues 50% Ton	**880,062**			**63,272**	**130,208**
Corn					
Surface(ha)	134,280	850	1,770	76,400	30,490
Production(qm)	15,077,661	35,955	185,850	9,550,000	2,780,688
Performance(qqm/ha)	112.3	42.3	105	125	91.2
Availability residues 50% Ton	**708,827**			**477,500**	**139,034**
Rice					
Surface (ha)	25,030	0	0	1,050	20,190
Production(qqm)	1,168,319	0	0	68,250	910,569
Performance (qqm/ha)	46.7	0	0	65	45.1
Availability residues 50% Ton	**45,528**				**45,528**
Rice husk availability 20% Ton	**18,211**				**18,211**

Annual cultures	Bio Bio	Araucania	Los Lagos	Metropolitana	Other place of country
Wheat					
Surface(ha)	**115,200**	**160,910**	**32,850**	7,700	1,000
Production(qqm)	**4,757,760**	**6,999,585**	**1,974,285**	425,810	31,600
Performance (qqm/ha)	41.3	43.5	60.1	55.3	31.6
Availability residues 50% Ton	**237,888**	**349,979**	**98,714**		
Corn					
Surface(ha)	7,100	230	0	16,950	490
Production(qm)	646,100	18,745	0	1,845,855	14,468
Performance(qqm/ha)	91	81.5	0	108.9	29.5
Availability residues 50% Ton				**92.293**	
Rice					
Surface (ha)	3,790	0	0	0	0
Production(qqm)	189,500	0	0	0	0
Performance (qqm/ha)	50	0	0	0	0
Availability residues 50% Ton					
Rice husk availability 20% Ton					

In phase 1, for all AGs using urea formaldehyde, the same product used on traditional particleboards, as the proportion of AGs increased in relation to wood, the thickness swelling increased (Table 6). These values (Moisture absorption and Thickness swelling) are greater than those given in Table 1, but the AGs board densities were lower than traditional particleboards. The behavior of this adhesive for use against moisture is inefficient (Kollmann *et al.* 1975; Pizzi 1993).

In phase 2, the boards made with rice rind obtained better results of swelling than in phase 1. Even after increasing board density and the dose of adhesive, the behavior of the boards in swelling still remained deficient. The properties of the AGs boards at greater density and dose of adhesive are presented in Table 7.

Table 6. Mechanical and Physicals Properties of Strawboard Panels

	Wood/AG	Density	MC	IB	Moisture Absorption (%)		Thickness Swelling (%)	
Ags	%	g/cm^3	%	N/mm^2	2 h	24 h	2 h	24 h
Corn stubble	90/10	0.61	6.31	0.47	86.88	127.67	102.00	129.85
	70/30	0.57	6.07	0.40	74.70	109.60	101.62	117.23
	50/50	0.59	6.14	0.44	95.17	121.29	92.68	107.07
	30/70	0.57	6.31	0.29	107.88	127.71	93.55	101.30
	10/90	0.50	5.66	0.15	129.30	152.18	88.54	96.66
Rice stubble	90/10	0.53	6.87	0.00	199.17	224.04	245.49	285.17
	70/30	0.57	6.25	0.06	145.92	176.23	200.62	219.85
	50/50	0.56	6.04	0.17	151.40	198.84	173.70	177.88
	30/70	0.55	6.16	0.21	126.92	162.85	135.47	131.17
	10/90	0.49	6.11	0.11	164.83	215.43	98.44	94.73
Wheat stubble	90/10	0.43	6.12	0.01	149.06	190.20	202.17	231.58
	70/30	0.48	5.92	0.01	140.10	177.20	158.52	180.88
	50/50	0.51	5.88	0.04	130.17	172.51	154.00	157.75
	30/70	0.48	5.90	0.04	154.24	179.00	120.24	119.64
	10/90	0.43	6.15	0.05	145.12	175.74	92.28	95.75
Rice husk	70/30	0.38	6.57	0.00	---	---	---	---
	50/50	0.38	6.24	0.00	---	---	---	---
	30/70	0.44	6.20	0.08	---	---	---	---
	10/90	0.43	6.20	0.01	---	---	---	---

Table 7. AG Board Properties after Modification of Density and Adhesive Content

AGs	AG/wood %	Density g/cm^3	MC %	Internal Bond N/mm^2	Moisture Absorption (%) 2 h	24 h	Thickness Swelling (%) 2 h	24 h
Rice stubble	70/30	0.63	8.11	0.04	80.25	127.20	105.25	133.95
	90/10	0.63	7.86	0.00	122.19	160.71	230.80	256.74
Wheat stubble	90/10	0.60	9.40	0.00	89.56	130.98	132.73	159.74
	70/30	0.63	9.24	0.01	72.74	109.48	99.15	137.74
Rice husk	70/30	0.53	7.53	0.00	80.39	99.34	82.84	59.90
	50/50	0.60	8.01	0.19	30.06	51.93	38.41	47.69
	30/70	0.66	7.59	8.09	9.08	27.98	34.43	42.86
	10/90	0.65	7.48	1.46	18.66	43.89	40.50	50.54

The ANOVAs indicate that AGs from wheat, corn, and rice, and their proportion with wood (90 through 10%) caused significant differences in the properties of internal bond, thickness swelling, and moisture absorption. The analysis of rice husk was not done, because the internal cohesion of the boards was deficient and did not allow tests to be carried out adequately for all proportions.

In phase 2 a factorial analysis was done for one variable, and with rice husk percentages of 10, 30, 50, and 70% were evaluated, whereas 70 and 90% were used for the other AGs; thus the only proportion in common was 70%, varying only the plant type. Thus, the results of this phase are only referential and have no statistical value.

As per the application of Duncan´s multiple range tests, it was done only for those treatments that obtained the best results in their properties, wheat and corn plants. In general terms, this test indicated that when comparing treatments, the properties were better for low proportions of wheat stubble, and results were statistically valid for 10, 20, and 30%. Also, better results were obtained with corn stubble.

DISCUSSION

The possibility of producing boards incorporating AGs in Chile seems now to have a low probability, due to the concentration of production in one company that uses only radiata pine wood (MASISA 2008). In competitive terms, a new company would work in a complicated market, at least at the national level. Because of this, the present study focused in analyzing the possibility of mixing wood fibre with others that could incorporate different characteristics, and/or to reduce the cost of the material used, in order to offer these AGs as another alternative to the existing production of particle boards (Garay 2007).

So, in the first phase of research the usual variables of the process were maintained; board density, adhesive level, forging time, moisture content, among others, with the purpose of studying the possibility of incorporating these materials to the production process without modifying the normal and traditional production process of particleboards.

A wide range of mixtures was analyzed in this research. The results indicate that the mechanical properties decreased as the proportion of AGs increased, although thickness swelling was improved by adding AG fiber. Because of this, in phase 2 the density and percentage of adhesive incorporated were modified. This improved the properties evaluated, and the results were analyzed statistically, corroborating the improvement. This method of successive approximations may lead to optimization of the characteristics of the product. Results when incorporating AGs up to 30% in boards made with the two stubble sources indicated the best results with wheat and corn.

Diverse studies compiled by Garay (2006, 2007) have presented the use of a wide variety of prime materials to fabricate particle boards. The internet page www.fiberfutures.org provides a continuously updated source of research results and news of industries worldwide producing boards with AGs. In Chile, research of these boards have been limited or have not been published.

Tanen (1996) evaluated the properties of boards with waste wood from a mouldings machine (originating of a factory of wood mouldings) and MDI (methyl di-isocyanate) adhesive. His results verified the significant effect of this adhesive in the improvement of the physical and mechanical properties of the board. That research demonstrated the improvement in the properties of the board achieved when mixing a low quality material with a high quality adhesive.

Pease (1998) indicated that the wax surface layer in wheat stubble makes the retention of the adhesive more difficult, and it is already known that to succeed in using AGs in the board industry, the MDI adhesives have been better in bonding than resins of urea, phenol, and melamine formaldehydes used extensively by the forest industry. Isocyanate forms too strong a bond, and forging is too rapid, though there is a benefit that formaldehyde is not emitted. A chemical cross linking occurs between the adjacent surfaces.

Using 10% MDI adhesive (Pease 1998), internal bond of the board was 225 psi, while only 3 psi in a board made with 15% UF (urea formaldehyde), and 120 psi in a wood particle board. Those results indicate that there are interesting possibilities for AGs, but a replacement of adhesives is to be considered.

In Chile, MDI is being used only to make OSB, and its incorporation requires a careful justification of its advantages, because of its higher cost than those adhesives based on formaldehyde. According to our results, it is necessary to evaluate AGs incorporating MDI, and also to study using low levels of AG (10 to 30%) in boards made with corn and wheat stubble, as these AG obtained the best results in our study, although the possibility of producing boards incorporating rice husk and MDI should not be ruled out.

Lee *at al.* (2004) evaluated mixtures of agricultural stubbles and wood from the Chinese tallow tree *Sapium sebiferum* (L.) and variations of MDI and UF. The best physical and mechanical properties of the boards occurred when mixing fibres from both sources and 1% and 4% of MDI and UF, with a considerable reduction of costs but not of properties.

The fabrication process of board particles uses hot presses at high pressure with UF or melamine formaldehyde resins, which compensate the unfavorable characteristics of some wood particles with respect to others (sawdust compared with chips, for example), in search of an optimal global economy (Poblete 2001).

The most important factors determining the properties of the board are its type, size, particle distribution and orientation, type and quality of the process, moisture content during pressing, and post-fabrication treatments.

CONCLUSIONS

1. If no modifications are adopted in the variables of the process, agricultural fibers can be incorporated at low proportions in production of particle boards.
2. With some modification, as in the density of the board and dose of the adhesive, the physical and chemical properties tend to improve.

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