FULL RECOVERY OF *ARUNDO DONAX* PARTICLEBOARD FROM SWELLING TEST WITHOUT WATERPROOFING ADDITIVES

Jose-Antonio Flores-Yepes,[a,*] Jose-Joaquin Pastor-Perez,[a] Francisco-Javier Gimeno-Blanes,[a] Isabel Rodriguez-Guisado,[a] and María-José Frutos-Fernandez,[a]

This paper presents the development of particleboard based on common reed, reproducing the industry standard manufacturing process applied to wood chipboard. One of the main properties of the resulting board was its resistance to water, due to the hydrophobic properties of the common reed, despite there being no incorporation of melamine or any other waterproofing additive. The boards that were developed were analyzed using 2 mm and 4 mm sieves for fibre selection, a manufacturing pressure of 3 N/mm^2 and 25 N/mm^2, and a volume of urea formaldehyde resin content ranging from 5.2% to 13% (8 to 20% liquid format). Standard destructive tests were performed. It was found that under certain applied conditions, namely high pressure and adequate resin proportion (a pressure of over 3 N/mm^2 and over 15% liquid resin), *Arundo donax L.* particleboard demonstrated full recovery from the swelling test. This finding highlights an unmatched property in terms of recovery from the swelling test of the designed board. This property confers a interesting property to be used in high humidity environments without the need for special resin or waterproofing process.

Keywords: Particleboards; Wood remainder; Shredder; Shredding machine; Particle board; Wood waste; Giant reed; Arundo donax

*Contact information: a: Universidad Miguel Hernández, Carretera de Beniel, Km. 3.2, Orihuela – 03310, Alicante, Spain; *Corresponding author: ja.flores@umh.es*

INTRODUCTION

Common reed (*Arundo donax* L.), also known as giant cane or common cane has traditionally been considered a bad boil or weed (Rowell *et al.* 1997), although it is easy to find references to its use in buildings over 100 years old. This product has been used in the construction business for decades, usually for reasons linked to its lower cost when compared to other materials. Nowadays, the common reed is only used for decorative purposes, or it is burned after an initial drying process, resulting in CO_2 emissions.

Common reed is native to central Asia and has gradually spread and established itself in all countries bordering the Mediterranean Sea (Polunin and Huxley 1965; Fornell 1990). The plant has spread widely to all areas of subtropical and warm-temperate regions of the world especially after its deliberate introduction by man in the nineteenth century. Recently, The European Commission, within the framework of its Ecosystem Vulnerability Key Action, identified the 15 invasive species that have had the greatest impact in the Mediterranean area, and common reed emerged as one of them (Balaguer 2004).

The industrial and commercial development of common reed particleboard, apart from having some appeal due to the newness of the material and its interesting properties, very similar to wood particleboard, could be considered a step further toward the recycling of this plant. This new application will curtail the indiscriminate burning of this natural plant and eventually also reduce the CO_2 emissions that occur during this process. One important point is the fact that common reed leaves could only be used for biomass, so the development of cane particleboard is not only an attempt to replace wooden particleboard, but also to provide an ecologically sustainable alternative for ornamental use, although the results presented in this paper suggest other applications as well.

The standard wood particleboard manufacturing process has been well described in the literature (Atchison and McGovern 1983; Rowell *et al.* 1997; Flores-Yepes *et al.* 2011b). This standardized process, using urea formaldehyde resin, is considered in this paper to evaluate jointly how pressure applied and resin proportion play a significant role with respect to final product properties. The presence of this resin has been an issue in recent publications, and a number of research studies are evaluating this resin replacement. New protocols based on the extraction of lignin (Aguilar-Vega and Cruz-Ramos 1995; Valadez-Gonzalez *et al.* 1999; Idarraga *et al.* 1999) from different materials such as rice cane, among others, are currently being investigated in search for a zero formaldehyde emissions process. References illustrate the important increase in terms of cost that would be required to implement these techniques (Jiménez *et al.* 2003; Bellido *et al.* 2003). In fact, the suggested manufacturing methods are much more energy intensive, leading to a more expensive and not so environmentally friendly process. Therefore, the use of urea formaldehyde resin is still widely prevalent, and for the time being no commercial alternatives have been applied on a large scale for indoor use. Meanwhile, worldwide manufacturers are committed to moderating the amount of urea formaldehyde resin content in order to reduce the potential harmful emissions in accordance with the 2004 recommendation from the International Agency of Research of Cancer (a World Health Organization subsidiary). This recommendation was based on the work of Hauptmann *et al.* (2004) on mortality in the formaldehyde industries, which raised the possibility of a rare type of cancer, naso-pharyngeal, linked to this product. It should be mentioned that another study (Viegas *et al.* 2010) raised the point that the population included in the Hauptmann study was highly exposed to a significant concentration of formaldehyde for a long period of time, which is not typical in conventional industrial practice. In all, urea formaldehyde resins are widely used due their cost-effectiveness, structural strength, and benefits such as productivity during the manufacturing process (speed setting) and versatility, meaning that there is no realistic short to medium term replacement in industrial production.

Although current trends are moving toward eliminating this component in the future, the current approach is to moderate and voluntarily reduce the proportion in the manufacturing processes. Examples of these situations are shown on the voluntary standard 3-08 EPP CPA in April 2008, the ANSI A208.1-2009, ANSI A208.2-2009, JIS A 5905, JIS A5908, PB, JAS 233, and PY.

In accordance with this rationale, in the present work, urea formaldehyde resin was used for a one-to-one benchmark against standard particleboard (allowing the specific effect of this new component to be evaluated), and resin content and proportion were analyzed in order to evaluate eventual reduction potential.

Although commercial chipboard is a very well established product for indoor use, it presents an important inconvenience due to its negative response to humidity; this type of product loses structural properties and almost melts when it gets wet. In addition to incorporating urea formaldehyde resin, waterproof boards incorporate melamine. This aggregated material raises the overall proportion of glue-resin to 10%, increasing its cost and weight. One alternative commercial solution is the use of phenolic adhesives alone or in combination with tannin extracts or polyisocyanate, which respond better to moisture than phenolic, and which harden without providing water to wood particles. All these alternatives would increase cost and at the same time incur a number of additional difficulties in the production process. In addition to the mentioned resins, a number of others could be mentioned, although the same rationale could be applied in terms of pricing and cost, which justifies the limited application of these products. An illustrative list will contain: hot melt polyolefins, polyurethanes and polyurethane reactive resins, polyethylene-vinyl acetate copolymers of polypropylene, certain types of amorphous epoxy resins, and sodium lignosulphate. The present work describes an inexpensive melamine-less application with full recovery from the swelling test.

MATERIALS, METHODS, AND DEVELOPMENTS

Materials

In terms of raw material, rods from 3.5 to 4.5 meters long with an approximate average diameter of 2 cm were acquired. Parts of the cane with a diameter smaller than 0.5 cm were discarded. In accordance with an initial process carried out by the provider, Cañas de Albatera, the rods provided were dry and leafless. Particles were developed through a hammer shredder and then classified and identified according to size. Following previous studies (Flores-Yepes *et al.* 2011a), optimal sieve sizes (4 and 2 mm) were used for the classification and selection of particles.

Phenol formaldehyde resin was used as the optimal selection for outdoor boards, and the urea formaldehyde was used for indoor boards (Peraza Sánchez *et al.* 2004). This approach is consistent with standards in wood particleboard industry. The boards were tested with different proportions of synthetic resin in order to obtain a number of references for trial boards. The resin characteristics were: liquid format, a viscosity of 300 to 400C.p. (at 28 ºC), a density of 1.265, and a pH ranging from 7.5 to 8.2, with 62 to 65% solid elements.

The introduction of water does not have any positive effects on the manufacturing process; moreover, once the optimal moisture reference for common reed is stabilized, the addition of water worsens the manufacturing/assembling process. The manufacturing process outlined in this paper uses only a small portion of the water necessary to facilitate the mixture of urea formaldehyde resin and cane-particles.

Urea formaldehyde resins are usually associated with a catalyst. This reagent, ammonium sulphate in our case, has a double effect on the manufacturing process (Vignote and Jiménez 1996; Jamaludin *et al.* 2000; García Esteban *et al.* 2002; Abdalla and Sekino 2004; Papadopoulos *et al.* 2004; Peraza Sánchez *et al.* 2004): (i) it speeds up the process by accelerating the hardening and thus becomes a key factor in manufacturing process, and (ii) it prevents formaldehyde emissions. This catalyst is available from different existing commercial brands. Between 0.05 and 1% dry weight of ammonium sulphate was used on the particles.

Methods

Particleboard production

The production process started with an initial pre-processing of raw materials. This phase included cutting the leaves using the common reed shredder with horizontal shaft and blades separated by a gap of between 1.7 and 2.07 mm, then sieving, classifying, and finally drying the particles to obtain a material with a moisture ratio of 3 to 5%.

The standard particleboard manufacturing process was followed for the production of particleboard. Proportions and sizes of common reed were manually selected to match the prototype board. Previous studies (Flores-Yepes *et al.* 2011a,b) were conducted with large cane particles (8 mm sieve), resulting in a significant reduction of board strength; therefore, the present study focuses on the development of boards based on using particles of a maximum size of 4 mm .

Particles were mixed with resin using a hand mixer. For this study the following resin liquid proportions were considered: 8% (5.2% dry weight), 10% (6.5% dry weight), 15% (9.75% dry weight), and 20% (13% dry weight). The test boards were finally built on hot press machine, using 25 N/mm^2 and 3 N/mm^2. A protective pre-treatment of the mould with high temperature polyethylene film was incorporated in order to facilitate mould release.

A minimum of four boards were produced per batch, for a pressure of both 25 N/mm^2 and 3 N/mm^2. Dosages corresponding to different families of board products being considered are shown in Table 1.

Table 1. Breakdown of Board Elements for Different Resin Content

Resin %	Resin (g) Liquid/Dry	Ammonium Sulphate (g)	Water (g)	Particles (g)
8%	12 / 7.8	0.6	25	150
10%	15 / 9.75	0.75	20	150
15%	22.5 / 14.62	1.25	20	150
20%	30 / 19.5	1.5	20	150

The method applied in this study for the manufacture of common reed particleboards was patented as “Method for Producing Hardboards from Giant Reed and Resulting Boards”, WO/2008/107504 (Flores-Yepes *et al.* 2008), and it is in commercial use through established contracts between patent-holders and commercial companies. This method was described in detail in a published paper (Flores-Yepes *et al.* 2011b), and further developments and results were published on the impact of pressure on the manufacturing process (Flores-Yepes *et al.* 2011a).

Testing of particleboards

The resulting particleboards were cut (50 x 50mm), weighed (precision weighing), dried (in a drying oven), and classified according to the standard EN 324-1 for board dimensioning (UNE-EN 1994e), and EN 322-94 for board moisture measurements (UNE-EN 1994c).

All produced boards were subjected to a bending test according to UNE 310-94 (EN 310, 1994 (UNE-EN 1994a). Experiment dimensioning, namely support-roller diameter and distance, were calculated according to board thickness.

The swelling test process consisted of three phases for the boards: (i) the initial board, (ii) the board after water saturation (24 hours water immersion), and (iii) the board after a drying process (the boards were inserted into the oven until the initial weight was recovered). For swelling and thickness measurement, UNE 317 standard was applied (EN 317, 1994) (UNE-EN 1994b). Test conditions were set as follows: temperature in the range of 20 ± 1ºC and pH in the range of 7 ± 1º, and the test was configured to ensure a minimum immersion of 25 ± 5 mm. The environmental conditions were maintained throughout the duration of the test. Thickness was registered before test (t_1), after immersion (t_2), and after drying process (t_3). Gain (G_t) and recovery (R_t) was calculated expressions shown on Eqs. 1 and 2, respectively. The present formulation is defined for a R_t value of one hundred in the case of full recovery.

$$G_t = \frac{t_2 - t_1}{t_1} \times 100 \tag{1}$$

$$R_t = \left(1 - \left(\frac{t_3 - t_1}{t_1}\right)\right) \times 100 \tag{2}$$

RESULTS AND DISCUSSION

Bending Test

Bending tests were performed for boards prepared with different resin contents (8%, 10%, 15%, and 20% in liquid format) and different pressures applied during manufacturing process (3 N/mm^2 and 25 N/mm^2). Figure 1 contains the registered load-deformation data during the test. Images in Fig. 1 are titled with *X.Y* format, where the first digit indicates the pressure applied (1 corresponding to 3 N/mm^2 and 2 for 25 N/mm^2) and the second digit denotes the resin content (1 for 8%, 2 for 10%, 3 for 15%, and 4 for 20%).

The load-deformation test for the boards manufactured using 3 N/mm^2 and 8% resin content barely exceeded 0.08 kN, while an increase in pressure to 25 N/mm^2 contributed significantly towards a breaking load value close to 0.12 kN. A 10% resin content with 3 N/mm^2 of pressure improved the results, and values exceeded 0.1 kN, and again an increase in pressure (25 N/mm^2) produced better results. Additional increases in resin content, over the 15%, yielded proportional improvements in final properties obtained.

In summary, key findings, as far as loading-deformation is concerned, are: (i) lower values in terms of Load-Deformation correspond to lower ratios of resin; (ii) the high pressure in the board manufacturing processes, showed better results (in terms of strength and deformation), even with a lower resin content.

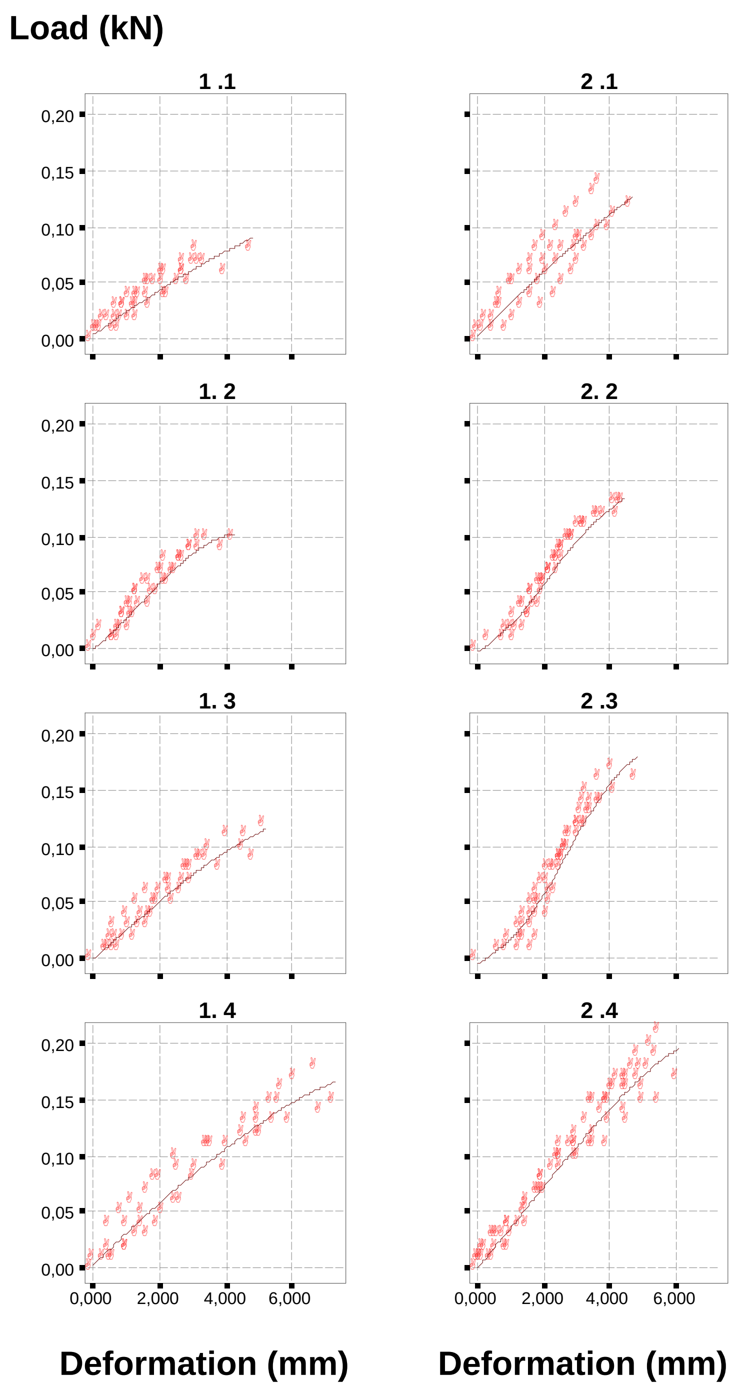

Fig. 1. Bending test results for boards developed with different resin contents and pressures applied during manufacturing process

Elasticity Modulus

Figure 2 compares the results of the elasticity modulus in the bending test for different values of pressure during the manufacturing process as well as different percentages of resin content. The highest quality was observed, in the case of 15% resin content, when the boards were subjected to a higher pressure during the manufacturing process. A different and graphical appearance was observed with the low-pressure method, in which the elasticity modulus increased directly with the resin content. It can be seen in the load-deflection graphics that for 3 N/mm^2, the elasticity modulus increases as the resin content increases. For 25 N/mm^2 of pressure during manufacturing, a local maximum was obtained with 15% liquid resin content. It should be noted that higher values of resin did not contribute positively to the elasticity modulus.

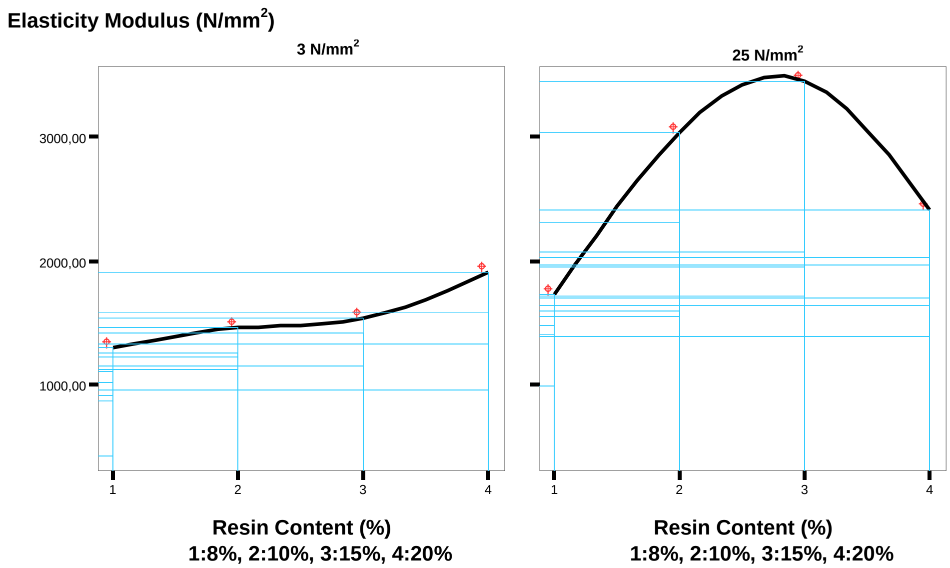

Fig. 2. Elasticity modulus obtained from the bending test

Swelling Test

For this study, we analyzed the behaviour of common reed particleboard when compared with different commercial wooden particleboards that were considered the gold standard. We compared 11 different board-products: commercial available Medium Density Fibreboard MDF, two standard wooden boards from two different standard particleboard providers (referred in this article as Particleboard A and B), and the 8%, 10%, 15%, and 20% resin cane particleboard based on a 4 mm sieve for 3 N/mm^2 and 25 N/mm^2.

Results provided evidence that none of the commercial chipboard recovered from the swelling test in terms of thickness. Chipboard A presented the best performance among commercial boards, with a recovery ratio over 82%. The best commercial chipboard swelled by 16% on average, and the lower quality boards by over 19%, while MDF swelled by 28%. In contrast, cane particleboards presented almost full recovery, although they required higher resin content than commercial boards; a resin proportion in the range of 15 to 20% was needed, while commercial chipboards are in the range of 12 to 15%). The high pressure common reed particleboards performed better for all resin proportions.

Boards manufactured with resin proportions lower than 15% (and 20% in the case of low pressure boards) exhibited damages or decomposition during the swelling process (see Table 2).

Table 2. Thickness Measure and Swelling Analysis for Different Boards*

		Initial	Water Saturation		Dried Board	
		t_1 (mm)	t_2 (mm)	G_t	t_3 (mm)	R_t
Particleboard A		13.2 ± 0.00	15.31 ± 0.69	16.00	15.51 ± 0.74	82.48
Particleboard B		16.2 ± 0.05	19.39 ± 0.28	19.72	21.63 ± 0.9	66.42
MDF Board		12.11 ± 0.04	15.53 ± 0.19	28.31	18.15 ± 0.48	50.03
3 N/mm^2	8%	8.14 ± 0.14	10.02 ± 0.34	23.16	12.7 ± 0.97	43.90
	10%	8.67 ± 0.18	9.32 ± 0.26	7.50	11.14 ± 0.67	71.57
	15%	8.67 ± 0.18	9.32 ± 0.26	7.50	11.14 ± 0.67	71.57
	20%	**9.45 ± 0.63**	**10.13 ± 0.71**	**7.19**	**9.53 ± 0.69**	**99.21**
25 N/mm^2	8%	6.67 ± 0.46	9.37 ± 0.35	40.35	13.15 ± 0.59	2.92
	10%	7.18 ± 0.22	8.28 ± 0.31	15.44	12.69 ± 1.15	23.17
	15%	6.14 ± 0.33	6.81 ± 0.50	10.83	7.19 ± 0.78	82.98
	20%	**7.84 ± 0.15**	**8.38 ± 0.12**	**6.89**	**7.85 ± 0.14**	**99.90**

For the sake of discussion, it could be argued that although particles may take up water during immersion, after drying, they return almost completely to their initial form, not suffering deteriorative effect. This result is consistent with the fact that, unlike wood, common reed grows in a semi-immersed environment, and therefore has better properties for this kind of environment. With regard to the decomposition of boards with lower proportion of resin and low pressure, it should be discussed that the very same properties that benefit the recovery from swelling test, may play an opposite role in favour of the weakening of the bonds between fibres and resin. As a consequence, it could eventually require higher values, in terms of resin content and pressure, to enhance board properties.

Table 3. Thickness Measure and Swelling Analysis for 4 and 2 mm Sieve Boards Manufactured with 20% Resin and with a Pressure of 25 N/mm^2

	Initial	Water Saturation		Dried Board	
	t_1 (mm)	t_2 (mm)	G_t	t_3(mm)	R_t
4 mm Sieve Boards	7.57 ± 0.46	8.04 ± 0.52	6.21	7.51 ± 0.51	101.00
2 mm Sieve Boards	7.46 ± 0.41	7.96 ± 0.48	6.69	7.50 ± 0.52	88.00

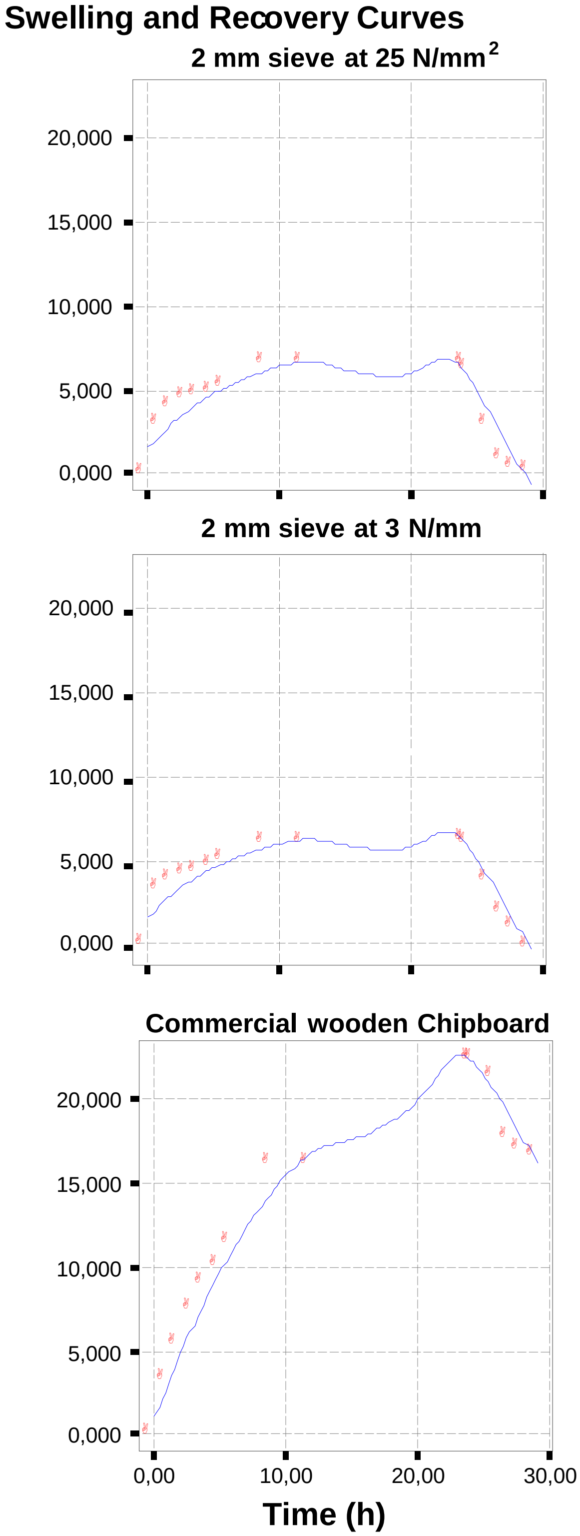

Fig. 3. Swelling test curves obtained

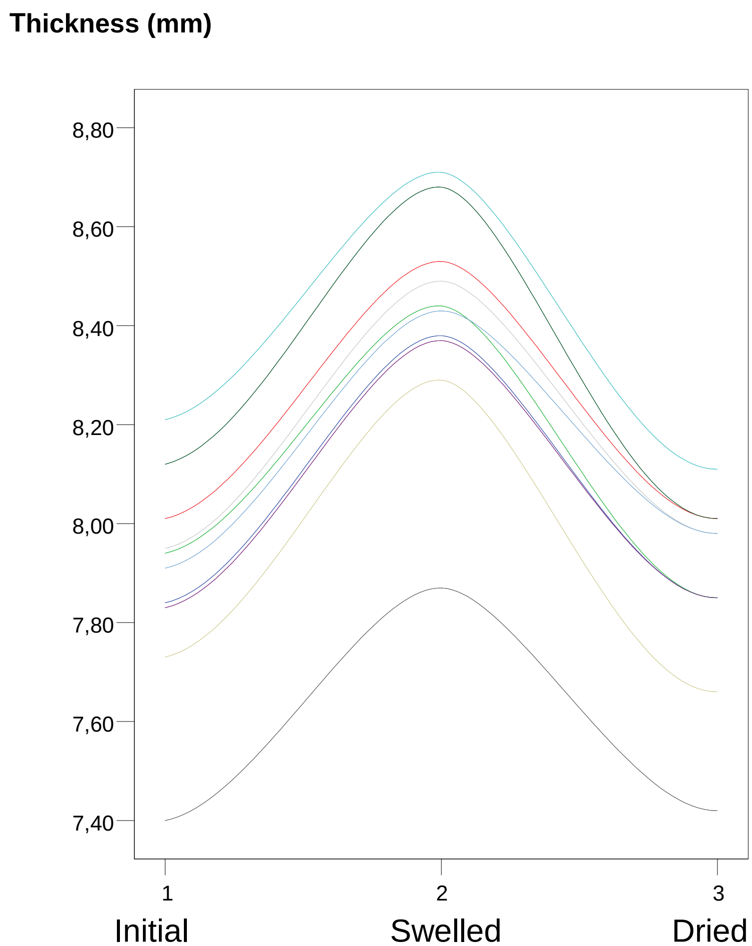

Fig. 4. Evolution of the thickness for each sample tested with 20% resin and 25 N/mm^2 pressure

A new experiment was developed to benchmark 4 mm and 2 mm sieve boards manufactured with 20% resin content through a 25 N/mm^2 pressure process. Results indicated no major differences between those boards. Table 3 displays the swelling and recovery after a natural drying process (exposure to air) and a final insertion for one hour into a drying oven at 103 ºC. A recovery of over 100% represents an over-exposure to the drying system, which caused an initial loss in the moisture of the boards. The figures show that both panels with and without the 4 mm sieve particles recovered completely from the swelling process.

The same study was also conducted for high and low pressure, and the resulting swelling curves showed in Fig. 3 were obtained. The maximum swelling reached 8.58% with a 4 mm sieve and at low pressure. These results compared very positively with those of the commercial wooden particleboard with a swelling ratio over 17%. Regarding swelling recovery properties, the following relevant results were found (see Fig. 3): (i) all common reed particleboards recovered almost completely (100% for the 2 mm sieve and 97.25% for the 4 mm sieve), (ii) commercial wooden particleboards retained 17.17% swelling after the drying process.

Since behaviour improved with increasing pressure and resin, the common reed particleboard developed with 25 N/mm^2 and 20% resin was identified as the highest-performing board. An additional behaviour analysis for the different thicknesses of common reed particleboards was developed, with the results shown in Fig 4. The almost 100% parallelism among all particleboards validate the results for all common reed particleboards developed with 20% resin content and 25 N/mm^2 of pressure.

CONCLUSIONS

1. In general terms, a higher resin proportion improves the behaviour of common reed particleboards when low pressure (3 N/mm^2) is being used. The best performance was obtained using high pressure and with a liquid resin content from 15% to 20% (9.75% to 13% dry weight). This 5% increase in terms of resin content did not significantly improve the performance of the boards developed under high pressure.
2. With regard to the standard destructive tests, and in particular the load-deformation test, the resin content is a prevalent factor, if it is compared to applied pressure during manufacturing process, in final board properties. In any case, an increase within the studied range in any of these factors contributed positively to the properties of the resulting material. As a second important conclusion, in terms of the bending test, a local maximum was obtained with 15% liquid resin content for the boards manufactured with 20 N/mm^2 of pressure. It should be noted that higher values of resin did not contribute positively to the elasticity modulus.
3. The most significant contribution of this study was obtained during the swelling test. As a result of this test, in which the proposed materials were benchmarked against existing commercial standard products, none of the commercial products fully recovered from the swelling test in terms of thickness. The best quality boards swelled by an average of 17% and the lower quality boards by over 30%, while MDF swelled by 28%.
4. Common reed particleboards, manufactured under the suitable pressure and with appropriate resin proportion (3 N/mm^2 and 15% liquid resin), recovered completely from the swelling test. This result compared very positively with that of any wooden particleboard, revealing its clear competitive advantage for certain uses. It has been proven in this research that common reed particleboard panels provide an important resistance to water.
5. According to our results, the reduction of resin content during the manufacturing process, as a way to reduce formaldehyde emission, is possible, although only in a very limited range (up to a minimum of 15% or 9.75% dry weight). Further reductions would lead to the malfunction of important properties (structural strength and resistance to water, among others).

6. As a general and final result, the present study's main contribution to industry is the fact that this product provides a cost effective alternative, especially for environments where humidity could be an inconvenience, because the common reed, when used as the primary element in the substitution of wood particles, needs no water-proofing treatment.

ACKNOWLEDGMENTS

This study was a result of the doctoral thesis of J.A. Flores Yepes (Flores-Yepes 2005).

REFERENCES CITED

Abdalla, A. M. A., and Sekino, N. (2004). "Veneer strand flanged I-beam with MDF or particleboard as web material II: effect of resin type, application rate, strand dimension, and pressing time on the basic properties," *Journal of Wood Science.* 50(5), 400-406.

Aguilar-Vega, M., and Cruz-Ramos, C. A. (1995). "Properties of henequen cellulosic fibers," *Journal of Applied Polymer Science* 56(10), 1245-1252.

Atchison, J. E., and McGovern, J. N. (1983). "History of paper and the importance of non-wood plant fibers," *Secondary Fibers and Non-wood Pulping* 3.

Balaguer, L. (2004). "Las plantas invasoras: ¿el reflejo de una sociedad crispada o una amenaza científicamente contrastada?," *Historia Natural* (5), 32-41.

Bellido, M., Egoavil-Cueva, G., and Gonzales, E. (2003). "Tableros de fibras de la madera de <<tornillo>> (Cedrelinga cateniformis ducke)," *Bosque (Valdivia)* 24(3), 39-44.

Flores-Yepes, J., Garcia-Ortupo, T., Pastor-Pérez, J. J., Andreu Rodriguez, F. J., Ferrandez-Villena, M., and Ferrandez-Garcia, M. T. (2008). "Method for producing hardboards from giant reed and resulting boards," September 12 2008, WO Patent WO/2008/107.504.

Flores-Yepes, J. A. (2005). *Fabricación y Análisis de Tableros de Aglomerado de Cañan Común (Arundo Donax L.).* PhD thesis, Polytechnic School of Orihuela - Miguel Hernandez University of Spain.

Flores-Yepes, J. A., Pastor, J. J., Martinez-Gabarron, A., Gimeno-Blanes, F. J., and Frutos, M. J. (2011) "Pressure impact on common reed particleboards manufacturing procedure," *Systems Engineering Procedia*. 1(2), 499-507.

Flores-Yepes, J. A., Pastor, J. J., Martinez-Gabarron, A., Gimeno-Blanes, F. J., Rodríguez-Guisado, I., and Frutos, M. J. (2011). "Arundo donax chipboard based on urea-formaldehyde resin using under 4 mm particles size meets the standard criteria for indoor use," *Industrial Crops and Products* 34(1), 1538-1542.

Fornell, T. C. (1990). Widespread adventive plants in Catalonia. *Biological invasions in Europe and the Mediterranean Basin*, Kluwer Academic Publishers, Dordrecht, 85-104.

García Esteban, L., Guindeo Casasús, A., Peraza Oramas, C., and Palacios de Palacios, P. (2002). *La Madera y su Tecnología*, Fundación Conde del Valle de Salazar. Madrid.

Hauptmann, M., Lubin, J. H., Stewart, P. A., Hayes, R. B., and Blair, A. (2004). "Mortality from solid cancers among workers in formaldehyde industries," *American Journal of Epidemiology* 159(12), 1117-1130.

Idarraga, G., Ramos, J., Zuniga, V., Sahin, T., and Young, R. A. (1999). "Pulp and paper from blue agave waste from tequila production," *J. Agric. Food Chem.* 47(10), 4450-4455.

Jamaludin, K., Jalil, A. A., Jalaluddin, H., Latif, M. A., and Nor, M. Y. M. (2000). "Interior grade particleboard from bamboo (*Gigantochloa scortechinii*): Influence of age, particle size, resin and wax content on board properties," *Journal of Tropical Forest Products* 6(2),142-151.

Papadopoulos, A. N., Hill, C. A. S., Gkaraveli, A., Ntalos, G. A., and Karastergiou, S. P. (2004). "Bamboo chips (*Bambusa vulgaris*) as an alternative lignocellulosic raw material for particleboard manufacture," *European Journal of Wood and Wood Products*. 62(1), 36-39.

Peraza Sánchez, F., Peraza Sánchez, J. E., and Arriaga Martitegui, F. (2004). *Tableros de Madera de uso Estructural*, Aitim, Rivas - Spain.

Polunin, O., and Huxley. A. (1965). *Flowers of the Mediterranean. London: Chatto and Windus xii*. First publ.

Rowell, R. M., Sanadi, A. R., Caulfield, D. F., and Jacobson, R. E. (1997). "Utilization of natural fibers in plastic composites: Problems and opportunities," *Lignocellulosic-Plastic Composites*. São Paulo, USP & UNESP, 23-51.

UNE-EN-310 (1994). "Determinación del módulo de elasticidad en flexión y de la resistencia a la flexion," UNE-EN.

UNE-EN-317 (1994). "Tableros de partículas y tableros de fibras. determinación de la hinchazón en espesor después de inmersión en agua," UNE-EN.

UNE-EN-322 (1994). "Determinación del contenido de la humedad en tableros derivados de la madera," UNE-EN.

UNE-EN-323 (1994). "Determinación de la densidad de tableros," UNE-EN.

UNE-EN-324 (1994). "Determinación del tamaño de tableros," UNE-EN.

Valadez-Gonzalez, A., Cervantes-Uc, J. M., Olayo, R., and Herrera-Franco, P. J. (1999). "Chemical modification of henequen fibers with an organosilane coupling agent," *Composites Part B: Engineering*. 30(3), 321-331.

Velásquez-Jiménez, J.A. (2003). *Producción de Tableros de fibras a partir de Miscanthus Sinensis*, PhD thesis, Universitat Rovira i Virgili, Tarragona - Spain.

Viegas, S., Ladeira, C., Nunes, C., Malta-Vacas, J., Gomes, M., Brito, M., Mendonca, P., and Prista., J. (2010). "Genotoxic effects in occupational exposure to formaldehyde: A study in anatomy and pathology laboratories and formaldehyde-resins production," *Journal of Occupational Medicine and Toxicology*. 5-25.

Vignote, S., and Jiménez, F. (1996). *Tecnología de la Madera*, Ministerio de Agricultura Pesaca y Alimentación, Madrid.

Article submitted: April 6, 2012; Peer review completed: June 16, 2012; Revised version received: June 27, 2012; Second revision received and accepted: September 3, 2012; Published: September 10, 2012.