IC-NOCMAT 2007 Maceió
International Conference on Non-Conventional Materials and Technologies: Ecological Materials and Technologies for Sustainable Building
Maceió, Alagoas, Brazil, 14th-17th October 2007
In Honour of Professor R.N.Swamy

FINE PARTICLE FIBERBOARDS FROM LIGNOCELLULOSIC WASTE MIXED WITH THERMOSETTING RESINS

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ABSTRACT

The objective of this work was to evaluate the properties of the fiberboards made from lingocellulosic waste mixed with thermosetting polymers. A two level factorial experimental design was used, to analyze four variables: lignocellulosic waste type (F), type of resin (T), resin percentage (%) and fiberboard density (D). Urea-formaldehyde and phenol-formaldehyde thermosetting resins were used, both in two levels 4% and 10%, mixed with two of the most widespread and abundant lignocellulosic waste in Ecuador: sugar cane bagasse and rice husk. Fiberboards with dimensions of 350mm x 350mm x 10mm were produced, with two densities to evaluate 0,9 gr/cm^3 y 0,7 gr/cm^3, to obtain a wide vision of the interaction of these variables. Static bending strength, tensile strength perpendicular to surface and thickness swelling due to water absorption were evaluated, according to the ASTM D 1037 standard. The results were compared with the ANSI A 208.1 standard, obtaining superior results according to this standard with compositions 1 and 2 (10% phenol-formaldehyde with sugar cane bagasse and density of 0.9 gr/cm^3 y 0.7 gr/ cm^3). The water absorption results were superior to the commercial ones; moreover, the values of water absorption are comparable with the ones of commercial fiberboards. In general, the best results were obtained with sugar cane bagasse mixed with phenol-formaldehyde polymer.

KEYWORDS: fiberboard, urea-formaldehyde, phenol-formaldehyde, sugar cane bagasse, rice husk

INTRODUCTION

There are many efforts around the world to develop friendly products with the ecosystem; because of this, there are many organizations showing a good ecological behavior: controlling the impact of their productive activities along the productive cycle, including the recycle capacity of their products and the final disposition of their remainders through the use of sustainable technologies and considering the employees involved on these processes.

The research done for this work was directed to solve this problem in Ecuador due to the generation of sugar cane bagasse and rice husk, waste from the production of sugar and rice. In the period between 1990 and 2005, the surface utilized to grow sugar cane increased 35% and the production increased 66% from 220000TM to 550000 TM. Similarly, rice production increased 114% from 700000 TM in 1991 to 1'500000 TM in 2005 [1], [2]. This has produced an increase in the generation of rice husk representing 20% in weight of the total production of rice and due to the low specific weight (100 Kg/m^3) makes its volume unmanageable.

The Cuban Sugar Cane Derivatives Research Institute (ICIDCA in Spanish) has developed several techniques for the utilization of the exceeding sugar cane bagasse, being the sugar industry one of the biggest in this country. Gómez et al describes a technical procedure for the elaboration of fiberboards from sugar cane bagasse; the fiberboard is made with three sheets, the exterior ones are made with smaller size particles than the middle ones, but these middle sheets are wider than the exterior sheets. The inorganic resin used as agglutinant depended on the final utilization of the fiberboard; for example, if the fiberboard is used for interior areas, urea-formaldehyde resin should be appropriate; if not the phenol-formaldehyde resins are adequate when the humidity is a determinant factor. The use of the bagasse mixed with cement and gypsum is also described [3].

Hse and Shupe [4], studied the properties of the sugar cane fiberboards and rice husk fiberboards, using a resin system based on urea-formaldehyde and poli-isocynates, obtaining the best results when the isocynate is sprayed before the application of the urea resin.

The objective of this work was to evaluate the physical and mechanical properties of sugar cane bagasse fiberboards and rice husk fiberboards mixed with phenol-formaldehyde and urea formaldehyde resins in order to make a statistical comparison between them and determine the best composition for fiberboards.

MATERIALS AND METHODS

Materials

25 kilograms of sugar cane bagasse was collected in the province of Imbabura (Northern part of Ecuador), to be used on this project. The amount of rice husk was 40 Kg and it was collected in the province of Guayas, the Ecuadorian heart of the rice productive zone.

The resins were provided by Alba Quimica, Brazil; two types of thermosetting polymers or resins were used: urea-formaldehyde (UF) and phenol-formaldehyde (PF), with the commercial name of CASCAMITE PB 5070 and CASCOPHEN HL 2080, respectively.

Preparation Of The Fibers

The sugar cane bagasse was initially put through a homogenization process, passing through a Wiley mill with rotating fags and a 5mm sieve, in order to obtain uniformity. Also, due to the morphological characteristics of the rice husk, this material was not milled. This step was omitted due its abrasive characteristic. Physical and mechanical behavior of the rice husk fiberboards was analyzed.

After the initial homogenization process, both the sugar cane bagasse and the rice husk passed through a dry process, initially at room temperature and then through an oven with recycling air. This process was done to inhibit the production of bubbles and possibly cracks in the fiberboards due to the change of energy of the water vapor.

The thermosetting resins were adequately stored in a cold area, according to factory requirements. The UF resin, CASCAMITE PB 5070, has a solid theoretical percentage of 66%; meanwhile the PF resin, CASCOPHEN HL 2080, has a solids theoretical percentage of 50%.

Fiberboard Processing

A two level factorial design was used to analyze four variables: lignocellulosic waste type (F), resin type (T), percentage of resin (%) and fiberboard density (D). The thermosetting resins were compared in two levels 4% and 10%, on a dry basis, mixed with the sugar cane bagasse and rice husk. 16 samples were prepared, according to the experimental design, with the appropriate calculations of fiber mass and resin amount. An estimated 3% of humidity was considered in the calculations of the fiber percentage calculations was considered and the theoretical solids percentage of the resin mentioned before were used.

The amount of UF and PF resins used were 4% and 10% according to the recommendations of the factory. The sugar cane bagasse particles and rice husk samples were weighted and then put into a rotational drum mixer, rotating at constant speed of 26 rpm. The resins, diluted in alcohol, were sprayed into the fibers through two nozzles with the aid of compressed air during five minutes. The fiber/resin mix was then weighted for each experiment and pressed manually in a wood bottomless mold with dimensions of 350 mm x 350 mm, over an aluminum sheet coated with a zinc stearate to prevent the adhesion of the fiber to the aluminum during hot-pressing. After, the wood mold was retired another aluminum sheet was placed over it.

The sample was then pressed in a hydraulic machine with electrical heating, with independent temperature adjustment in the plates and analogical control of the applied pressure. The following variables were set at constant values: pressure time, pressure and temperature. The pressing cycle was set in 10 minutes, 160 ºC and 60 Kg/ cm^2. These setting values were selected according to the bibliography and recommendations of the resin manufacturer.

The obtained fiberboards had dimensions of 350 mm x 350 mm x 10 mm, in a single pressure cycle; they were cut according to figure 1, obtaining enough samples for testing: two samples for the static bending, two for the tensile strength parallel to surface and finally two for the water absorption tests. According to the characteristics of the experimental design proposed we had three fiberboards for each fiber/resin composition; having enough data to implement the statistical analysis.

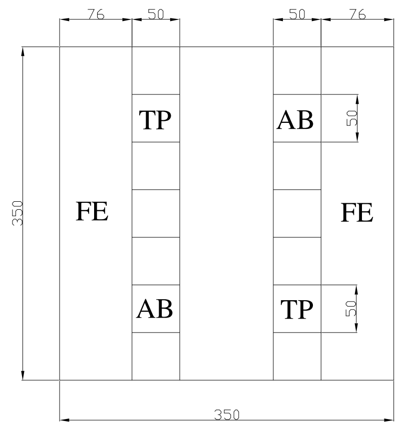

FIGURE 1. TESTING PANELS FIGURE (TP-Tensile Perpendicular, AB-Water Absorption, FE- Static Bending)

DISCUSSION OF RESULTS

Once the different composition fiberboards were obtained, the different testing samples were tested for static bending, tensile strength perpendicular to surface and thickness swelling due water absorption according to the ASTM D1037 standard.

Static Bending

Figure 2 shows the module of rupture response of all the compositions proposed. The maximum value of 10.56 MPa was obtained with the sugar cane bagasse with 10% of PF and a density of 0,9 gr/cm^3 (composition 1) followed by sugar cane bagasse with 10% of UF and a density of 0,9 gr/cm^3 (composition 5).

According to the statistical analysis and assuming no interaction between the four variables, it can be established that the percentage of resin is the most important variable, due to the fact that the effect value 0.3893 obtained when 10% of resin was used instead of 4% resin.

Meanwhile the influence of the density increases the modulus in 0.2472 MPa with the density of 0,9 gr/cm^3 instead of 0,7 gr/cm^3. The effect between the sugar cane bagasse and the rice husk was represented with +0, 2882 MPa on average.

When including in the analysis the effect that the interactions had between the variables, it was confirmed that the best compositions were 1 and 5:

- Density 0,9 gr/cm^3, percentage resin 10%, sugar cane bagasse and PF with a rupture modulus of 10,56 MPa.
- Density 0,9 gr/cm^3, percentage resin 10%, sugar cane bagasse and UF with a modulus of rupture of 9.44 MPa.

In the analysis for the rice husk, the highest value of module of rupture was found in composition 9:

- Density 0,9 gr/cm^3 , percentage resin 10% PF, with a rupture modulus of 6.16 MPa

With these results, according to the standard ANSI A208.1, these three fiberboards can be classified within the LD-2 category, as low density fiberboards class 2.

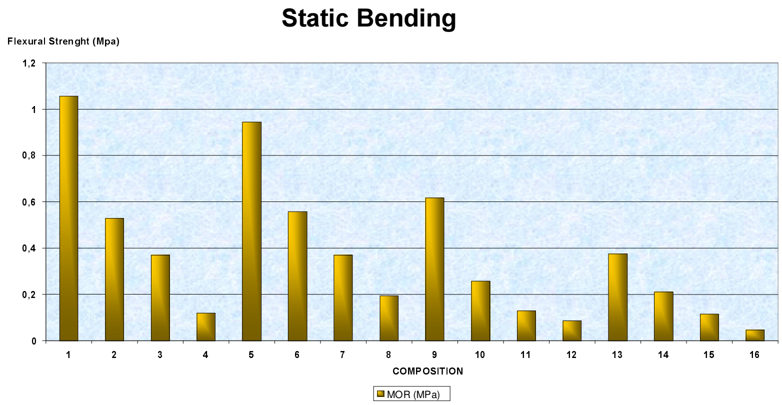

FIGURA 2. BEHAVIOR OF THE MODULUS OF RUPTURE VS. COMPOSITION

In figure 2, it can be seen that compositions 1 and 5 have proximate values of Modulus of Rupture (MOR), independently of the type of resin. The next value of MOR observed belongs to composition 9, which shows a significant difference compared to the first two.

The main effects and main interactions are listed in Table 1.

TABLE 1. MAIN EFFECTS AND ITS INTERACCTIONS WITH ALPHA VALUE OF 0.10

Variable	**Effect**
Percentage of Resin (%)	+0.3893
Density (D)	+0.2472
Type of Fiber (F)	-0.2882
D * %	+0.1124
F * %	-0.1188
D * F	-0.0882

From this analysis it can be established that the four variables and their interactions are significant.

Tensile strength perpendicular to the surface

The interaction with three and four variables was not significant, and they were not further considered in the experimental analysis. Table 2 shows the results for the tensile strength perpendicular to the surface analysis.

TABLE 2. EFFECT AND P-VALUES OF THE MAIN FACTORS AND INTERACTIONS

Variable	Effect	p-value
D	-7.89	0.561
%	32.48	0.051
T	-2.69	0.841
F	-25.71	0.099
D*%	-8.03	0.555
D*T	4.65	0.729
D*F	13.62	0.332
%*T	-0.68	0.959
%*F	-24.60	0.110
T*F	-4.18	0.755

Given the high p-values, it can be established that neither the type of resin (T) nor its interactions (D*T, %*T and T*F) had influence on the tensile strength perpendicular to the surface; therefore, they were excluded from the analysis. The data was then analyzed again without T and its interactions, and the following results were obtained:

TABLE 3. EFFECT AND P-VALUE OF THE MAIN FACTORS AND THE INTERACTIONS WITHOUT THE TYPE OF FIBER

Variables	Effect	p-value
D	-7.89	0.438
%	+32.48	0.009
F	-25.71	0.027
D*%	-8.03	0.431
D*F	13.62	0.195
%*F	-24.60	0.032

The lowest p-values were obtained for resin percentage (%), type of fiber (F) and the interaction between them, and due to this it was established that these factors influenced this experiment.

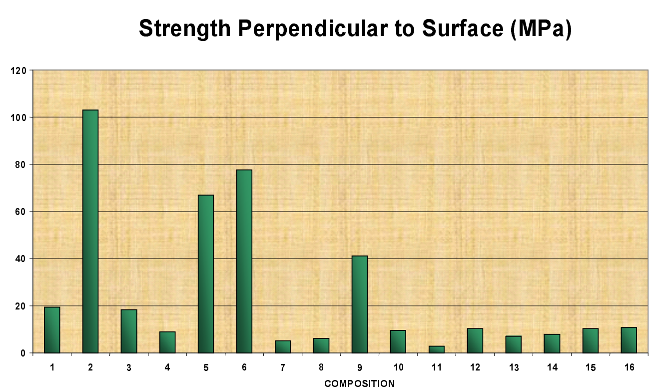

FIGURE 3. BEHAVIOR OF THE TENSILE STRENGHT PERPENDICULAR TO THE SURFACE VS. COMPOSITION

According to these results, the best values of the tensile strength perpendicular to the surface were given by the compositions with 10% of resin and sugar cane bagasse. The highest value was given by composition 2 (sugar cane bagasse with PF at 10% level and a density of 0.7 gr/cm^{3,}) with a value of 103 KPa. This value fell within the standard ANSI A208.1 for LD-2 fiberboards, as low density fiberboards class 2

TABLA 4. BEST RESULTS OBTAINED IN THE TENSILE STRENGTH PERPENDICULAR TO THE SURFACE .

Density (D)	Percentage of Resin (%)	Type of Resin (T)	Type of Fiber (F)	Tensile strength perpendicular to the surface (KPa)
-	+	-	-	103.09
+	+	-	-	19.39
-	+	+	-	77.67
+	+	+	-	66.86

Water Absorption

This factor is directly related to the amount of water that the fiberboard can absorb under extreme conditions. A trend was established, the bigger amount of absorption the bigger the variation on the thickness of the fiberboard. The high percentages of resin (10%) were the ones that presented better behavior than the ones with 4% resin as it can be seen in figure 4.

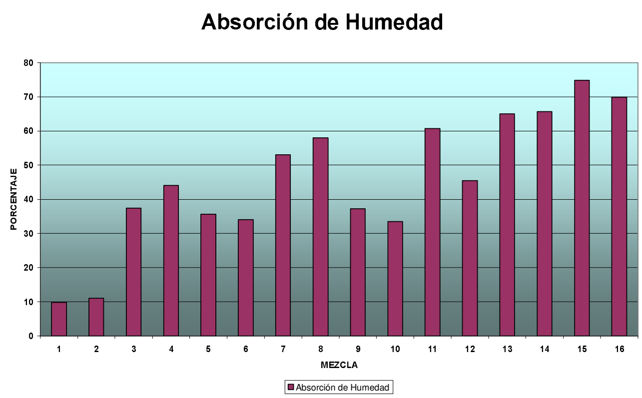

FIGURE 4. BEHAVIOR OF WATER ABSORTION VS. COMPOSITION

The results indicated that density was not a significant variable respect to the water absorption due to its p-value. The p-values of the interactions were high (0.48), and for this reason they were excluded from the analysis. Analyzing the data without the density variable, it was seen that the other three variables (% Resin, type of fiber and type of resin) presented statistical influence on the results of water absorption.

According to this second analysis, the best compositions were the ones with 10 % PF and sugar cane bagasse. The compositions with higher resistance to water absorption were compositions 1 (density 0,9 gr/cm^3, percentage resin 10%, sugar cane bagasse and PF and 2 (sugar cane bagasse with PF at 10% level and a density of 0.7 gr/cm^3). The results were very close in value regardless of the density.

CONCLUSIONS

According to the results and statistical analysis we can conclude the following:

1. The type of resin does not influence the tensile strength and its effect on the rupture modulus is doubtful.
2. The percentage of resin has a definite influence on the rupture modulus as well as the tensile strength perpendicular to the surface; the only restriction is the cost of the increased addition of resin on the composition over 10%.
3. It was noted that the best results for water absorption were obtained when the compositions included PF on their composition.
4. The sugar cane bagasse presented better values of water absorption than the risk husk ones.
5. The density of the fiberboards does not influence the water absorption resistance according to the statistical values.
6. According to the results obtained in this work the values obtained fall within the standard ANSI A208.1 as low density fiberboards Type 2.
7. Since the minimum requirements of LD-2 fiberboards were met, this work shows the technical feasibility of utilizing Ecuadorian lignocellulosic agricultural waste and the possibility to obtain with such waste a useful product.
8. As a final conclusion, the three variables analyzed (Module of rupture, tensile strength perpendicular to surface, and thickness swelling due water absorption) showed the best results with 10% of PF resin mixed with sugar cane bagasse and fiberboard density of 0.9 gr/cm^3.

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