

## Physical and Mechanical Properties of Particleboard Manufactured from Wood, Bamboo and Rice Husk

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In this work, the physical-mechanical properties of particleboards manufactured with wood (*Eucalyptus grandis*), bamboo (*Bambusa vulgaris*) and/or rice husk (*Oryza sativa*) particles, combined or not, were assessed. They were produced in the following proportions: 100% wood; 100% bamboo; 100% rice; 50% wood and 50% bamboo; 50% wood and 50% rice husk. In order to characterize the manufactured particleboards, their physical (density; moisture content; water absorption and thickness swelling) and mechanical properties (static bending; internal bonding and screw withdrawal) were assessed. The results indicated that the use of rice husk caused reduction in particleboard quality. Particleboards manufactured with bamboo showed better quality than those using rice husk as raw material. For most parameters, the particleboards manufactured exclusively with wood particles showed similar performance to bamboo and wood-bamboo particleboards.

**Keywords:** panels, rice husk, *Bambusa vulgaris*, physical-mechanical properties

### 1. Introduction

Owing to the rise in wood consumption, the reserves of native woody species have been decreasing, causing the search for new renewable lignocellulosic materials that may efficiently meet the demand. This environmental pressure supports research regarding new products and a better utilization of the raw material available. Residue reutilization has been increasing, thus several researches have been investigating the characteristics of particleboards produced with these residues. Furthermore, there is the possibility of combining wood with other lignocellulosic materials aiming at obtaining more profitable products and with environmental marketing strategies, without reducing its quality.

The particleboard industry in Brazil uses mostly wood shavings from reforested, resulting in a higher quality product due to better control of the homogeneity of raw material. However, in view of Brazil's agricultural boom and the resulting increase in agricultural wastes, a recent alternative for particleboard production may be the use of agroindustrial lignocellulosic wastes to replace solid wood particles in the manufacture of composite panels<sup>1</sup>.

At first, any lignocellulosic material can be used as raw material for particleboard manufacturing. Besides wood, they can use residues from agribusiness such as: cereal straw, bagasse of sugar cane, cornstalks and corn cobs, cotton stalks, kenaf, rice husks, sunflower stalks and hulls, among others<sup>2</sup>. Within these, rice husk presents the highest potential for utilization. Rice is one of the most consumed cereals in the world. Only in Brazil, which is just the

ninth largest producer in the world, a production of nearly 12 million tons of rice per crop (about 2% of the global production) is estimated, whereas most part is concentrated in its southern states. Considering that the husk accounts for nearly 20% of the grain weight, annually, it would be generated about 2.4 million tons of this residue by that country<sup>3</sup>. Ndazi et al.<sup>4</sup> mentioned that rice husk is one of the agricultural residues easily available in large amounts and, therefore, can be considered an excellent raw material for manufacturing particleboards. However, particleboards produced with this material have been presenting deficient gluing owing to the lack of direct interaction between this product and commercial adhesives. This behavior was also verified by Ajiwe et al.<sup>5</sup> and Melo et al.<sup>3</sup>, while assessing particleboards manufactured with different proportions of wood and rice husk particles.

Apart from residues, the raw materials found in large amount at regional level can decrease the final cost of the product. This is the case of bamboo, which has been used at industrial scale in several Asian countries such as: China, India, Thailand, Vietnam and Malaysia<sup>6,7</sup>. In Brazil, in spite of genera (34) and species (232, whereas 174 are endemic) diversity, bamboo's potential has been poorly utilized<sup>8</sup>. Several studies have indicated that particleboards using bamboo as raw material present satisfactory performance with respect to physical-mechanical properties<sup>9-10</sup>.

Hiziroglu et al.<sup>11</sup>, while studying particleboards manufactured with different proportions of wood (*Eucalyptus camaldulensis*), rice straw and bamboo particles, observed for the particleboards made with wood-rice straw, rice

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straw-bamboo, and for the combination between them, inferior mechanical properties (internal bonding, modulus of elasticity and modulus of rupture) compared to those manufactured only with wood particles. These authors still verified, with respect to physical properties, lower dimensional stability for these particleboards. However, wood-bamboo particleboards obtained similar or better performance than those manufactured only with wood particles.

In the present study, it was assessed the physical and mechanical properties of particleboards manufactured with wood, rice husk and bamboo particles, in different combinations.

## 2. Material and Methods

### 2.1. Raw material collection and preparation

Particleboard manufacturing was carried out using eucalyptus wood (W), rice husk (R) and bamboo (B) particles. The wood particles (*Eucalyptus grandis* W. Hill ex Maiden) were obtained from six trees from homogeneous forest stands with nearly 15 years. The boards were obtained from the trees, which, were then resawed with perpendicular-to-grain cut, obtaining blocks with 5-cm width (tangential), 7-cm length (longitudinal) and variable thickness (radial), according to the diameter and position of the board removal from the log. The blocks were transformed in flakes in a knife mill, and, then, in particles after being processed in a hammer mill with 8.0-mm diameter mesh sieve. Afterwards, fines were removed by a sieve with 1.0 × 1.0 mm mesh.

The rice husks (*Oryza Sativa* L.) were obtained from a rice processing mill. First, the material was cleaned and selected. Then, the husks were processed in hammer mill using a sieve with 6.0-mm mesh. Afterwards, the fines were removed by a sieve with 1.0 × 1.0 mm mesh. Yet, the bamboo culms (*Bambusa vulgaris* Schr.) were obtained in clumps of nearly four years of age. They were cut at 2 m above ground level and, then, cut in longitudinal direction and immersed into water so as to increase its internal face exposition, to remove part of the starch and to facilitate its grinding process<sup>9</sup>. The culms were grinded by a hammer mill coupled with a 6.0-mm diameter mesh sieve. After drying in oven at 60°C temperature, this material was sieved in 1.0 × 1.0 mm mesh, aiming at better selecting the material and removing the fines.

### 2.2. Particleboards manufacturing

The wood, rice husks and bamboo particles selected were conditioned in oven at 60°C during 24 hours, where they reached equilibrium moisture content of nearly 3%. They were used separately or combined in different proportions (Table 1). In all cases, it was used the urea-formaldehyde adhesive (350 cP viscosity and 65% content of solids) in the proportion of 8% of the particles dry mass. It was still added 1% of paraffin in the same conditions. The particle mass of the particleboards (pure or combined) was represented by 91% of the manufactured particleboard mass loss. The adhesive and the paraffin were added to the particles mass through a pistol triggered by air compressor in a rotating roller.

**Table 1.** Proportion of particle type for each treatment.

Treatment	Proportion		
	Wood	Bamboo	Rice husk
W	100	-	-
B	-	100	-
R	-	-	100
WB	50	50	-
WR	-	50	50

W = wood particles; B = bamboo particles; R = rice husk particles.

Afterwards, the mass of particles with adhesive and paraffin was taken to a wooden mould with 50 cm × 50 cm × 20 cm, where it was manually pressed. Then, the definitive pressing was carried out in hydraulic press, at 180°C temperature and 3.0 N/mm<sup>2</sup> pressure. The shutdown period of the press was 40 seconds, and 8 minutes was the total pressing period necessary to promote water evaporation and adhesive solidification. Overall, 30 particleboards were produced (six per treatment), all with pre-established nominal specific mass of 0.65 g/cm<sup>3</sup> and dimensions of 50 cm × 50 cm × 0.95 cm.

### 2.3. Assays performed and analyses of the results

In order to evaluate the properties of the particleboards produced, physical (density; moisture content; water absorption and thickness swelling) and mechanical (static bending; internal bonding and screw withdrawal) assays were carried, according to the American Society for Testing and Materials – ASTM D 1037<sup>12</sup> standard. The average values observed for the physical-mechanical properties were compared with the minimum required by the norm of the American National Standards Institute – ANSI 208.1<sup>13</sup>. For all cases, the data obtained was assessed through analysis of variance with further comparison of means by Student's T test ( $p < 0.05$ ).

## 3. Results and Discussion

### 3.1. Physical properties

The data obtained for specific mass and equilibrium moisture content of the particleboards for the different treatments evaluated did not differ statistically. In respect of specific mass, the mean values obtained for the treatments varied from 0.63 g/cm<sup>3</sup> to 0.69 g/cm<sup>3</sup>. Moisture content verified varied from 8.29% to 8.75%. This low variation enables greater reliability with regard to the other results obtained, as moisture and specific mass, especially, influence significantly the physical-mechanical properties of the particleboards<sup>14</sup>.

With respect to water absorption, it was observed that after the 2-hour and 24-hour period post-immersion, particleboards manufactured exclusively with alternative particles (B and R) or through their mixture with wood particles (WB and WR) showed increase in percentages of water absorption (Figure 1). Similar results were observed by Melo et al.<sup>3</sup> and Calegari et al.<sup>9</sup>. According to these

authors the highest percentages of water absorption for these particleboards can be related to the high content of silica (R) and to the lower content of lignin (B) present in these materials. Such components interfere with the particles' adhesion and gluing processes, such as silica, or with the increase on the proportion of celluloses and polyoses chemical constituents with hydrophilic behavior, such as lignin.

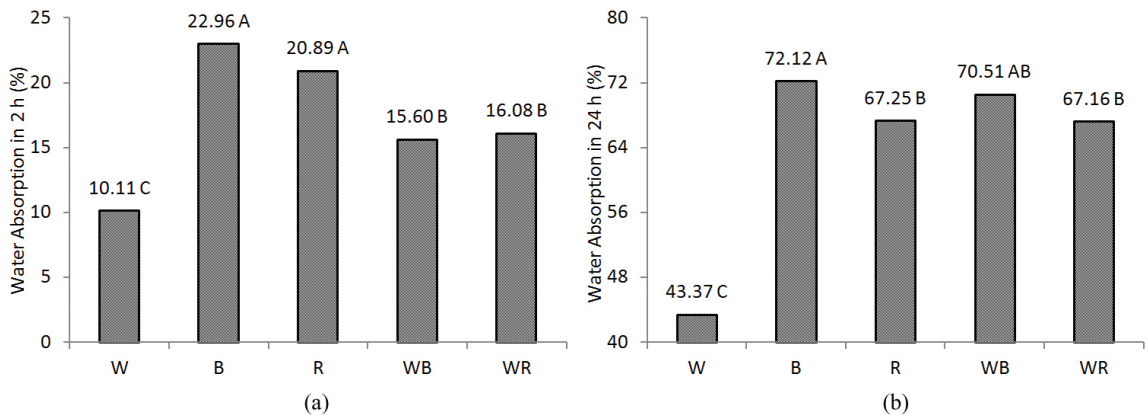
Regarding thickness swelling (Figure 2), the highest instability was verified for particleboards that only used rice husk (R), or for those wherein these were mixed with wood (WR). The particleboards which used bamboo (B and WB) presented loss of early stability, i.e. higher thickness swelling – after 2-hour immersion; however, when the swelling of the samples after 24 hours is considered, these particleboards showed similar performance compared to those only with wood particles (W). The percentages of thickness swelling observed for W, B and WB particleboards fulfilled the ANSI 208.1<sup>13</sup> requirements for commercialization, which accepts absorption percentages of up to 35% at 24-hour after immersion. The good performance of particleboards manufactured with bamboo, with respect to its dimensional stability, was also observed by Hiziroglu et al.<sup>11</sup>. The same authors also evinced that particleboards produced with rice straw showed high water absorption and thickness swelling,

which significantly reduced when the particleboards were mixed with wood in the same proportion.

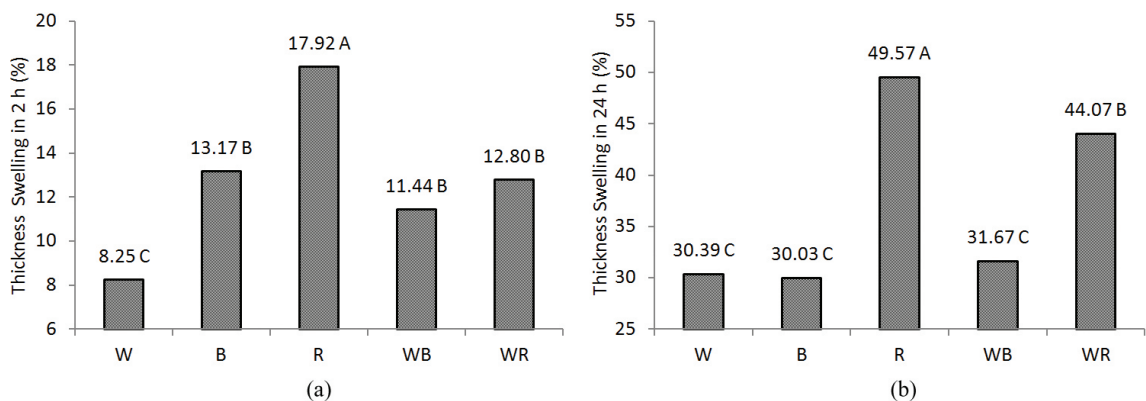
### 3.2. Mechanical properties

The use of R particles indicated a reduction in rigidity ( $E_M$ ) and resistance ( $f_M$ ) to static bending (Figure 3). Other researchers, such as Ajiwe et al.<sup>5</sup>, Han et al.<sup>15</sup>, Lee and Kang<sup>16</sup>, Ndazi et al.<sup>4</sup> and Melo et al.<sup>3</sup>, also obtained similar results, wherein the rise in the proportion of rice husk in particleboards caused a decrease in resistance and rigidity parameters of these materials. Similarly, the use of rice straw for panel manufacturing, as verified by Hiziroglu et al.<sup>11</sup>, also presented results similar to this study.

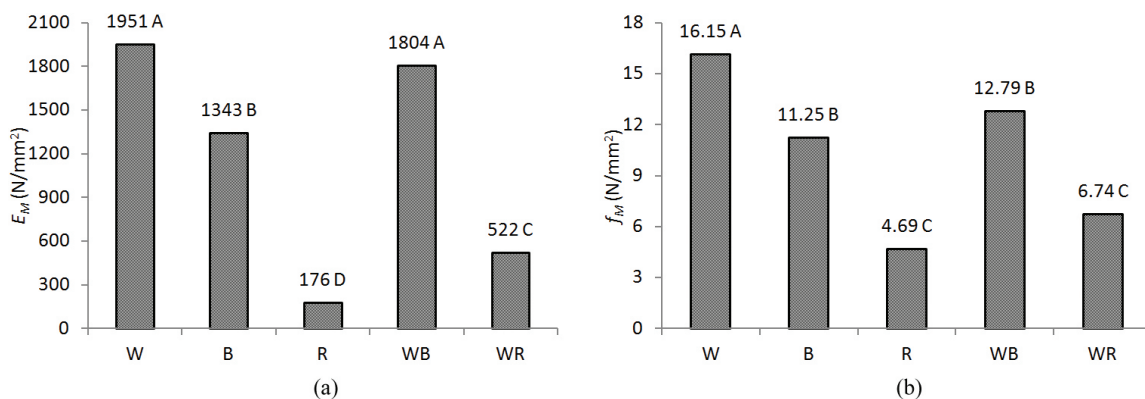
With respect to the particleboards which used B particles, even though they have presented lower  $E_M$  and  $f_M$  than the particleboards which exclusively used W particles, their influence on the performance of the particleboards was less damaging than those using R particles. Regarding  $EM$ , it was observed statistically similar results between W and WB particleboards. The good performance of bamboo particles in particleboards was also observed by Lee et al.<sup>17,18</sup>, Xu et al.<sup>19</sup>, Hiziroglu et al.<sup>11</sup> and Calegari et al.<sup>9</sup>. The minimum values standardized by ANSI A 208.1<sup>13</sup> for medium density particleboards (0.60 g/cm<sup>3</sup> to 0.85 g/cm<sup>3</sup>)



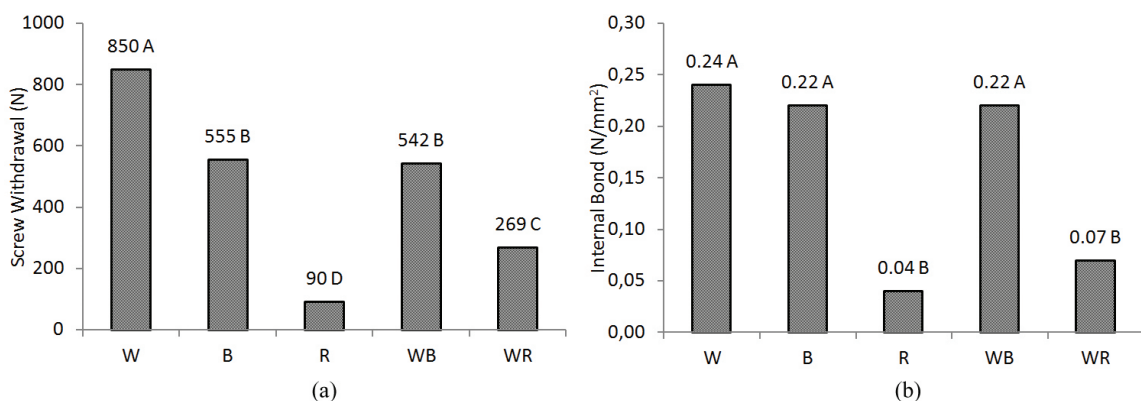
**Figure 1.** Water absorption in 2 and 24 hours of the panels. W = wood particles; B = bamboo particles; R = rice husk particles.



**Figure 2.** Thickness swelling in 2 and 24 hours of the panels. W = wood particles; B = bamboo particles; R = rice husk particles.



**Figure 3.** Results of the static bending tests. W = wood particles; B = bamboo particles; R = rice husk particles.



**Figure 4.** Results of the screw withdrawal and internal bond tests. W = wood particles; B = bamboo particles; R = rice husk particles.

are 1760 N/mm<sup>2</sup> for  $E_M$  and 11 N/mm<sup>2</sup> for  $f_M$ , which were reached by the W and WB particleboards.

The assessed particleboards presented significant difference when resistance to screw withdrawal was evaluated (Figure 4). The highest resistance was observed for samples using W particles, followed by those with B and WB particles. The lowest resistance to screw withdrawal was observed for particleboards produced with R and WR particles. Similar results were found by Calegari et al.<sup>9</sup> for bamboo-wood particleboards and by Melo et al.<sup>3</sup> for wood-rice husk particleboards.

Within the properties evaluated in the present work, internal bonding is one of the most important for the qualitative characterization of the particleboards. This parameter indicates how significant was the interaction performed between the particles and the adhesive used, and is directly related to all the other physical-mechanical properties evaluated in this study. Particleboards produced with W, B and WB particles presented similar values of resistance to bonding. The potential of bamboo use for particleboard manufacturing was also pointed by several studies<sup>8-11,20</sup>. Yet, for particleboards manufactured with R and WR particles, the internal bonding was substantially affected. The low values of internal bonding may be related to the cylindrical and hollow structure of the rice

husk particles, which may have acted as a barrier during resin application<sup>3</sup>. Another probable influence is the low permeability mentioned by Youngquist et al.<sup>2</sup>, which may have interfered on the particles' gluing. Lee and Kang<sup>16</sup> also observed that the use of rice husk particles in particleboards promoted great reduction in their physical and mechanical resistance properties. However, its increase in small concentrations, up to 10%, likewise observed by Melo et al.<sup>3</sup>, may not present any significant impact on the particleboards' properties.

The minimum values required by ANSI A 208.1<sup>13</sup> standard for resistance to screw withdrawal and internal bonding for the types of particleboards studied are nearly 1,000 N and 0.40 N/mm<sup>2</sup>, respectively. None of the treatments evaluated managed to fulfill the requirements established by these parameters.

#### 4. Conclusions

The use of bamboo particles was proved as promising for the production of particleboards, not only for those made exclusively with bamboo particles, but also through the combination with wood particles. In certain cases, it was observed similar results obtained by these compared to particleboards manufactured exclusively with wood particles. The bamboo particles has potential for this purpose, with the

possibility of adjustment of some production parameters for reaching performance equivalent to wood panel.

Rice husk particles presented restrictions for utilization in particleboard manufacturing, once their use, isolated or combined with wood particles, provided major reduction in the physical-mechanical properties of the particleboards.

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