

Relation of Transverse Air Permeability with Physical Properties in Different Compositions of Sugarcane Bagasse Particleboards

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Studies concerning the production of particleboards with sugarcane bagasse as an alternative fibrous material have been carried out as an attempt to provide a sustainable and viable destination for this residue. This work aimed to evaluate the influence of several processing variables related to the microstructure of sugarcane bagasse particleboards (mat type, adhesive type and adhesive content) on their permeability and water sorption properties. Air permeability data was collected by the rotameter method. Superficial air permeability (k_g), Darcian constant (k_d) and non-Darcian constant (k_2) were measured. k_g was related to sorption behavior of the particleboards. 1-layer particleboards presented significantly higher k_g values than the 3-layer particleboards. In general, adhesive type, position and content did not influence k_g of particleboards. However, these processing variables influenced interactions between fluid and material and tortuosity of the porous media. Particleboards produced with urea-formaldehyde with high k_g presented higher water absorption and thickness swelling after 24 hours. Such relations were not observed in particleboards produced with melamine-urea-formaldehyde.

Keywords: *air permeability, sugarcane bagasse, water absorption, thickness swelling, mat*

1. Introduction

The large amount of wood consumption could mean a high worldwide deforestation rate that can cause environmental impacts. This context leads to introduction of new composites with enhanced properties, such as particleboards, oriented strand boards, plywoods, and hardboards. These products are currently known as suitable engineering materials for building and construction¹⁻³.

Non-wood lignocellulosic biomass such as grass, straw and agricultural residues present great potential for panels manufacturing, including particleboards^{4,3}. Sugarcane bagasse is considered among agricultural residues the most promising substitute for wood in particleboard production due to its anatomical and chemical characteristics⁵. This lignocellulosic residue is produced in large amounts by sugar crushing and extraction, hence its disposal on sugar industries may cause economic and environmental problems⁶⁻⁸. Transforming this waste in bagasse particleboards may contribute to sustainability and provide an interesting solution for value aggregation⁹.

Several researchers^{5,7,9-12} have been carrying out concerning production of particleboards and fiberboards with sugarcane bagasse as an alternative raw material. Some of them reported that sugarcane particleboards present high water absorption and poor dimensional stability, which may be influenced by the raw material and processing variables

such as adhesive type and content^{9,11}. Panels made from lignocellulosic residues adsorb or desorb moisture according to the changes in environmental temperature and humidity. This dimensional instability may interfere in the quality of the product in service¹³.

Permeability describes how easy fluids are transported throughout the structure of a porous solid material under pressure gradient¹⁴. This physical property is extremely important to the development of durable materials, since it can be associated with their structural properties and resistance to penetration of environmental degradation agents¹⁵. Permeability strongly depends on the microstructure of materials, which is affected by processing variables¹⁶. Some researchers have studied the permeability of particleboard mats with the aim to analyze the rate of convective heat transference to the panel core for adhesive curing during pressing¹⁷⁻²⁰.

To our knowledge, there is a lack of information in the literature about the influence of air permeability on water absorption and thickness swelling of post-pressed particleboards. For this reason, this work aimed to evaluate the influence of several processing variables related to the microstructure of particleboards (mat type, adhesive type, adhesive position and adhesive content) on the permeability and water resistance properties of laboratorial and commercial sugarcane particleboards.

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2. Material and Methods

2.1. Raw materials

Sugarcane bagasse obtained from Monte Alegre alcohol refinery (Minas Gerais state, Brazil), urea-formaldehyde (UF - solid content of 52 wt. (%)) and melamine-urea-formaldehyde (MUF - solid content of 54 wt. (%)) adhesives were used for manufacturing the laboratorial particleboards. The wax emulsion was applied at 1 wt. (%) as water repellent during particleboard production.

2.2. Particleboard production

Sliver particles were produced in a hammer mill using sieves with openings of 6.14 and 1.72 mm for core and surface layers of the panels, respectively. The material was dried to 3 wt. (%) moisture content at 60 ± 5 °C before particleboard manufacturing. The effects of mat type (1-layer and 3-layer), adhesive types (UF, MUF, UF/MUF/UF mixture and MUF/UF/MUF mixture) and adhesive contents (9 and 12 wt. (%)) for both surface and middle layers were evaluated. In addition, commercial sugarcane bagasse particleboards produced in China were used for comparison. The experimental design for the particleboards is summarized in Table 1.

The boards were manufactured similarly to the procedures described by Barros Filho et al.⁹. Particles were put in a blender where the adhesives and wax emulsion were applied by an air spray gun. The material was molded in a mat-forming box (48 × 48 cm) and a manual press machine was used to perform a pre-pressing at 0.78 MPa. The mat was then submitted to hydraulic press and the boards were made by using 8 min of pressing under 3.92 MPa and a temperature of 150 °C. 3-layer particleboards were produced with smaller particles on the surface and larger particles in the core. The proportion was 20/60/20% for surface/core/surface of the particleboard mass. 1-layer particleboards were produced with larger particles. The target apparent density of 0.700 g.cm⁻³ and nominal thickness of 15 mm were held constant for all particleboards. Four laboratorial particleboards were produced for each mix design.

Four commercial particleboards were reduced to the final nominal dimension of 48 × 48 cm. They presented the same thickness of laboratorial particleboards.

All the boards were conditioned at 20 ± 2 °C and $60 \pm 3\%$ RH during about 25 days, leading to a final moisture content of about 10%.

2.3. Air permeability test

Figure 1 depicts the sampling scheme for obtainment of specimens for the permeability test. Four 2.0 × 2.0 × 1.5 cm specimens were extracted from each particleboard.

Since air permeability was evaluated in transversal direction, the specimen's edges, which were not under evaluation, were sealed with structural epoxy based fluid adhesive previously prepared by the mixture of A (epoxy resin) and B components (polyamine-amid) at a proportion of 1:1.5. After 7 days of epoxy curing, the material was once more stabilized in an acclimatizing room (20 ± 2 °C and $65 \pm 3\%$ RH). The specimen's edges were then covered using a 2.5 cm-long piece of rubber tube with diameter of 2.5 cm.

The air permeability of each sample was measured according to the rotameter method, which uses atmospheric air as a fluid. The transverse air permeability at room temperature (25-30 °C) of each sample was measured in an apparatus adapted from Silva et al.²¹ and Siau¹⁴,

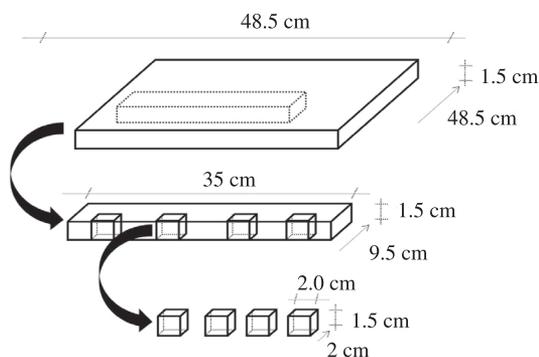


Figure 1. Sampling scheme for obtainment of the specimens for air permeability tests.

Table 1. Descriptors of the particleboards.

Particleboards	Adhesive		Mat
	Type	Content (wt. (%))	
UF9-1L	UF ¹	9	1-layer
MUF9-1L	MUF ²		
UF9-3L	UF	9	3-layer
MUF9-3L	MUF		
MUF/UF9-3L	MUF/UF/MUF	12S/9C/12S ³	
UF/MUF9-3L	UF/MUF/UF		
UF12/9-3L	UF	9S/12C/9S	
MUF12/9-3L	MUF		
UF9/12-3L	UF	9S/12C/9S	
MUF9/12-3L	MUF		

Commercial sugarcane particleboards

¹UF: urea-formaldehyde; ²MUF: melamine-urea-formaldehyde; ³S/C/S: surface/core/surface of 20/60/20% of the particleboard mass.

as presented in Figure 2. The apparatus consisted of two molded 0.02 m size PVC tubes, which allow fitting $2.0 \times 2.0 \times 1.5$ cm rectangular specimens between them. The tubes were positioned on a wooden platform. One of them was connected to a vacuum pump and the other to three flowmeters which measure the following air flow ranges: 2.8×10^{-6} to 27.8×10^{-6} m³/s⁻¹, 2.8×10^{-6} to 50×10^{-6} m³/s⁻¹ and 27.8×10^{-6} to 305.5×10^{-6} m³/s⁻¹. The specimens were positioned between the PVC tubes and hot glue was applied to prevent air leakage. The air permeability was determined by turning on the vacuum pump to force the air flow through the specimen surfaces. The values obtained were the pressure made by the pump and the air flow rate given by each flowmeter.

The atmospheric pressure value used was 9239.3 Pa. The flow time considered for all specimens was 1 minute, due to the instantaneous stabilization of the flowmeters. The transverse superficial air permeability was determined by the Equation 1⁴:

$$kg = \frac{QLP}{A\Delta P P m} \quad (1)$$

where, kg is the superficial air permeability (m³.m⁻¹.s⁻¹.Pa⁻¹), Q is the volumetric flow range (m³/s⁻¹), L is the specimen thickness (m), P is the pressure during the flow rate measurement (Pa), A is the transversal area of the sample perpendicular to the flow direction (m²), Pm is the average pressure in the specimen (Pa).

The experimental data was also adjusted in order to determine the permeability constants k_1 (Darcian constant) and k_2 (non-Darcian constant), which represent respectively the viscous effect of the shearing (friction and interactions between fluid and porous media) and the tortuosity of the porous media when the shearing velocity is high²². The higher the k_1 and k_2 values, the higher the permeability of the porous media. The permeability constants k_1 and k_2 were obtained by fitting the experimental data using Forchheimer's equation (Equation 2), expressed for flow of compressible fluids as showed by Inocentini et al²³:

$$\frac{P_{atm}^2 - P^2}{2Pl} = \left(\frac{\mu}{K1}\right)VS + \left(\frac{\rho}{K1}\right)VS^2 \quad (2)$$

where P_{atm} and P are the absolute inlet and outlet air pressures (Pa) which correspond to the atmospheric pressure and to the pressure during the flow rate measurement respectively; VS is the fluid velocity (m/s⁻¹); L is the sample thickness (m); μ is the fluid viscosity (air viscosity $\sim 1.8 \times 10^{-5}$ Pa.s); and ρ is the fluid density (air density ~ 1.08 kg.m⁻³).

2.4. Tests for water absorption and thickness swelling

The following physical properties were determined according to ASTM D1037-100²⁴ procedures: apparent density, water absorption and thickness swelling after 2 and 24 hours water immersion. Two specimens of each particleboard were used for physical tests.

2.5. Data analysis

The experimental design was entirely randomized. Eleven laboratorial particleboards, each one with four repetitions, were compared. The apparent density and kg data were submitted to the analysis of variance and the particleboards were compared by Scott-Knott test at 5% of significance. The permeability of 1-layer particleboards and 3-layer particleboards were compared by statistical contrast. The relation of kg with k_1 , k_2 and dimensional stability of particleboards was also analyzed. The statistical software SISVAR was used to perform the analysis. The relation of kg with k_1 , k_2 and dimensional stability of particleboards was analyzed.

3. Results and Discussion

The averages of measured apparent density in the laboratorial boards ranged from 0.63 to 0.66 g.cm⁻³. Commercial sugarcane particleboards (C1) presented significantly higher apparent density (0.71 g.cm⁻³) than laboratorial particleboards.

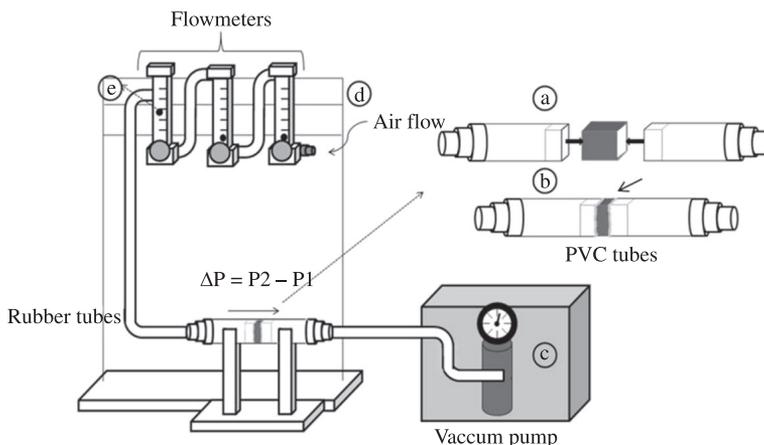


Figure 2. General view of the air permeability measurement apparatus. a) specimen positioned between the PVC tubes; b) hot glue application (arrow); c) vacuum pump; d) air flow entrance; and e) air flow measurement.

The average values and standard deviation of superficial air permeability (kg) of particleboards are given in Figure 3. The average values ranged from 0.15×10^{-10} to $1.16 \times 10^{-10} \text{ m}^3 \cdot \text{m}^{-1} \cdot \text{s}^{-1} \cdot \text{Pa}^{-1}$. Similar permeability measurements have been reported in the literature only for wood and cold pressed wood particle mats. Values ranging from 6380×10^{-10} and $84.1 \times 10^{-10} \text{ m}^3 \cdot \text{m}^{-1} \cdot \text{s}^{-1} \cdot \text{Pa}^{-1}$ were obtained for pine and eucalyptus woods, respectively²¹, through the same methodology applied in this work. Hata¹⁷ presented a permeability of $4.11 \times 10^{-8} \text{ m}^3 \cdot \text{m}^{-1} \cdot \text{s}^{-1} \cdot \text{Pa}$ for wood particleboards produced with density of $0.3 \text{ g} \cdot \text{cm}^{-3}$. Denser particleboards of $0.600 \text{ g} \cdot \text{cm}^{-3}$ were found completely impermeable. The lowest average permeability obtained by Hood²⁵ for oriented strand boards (OSB) mats was $7.8 \times 10^{-8} \text{ m}^3 \cdot \text{m}^{-1} \cdot \text{s}^{-1} \cdot \text{Pa}$. The higher results may be attributed to the lack of density profile in the cold-pressed mats analyzed without adhesive.

Commercial sugarcane particleboards showed significantly (p -value < 0.05) higher apparent density and lower kg than laboratorial particleboards. Particleboards with higher density had lower permeability because the resistance against air flow in the mats increases with the decrease of voids^{17,20}.

1-layer particleboards presented superficial kg values statistically superior (p -value < 0.05) to those from 3-layer particleboards, except for MUF/UF9-3L particleboards.

The contrast between the average values was significant and showed that the permeability of 1-layer particleboards is $0.04 \times 10^{-10} \text{ m}^3 \cdot \text{m}^{-1} \cdot \text{s}^{-1} \cdot \text{Pa}^{-1}$ higher than the permeability of 3-layer particleboards. This is mainly attributed to the larger particles in the surface of 1-layer boards, which create larger voids among themselves when compared to the smaller particles used in 3-layer particleboards. Shang et al.²⁶ found similar results for wood particle aggregates in which permeability increased with the increase of wood particle size from 3 mm to above 30 mm.

Moreover, the surfaces composed by smaller particles presented a higher superficial area resulting in a longer air-flow pathway. This increases the lack of interconnection between the voids and consequently decreases the superficial permeability of the boards²⁵. Since small particles comprise the surface of a 3-layer particleboard, a higher number of particles is required and an increased tortuosity of the porous media may occur, as discussed below.

In general, type, position and content of adhesives did not influence kg of the particleboards, since no significant differences (p -value > 0.05) were observed between permeability values of most 3-layer particleboards. However, these processing variables seemed to affect interactions between fluid (air), and material, besides tortuosity of the porous media. The relation between superficial air permeability (kg) and k_1 and k_2 constants is shown in Figure 4.

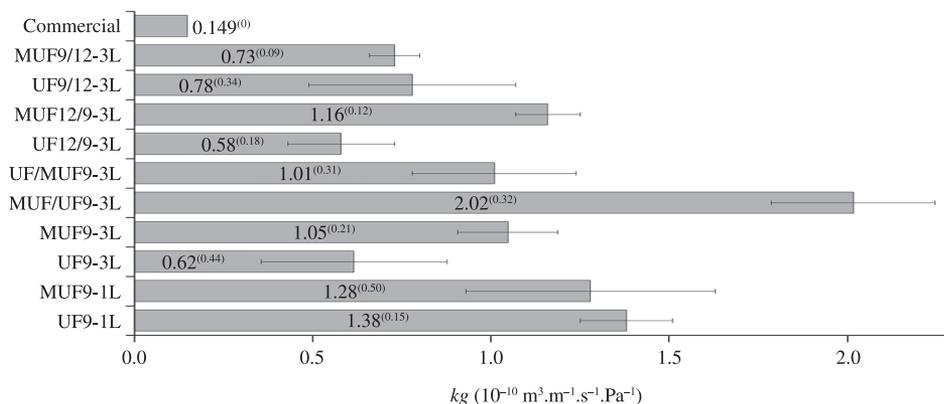


Figure 3. Average and standard deviation values of superficial air permeability (kg).

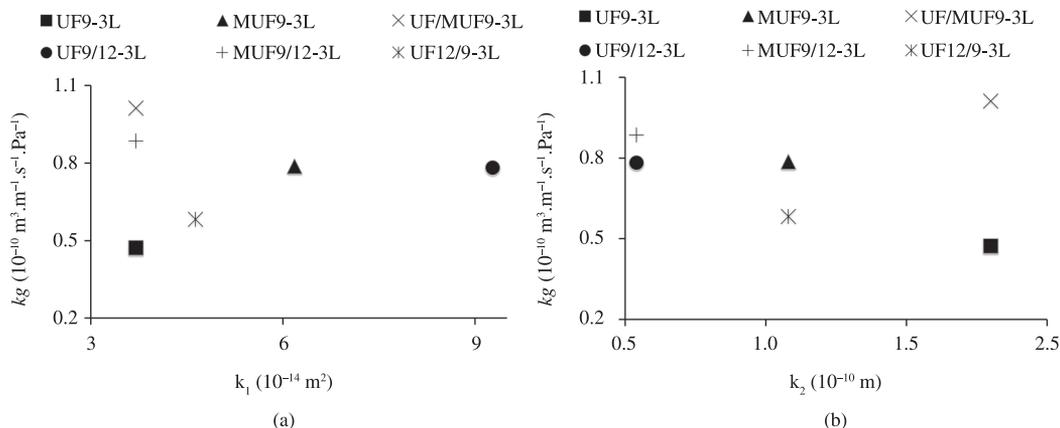


Figure 4. Relation between superficial air permeability, kg , and (a) Darcian constant, k_1 , and (b) non-Darcian constant, k_2 .

Some of the permeability data of particleboards did not allow the adjustment of polynomial model, which is necessary for k_1 and k_2 constants calculation. Experimental measurements of permeability may be difficult to be implemented on materials with high porosity such as fiber-based boards¹⁶.

The decrease of k_1 indicates that friction and interactions between fluid and porous media increased. The increase of k_2 can signify the diminution of porous media tortuosity due to reduction of capillary forces¹⁵. For 3-layer and MUF/UF-3L particleboards it was not possible to calculate k_1 and k_2 constants due to the high permeability of these panels. The same occurred for commercial particleboards because only one sample presented permeability.

A comparison between UF9-3L and MUF9-3L indicates that the use of melamine-urea-formaldehyde increased superficial air permeability, decreased friction between air and particles, but increased tortuosity of the porous media. The results showed that a higher adhesive content (12%) in the surface of the panels caused the decrease of superficial air permeability (kg) due to increase in air friction, since UF12/9-3L particleboards presented lower kg and k_2 values in relation to UF9/12-3L particleboards. However, the lower k_1 was found for the formers. Particleboards made with two adhesive contents positioned in the different layers, UF9/12-3L and MUF9/12-3L, presented the same k_2 values and kg , but a much higher k_1 value was observed for the particleboards made with urea-formaldehyde.

Many samples (20%) were completely impermeable to air probably due to the lack of connection among voids in the porous structure of the particleboard samples. Only 3-layer and commercial particleboards provided completely impermeable specimens. Figure 5 illustrates possible pathways for air flow through the porous structure of 3-layer and 1-layer particleboards.

The impermeability of 3-layer particleboards may have happened due to three pathways of the air flow showed in Figure 5. The air flow reaches the whole surface of the specimen. Some voids allow only part of the air flow to enter into the sample and, once inside, part of the flow does not pass through the first layer, compounded by smaller particles, due to the lack of connection between the voids (red lines). Inside the core layer, part of the flow is limited by the smaller particles of second surface layer (green lines), where part of the flow is retained due to the lack of interconnection among the voids (yellow lines). In 1-layer particleboards, part of the air flow (blue lines) reaches the opposite surface and presents less tortuosity, increasing the values of kg for these samples.

Figure 6 shows the average values of water absorption after 2 hours and 24 hours of immersion in relation to kg values of the particleboards produced with urea-formaldehyde adhesive. The values ranged from 5 to 11% and from 24 to 42% for 2 hours and 24 hours of water immersion, respectively. The water absorption values observed in the present work are lower than those reported by Barros Filho et al.⁹ for similar particleboards produced with industrial sugarcane bagasse (WA_{2h} = 13.4% and WA_{24h} = 98.8%). However, the present results are similar to the average values found by Mendes et al.¹¹ for panels produced with sugarcane bagasse and urea-formaldehyde adhesive (WA_{2h} = 5% and WA_{24h} = 42%).

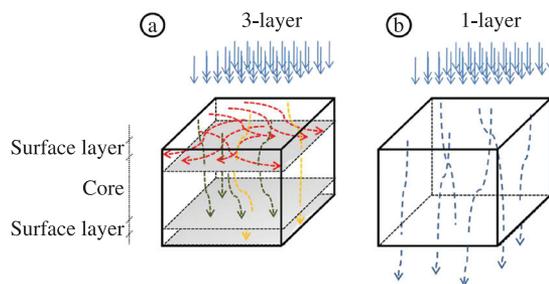


Figure 5. Illustrative scheme of possible pathways for air flow through the structure of a sample (with sides sealed) of particleboard. a) 3-layer particleboards; b) 1-layer particleboards. Red, green and yellow arrows indicate retained air flow, while blue arrows indicate continuous flow.

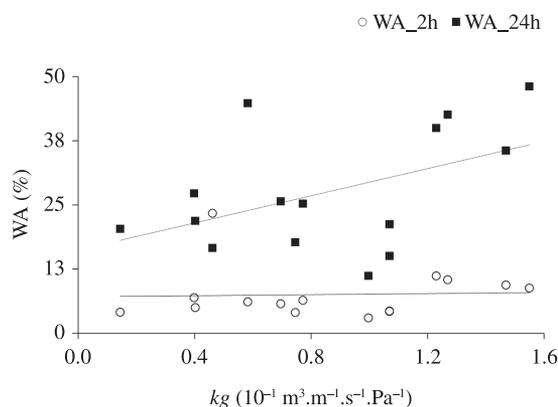


Figure 6. Superficial air permeability (kg) vs. water absorption (WA) after 2 hours and 24 hours for urea-formaldehyde particleboards.

After 2 hours of water immersion, no relation between water absorption and air permeability was observed. However, after 24 hours of water immersion, 1-layer particleboards produced with urea-formaldehyde, which presented higher kg values, also presented the highest water absorption value. A larger contact area provided by smaller particles in the surface should have allowed higher water absorption²⁷, but the opposite was observed in this work due to the decrease of voids which diminished water absorption⁵. The lower permeability of 3-layer particleboards may be ascribed to a physical barrier to gas and water entrance created by the smaller particles, since they present smaller voids and increased contact area²⁸.

Despite presenting the lowest air permeability among 3-layer particleboards produced with urea-formaldehyde, the UF9-3L particleboards presented higher water absorption after 24 hours water immersion than UF12/9-3L and MUF9/12-3L particleboards. Therefore, the lowest adhesive content (9%) used in both surface and core of the particleboards presented higher influence on water absorption than permeability to fluids.

Figure 7 shows the average values of thickness swelling after 2 hours and 24 hours of water immersion in function of kg for particleboards produced with urea-formaldehyde adhesive. Thickness swelling of the laboratorial sugarcane particleboards produced with urea-formaldehyde ranged

from 3% to 6% after 2 hours of water immersion and from 13% to 22% after 24 hours of immersion.

It was noticed in this research that all values of thickness swelling after 2 hours were lower than those found by Mendes et al.¹¹ for panels produced with sugarcane bagasse and urea formaldehyde as adhesive. However, the authors found lower thickness swelling after 24 hours of water immersion (TS_{2h} = 7.8% and TS_{24h} = 11.8%). Barros Filho et al.⁹ reported higher values for thickness swelling after 2 hours and 24 hours of water immersion than those found in the present work for similar particleboards (TS_{2h} = 7.6% and TS_{24h} = 18.1%).

No relation between thickness swelling and air permeability after 2 hours of water immersion was observed. However, after 24 hours of water immersion, particleboard swelling increased with increases in air permeability. 1-layer particleboards produced with larger particles presented the highest values for both 2 hours and 24 hours water absorption. The reduction of the specific surface of the particles with the increase in particle size resulted in lower water absorption and thickness swelling²⁹. On the other hand, the results showed that smaller particles in the surface might have decreased permeability and resulted in lower water absorption and thickness swelling. Large particles resulted in lower surface area available for bonding, weaker contact among the particles and higher voids in the microstructure of the particleboards. The same could be observed in the present work, which may indicate that not all large particles were well bonded by the adhesive, resulting in higher thickness swelling³⁰.

Considering the adhesive content, the UF9-3L particleboards (urea-formaldehyde at 9%) presented the highest water absorption and thickness swelling among 3-layer particleboards. UF12/9-3L particleboards presented lower thickness swelling than UF9/12-3L particleboards, which were produced with urea formaldehyde at 12% and 9%, respectively. In addition, UF9/12-3L particleboards presented higher kg.

Figures 8 and 9 showed average values of water absorption and thickness swelling (after 2 hours and 24 hours

of water immersion), respectively, in function of kg for particleboards produced with melamine-urea-formaldehyde adhesive. Water absorption values after 2 hours and 24 hours of immersion for sugarcane particleboards produced with melamine-urea-formaldehyde ranged from 5 to 8% and from 21 to 38%, respectively. Thickness swelling values varied from 2 to 3% after 2 hours and from 10 to 12% after 24 hours.

Average values of water absorption and thickness swelling for panels produced with melamine-urea-formaldehyde were inferior to those produced with urea-formaldehyde. Values of water absorption after 2 hours of water immersion were close to those reported by Barros Filho et al.⁹ for similar particleboards produced with industrial sugarcane bagasse. However, those authors found higher water absorption after 24 hours of immersion and higher thickness swelling after 2 and 24 hours of water immersion (WA_{2h} = 6.7%; WA_{24h} = 91.2%; TS_{2h} = 7.2%; TS_{24h} = 18.0%).

No relation between kg and water absorption or thickness swelling after 2 hours and 24 hours of water immersion was observed (Figure 9). 1-layer particleboards produced with melamine-urea-formaldehyde, which had higher kg, did not present higher values of water absorption and thickness swelling. Melamine-urea-formaldehyde

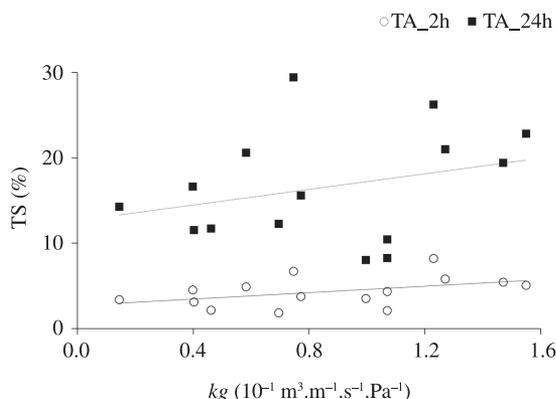


Figure 7. Superficial air permeability (*kg*) vs. thickness swelling (*TS*) after 2 hours and 24 hours for urea-formaldehyde particleboards.

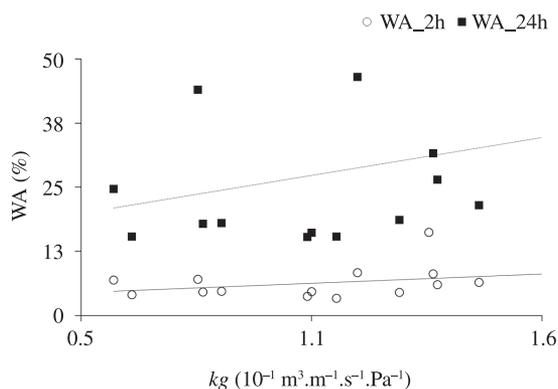


Figure 8. Superficial air permeability (*kg*) vs. water absorption (*WA*) after 2 hours and 24 hours for melamine-urea-formaldehyde particleboards.

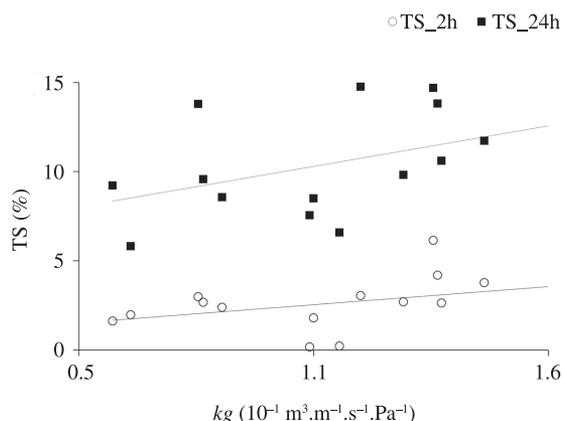


Figure 9. Superficial air permeability (*kg*) vs. thickness swelling (*TS*) after 2 hours and 24 hours for melamine-urea-formaldehyde particleboards.

Table 2. Physical properties of 3-layer particleboards produced with two adhesives mixtures and commercial particleboards.

Particleboard	Water absorption		Thickness swelling	
	2 hours (%)	24 hours (%)	2 hours (%)	24 hours (%)
MUF/UF9-3L	15 ^(6.48)	64 ^(15.25)	8.5 ^(2.77)	24.2 ^(4.36)
UF/MUF9-3L	9 ^(5.38)	35 ^(15.70)	4.2 ^(1.39)	15.6 ^(2.95)
Commercial	9 ^(0.24)	34 ^(12.97)	2.6 ^(0.64)	11.5 ^(2.18)

Standard deviation (%) between parentheses.

presents higher resistance to higher moisture contents than urea-formaldehyde³¹. Therefore, the adhesive's content and position in the mat were the main factors that affected the ease at which the particleboard absorbs fluids.

The physical properties of MUF/UF particleboards are presented in Table 2. Despite the higher moisture-resistance of melamine-urea-formaldehyde (MUF) adhesive and its position in the surface of panels, the MUF/UF9-3L particleboards presented higher values of thickness swelling and water absorption than UF/MUF9-3L particleboards. It is important to mention that MUF/UF9-3L particleboards presented the highest air permeability values among all particleboards studied. Therefore, in this case, a clear relation between high permeability and higher values for physical properties was observed.

The values of thickness swelling after 24 hours were compared with the values recommended by the EN 312-3³² standard for use in humid conditions (Type P3). The standard establishes that the thickness swelling after 24 hours must be lower than 14% for non load-bearing boards. Therefore, the use of both urea-formaldehyde and melamine-urea-formaldehyde in the composition of sugarcane particleboards is not recommended. 1-layer and 3-layer particleboards made with urea-formaldehyde at 9% in the surface and core layers (UF9-1L and UF9-3L) were not suitable.

Finally, most of the laboratorial particleboards presented higher water absorption and thickness swelling than commercial particleboards. In general UF9-1L and MUF/UF9-3L particleboards presented the highest k_g values and less appropriate physical properties.

4. Conclusions

Studies concerning the analysis of physical and mechanical properties of sugarcane particleboards are common in the literature, but there is a lack of information about their microstructure. The air permeability is a physical property of extreme importance to the development of durable fibrous cellulosic products and it strongly depends on their microstructure. The influences of mat type and adhesive type, position and content on superficial air permeability (k_g), Darcian constant (k_1) and non-Darcian constant (k_2) were investigated for sugarcane particleboards. k_g was related to k_1 , k_2 , and water sorption resistance of the particleboards. The following conclusions were obtained:

- 1-layer particleboards presented higher superficial air permeability (k_g) than 3-layer particleboards, which surface is made of smaller particles;
- In general, type, position and content of adhesives did not influence superficial air permeability (k_g) of particleboards. However, these processing variables caused impact on the interactions between fluid and porous media and on the tortuosity of the porous media (k_1 and k_2);
- No relation between sorption characteristics and superficial air permeability (k_g) after 2 hours of water immersion for particleboards produced with urea-formaldehyde was detected. However, after 24 hours water immersion, particleboard swelling and absorption increased as air permeability increased. Such relations were not observed for particleboards produced with melamine-urea-formaldehyde; and
- Under physical tests, most of the panel compositions used complied with the European Committee for non load-bearing boards, while the use of both urea-formaldehyde and melamine-urea-formaldehyde in 3-layer mats is not recommended for sugarcane particleboard production due to the high k_g values and water uptake observed.

Further studies are needed in order to establish a relation between the permeability and some measurable geometric quantities (e.g., porosity, tortuosity, pore size distribution, connectivity and specific surface). X-ray tomography and morphological 3D image may be useful tools for such characterizations. Regarding water resistance, the information provided in this work shows that industry should produce sugarcane bagasse particleboards with low air permeability. However, future investigations must be carried out to verify the influence of air permeability on packaging quality of particleboards, as well as on their thermal and acoustic insulation.

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