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PROPERTIES OF PARTICLEBOARDS SUBMITTED TO HEAT TREATMENTS

PROPRIEDADES DE PAINÉIS AGLOMERADOS SUBMETIDOS AO TRATAMENTO TÉRMICO

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ABSTRACT

The particleboards are the most consumed in the world, where much of the demand is associated to furniture sector. This study aims to assess the heat treatment effect on particleboard panels. The experiment consisted of four treatments and the control sample, evaluating temperatures of 160°C and 180°C for six and twelve minutes. Commercial particleboard panels were produced with particles of *Eucalyptus* sp. and urea-formaldehyde synthetic resin. Samples for physical testing (water absorption, and thickness swelling) and mechanical (static bending strength and screw withdrawal strength) were taken from these panels. For physical properties, the assessed heat treatments influenced significantly the water absorption of the panels after 24 hours of immersion. The treatment that utilized temperature of 180°C for six minutes provided the best performance. Concerning to the mechanical properties, the evaluated treatments had non-significantly influence in the panels strength.
Keywords: wood panels; thermal rectification; wood technology.

RESUMO

Os painéis aglomerados são os mais consumidos no mundo, sendo que grande parte da demanda destes painéis está associada ao setor moveleiro. O presente estudo teve como objetivo avaliar o efeito do tratamento térmico em painéis aglomerados. O experimento consistiu de quatro tratamentos mais a testemunha, avaliando as temperaturas de 160 e 180°C por períodos de seis e doze minutos. Foram utilizados painéis aglomerados comerciais produzidos com partículas de *Eucalyptus* sp. e, resina sintética ureia-formaldeído. Destes painéis foram retiradas amostras para os ensaios físicos (absorção de água e inchamento em espessura) e mecânicos (resistência à flexão estática e resistência ao arrancamento de parafuso). Para as propriedades físicas, os tratamentos térmicos avaliados influenciaram significativamente a absorção de água dos painéis após 24 horas de imersão. O tratamento que utilizou a temperatura de 180°C por seis minutos foi o que proporcionou o melhor desempenho. Já para as propriedades mecânicas, os tratamentos avaliados não influenciaram significativamente a resistência dos painéis.
Palavras-chave: painéis de madeira; termorretificação; tecnologia da madeira.

INTRODUTION

The wood and its derivatives products can take on and give off water to balance out with the environment due a porous structure and capillarity phenomenon. As a result, there are dimensional and

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constitution variations, which interfere in a physical-mechanical properties of the wood. Due these features, the wood is a hygroscopic material, causing changes in the equilibrium moisture content levels with the environment relative humidity. This may be explained by its chemical composition, which is formed basically by cellulose, hemicellulose and lignin polymers, being the hemicellulose the most hydrophilic one, therefore, which most contributes to dimensional changes.

The wood panel dimensions increase by absorbing water, a phenomenon known as swelling. Such dimensional variations are related to many factors, as the quality of raw material, adhesive type and additive content. The volume increases (wood swelling), occur mainly due the inclusion of water molecules in submicroscopic spaces located between the microfibrils. On the other hand, the volume reduction is explained by the water molecules output, causing the approximation of the micelles and the wood retraction (MELO et al., 2013). The particleboard panels composite of various shape and sizes of wood particles bonded with a synthetic adhesive and consolidated under pressure and heat (FREIRE et al., 2011). It is one of the most consumed panels in the world, mainly used in furniture manufacturing. However, the particleboard panel has a low dimensional stability due to the material compression requirement in the production process, which implies the incorporation and maintenance of a high stress levels after panel consolidation. Thus, when the panels are in contact with water, these compressive stresses are released, causing thickness swelling. Thus, it is required an improvement and development of new techniques to minimize these effects.

Del Menezzi and Tomaselli (2005), highlight many types of treatments, which may be utilized to improve the wood dimensional stability and the wood composites, among these, the heat treatment is highlighted. The authors emphasize that the use of heat is the most utilized method in Europe to improve the dimensional stability. Unsal et al. (2006), showed that temperatures above 200°C improve the dimensional stability of particleboard. Boonstra et al. (2006), showed that heat treatment with temperatures below 200ºC has a potential to improve the dimensional stability of wood panels. However, Sekino et al. (2005), reported a significant reduction of the bond strength of particleboard in this range temperature.

Carvalho et al. (2015) evaluated the effect of post-production heat treatment on particleboard. showing that only heat treatment conducted at 260°C for a period of 12 min promoted significant reductions in all the properties evaluated – providing greater stability and lower strength. Wandscheer et al. (2016) concluded that the physical and mechanical properties of medium density fiberboard (MDF) panels were not altered by treatment at 160ºC and 180º for six and twelve minutes. Thus, the heat treatment of wood panels appears as a technique that may be utilized to improve the wood panel quality. Then, the aim of this study was assess the heat treatment effect on physical-mechanical properties of particleboard panels.

MATERIALS AND METHODS

Raw materials and evaluated treatments

Five particleboard panels were obtained from the local market with commercial dimensions of 160 cm x 280 cm x 1.5 cm, with *Eucalyptus* sp. as raw material and urea-formaldehyde synthetic resin. Twenty-five samples were utilized for tests with 42 cm x 42 cm x 1.5 cm, composing a unit.

The samples were randomly selected in groups of five, to compose different heat treatments. The panel was maintained on the forced air circulation oven, where the heat treatments were performed. The treatments were performed in temperatures of 160°C and 180°C for six and twelve minutes as expressed in Table 1.

Physical test was performed for heat treated samples and not heat treated samples (moisture content; density; water absorption; thickness swelling, hygroscopic swelling and not return rate in thickness) and mechanical (static bending strength and screw withdrawal strengths), utilizing the American Society for Testing and Materials - ASTM D 1037 (2012) standard. After treatment, the samples for physical test were reduced in 15 x 15 x 1.5 cm of width, length and thickness, and 42 x 7.5 x 1.5 cm were maintained for mechanical test.

TABLE 1: Evaluated heat treatments for particleboards.
TABELA 1: Tratamentos térmicos avaliados para os painéis aglomerados.

Treatments Identification	Time (minutes)	Temperature (ºC)	Number of Panels
0-0 (Control)	-	-	5
6-160	6	160	5
6-180	6	180	5
12-160	12	160	5
12-180	12	180	5

Physical properties

The dimensions and weight at equilibrium moisture content of the samples were performed before heat treatment, and the dimensions and weight were performed again after treatment. These data were utilized to calculate the apparent density (ρ) and the equilibrium moisture content (EMC) of each sample.

Sample weights were measured with an analytical equilibrium of 0.01g accuracy to determine water absorption (WA) and thickness swelling (TS). Dimensions were measured with a dial indicator for thickness, and a digital caliper was utilized for width and length with an accuracy of 0.01 mm, before and after immersion in water for 2 hours and for 24 hours.

The samples were submitted to acclimated process for two months and their dimensions and weights were performed again for residual swelling determination and hygroscopic swelling, after water immersion tests.

Mechanical properties

The tests were performed in a universal testing machine with a 30-ton load capacity, for static bending strength diagnosis. The gap between the supports was 24 times the thickness (1.5 cm) and the load application speed was approximately 5 mm/min (ASTM D - 1037, 2012). The elasticity modulus and the rupture Modulus of the panels for each treatment were determined from this test.

The assessment of screw withdrawal strength was performed with the same test-bodies utilized for static bending tests. After samples ruptures, the two resulted sides were bonded on each another, which generated a new sample with 21 x 7.5 x 3.0 cm, length, width and thickness.

The produced samples got a hole along the thickness by using a power drill with a 3.2 mm drill. This hole received screws with 3.5 mm diameter, 2.54 cm length and 16 screws threads/inch, which were introduced up to 2/3 of its length. Subsequently, tests were performed in the universal testing machine, where it was obtained the maximum strength to screw withdrawals, using the approximate speed of 3 mm/min.

Data analysis

The results obtained for the parameters: density (before and after treatment), water absorption (at 2 hours and 24 hours), thickness swelling (at 2 hours and 24 hours), residual swelling, hygroscopic swelling, static bending and screw withdrawal strength for different treatments were assessed by variance analysis with subsequent comparison by Tukey test at 5% of significance. All conditions for statistical analysis (homogeneity of variance, independence and normality data) were evaluated previously.

RESULTS AND DISCUSSION

Physical properties of the panels

The density ranged from 0.638 to 0.642 g cm^{-3} (Table 2). However, there was non-significant difference between treatments. The amount of heat or the process duration time were not able to cause a reduction in density. Thus, the result is considered a positive aspect, since there was non-significant reduction of this parameter, which is directly related to the mechanical strength., the density is one of the parameters that most influence the quality of the panel productions. Maloney (1993) explains that a high density to the panels causes a large mechanical strength. However, thicker panels show generally less dimensional stability, which may be related to higher amount of wood particles and, consequently, higher material densification during the pressing process, releasing the compressive stress.

Brito et al. (2006), evaluating the basic density and shrinkage of *Eucalyptus grandis* wood at different temperatures (120°C, 140°C, 160°C, 180°C and 200°C), concluded that the weight loss of the specimen is due to high temperature levels.

TABLE 2: Density of the particleboards samples, before and after heat treatment.
TABELA 2: Densidade dos painéis aglomerados, antes e após o tratamento térmico.

Treatments (minutes – °C)	Screws Withdrawal Strength (N)^{NS}
0-0	723.04
6-160	639.35
12-160	705.50
6-180	650.33
12-180	673.85

Where: ^{NS} = not significant ($p \geq 0.05$).

The results achieved with the water immersion test in two hours are shown in Figure 1. The mean values ranged from 5.64% to 6.11%. Thus, there was non-significant statistical difference between the different treatments. The water absorption results of two hours were lower than those achieved by Iwakiri et al. (2012) who obtained 7.36% to 19.83% for homogeneous and multilayer particleboard panel productions of *Pinus taeda*e and *Melia azedarach* with different resin content. Cademartori et al. (2015), studying the tec-

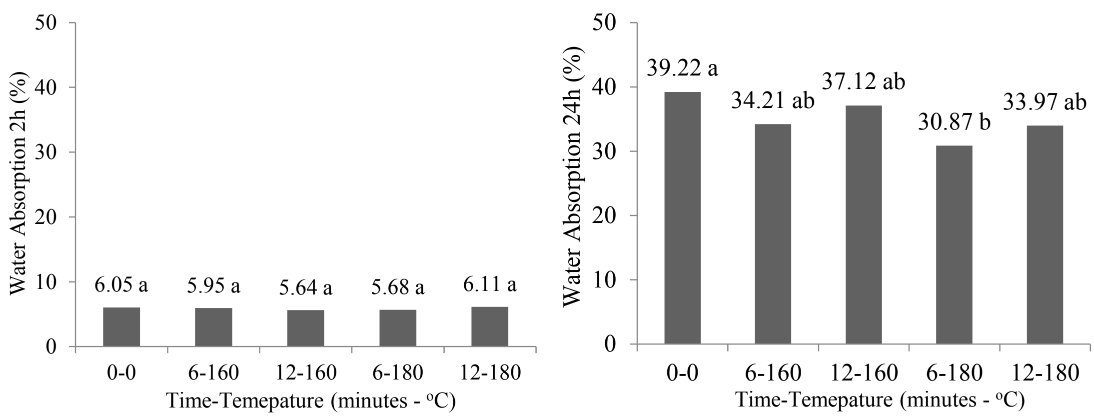

FIGURE 1: Average values of water absorption for 2 and 24 hours.
FIGURA 1: Valores médios de absorção de água em 2 e 24 horas.

hnological properties of thermo rectified wood of *Eucalyptus grandis*, from interaction between factors, allowed to proof that the wood water absorption rate did not vary significantly regarding to the treatment applied at 180°C, 200°C, 220°C to 240°C for four hours.

The water absorption values after a 24-hour immersion ranged from 30.87% to 39.22%. Iwakiri et al (2012) observed mean values of absorption for particleboard panels between 20.58% and 43.29%, with results close to those found in this study. The treatment at 180°C for six minutes differs statistically from the others. Thus, the panels addressed in such conditions, had the lowest water absorption for 24 hours of immersion, and promoted positive results in relation to the increase of its dimensional stability. The hydrophobic character of the cell wall may have contributed to these results, according to Del Menezzi et al. (2008). The change in the chemical structure of some compounds, caused by heat treatment, may be a probable explanation for the increased hydrophobic character. Due to the lower number of hydroxyl groups present in the cell wall, after heat treatment, decreasing the water flow through the adsorption places.

For the same temperature, six minutes showed better performance for water absorption than twelve minutes. Mendes et al. (2002) explains that, this water absorption reduction occurs due the water access in denser panels is smaller at the beginning because of the large amount of compacted woody weight for the same thickness, producing a physical barrier to prevent capillary water absorption.

Figure 2 shows the mean thickness swelling values for two hours, ranging between 2.37% to 2.92%. Cunha et al. (2014) assessing the particleboard wood panel productions of *Eucalyptus benthamii*, *Eucalyptus dunnii* and *Eucalyptus grandis* found better results than those obtained in this study, ranging from 3.09% to 7.21%. Different heat treatments assessed had non-significant difference for water absorption after two hours of immersion. The effect was inconsiderable for samples thermally treated. For particleboard, Carvalho et al. (2015) found improve stability only for heat treatment conducted at 260°C for a period of 12 min.

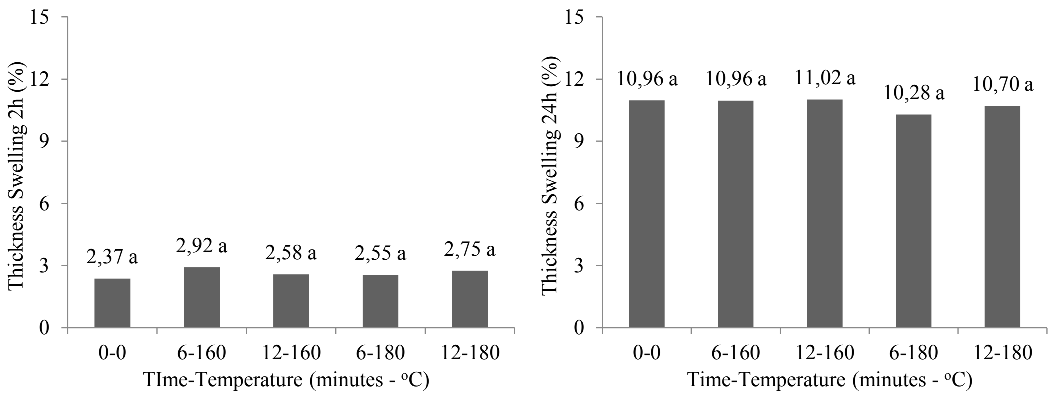

FIGURE 2: Average values of thickness swelling for 2 and 24 hours.
FIGURE 2: Valores médios de inchamento em espessura em 2 e 24 horas.

As for thickness swelling for 24 hours, non-significant difference between the samples was considered, ranged from 10.28% to 11.02%. The tests were also in accordance with the American National Standards Institute – ANSI A 208.1 (2009) which establishes a maximum swelling of 40% for 24 hours. The results assessment shows that the thickness swelling percentages obtained in this study, are also within the values required by the DIN 68761(1)-1961 standard (GERMAN STANDARDS COMMITTEE, 1971), which establishes the maximum swelling of 6% and 15% for 2 hours and 24 hours, respectively, for panels bonded with urea-formaldehyde.

The thickness swelling results for commercial particleboard samples of this study were lower than the results shown by Freire et al. (2011). The authors found mean values of thickness swelling from 8% and 16%, respectively, for 2 hours to 24 hours of immersion in water, when they studied the physical properties of commercial particleboards made with sugar cane bagasse and *Eucalyptus* sp. wood.

Del Menezzi and Tomaselli (2006) assessing the dimensional stability in oriented particle panels using two temperatures (190°C and 220°C) states that the temperature reduces the thickness swelling values, i.e., the panels became more stable with the treatment temperature increase. Study developed by Xiangquan (1997) in particleboard panels produced with *Populus* wood, assessing two temperatures (190°C and 220°C) in five times (5, 10, 15, 20 and 25 minutes), also concluded that the panels swelling decreases as it increases the time and temperature of treatment, concluding that the applied technique is positive for increased dimensional stability of particleboard panels.

The residual swelling occurs due to the compressive stresses release, which moisture removal does not allow the retreat to the initial thickness, also known as non-return rate thickness (TNRE). According to the results (Figure 3), it ranged from 1.13% to 1.76%. Statistically significant differences occurred between the proposed treatments. The heat treatment at 180°C for 6 and 12 minutes, showed the lowest residual swells.

Regarding hygroscopic swelling resulting from the hygroscopic effect of wood particles, it ranged between 9.15% and 9.43%. There was non-significant difference for this parameter among the assessed treatments. Assessing the influence of ten heat treatment in maritime and beech pine woods, Repellin and Guyonnet (2005) highlighted that, not only the hemicellulose degradation is essential for hygroscopic reduction, but also the lignin structure modification, which despite not having affinity with water, undergoes through a rearrangement and the result is a lower wood hygroscopic.

The heat treatment in the samples, by not having a significant result, shows that, to achieve positive results for hygroscopic and residual swelling, it must increase the treatment temperature and time to degradation occurrence of its more hydrophilic constituent, the hemicellulose, and thus, has a possible increase in the dimensional stability.

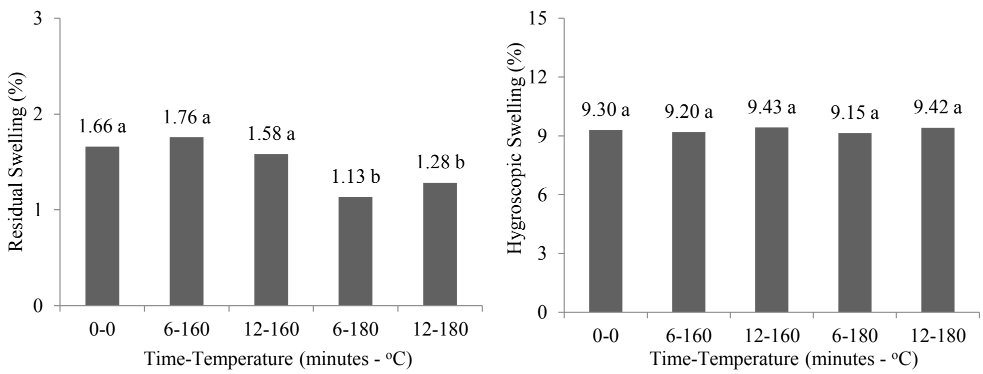

FIGURE 3: Average values of residual and hygroscopic swelling.
FIGURE 3: Valores médios para os inchamentos residual e higroscópico.

Mechanical properties of the panels

The mean values of rupture modulus (MOR) and elasticity modulus (MOE) to static bending, for each treatment, are shown in Figure 4. According to the data, there was non-significant difference between treatments for both MOR and MOE. These results indicate that heat treatments non-significantly alter this panel properties strength. The results are similar to that found for Wandscheer et al. (2016) for MDF panels.

The wood heat degradation reactions are highly influenced by time, temperature, stress, moisture, and treatment type (KUBOJIMA et al., 2000). However, no changes were perceived in this assessment results when compared to the control sample. Temperatures or maintain time in the oven were not expressive for significant changes.

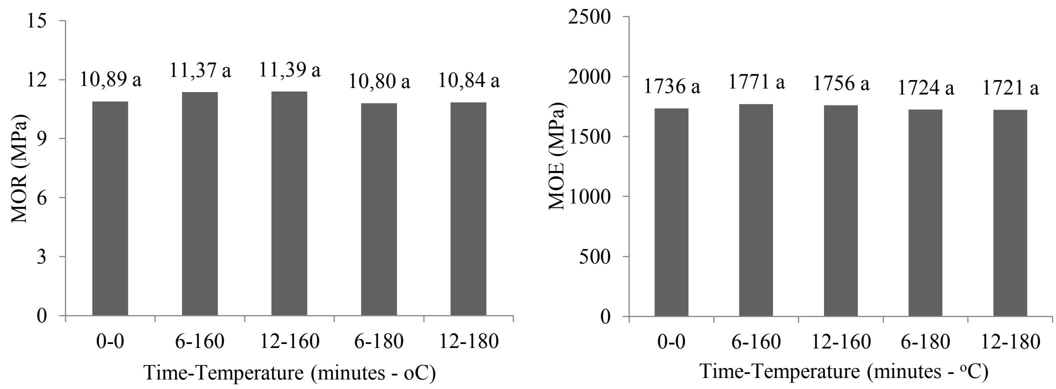

FIGURE 4: Average values of the rupture modulus (MOR) and elasticity modulus (MOE) in static bending.
FIGURA 4: Valores médios observados para o módulo de ruptura (MOR) e para o módulo de elasticidade (MOE) em flexão estática.

For sugarcane bagasse particleboard treated with temperatures at 200oC, 230oC and 260oC for a period of eight and twelve minutes, Carvalho et al. (2015), observed strength reduction from 230oC and twelve minutes of heat treatment. Calonego et al. (2010) studied the heat treatment effect in Eucalyptus grandis wood properties and verified that the static bending of the wood was not significantly altered by the heat treatment. According to the author, the rearrangement of chemical constituents after heat treatment of wood and/or the cellulose crystalline area increase, and the consecutive approximation of the micelles showed by Wikberg and Maunu (2004) are mostly the most considerable explanation.

In Table 3, we observe the comparisons between mean values obtained for the screws withdrawal strength (AP) of the different treatments. The screw withdrawal presented factors ranging between 65.24 and 73.78. 102 kgf is the minimum value required by ANSI A 208.1 (2009) standard for screw withdrawal strength. Among the values, any treatment showed satisfactory results, including control samples. Significant differences among the treatments were not observed as well.

TABLE 3: Average values of screw withdrawal strengths.
TABELA 3: Valores médios de resistência ao arrancamento de parafusos.

Treatments (minutes – °C)	Screws Withdrawal Strength (N)^{NS}
0-0	723.04
6-160	639.35
12-160	705.50
6-180	650.33
12-180	673.85

Where: NS = not significant ($p > 0.05$).

CONCLUSION

For physical properties, the heat treatments influenced significantly the water absorption of the panels after 24 hours of immersion. The treatment that utilized the temperature of 180°C for six minutes had a best performance. As for the mechanical properties, the treatments did not significantly influence the panel strengths.

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