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PRODUCTION OF LOW-DENSITY PARTICLEBOARDS FROM *Ochroma pyramidale* WOOD

Polliana D'Angelo Rios[1,♠]

https://orcid.org/0000-0002-3700-7084

Rodrigo Buss[2]

https://orcid.org/0000-0002-8373-2746

Natalia Durigon Melo[2]

https://orcid.org/0000-0003-2391-8829

Daniela Hoffmann[2]

http://orcid.org/0009-0009-4665-6455

Leonardo Seibet Kuhn[3]

https://orcid.org/0000-0002-5424-9077

Luana de Souza[4]

https://orcid.org/0000-0003-3263-2582

Rafaela Stange[5]

https://orcid.org/0000-0001-6116-9019

Alexsandro Cunha[1]

https://orcid.org/0000-0001-5554-5276

ABSTRACT

Given the need to identify alternative wood species for the sustainable production of low-density particleboards, this study aimed to produce and evaluate low-density particleboard panels made from *Ochroma pyramidale* (balsa). Trees of *Ochroma pyramidale* (balsa) aged 6 and 10 years (three trees per age group) were harvested for this purpose. Homogeneous low-density panels were then fabricated using two different ages of *Ochroma pyramidale* (balsa) in combination with *Pinus spp.* as a control. The panels were produced with densities of 200 kg/m³; 300 kg/m³; 400 kg/m³ and 500 kg/m³, resulting in a total of 13 different treatments. During the pressing process, a temperature of 180 °C, a specific pressure of 30 kgf/cm², and a pressing time of 18 minutes were applied. Physical and mechanical properties were assessed on the panels after immersion in water for 2 hours and 24 hours. The physical tests revealed an increase in swelling as the panel density increased at both 2-hour and 24-hour intervals. Conversely, water absorption decreased as the density of the panels increased, for both immersion times. Mechanical testing, including modulus of rupture, modulus of elasticity,

[1]Universidade do Estado de Santa Catarina. Lages, SC, Brasil.
[2]Universidade do Estado de Santa Catarina. Programa de Pós-Graduação em Engenharia Florestal. Lages, SC, Brasil.
[3]Universidade Federal de Lavras. Programa de Pós-Graduação em Engenharia. Lavras, MG, Brasil.
[4]Universidade do Estado de Santa Catarina. Programa de Pós-Graduação em Ciência do Solo. Lages, SC, Brasil.
[5]Universidade Federal do Paraná. Programa de Pós-Graduação em Engenharia Florestal. Curitiba, PR, Brasil.
♠Corresponding author: polliana.rios@udesc.br
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and perpendicular tensile strength, showed an increasing trend in values, indicating enhanced mechanical properties with higher panel density. Overall, *Ochroma pyramidale* (balsa) demonstrates significant potential as an alternative species to produce wood panels.

Keywords: Balsa wood, particle boards, mechanical properties, physical properties, *Pinus* spp.

INTRODUCTION

Although Ochroma pyramidale wood exhibits characteristics that make it a promising raw material for the production of low-density panels, there is still limited information regarding its physical and mechanical performance for this purpose. The lack of studies on this subject makes it difficult to determine whether the species can fully meet the requirements demanded for such applications.

Particleboards are manufactured from wood particles, incorporating synthetic resin, and consolidated under heat and pressure. Globally, industrial wood residues, by-products from forestry operations, lower-quality wood (which is not suitable for other forms of industrialization), wood from planted forests, and recycled wood are commonly used as raw materials. In Brazil, wood from planted forests, particularly Eucalyptus and Pinus species, serves as the primary source of raw material (Iwakiri 2005, Maloney 1993, Mattos *et al.* 2008).

Among the various types of reconstituted wood panels, particulate wood panels hold significant importance due to their minimal raw material quality requirements (Trianoski 2010). Production of MDP (Medium-Density Particleboard) panels has grown by 8,9% driven by the diverse range of products and the high dynamism of the particleboard market, largely fueled by the rapid growth of the furniture industry, which is the primary consumer of this type of panel (IBÁ 2017, Macedo and Roque 2006).

Regarding adhesives, urea-formaldehyde (UF) resin is commonly used in the panel industry, offering advantages such as low cost, quick curing, and minimal impact on the coloring of the panel. However, it is more suitable for interior applications (Iwakiri 2005, Marra 1992).

The selection of species for raw materials must be carefully considered, as it can have both positive and negative effects on the final product. From a technological perspective, the use of alternative raw materials can enhance the quality and properties of particleboard panels, due to the unique characteristics inherent in each species. For instance, certain species can produce lightweight panels, ideal for use in applications such as coating. Additionally, promoting the use of these species can help expand the range of planted forest species, providing more options for raw materials, provided the required product quality standards are met (Trianoski 2010).

Balsa (Ochroma pyramidale (Cav. ex Lam.) Urb.) (Malvaceae), commonly known as balsa, was previously classified as Ochroma lagopus Swartz. This species is widely distributed in tropical America, particularly in the Brazilian states of Amazonas, Acre, and Pará. It is also gaining attention in commercial plantations in Brazil's Central-West and Northern regions due to its rapid growth under favorable climate and soil conditions. These regions thus present an opportunity for expanding the cultivation of balsa as a viable forest species for the market, with emphasis on the Amazon region and the state of Mato Grosso, where the climatic conditions are ideal for the development of the species and where a documented history of management practices already exists (Barbosa *et al.* 2003; Charão *et al.* 2021; Oliveira *et al.* 2015; Magalhães *et al.* 2018).

Due to its properties, balsa is widely used in naval and civil construction as a thermal and acoustic insulator, as well as in the production of models, crafts, windsurfing boards, and model aircraft, among other applications. Given its low density, balsa holds potential as an alternative species for producing low-density panels.

Therefore, the objective of this study was to produce and evaluate low-density particleboard panels using balsa (Ochroma pyramidale (Cav. ex Lam.) Urb.) wood from two different ages, with Pinus spp. employed as the control species.

MATERIAL AND METHODS

Material

Six balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) trees, sourced from the Balsa-Brasil project, were used in this study, consisting of three trees aged 6 years and three aged 10 years. The material was transported to the Center for Agro-Veterinary Sciences (CAV) at the State University of Santa Catarina (UDESC), located in Lages, SC, Brazil.

The control treatments for the project were prepared using a commercial mix of wood particles from loblolly pine (*Pinus taeda* L.) and slash pine (*Pinus elliottii* Engelm.) species.

The basic density of balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) was determined by collecting discs from heights of 0 %, 25 %, 50 %, 75 %, and 100 % along the trunks of the six trees. After extracting the discs for density measurements, the remaining balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) material was processed into logs and transported to Bonet Madeiras e Papéis, located in Santa Cecília, SC. The logs were then processed through a Hombak U-74 particle mill, which is used by the company in its industrial operations. The resulting wood particles were transported back to the laboratory at the Center for Agro-Veterinary Sciences for further analysis.

The adhesive used for producing the particleboard panels was urea-formaldehyde (UF), with a resin content of 12 %, and an additional 1 % paraffin emulsion. All materials, including the resin and paraffin emulsion, were supplied by Bonet Madeiras e Papéis. Additionally, as a reference for comparison, the company also provided a *Pinus spp.* panel with a density of 300 kg/m³. It is noteworthy that this density value represents the standard density typically used by the company for its panels.

Regarding the basic density of *Pinus spp.*, the literature indicates that for the commercial mix of loblolly pine (*Pinus taeda* L.) and slash pine (*Pinus elliottii* Engelm.) used in particleboard production, the basic density ranges from 322 kg/m³ to 420 kg/m³ for trees aged between 8 and 13 years. Therefore, an average density of 350 kg/m³ was adopted for the *Pinus spp.* material used in the study.

Compression ratio

The relationship between the density of the panel and the density of the wood used is referred to as the compaction ratio. This parameter is crucial for the dimensional stability and mechanical strength of the panel. According to Maloney (1993), the most recommended species to produce reconstituted panels are those with a density of up to 500 kg/m³. Kelly (1977) states that using low-density wood results in a higher compaction ratio for the panels, which increases the contact area between the particles. This, in turn, enhances the static bending strength and internal bonding properties of the panel.

Paricleboard

The work consisted of 13 treatments, with 3 replications each, totaling 39 homogeneous panels, with different density values 200 kg/m³; 300 kg/m³; 400kg/m³, 500kg/m³ and with 12 % resin urea formaldehyde (UF) content and 1 % paraffin emulsion (Table 1).

Table 1: Treatments used in the project.

Treatment	Density (kg/m³)	Species
T1		*Pinus* spp.
T2	200	*O. pyramidale* 6 years
T3		*O. pyramidale* 10 years
T4		*Pinus* spp.
T5	300	*O. pyramidale* 6 years
T6		*O. pyramidale* 10 years
T7		*Pinus* spp.
T8	400	*O. pyramidale* 6 years
T9		*O. pyramidale* 10 years
T10		*Pinus* spp.
T11	500	*O. pyramidale* 6 years
T12		*O. pyramidale* 10 years
T13	300	Commercial

To account for the geometry of the particles, random measurements were taken using a caliper and digital micrometer, recording the length, width, and thickness of 100 particles. The slenderness index was calculated as the ratio of length to thickness, while the flatness ratio was determined by the ratio of width to thickness. The surface area of the particles was calculated using the method proposed by Moslemi (1974).

In order to achieve the target moisture content for panel production, *Pinus* spp. and balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) were dried in an oven at 80 °C. Moisture content was monitored at regular intervals using an infrared thermobalance until the particles reached an ideal moisture content of 4 % (±2 %).

The material was then pressed at a temperature of 180 °C, with a specific pressure of 30 kgf/cm², for 18 minutes.

Test specimens for determining the physical and mechanical properties of the panels were prepared as illustrated in Figure 1. During this process, the edges of the panels were removed.

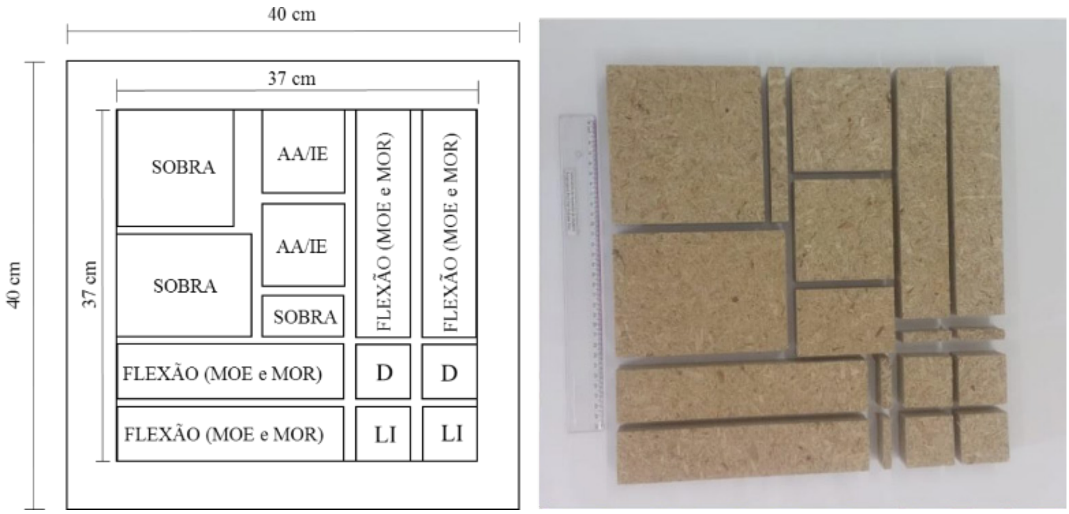

Figure 1: Layout for removing the specimens.

The following specimens were extracted from the panel: two for water absorption and thickness swelling tests, four for static bending tests, two for density measurements, and two for internal bonding tests.

Statistical analysis

Statistical analysis was performed on all datasets. The experiment followed a 4x4 factorial design, incorporating both qualitative (different species) and quantitative (different densities) factors.

To assess the normality of the data, the Kolmogorov-Smirnov test was applied, and homogeneity of variance was tested using the Bartlett test. Data that did not meet the assumptions of normality and homogeneity were subjected to Box-Cox transformation. Following confirmation of normality and homogeneity, analysis of variance (ANOVA) was conducted.

In cases where an interaction between variables was found, regression analysis was performed for the qualitative factor as a function of the quantitative factor. For instances where no interaction was observed, the Scott-Knott mean test was used for comparing the qualitative factors.

All statistical tests were conducted at a 95 % significance level using the Sisvar 5.6 Build software developed by Ferreira (2011) and the Action add-in for Microsoft Excel.

RESULTS AND DISCUSSION

Basic species density

The density values obtained for balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) were 254 kg/m ^{3} and 270 kg/m^3 for trees aged 6 and 10 years, respectively. According to Carvalho (2010), the density of balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) can range from 70 kg/m^3 to 350 kg/m^3, which is consistent with the values observed in this study.

Wood particle

The quality of wood panels is closely linked to the geometry of the particles used. After obtaining the dimensions of the particles (thickness, length, and width), the slenderness index (IE), flatness ratio (Pla), and surface area (AS) of the particles were calculated. These values are presented in Table 2.

Table 2: Values for thickness, length, width, slenderness index (IE), flatness ratio (Pla), and surface area (AS) of the particles.

Species	Thickness (mm)	Lenght (mm)	Width (mm)	IE -	Pla (mm)	AS (cm^2/g)
O.pyramidale 10 years	1,11	24,08	5,94	32,21 a (35,70)	7,71 a (60,50)	11,77 a (50,19)
O.pyramidale 6 years	1,18	24,91	4,95	28,72 a (43,77)	6,10 a (63,69)	10,73 a (45,01)
Pinus spp	0,74	19,41	3,55	44,20b (74,37)	7,71 a (67,43)	20,14 b (56,73)

Means followed by different letters show a significant difference using the Scott-Knott test at the 95 % confidence level. CV: Coefficient of Variation (%), in parentheses. Where: IE: slenderness index, Pla: flatness ratio and AS: surface area.

Regarding the IE values, Pereira (2016) reported a value of 53,47 for *Pinus spp.*, which is similar to the values found for balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) in this study. According to Alberto (1992), higher slenderness ratios are generally more desirable, as they typically contribute to greater mechanical strength and dimensional stability of the panels.

Panel density

The average apparent density values obtained in this study were lower than the nominal densities of 200 kg/m³; 300 kg/m³; 400 kg/m³ and 500 kg/m³ (Figure 2). This discrepancy can be attributed to the operational conditions at the laboratory level, including potential losses of particles during handling throughout the panel production process (Santos *et al*. 2009, Iwakiri *et al*. 2012). Another factor that may have contributed to the difference is the lateral sliding of particles, which can cause an increase in panel dimensions after pressing. Additionally, during specimen squaring, lateral particle loss due to pullout can further affect density measurements.

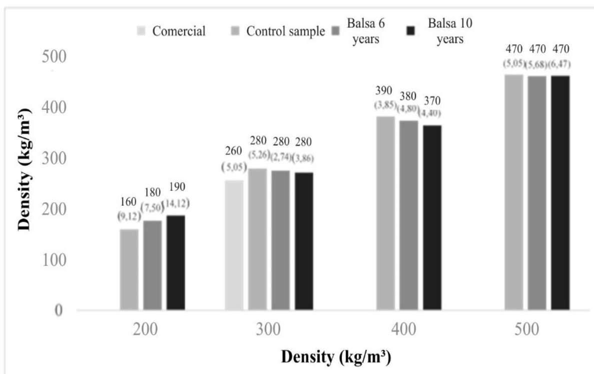

Figure 2: Panel density values.

The panels were classified as low density (<600 kg/m³) according to the CS 236-66 standard (Commercial Standard CS 1968). These values also comply with the CEN/TS 16368:2014 standard, which establishes that lightweight particleboards are those with a density below 600 kg/m³.

Compression ratio

For the compaction ratio variable, statistical analysis revealed an interaction between species and density (Figure 3). Values ranged from 0,44 (T1) to 1,81 (T11). According to Maloney (1993), the ideal range for the compaction ratio is between 1,3 and 1,6. Panels with compaction ratios greater than 1,6 tend to exhibit a deterioration in physical properties, although their mechanical properties may improve. Conversely, panels with compaction ratios below 1,3 typically show a reduction in mechanical properties.

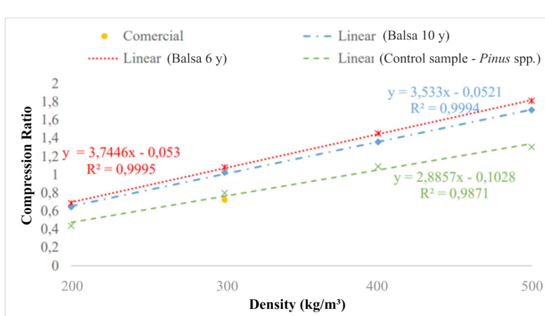

Figure 3: Regression Analysis for the compression ratio variable.

The regression analysis demonstrated a strong correlation between density and compaction ratio across all treatments. Balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) (6 years) exhibited the highest compaction ratio, followed by balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) (10 years), while Pinus spp. showed the lowest. The commercial panel also made of *Pinus* spp. displayed an intermediate behavior, aligning more closely with *Pinus* spp., suggesting comparable densification characteristics.

The density treatments of 400 kg/m³ and 500 kg/m³ (T7, T8, T9, T10, T11, and T12) exhibited desirable compaction ratio values according to the literature, indicating a better balance and stability in both physical and mechanical properties.

Panel humidity

The statistical analysis revealed no interaction between the density and species variables regarding humidity. No significant differences in humidity were observed across the different densities evaluated (Figure 4). The humidity ranged from 7,77 % (T6) to 9,85 % (T1).

The panels should achieve an equilibrium moisture content of 12 % by conditioning at a constant temperature and relative humidity. Trianoski (2010) emphasizes that the reduction in moisture content is linked to the transformation of wood into particles, the subsequent mixture of adhesives and paraffin, and the application of high temperatures and pressure during the panel pressing process. These factors contribute to the panels' reduced ability to stabilize with the surrounding environment.

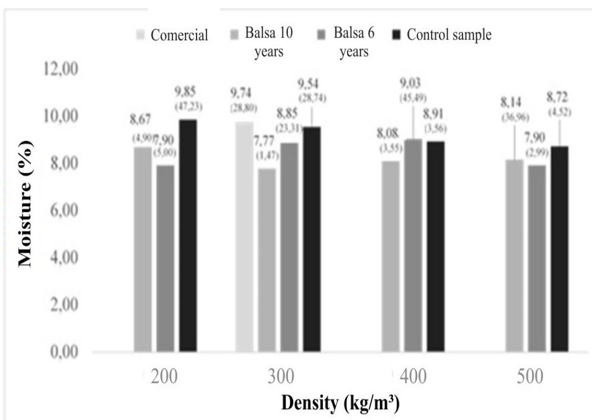

Figure 4: Moisture content values different panel densities.

Swelling at 2 and 24 hours

For the thickness swelling test, the average values ranged from 1,4 % (T1) to 26,9 % (T11) after 2 hours of immersion, and from 3,7 % (T13) to 39,0 % (T11) after 24 hours of immersion (Figure 5). In all panel compositions studied, swellings increased in nearly all treatments as the density increased, both for the 2-hour and 24-hour immersion tests.

This increase in swelling may be attributed to the higher compaction ratios observed in these panels, which result in greater hygroscopicity of the cell wall, an increased number of sorption sites, and the release of compression stresses generated during the pressing process (Melo 2013).

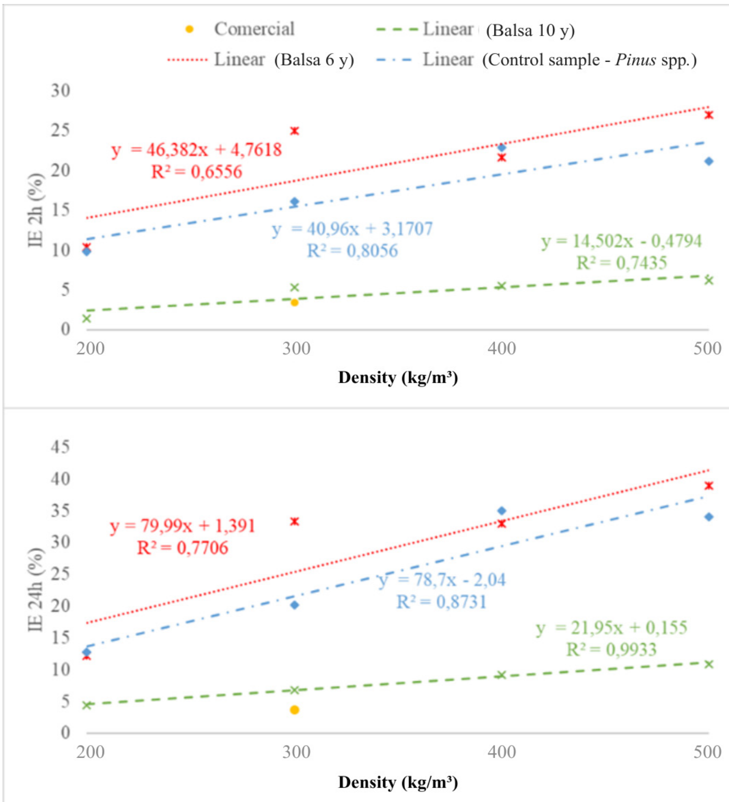

Figure 5: Regression analysis for the variables thickness swelling in 2 hours and 24 hours.

According to CS Standard-236-66, low-density commercial panels must exhibit a maximum thickness swelling of 35 %. Thus, the treatments analyzed in this study comply with the standard when considering thickness swelling after 24 hours.

The results indicate that balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) panels, particularly those from 6-year-old trees, exhibit a higher tendency for thickness swelling, whereas those from 10-year-old trees show a slight improvement in dimensional stability. In contrast, *Pinus spp.* panels (both control and commercial) display lower swelling, demonstrating greater resistance to water absorption. The strong correlation observed between density and swelling underscores the importance of this parameter in the dimensional stability of particleboards.

Colli *et al.* (2010), in their study on low-density panels (360 kg/m³) made from paricá (*Schizolobium amazonicum* (Huber) Ducke) with varying proportions of coconut fibers, reported swelling values of 11,26 % and 9,12 % for 2 hours, and 13,11 % and 10,46 % for 24 hours, respectively, using 6 % and 8 % urea-formaldehyde (UF) resin. These values were higher compared to the control treatment in their study, and when compared to treatments using balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.), greater absorption was observed in both evaluations.

Iwakiri (2005), in his study of different densities and resins using *Pinus spp.*, found thickness swelling values of 27,42 % and 29,99 % for 2 hours and 24 hours, respectively. These values are higher than those observed in the present study for the 2-hour test and lower for most 24-hour evaluations.

Mendes *et al.* (2014), in their research on low-density panels made from various *Eucalyptus* clones, using 6 % adhesive and a density of 600 kg/m³, reported swelling values ranging from 13,3 % to 28,8 % for 2 hours and 29,9 % to 40,8 % for 24 hours. These results are similar to most of the findings in the present study, particularly for densities of 400 kg/m³ and 500 kg/m³.

Stange *et al.* (2024), in their investigation on the influence of different paraffin percentages in particleboards made from balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) wood aged 10 and 12 years with a density of 500 kg/m³, reported thickness swelling values ranging from 46,1 % to 23,18 % after 2 hours and from 52,80 % to 34,15 % after 24 hours. These values were higher than those observed in the present study.

2-hour and 24-hour water absorption

For the 2-hour water absorption test, the average values obtained in this study ranged from 54,6 % (T10) to 235 % (T2) (Figure 6). For the 24-hour water absorption test, values ranged from 82,3 % (T10) to 306,6 % (T2). Statistical analysis revealed an interaction between the panel density and species variables.

In both evaluations, lower water absorption was observed as the panel density increased. This trend was consistent across nearly all treatments and can be attributed to the greater compaction of the panels at higher densities, which reduces porosity and, consequently, leads to lower absorption.

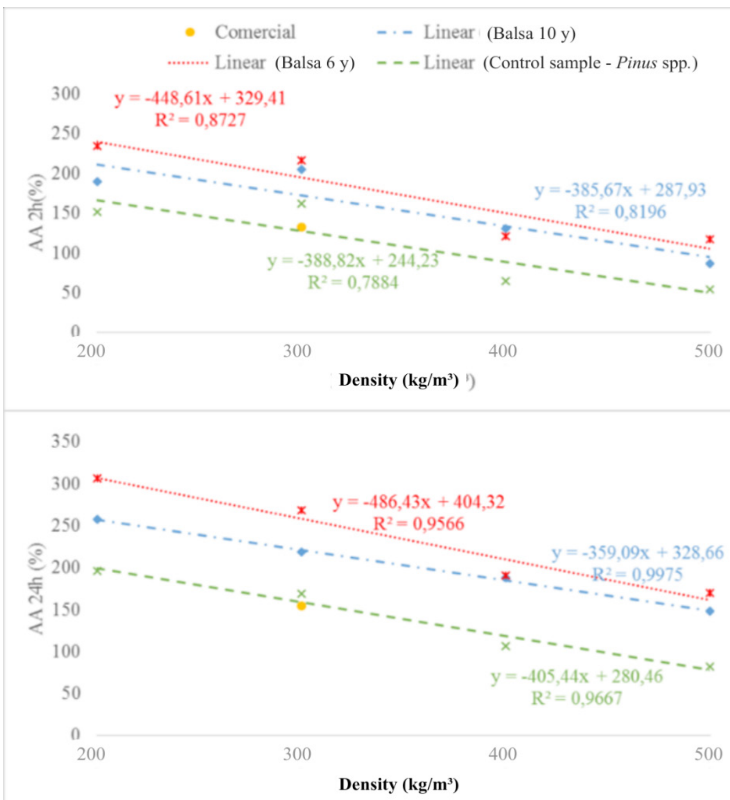

Figure 6: Regression analysis of the variables AA2h and AA24h.

The balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) panels, particularly those from 6-year-old trees, exhibit high water absorption, which may limit their applicability in high-humidity environments. Increasing the tree age to 10 years enhances moisture resistance; however, *Pinus spp.* panels remain the most dimensionally stable. The strong correlation between density and water absorption highlights the critical role of this parameter in improving the performance of particleboards.

Colli *et al*. (2010), in their study on low-density panels (360 kg/m³) made from paricá (*Schizolobium amazonicum* (Huber) Ducke) and different proportions of coconut fibers, reported water absorption values of 228,50 % and 211,83 % with 6 % and 8 % resin, respectively. These values are similar to those observed in treatments with a density of 300 kg/m³ in the present study. Soares *et al*. (2017), in their work with low-density panels using *Eucalyptus* wood mixed with various proportions of sugarcane bagasse, found average water absorption values of 111,5 % and 132,8 % for the 2-hour and 24-hour tests, respectively. Similarly, Scatolino *et al*. (2017) reported water absorption values of 120,5 % and 138 % for 2 hours and 24 hours of immersion, respectively, in low-density panels produced with *Eucalyptus* wood.

These values are comparable to those observed in the present study at densities of 300 kg/m³, 400 kg/m³, and 500 kg/m³ in some treatments. Iwakiri (2005), in his research on panels with varying densities and resins using *Pinus spp.*, found a 2-hour water absorption value of 124,016 %, which is similar to the results observed for balsa species at densities of 400 kg/m³ and 500 kg/m³, at both ages. Mendes *et al.* (2014), in their study on low-density panels made from different *Eucalyptus* clones with 6 % adhesive and a density of 600 kg/m³, reported absorption values ranging from 35,7 % to 63,9 % for 2 hours and 94,1 % to 108,8 % for 24 hours. These values were higher than those observed in the present study, except for the control treatment at a density of 500 kg/m³, which had superior results.

Internal bond

Statistical analysis revealed an interaction between the variables evaluated in the internal bond test (Figure 7). The species *Pinus spp.*, used as a control, exhibited higher internal bond values across all treatments. This result suggests that several factors may have influenced the outcome. One key factor is the geometry of the particles, as the balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) wood was processed using an industrial chipper designed for *Pinus spp.* wood. According to CEN/TS 16368:2014, the control treatment manufactured with *Pinus* spp. particles meets the internal bond requirements established by the standard for type LP1 - use in dry conditions. In the case of balsa wood, the treatment with a nominal density of 500 kg/m³ shows values that approach the reference range defined by the standard (0,20-0,15 MPa). The anatomical structure of balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) contains large-sized pores, which contribute to its low density. Consequently, the angle of the chipper knives, which was adjusted for *Pinus* particles, was not optimal for producing particle geometries that would enhance internal bonding properties in balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.).

Another contributing factor is the resin content, which was 12 % in both treatments. However, due to the difference in material quantity between species, balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) with an average density of 260 kg/m³ formed a thicker mat compared to *Pinus spp.*, which has an average density of 360 kg/m³. This suggests that the balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) mat received a smaller resin coating per particle, with the larger pore size of the balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) particles leading to greater resin absorption. As a result, the balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) panels likely exhibited a less uniform distribution of resin, which may have contributed to the observed differences in internal bond strength.

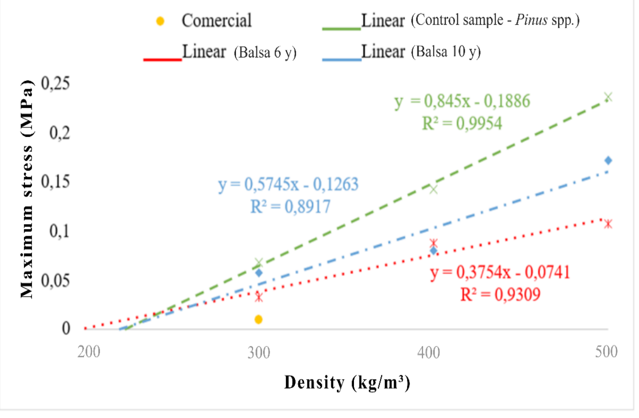

Figure 7: Regression analysis for the internal bond variable.

The correlation values found show a significant influence on the panel density when analyzed in conjunction with the internal bond. All treatments demonstrated superior results when compared to those found for the commercial panel of *Pinus* spp. The panels produced with balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) in the 10-year treatment exhibit a superior internal bond compared to those produced with balsa (*Ochroma *pyramidale* (Cav. ex Lam.) Urb.) at 6 years. Both treatments still present lower values when compared to the panels made from *Pinus* spp.

When compared to the study by Colli *et al*. (2010), which evaluated low-density panels (300 kg/m³) made from paricá (*Schizolobium amazonicum* (Huber) Ducke) wood with different proportions of coconut fiber, they found internal bond values of 0,15 MPa and 0,21 MPa for panels with 6 % and 8 % resin, respectively. These values are similar to those observed in the present study for panels with densities of 400 kg/m³ and 500 kg/m³.

Iwakiri (2005), in his work with different densities and resin contents using *Pinus spp.*, found an internal bond strength of 0,19 MPa for panels with a density of 650 kg/m³ and an 8 % UF resin content. These values are similar to those found for the 500 kg/m³ density in the current study.

Mendes *et al.* (2014) reported internal bond values ranging from 0,14 MPa to 0,26 MPa in their study on low-density panels made from various *Eucalyptus* clones, using 6 % resin and a density of 600 kg/m³. These values are comparable to those found in the present study for the 500 kg/m³ density, particularly for the 10-year-old balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) and control species.

Static bending

For both the modulus of elasticity in bending (MOE) and bending strength or modulus of rupture (MOR), statistical analysis revealed an interaction between the variables of density and species (Figure 8). The average MOE values ranged from 36,84 MPa (T1) to 1815,47 MPa (T11), while the MOR values ranged from 0,17 MPa (T1) to 13,46 MPa (T11).

Despite the balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) species exhibiting unfavorable indicators regarding particle geometry, it demonstrated satisfactory results when compared to the control and commercial panels, often surpassing them. The same trend was observed for the MOR, which followed the same pattern as the MOE. Upon analyzing the different species and densities, it is evident that the 6-year-old balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.) wood exhibited the best overall performance in both MOE and MOR evaluations.

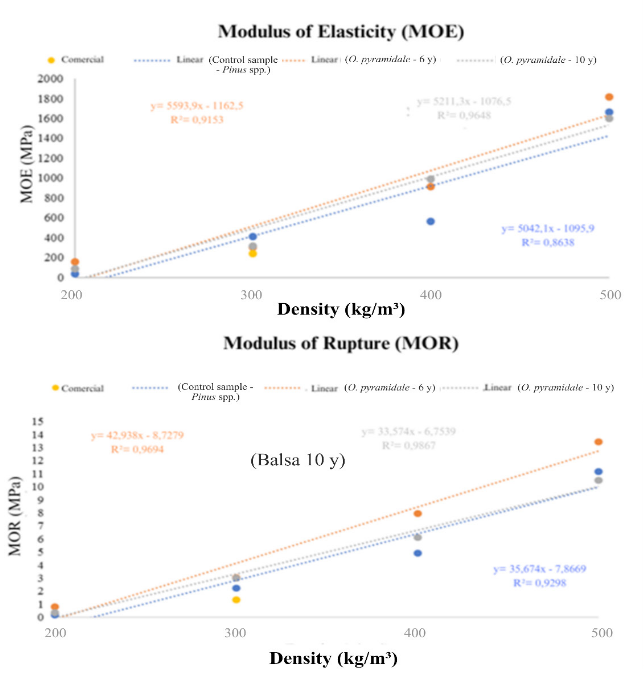

Figure 8: Regression analysis for the MOE and MOR variables.

For the modulus of elasticity in bending (MOE), the values specified by CEN/TS 16368:2014 indicate that only panels with densities equal to or greater than 400 kg/m³ meet the requirements for LP1 use. Considering the LP2 classification, only the panels with an apparent density of 400 kg/m³ reached values above 900 MPa. This same behavior was also observed for the bending strength (MOR) variable.

The results demonstrated satisfactory values for the low-density panels, with some MOE and MOR values surpassing those reported by Longo *et al*. (2015). In their study, Longo *et al.* (2015) found MOE values of 631 MPa and 552 MPa and MOR values of 4,6 MPa and 2,1 MPa for cedrorana (*Cedrelinga cateniformis* (Ducke) Ducke) and itaúba (*Mezilaurus itauba* (Meisn.) Taub. ex Mez), respectively, in medium-density panels with a density of 650 kg/m³ made from tropical species.

Colli *et al.* (2010), in their study on low-density panels (360 kg/m³) made from paricá (*Schizolobium amazonicum* (Huber) Ducke) and various proportions of coconut fibers, found MOE values of 191,8 MPa and 258,6 MPa, and MOR values of 3 MPa and 4,10 MPa for panels with 6 % and 8 % resin, respectively. These values are lower than those observed in the present study for densities above 300 kg/m³.

The values for densities above 300 kg/m³ in this study also exceeded those found by Iwakiri (2005), who reported MOE and MOR values of 267,09 MPa and 0,685 MPa, respectively, for a treatment with 650 kg/m³ density and 8 % UF resin in panels made from *Pinus spp.* with varying densities and adhesives.

Czarneck *et al.* (2025) in their study on low-density panels (550 kg/m³) made from juvenile wood of *Pinus* and *Betula* reported average MOR values of 9 MPa and 9,9 MPa, and MOE values of approximately 960 MPa and 1450 MPa for *Pinus* and *Betula*, respectively. These values are lower than those observed for the panels with a density of 500 kg/m³ in the present study.

Mendes *et al.* (2014) found MOE values ranging from 927,5 MPa to 1157,6 MPa and MOR values from 3 MPa to 6,2 MPa in their study on low-density panels made from different *Eucalyptus* clones, using 6 % resin and a density of 600 kg/m³. For MOE, these values were similar to those found in the present study.

CONCLUSIONS

The density of *O. pyramidale* was found to be 254 kg/m³ for 6-year-old trees and 270 kg/m³ for 10-year-old trees. These density values are suitable to produce low-density particleboards, providing an adequate balance between strength and lightness in the panels produced.

Regarding the physical properties, the contrasting behavior observed highlights important characteristics of the material's performance. Panels with higher density exhibited lower water absorption, whereas lower-density panels showed better results for thickness swelling. This behavior is likely associated with the porosity of the raw material, reinforcing the need for improved adjustments in the manufacturing process.

In terms of mechanical properties, specifically the modulus of elasticity in bending (MOE) and bending strength or modulus of rupture (MOR), the panels produced from 6-year-old *O. pyramidale* showed the best performance. This may be related to a favorable stiffness-to-weight ratio for wood panel production, making this material particularly suitable for low-density particleboard applications. However, for the internal bond test, the control panel outperformed the panels made from *O. pyramidale*. This result may be associated with the anatomical characteristics of the species, especially its high porosity, which highlights the importance of improving particle geometry.

Overall, *O. pyramidale* demonstrates strong potential as an alternative species for wood panel production, offering promising characteristics for various panel properties due to its low density and satisfactory physical and mechanical performance. These results reinforce the viability of using *O. pyramidale* and contribute to a deeper understanding of its application in the manufacture of low-density particleboards.

Authorship contributions

P. D. R.: Conceptualization, formal analysis, funding acquisition, investigation, methodology, project administration, resources, supervision, validation, visualization, writing – original draft, writing - review & editing. R. B.: Data curation, formal analysis, investigation, project administration, resources, supervision, validation, visualization, writing - original draft. N. D. M.: Data curation, investigation, validation, visualization, writing - original draft, writing - review & editing. D. H.: Validation, visualization, writing - original draft, writing - review & editing. L. K.: Writing - review & editing. L. M. S.: Writing - review & editing. R. S.: Writing - review & editing. A. B. C.: Funding acquisition, investigation, resources.

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Declaration of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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