Chapter 41

Evaluation of the physical and mechanical properties of paricá wood (*Schizolobium amazonicum*) used in the plywood industry in the State of Maranhão

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Vinicius de Sousa Lima
State University of the Tocantina Region of Maranhão, Açailândia, Maranhão, Brazil

Sandriel Lima Nascimento
State University of the Tocantina Region of Maranhão, Açailândia, Maranhão, Brazil

Jéssica Almeida dos Santos
State University of the Tocantina Region of Maranhão, Açailândia, Maranhão, Brazil

Ednilson da Cruz Rodrigues
Federal Institute of Maranhão, Açailândia, Maranhão, Brazil

Bruno Lucio Meneses Nascimento
State University of the Tocantina Region of Maranhão, Açailândia, Maranhão, Brazil

Rita Dione Araújo Cunha
Federal University of Bahia/Technology, Project and Planning Center, Salvador, Bahia Brazil

Sandro Fabio Caesar
Federal University of Bahia/Department of Construction and Structures, Brazil

João Miguel Santos Dias
State University of the Tocantina Region of Maranhão, Açailândia, Maranhão, Brazil

ABSTRACT
Paricá (*Schizolobium amazonicum*) is a species native to the Amazon region, whose physical and mechanical characteristics are the basis of the acceptance of this species by the timber market, especially through its use for the production of plywood panels and parallel blade panels (LVL). The objective of this work was to evaluate the physical and mechanical properties of paricá wood used in the plywood industry in the State of Maranhão. Moisture content, apparent and basic densities, volumetric variation, parallel and perpendicular compressive strengths to the total, shear strength parallel to the total, bending strength and elasticity modules to the compression parallel to the total and flexion were analyzed. The plot of wood analyzed presented moisture content in air balance (11.33%), low apparent density (275.57 kg.m-3) and reduced volumetric variation (8.75%), and these properties were below the values presented by the bibliography for woods of similar ages. The mechanical properties analyzed (compressive strength parallel to the great, normal compressive strength to the great, modulus of rupture in the flexion, modulus of elasticity in flexion, shear strength parallel to the great and modulus of elasticity to the compression parallel to the great) also presented values lower than the average of the results obtained in the bibliography. Thus, the use of paricá wood in plywood panels is a valid alternative, considering that they are light and stable with regard to dimensional variation, when compared with products from eucalyptus wood. However, it is pertinent to carry out actions aimed at improving the mechanical properties of paricá wood, in order to increase the properties of strength and stiffness.

Keywords: Wood, Compensated, Parica, Physical characterization, Mechanical characterization.

1 INTRODUCTION

Wood is a differentiated material because it has peculiar aesthetic, economic and technical characteristics (Costa et al. 2017). When derived from managed forests, wood is a raw material with availability compatible with the demands of the civil construction market and guarantees the environmental sustainability of the construction process (Borges, 2013). According to IBA (2021), Brazil has about 9,550,000 ha of planted forests, of which 96% correspond to eucalyptus plantation areas (*Eucalyptus spp.)* and pine (*Pinus spp.*), the remaining 4% being corresponding to the exploration of species such as rubber tree (*Hevea brasiliensis*), acacia (*Acacia mangium*), teak (*Tectona grandis*) and paricá (*Schizolobium amazonicum*).

The paricá (*Schizolobium amazonicum*) is a species native to the Amazon region, being cultivated in Brazil since the 1990s. The cultivation of this species represents, mainly in the northern region of the country, an important means of ecological and forest restoration (Gomes, Pereira & Aguiar, 2021). As advantages, paricá has rapid growth and few natural defects (Vidaurre et al.2018), reflecting the fact that it was, in 2018, the sixth most cultivated species in Brazil (IBA, 2019), with its predominance in the states of Pará and Maranhão (Santos, 2012). According to Silveira et al. (2017), the physical and mechanical characteristics of paricá are the basis of the acceptance of this species by the timber market, especially through its use for the production of plywood panels and parallel blade panels (LVL) (Costa et al. 2020).

The economic relevance of Brazil's plywood panels is reflected in the growing exports in recent years, which increased from US$ 276 million in 2020 to US$ 347 million in 2021. Comparing the period from January to March 2021 and 2022, exports of plywood panels from Brazil increased their export volume by about 53.8% (IBA, 2022). Paricá plywood panels are used mainly in the furniture, construction and packaging industries (ABIMCI, 2015). In Brazil, the works of Moreira (1999), Figueroa (2008), Almeida et al. (2013), Melo et al. (2013), Terezo et al. (2015), Mascarenhas (2015), Cavalheiro et al. (2016), Vidaurre et al. (2018), Moritani (2018) and Modes et al. (2020) analyzed the physical and mechanical properties of paricá wood. Of these studies, only the studies by Terezo et al. (2015) and Vidaurre et al. (2018) made the complete mechanical characterization of the sawn wood of the species in question, which corroborates with Gonçalves, Mascarenhas and Melo (2020), who report that there are still few studies that deal with the physical and mechanical characterization of paricá.

The study by Terezo et al. (2015) evaluated the physical and mechanical properties of paricá wood aged 6, 10, 19 and 28 years, from the municipalities of Aurora do Pará - PA and Tomé-açu - PA, having verified that the analyzed lots belonged to resistance class C20 resistance. The work of Vidaurre et al. (2018) consisted in the evaluation of the physical and mechanical properties of paricá sawn wood aged between 5 and 11 years, with origin in crops in the regions of Itinga do Maranhão - MA, Dom Eliseu - PA and Paragominas - PA.

The absence of quality control may lead to defects in panels that, according to Gilbert et al. (2017), may interfere with their physical and mechanical properties of the panels. According to Almeida (2021), the most common production defects in plywood are: bonding surface with non-uniform adhesive distribution; lower bonding quality due to problems in curing the adhesive, being related to the high extractive content. According to the same author, the mechanical and physical properties of wood, as well as its natural defects, influence the overall performance of plywood panels. Thus, it is of paramount importance to evaluate the physical and mechanical properties of the wood that makes up the raw material of plywood panels. On the other hand, so far, no work has been published taking into account the physical and mechanical characterization of paricá wood used exclusively in the plywood industry of the State of Maranhão.

Thus, the objective of this work is to evaluate the physical and mechanical properties of paricá wood used in the plywood industry in the State of Maranhão. For the mechanical characterization, the moisture content, apparent and basic densities, volumetric variation, tensile and perpendicular compressive strengths to the great, shear strength parallel to the total, bending strength, as well as the rigidity to the compression parallel to the maximum and the modulus of elasticity in the flexion were experimentally analyzed.

2 METHODOLOGY

To perform the physical and mechanical characterizations, specimens (CPs) were used, obtained from 5 wood taps of paricá, with 5 years of age, from plantations located in the rondon region of Pará. The toras were randomly selected from the storage yard and provided by Mapri compensados, based in Itinga - Maranhão. The trunks had dimensions of 20 cm in diameter and 2.20 m in length. Each tora was sawn in the diametrical direction with the aid of a chainsaw, resulting in two parts with semi-circular section. This procedure was carried out in order to facilitate its transport and storage in the Laboratory of Structures and Building Materials - LEMATCON - Timoshenko of the State University of the Tocantina region of Maranhão (UEMASUL), located on the campus of Açailândia - MA, where all the tests took place.

Due to the dimensional limitation of the trunks, four of the five of the five torsions were selected to obtain – from each one – 12 CPs for the test of determination of moisture content () and apparent $U\rho_{ap}$density (), 12 CPs for the compressive strength assay parallel to the greatf_{c0}) and 3 CPs for the bending test at three points. It was only possible to obtain 3 CPs per tora for the bending test at three points, according to the methodology of the ABNT NBR 7190-3:2022 standard, due to the dimensional limitations of the paricá claws. From the fifth tora, 6 CPs were made for the normal compression test at the grand, 6 CPs for the shear test parallel to the grand and 12 CPs for the determination of basic density and volumetric variation.

All physical and mechanical tests were performed according to Annex B of ABNT NBR 7190-3:2022 - *Wood Structures Project. Part 3: Test methods for fault-free specimens for native forest wood* (Table 1), except for the determination of moisture content, which in this case considered mass measurements in 24-hour time intervals, according to the methodology adopted by Silva et al. (2019).

Table 1: Dimensions of the CPs of the physical and mechanical characterizations and loading rates used.

Property	**total number of CPs**	**width (cm)**	**height (cm)**	**length*(cm)**	**analysis area (mm²)**	**charging rate (MPa/min)**
U (%)	48	2,93	1,91	5,06	-	-
ρ_{ap} ($^{kg.m-3}$)	48	2,93	1,91	5,06	-	-
f_{c0} (MPa)	48	4,90	4,73	15,24	2317,10	10,00
MOR (MPa)	12	4,90	4,88	115,03	2390,73	10,00
f_{c90} (MPa)	6	4,95	4,97	9,99	2463,81	10,00
f_v (MPa)	6	5,01	-	5,01	2510,22	2,50
$\rho_{bás}$ ($^{kg.m-3}$)	12	3,01	2,08	5,03	-	-
ΔV (%)	12	3,01	2,08	5,03	-	-

*measured in the direction of the grand. U: moisture content; ρ_{ap}: apparent density; f_{c0}: compressive strength parallel to the grand; MOR: bending rupture module; f_{c90}: normal compressive strength to the grand; f_v: shear resistance parallel to the great; $\rho_{bás}$: basic density; ΔV: volumetric variation. Source: The authors.

Initially, the CPs intended to determine the moisture content and apparent density had their dimensions measured through an analog caliper STORM. The PCs were introduced into a Lucademia drying oven, model 80/100, and were subjected to a temperature of 103 ± 2º C. The masses were measured with the aid of a Bel precision scale, model S622, until a mass variation of less than or equal to 0.5% between two consecutive results was obtained, accordance with the methodology set out in Annex B to ABNT NBR 7190-3:2022. For the measurement of basic density and volumetric variation, annex B of the ABNT NBR 7190-3:2022 standard was used, and the same instruments and equipment were used, and the PCs were immersed in water for a period that allowed to obtain a mass variation of less than or equal to 0.5% between two consecutive results, and then this volume was saturated.

For the determination of the mechanical properties of paricá wood, namely the compressive strength parallel to the great, shear strength parallel to the great, normal compressive strength to the grand, modulus of elasticity to the compression parallel to the grain, bending modulus and modulus of elasticity in the bending, a universal machine INSTRON EMIC 23-100 was used, with its accessories originally intended for the performance of each test. The test methodologies are prescribed in Annex B of ABNT NBR 7190-3:2022, and the loading rates presented in Table 1 were used.

In the case of burrows that were randomly obtained from the storage yard of the aforementioned plywood company, the homogeneity of the results obtained was investigated. Thus, to verify whether there is statistical difference between the values of moisture content, apparent density, compressive strength parallel to the great, bending resistance modulus (MOR) and modulus of bending elasticity (EOM) obtained for the 1, 2, 3 and 4, Tukey tests were performed. For the compressive strength parallel to the grand, the Coefficients of Variation were also analyzed, according to the standard ABNT NBR 7190-3:2022, to verify the homogeneity of the lot.

3 RESULTS AND DISCUSSION

3.1 PHYSICAL CHARACTERIZATION

Table 2 presents the results regarding the moisture content and apparent density for the four tins, as well as the basic density and volumetric variation for the fifth course. The mean values of moisture content of the four tass presented values between 10.12% and 10.72%. To verify the homogeneity of the results, the Tukey test presented in Table 3 allows us to affirm that there is no statistical difference between the moisture contents obtained for the four tass. This fact can be explained by the fact that the four toras were stored in the same place (LEMATCON), being protected from the incidence of rainfall because it is an indoor environment of a building.

For Tora 5, an average value of 12.28% was found, since the CPs of this tora were tested later, during the month of December 2021, and, according to Climatempo (2022), it is a month with high rainfall and, consequently, the moisture content of the wood tends to increase. In any case, the moisture content of the wood analyzed falls under moisture class 1 of ABNT NBR 7190-1:2022 - *Wood Structures Project. Part 1: Sizing criteria*, since the average moisture content of the five tins was 11.33%.

This moisture content value allows bonding with adhesives used in the manufacture of paricá plywood (Matos et al. 2019). On the other hand, considering the moisture content obtained and the variation of relative humidity throughout the year in the production region of the plywood panels analyzed (Silva et al. 2019), especially during the rainy season, it may cause significant wood swelling and retraction to occur.

Table 2. Results of the physical properties of paricá wood.

	Tora 1		**Tora 2**		**Tora 3**		**Tora 4**		**Tora 5**	
	U (%)	**ρ_{ap} ($kg.m^{-3}$)**	**U (%)**	**ρ_{ap} ($kg.m^{-3}$)**	**U (%)**	**ρ_{ap} ($kg.m^{-3}$)**	**U (%)**	**ρ_{ap} ($kg.m^{-3}$)**	**$\rho_{bás}$ ($kg.m^{-3}$)**	**ΔV (%)**
#CPs	12		12		12		12		12	
Maximum	10,63	268,37	11,26	297,13	10,87	295,22	10,56	342,08	249,69	10,75
Average	10,12	247,24	10,72	258,51	10,39	261,87	10,29	334,65	236,42	8,75
Minimum	9,59	229,62	10,38	233,78	9,62	231,28	9,89	324,69	220,67	8,12
CV (%)	3,19	4,72	2,32	6,11	3,77	8,84	2,14	1,53	4,24	7,73

nº CPs: number of specimens; CV: Coefficient of variation; : Moisture content; Uρ_{ap}: Apparent density; : Basic density; : Volumetric variation. $\rho_{bás}$ΔVSource: The authors.

Table 3. Tukey test at 5% probability level for moisture content.

	$\overline{U_1}$	$\overline{U_2}$	$\overline{U_3}$	$\overline{U_4}$
$\overline{U_1}$	-	0,330	0,263	0,170
$\overline{U_2}$	-	-	0,327	0,328
$\overline{U_3}$	-	-	-	0,093
$\overline{U_4}$	-	-	-	-

$\overline{U_1}$, , and : averages of the moisture contents of the snares 1, 2, 3 and 4, respectively; results below 0.331 indicate non-significant differences for the 5% probability level. Source: The authors$\overline{U_2 U_3 U_4}$

The lowest value found for apparent density was 229.62 kg.m-3, the highest being equal to 342.08 kg.m-3 and the average of the four tass at 275.57 kg.m-3. To verify the homogeneity of the results in relation to the apparent density of the snares 1, 2, 3 and 4, a Tukey test with 5% significance was also performed (Table 4). As it is possible to verify in the results obtained, only the 4th presented significant divergences for the other shallows. The difference in apparent densities may be directly related to the tree's growth conditions or to the positioning in relation to the trunk from which the log was extracted. However, despite the divergence given by the Tukey test, the wood sample analyzed does not exceed the value of 550 kg.m-3, which is the maximum apparent density limit for low density wood (Silva, Vale and Miguel, 2015).

Table 4. Tukey test at the 5% probability level for apparent density.

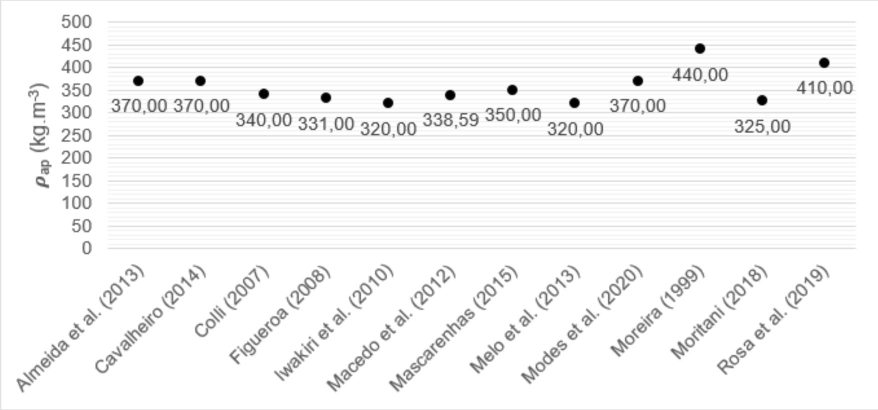
	$\overline{\rho_{ap1}}$	$\overline{\rho_{ap2}}$	$\overline{\rho_{ap3}}$	$\overline{\rho_{ap4}}$
$\overline{\rho_{ap1}}$	-	11,276	14,630	87,414
$\overline{\rho_{ap2}}$	-	-	3,354	76,138
$\overline{\rho_{ap3}}$	-	-	-	72,784
$\overline{\rho_{ap4}}$	-	-	-	-

$\overline{\rho_{ap1}}$, , and : averages of the apparent densities of the sands 1, 2, 3 and 4, respectively; results below 16.84 indicate non-significant differences for the 5% probability level. Source: The authors.$\overline{\rho_{ap2}\rho_{ap3}\rho_{ap4}}$

Regarding the results obtained for the apparent density, according to Dias (2018), the wood analyzed is low density, which corroborates the statements of Melo and Del Menezzi (2014), in which paricá wood is a light wood and low density, and its density is less than 400 kg.m-3. Compared to other studies of physical characterization of paricá wood, Figure 1 presents the values obtained in the analyzed bibliography. It is possible to verify that the mean value obtained in this study (275.57 kg.m-3) is lower by about 37.37% compared to Moreira's work (1999) and 13.88% lower than the work of Melo et al. (2013). In general, the wood analyzed in the present study is below the average of the results obtained by the other studies.

According to Silva et al. (2020), the apparent density is directly related to the thicknesses of the cell walls of wood, which, in turn, vary according to the tree's growth conditions, such as: soil quality, sun exposure and rainfall (Rocha, 1994). On the other hand, Terezo et al. (2015) report that the age of the wood analyzed (5 years) may also be the basis of the difference analyzed, since the authors report that the apparent density presents a proportionality in relation to the age of the cells. The same authors report that the relationship between age and wood density is difficult to determine, because of tree growth conditions. Thus, the apparent densities presented mean values of 327.99 kg. $^{m-3}$ for 6 years, 347.47 kg. $^{m-3}$ for 10 years, 272.87 kg. $^{m-3}$ for 19 years and 296.26 kg. m-3 for 28 years.

Figure 1 - Results of apparent density of paricá obtained in the bibliography.

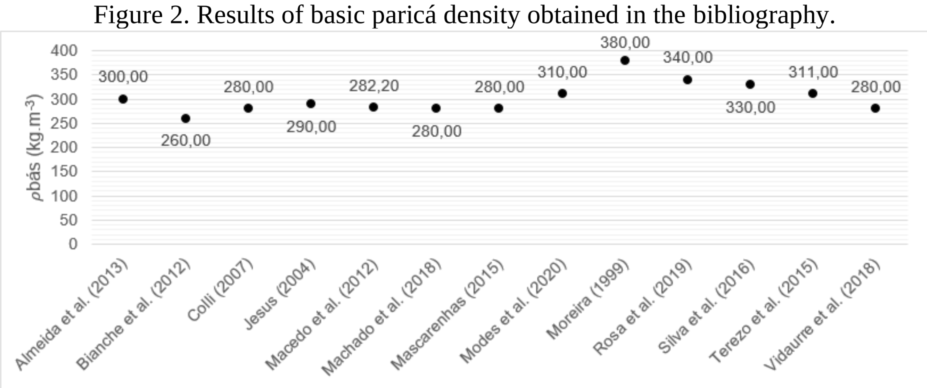


Source: The authors

Since the five loggings were obtained simultaneously and from the same planting site, in addition to the fact that the moisture content of the sample is characterized as class 1, the apparent density belongs to the low density wood class, combined with the organoleptic properties (color, texture, density, hardness and wood designs) of the five timbers being equal, it was considered that the results obtained and presented in Table 2 are representative for the five tins. Therefore, the 5 thum, obtained the average value of the basic density of the lot of 236.42 kg.m-3, the minimum value of 220.67 kg.m-3 and the maximum of 249.69 kg.m-3.

Compared to other studies of physical characterization of paricá wood, Figure 2 presents the values of basic density obtained in the analyzed bibliography. It is possible to verify that the mean value of basic density obtained in this study (236.42 kg.m-3) is lower by about 37.78% compared to moreira's (1999) and 9.07% in relation to the work of Bianche et al. (2012). The mean basic density of the studies in Figure 2 is 301.78 kg.m-3, so the wood used in this study was below the average of the results obtained by the other studies. In the same way that it was reported for the apparent density, the justification for the fact that the basic density is lower than the average of the studies present in Figure 2 is in the conditions of tree growth, age at the time of cutting and positioning of the sample in the trunk.

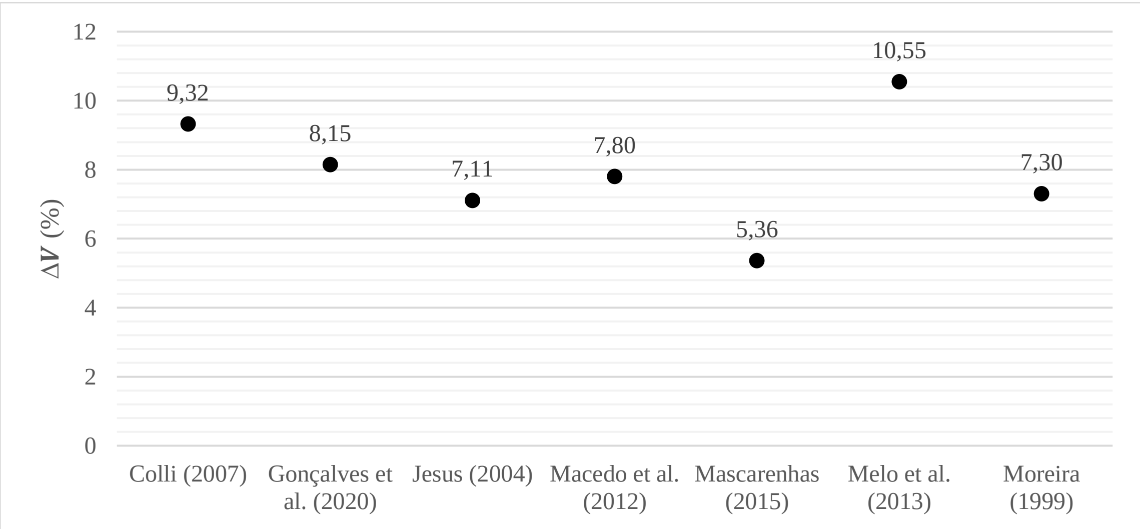
Figure 2. Results of basic paricá density obtained in the bibliography.



Source: The authors

Regarding the volumetric variation, values equal to 8.12%, 8.75% and 10.75% were found, respectively, the minimum, average and maximum. The wood analyzed in the present study presents values of volumetric variation that fit the data interval between the values of Mascarenhas (2015) and Melo et al. (2013), being, respectively, equal to 5.36% and 10.55%. It is possible to verify that the mean value obtained in this study (8.5%) is lower in about 17.01% compared to the work of Melo et al. (2013) and 63.25% higher than the work of Mascarenhas (2015). The mean volumetric variation values obtained in this study (8.75%) are above the average of the results obtained by the other studies presented in Figure 3, being equal to 7.94%. Despite being close to the average, the fact that the volumetric variation is superior may be related to the place of removal of The PCs in the trunk of the tree, since Oliveira, Tomazello and Fiedler (2010) report that the retratibility of the wood increases with the distance from the medulla, measured in the radial direction of the wood, regardless of the growing conditions and age of the tree.

Figure 3. Results of volumetric variation of paricá obtained in the bibliography.



Source: The authors

Gil et al. (2018) and Oliveira, Tomazello and Fiedler (2010) highlight that the study of volumetric variation is relevant, since it is closely related to the emergence of drying defects. In the study conducted by Oliveira, Tomazello and Fiedler (2010), in which the retractability of wood of seven *species of Eucalyptus spp was evaluated.* , a minimum volumetric variation of 15.9% was observed for *Eucalyptus grandis and* a maximum of 27.2% for *Eucalyptus paniculata*. As it is known, the low dimensional stability observed for these eucalyptus subspecies is related to the frequent appearance of drying defects.

Thus, taking into account the values of minimum volumetric variation obtained by Oliveira, Tomazello and Fiedler (2010) and for the species studied in this study (8.12%), it is possible to affirm that the probability of drying defects is lower for the paricá species, and this aspect is more interesting from the point of view of the structural application of this wood in buildings, in addition to its incorporation into plywood panels.

3.1 Mechanical characterization

As already mentioned, the mechanical characterization of paricá wood consisted of the experimental determination of the resistances to parallel and normal compression to the great, shear resistance parallel to the great, bending resistance, in addition to the stiffness to compression parallel to the grain and flexion. The results of the mechanical characterization are present in Table 5, which shows the minimum, maximum, average, characteristic and coefficient of variation for the compressive strength parallel to the total (f_{c0}) for the moisture content presented in 3.1.

It is possible to verify that the lowest value obtained for the compressive strength parallel to the grand, was 12.57 MPa, while the highest value was 26.63 MPa. The mean value of the four taints was 20.36 MPa and the characteristic values for compressive strength parallel to the total varied between 14.84 MPa and 23.02 MPa. The characteristic value for the four lores, considering the reference moisture content of 12%, corrected by the expression present in item 6.2.1 of the ABNT NBR 7190-3:2022 standard, was 15.55 MPa.

Table 5. Results of compressive strength parallel to the grain of paricá wood.

	Tora 1	**Tora 2**	**Tora 3**	**Tora 4**
	f_{c0} (MPa)	**f_{c0} (MPa)**	**f_{c0} (MPa)**	**f_{c0} (MPa)**
#CPs	12	12	12	12
Maximum	21,63	26,63	20,14	25,55
Average	18,47	22,11	17,47	23,39
Minimum	14,70	15,90	12,57	19,17
CV (%)	10,97	14,00	12,62	7,22
Characteristic values	16,07	17,60	14,84	23,02

nº CPs: number of specimens; CV: Coefficient of variation; : compressive strength parallel to the grandf_{c0}.
Source: The authors.

To verify the homogeneity of the results of the 1, 2, 3 and 4, a Tukey test with 5% significance was performed and the coefficient of variation was calculated. C f_{c0}it was reported that the Tukey test (Table 6) only confirmed the homogeneity of the results between the 1st and 3rd and, concomitantly, between the 2nd and 4th. The coefficient of variation (Table 7) revealed that all results are below the value of 18%, indicated by the ABNT NBR 7190-3:2022 standard as the reference below which can be considered to be a homogeneous lot.

Table 6. Tukey test at 5% probability level for compression strength parallel to the grand.

	$\overline{f_{c0_1}}$	$\overline{f_{c0_2}}$	$\overline{f_{c0_3}}$	$\overline{f_{c0_4}}$
$\overline{f_{c0_1}}$	-	3,634	1,005	4,915
$\overline{f_{c0_2}}$	-	-	4,639	1,281
$\overline{f_{c0_3}}$	-	-	-	5,920
$\overline{f_{c0_4}}$	-	-	-	-

$\overline{f_{c0_1}}$, , e : averages of the results of the compressive strengths parallel to the mains of the snares 1, 2, 3 and 4, respectively; results below 2,530 indicate non-significant differences for the 5% probability level. Source: The authors.$\overline{f_{c0_2} f_{c0_3} f_{c0_4}}$

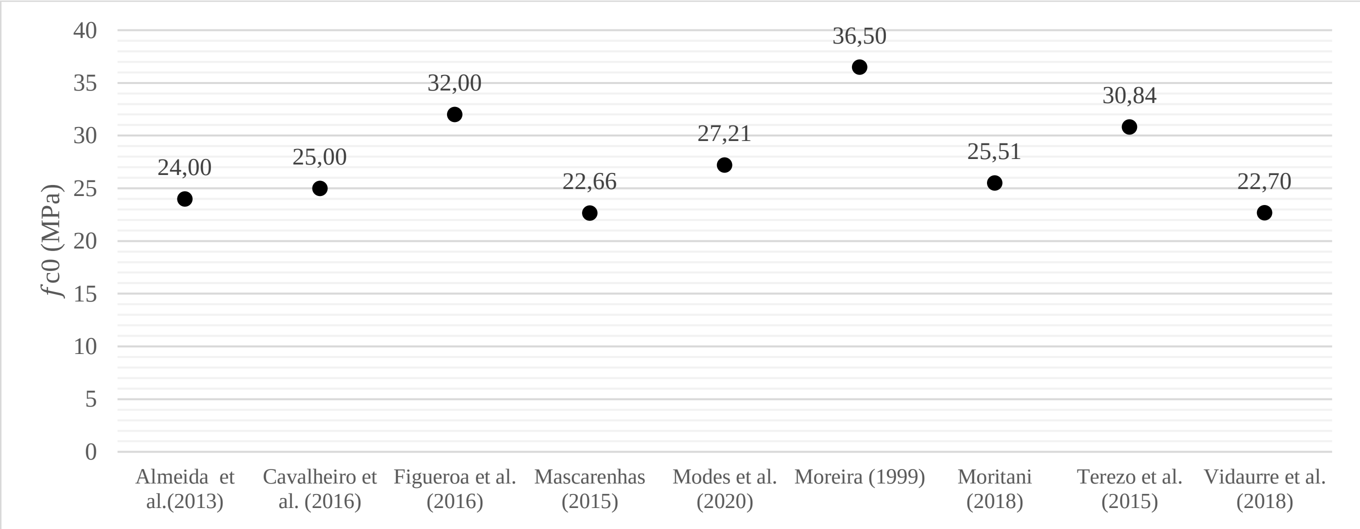
Table 7. Coefficient of variation between the compressive strengths parallel to the grand of the four tins.

	$CV_{f_{c0_1}}$	$CV_{f_{c0_2}}$	$CV_{f_{c0_3}}$	$CV_{f_{c0_4}}$
$CV_{f_{c0_1}}$	-	15,58%	11,87%	14,83%
$CV_{f_{c0_2}}$	-	-	17,88%	11,10%
$CV_{f_{c0_3}}$	-	-	-	17,53%
$CV_{f_{c0_4}}$	-	-	-	-

$CV_{f_{c0_1}}$,,e : coefficients of variation referring to the compressive strengths parallel to the large of the lines 1, 2, 3 and 4, respectively. Source: The authors.$CV_{f_{c0_2}}$ $CV_{f_{c0_3}}$ $CV_{f_{c0_4}}$

Figure 4 shows the comparison of the results obtained in this study with the other studies that involved the study of compressive strength parallel to the great of paricá wood. All mean values found in the literature were higher than the mean value found in this study. The mean compressive strength parallel to the total observed in this study for the four tins (20.36 MPa) is about 25.64% lower than the overall average of all values found in the literature.

Figure 4. Mean values of compressive strength parallel to great present in the literature.



Source: The authors.

In Table 8, it is possible to find the maximum, average, minimum and coefficient of variation values for bending or modulus of rupture (MOR) and the modulus of elasticity in flexion (MoE). Mor values ranged from 20.34 MPa to 36.34 MPa, and the mean values of each tora ranged from 22.29 MPa to 27.39 MPa. The Values of the EOM varied between 5405.09 MPa and 7015.86 MPa, and the mean values varied between 5757.22 MPa and 6362.86 MPa.

Table 8. Results related to bending strength and modulus of elasticity in the bending of paricá wood.

	Tora 1		**Tora 2**		**Tora 3**		**Tora 4**	
	MOR (MPa)	**MOE (MPa)**	**MOR (MPa)**	**MOE (MPa)**	**MOR (MPa)**	**MOE (MPa)**	**MOR (MPa)**	**MOE (MPa)**
#CPs	3	3	3	3	3	3	3	3
Maximum	25,22	6382,25	36,34	7015,86	27,40	6054,98	32,51	6554,67
Average	22,29	5975,17	27,16	6362,86	26,80	5757,22	27,39	6088,28
Minimum	20,34	5519,75	21,86	5709,56	26,11	5405,09	24,46	5688,50
CV (%)	11,59	7,25	29,38	10,27	2,41	5,70	16,24	7,18

nº CPs: number of specimens; CV: Coefficient of variation; : bending resistance; MORMOE: modulus of elasticity in bending. Source: The authors.

To verify the homogeneity of the MOR and MoE results for the bending assay, a Tukey test with 5% probability was performed (Table 9). Consequently, the results presented in Table 9 allow us to infer that the four bells do not present statistically relevant differences for the MOR and the EOM. Thus, it is possible to admit that the results obtained for the four plots constitute representative values of a homogeneous lot.

Table 9. Tukey test at 5% probability level for MOR and MoE.

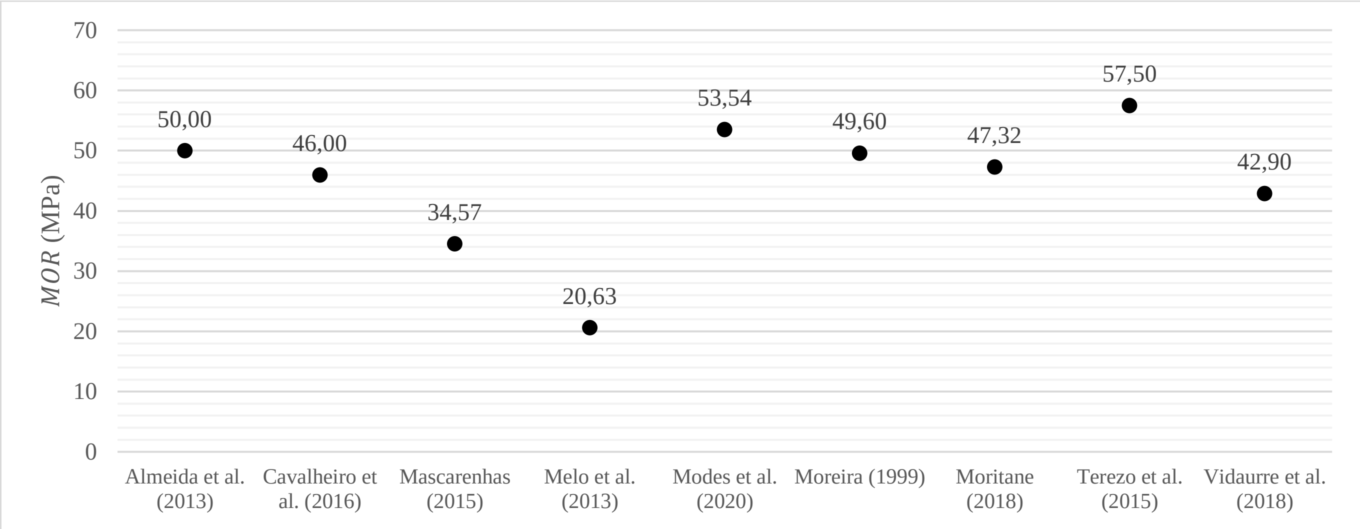
	Tora 1		**Tora 2**		**Tora 3**		**Tora 4**	
	$\overline{\textbf{MOR}}$	$\overline{\textbf{MOE}}$	$\overline{\textbf{MOR}}$	$\overline{\textbf{MOE}}$	$\overline{\textbf{MOR}}$	$\overline{\textbf{MOE}}$	$\overline{\textbf{MOR}}$	$\overline{\textbf{MOE}}$
Tora 1	-	-	4,864	387,691	4,507	217,946	5,100	113,111
Tora 2	-	-	-	-	0,357	605,637	0,236	274,580
Tora 3	-	-	-	-	-	-	0,593	331,057
Tora 4	-	-	-	-	-	-	-	-

$\overline{\text{MOR}}$ e : means of bending strength and modulus of elasticity in bending, respectively; results below 12,446 to and below 1249,539 to indicate non-significant differences for the 5% probability level. Source: The authors.$\overline{\text{MOEMORMOE}}$

Figure 5 presents the results found by other authors for the bending resistance of the paricá. It is possible to verify that the mean value obtained in this study (23.73 MPa) is lower by about 58.73% compared to the work of Terezo et al. (2015) and 15.03% higher than the work of Melo et al. (2013). In general, the bending strength of the wood analyzed in the present study is below the average of the results obtained by the other studies, although the correction was not made as a function of the moisture content (from 11.33% to 12%), according to item 5.6.1 of the ABNT NBR 7190-1:2022 standard. If this correction were performed, the MOR value would be less than 23.73 MPa, given the negative influence of the increase in wood moisture content on mechanical properties, for values below the Fiber Saturation Point (comprised in a range of about 25% to 30%).

The fact that the mean value of the MOR is below the mean of the results of the research bibliography corroborates the tendency of the plot of wood analyzed to present lower physical and mechanical properties. Since the anatomical structure of the wood is at the base of the physical and mechanical properties of the wood, consequently these present relationships with each other. An example of this is the work of Christoforo et al. (2020), which presents relationships between hardness and apparent density (physical property), compressive strength parallel to fibers and MOR (mechanical properties). Thus, with lower values of physical properties, compared to bibliography, it is expected that the resistance properties also present lower results.

Figure 5. Values of the literature for the mean value of the bending resistance of the paricá.

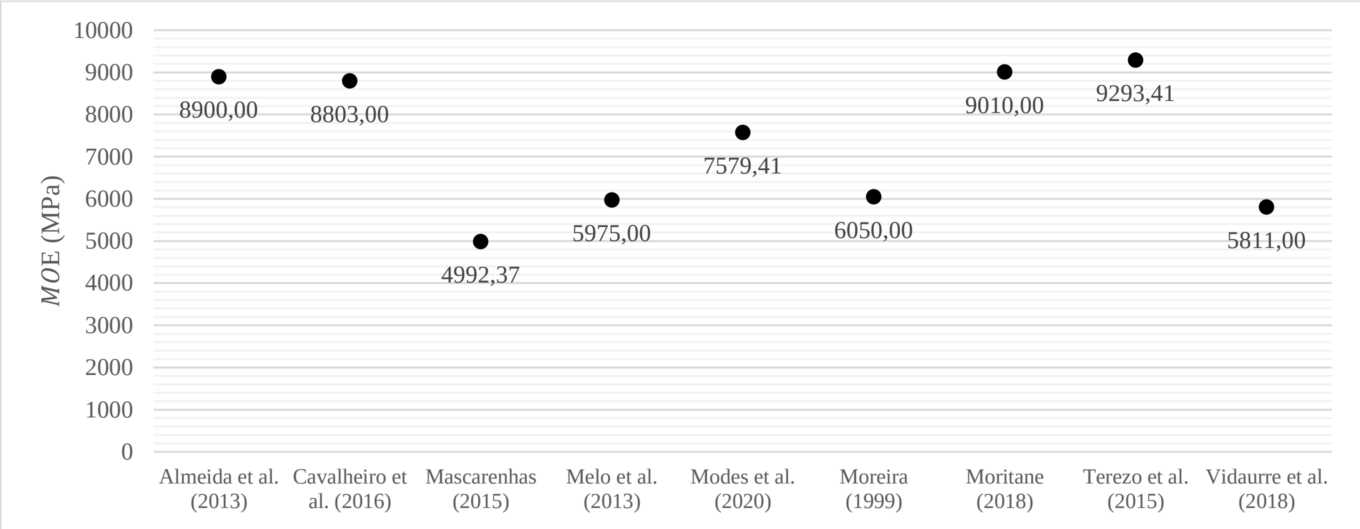


Source: The authors

Compared to other mechanical characterization studies of paricá wood, Figure 6 presents the Values of the EOM obtained in the analyzed bibliography. It is possible to verify that the mean value obtained in this study (5796.35 MPa) is lower by about 37.63% compared to the work of Terezo et al. (2015) and 16.10% higher than the work of Mascarenhas (2015). In general, the modulus of elasticity in the bending of wood analyzed in the present study is below the average of the results obtained by the other studies, being only above the value achieved by Mascarenhas (2015).

Just as the MOR obtained for the sample analyzed in this study is below the average of the results, the EOM will also follow this trend, since there are, for fletidas parts, relationships between stiffness and resistance of fletide parts. Vivian et al. (2012) corroborate this fact, since they report that there is a positive correlation between the MOR and the EOM, having obtained a Pearson coefficient of 0.85 for a sample of *eucalyptus cloeziana wood pieces*. In addition, França et al. (2021) also presented positive correlations between the MOR and the EOM, whose coefficients of determination R^2 varied between 0.60 and 0.69, when they analyzed pine wood (*pinus spp.*) from plantations in the United States of America.

Figure 6. Values of the literature for the mean value of the modulus of elasticity to the bending of the paricá.



Source: The authors

As it was possible to verify through the Tukey tests and for the coefficients of variation for the compressive strength parallel to the great, MOR and MoE of the plots 1, 2, 3 and 4, it is possible to say that these make up a homogeneous lot. Since the 5th tora was also obtained in conjunction with the four aforementioned toras and, given the fact that it was extracted from the same planting site and stored under the same conditions, it was assumed that the test CPs of shear resistance resistance parallel to the great, normal compression to the great and modulus of elasticity to the compression parallel to the great, are also representative for any lot.

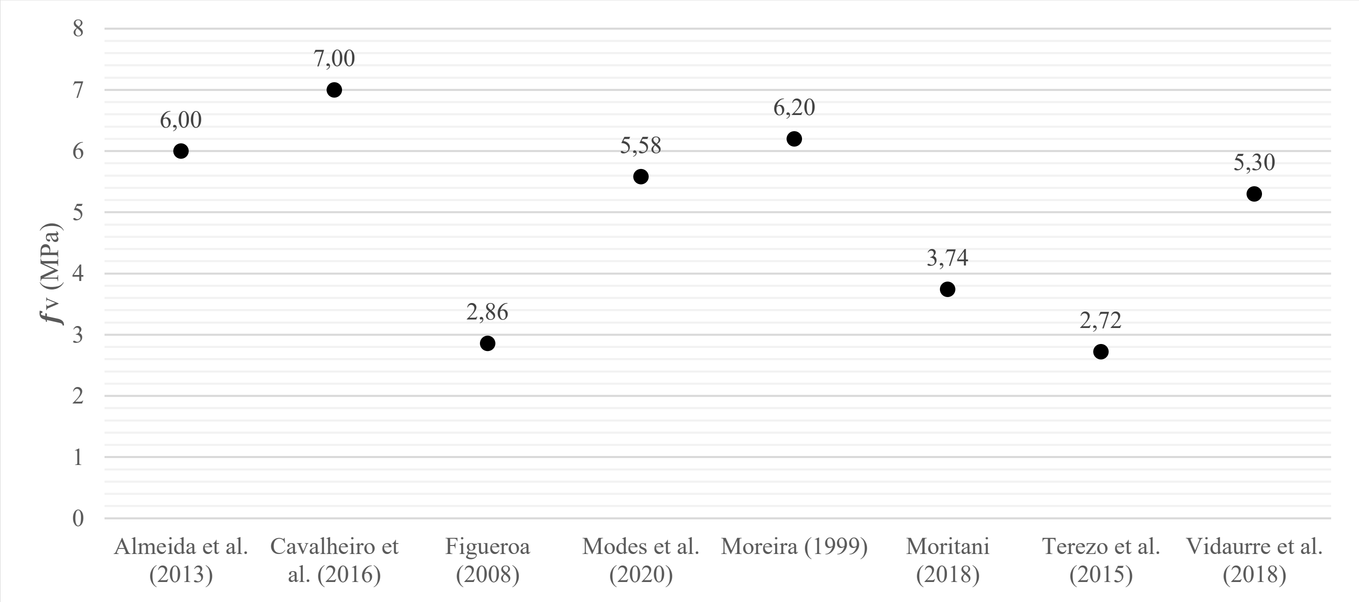
The results of the normal compression test at the grand, shear parallel to the great and the modulus of elasticity to the compression parallel to the great, obtained from the PCs from the 5th, are present in Table 10. The mean value of normal compressive strength to the grand was 1.29 MPa, while the characteristic value was 1.25 MPa. For shear resistance parallel to the total, an average value of 4.00 MPa and a characteristic value of 3.46 MPa were observed. For the modulus of elasticity to compression parallel to the great, an average value of 7358.90 MPa was found. It should be noted that the values obtained for the 5th tora were found in a context of average moisture content equal to 12.28%.

Table 10. Mechanical properties of Tora 5.

	f_{c90} (MPa)	f_v (MPa)	E_{c0} (MPa)
#CPs	6	6	6
Maximum	1,47	4,46	9694,63
Average	1,29	4,00	7358,90
Minimum	1,14	3,37	5650,61
CV (%)	10,14	10,32	19,69
Characteristic values	1,25	3,46	-

f_{c90}: normal compressive strength to the grand; : shear resistance parallel to the great; : modulus of elasticity to compression parallel to the grand. Source: The authors.$f_v E_{c0}$

Figure 7. Values of the literature for shear resistance parallel to great.



Source: The authors

In their study of physical and mechanical characterization of paricá wood at different ages, Terezo et al. (2015) found an average value of 3.15 MPa for normal compressive strength at 6 years of age. In Vidaurre et al. (2018), an average value of 3.20 MPa was verified for paricá wood at 5 years of age, being higher than the average value found in this study (1.29 MPa).

The wood analyzed in the present study presents values of shear strength parallel to the great that fall within the data range between the values of Cavalheiro et al. (2016) and Terezo et al. (2015), being, respectively, 7.00 MPa and 2.72 MPa. It is possible to verify that the mean value obtained in this study (4.00 MPa) is lower in about 42.86% compared to the work of Cavalheiro et al. (2016) and 47.06% higher than the work of Terezo et al. (2015). The mean value of shear strength parallel to the total obtained in this study (4.00 MPa) is below the average of the results obtained by the other studies presented in Figure 7. The difference in shear strength parallel to the great may be related to the extraction position of the tree trunk (in the longitudinal or radial direction), since, according to Oliveira et al. (2006), the mechanical resistance increases as a function of the distance in the radial direction in relation to the medulla. On the other hand, the wood growth conditions analyzed in this work also justify the lower value of mechanical resistance.

For the modulus of elasticity to compression parallel to the total, the mean value found in this study (7358.90 MPa) is about 0.53% higher than the value found by Almeida et al. (2013) who, working with paricá wood at 10 years of age, found an average value of 7320 MPa for this mechanical property.

The plot of wood analyzed was five years old and presented an average moisture content of 11.33%, being classified in moisture class 1, according to Table 1 of the ABNT NBR 7190-1:2022 standard. As for the apparent and basic densities, mean values of 275.57 $^{kg.m-3}$ and 236.42 kg.m-3 were obtained, respectively, characterizing this wood as low density. The volumetric variation for the paricá wood lot analyzed was 8.12%. The mean compressive strength value parallel to the total was 20.36 MPa, while the characteristic value was 15.55 MPa, and the coefficient of variation value was less than 18%, characterizing the lot as homogeneous. For the bending test, a mean MOR value equal to 25.91 MPa was obtained, while the mean MoE was 6045.88 MPa. The shear strength parallel to the mean total was 4.00 MPa, the normal compressive strength to the mean grand was 1.29 MPa and the mean value of the modulus of elasticity to the compression parallel to the total was 7356.90 MPa.

The volumetric variation and apparent density of paricá wood analyzed were lower than the values obtained by studies involving eucalyptus wood analysis (*Eucalyptus spp.*) used in the manufacture of plywood panels, which shows that the use of this species confers products less susceptible to the appearance of drying defects and lighter. On the other hand, the mechanical performance of plywood panels is influenced by the physical and mechanical properties of the wood used and, since the results obtained in this study were lower – in general – in relation to the results from the bibliography analyzed for the same wood species, it is relevant to consider the possibility of performing actions aimed at improving the production of the raw material, in order to improve the strength and stiffness properties of the paricá wood produced.

4. Conclusion

The lot of paricá wood (*Schizolobium Amazonicum*) presented moisture content in air balance (11.33%), low apparent density (275.57 kg.m-3) and reduced volumetric variation (8.75%), and these properties were below the values presented by the bibliography for woods of similar ages. The mechanical properties analyzed (compressive strength parallel to the great, normal compressive strength to the great, modulus of rupture in the flexion, modulus of elasticity in flexion, shear strength parallel to the great and modulus of elasticity to the compression parallel to the great) also presented values lower than the average of the results obtained in the bibliography.

Thus, the use of paricá wood in plywood panels is a valid alternative, considering that they are light and stable with regard to dimensional variation, when compared with products from eucalyptus wood. However, it is pertinent to carry out actions aimed at improving the mechanical properties of paricá wood, in order to increase the properties of strength and stiffness.

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