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Longitudinal and Radial Variation in *Aspidosperma pyrifolium* Wood Density

Ramona Rodrigues Amaro de Oliveira[1,*], Joana Alice Galdino de Souza[1], Ana Karla Vieira da Silva[1] Márcia Ellen Chagas dos Santos[1], Edgley Alves de Oliveira Paula[1], Rafael Rodolfo de Melo[1]

Abstract
The Caatinga is a biodiversity biome. However, it lacks information about the timber potential of native vegetation. *Aspidosperma pyrifolium* Mart. is a native species with diverse qualities and uses for wood. The quality of wood can be assessed based on its technological properties. Therefore, determining the variability of the main physical parameters of *A. pyrifolium* wood contributes to the diagnosis of its correct use and expands knowledge about plant species from the Caatinga. This research aims to evaluate the physical parameters of *A. pyrifolium* wood and the variation in basic density in the longitudinal and radial directions. Collected material in the Governador Dix-Sept Rosado, Rio Grande do Norte State. Three trees without apparent defects and DBH between 8 cm and 12 cm were felled. Five 10cm thick discs were removed and positioned along the shaft at 0% (base), 25%, 50%, 75%, and 100% of the total height. In the laboratory, the specimens were prepared and divided in the radial direction (next to pith, intermediate, and next to bark) in order to characterize the basic density, moisture content, and porosity. The average density was 0.68 g/cm³, classified as moderately heavy wood, varying in both directions, with no interaction between the factors. A decreasing behavior of basic density was observed in the base-top and pith-to-bark direction. The average results for equilibrium moisture content and porosity were 8.46% and 55.58%, respectively.

Keywords
Physical properties — Caatinga — Wood quality — Basic density

[1] *Federal University of Semi-Arid Region - UFERSA, CEP 59625-900, Avenida Francisco Mota, s/n, Presidente Costa e Silva, Mossoró-RN, Brazil.*
***Corresponding author**: ramona_amaro@hotmail.com

1. Introduction

Aspidosperma pyrifolium Mart. is a non-endemic native forest species of the caatinga, with a significant occurrence in the biome. It belongs to the Apocynaceae family, has a shrub to arboreal size, and is deciduous (Carvalho, 2010). About ecological groups, it is classified as late secondary, has anemochorous dispersion, and individuals with an average height of 8.7 m. The plant's flowering period occurs from October to November and fruiting between August and September (Maragon et al., 2010). The species stands out for its diverse uses. The wood is of excellent quality, as it is moderately heavy, soft, easy to work with, has a thin texture, and is resistant to attack by xylophages and weather conditions that cause deterioration. Due to these factors, *A. pyrifolium* wood is widely used in civil construction and furniture.

Furthermore, because the plant is beautiful and large, it is commonly used in urban landscaping (Lorenzi, 1998). The plant extract from the plant's leaves has antiparasitic properties (Santos, 2010). In the interior of the state of Ceará, people use the bark for medicinal purposes and the wood for producing firewood and charcoal (Silva et al., 2016). The species also has beekeeping interest, thus obtaining the potential to be used in bee culture sites (Oliveira, 2019).

The Caatinga is the predominant biome in the semi-arid region of northeastern Brazil. The regional climate is dry and hot, with low rainfall, high sunshine, and irregular rainfall in space and time, with rainfall concentrated in the first months of the year. Annual averages for precipitation and temperature vary between 400mm to 800mm and 24℃ to 28℃, respectively (Moura et al., 2019). The caatinga is characterized by xerophilic vegetation, mainly composed of deciduous species, shrubs, arboreal individuals, bromeliads, grasses, and cacti. The biome has different physiognomies and a wealth of fauna and flora species (Fernandes, 1992). The Caatinga biome has

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undergone a drastic reduction in native vegetation cover. The process of environmental degradation in the region is mainly caused by the inadequate extractive exploitation of natural resources, both for the use of biomass for energy purposes and for the occupation of areas with crops and livestock (Santana, 2016). Scientific studies on forest species native to the caatinga are incipient when looking for data on wood's anatomical, chemical, and mechanical characteristics. Research is fundamental, as it allows us to understand the potential of wood, add new values and uses, and help minimize illegal extraction.

Among the physical properties, basic density is one of the main parameters that helps determine the suitability of wood, as it has a high correlation with mechanical properties. From a technological point of view, evaluating the variety of this parameter in the tree is essential in the longitudinal (from base to top) and radial (from pith to bark) directions due to the heterogeneity of wood within the same individual (Gonzaga, 2006). Given the above, this work aims to evaluate the average physical parameters of basic density, porosity, and moisture content, in addition to the radial and longitudinal variation of the basic density of *Aspidosperma pyrifolium* Mart wood.

2. Material and Methods

The material used came from a native settlement in Governador Dix-Sept Rosado, Rio Grande do Norte, Brazil. The region has a Semi-arid climate and vegetation consisting of hyperxerophilic caatinga and carnauba forests. The predominant soils are Redzina and Eutrophic Cambisol (IDEMA, 2008). The study was carried out using the *Aspidosperma pyrifolium* Mart forest species. Three trees were felled according to the procedures used to characterize wood according to the ASTM D143-22 guidelines. As the material originates from native forests, it was impossible to define the trees' age.

Two management techniques are applied to the Caatinga biome: clear-cutting (complete felling of trees) is used mainly in energy production, and selective cutting is carried out based on diameter classes or by species to obtain specific products, such as stakes and posts (Rede de Manejo Florestal da Caatinga, 2005). Therefore, the individuals who did not have knots and forks with a diameter at breast height (DBH) between 8cm and 12cm were selected. These were the dimensions chosen in accordance with the Caatinga forest management techniques for selecting trees for civil construction (Instrução Normativa MMA n°1 25/06/2009). Five 10cm thick discs were removed from each tree in the longitudinal direction at 0% (base), 25%, 50%, 75%, and 100% of the height, as seen in Figure 1.

The preparation of samples for physical analysis of

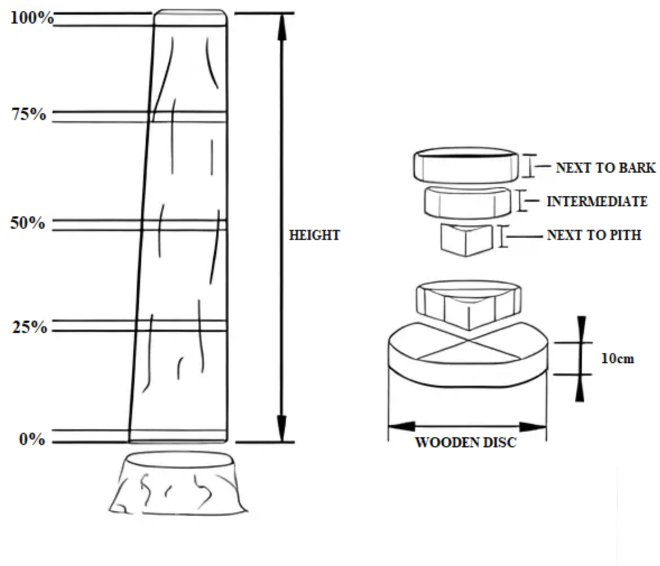

Figure 1. Sampling method for determining the basic density of *A. pyrifolium*.

the wood consisted of removing wedges from ¼ of each disc. Three samples were taken from each fraction in the radial direction (next to pith, intermediate, and next to bark), as seen in Figure 1. The mass of the samples at equilibrium moisture content was measured and then submerged in water for two weeks until stabilized in saturation to realize the volume of the specimens. The saturated samples were weighed, and the volume was determined using the water displacement method, as seen in. Furthermore, the samples were placed in the oven for 48 hours at 105ºC, and upon reaching a constant mass, the specimens were measured to obtain the dry mass. It was possible to obtain data to determine the basic density using the method proposed by Vital (1984), the porosity according to the formula proposed by MacLean (1952), and the moisture content of the wet base, as observed in the equations below.

$$\rho = \frac{Ms}{V} \text{ (Equation 1)}$$

$$TU = \lfloor \frac{(Mtu - Ms)}{Mtu} \rfloor \times 100 \text{ (Equation 2)}$$

$$\varnothing = \left[1 - \frac{\rho}{1{,}54}\right] * 100 \text{ (Equation 3)}$$

Where: ρ = basic density (g.cm^{-3}); Ms = mass loss (g); V = volume (cm^3); Tu = moisture content; Mtu = mass in the equilibrium moisture content (g); ϕ = porosity (%).

In analyzing the results, variance analysis (ANOVA) with a factorial arrangement was used to acquire data on variations in basic density. For this, two factors were evaluated: the longitudinal position with five levels (0%,

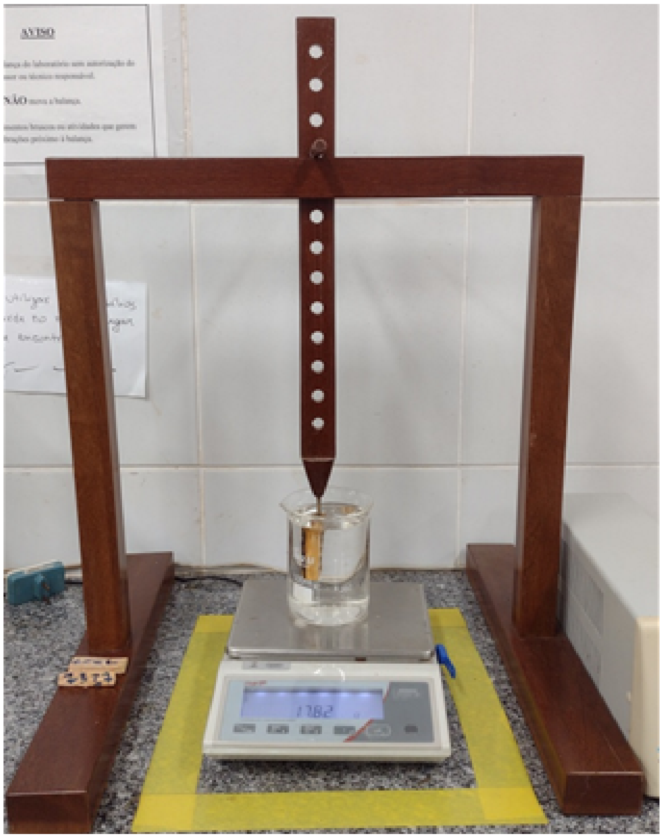

Figure 2. Determination of the volume of *A. pyrifolium* samples using the water displacement method.

25%, 50%, 75%, and 100%) and the radial position with three levels (pith, intermediate, and bark). In analyzing and evaluating data on variations in basic density, the Scott-Knott test was used at 5% significance for the factors, with no significant interaction detected by the F test. The means of basic density, porosity, and moisture content were calculated. There was no statistical analysis regarding porosity and moisture content.

3. Results and Discussion

The average values of the wood properties of *A. pyrifolium* Mart. are described below. For basic density, the average value observed was 0.68g.cm^{-3}, considered by INDEA (2011) as moderately heavy wood. The result differs little from the findings in the literature. Santos et al. (2020) and Carneiro et al. (2013) evaluated *A. pyrifolium* wood from areas under forest management located in the interior of the state of Rio Grande do Norte and found a basic density of 0.63g.cm^{-3} and 0.62g.cm^{-3}, respectively.

Oliveira (2003) identified, for trees from native populations of *A. pyrifolium* located in Patos (Paraíba State), an average basic density of 0.81g.cm^{-3}, a value higher than that observed in the present study. Different values of basic density for the same species may be related to the genotype and edaphoclimatic conditions of the location, which may justify the different values observed between studies since the Caatinga biome presents very irregular rainfall and has different phyto-physiognomies. Another factor influencing this parameter's variation is the tree's age, which is not reported in the present study and both citations (Modes et al., 2019; Moura et al., 2019).

The result of the average equilibrium moisture content was 8.46%. The moisture content in wood has an inverse correlation with density. This behavior may be related to the parameters used to obtain the basic density (saturated volume and dry mass), as increasing the moisture content above the fibers' saturation point increases the wood's mass, resulting in lower parameter values (Candaten, 2018). For average porosity, the value observed was 55.58%. Oliveira (2003) identified small and excessively numerous pores for the species *A. pyrifolium*, with an average of 168 pores/mm².

According to Faria et al. (2018), the more significant number of empty spaces (pores) may represent a disadvantage, as the density will be lower, thus, the mechanical resistance. Table 1 displays the factorial variance analysis regarding the variation in basic density along the stem and the interaction between the factors. From the above, it is possible to observe that the interaction between the factors was insignificant, as it presented values above 0.05. Therefore, the factors were evaluated independently. The different positions of the radial and longitudinal directions affect the basic density of *A. pyrifolium* wood. Batista et al. (2020), when evaluating the longitudinal variations of five Caatinga species, observed behavior like that of the present work, with a significant relationship between the basic density and the longitudinal axis along the stem of *A. pyrifolium*.

Table 1. Variance analysis (ANOVA) for the basic density variable in *Aspidosperma pyrifolium* wood referring to the different positions in the longitudinal and radial direction of the trunk and the interaction between the factors.

Source of variation	Degrees of freedom	Mean Square	P >Fc
Longitudinal	4	0.008552	0.0054*
Radial	2	0.015882	0.0012*
Longitudinal x radial	8	0.000607	0.9504 ns
Error	30	0.001876	
Total	44		
CV (%)	6.33		

*F test significant at 5% probability level, ns not significant.

Table 2 presents the results of the basic density variations that occur in the positions of the tree in different directions. The values observed from the base to the top have a decreasing behavior, in which the base and the 25% position did not obtain statistical differences. These differ statistically from the other positions, demonstrating a constant pattern without significant differences. This trend aligns with the literature for native species of the caatinga. Araújo, Paulo, and Paes (2007), when studying the wood of *Mimosa tenuiflora*, and Gonçalves, Lelis, and Abreu (2010), when characterizing the wood of *Mimosa caesalpiniaefolia*, showed a similar situation with a reduction in basic density towards base-top.

Tichi, Gholamiyan and Divkolae (2021), studying *Parrotia persica* wood, also observed a reduction in basic density along the longitudinal axis with increasing stem height. From assessments of biometric properties, the authors observed that fiber length, fiber diameter, and fiber wall thickness decreased with increasing tree height. The authors report that the results can be explained by the more significant proportions of juvenile wood present in the upper zone of the trunk and the more significant quantities of adult wood present at the base of the stem, which justifies the decrease in basic density along the stem.

Table 2. Variation in the basic density of *A. pyrifolium* wood in different trunk positions in the longitudinal direction.

Longitudinal direction (%)	Basic density (g.cm-3)
0 (Base)	0.731 (± 0.055) a
25	0.699 (± 0.048) a
50	0.662 (± 0.045) b
75	0.672 (± 0.047) b
100	0.657 (± 0.043) b

Means followed by different vertical letters differ statistically by the Scoot-Knott test at the 95% probability level. Standard deviation in parentheses.

Table 3 demonstrates the variations in basic density in the radial direction of *A. pyrifolium* wood. Melo et al. (2006), studying seven woods from the Brazilian semiarid region, identified the variation in basic density in the radial axis for all species evaluated. According to Woodcock and Shier (2002), for hardwood trees, the differences in this parameter in the radial direction of the wood reflect the species' development strategies and successional characteristics. The observed behavior for variations in the radial direction was a reduction in basic density in the pith-to-bark direction.

The highest value of this parameter was in the pith, which differed significantly from the other positions, and the intermediate and bark did not obtain statistical differences. The same pattern was identified by Melo et al. (2007) for native woods from the caatinga - *Schinopsis brasiliensis* and *Tabebuia impetiginosa*, by Candaten et al. (2020) and by Tomislav et al. (2021). According to Eleoterio et al. (2018), this pattern is typical in species of late secondary successional stages with higher values of basic density, characteristics present in *A. pyrifolium*. The authors report that the lower basic density in the shaft's outer positions is related to sapwood, a portion of the wood that still needs to go through the certification process. This explanation may justify the reduced density in the bark and intermediate positions in the present study.

Table 3. Variation in the basic density of *A. pyrifolium* wood in different trunk positions in the radial direction.

Radial direction	Basic density (g/cm³)
Next to bark	0.654 (± 0.041) b
Intermediate	0.680 (± 0.055) b
Next to pith	0.719 (± 0.052) a

Means followed by different vertical letters differ statistically using the Scoot-Knott test at 95% probability. Standard deviation in parentheses.

The basic density of a tree's wood is not homogeneous and can vary along the stem in the radial and longitudinal directions. Variations in basic density throughout the wood do not have a standard behavior. They are the result of several factors, both internal to each individual, such as the genotype, anatomical variations of the constituent elements of the wood, and dimensions of the cell walls, as well as the quality of the site and age of individuals (Cruz, Pio and Iwakiri, 2019; Santos et al., 2013; Melo et al., 2013). Zaque, Ferreira and Melo (2018) state that excessive competition between individuals causes heterogeneity in basic density along the stem. Panshin and De Zeeuw (1980) proposed several models of basic density variation in both directions to assist in analysis.

4. Conclusion

The average basic density of *Aspidosperma pyrifolium* Mart varied in both the longitudinal and radial directions but without interactions. In the longitudinal direction, the highest value was in the base positions, 25% did not differ, and the radial value was in the pith position.

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Author Statements

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- ✓ There is no evidence of plagiarism in this article.

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