WOOD PROPERTIES OF FOUR TROPICAL SPECIES FROM MINING AREAS IN AMAZON, BRAZIL. PART 2: DENSITY, EXTRACTIVES, AND COLOR

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Abstract. The objective of this research was to study the characteristics of four tropical species (*Jacaranda copaia*, *Astronium lecointei*, *Caryocar villosum*, and *Protium altissimum*) stored in different periods. Part 1 of this study described the anatomical features of these species, and Part 2 focused on the physical properties, more specifically density, water-soluble extractives, and color changes along the different times of exposure. Samples were collected from logs exposed for different exposure times (0, 1, 4, 6, and 8 yr of exposure). Changes in the basic density were observed for all four species studied; in *Caryocar villosum* and *Jacaranda copaia*, the changes were highly related to the period of exposure. For extractives content, both in hot and cold water, alternated according to the storage time, being directly proportional in *Jacaranda copaia*. The color of the wood of all species tended to darken with the time of exposure in storage yards, with the species *Astronium lecointei* being the one that showed the greatest variation in color over time.

Keywords: Physical properties, Amazon forest, tropical species.

INTRODUCTION

Commercial mines are commonly located in forested regions, causing the devastation of the natural resources (Hunter 2007; Chu and Karr 2016). Issues related to mining and concern for the environment gained attention at the beginning of the 21st century and have become critical in national and international scenarios related to sustainable development (Vieira and Rezende 2015).

Mining activity in Brazil makes up a significant part of the economy (IBRAM 2015), and this sector has caused intense transformations in Brazil's economic structure and spatial organization (Chaves and Silva 2016).

However, for such activity to occur, it is necessary to remove the vegetation to excavate the soil. Lana (2015) observed that this step produces direct negative effects on the environment and causes the death of animals and possible contamination of abiotic components such as water and soil. The suppression of vegetation usually generates a significant volume of woody material, which usually goes through the packing and subsequent storage stage (Miura 2013), sometimes in open-air storage yards or areas close to the access roads to the site.

The duration of this decomposition process can vary according to the degree of natural resistance to biological attack, which is influenced by the environmental conditions at the site. Silveira et al (2018) mentioned the chemical composition of wood as a determining factor for decomposition and this varies between species and even between cells of the same wood, as well as the presence of extractives, which can inhibit degradation.

Wood is subject to several factors that can accelerate the decomposition process, such as the fungi, insects, and bacteria present at the site and abiotic chemical and physical agents, such as high RH, high solar radiation, thermal variation, and rainfall (Gonzaga 2006; Trevisan et al 2007; Moreschi 2013).

Areas licensed for mining activities under state jurisdiction are subject to law no. 6958 of April 3, 2007, which allows them to use wood from plant suppression for three possible purposes: construction of houses, schools, and clinics for the treatment of chemical dependents. law no. 8515 of June 30, 2017, also allows the commercialization of woody material removed for excavation, through cooperatives, companies, or nonprofit entities. However, these possible receptors sometimes do not have the resources to carry out the transport and transformation of this raw material into a product. This factor often results in wood being left for an extended period in storage yards in the enterprise, providing favorable conditions for biodegradation.

Wood in the process of decomposition will experience loss of mass, changes in chemical composition, color change, and increased permeability (Vivian et al 2014; Leao et al 2017). Wood in this state has a significant reduction in its mechanical properties, and these factors may compromise the quality of the material in future uses.

The difficulty in disposing of forest products from plant suppression results in slow degradation in storage yards instead of being used to produce products (Derivi et al 2016). According to the same author, another factor that could help in the effective utilization of suppressed woody material would be to plan of execution of the vegetal suppression, since this activity involves the cutting, transport, classification of different materials, and subsequent storage.

In Part 1 of this study, the anatomical characteristics of this material were studied. The goal of Part 2 was to examine the effects of different stages of degradation on density, color, and chemical composition. The results will help future decision-making regarding the most efficient use of this material, thus combining economic development with the preservation and conservation of the environment.

MATERIALS AND METHODS

Specimen Collection and Preparation

The species evaluated in this research were Parápará (*Jacaranda copaia* (Aubl.) D.Don); Muiracatiara (*Astronium lecointei* Ducke); Piquiá (*Caryocar villosum* (Aubl.) Pers.); and Breu Barrote (*Protium altissimum* (Aubl.). From each species, logs were obtained from plant suppression for bauxite exploration in Paragominas, Pará, Brazil.

For *Astronium lecointei*, *Caryocar villosum*, and *Protium altissimum*, samples were collected from log piles exposed for 8, 6, 4, 2, or 0 yr (less than a year of exposure). Because of the advanced stage of degradation in *Jacaranda copaia*, it was not possible to obtain sampling after 6 and 8 yr. Anatomical identification was conducted in the field before samples were taken to the laboratory for further anatomical characterization. These results were presented in Part 1 of the study.

Basic Density

For the evaluation of basic density, disks were cut into samples measuring 3 × 4 × 3 cm (transverse × tangential × radial), and this test was conducted following the procedures of NBR 11.941 (ABNT 2003a). A total of 15 replicates per exposure time per species were used.

Water Soluble Extractives Content

For solubility in water, samples from each species were ground in an IKA analytical mill. Then, the fragments obtained from the crushing were classified through 40- and 60-mesh sieves. The sawdust fractions that were retained on the 40-mesh sieve were discarded, and those that were retained on the 60-mesh sieve were used. The evaluation of extractives content in cold and hot water tests was conducted according to NBR 14.577 (ABNT 2003b).

Surface Color Changes

The color parameters were measured using a Konika Minolta camera (model CR-410). A total of 54 samples were fractionated into 60 mesh, and approximately 15 g of each sample was divided into 3 g portions, placed in a Petri dish on a white surface, and imaged. Five images were collected for each sampler, totaling 270 readings. Values of lightness (L), a* chromaticity coordinates red (+) or green (−), and b* chromaticity coordinates yellow (+) or blue (−) were obtained, and equations from Camargos and Gonçalez (2001) were used to calculate chroma (C) and hue angle (h*).

$$C = [(a^*)^2 + (b^*)^2]^{0,5} \tag{1}$$

Where C is the calculated chroma; a* is the chromaticity coordinates red (+) or green (−); and b* is the chromaticity coordinates yellow (+) or blue (−)

$$h^* = \text{tang}^{-1}\left(\frac{b^*}{a^*}\right) \tag{2}$$

where h* is the hue angle; a* is the chromaticity coordinates red (+) or green (−); and b* is the chromaticity coordinates yellow (+) or blue (−).

Additionally, the total color change, ΔE*, was calculated using Eq 3,

$$\Delta E^* = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2} \tag{3}$$

where Δ is the difference between the first and second measurements. Here, L* represents the degree of grayness and corresponds to lightness. The parameter a* represents the red-green axis, whereas b* is a parameter for the blue-yellow axis; ΔL* represents the difference of the degree of grayness and corresponds to lightness; Δa* is the difference in the red-green axis a*; and Δb* is the difference in the blue-yellow axis b*. Both calculations are based on highest to lowest periods of storage.

Statistical Analysis

Means, standard deviations, and coefficients of variation were calculated using the AgroEstat (Barbosa and Maldonado 2015) and IBM SPSS programs.

For the verification of assumptions for the application of the analysis of variance (ANOVA), the data were subjected to the Levene homogeneity of variances and Kolmogorov-Smirnov normality tests, while the independence of the residuals was performed by means of graphical analysis. If assumptions were not met, the Box-Cox transformations were applied to the data, and then the transformed data were used to perform the statistical analysis. However, for easier comprehension of the results, they were presented as nontransformed data.

An F test was performed to detect significant differences between species and storage time. Tukey's tests were performed where significant differences were noted ($\alpha = 0.05$).

In the analysis of the trends of density, extractive contents, and color as a function of storage time, adjustments were fitted to linear and quadratic polynomial regression models for each species. The models were selected based on the significance of the regression model using F tests, coefficients of determination, and residual standard deviation.

RESULTS AND DISCUSSION

Overall Characteristics of Samples Collected

Table 1 shows the average diameters of the logs collected from each species and year. All logs removed from different stockpiles had rough surfaces, with cracks and splits along both the transversal and longitudinal sides, especially in logs with more than 6 yr of storage as shown in Fig 1. The specimens had variations in color, with a darker and grayer tone in the samples from the piles with 8 and 6 yr of storage, probably caused by the direct incidence of sunlight (Figs 1[a] and [b]).

Basic Density

Table 2 shows the descriptive statistics and means comparison of basic density among the four species studied. *Jacaranda copaia* had the lowest mean basic density, which can be a consequence of the dimensions of the cellular elements such as vessel, and thicker fiber lumens, resulting in thinner cell walls and, consequently, lower density as shown in Part 1 of the study.

As stated by Panshin and de Zeeuw (1980), basic density is a characteristic resulting from the interaction between the chemical and anatomical properties of wood. Therefore, the variations can be caused by differences in cell dimensions, the interactions between these elements, the variation in the chemical components, and the position in the wood.

The basic density of the analyzed species should decrease with increasing storage time, which did not occur continuously and gradually (Fig 2). This can be explained by the fact that the samples

Table 1. Diameter of logs collected in the field.

Species	2009	2011	2013	2015	2017	Mean (cm)
Jacaranda copaia	—	—	65 cm	75 cm	64 cm	68
Protium altissimum	74 cm	81 cm	93 cm	83 cm	75 cm	81
Caryocar villosum	160 cm	91 cm	87 cm	126 cm	166 cm	126
Astronium lecointei	60 cm	68 cm	72 cm	65 cm	70 cm	67

Figure 1. Logs piling under different periods of exposure: (a) 8 yr; (b) 6 yr; (c) 4 yr; (d) 2 yr; and (e) 0 yr of exposure.

were obtained from different trees with different diameters. Density variations can occur between different species, within the same species, or even in the same individual (Lira 2016; Schmit 2017). Trees with larger diameters are often associated with older trees, but trees can also differ depending on site conditions. According to Silva and Oliveira (2003), the age of the plant influences the variation

Table 2. Mean values for density (g/cm^3) of each species as a function of storage time.

Years of exposure	*Protium altissimum*	*Caryocar villosum*	*Astronium lecointei*	*Jacaranda copaia*
0	0.68^{a}	0.68^{b}	0.70^{ab}	0.29^{a}
2	0.71^{a}	0.67^{b}	0.66^{b}	0.32^{a}
4	0.72^{a}	0.65^{b}	0.78^{a}	0.31^{a}
6	0.69^{a}	0.76^{a}	0.73^{ab}	—
8	0.73^{a}	0.72^{ab}	0.67^{b}	—
Overall average	0.70	0.70	0.71	0.31
CV (%)	9.06	9.39	14.04	34.35
Source (Melo and Camargos 2016)	0.74	0.63	0.79	0.31

Means with the same letter designation are not significantly different ($p > 0.05$).

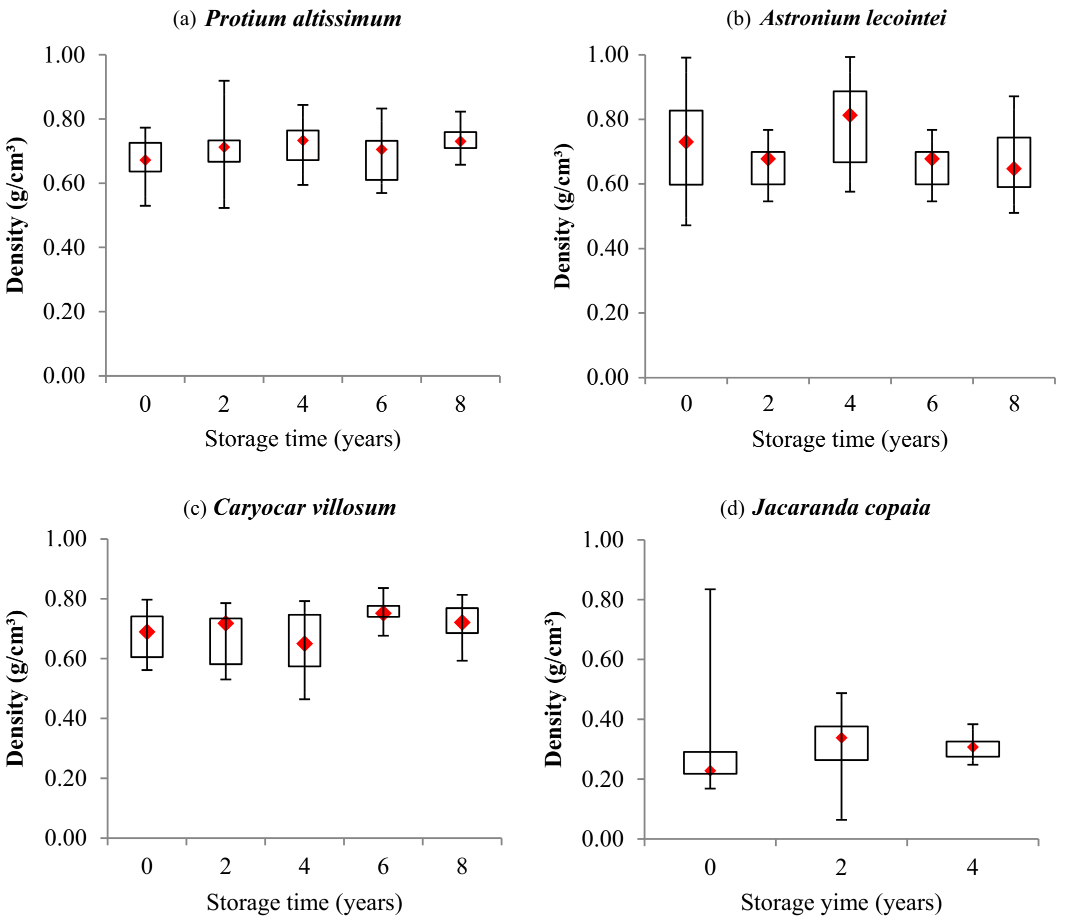

Figure 2. Mean values of density in a function of storage time: (a) *Protium altissimum*, (b) *Astronium lecointei*, (c) *Caryocar villosum*, and (d) *Jacaranda copaia.*

of the dimensions of the trees, and consequently, the basic density of wood.

Except for *Caryocar villosum*, the studied species presented values of basic density (considering the year 0 of stacking) lower than that reported in the literature. This fact may be associated with samples from different trees with different diameters and ages.

The relationships between the basic density and the storage time are shown in Table 3. The regression analysis was only statistically significant for *Caryocar villosum* and *Astronium lecointei* wood.

Table 3. Regression equations for density in the studied species.

Species	Equations	R^2	p
Protium altissimum	Not significant	—	>0.05
Caryocar villosum	$y = 0.66 + 0.01x$	0.33	0.006
Astronium lecointei	$y = 0.68 + 0.03x - 0004x^2$	0.32	0.030
Jacaranda copaia	Not significant	—	>0.05

For *Caryocar villosum*, the coefficient of determination (R^2) for the polynomial regression was 0.33, indicating that 33% of the variation of the dependent variable, density, in *Caryocar villosum* is explained by the model. Basic density in *Caryocar villosum* of the wood tended to increase with the time of storage, indicating that the factor "time" tends to interfere with the density of the wood. This result can also be related to the difference in the diameters of the samples collected since the samples with 8 yr of storage correspond to larger values of diameters (160 cm).

For *Astronium lecointei*, a variation in the basic density of the wood was observed, with values oscillating throughout the sampling period, with a tendency to decrease as the storage time increased. The R^2 for the polynomial regression in *Astronium lecointei* was 0.32, showing that the model explains 32% of the variation in density due to storage time. The models for *Protium altissimum* and *Jacaranda copaia* were not statistically significant.

Extractives Content

Extractives are commonly related to the natural durability of wood, being phenolic and polyphenolic in character, and they accumulate in resin canals, parenchyma cells, lumens, and cell walls, resulting, in most cases, in a dark coloring of the heartwood (Fengel and Wegener 1989; Oliveira et al 2005), following this line of reasoning, darker colored woods can be considered more resistant than lighter colored woods.

This difference in color can be observed in *Protium altissiumum* and *Astronium lecointei*, which has a distinction between heartwood and sapwood (observing darker coloration in the heartwood), and it was not observed in *Jacaranda copaia* and *Caryocar villosum*, which have lighter coloring. However, despite having a light color, *Caryocar villosum* showed the highest extractive values, both in hot and cold water.

It can be seen in Table 4 that the levels of water-soluble extractives (hot and cold) showed significant regressions (except in *Protium altissimum*—hot water) for all species analyzed. Table 5 shows the average solubility values in hot and cold water for the four species studied as a function of storage time by Tukey's test at 5% probability.

Regarding the extractive content in hot water, it was observed that there is a tendency to increase the value, according to the increase in the storage time in *Jacaranda copaia*. The opposite was observed in *Caryocar villosum*, while for *Astronium lecointei* the values fluctuated as the storage time increased, with a higher value being found with 8 yr of storage in relation to the beginning of the storage period, as shown in Fig 3.

Regarding the extractives soluble in cold water, in the four analyzed species, variation of the contents was observed during the storage time. In *Caryocar villosum,* there is a tenuous tendency to reduce the contents as the storage time increases. The behavior of *Protium altissimum* and *Astronium lecointei* was similar, showing a decrease with 4 yr of storage and a subsequent increase, the proportion that increases the storage time of the wood. The same model was observed in *Jacaranda copaia*. However, the increase of the extractive contents in the longest storage period was more pronounced, as can be seen in Fig 4.

Table 4. Regression analysis for extractives content.

Variables	Species	Equation	R^2	p
Hot water extracts (%)	*Protium altissimum*	Not significant	—	>0.05
	Caryocar villosum	$y = 7.93 + 1.10x - 0.18x^2$	0.87	0.006
	Astronium lecointei	$y = 7.46 + 0.30x - 0.03x^2$	0.08	0.004
	Jacaranda copaia	$y = 6.07 + 0.53x$	0.95	<0.0001
Cold water extract (%)	*Protium altissimum*	$y = 8.36 - 1.52x + 0.17x^2$	0.78	0.001
	Caryocar villosum	$y = 7.57 + 0.87x - 0.12x^2$	1.00	<0.0001
	Astronium lecointei	$y = 7.54 - 0.73x + 0.09x^2$	0.64	<0.0001
	Jacaranda copaia	$y = 8.20 - 4.15x + 1.20x^2$	1.00	0.001

Table 5. Mean values for hot and cold extractive content as a function of exposure time.

Variables	Years	*Protium altissimum*	*Caryocar villosum*	*Astronium lecointei*	*Jacaranda copaia*
Hot water (%)	0	7.20[c]	7.83[ab]	6.97[c]	5.93[c]
	2	8.33[a]	9.37[a]	9.30[a]	7.40[b]
	4	7.57[bc]	10.27[a]	6.93[c]	8.03[a]
	6	7.30[c]	7.20[ab]	8.43[b]	—
	8	8.13[ab]	5.77[b]	7.97[b]	—
CV (%)	—	2.90	16.43	2.73	—
Cold water (%)	0	7.87[a]	7.60[b]	7.21[a]	8.20[a]
	2	7.10[ab]	8.77[a]	7.21[a]	4.70[b]
	4	4.75[b]	9.07[a]	5.73[b]	10.80[a]
	6	4.77[b]	8.43[a]	5.96[b]	—
	8	7.63[a]	6.60[c]	7.57[a]	—
CV (%)	—	14.64	3.58	6.01	—

Means with the same letter designation are not significantly different ($p > 0.05$).

Higher values in hot water extraction are expected, since this method solubilizes more extractives than cold water, due to the water temperature acting as a catalyst of chemical reaction. Therefore, it increases the extraction efficiency in terms of quantity (Ferreira et al 2015).

Comparing the extraction in hot and cold water, *Caryocar villosum* showed similar values, following a trend of decreasing contents with the longest period of the storage time (8 yr). Opposite behavior was observed in *Astronium lecointei*, with a decrease in the contents with 4 yr of storage, both in hot water and in cold water.

In *Protium altissimum,* the highest extraction values were observed in hot water, as well as a tendency to increase these extractives with increasing storage time. In cold water, the same predisposition was observed in *Jacaranda copaia*; it was observed that the contents in hot water increased as the storage time increased, while for cold water the contents did not show a trend pattern, as seen in Fig 5.

Color Changes

Regression analyses were significant in all colorimetric parameters in all species, with the exception of the parameter L* (luminosity) in *Protium altissimum* and C (color saturation) in *Jacaranda copaia*, evidencing the effect of color change over the storage period in the studied wood, as shown in Table 6.

The average value of 15 different measurements is shown in Table 7. Changes in color and classification of the final color by year of observation

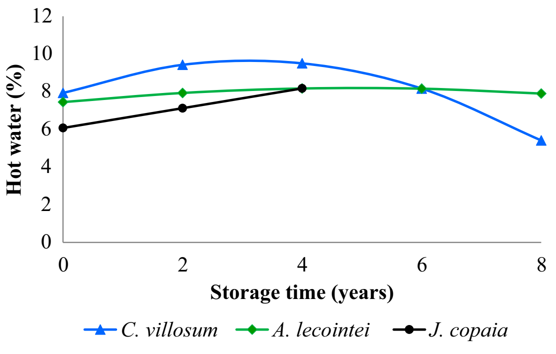

Figure 3. Variation in hot water-soluble extractives from different storage times.

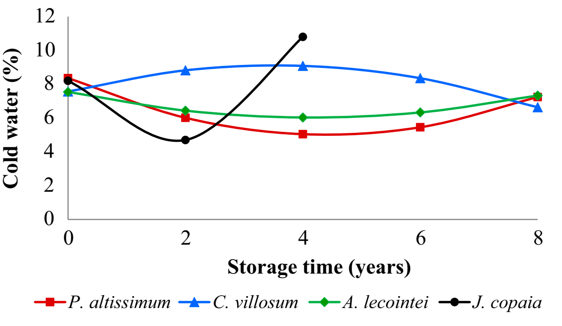

Figure 4. Variation in cold water-soluble extractives from different storage times.

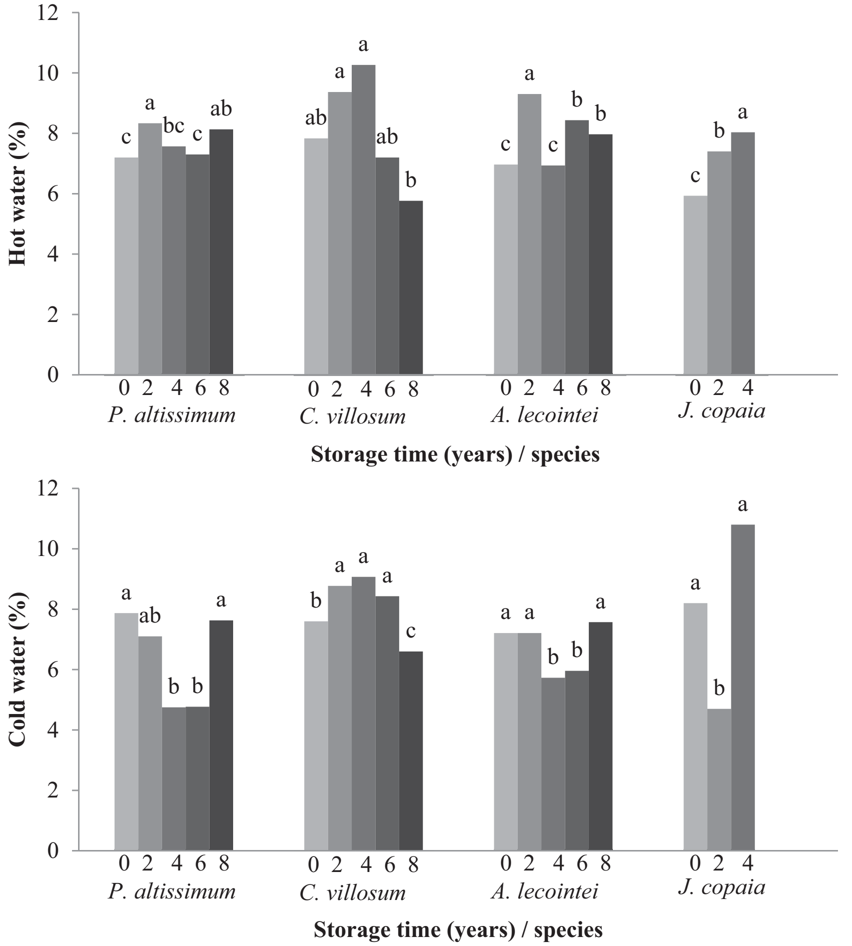

Figure 5. Comparison of extractive contents between species.

Table 6. Regression analysis for luminosity, color saturation, and hue angle as a function of storage time.

Variables	Species	Equations	R^2	p
Luminosity	*Protium altissimum*	Not significant	—	>0.05
	Caryocar villosum	$y = 64.07 + 2.47x - 0.40x^2$	0.89	<0.0001
	Astronium lecointei	$y = 57.94 - 3.89x + 0.27x^2$	0.82	<0.0001
	Jacaranda copaia	$y = 63.62 - 1.98x$	1.00	<0.0001
Color saturation	*Protium altissimum*	$y = 28.38 - 0.28x$	0.20	0.038
	Caryocar villosum	$y = 30.06 + 0.13x - 0.08x^2$	0.91	0.007
	Astronium lecointei	$y = 34.16 - 3.12x + 0.28x^2$	0.89	0.002
	Jacaranda copaia	Not significant	—	>0.05
Hue angle	*Protium altissimum*	$y = 61.40 - 0.85x + 0.09x^2$	0.39	0.017
	Caryocar villosum	$y = 72.29 + 0.84x - 0.11x^2$	0.60	0.002
	Astronium lecointei	$y = 64.22 - 1.81x + 0.13x^2$	0.85	0.001
	Jacaranda copaia	$y = 73.98 - 2.06x + 0.34x^2$	1.00	<0.0001

Table 7. Mean values for luminosity, color saturation, and hue angle as a function of storage time.

Variables	Years	*Protium altissimum*	*Caryocar villosum*	*Astronium lecointei*	*Jacaranda copaia*
Luminosity	0	48.25^{a}	63.41^{b}	56.39^{a}	63.67^{a}
	2	42.63^{b}	68.51^{a}	55.37^{a}	59.55^{b}
	4	48.78^{a}	68.29^{a}	43.68^{b}	55.76^{c}
	6	43.12^{b}	62.7^{bc}	44.34^{b}	—
	8	45.62^{ab}	59.41^{a}	44.76^{b}	—
CV (%)	—	9.74	5.15	5.80	6.25
Color saturation	0	29.95^{a}	30.13^{a}	33.59^{a}	19.9^{a}
	2	24.99^{c}	29.58^{a}	30.76^{ab}	21.26^{a}
	4	28.66^{ab}	30.06^{a}	24.51^{c}	18.5^{a}
	6	26.06^{bc}	27.25^{b}	26.00^{bc}	—
	8	26.59^{bc}	26.08^{b}	27.14^{bc}	—
CV (%)	—	12.01	5.87	17.09	17.80
Hue angle	0	61.71^{a}	71.81^{b}	63.66^{a}	73.98^{a}
	2	58.94^{bc}	74.61^{a}	62.73^{a}	71.21^{b}
	4	60.86^{ab}	73.42^{ab}	57.69^{b}	71.12^{b}
	6	58.51^{c}	72.69^{ab}	58.36^{b}	—
	8	60.26^{abc}	72.08^{b}	58.25^{b}	—
CV (%)	—	3.35	2.82	3.44	1.38

Means with the same letter designation are not significantly different ($p > 0.05$).

were based on Camargos and Gonçalez (2001) proposed color classes.

In *Protium altissimum*, the colorimetric factor luminosity (L) ranged from 42 to 48, the color saturation (C) ranged from 24 to 29, the hue angle (h) ranged from 58 to 61, indicating a darkening of the wood, observed by the decrease in the value of L, with the longer storage time, changing from "yellow-brown" to "reddish-brown", as shown in Fig 6.

For *Caryocar villosum*, the variations in colorimetric parameters were 59-68 in the lightness,

Figure 6. Macroscopic images of *Protium altissimum* (a-c: cross-section, tangential, and radial, respectively); variation in color due to storage times from 0 to 8 yr (d-h, 0, 2, 4, 6, and 8 storage years, respectively).

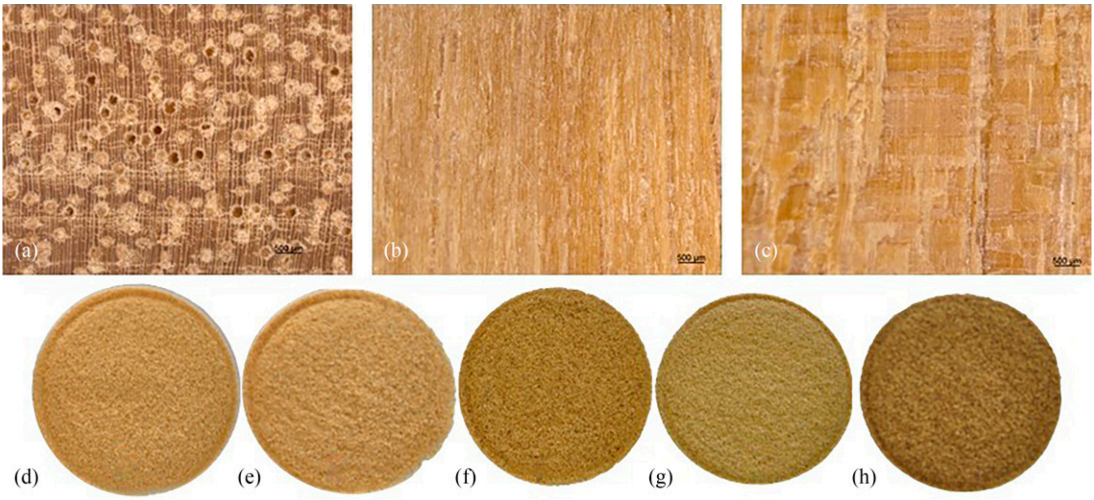

Figure 7. Macroscopic images of *Caryocar villosum* (a-c: cross-section, tangential, and radial, respectively); variation in color due to storage times from 0 to 8 yr (d-h, 0, 2, 4, 6, and 8 storage years, respectively).

26-30 in the color saturation, and 71-74 in the ink angle, with color ranging from "light yellow" to "olive-yellow" (Fig 7).

Astronium lecointei presented the variations of 44-56 in the lightness criterion, 24-33 in the color saturation, and 57-63 in the ink angle, indicating variation in color from "yellow-brown" to "brown-reddish", as shown in Fig 8.

It was observed in *Jacaranda copaia* that the luminosity varied between 55 and 63, the color saturation varied between 24 and 33, and 71-73 for the ink angle, in this species the coloration varied from "pink-gray" to "olive", according to Fig 9, the total color change shown in Table 8.

Similar colorimetric patterns were observed for *Astronium lecointei* and *Caryocar villosum*

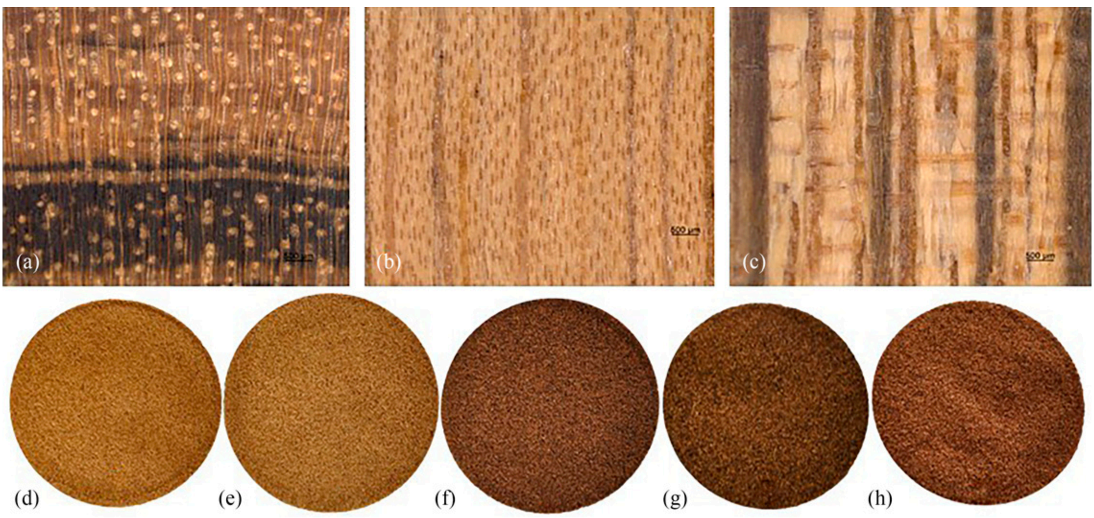

Figure 8. Macroscopic images of *Astronium lecointei* (a-c: cross-section, tangential, and radial, respectively); variation in color due to storage times from 0 to 8 yr (d-h, 0, 2, 4, 6, and 8 storage years, respectively).

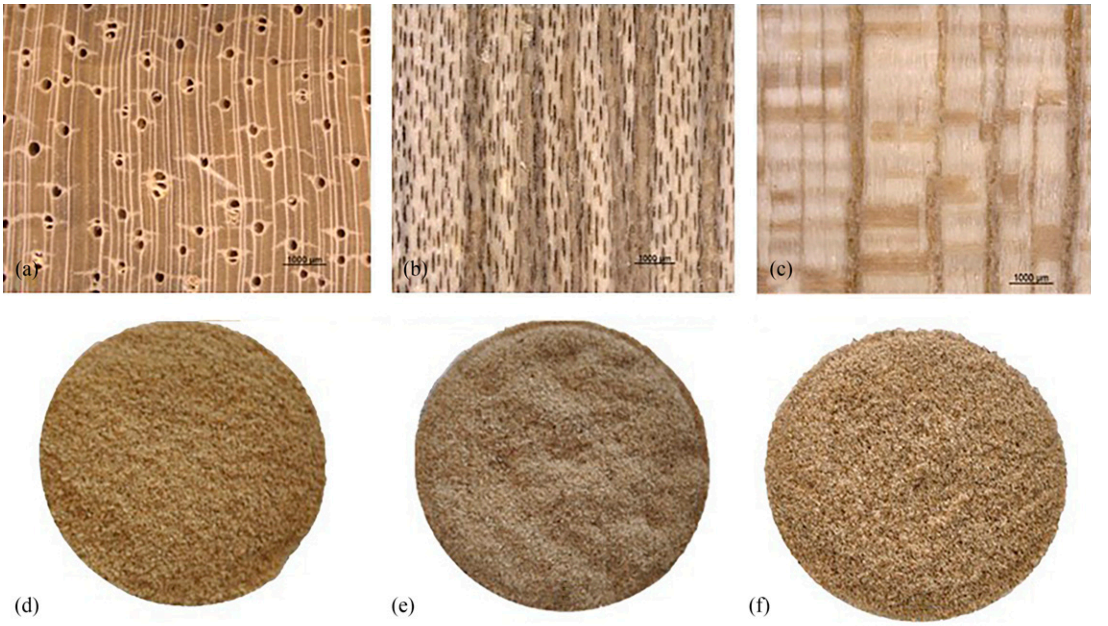

Figure 9. Macroscopic images of *Jacaranda copaia* (a-c: cross-section, tangential, and radial, respectively); variation in color due to storage times from 0 to 8 yr (d-h, 0, 2, 4, 6, and 8 storage years, respectively).

considering year 0 of storage in Silva et al (2017), who determined the wood colorimetry of 30 tropical species, and for *Protium altissimum* in Lima et al (2021), who used colorimetry as a classification parameter for forest wood residues.

The values of luminosity (L), color saturation (C), and ink angle for each species, as a function of storage time, are represented in Fig 10.

The results found show negative ΔL^*, Δa^*, and Δb^* indicate darker samples, with a greater proportion of green and a greater tendency toward bluish pigmentation. Based on the table elaborated by Hikita et al (2001), in which he defines the degree of color difference assimilation, all the studied species presented a total color variation categorized as "very appreciable" (above 6.0).

Table 8. Changes in color parameters due to exposure time.

	Color parameters			
Species	ΔL	Δa*	Δb*	ΔE
Protium altissimum	−5	−1	−3	6
Caryocar villosum	−4	−1	−4	7
Astronium lecointei	−12	−1	−7	14
Jacaranda copaia	−8	0	−2	8

The color change observed in all analyzed species corroborates with Burtin et al (1998), which states that the degradation caused by photochemical reactions associated with the chemical components present in the wood, can cause color change.

Many wood species are highly valued by their color; however, this is an unstable characteristic and susceptible to changes (Wiedenhoeft 2010; Bonfatti Jr and Lengowski 2017), which was observed in this study. The changes in color observed in the samples studied occurred due to a combination of climate factors combined with biological attacks.

Astronium lecointei showed the greatest color change over the storage time ($\Delta E = 14$), it also presented the highest average density and the secondhighest value of extractives. It is known that chromophore compounds (such as extractives) are high absorbers of solar radiation, causing variation in the color of wood exposed to light, among

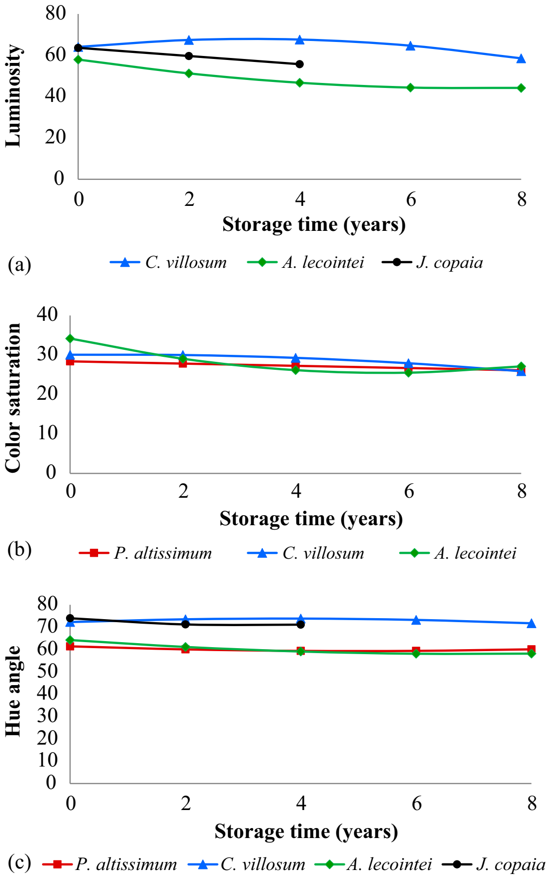

Figure 10. Equations for regression analysis on color parameters measured in each species. (a) Luminosity; (b) color saturation; and (c) hue angle.

these, the phenolic compounds present in wood extractives are associated with a greater degree of photo discoloration (Ishiguri et al 2003; Pandey 2005).

Protium altissimum showed the smallest variation in the total color change ($\Delta E = 6$) and a decrease in the L* value, interpreted as a darkening of the color. A contradictory understanding was presented by Barros et al (2014), who, studying *Protium puncticulatum*, obtained results that indicated bleaching of the sample when exposed to bad weather.

In *Jacaranda copaia* the decrease in the chromatic variable L* evidences the darkening of the color with the increase of the storage time. With similar extractive content and equivalent colorimetric parameters, *Couratari oblongifolia* analyzed by Costa et al (2011), was subjected to photodegradation under UV radiation, showing the same tendency to darken the wood as in *Jacaranda copaia*. Freitas et al (2016) analyzed *Simarouba amara*, which is anatomically similar to *Jacaranda copaia*, evaluating the effect of thermomechanical treatment on the properties of this wood and found that it also darkened-observing a decrease in the colorimetric parameter luminosity (L*), with temperature application.

The color of the wood of *Caryocar villosum* was also darkened with increasing storage time Additionally, in this species, the highest values of water-soluble extractives were observed, both in hot water and in cold water.

CONCLUSIONS

This study evaluated differences in density, extractives content, and color change of four Amazonian species under different times of exposure. The basic density was affected with the storage period, increasing in *Caryocar villosum* and decreasing in *Astronium lecointei* with a tendency to increase in *Jacaranda copaia* and an oscillation along the storage time in *Protium altissimum*.

The solubility of species in water showed changes with the storage time, increasing with the storage time in *Protium altissimum*, *Astronium lecointei*, and *Jacaranda copaia*, and decreasing in *Caryocar villosum*.

The storage time interferes with the color of the wood, as evidenced by the decrease in the colorimetric parameter luminosity (L*), causing a darkening of the color in all species.

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