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MULTIVARIATE ANALYSIS APROACH OF COLORIMETRIC CHARACTERISTICS AND VISIBLE SPECTRA OF WOOD FROM AMAZONIAN SPECIES

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The objective of this study was to compare the colorimetric characteristics and visible spectra behavior of solid wood belonging to three botanical families: Fabaceae, Lauraceae, and Proteaceae, from the state of Pará. Multivariate analysis approach was used in this study, integrating Linear Discriminant Analysis (LDA) and Support Vector Machine (SVM) classifiers. For the analysis, data were randomly obtained directly from samples in the three directions of the anatomical planes of wood (transverse, tangential longitudinal, and radial longitudinal). When analysing all anatomical planes, samples of *Euplasa* sp. and *Roupala* sp. (Proteaceae) were classified as light wood (L*>56), while *Pseudopiptadenia suaveolens* (Fabaceae) and *Ocotea* sp. (Lauraceae) were classified as light only in the radial and tangential anatomical planes. The spectra of the genera *Euplassa* and *Roupala*, from the Proteaceae family were significant, presenting different spectral behavior from the other samples in the 360–660 nm range. In general, the SVM classifier demonstrated better performance in distinguishing the studied species/genera. The colorimetric technique associated with multivariate analysis has potential for use in the characterization of Amazonian wood.

Keywords: Solid wood, wood discrimination, sustainable forest management, extractive reserve, non-destructive method

INTRODUCTION

The Amazon Forest has a vast unexplored area that stands out as the biome with the greatest biodiversity on Earth. However, its composition is not homogeneous and covers several types of forests (Bredin et al. 2020), including different growth stages and development conditions of the species.

The exploitation of forest areas through wood harvesting, often without adequate management, causes damage and biophysical changes. These inappropriate practices can compromise tree growth, making it necessary to adopt appropriate methods to ensure the sustainable development of the forest (Benner & Lertzman 2022). For this reason, sustainable forest management is essential to use and preserve forest resources responsibly, reducing the environmental impact of logging, aiming to ensure the sustainability of forests in the long term (Silva et al. 2020).

In Brazil, there are extractive reserves in the category of sustainable use conservation units, where community forest management for logging purposes is permitted, and the competent environmental institution issues the forestry exploitation authorisation (AUTEX), with the specification of the wood volume allowed by species, among other information. One problem encountered is the identification carried out in forests and the contradiction between popular and scientific nomenclature (Santos et al. 2020).

In accordance with data available by Brazilian Ministry of Environment (MMA 2024), only in 2023, were emitted or requested DOF (Forest Origin Document necessary for wood and wood products commerce in Brazil) for 34 products of *Hymenaea courbaril* (principally boards, 8878 m^3), 31 products from *Hymenolobium petraeum* (mainly 12,737 m^3 of cut wood) and *Dipteryx odorata* (mostly 12,794 m^3 for deck), being these species in the list of first 10 species marketed in Brazil. When the search is refined for AUTEX origin (sustainable managed regions), first species listed with scientific name is *Dipteryx odorata*, which is sold as cumaru, cumaru ferro and cumaru amarelo; and *Hymenolobium petraeum* is the eleventh, named angelim pedra, angelim or sucupira amarela. When observing classification based on vernacular name, maçaranduba is first, angelim pedra is the fourth and cumaru ferro the seventh, demonstrating the importance of a correct identification of cut wood based on scientific nomenclature, also because the price of m^3 is different.

Currently, there are several national and international institutions committed to verifying the implications of existing policies in combating logging activities and illegal timber exports. This effort aims to prohibit and/or discourage the selective exploitation of forest species with timber potential (Soares et al. 2017, Bosch 2021), which generally results in the exclusion of non-commercial species and smaller individuals, causing damage to the tree canopy and forest biodiversity (Bousfield et al. 2023).

Techniques that contribute to timber inspection include colorimetry and visible spectroscopy (VIS), which are rapid and non-destructive, and can be applied directly in forest or industry with portable equipment's, in species classification or quality evaluation. These techniques have been used to distinguish wood in several studies, such as Santos et al. (2022a) discriminating wood species sold as "tauari" in the Brazilian Amazon, Reis et al. (2023) and Santos et al. (2021) evaluating tropical tree species from the Amazon rainforest, between others.

Wood processing industries need methods with these characteristics, with less time and greater reliability in the selection and classification of wood species (Yang & Evans 2003). Furthermore, wood identification is also important for evaluating the products properties, particularly in relation to consumer protection (Santos et al. 2022b). This becomes even more relevant as there is an increasing trend in the import of lower quality substitute wood (Koch et al. 2015).

Thus, the objective of the study was to compare the behavior of colorimetric characteristics and visible spectra of some wood samples from genus/species belonging to three different botanical families: Fabaceae, Lauraceae and Proteaceae, from a Sustainable Forest Management Area, with the aim of collaborating with data for inspection based on colorimetric characteristics, as an auxiliary or preliminary tool.

MATERIAL AND METHODS

Test samples

The trees were cut in Extractivist Communities Paraiso and Arimum, in the "Verde para Sempre" Extractive Reserve (01° 55' 45.4"S; 52° 56' 10.5" W), a Sustainable Forest Management Area, located in the municipality of Porto de Moz, Pará state. The samples were collected with authorisation from the Ministry of the Environment and Chico Mendes Institute for Biodiversity Conservation via the Authorization and Biodiversity Information System and are registered in the National System for Genetic Heritage Management under code A96552E.

As an Extractivist Reserve, there is restriction to tree cut, thus few trees for each species were collected. Also, in function of tree diameter, the number of samples for each species was variable. A disc with 5 cm thickness from different species (Table 1) was cut at the tree base (10 cm from cut portion), and radial samples with 2.5 × 2.5 × 2.5 cm were obtained and oriented in anatomical surfaces for analysis (Figure 1).

In this study, 202 solid wood samples were analysed, coming from two Communities and belonging to three botanical families. It should also be noted that regardless of origin,

Table 1 Evaluated wood samples

Code	Scientific name	Family	Community	Trees	n	Data number
AP	*Hymenolobium petraeum*	Fabaceae	Paraíso	1	14	252
CU	*Dipteryx odorata*	Fabaceae	Arimum	1	11	198
LC	*Ormosia* sp.	Fabaceae	Paraíso	1	12	216
FT	*Enterolobium maximum*	Fabaceae	Paraíso	1	13	234
JA	*Hymenaea courbaril*	Fabaceae	Paraíso	1	18	324
JA	*Hymenaea courbaril*	Fabaceae	Arimum	1	8	144
TIM	*Pseudopiptadenia suaveolens*	Fabaceae	Paraíso	2	15	450
PR	*Aniba* sp.	Lauraceae	Paraíso	1	11	198
LP	*Nectandra* sp.	Lauraceae	Arimum	1	12	216
LPI	*Ocotea* sp.	Lauraceae	Arimum	1	11	198
LR	*Ocotea* sp.	Lauraceae	Paraíso	1	13	234
IT	*Mezilaurus* sp.	Lauraceae	Arimum	1	27	486
ITA	*Mezilaurus* sp.	Lauraceae	Paraíso	1	8	144
LB	*Euplassa* sp.	Proteaceae	Arimum	1	11	198
LV	*Roupala* sp.	Proteaceae	Arimum	1	8	144
			Total	16	202	3636

n = number of solid wood cubes of each species.

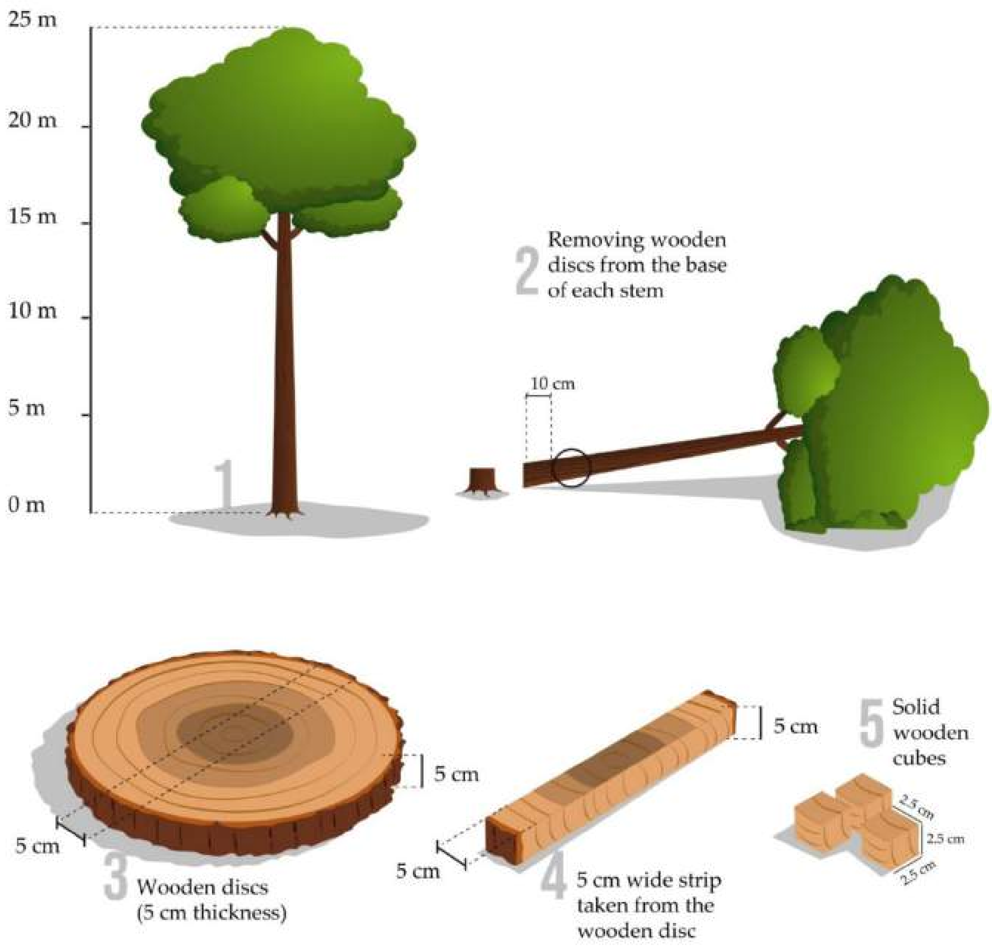

Figure 1 Sampling scheme

the samples identified at the species level were analysed together. While the samples identified at the genus level were analysed separately.

Colorimetric evaluation

In order to uniformise surface and eliminate oxidation, all samples were polished with 1500 sandpaper and remained in a room with temperature of 23 °C ± 2 °C and relative humidity of 60% ± 5% until further analysis. Colorimetric parameters were obtained in a CM-5 spectrophotometer (Konica Minolta, Japan), operating with standard conditions: 10° of observation angle, D65 as illuminant and aperture of 3 mm. Visible spectra was obtained in the range of 360–740 nm, with resolution of 10 nm.

Data from luminosity (L*), chromatic coordinates from green-red (a*) and blue-yellow (b*) axis were obtained and chroma (C*) and hue angle (h) was calculated in accordance with equations 1 and 2, respectively.

$$C^* = \sqrt{a^{*2} + b^{*2}} \qquad (1)$$

$$h = \arctan\left(\frac{b*}{a*}\right) \qquad (2)$$

In each wood cube, 18 data were obtained, six in each anatomical surface, i.e., transversal, longitudinal tangential and longitudinal radial, in a total of 3636 different data (Table 1).

Statistical analysis

All analysis was done in R (version 3.4.3) software. The analysis of variance (ANOVA) was performed with colorimetric parameters L*, a*, b*, C* and h, in a complete randomised design and two-factor scheme, i.e., species x anatomical surface, with 18 replicates for each wood cube and 6 for each anatomical surface. Shapiro-Wilk (α = 0.05) test was applied to verify data normality with the ExpDes.pt package.

The Snedecor F-test of ANOVA (α = 0.05) was applied to investigate the significance of the factors' interaction. When interactions were verified, interaction unfolding was performed, and the Tukey test (α = 0.05) was performed. The objective of this procedure was to analyse the behavior of species factors in each wood anatomical section and vice-versa.

Mean values of colorimetric parameters were applied in wood color classification based on the color table of chart described by Camargos & Gonçalez (2001). Mean reflectance curves

Table 2 Data applied for LDA and SVM analysis

Code - Scientific name	Spectra for model construction		Spectra for external validation	
	All surfaces	Only one surface	All surfaces	Only one surface
AP - *Hymenolobium petraeum*	180	60	72	24
CU - *Dipteryx odorata*	144	48	54	18
FT - *Enterolobium maximum*	162	54	72	24
JÁ - *Hymenaea courbaril*	324	108	144	48
LC - *Ormosia* sp.	162	54	54	18
TIM - *Pseudopiptadenia suaveolens*	324	108	126	42
IT - *Mezilaurus* sp.	90	30	54	18
ITA - *Mezilaurus* sp.	342	114	144	48
LP - *Nectandra* sp.	162	54	54	18
LPI - *Ocotea* sp.	144	48	54	18
LR - *Ocotea* sp.	162	54	72	24
PR - *Aniba* sp.	144	48	54	18
LB - *Euplassa* sp.	144	48	54	18
LV - *Roupala* sp.	90	30	54	18
Total	2574	858	1062	354

of visible spectra were plotted with the ggplot2 package (Wickham 2016).

The possibility of grouping species based on colorimetric parameters (L*, a*, b*, C*, h) were verified and visible reflectance spectra, principal component analysis (PCA) was tested with FactoMineR package (Lê et al. 2008), and principal results were extracts with FactoInvestigate package (Thuleau & Husson 2023). The score graphic of two PC and the contribution of each colorimetric parameter (its loading) to species grouping/differentiation was evaluated.

A Linear Discriminant Analysis (LDA) and Support Vector Machine (SVM) classification was applied to verify adequate discrimination based on visible spectra of species. Data were divided into 70–75% for classification and 30–25% for external validation (Table 2) for each species, as there are different number of samples. The LDA model was constructed with Mahalanobis distance, applying equal prior probabilities and scores of the first 3 PCs. SVM was based on the radial basis function – C = 1, Weight A/(SDev+B) and cross-validation segment size = 5. Spectra were evaluated based on all surfaces and divided by anatomical surface, i.e., only transversal, only longitudinal tangential, and only longitudinal radial. Wood cubes applied in model construction were not used in external evaluation.

RESULTS

Wood from three evaluated families, Fabaceae, Lauraceae and Proteaceae, had different tonality and colour, based on colorimetric parameters (Table 3), with some proximity between genus from same family. In general, the wood of species belonging to the Fabaceae botanical

Table 3 Mean values and standard deviation (in parenthesis) of colorimetric parameters and colour classification based on Camargos and Gonçalez (2001)

Sample	L*	a*	b*	C*	h	Colour classification
AP - *Hymenolobium petraeum*	48.35 (5.31)	13.93 (1.94)	20.11 (3.50)	24.52 (3.66)	55.02 (3.77)	Reddish-Brown
CU - *Dipteryx odorata*	47.32 (7.43)	11.51 (1,82)	16.64 (3.52)	20.34 (3.39)	54.72 (5.91)	Dark-Brown
FT - *Enterolobium maximum*	50.31 (3.63)	11.53 (1.29)	18.91 (1.59)	22.16 (1.88)	58.66 (2.11)	Light-Brown
JA - *Hymenaea courbaril*	48.11 (8.81)	11.82 (2.87)	18.57 (4.23)	22.15 (4.50)	57.11 (7.01)	Light-Brown
LC - *Ormosia* sp.	56.35 (5.20)	11.13 (3.05)	17.58 (5.61)	20.83 (6.30)	56.94 (3.32)	Light-Brown
TIM - *Pseudopiptadenia suaveolens*	58.89 (8.38)	13.34 (3,00)	23.98 (3.17)	27.60 (3.19)	60.93 (6.36)	Brownish-yellow
IT - *Mezilaurus* sp.	51.73 (3.91)	12.69 (2.47)	30.13 (5.35)	32.78 (5.41)	66.95 (4.00)	Brown-Olive
ITA - *Mezilaurus* sp.	43.36 (4.37)	11.56 (1.52)	22.71 (3.94)	25.53 (3.92)	62.68 (3.66)	Olive
LP - *Nectandra* sp.	48.19 (7.74)	6.80 (2.09)	15.75 (5.65)	17.17 (5.97)	65.83 (3.05)	Olive
LPI - *Ocotea* sp.	54.28 (7.04)	8.42 (2.82)	21.91 (8.24)	23.50 (8.63)	68.02 (4.03)	Rose-Grayish
LR - *Ocotea* sp.	57.21 (7.04)	7.79 (2.13)	24.22 (8.00)	25.47 (8.20)	71.39 (3.35)	Olive-Yellowish
PR - *Aniba* sp.	42.69 (6.83)	8.28 (1.79)	17.13 (5.26)	19.12 (5.24)	63.05 (5.78)	Olive
LB - *Euplassa* sp.	66.64 (3.86)	10.33 (2.85)	18.79 (4.89)	21.46 (5.58)	61.12 (2.71)	Rose
LV - *Roupala* sp.	64.02 (2.44)	7.01 (1.20)	8.99 (1.27)	11.44 (1.46)	52.05 (4.81)	Rose-Graywish

family tended to show different shades of brown (reddish-brown, dark brown, light brown, brownish-yellow), wood from the Lauraceae family were classified with olive tones (yellowish-olive, olive-brown and olive) and the two species from the Proteaceae family presented wood with a pink to greyish-pink tone.

Mean values of colorimetric parameters for evaluated species (Figure 2, Figure 3, Figure 4) varied in function of botanic Family or different

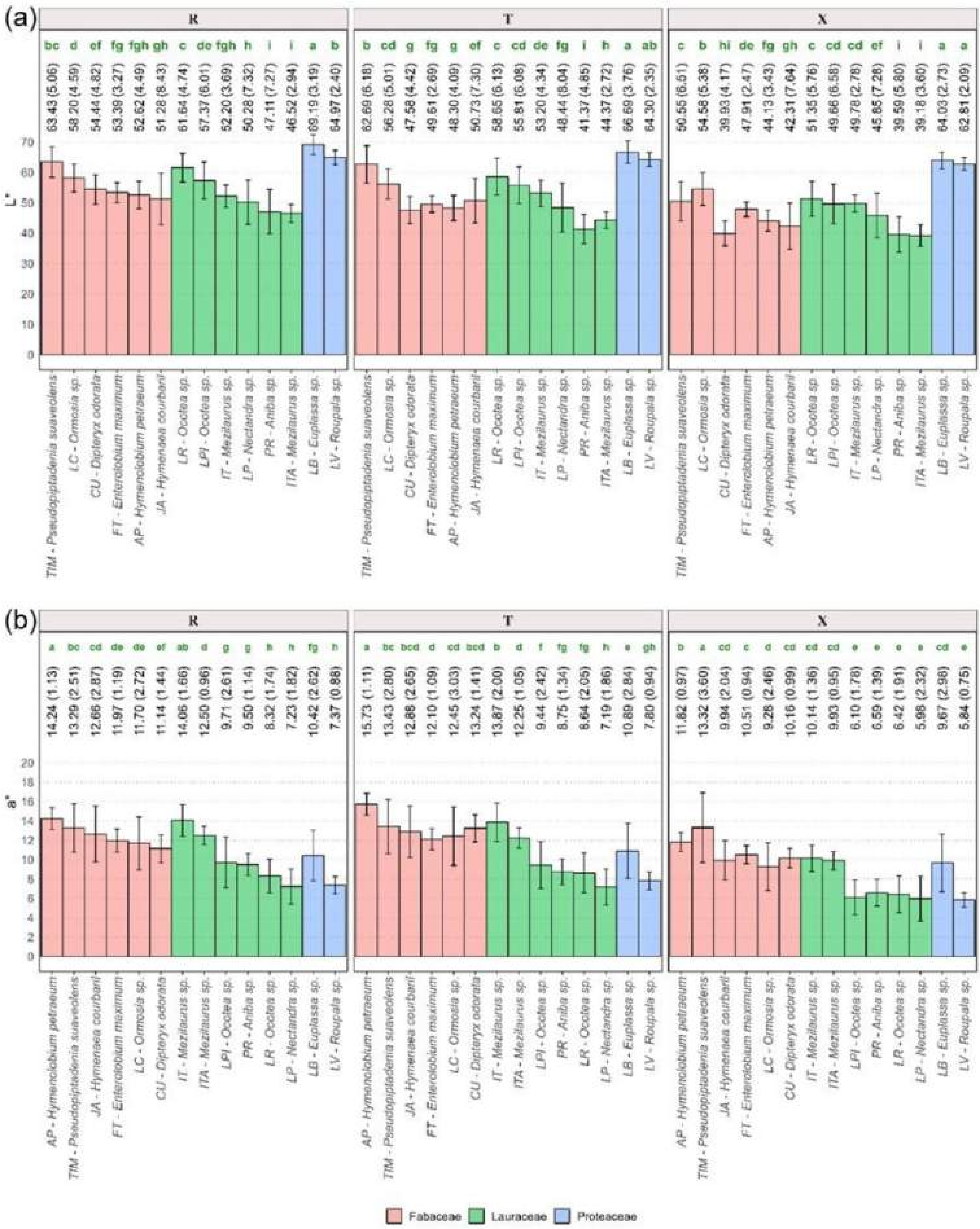

Figure 2 Mean and standard deviation of the parameters L* (a) and a* (b) on the anatomical surfaces evaluated

Note: For each anatomical surface, equal letter indicates that there is no statistical difference based on Tukey test at 95% of probability L* = luminosity, a* = chromatic coordinate a*; X = transversal surface, R = longitudinal radial surface, T = longitudinal tangential surface anatomical surfaces. It was not observed a pattern among all colour characteristics.

Principal Component Analysis (PCA) was performed with colorimetric parameters to evaluate the presence of patterns for separation at species or family level. Number of components to retain was two, because they had eigenvalues (λi) higher than 1. Total variance explained by two first principal component was 83.4%, with 54.2% and 29.2% for PC-1 and PC-2, respectively

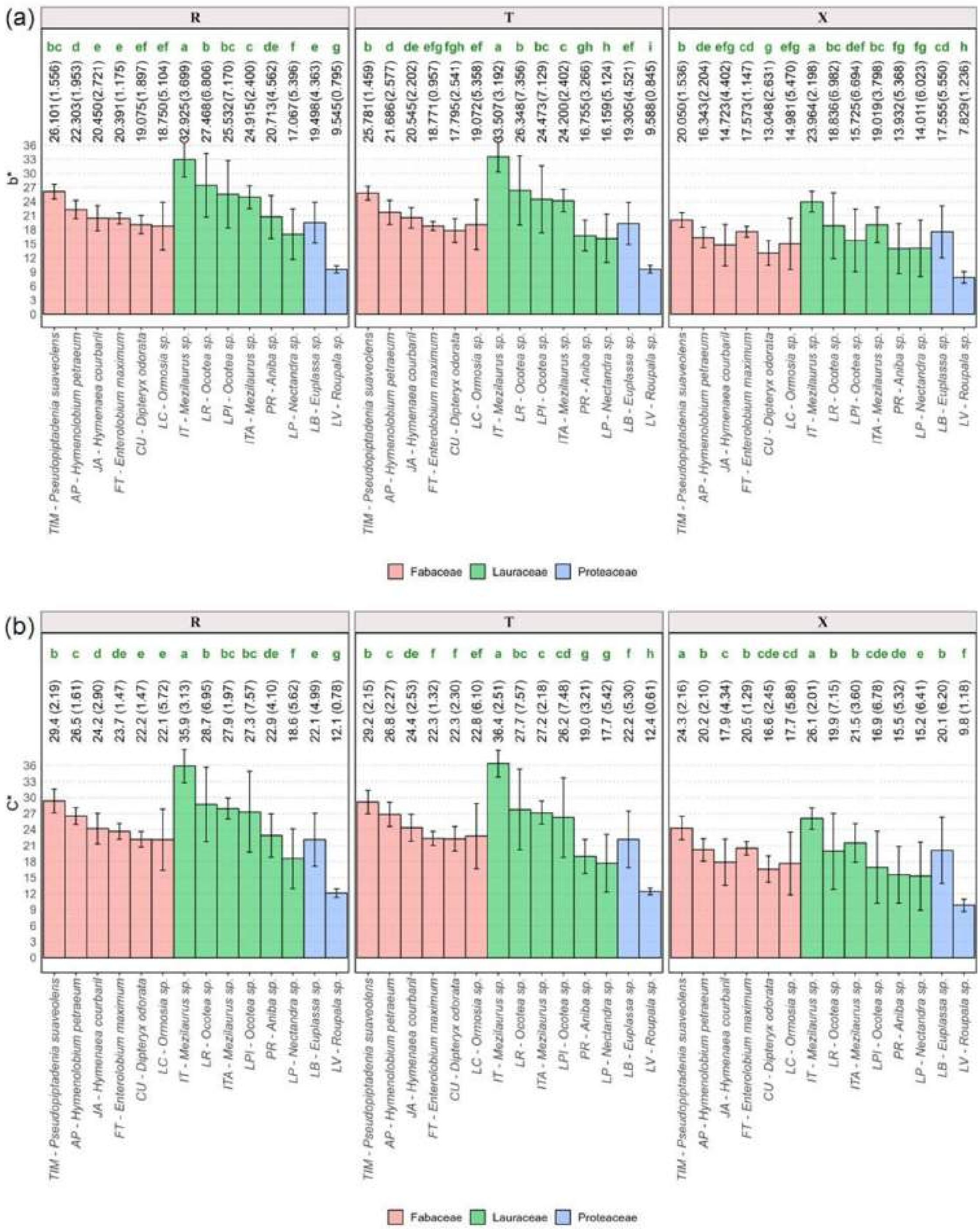

Figure 3 Mean and standard deviation of the parameters b* (a) and C* (b) on the anatomical surfaces evaluated

Note: For each anatomical surface, equal letter indicates that there is no statistical difference based on Tukey test at 95% of probability b* = chromatic coordinate b*, C* = chroma; X = transversal surface, R = longitudinal radial surface, T = longitudinal tangential surface

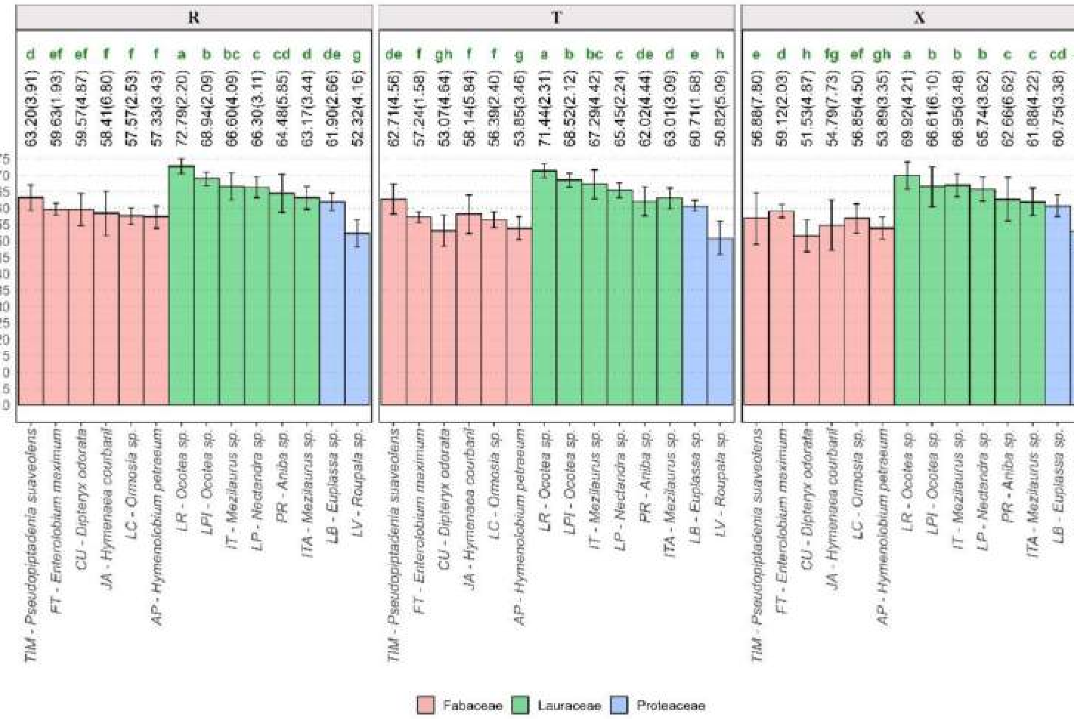

Figure 4 Mean and standard deviation of hue angle (h) in each anatomical surface of evaluated species

Note: For each anatomical surface, equal letter indicates that there is no statistical difference based on Tukey test at 95% of probability X = transversal surface, R = longitudinal radial surface, T = longitudinal tangential surface

(Figure 5a), being confinable the use of these two PCs to infer about tendencies. Loadings indicate the contribution of each variable in each PC and the signal represent if they are directly or inversely proportional (Figure 5b & 5c).

Visible spectra (Figure 6) was similar for most species in all wavelength, with more proximity in reflectance curve of Lauraceae and Fabaceae species. Spectra from genus *Euplassa* and *Roupala*, from Proteaceae family, had different behavior principally in region from 360–660 nm, and in regions from 660–720 nm showed similarity with *Pseudopiptadenia suaveolens* and *Ormosia* sp., from Fabaceae family. Visually separation/grouping of species based on reflectance spectra are in accordance with color classification based on colorimetric parameters (Table 2).

Principal component analysis with reflectance spectra (Figure 7a) indicate that PC-1 and PC-2 explains 83.9% and 14.4% of variance, respectively, in a total of 98.3%. Regions from 530-570 nm had high contribution to PC-1 and region from 360-390 nm and 740 nm to PC-2 (Figure 7b & 7c). It is possible to distinguish samples from *Pseudopiptadenia suaveolens* (Fabaceae) in function of high values in the range of 650–740 nm, and some grouping of *Euplassa* sp. and *Roupala* sp. Other species had great similarity in visible reflectance spectra.

No pattern of differentiation was observed in the external classification based on LDA and SVM (Table 4) using the spectra of all surfaces or separating according to the anatomical plane. In general, the SVM classification is more efficient in distinguishing the species/genus studied.

DISCUSSION

According to the colour classification (Table 3), in general, the wood of species belonging to the Fabaceae botanical family tended to different shades of brown (reddish-brown, dark brown, light brown, brownish-yellow), wood from the Lauraceae family were classified with olive tones (yellowish-olive, olive-brown and olive) and the two species from the Proteaceae family presented wood with a pink to greyish-pink tone.

The colour of wood is primarily determined by genetic components and environmental

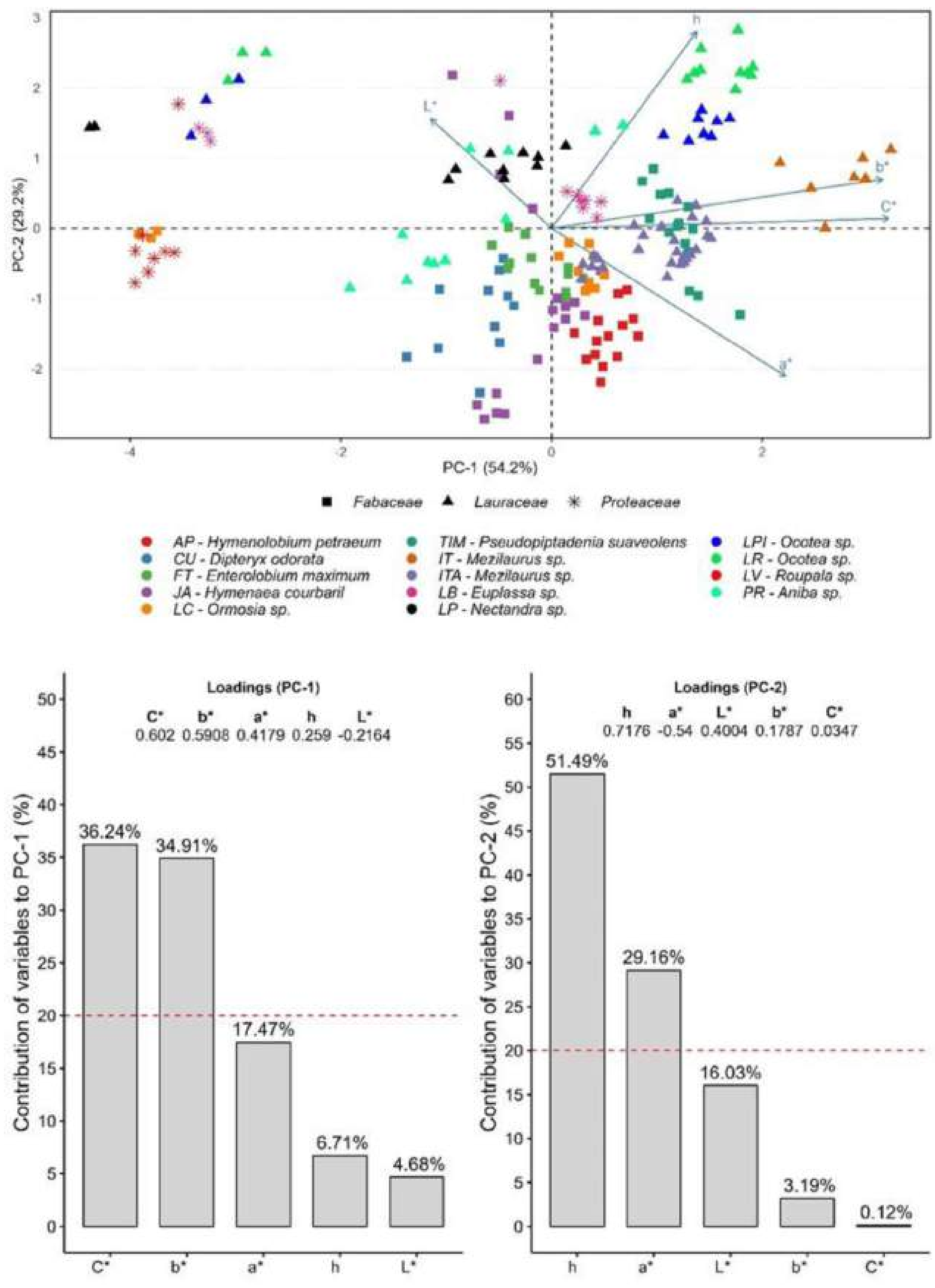

Figure 5 Score graphic of PCA based on colorimetric parameters of 14 evaluated species

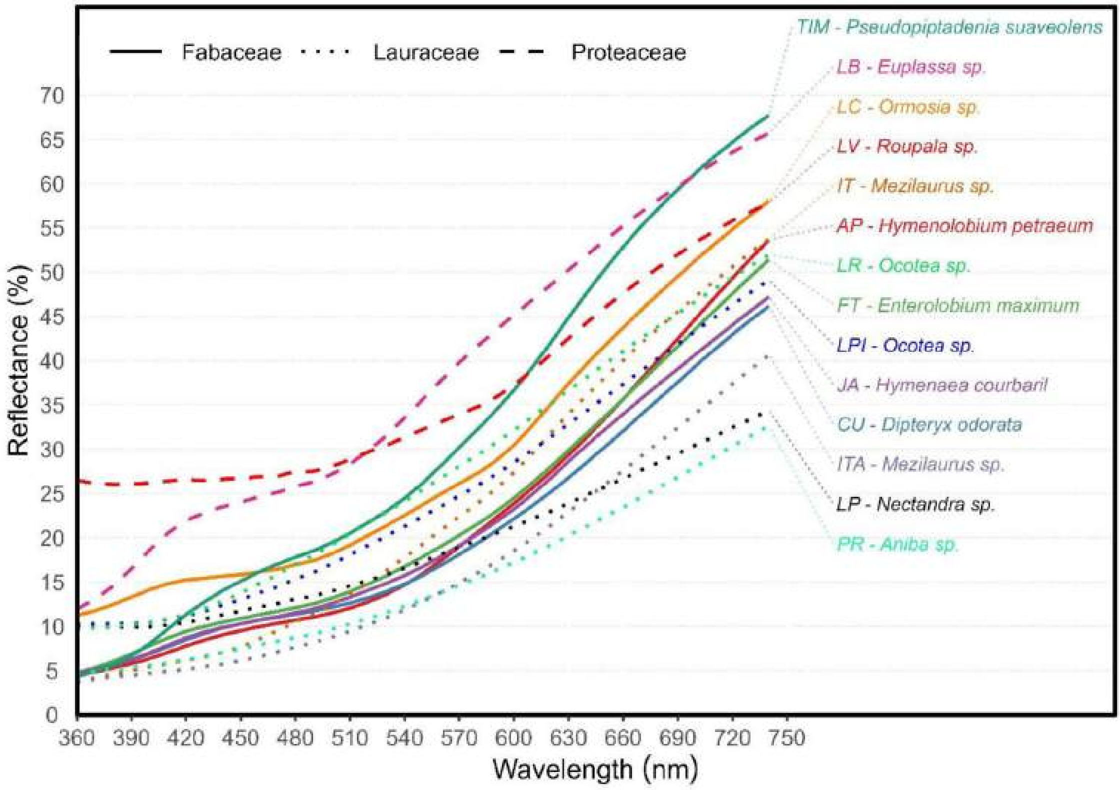

Figure 6 Mean reflectance spectra in visible region for 14 evaluated species

influences. Thus, it can be stated that the wood colour of the same species may differ in tone, being also influenced by the surface analysed, tree age, trunk position and the angle of incidence of light. This behavior was verified by Ribeiro et al. (2018) which described *Hymenaea courbaril* wood as brownish-yellow and Costa et al. (2021) that classified it as rose and brownish-yellow, different from results of this study designating it as light brown.

In this research, the average luminosity (L*) ranged from 39.18 to 69.19. According to the classification of Camargos & Gonçalez (2001), based on the L* parameter, dark woods have luminosity less than or equal to 56 (L*≤ 56) and light woods have values greater than 56 (L*>56). In this study, therefore, *Euplassa* sp. and *Roupala* sp. (Proteaceae) were classified in the group of light woods, while *Pseudopiptadenia suaveolens* and *Ormosia* sp. (Fabaceae), as well as LR - *Ocotea* sp. (Lauraceae), were classified as light woods only in the radial and tangential sections.

Variation of colour according to surfaces were also reported by Hirata et al. (2020) evaluating cubes prepared from 30 softwoods and 30 hardwoods at end grain, edge grain, bark side and pith side of each test piece. Authors verified that the end grain had a lower L* compared to the other planes, it was reddish and yellowish and had the strongest correlation with the density and average width of annual ring.

Regarding the colorimetric parameter L*, in most cases, wood from LB - *Euplassa* sp. and LV - *Roupala* sp., belonging to the Proteaceae family, presented significantly higher averages (Figure 2a). Probably, this behavior can be justified by the similarities in the anatomical structures of these woods. In the radial section, the mean L* of *Euplassa* sp. was superior to *Roupala* sp. The wood of *Roupala* sp., in turn, showed an average luminosity equal to *Pseudopiptadenia suaveolens* (Fabaceae), in the radial and tangential sections.

In most cases, the samples ITA - *Mezilaurus* sp. and PR - *Aniba* sp., belonging to the Lauraceae family, presented significantly lower means for the colorimetric parameter L* across all three anatomical sections of the wood. In the transversal surface, these species had a similar average only to *Dipteryx odorata* (Fabaceae).

In relation to the chromatic coordinate a*, *Hymenolobium petraeum* (Fabaceae) presented a significantly higher average, most of the time,

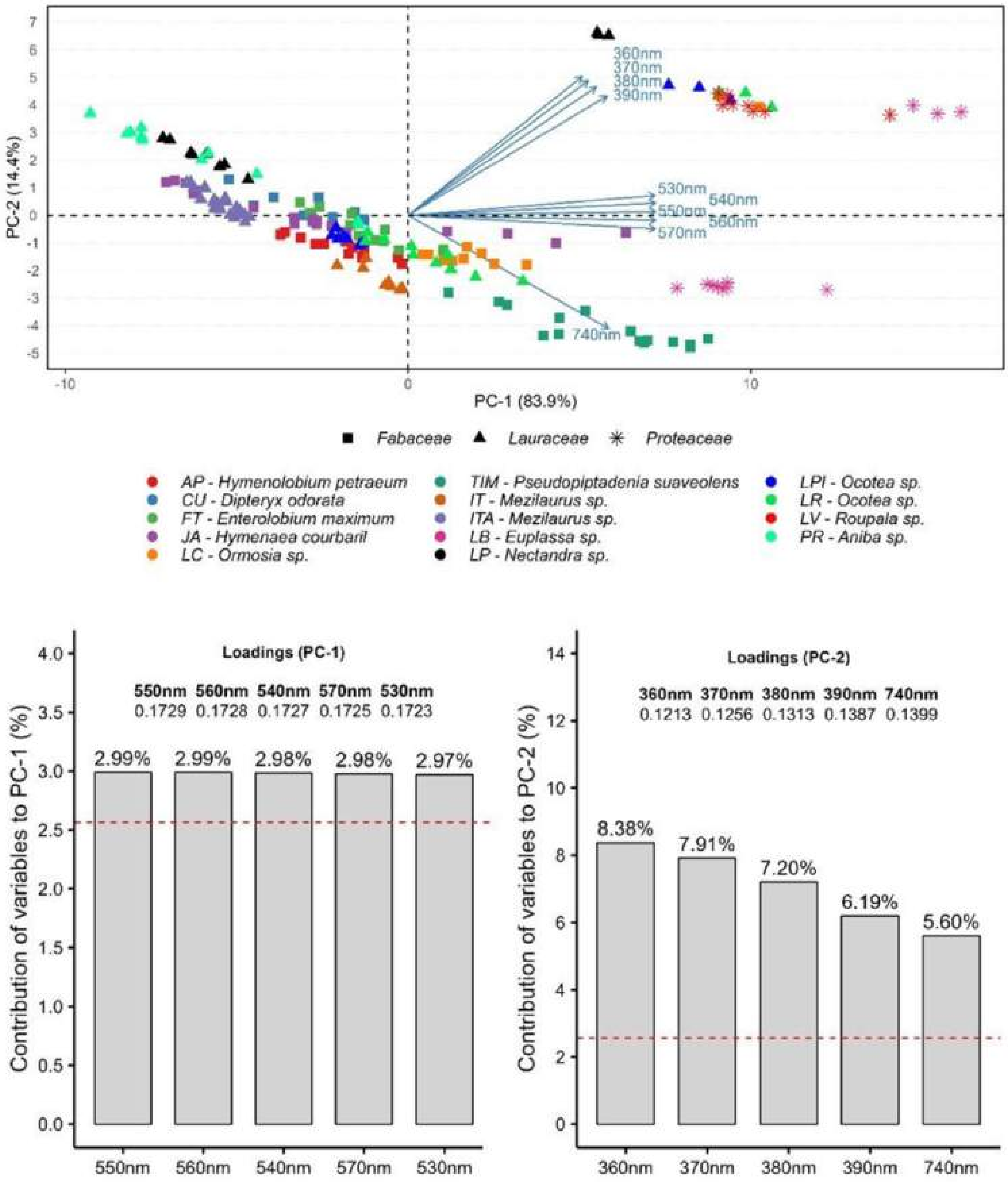

Figure 7 Score graphic of PCA based on visible reflectance spectra of 14 evaluated species

Table 4 Correct classification in external validation by species based on LDA and SVM analysis with all surface and divided based on anatomical surface

	Correct Classification (%)							
	LDA				SVM			
	all	X	R	T	all	X	R	T
AP – *H. petraeum*	23.6	87.5	83.3	62.5	76.4	75.0	91.7	87.5
CU – *D. odorata*	16.7	44.4	16.7	50.0	68.5	66.7	55.6	72.2
FT – *E. maximum*	18.1	16.7	31.6	37.5	83.3	62.5	75.0	79.2
JA – *H. courbaril*	39.6	45.5	34.1	38.6	25.7	27.1	27.1	22.9
LC – *Ormosia sp.*	74.1	94.4	88.9	**100**	85.2	72.2	94.4	**100**
TIM – *P. suaveolens*	37.3	19.0	40.5	69.0	65.1	40.5	52.4	76.2
IT – *Mezilaurus* sp.	38.9	55.6	88.9	66.7	81.5	66.7	94.4	72.2
ITA – *Mezilaurus* sp.	38.2	33.3	39.6	58.3	83.3	66.7	87.5	70.8
LP – *Nectandra* sp.	29.6	55.6	22.2	27.8	81.5	77.8	61.1	72.2
LPI – *Ocotea* sp.	16.7	50.0	27.8	61.1	61.1	83.3	72.2	94.4
LR - *Ocotea* sp.	61.1	41.7	79.2	83.3	54.2	66.7	62.5	62.5
PR – *Aniba* sp.	66.7	61.1	94.4	**100**	70.4	88.9	66.7	55.6
LB – *Euplassa* sp.	72.2	**100**	94.4	88.9	92.6	88.9	94.4	**100**
LV – *Roupala* sp.	41.9	38.9	44.4	50.0	57.4	66.7	44.4	55.6

X = transversal surface, R = longitudinal radial surface, T = longitudinal tangential surface

for the radial and tangential sections (Figure 2b). The exception is in the radial section, where the average for *H. petraeum* was the same as that found for IT – *Mezilaurus* sp. In the transversal sections, on the other hand, *P. suaveolens* (Fabaceae) was the species with the highest average for the a* parameter, followed by *H. petraeum*. In general, the lowest means for the a* parameter were found for wood belonging to the Lauraceae and Proteaceae families. In the tangential section, LP - *Nectandra* sp. and LV - *Roupala* sp. presented lower averages and were equal to each other. Likewise, in the radial section, these samples exhibited significantly lower averages, but also equal to LR - *Ocotea* sp. In the cross section, other samples (LPI - *Ocotea* sp. and PR - *Aniba* sp.) showed lower averages and similar to LP - *Nectandra* sp., LV - *Roupala* sp. and LR - *Ocotea* sp.

Evaluating the colorimetric parameter b*, IT - *Mezilaurus* sp. (Lauraceae) presented higher averages in all anatomical sections (Figure 3a). Meanwhile, significantly lower means were found for LV - *Roupala* sp., in all anatomical sections.

In relation to the C* parameter (Figure 3b), IT - *Mezilaurus* sp. (Lauraceae) showed higher values in transversal, radial and tangential sections, being statistically equal to *P. suaveolens* (Fabaceae) only in the transversal section. On the other hand, LV - *Roupala* sp. exhibited significantly lower averages in the three anatomical sections.

Regarding the hue angle (h) (Figure 4), LR - Ocotea sp. (Lauraceae) presented higher average values in all anatomical sections. In general, most Lauraceae genus showed means significantly higher than those found for species/genus from the Fabaceae and Proteaceae families.

In general, colorimetric parameters showed potential to discriminate different species, within and between different families. The best differentiation of some species was achieved for different colorimetric parameters and anatomical sections of the wood.

Other studies have utilised colorimetry to characterise and discriminate between wood species. Silva et al. (2017) reported differences in the colorimetry of wood from thirty tropical species. Sousa et al. (2019) conducted research aimed at supporting the inspection of wood commercialisation using colorimetry and described differences between the results of the species analysed. Additionally, Naide Acosta et al. (2024) investigated the influence of wood anatomical sections and classification methods on the discrimination of wood with similar shades, commercialized in the southern region of Brazil as 'marfim' pattern.

Literature data on the same species evaluated in this study corroborate differences depending on the evaluated material. For example, results for *Dipteryx odorata* had mean values lower than data described by Paula et al. (2016), which did not verify the difference between radial and tangential surfaces, and a* values were similar to those obtained by Costa et al. (2021), but other parameters were lower. Colorimetric parameters obtained for *Pseudopiptadenia suaveolens* are higher than observed by Medeiros et al. (2021); for *Hymenaea courbaril,* mean values are lower than data obtained by Ribeiro et al. (2018) and Costa et al. (2021), and when the analysis was done on anatomical surfaces, luminosity (L*) was similar in radial and tangential sections, and other parameters were also lower.

These variations show the need for a great database and multivariate statistics to use colorimetric parameters in wood identification but indicate the possibility of application as a complementary tool with quick response using portable equipment.

Using the biplot graph of principal component analysis (Figure 5a) it is possible to infer the contribution of colorimetric parameters in the grouping or separation between wood species/genus and families. In general, wood samples from the same species/genus showed a greater tendency to approximate each other. Furthermore, samples of species from the same family were commonly closer together.

The wood samples from LV - *Roupala* sp. (Proteaceae) were characterised by high L* values, with visible separation in relation to the other species. Additionally, some samples of *Ormosia* sp. (Lauraceae) shared similar characteristics (high L* values) with LV - *Roupala* sp. Moreover, IT - *Mezilaurus* sp. (Lauraceae) also showed clear separation, with its samples exhibiting high b* and C* values.

Regarding the separation between botanical families, a better distinction was observed for Fabaceae. Only *Ormosia* sp., with high a* values, and *P. suaveolens,* with high b* and C* values, had similar parameters with wood from the Lauraceae family (ITA - *Mezilaurus* sp.) and Proteaceae (LV – *Roupala* sp.). This greater proximity may be related to natural changes resulting from the tree growth process among other biotic and abiotic factors.

Chromaticity (C*) showed a greater contribution to the variance explained by PC-1, while the hue angle (h) showed greater weight in PC-2. Only the L* and the a* coordinates were inversely correlated with PC-1 and PC-2, respectively.

The families in general showed similar spectral behavior (Figure 7), with closer reflectance values for the Lauraceae and Fabaceae families, especially in the wavelength range from 370 nm to 570 nm.

The best performance in classification was with SVM with the average data of all sample spectra (Table 4), where the majority of species presented a correct classification greater than 54%. The highest percentage of correct answers was for the LB - *Euplassa* sp. (92.6%), which was only confused with JA - *H. courbaril* (7.4%). Only the species JA - *H. courbaril* showed greater confusion in the external classification (25.7%), mainly with other species of the Fabaceae family, such as AP - *H. petraeum* (6.9%), CU - *D. odorata* (9 .7%), FT - *E. maximum* (25.7%), LC - *Ormosia sp.* (6.9%) and TIM – *P. suaveolens* (12.5%). This greater confusion between species of the Fabaceae family is explained by the similar behavior of the visible spectra at wavelengths from 390 nm to 570 nm (Figure 6).

CONCLUSION

The colorimetric parameters and visible reflectance spectra allowed discriminating species/genera from different families. In general, data are influenced by the anatomical section of the wood and, commonly, vary between species, whether from the same family or from different families. In colorimetry, the parameters with the greatest potential for distinguishing between species were L*, b* and h. In visible spectroscopy, the regions of the spectra from 530 nm to 570 nm presented a greater contribution to the variance explained by PC-1, while the spectra from 360 nm to 390 nm and 740 nm presented greater weights in PC-2.

When distinguishing samples, the best results were observed for the SVM classifier, reaching up to 100% correct classification for samples of *Ormosia* sp. and *Euplassa* sp. Therefore, the colorimetric technique in association with multivariate analyses has potential for use in characterising Amazonian wood.

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