



Characterization of wood popularly known as “Louros” in the Brazilian amazon by visible spectroscopy and CIELAB parameters

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Abstract

Aim of study: The objective of this work was to evaluate the potential of colorimetry to discriminate wood from the “louros” group, in particular to contribute to a database of Brazilian native species for future application in logging control actions.

Area of study: The wooden discs were collected in a Sustainable Forest Management Area (AMFS) belonging to two extractivist communities, Paraiso and Arimum, both in the “Green Forever” Extractivist Reserve, in the municipality of Porto de Moz, Pará state, Brazil.

Materials and methods: Colorimetric evaluation was carried out based on data from the CIEL*a*b* system, analyzed using PCA and ANOVA in a completely randomized design in a two-factor scheme.

Main results: PCA produced some evidence of color patterns and some parameters may be more useful in characterization. Longitudinal surfaces were more indicated for this group characterization. The data from CIEL*a*b* system produce helpful information for distinction of wood from “louros” group, and so, the colorimetric technique can be an auxiliary tool for separation of this group, complementary to other techniques as wood anatomy.

Research highlights: Correct discrimination of wood from “louros” group in commerce control; Brazilian native species.

Keywords: Species distinction; Lauraceae; proteaceae; color parameters.

Abbreviations used: Commission International de L’Eclairage: CIE, Sustainable Forest Management Area: AMFS, Ministry of the Environment: MMA, Chico Mendes Institute: ICMBio, Authorization and Biodiversity Information System: SISBIO, National System for Genetic Heritage Management: SisGen, Analysis of variance: ANOVA, Principal Component Analysis: PCA, *Aniba* sp.: PR, *Euplassa* sp.: LB, *Roupala* sp.: LV, *Ocotea* sp.: LR, *Ocotea* sp.: LPI, *Mezilaurus* sp.: IT, *Mezilaurus* sp.: ITA.

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Supplementary material: Tables S1 to S3, and Figure S1 accompany the paper on FS website.

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Introduction

The Lauraceae family has 52 genera and approximately 3,000 species, distributed in pantropical regions (Rohwer, 1993; Flora do Brasil, 2020). It forms a taxonomic group with great difficulty of species identification, because wood even from different genera have close

morphological similarity (Caiafa & Martins, 2007). This family is important in the floristic composition of the Atlantic Forest and Amazon Forest regions (Souza & Lorenzi, 2008). The wood has high economic value, principally from the genera *Ocotea* sp., *Nectandra* sp., *Mezilaurus* sp. and *Aniba* sp., which are marketed for civil and boat construction (including veneers and boards), cabinet and

furniture making, carpentry and barrel making. Besides this, various parts of the trees of some species have medicinal properties (Gottlieb, 1972; Ribeiro *et al.*, 1999).

The Proteaceae family has 80 genera and 1,750 species of shrubs and trees (Weston & Barker, 2006). In Brazil, it is distributed in the Amazon and Atlantic forests, with approximately 33 species (Flora do Brasil, 2020). For wood application, the genera most used are *Roupala* sp., and *Euplassa* sp.

In Pará state, Brazil, the group commonly known as “louros” from the Lauraceae and Proteaceae families has high commercial value, particularly the species called in Portuguese louro pimenta, louro preto, louro vermelho, louro branco, louro rosa, itauba, itauba-amarela and preciosa (SEMAS-PA, 2016). Woods of itauba, itauba-amarela and preciosa, even without the denomination of “louros” are within this group.

So, the use of accurate, fast and nondestructive techniques for species identification is important. Among these methods are colorimetry and visible spectroscopy, which can be applied for discrimination or characterization of wood in function of color parameters, principally when associated with texture and grain pattern (Camargos & Gonçalves, 2001). However, many factors can influence wood color, such as chemical and anatomical composition, sawing pattern, position of samples in the trunk, height, diameter, tree age, exposure to natural or artificial light, and genetic factors intrinsic to each species (Pastore *et al.*, 2004; Montes *et al.*, 2008; Montes *et al.*, 2013; Vieira *et al.*, 2019).

To standardize color parameters numerically, the CIEL*a*b* system was established by the CIE (Comision International de L'Eclairage), based on color definition of three parameters: lightness or luminosity (L^*), related to position on a black-white axis; chromatic coordinate of the green-red axis (a^*) and blue-yellow axis (b^*), and also the saturation or chroma (C^*) and hue angle (h) based on a^* and b^* (Camargos & Gonçalves, 2001).

In function of the social, economic and ecological importance of species from the Lauraceae and Proteaceae family, we studied the potential of colorimetry to discriminate wood from the “louros” group, in particular to contribute to a database of Brazilian native species for future application in logging control actions.

Finally, this study is a contribution to the knowledge about potential of colorimetry in characterization or distinction of wood species with commercial value in Brazilian Amazon. So, we intend to answer some questions: i) Colorimetry based on CIEL*a*b* system can produce valuable information's about color pattern and, as a result, be an auxiliary tool for wood distinction in “louros” group? ii) Which colorimetric parameter contribute more significantly for this species differentiation? and iii) Some anatomical surface has better color data for this species distinction?

Material And Methods

Acquisition of wood samples

The wooden discs were collected in a Sustainable Forest Management Area (AMFS) belonging to two extractivist communities, Paraiso and Arimum, both in the “Green Forever” Extractivist Reserve, located at 01°55'45,4" S and 52°56'10,5" W, in the municipality of Porto de Moz, Pará state, with total area of 1,289,362,78 hectares. The authorized volumes for exploitation of wood, per year are in Paraiso 2,198.64 m³ (Authorization n. 7/2017), and in Arimum 4,740.74 m³ (Authorization n. 9/2016).

The study was approved by the Ministry of the Environment (MMA) and Chico Mendes Institute (ICM-Bio) under number 64485-1 via the Authorization and Biodiversity Information System (SISBIO). All species analyzed are registered in the National System for Genetic Heritage Management (SisGen) under code A1D7BF7.

The selection of species for sampling, based on popular names, was constructed in function of the results of two forest censuses, conducted in 2016 and 2017. Trees were selected in function of availability in both communities, from August 23-25, 2018. Some trees marked for exploration were selected for cut. Fig. S1 [suppl.] illustrate the sampling procedure and material prepare for colorimetric analysis: I) selection of one specimen by species; II) one disc, with 5 cm of thickness, was sampled at 10 cm from the region where a tree was cut; III) a diametrical sample was obtained in each disc; IV) diametrical sample with 5 cm of thickness and 5 cm of width; V) final samples with dimensions of 2.5 x 2.5 x 2.5 cm, oriented in anatomical sections for analysis. The number of samples varied in function of tree diameter and quality of diametrical samples.

Genus confirmation was performed in Laboratory for Wood Anatomy and Quality of Federal University of Paraná. A total of 101 solid wooden cubes were evaluated (Table 1). Geographic coordinates and diameter at breast height (DBH, measured at 1.30 m from soil) are in Table S1 [suppl.]. The tree sampling was in the radial position of the trunk, but no separation of heartwood and sapwood was done. All samples were identified at the genus level, because the wood anatomical traits are very similar, and insufficient information is available for adequate distinction at the species level.

Colorimetry

Colorimetric evaluation was carried out based on the CIEL*a*b* system, with a Konica Minolta CM-5 spectrophotometer, with the Spectra Magic NX software, using illuminant D65 and observation angle of 10°. Samples remained in a room with temperature of 24° C and 60% relative humidity. To standardize surfaces and eliminate influence of

Table 1. Woods popularly known as “Louros” collected in Paraiso and Arimum communities

Vernacular name	Code	Scientific name	Family	Community	Solid wooden cubes	Data number
Preciosa	PR	<i>Aniba</i> sp.	Lauraceae	Paraiso	11	198
Louro vermelho	LV	<i>Roupala</i> sp.	Proteaceae	Arimum	8	144
Louro rosa	LR	<i>Ocotea</i> sp.	Lauraceae	Paraiso	13	234
Louro pimenta	LPI	<i>Ocotea</i> sp.	Lauraceae	Arimum	11	198
Louro preto	LP	<i>Nectandra</i> sp.	Lauraceae	Arimum	12	216
Louro branco	LB	<i>Euplassa</i> sp.	Proteaceae	Arimum	11	198
Itauba amarela	ITA	<i>Mezilaurus</i> sp.	Lauraceae	Paraiso	8	144
Itauba	IT	<i>Mezilaurus</i> sp.	Lauraceae	Arimum	27	486
Total					101	1,818

oxidation, all samples were polished with sandpaper #80. Data were collected randomly in the three anatomical surfaces of each sample: transversal, longitudinal tangential, and longitudinal radial. Visible reflectance spectra in the range 360–740 nm were obtained and the parameters luminosity (L^*) and chromatic coordinates from green-red (a^*) and blue-yellow (b^*) axes were recorded, in a total of 18 readings per sample (6 from each surface), for a total of 1,818 readings, in a total of 101 solid wooden cubes. The values of saturation or chroma (C^*) and hue angle (h) were calculated in accordance with Eq.1 and Eq.2, respectively.

$$C^* = (a^2 + b^2)^{1/2} \quad (1)$$

$$h = \arctg\left(\frac{b^2}{a^2}\right) \quad (2)$$

Statistical analysis

The colorimetric parameters (L^* , a^* , b^* , C^* and h) were submitted to analysis of variance (ANOVA) in a completely randomized design in a two-factor scheme (8 x 3) (species x anatomical section), with 18 replicates by solid wooden cubes, 6 replicates in each anatomical section. The normality of data was evaluated by Shapiro-Wilk ($\alpha = 0.05$) test. Analysis was done in R (version 3.4.3) with the ExpDes.pt package (Ferreira *et al.*, 2013). The Snedecor F-test of ANOVA ($\alpha = 0.05$) was applied to verify the significance of the factors' interaction. When significant interactions were found, interaction unfolding was performed, and the Tukey test ($\alpha = 0.05$) was applied. The objective of this procedure was to analyze the behavior of species factors in each wood anatomical section and viceversa.

Wood is a heterogeneous and anisotropic material, and because of this has great variability. Therefore, a single tree has differences in the anatomical characteristics of the wood, for example, the color, design, which are related to the sensory characteristics. For that reason, for the factorial ANOVA, each data obtained in different positions on the three surfaces of each solid wood cube was considered an independent sample unit.

To evaluate the influence of colorimetric parameters for species grouping, Principal Component Analysis (PCA) was carried out with the FactoMineR package (Kassambara & Mundt, 2017; Lê & Husson, 2008), and the principal results were extracted with the FactoInvestigate package (Thuleau & Husson, 2020). For PCA analysis, data were standardized to mean zero and standard deviation of 1. Decision about number of principal components were done considering cumulative percentage of explained variance and number of eigenvalue higher than 1. Eigenvalue represents the amount of variation in each PC. Additionally, loadings were evaluated and the contribution, in percentage, of each parameter for PCs were calculated. A biplot graph was constructed to verify the relationship of PCA samples and the contribution of each variable to the principal components. Reflectance curves of visible spectra were plotted with the ggplot2 package (Wickham, 2016).

Results

Two-factor analysis

The Snedecor F-test of ANOVA ($\alpha = 0.05$) indicate that species x anatomical section interactions were highly significant for all colorimetric parameters (L^* , a^* , b^* , C^* , h), enabling inferring that the factors do not act independently, *i.e.*, at least one level of the factor “species” has different behavior in one level of the factor “anatomical section”, and *viceversa*. Details of the “species x anatomical section” interactions for each colorimetric parameter are reported in Fig. 1. The main results of analysis of “species in each anatomical section” and “anatomical section in each species” are reported in Table S2 [suppl.] and Table S3 [suppl.].

Principal component analysis

In PCA, two principal components had eigenvalues (λ_i) higher than 1: PC-1 represents 64% ($\lambda_1 = 3.20$) and

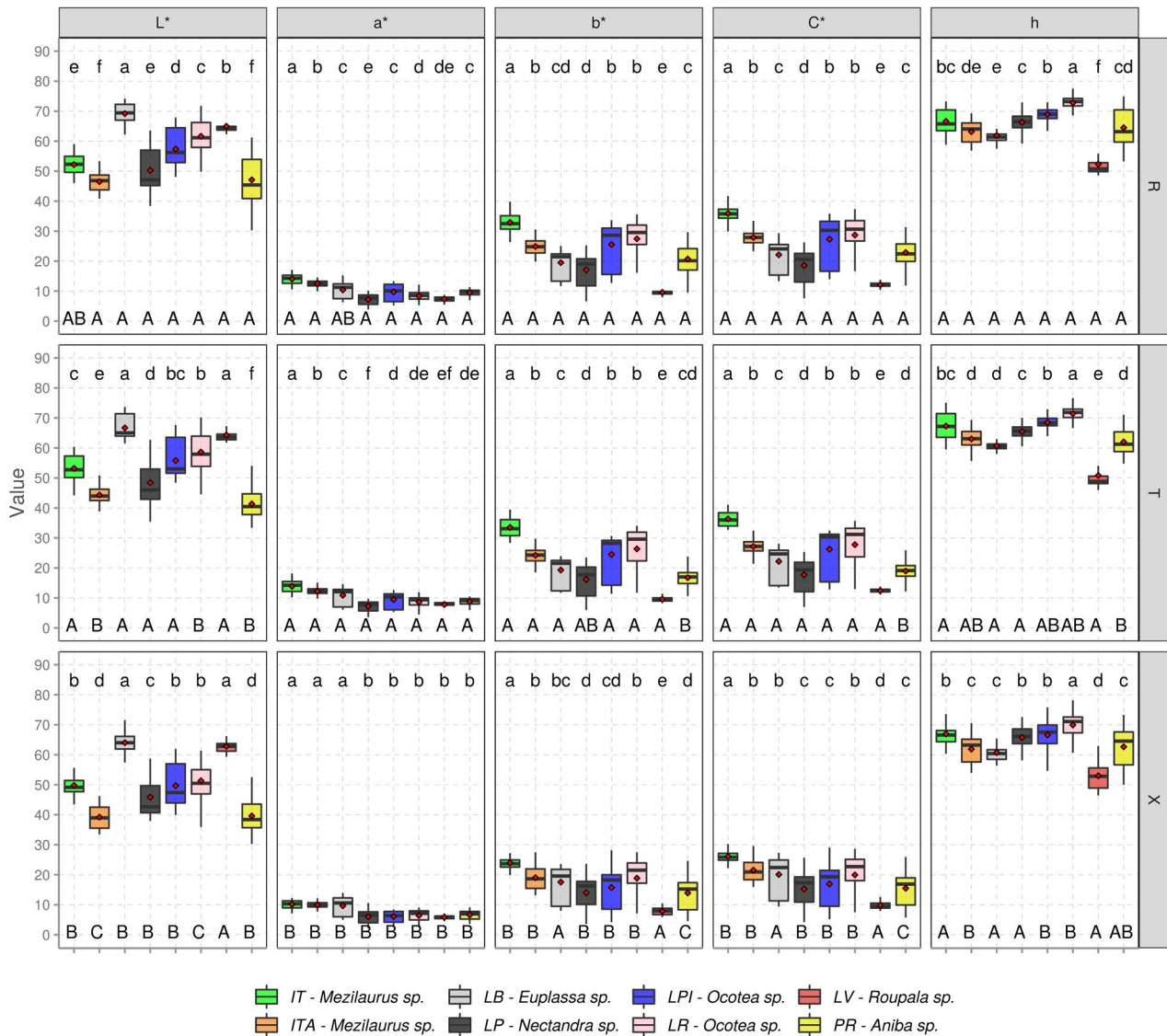


Figure 1. Results of the unfolding analysis of the interaction between species versus anatomical section of wood known as “Louros” in the Brazilian Amazon. Where: Small letters compare mean colorimetric parameters in each subgraph, between species and for each anatomical section. Capital letters compare mean colorimetric parameters, between anatomical sections for each species. Tukey test at $\alpha = 0.05$. R = radial surface, T = tangential surface, X = transversal surface, L* = luminosity; a* = green-red chromatic coordinate, b* = blue-yellow chromatic coordinate, C* = chroma or saturation, h = hue angle.

PC-2 20.6% ($\lambda_i = 1.03$) of total variation in standardized data (Fig. 2). In biplot graphic (Fig. 2A) it is possible to verify the existence of a great positive correlation between parameters b* and C*, *i.e.*, woods with high value of b* had high value of C*. On the other hand, parameters L* and a* had negative correlation, *i.e.*, wood with higher values of a* had lower values of luminosity. Hue angle (h) had almost perpendicular distribution in relation do L* and a*, and so low correlation between them.

Percentage of contribution and loadings of each parameter was investigated (Figs 2B and 2C). Parameters b* and C* showed more influence in explained variance by PC-1, with correlation of 0.9843 and 0.9805, respectively, and hue angle presented higher effect in PC-2, contributing with 50% of total variance explained. Parameters C*,

b*, a* and h had positive correlation with PC-1, and parameter a* had negative correlation to PC-2.

Reflectance spectra

The visible reflectance spectra of wood of the “louros” group indicate some differences (Fig. 3). In first wavelengths, from ~ 360 to 450 nm there is a tendency of three groups formation that can be visually identified. Group 1: Samples of LB - *Euplassa* sp. and LV - *Roupala* sp. have higher reflectance in comparison to other samples, contributing to differentiation of Proteaceae family in relation to Lauraceae. Group 2: LR - *Ocotea* sp., LPI - *Ocotea* sp. and LP - *Nectandra* sp. had similar reflectance until 430 nm, from

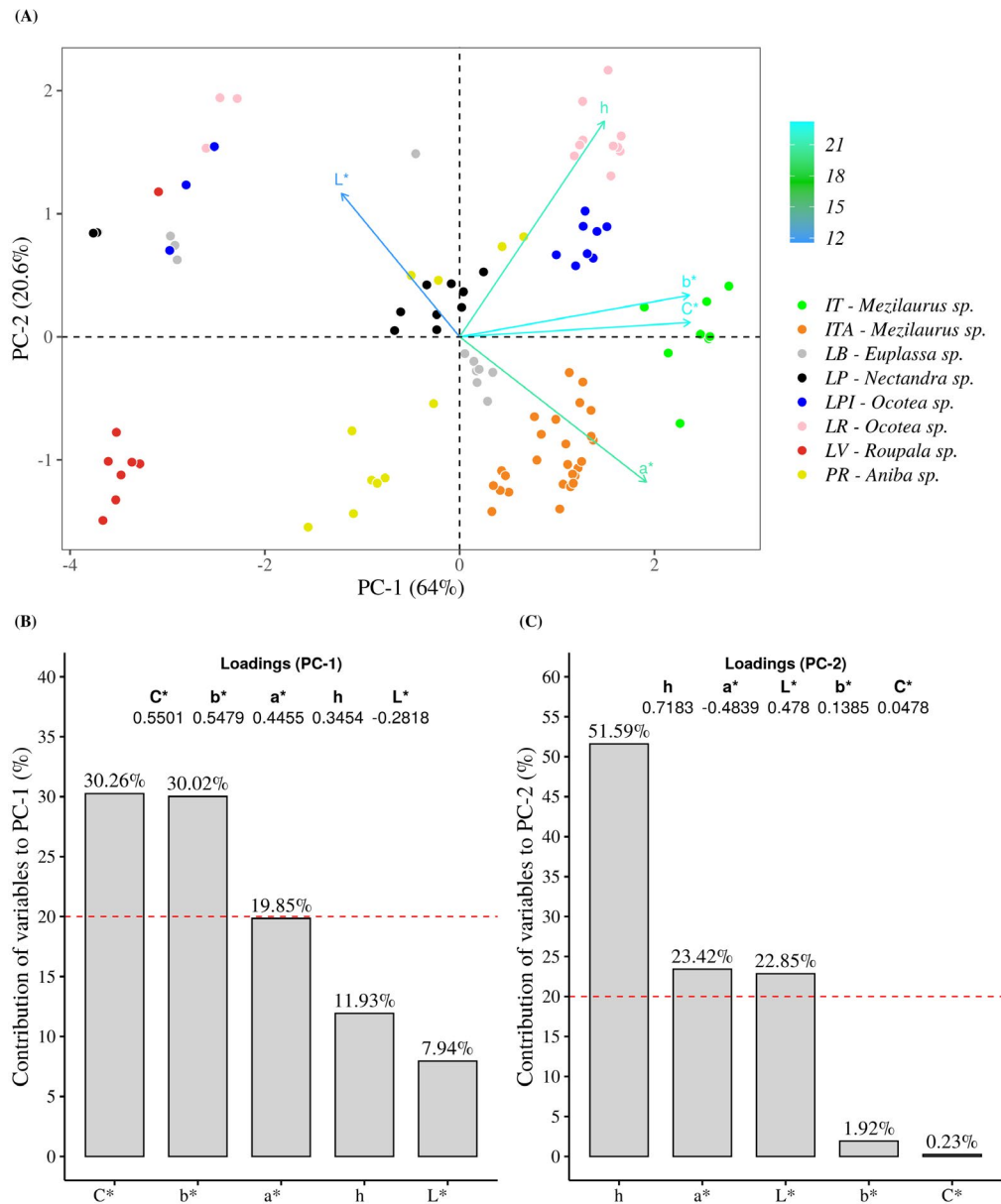


Figure 2. Biplot chart (A) and contribution (in percentage) and loadings of colorimetric parameters to each principal component (B and C). red dot line: indicates the amount of variation that each parameter would contribute, if all showed the same proportion of contribution in the PC.

440 nm onward, genus *Ocotea* has higher reflectance in comparison to genus *Nectandra*, with influence of yellowish and reddish color. Group 3: Samples from PR – *Aniba* sp. had lower reflectance. When we compare samples from genus *Mezilaurus* (IT and ITA) reflectance spectra was similar from 360–450 nm, and ITA has higher reflectance in other wavenumbers, relating to yellowish color.

Discussion

The colorimetric parameters of wood of the “louros” group varied substantially. In the mean data for sections, luminosity (L*) varied from 42.69 to 66.64; chromatic

coordinate a* had values from 6.80 to 2.69 and chromatic coordinate b* had values from 8.99 to 30.13; chroma (C*) varied from 11.44 to 32.78; and the hue angle (h) from 52.05 to 71.42. In accordance with the classification described in Camargos & González (2001), wood with luminosity values lower than or equal to 56 ($L^* \leq 56$) are considered dark, and with values higher than 56 ($L^* > 56$) are classified as light. So, louro branco (LB - *Euplassa* sp.), louro vermelho (LV - *Roupala* sp.) and louro rosa (LR - *Ocotea* sp.) were classified as light woods, and others as dark.

Wood from LB - *Euplassa* sp. and LV - *Roupala* sp. were similar in almost all anatomical characteristics, except number of strand cells in the axial parenchyma, which

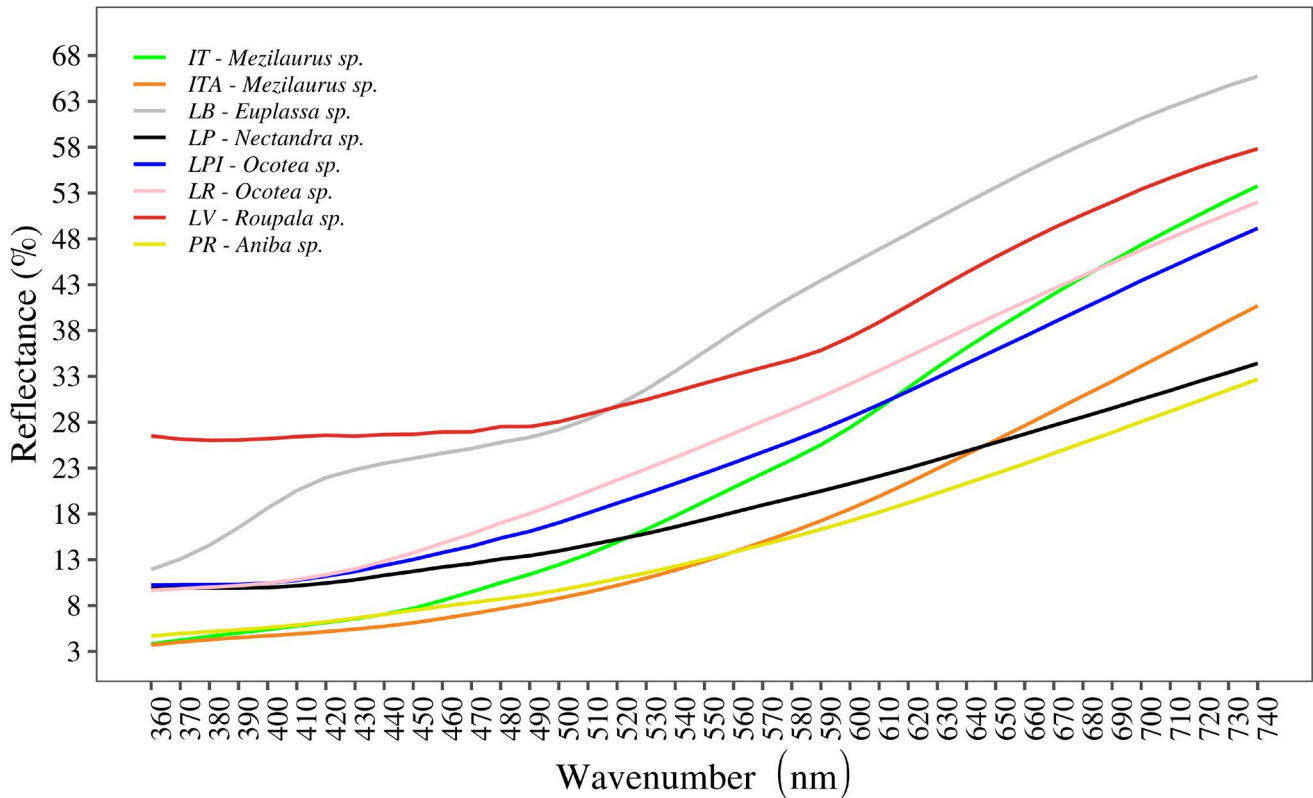


Figure 3. Mean visible reflectance spectra of samples of the “Louros” group collected in Paraiso and Arimum communities, Pará state.

in *Euplassa* sp. varied from one to two, and in *Roupala* sp., from one to six, which can contribute to variations in the parameter L^* on the radial surface. This also occurred in function of the chemical composition of parenchyma cells, which store substances and can contain a large variety of extractives. In a study with Jatobá wood (*Hymenaea courbaril* L.), Baar *et al.* (2014) described positive correlation between extractives content and parameter L^* , in other words, generally higher extractives content was related to lighter wood color.

Considering species factor, wood from LR - *Ocotea* sp. and LPI - *Ocotea* sp. had similar means in L^* , when evaluating separately tangential or transversal sections. This can be related to anatomical characteristics of the species, since they are from the same botanical genus. The results of this study are similar to those described by Silva *et al.* (2017) in the tangential section of *Ocotea* sp. ($L^* = 56.72$; $a^* = 8.84$; $b^* = 22.45$; $C^* = 24.17$ and $h = 68.6$).

There were no significant differences between color parameters a^* , b^* , C^* and h in tangential and radial sections for most evaluated wood. The similarity of longitudinal sections (radial and tangential) can be explained by anatomical characteristics in contrast to transversal section where it is possible to identify growth rings (González *et al.* 2001). Melo *et al.* (2019) described similar findings when evaluating 18 species of commercial wood from the Brazilian Amazon. For *Mezilaurus itauba*, the value was

lower ($L^* = 54.40$) than our results, and for *Ocotea* sp. it was similar ($L^* = 60.12$) for LR - *Ocotea* sp. Similar data were also described by Barreto & Pastore (2009), with lower values for *Mezilaurus itauba* with extractives ($L^* = 42.97$) and without them ($L^* = 41.81$).

Samples of PR - *Aniba* sp. had differences in the colorimetric parameters L^* , b^* , C^* and h between tangential and radial sections, which is related to anatomical characteristics, as described in other studies. This can be the result of cell arrangement, vessel and ray dimensions (Nishino *et al.*, 1998; Sousa *et al.*, 2019).

Lower values of L^* on the transversal surface of LB - *Euplassa* sp., LPI - *Ocotea* sp. and LP - *Nectandra* sp. can be related to fiber cell walls. Parameters C^* and h are calculated and influenced by values of chromatic coordinates a^* and b^* . Therefore, mean values of C^* for IT - *Mezilaurus* sp. and LV - *Roupala* sp. had the same tendency of a^* and b^* .

There is consensus that wood color is influenced by many factors, such as tree age, chemical composition, origin of material and genetic factors (Arce & Moya, 2015; González *et al.*, 2014; Montes *et al.*, 2013; Silva *et al.*, 2017), and wood density (Sousa *et al.*, 2019) and characteristics of each wood anatomical section (Nishino *et al.*, 2000). In function of exposed above, it was not possible to differentiate samples based only on mean test, being necessary the application of Principal Component Analysis (PCA).

Based on PCA analysis, it was verified that colorimetric parameters provided important information's for distinction of wood from “louros” group, besides some species had higher similarity in some parameters. Hue angle, for example, was useful for characterization of LR – *Ocotea* sp. (higher values) and PR – *Aniba* sp. (lower values). Also, this parameter influenced separation of LR – *Ocotea* sp. and LPI – *Ocotea* sp., from the same genus, but species with different color.

Wood from ITA – *Mezilaurus* sp. and IT – *Mezilaurus* sp. were especially near, but the luminosity brings information for this species distinction, and parameters a^* , b^* and C^* had lower influence. In general, ITA – *Mezilaurus* sp. had lower values of L^* and IT – *Mezilaurus* sp. had higher values of b^* and C^* .

Colorimetric parameters for LV – *Roupala* sp. allowed an adequate distinction from other species. Wood from LP – *Nectandra* sp. (black, central) and LB – *Euplassa* sp. (gray, central) had similar characteristics, but was separated by L^* and a^* parameters.

In relation to visible reflectance spectra, the behavior of all wood samples from the “louros” group showed the influence of yellow and red in color formation, with some more reddish than others. In some cases, visible spectra can be applied for species or genus characterization, as described by Nisgoski *et al.* (2017) when evaluating seven species of the genera *Eucalyptus* and *Corymbia*, who reported the formation of two groups, wood with red-rose or gray-yellow-brown color, and highlighted the influence of the region from 640 – 740 nm for species distinction.

“Louros” group is among the principal wood commercially explored in Brazilian Amazon. So, this study has impact in species conservation producing information that can contribute to a database and in the future contribute to practical applications in forest supervision and to diminish ecologic and socio-economic damage, and increase the sale credibility of tropical wood.

Conclusions

The results indicate that data from CIEL* a^*b^* system produce helpful information for distinction of wood from “louros” group, and so, the colorimetric technique can be an auxiliary tool for separation of this group, complementary to other techniques as wood anatomy.

Based on principal component analysis, wood differentiation is the result, in higher or lower percentage, of colorimetric parameters variation. Hue angle was indicated to discriminate LR – *Ocotea* sp. and LPI – *Ocotea* sp. and luminosity was more important in distinction of ITA – *Mezilaurus* sp. and IT – *Mezilaurus* sp.

Considering anatomical surface, a similar tendency was observed for longitudinal radial and longitudinal

tangential data. In general, longitudinal surfaces were more indicated for this group characterization, but there was no distinction of the eight evaluated wood, independently of anatomical section or colorimetric parameter.

We advertise the importance of similar research with other species, more sample variation inside the trunk, to contribute to a better generalization of data for practical use.

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