An Acad Bras Cienc (2022) 94(1): e20191479 DOI 10.1590/0001-3765202220191479
Anais da Academia Brasileira de Ciências | *Annals of the Brazilian Academy of Sciences*
Printed ISSN 0001-3765 I Online ISSN 1678-2690
www.scielo.br/aabc | www.fb.com/aabcjournal

FORESTRY SCIENCE

Colorimetry as a tool for description of some wood species marketed as "tauari" in Brazilian Amazon

JOIELAN X. DOS SANTOS, HELENA CRISTINA VIEIRA, DEIVISON V. SOUZA, GRACIELA INÊS B. DE MUÑIZ, PATRÍCIA SOFFIATTI & SILVANA NISGOSKI

Abstract: The aim of this study was to verify the potential of the colorimetric technique in the identification of some species marketed as "tauari" in the Brazilian Amazon. CIE L* a* b* parameters were applied to determine the colour of 35 wood samples from the main wood poles of the State of Para, Brazil, and the scientific collections of the Museu Paraense Emilio Goeldi (Walter A. Egler Collection) and Embrapa Amazônia Oriental. From each sample, data were obtained in the three wood surfaces: transversal, longitudinal tangential and longitudinal radial. The coordinate b*, which showed the yellow pigment, exerted greater weight in the color characterization of the 35 samples marketed as tauari, being more evident in the tangential and radial sections. In PCA, MGW wood samples showed considerably distinct color patterns in relation to PA and IAN samples, and the h and L* parameters provided better informations for distinguishing species from sample sources. The colorimetric technique can be used as an auxiliary tool in the identification of wood. However, the simultaneous use of colorimetry with the anatomical description of wood is suggested, given the complexity of the species-level separation in "tauari" group.

Key words: color parameters, Couratari, Lecythidaceae, wood discrimination.

INTRODUCTION

The Amazonian forest has high economic importance, being a great source of income in the Northern region, both for extractivism, as well as for the wood trade. In the states of the Amazon, the commercialization and industrial processing of wood are among the main economic activities, alongside industrial mining and agriculture (Lentini et al. 2011). In the state of Pará, the income obtained from the sale of wood in 2015 was approximately 87 million of dollar (Pará 2015).

The Lecythidaceae family has pantropical distribution, concentrated in the neotropical region, including about 25 genera and 300 species (Souza et al. 2008). In Brazil the family is represented by 10 genera and approximately 121 species (Flora do Brasil 2020). The main genera of this family are: *Allantoma* Miers, *Cariniana* Casar. and *Couratari* Cambess. and the natural diversity of the *Couratari* genus occurs in northern Amazonia, with 53% of its species (Mori 1990).

Lecythidaceae species, besides their great ecological importance for the neotropical forests, are also of economic importance for the region. Woods of these species are highly valued in the Amazon region, especially in the state of Pará, where approximately 1 million m³ of wood from the tauari group has been marketed in the period from 01/01/2014 to 21/02/2016 (SEMAS-PA 2014, 2015, 2016). The high commercialization of this group is justified because the wood is moderately soft to cut, offering good finishing, being widely used in civil construction, with a wide commercialization for both domestic and foreign markets (Bernal et al. 2011, Paula & Costa 2011). However, they present great difficulty in distinguishing species, besides having several common names in commercial transactions and this generates socioeconomic and environmental consequences (Martins et al. 2003). Also, Procópio & Secco (2008) described that the utilization of only one scientific name by wood sector for species from "tauari" group, can result in damages for real information about species population.

In general terms, for the identification of forest species, reproductive and vegetative materials are used. However, in the timber sector it is necessary to perform the anatomical identification of wood, a technique that requires a lot of time and specialized people for this task to be done correctly. With the emergence of technological advances, new non-destructive methods for wood characterization were discovered, thus allowing the improvement of the use of this raw material (Oliveira et al. 2005).

Therefore, the use of non-destructive methods for species distinction, especially of the tauari group, is of great value, since in the Brazilian Amazon the discrimination of tauari wood is a problematic factor, given the great diversity and origins, often grouped under the same species (Coradin & Camargos 2002). Among these non-destructive techniques are colorimetry as a method that can be used to assist in the process of species discrimination. Camargos & Gonçalez (2001) highlight that color is one of the most extraordinary characteristics for species identification and indication of uses, especially when associated with the texture and design aspects of wood.

Colorimetry has been applied for wood distinction in diverse studies, for example by Vieira et al. (2019) evaluating some Myrtaceae species from Atlantic Forest, Barros et al. (2013) and Sousa et al. (2019) describing tropical species from Amazon Forest. However, colorimetric parameters can be influenced by many factors, for example, species (Silva et al. 2017), tree age (Arce & Moya 2015), genetic parameters (Sotelo-Montes et al. 2008), localization of forest (Sotelo-Montes et al. 2013), kiln conditions (Gonçalez et al. 2014), chemical composition (Moya et al. 2012), exposition to natural or artificial light (Pastore et al. 2004, Baar & Gryc 2012, Laskowska et al. 2016).

In function of exposed above, based on socioeconomic and ecological importance of "tauari" group, and difficulty of species discrimination, this study has the objective to verify the potential of colorimetric parameters in identification of wood species marketed as "tauari" in Brazilian Amazon.

MATERIALS AND METHODS

Wood marketed as "tauari" were collected randomly in 15 sawmills in ten municipalities of Pará state. In order to avoid a tendency during the separation of the samples, those responsible for the sawmills were asked about the common name of the selected woods. It was not possible to know if sawn wood was from a Sustainable Forest Management Plan (PMFS). Aiming at the representativeness of the commercialization of the species in question, the sampling covered all the radial variation of the board, thus, there was no separation of the samples between heartwood and sapwood. A total of 18 samples with dimensions of 50 x 20 x 5 cm (length, wide and thickness) were obtained. Species identification was done in Wood Anatomy and Quality Laboratory (LANAQM) at Universidade Federal do Paraná (UFPR), Paraná State, Brazil, based on anatomical description and after comparison to scientific collections from Emilio Goeldi Paraense Museum (Walter A. Egler Collection) and Embrapa Amazônia Oriental. Samples were identified as from Lecythidaceae family and two genera: six *Couratari stellata* A.C. Sm., seven *Couratari oblongifolia* Ducke & R. Knuth, four *Couratari guianensis* Aubl. and one *Eschweilera* sp. Mart.ex DC. The access to material is registered at Conselho de Gestão do Patrimônio Genético (CGEN/SISGEN) under number ADE10D5.

Samples were cut with 2.5 x 2.0 x 2.0 cm (transversal, radial and tangential surface) and to eliminate oxidation effects and saw marks in surfaces, material was polished with sanding granules 100. To reach the equilibrium moisture content close to 12%, the material was stored at controlled atmosphere with temperature of 25 ± 2 °C and relative humidity of 60 ± 2%.

Colorimetric evaluation was performed using a Konica Minolta CM-5 spectrophotometer with a spectral range from 360–740 nm, D65 light source and 10º observation angle. CIE L*a* b* parameters are the most applied in wood color determination in function of its fast and easily interpretation and calculations. Three data were obtained in each anatomical surface, in a total of 18 by sample. Lightness (L*), green-red chromatic coordinate (a*) and blue-yellow chromatic coordinate (b*) were obtained in transversal, radial and tangential sections. Values of chroma (C*) and hue angle (h) were calculated with equations 1 and 2. Final colour of wood from "tauari" species was classified in basis of colour table suggested by Camargos & Gonçalez (2001).

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

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

To calculate variations in color parameters of "tauari" samples, first *Kolmogorov-Smirnov (K-S)* test, at 95% of probability was done to verify normal distribution of data. After its verification, to compare mean values, Tukey test was applied also at 95% of probability (α = 0.05). Descriptive statistics and variance analysis (ANOVA) were evaluated with software Statgraphics (XVII-X64). Reflectance curve of visible spectra were processed at Unscrambler X (versão 10.4).

To evaluate the potential of technique in species identification, data obtained from 17 samples from scientific collections were added in analysis: nine from Xiloteca (Walter A. Egler Collection) from Emilio Goeldi Paraense Museum, six *C. guianensis*, two *C. stellata* and one *C. oblongifolia*; and eight from Embrapa Amazônia Oriental, Pará state, with four *C. guianensis*, two *C. stellata* and two *C. oblongifolia*. Information about time of storage and preserving product added were not disponible. So, a total of 35 samples were analyzed.

To verify the influence of species and the samples source (scientific collections x sawmill) a Principal Component Analysis (PCA) was done based on colorimetric parameters (L*, a*, b*, C* and h) with Facto Mine R (Le et al. 2008). To graphic implementation in PCA function *fviz_pca_biplot* and *fviz_contrib* from facto extra (Kassambara & Mundt 2017). Both packages are available in R (R Core Team 2017) statistic program (version 3.4.3).

RESULTS AND DISCUSSION

Variation of color among species collected in sawmills

Mean values and standard deviation of colorimetric parameters by species from samples collected in different municipalities of Pará state are in (Table I).

Parameters L* (64.57 to 69.41), a* (6.96 to 8.00) and h (72.59 to 74.45), do not present significant statistical differences by Tukey test (α = 0.05). In chromatic coordinate b*, *Eschweilera* sp. showed the great value and was distinct from other species. In Chroma (C*) few differences were observed in species, because the parameter is calculated with a* and b* values. For all species, high values from lightness (L*) and low values from a* resulted in a brightness wood. Similar results were observed in *Cariniana micrantha* Ducke (Tauari-vermelho), *Protium puncticulatum* J.F. Macbr (Breu-vermelho), *Caryocar glabrum* (Aubl.) Pers. and (Pequiarana) (Barros et al. 2013).

Wood with values from lightness smaller or equal to 56 (L* ≤ 56) are considered darker and greater than (L* > 56) are classified as bright. Therefore, all species evaluated here are in Cluster 5 (bright-yellow) in classification table of Camargos & Gonçalez (2001). The resultant color is the sum of reflected wavelengths in visible light, surface roughness, and internal structure of wood piece and refraction properties of interacting substances (Meints et al. 2017). Darker woods in general present lower values of L* and higher values of a* and brightness woods present the opposite characteristic (Silva et al. 2017).

Similarly, a decrease in brightness and increase in yellow color was observed in teak with 15 years in comparison to 11 years old (Arce & Moya 2015). Genetic variation was verified in some wood color traits of *Calycophyllum spruceanum* (Benth.) Hook. f. ex K. Schum. and related to families within provenances (Sotelo-Montes et al. 2008). Evaluating chemical composition of *Vochysia guatemalensis* Donn. Sm. and *Acacia mangium* Willd., Moya et al. (2012) commented that the influence of phenolic content and total extractives in color parameters is function of species. In *V. guatemalensis* L* decreases as total extractive and phenolic content increases; however, parameter a* increases as the content of extractives and phenols increases. In *A. mangium*, the amount of phenols showed no relationship with the color parameters and an increase in the content of total extractives in water and ethanol-toluene increases parameter a*, but decreases parameter L*.

Reflectance curve (Figure 1) of visible spectra shows direct relation to wavelength, with more reflectance in bands of yellow and red color. Samples from *Eschweilera* sp. present more reflection after 550nm, were begin yellow color radiation and *C. stellata*, *C. oblongifolia* and *C. guianensis* showed similar trend in all wavelengths, but *C. guianenis* reflected with little difference after 550 nm. The behavior of all species shows the influence of yellow and red coordinates in wood color formation.

In seven species from genera *Eucalyptus* L'Hér. and *Corynmbia* K.D. Hill & L.A.S. Johnson, Nisgoski et al. (2017) verified the formation of two groups based on color reflectance, namely red/rose and grey/yellow/brown and the influence of wavelengths from 640-740 nm. On the other hand, in a study with different toposequence position of *Stryphnodendron adstringens* (Mart.) Coville it was verified a tendency of grouping wood samples from 0-200m in sequence (807-835m for altitude) (Nisgoski et al. 2018).

Table I. Mean values and standard deviation for colorimetric parameters by species in "tauari" group.

Species		L*		a*		b*		C*		h	
	SN	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Couratari oblongifolia	126	64.57a	6.89	7.03a	1.65	23.27b	1.64	24.28b	1.61	74.45a	3.63
Couratari *stellata*	108	66.80a	5.79	7.28a	1.85	23.06ab	2.70	24.22ab	2.98	72.59a	3.17
Couratari guianensis	72	64.75a	10.45	6.96a	3.29	22.08a	3.31	23.35a	3.48	72.83a	7.49
Eschweilera sp.	18	69.41a	1.76	8.00a	0.98	26.23c	2.06	22.79ab	7.98	73.07a	1.32
Total	324										

L* = lightness; a* = chromatic coordinate axis green-red; b* = chromatic coordinate axis blue-yellow; C* = saturation or Chroma; h = hue angle; SN = sampling number for each specie. SD= standard deviation. Means with the same letter in column do not present statistical differences at 95% probability by Tukey test.

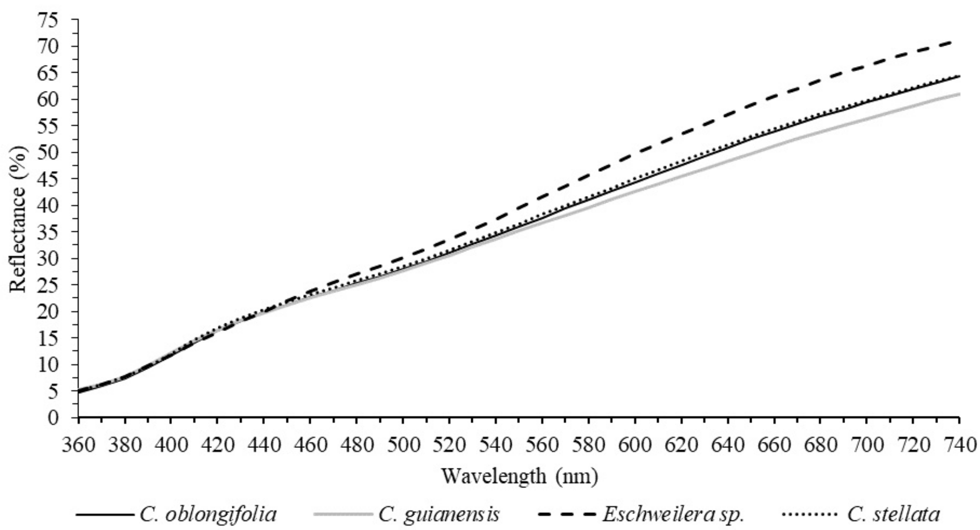

Figure 1. Reflectance curve of visible spectra by species from samples collected in different municipalities of Pará state.

Variation of color among sections within species collected in sawmills

Color parameters are influenced by species and also can vary in function of anatomical section evaluated, so data were analyzed by section in each species (Table II).

For *C. oblongifolia,* low lightness (L*) was observed in transversal section; parameters b* and C* were different in transversal and radial sections; parameters a* and h are similar in all surface. In *C. stellata* transversal surface are less luminous, parameters b* and C* presented higher values in radial section, and parameters a* and h are not different between sections. Surfaces of *C. guianensis* showed similar color parameters and it was not observed influence of section. In *Eschweilera* sp. low lightness in transversal section was also verified, with some

Table II. Mean values and standard deviation in colorimetric parameters by sections (transversal, radial and tangential) for samples collected in different municipalities of Pará state.

Species	Colorimetric parameters	Anatomical section		
		Transversal	Tangential	Radial
Couratari oblongifolia *[**n = 42]*	L*	62.01 a	67.85 b	67.92 b
		(7.41)	(7.58)	(8.37)
	a*	7.45 a	7.51 a	8.03 a
		(2.22)	(2.76)	(3.10)
	b*	22.62a	23.75 ab	24.54 b
		(2.87)	(2.42)	(3.13)
	C*	23.91 a	25.01 ab	25.95 b
		(2.97)	(2.94)	(3.61)
	h	71.80 a	72.79 a	72.24 a
		(5.02)	(4.78)	(5.50)
Couratari stellata *[**n=36]*	L*	63.91 a	68.76 b	67.71 b
		(5.01)	(4.15)	(6.83)
	a*	7.27 ab	6.68 a	7.87 b
		(1.38)	(1.39)	(2.43)
	b*	21.95 a	22,68 a	24.55 b
		(2.04)	(1.61)	(3.45)
	C*	23.16 a	23.67 a	25.83 b
		(2.09)	(1.82)	(3.91)
	h	71.67 a	73.66 b	72.45 ab
		(3.24)	(2.55)	(3.40)
Couratari guianensis *[**n=24]*	L*	64.45 a	65.91 a	63.88 a
		(9.66)	(12.77)	(8.86)
	a*	5.77 a	7.33 a	7.77 a
		(2.15)	(3.59)	(3.68)
	b*	21.44 a	23.14 a	21.65 a
		(2.93)	(3.43)	(3.42)
	C*	22.37 a	24.52 a	23.16 a
		(2.33)	(3.46)	(4.18)
	h	74.50 a	72.71 a	71.27 a
		(7.48)	(8.24)	(6.64)

Table II. Continuation.

Species	Colorimetric parameters	Anatomical section		
		Transversal	Tangential	Radial
Eschweilera sp. *[**n=6]*	L*	67.92 a	69.76 ab	70.55 b
		(1.47)	(0.30)	(1.97)
	a*	6.88 a	8.79 b	8.32 b
		(0.56)	(0.40)	(0.66)
	b*	23.81 a	27.41 b	27.47 b
		(1.24)	(1.11)	(1.05)
	C*	24.78 a	18.68 a	24.92 a
		(1.33)	(10.53)	(8.59)
	h	73.89 a	72.19 a	73.13 a
		(0.64)	(0.96)	(1.67)

L* = lightness; a* = chromatic coordinate axis green-red; b* = chromatic coordinate axis blue-yellow; C* = saturation or Chroma; h = hue angle. **n = Sampling number in each cutting direction for each specie. Means with the same letter between sections do not present statistical differences at 95% probability by Tukey test.

similarity to tangential section; chromatic coordinates a* and b* were lower in transversal section and parameters C* and h showed no difference between sections.

Therefore, it is possible to infer that wood from "tauari" group shows nuance of reddish pigments more evident in tangential/radial sections. This can be confirmed by results of chroma (C*) which vary proportionally to a* and b* values. Based on colorimetric parameters it was observed different shade in the three wood sections: transversal, radial and tangential. Coordinate b* performed more influence in characterization of yellow color in "tauari" group and it was more perceptible in radial and or tangential sections.

Barros et al. (2013) also verified differences in color in function of section in *C. micrantha*, *P. puncticulatum* and *C. glabrum* three species. They comment that L* and C* were higher in radial section and that L* and h in transversal section are lower than longitudinal surfaces. They justified the variation in function of chemical and anatomical composition of wood. Gonçalez et al. (2014) observed variation in radial and tangential section for colorimetric parameters in *Simarouba amara* Aubl. dried in different methods, but not in a* and h.

Similarity of color parameters from scientific collections and sawmills samples

Species *C. guianensis*, *C. oblongifolia* and *C. stellata* are present in scientific collections of Xiloteca (Walter A. Egler Collection) from Emilio Goeldi Paraense Museum (MGW) and Embrapa Amazônia Oriental (IAN), and samples collected in sawmills in Pará state (PA). A comparison of all samples of each species (Figure 2) was done to verify the potential of colorimetry in species discrimination because wood naturally become darker in function of changes in chemical composition, principally oxidation.

Differences in all colorimetric parameters were observed in *C. guianensis* in function of samples source. Chromatic coordinate a* was lower in samples collected in municipalities of Pará state (PA). On the other hand, samples from Emilio Goeldi Museum (MGW) resulted in

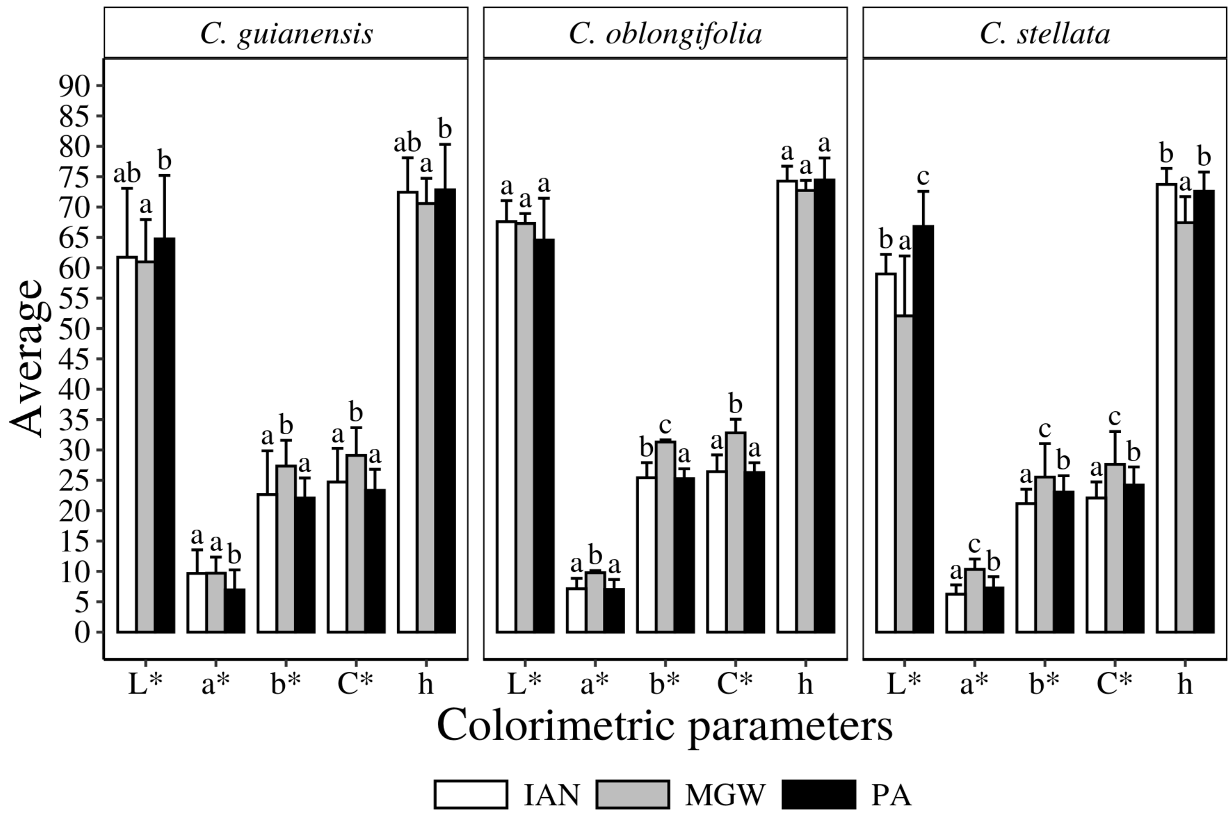

Figure 2. Comparison of colorimetric parameters for three species. L* = lightness; a* = chromatic coordinate axis green-red; b* = chromatic coordinate axis blue-yellow; C* = saturation or Chroma; h = hue angle; IAN = Scientific collection of Embrapa Amazônia Oriental; MGW = Scientific collection of Xiloteca (Walter A. Egler Collection) from Emilio Goeldi Paraense Museum; PA = samples from sawmills in ten municipalities of Pará state; vertical bars in columns indicate standard deviation in each parameter in same species do not present statistical difference at 95% probability by Tukey test.

lower values of b* coordinate and C* parameter. Lightness (L*) varied from 60.96 to 64.74 reflecting in brightness of samples as classified by Camargos & Gonçalez (2001).

In *C. oblongifolia* mean values for lightness (L*) and hue angle (h) were similar for samples collected in municipalities of Pará state (PA) and scientific collections (IAN, MGW). Mean values for chromatic coordinates a* and b*, and also C*, were higher for MGW. Yellow color in this species was influenced by greater values of lightness and lower values of a*, independently of wood samples source.

Lightness (L*) in *C. stellata* was lower (52.08) in samples from MGW and varied from 58.93 (IAN) and 66.79 (PA), probably result of storage time. Parameters a*, b* and C* were higher in samples from MGW and lower in samples from IAN. Hue angle (h) were similar in material collected in municipalities of Pará state (PA) and samples from IAN, and samples from MGW showed the lower values in this parameter. Results of hue angle and chroma in this species correspond to a yellow brownish color.

In order to verify the influence of each colorimetric parameter and samples source (IAN, MGW, PA) on species discrimination, a principal component analysis was performed. The number of components to retain was two, as they presented eigenvalues (λi) greater than

1 and the cumulative percentage of variance for the first two PCs was approximately 97%. The first main component (PC-1) accounted for 62.2% (λi = 3.11), while the second (PC-2) retained 34.5% (λi = 1.72) of the total variation of standardized data (Figure 3). Therefore, the inference over apparent patterns from the first two main components can be considered reliable, with other dimensions being less informative.

Through biplot (Figure 3a) it is possible to understand how the samples relate and, simultaneously, the contribution of each colorimetric parameter to the first two main components. MGW wood samples were characterized by high values of b* and C* (Couratari guianensis and Couratari oblongifolia) and low values for h and L* (Couratari stellata). In this case, it is likely that the samples oxidation and storage time have a strong influence on the values found. MGW species were clearly separated from each other, as well as from other sources (IAN and PA).

IAN and PA samples were spatially closer and shared higher values for h and L*. This can be explained, at least partially, by the similarity of the sample collection locations, most of which from the same region. In this case, h and L* parameters seem to provide relevant information for the species distinction of the two sample sources (PA and IAN).

In the biplot it is possible to identify the correlations among colorimetric parameters. There is a strong positive correlation between the b* and C* parameters, since their vectors formed an acute angle close to zero degree. This means that, in general, wood samples with a high b* value also tend to have a high C* value. On the other hand, L* luminosity was not correlated with b* coordinate and C* chromaticity, since its vectors tended to form an angle close to 90 degrees. Finally, a* and h parameters tended to a negative correlation, that is, woods with a greater a* coordinate tend to show a smaller hue angle.

Contributions (in percentage) and loads of each colorimetric parameter for the first two PCs are presented in Figures 3b and 3c. Loads dimension inform about the contribution of each parameter in the main components construction, and the sign indicates whether they are directly or inversely correlated. Chromatic coordinate a* showed a greater contribution to the variance explained by PC-1, whereas the L* luminosity, presented greater weight in PC-2. The a*, C* and b* parameters showed positive correlations with PC-1, while h and L* were negatively correlated. Only the chromatic coordinate a* had negative loading at PC-2, indicating a negative correlation with this component.

In general, samples source of material (scientific collections or sawmill) contributed to some differences in colorimetric parameters of this species, what was expected. Natural photo degradation occurs in wood, and in general lightness decreases (Baar & Gryc 2012). Color differences within species among 1-2 are common and accepted, also texture of wood surface present influence (Buchelt & Wagenführ 2012). Chemical composition and species can influence changes in colorimetric parameters after storage. In an experiment with *Cordia goeldiana* Huber, reduction in L* and increase in chromatic coordinates a* and b* was verified after exposition to ultraviolet radiation (Gonçalez et al. 2010) and also in *Betula pendula* Roth, notable changes in color were observed (Mononen et al. 2002). On the other hand, Stenudd (2008) observed no influence of storage in *Fagus silvatica* H. Lév. during 13 weeks under low temperature and in *Alnus glutinosa* (L.) Gaertn. the most evident change was an increase in lightness 20-60 minutes after cutting (Salca et al. 2015).

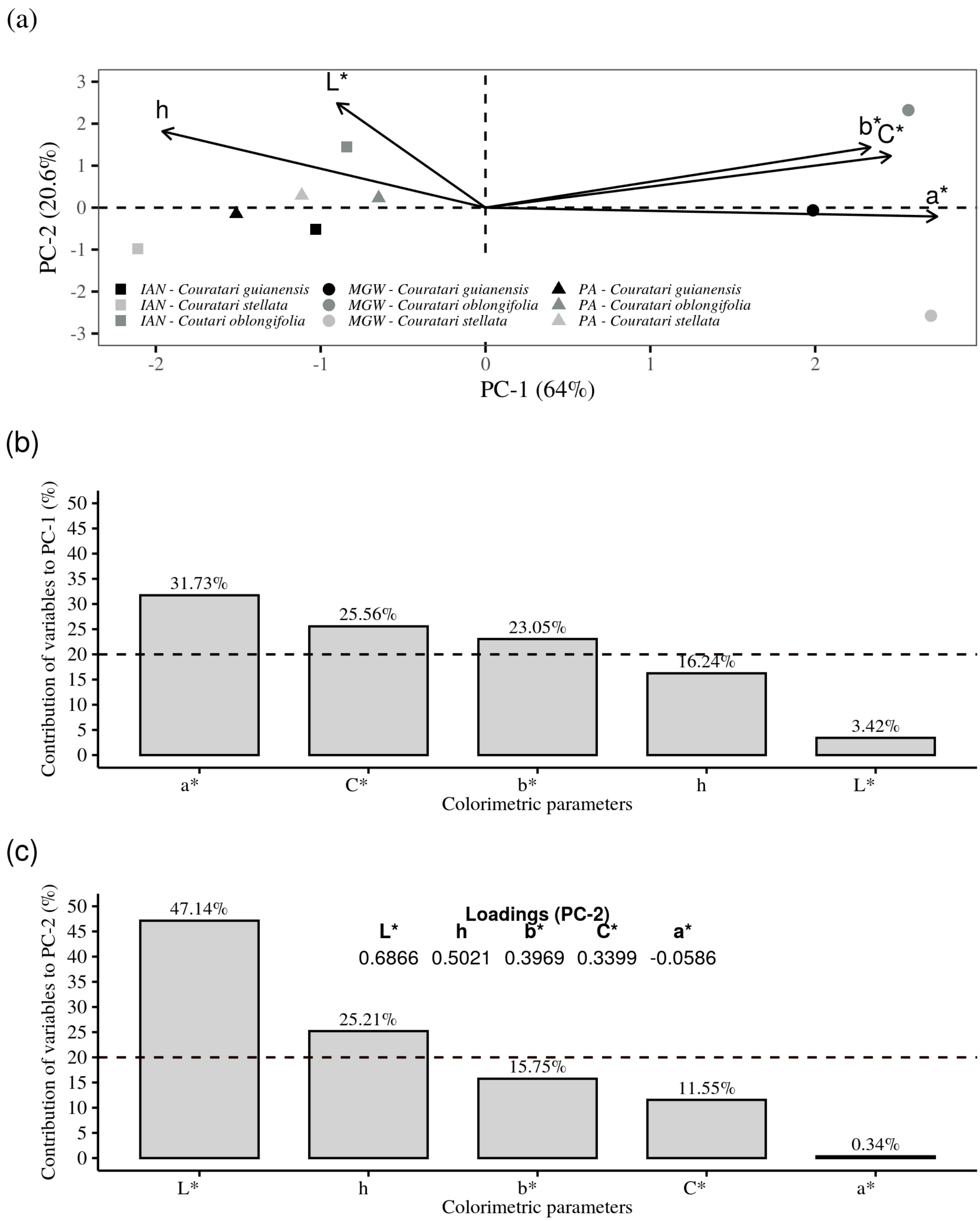

Figure 3. Score plot of principal component analysis (a); contribution of each colorimetric parameter in variance explained by PC-1 for three species of tauari group (b). L* = luminosity; a* = chromatic coordinate axis green-red; b* = chromatic coordinate axis blue-yellow; C* = saturation or Chroma; h = hue angle; IAN = Scientific collection of Embrapa Amazônia Oriental; MGW = Scientific collection (Walter A. Egler) from Emilio Goeldi Paraense Museum; PA = samples from sawmills in ten municipalities of Pará state. Dotted line in graphics B and C: indicates the amount of variation that each parameter would contribute, in case all showed the same proportion of contribution in CP.

Colorimetric parameters also are influenced by natural degradation or thermal treatment of wood (Torres et al. 2012, Cademartori et al. 2013). The application of wood colorimetric parameters in species discrimination or grouping is scarce; some examples are the separation of eucalyptus (Martins et al. 2015, Nisgoski et al. 2017) and some tropical species in Brazil (Silva et al. 2017). Zhao (2013) proposed a wood species classification using color surface data and related good results in intra and inter specific variations. An industrial application with color parameters was tested by Bombardier & Schmitt (2010) evaluating the efficiency of a classification method based on fuzzy linguistic data for the recognition of gradual color in wood. The use of technique in species identification must consider the natural variation within a tree, related to changes in sapwood and heartwood, and also within species, because it is influenced by environment characteristics (Bradbury et al. 2011, Sotelo-Montes et al. 2013). Beside it, samples source of each species can show great influence in wood quality, in special, on its physical and mechanical properties, and also colorimetric parameters (Gonçalez et al. 2009).

CONCLUSIONS

In this study, it was found evidences that information provided by the colorimetry technique can be useful for species discrimination and, therefore, is a potential support tool in the identification of "tauari" wood. Due to the complexity in identifying the "tauari" group, it is suggested the colorimetry in association with other techniques, such as wood anatomy, for a correct discrimination of the material.

In main components analysis, MGW wood samples showed quite different color patterns in relation to the samples of PA and IAN, and the information of some parameters, especially b* and C*, are useful for distinguishing species. Furthermore, h and L* parameters seem to provide relevant information for distinguishing species from the PA and IAN sample sources.

The coordinate b*, which showed the yellow pigment, exerted greater weight in the color characterization of the 35 samples marketed as tauari, being more evident in the tangential and radial sections. Small quantitative differences in colorimetric parameters, evidence the difficulty of species discrimination from "tauari" group and, in part, explain the exploitation and mistaken commerce of other timber species, resulting, sometimes, in financial damage for buyers, in addition to the great loss of biodiversity.

Acknowledgments

To the Museu Paraense Emílio Goeldi and to the Embrapa Amazônia Oriental, for making available the wood samples of "tauari" and, to enable the development of this research, Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPQ Brazil (PQ 303374/2016-0), and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES Brazil (Financial Code 001).

REFERENCES

ARCE N & MOYA R. 2015. Wood characterization of adult clones of *Tectona grandis* growing in Costa Rica. Cerne 21(3): 353-362.

BAAR J & GRYC V. 2012. The analysis of tropical wood discoloration caused by simulated sunlight. Eur J Wood Wood Prod 70(1-3): 263-269.

BARROS SVS, MUÑIZ GIB & MATOS JL. 2013. Colorimetric characterization of three wood species from the Amazon Forest. Cerne 20(3): 337-342.

BERNAL RA, CORADIN V, CAMARGOS J, COSTA C & PISSARRA J. 2011. Wood anatomy of Lecythidaceae species called "tauari". Iawa J 32(1): 1-17.

BOMBARDIER V & SCHMITT E. 2010. Fuzzy rule classifier: Capability for generalization in wood color recognition. Eng Applartif Intel 23: 978-988.

BRADBURY G, POTTS BM, BEADLE CL, DUTKOWSKI G & HAMILTON M. 2011. Genetic and environmental variation in heartwood colour of Australian blackwood (*Acacia melanoxylon* R.Br.). Holzforschung 65: 349-359.

BUCHELT B & WAGENFÜHR A. 2012. Evaluation of colour differences on wood surfaces. Eur J Wood Wood Prod 70: 389-391.

CADEMARTORI PHG, SCHNEID E, GATTO DA, STANGERLIN DM & BELTRAME R. 2013. Thermal modification of Eucalyptus grandis wood: variation of colorimetric parameters. Maderas – Cienc Tecnol 15: 57-64.

CAMARGOS JAA & GONÇALEZ JCA. 2001. Applied colorimetry as instrument in the elaboration of a timber color chart. Brasil Florestal 71: 30-41.

CORADIN VTR & CAMARGOS JAA. 2002. A estrutura anatômica da madeira e princípios para sua identificação. Brasília: Ministério do Meio Ambiente, dos Recursos Hídricos e da Amazônia Legal, Brasília, DF (Brazil). Laboratório de Produtos Florestais, 28 p.

FLORA DO BRASIL. 2020. Lecythidaceae em construção. Jardim Botânico do Rio de Janeiro. Disponível em: <http://floradobrasil.jbrj.gov.br/reflora/floradobrasil/FB145>. Acesso em: 28 Nov. 2019.

GONÇALEZ JC, FÉLIX TLF, GOUVEIA FNG, CAMARGOS JAA & RIBEIRO PG. 2010. Effect of ultraviolet radiation on the color of freijó wood (Cordia goeldiana Huber) after application of finishing products. Cienc Florest 20 (4): 657-664.

GONÇALEZ JC, MARQUES MHB, KARAS MCS, JANIN G & RIBEIRO PG. 2014. Effect of drying process on Marupá wood color. Maderas – Cienc Tecnol 16(3): 337-342.

GONÇALEZ JC, VIEIRA FS, CAMARGOS JAA & ZERBINI NJ. 2009. Influence of site in wood properties of *Pinus caribeae* var. *hondurensis*. Cerne 15: 251-255.

KASSAMBARA A & MUNDT F. 2017. Factoextra: Extract and Visualize the Results of Multivariate Data Analyses. R package version 1.0.5. https://CRAN.R-project.org/package=factoextra.

LASKOWSKA A, DOBROWOLSKA E & BORUSZEWSKI P. 2016. The impact of ultraviolet radiation on the colour and wettability of wood used for facades. Drewno 59(197): 99-111.

LE S, JOSSE J & HUSSON F. 2008. FactoMineR R: An R Package for Multivariate Analysis. J Stat Softw 25(1): 1-18.

LENTINI IM, VERÍSSIMO A & PEREIRA D. 2011. A expansão madeireira na Amazônia. Belém: Imazon, 2011. Disponível em: http://www.imazon.org.br/publicacoes/o-estado-da-amazonia/a-expansao-madeireira-na-amazonia-1. Acesso em: 20 nov. 2019.

MARTINS MF, BELTRAME R, DELUCIS RA, GATTO DA, DE CADEMARTORI PHG & DOS SANTOS GA. 2015. Colorimetry as grouping tool of eucalyptus clones wood. Brazilian J Forestry Res 35 (84): 443-449.

MARTINS SRCV, MICHAEL GH & IAN ST. 2003. Identificação botânica na Amazônia: situação atual e perspectivas. Embrapa Amazônia Oriental 4: 1-77.

MEINTS T, TEISCHINGER A, STINGL R & HANSMANN C. 2017. Wood colour of central European wood species: CIELAB characterisation and colour intensification. Eur J Wood Prod 75: 499-509.

MONONEN K, ALVILA L & PAKKANEN TT. 2002. CIEL*a*b* Measurements to determine the role of felling season, log storage and kiln drying on coloration of silver birch wood. Scand J For Res 17(2): 179-191.

MORI S. 1990. Diversification and conservation of neotropical Lecythidaceae. Acta Bot Bras 4: 45-68.

MOYA R, FALLAS RS, BONILLA PJ & TENORIO C. 2012. Relationship between wood color parameters measured by CIELAB system and extractive and phenol content of *Acacia mangium* and *Vochysia guatemalensis* from fast growth plantations. Molecules 17(4): 3639-3652.

NISGOSKI S, GONÇALVES TAP, OLIVEIRA NM, BITTENCOURT SC, LIMA GS & MUNIZ GIB. 2018. Influence of toposequence position of *Stryphnodendron adstringens* trees on discrimination of samples based on spectroscopy. Braz J Wood Sci 9(2): 112-122.

NISGOSKI S, MUNIZ GIB, GONÇALVES TAP & BALLARIN AW. 2017. Use of visible and near-infrared spectroscopy for discrimination of eucalypt species by examination of solid samples. J Tropic Fort Sci 29: 371-379.

OLIVEIRA FGR, MILLER KP, CANDIAN M & SALES A. 2005. Influência da seção transversal na velocidade ultra-sônica na madeira de *Eucalyptus citriodora*. Cerne 11(2): 197-203.

PARÁ. 2019. Secretaria de Meio Ambiente e Sustentabilidade. Comercialização total por destino das vendas: 2015. Disponível em: http://monitoramento.sema.pa.gov.br/sisflora/index.php /relatórios. Acesso em: 20 nov. 2019.

PASTORE TC, SANTOS KO & RUBIM JC. 2004. A spectrocolorimetric study on the effect of ultraviolet irradiation of four tropical hardwoods. Bioresource Technol 1(93): 37-42.

PAULA JE & COSTA KP. 2011. Densidade da madeira de 932 espécies nativas do Brasil. Porto Alegre: Cinco continentes, 248 p.

PROCÓPIO LC & SECCO RDS. 2008. A importância da identificação botânica nos inventários florestais: o exemplo do" tauari" (*Couratari* spp. e *Cariniana* spp.-Lecythidaceae) em duas áreas manejadas no estado do Pará. Acta Amazonica 38(1): 31-44.

R CORE TEAM. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

SALCA EA, GOBAKKEN LR & GJERDRUM P. 2015. Progress of discoloration in green, freshly cut veneer sheets of black alder (*Alnus glutinosa* L.) wood. Wood Mat Sci & Engineering 10(2): 178-184.

SEMAS – PA, SECRETARIA DE ESTADO DE MEIO AMBIENTE E SUSTENTABILIDADE DO PARÁ. 2014. Relatório de extração e movimentação de toras de madeiras nativas: período de 01/01/2014 a 31/12/2014. Disponível em: https://monitoramento.semas.pa.gov.br/sisflora/relatorios.html. Acessado em: 20 nov 2019, 76 p.

SEMAS – PA, SECRETARIA DE ESTADO DE MEIO AMBIENTE E SUSTENTABILIDADE DO PARÁ. 2015. Relatório de extração e movimentação de toras de madeiras nativas: período de 01/01/2015 a 31/12/2015. Disponível em: https://monitoramento.semas.pa.gov.br/sisflora/relatorios.html. Acessado em: 20 nov 2019, 67 p.

SEMAS – PA, SECRETARIA DE ESTADO DE MEIO AMBIENTE E SUSTENTABILIDADE DO PARÁ. 2016. Relatório de extração e movimentação de toras de madeiras nativas: período de 01/01/2006 a 21/02/2016. Disponível em: https://monitoramento.semas.pa.gov.br/sisflora/relatorios.html. Acessado em: 20 nov 2019, 167 p.

SILVA RAF, SETTER C, MAZETTE SS, DE MELO RR & STANGERLIN DM. 2017. Colorimetry of wood from thirty tropical species. Braz J Wood Sci 8(1): 36-41.

SOTELO-MONTES C, HERNÁNDEZ RE, BEAULIEU J & WEBER JC. 2008. Genetic variation in wood color and its correlations with tree growth and wood density of *Calycophyllum spruceanum* at an early age in the Peruvian Amazon. New For 35: 57-73.

SOTELO-MONTES C, WEBER JC, GARCIA RA, SILVA DA & MUÑIZ GIB. 2013. Variation in wood color among natural populations of five tree and shrub species in the Sahelian and Sudanian ecozones of Mali Can J For Res 43: 552-562.

SOUSA WCS, DE JESUS BARBOSA L, SOARES AAV, GOULART SL & PAULA PROTÁSIO T. 2019. Wood colorimetry for the characterization of amazonian tree species: a subsidy for a more efficient classification. Cerne 25(4): 451-462.

SOUZA V, LORENZI H & NETO ACR. 2008. Botânica Sistemática: guia ilustrado para identificação das famílias Fanerógamas nativas e exóticas no Brasil, baseado em APG II, 2nd ed., Nova Odessa: Instituto Plantarum, 704 p.

STENUDD S. 2008. The influences of log storage and kiln drying climate on the colour of non-steamed beech (*Fagus sylvatica* L.) wood. Wood Mat Sci & Engineering 3(2): 71-77.

TORRES SS, JOMAAW M & PUIGGALI JR. 2012. Colour alteration and chemistry changes in oak wood (*Quercus pedunculata)* during plain vacuum drying. Wood Sci Technol 46: 177-191.

VIEIRA H C, DA SILVA E L, DOS SANTOS JX, DE MUÑIZ G IB, MORRONE SR & NISGOSKI S. 2019. Wood colorimetry of native species of Myrtaceae from an Araucaria forest. Floresta 49(2): 353-362.

ZHAO P. 2013. Robust wood species recognition using variable color information. Optik 124(17): 2833-2836.

How to cite

DOS SANTOS JX, VIEIRA HC, SOUZA DV, MUÑIZ GIB, SOFFIATTI P & NISGOSKI S. 2022. Colorimetry as a tool for description of some wood species marketed as “tauari” in Brazilian Amazon. An Acad Bras Cienc 94: e20191479. DOI 10.1590/0001-3765202220191479.

Manuscript received on December 6, 2019;
accepted for publication on July 1, 2020

JOIELAN XIPAIA DOS SANTOS[1]
https://orcid.org/0000-0002-5480-4261

HELENA CRISTINA VIEIRA[1]
https://orcid.org/0000-0001-9008-5463

DEIVISON VENICIO SOUZA[2]
https://orcid.org/0000-0002-2975-0927

GRACIELA INÊS BOLZON DE MUÑIZ[1]
https://orcid.org/0000-0003-4417-0178

PATRÍCIA SOFFIATTI[3]
https://orcid.org/0000-0001-5634-7650

SILVANA NISGOSKI[1]
https://orcid.org/0000-0001-9595-9131

[1]Universidade Federal do Paraná - UFPR, Departamento de Engenharia e Tecnologia Florestal, Av. Prefeito Lothario Meissner, Jardim Botânico, 632, 80210-170 Curitiba, PR, Brazil

[2]Universidade Federal do Pará-UFPA, Faculdade de Engenharia Florestal, Rua Coronel José Porfírio, 251, 568370-000 Altamira, PA, Brazil

[3]Universidade Federal do Paraná - UFPR, Departamento de Botânica, Jardim das Américas, 540, 81531-990 Curitiba, PR, Brazil

Correspondence to: **Joielan Xipaia dos Santos**
E-mail: joilan87xipaya@gmail.com

Author contributions

Conceptualization, JXS, HCV and SN; Data curation, SN; Formal analysis, JXS, HCV and DVS; Methodology, JXS, HCV, DVS, and SN; Supervision, GIBM, PS and SN; Validation, SN; Visualization, JXS; Writing – original draft, JXS, HCV and DVS; Writing – review & editing, GIBM, PS and SN.