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ORIGINAL ARTICLE

Grouping of commercial tropical timber using wood color

Agrupamento de madeiras tropicais comerciais pela cor

Rafael Rodolfo de Melo[1*]
Diego Martins Stangerlin[2]
Cláudio Henrique Soares Del Menezzi[3]
Vinicius Gomes de Castro[1]
Maila Janaína Coelho de Souza[4]
Dayane Targino de Medeiros[1]

[1] Universidade Federal Rural do Semi-Árido (Ufersa), Av. Francisco Mota, 572, 59625-900, Mossoró, RN, Brazil
[2] Universidade Federal de Mato Grosso (UFMT), Av. Alexandre Ferronato, 1200, 78550-728, Sinop, MT, Brazil
[3] Universidade de Brasília (UnB), Asa Norte, s/n, 70904-970, Brasília, DF, Brazil
[4] Universidade Federal do Rio Grande do Norte (UFRN), Rodovia RN 160, Km 03, s/n, 59280-000, Macaíba, RN, Brazil
***Corresponding Author:**
E-mail: rafael.melo@ufersa.edu.br

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ABSTRACT: This work aims to evaluate the color of 18 tropical species collected in sawmills located in the north region of Mato Grosso state, Brazil. In total, samples were produced from six trees for each species. The selected samples were sanded and evaluated by spectrophotometer, using the measurements system Cielab, to obtain the variables: brightness (L), the chromatic coordinates (a* and b*), saturation (C) and hue angle (h). There was no difference between the color of tangential or radial wood planes. The species could be grouped in 6 different classes based on the similarity of the pieces superficial colors. Grouping species by color is a possibility for marketing in local wood market, where often clients search for products based only in their aesthetic appearance.

RESUMO: *Este trabalho teve como objetivo realizar a caracterização colorimétrica de 18 espécies tropicais coletadas em serrarias da região norte do estado do Mato Grosso, Brasil. Ao todo, foram utilizadas madeiras provenientes de seis árvores para cada uma das espécies. As amostras selecionadas foram lixadas e avaliadas por meio do espectrofotocolorímetro, utilizando o sistema de medições Cielab, para obter as variáveis: claridade (L), coordenadas cromáticas (a* e b*), saturação (C) e ângulo de tinta (h). Não foi observada diferença entre a cor dos planos tangenciais e radiais das madeiras. As espécies puderam ser agrupadas em seis diferentes classes com base na similaridade da cor superficial das peças. O agrupamento de espécies pela cor é uma possibilidade de marketing para mercados locais, em que muitas vezes o cliente busca o produto com base na aparência estética.*

1 Introduction

Wood products market is increasingly demanding high quality from the wood based material used in its products. However quality concept varies and depends of the final use of the product. Thus, each product would request a specific timber to attend their own requirements.

The color is one of the most important wood features as it can be used both for identification of the wood species and indication of their proper use, especially when associated with texture and design aspects (Gonçalez et al., 2014). However, color can be changed according to the moisture content, temperature, level of deterioration caused by xylophagous organisms' attacks, or also, photochemical reactions of chemical elements of the wood (Stangerlin et al., 2013).

Wood color varies due its complex anatomy and chemistry composition. For example, presence of hydroxyls group (-OH) can intensify the coloration or enable the absorption of light; red hue usually is related to extractives presence; and yellow tones can be a lignin photochemistry response (Sandoval-Torres et al., 2010). Once wood composition varies among cell types, wood color will also varies considerably between species, between individual trees of the same species and parts of the same individual (Klumpers et al., 1993; Mori et al., 2004; Moya & Berrocal 2010), genetic factors, and growth conditions (Moya & Calvo-Alvarado 2012);

However, defining color is not easy as the presence of perceivers and occurrence of subjective interpretations are necessary for the perception of color. There are several theories and approaches to study color. Physicists define color as a phenomenon in the field of optics (specifically, types of reflectance) (Byrne & Hilbert 2003).

Colorimetry is largely concerned with physical color as it can convert the properties that are using to distinguish different color to mathematical models. Among color models, CIE L*a*b*, also called Cielab, is one more often applied to measure wood color. Camargos & Gonçalez (2001) used this method in their groundbreaking study about classification of wood in Brazil based on their color. Cielab model determines the color depending of the lightness of the color (L* components), the chroma a* (positive values indicate red and negative values refer to green) and chroma b* (positive values refer to yellow and negative to blue) (Ibraheem et al., 2012).

Colors in general can be controversial, the human responses to them can vary across culture, gender and age, among others. But it is important to any market be aware of the perceived importance of colors, as colors can drastically affect sales (Singh, 2006). This is true for wood material that is often preferred because of its aesthetic value. Thus, the aims of this study were analytic measure the color of commercial tropical timber and propose groups of timbers with similar colors that could be market together.

2 Material and Methods

Samples of different tropical timbers were collected in eighteen sawmills located in the northern region of Mato Grosso, Brazil (Latitude: 11° 52' 23'' South, Longitude: 55° 29' 54'' West). The material was tagged and sent to the Forest Products Laboratory (LPF) of the Brazilian Forest Service (SFB) in Brasília, for scientific identification by comparison with the material of its xylotheque (Index Xilarium FPBw).

Eighteen species were identified (Table 1). To ensure the intraspecific variability, samples from each species were produced from at least six individuals. The chosen species were selected considering the expressiveness of its participation in the trade of native tropical wood from the Amazon region, based on the analysis of Vouchers Forest Credits Release (CLCF) of forest management plans in the region (Melo et al., 2015).

Table 1. List of assessed forest species

Tabela 1. Lista de espécies florestais avaliadas

Vernacular Name	Scientific Name
Pente de macaco	*Apeiba echinata* Gaernt.
Grapiá	*Apuleia leiocarpa* (Vogel) J.F.Macbr.
Tamaquaré	*Caraipa sp*
Copaíba	*Copaifera* sp.
Sucupira	*Diplotropis* sp.
Cumaru	*Dipteryx odorata* (Aublet) Willd.
Cedrinho	*Erisma uncinatum* Warm.
Cupiúba	*Goupia glabra* Aubl.
Jatobá	*Hymenaea courbaril* L.
Angelim pedra	*Hymenolobium petraeum* Ducke
Pará-Pará	*Jacaranda copaia* (Aubl.) D. Don.
Cambará	*Vochysia* sp.
Itaúba	*Mezilaurus itauba Taub. ex Mez.*
Canelão	*Ocotea* sp.
Angelim saia	*Parkia* sp.
Cambará	*Qualea* sp.
Tachi	*Sclerolobium* sp.
Amescla	*Trattinnickia* sp.

Samples were lightly sanded to remove impurities, with 100-grit sandpaper. Subsequently, the colorimetry tests were performed in a spectrophotometer Konica Minolta, model CR 400. All samples were composed exclusively of heartwood. The tests were performed in the tangential and radial sections of each wood sample, obtaining an average value for each piece. Three readings for each side were held. The samples did not show patterns in dimensions, which did not interfere with data collection. CIELAB color model was used and the equipment read the brightness (L*), the chromatic coordinates (a* and b*), hue (h*) and saturation (C).

The color identification observed for each species was adopted as standard colors of tropical woods suggested by Camargos & Gonçalez (2001). The colorimetric parameters were also analyzed using descriptive statistics and simple correlation (Pearson) for colorimetric parameters observed for the different evaluated tropical species in a 95% confidence level.

3 Results and Discussion

All analyzed colorimetric parameters did not show a statistical difference between the assessed plans – radial and tangential.

The statistically similarity between axes differs from results observed in literature. Atayde et al. (2011) observed different colors between tangential and radial sections of tropical wood Muirapiranga (*Brosimum* sp.). In that case, the only parameter statistically equal between sections was a*, but even then tangential cuts were more reddish than radial ones (with yellow tones) as b* values were higher in the radial axe than in the tangential.

According to Nishino et al. (2000), colorimetric differences between radial and tangential sections can be related to anatomical features, such as the arrangement of cells, wide rays, and spiral grain. Martins et al. (2015) also observed differences between colorimetric parameters of the radial and tangential planes. Although it is common, the color difference between planes is not always observed. Barros et al. (2014) could not find a statistically difference when analyzed the color of Amazonian wood *Cariniana micrantha* (Tauari-vermelho) and *Protium puncticulatum* (Breu-vermelho). Cademartori et al. (2013) did not observed difference between the sections of *Eucalyptus grandis*, *E, saligna* and *E, cloeziana* wood. Esteves et al. (2008) also did not found a color difference between tangential and radial cuts of *Pinus pinaster* and *Eucalyptus globulus* wood.

The average values of colorimetric parameters observed for each evaluated tropical species can be seen in Table 2. Seven species similar to the ones studied had their colorimetric parameters already analyzed by Silva et al. (2017). On this study, all seven species showed a lower a* value than the ones reported (*Apuleia leiocarpa*, *Dipteryx odorata*, *Erisma uncinatum*, *Goupia glabra*, *Hymenaea courbaril*, *Hymenolobium petraeum* and *Mezilaurus itauba*).

Table 2. Average values observed for different colorimetric parameters of the different evaluated tropical timber

Tabela 2. Valores médios observados para os diferentes parâmetros colorimétricos das diferentes madeiras tropicais avaliadas

Species	L*		a*		b*		C*		h	
	A	SD	A	SD	A	SD	A	SD	A	SD
A. echinata	62.81	±3.41	4.63	±0.48	16.82	±1.40	17.45	±1.36	74.67	±3.99
A. leiocarpa	63.41	±4.79	8.90	±0.93	26.02	±1.50	27.50	±2.00	71.28	±4.15
Caraipa sp	50.94	±4.53	5.64	±0.51	15.65	±2.56	16.64	±1.64	70.21	±5.36
Copaifera sp.	57.08	±3.20	11.06	±1.08	21.53	±2.53	24.34	±2.71	58.43	±4.11
Diplotropis sp.	51.30	±2.45	7.98	±1.00	19.27	±1.04	20.89	±1.54	67.18	±4.76
D. odorata	54.93	±4.38	8.66	±0.68	19.09	±1.36	21.03	±1.44	65.49	±5.77
E. uncinatum	51.29	±2.35	9.27	±1.06	17.61	±2.02	19.95	±2.48	62.34	±3.42
G. glabra	56.82	±3.57	12.74	±1.72	21.76	±1.67	25.30	±1.98	53.17	±6.44
H. courbaril	63.40	±2.54	10.47	±0.74	24.50	±0.95	26.53	±1.09	66.50	±6.57
H. petraeum	63.01	±5.73	13.27	±1.25	23.36	±0.49	26.88	±1.96	60.40	±3.98
J. copaia.	66.97	±8.11	4.27	±0.58	16.44	±2.95	16.99	±1.75	75.46	±6.71
Vochysia sp.	55.97	±4.34	12.68	±1.00	21.34	±2.50	24.85	±2.04	59.36	±5.12
M. itauba	54.40	±4.10	4.84	±0.67	19.22	±1.16	19.87	±1.38	75.40	±4.18
Ocotea sp.	60.12	±3.41	6.60	±0.30	22.60	±1.60	23.67	±1.50	73.73	±4.58
Parkia sp.	63.11	±4.89	4.53	±0.28	20.03	±3.24	20.54	±3.03	77.28	±3.41
Qualea sp.	56.00	±6.11	10.50	±1.10	22.07	±3.14	24.54	±4.35	64.62	±5.37
Sclerolobium sp.	56.07	±8.87	7.05	±1.40	18.37	±3.26	19.58	±3.41	68.91	±7.19
Trattinnickia sp.	60.48	±3.26	7.21	±1.29	18.53	±2.47	19.95	±3.08	69.24	±3.41

A: Average; SD: Standard deviation.

Three of them also showed lower b* values (*Apuleia leiocarpa*, *Dipteryx odorata* and *Goupia glabra*). Brightness values (L*) were similar in general, but *Dipteryx odorata* tend to be darker and *Hymenaea courbaril* lighter than wood on literature. Barreto & Pastore (2009) also evaluated the color of *Apuleia leiocarpa* and *Mezilaurus itauba* wood. Both species also showed lower values of L*, a* and b* than the ones observed in this study. But, Silva et al. (2007) studied the same *Mezilaurus itauba* wood and reported a higher value of a*. According to Costa et al. (2011), *Hymenaea courbaril* wood showed lower values of L* and b*, but higher influence of a* parameters than wood of the same specie analyzed here.

The correlation between the colorimetric parameters showed strong interactions between the coordinate b* and the saturation (C) (r = 0.96), the coordinate a* and hue (h*) (r = 0.92) and the coordinate a* and the saturation (C) (r = 0.80) (Table 3). Cademartori et al. (2013) observed correlation between L* and chroma a* and b* for *Eucalyptus grandis* wood. A similar correlation (between L* and a*) was also observed in other Eucalyptus species (Garcia et al., 2014). However, this kind of interaction could not be seen in the color behavior of the tropical woods.

Table 3. Pearson correlation for colorimetric parameters observed for the different evaluated tropical species

Tabela 3. Correlação de Person para os parâmetros colorimétricos para as faces radial e tangencial da madeira das espécies florestais avaliadas

	L*	a*	b*	C*	h
L*	1.00	-0.13^{ns}	0.33^{ns}	0.21^{ns}	0.35^{ns}
a*		1.00	0.62*	0.80*	-0.92*
b*			1.00	0.96*	-0.32^{ns}
C*				1.00	-0.55^{ns}
h					1.00

ns: no significant; *: significant at 95% by t test.

The timbers were grouped based on their colorimetric parameters according to classification suggested by Camargos & Gonçalez (2001) (Table 4). All 18 evaluated species could be classified in 6 color categories: greyish pink; yellowish olive; reddish brown; light yellow; pinkish gray and olive.

It could be observed a tendency of the studied woods present a dark red color, as it is common in Amazonian woods (Nishino et al., 1998; Barros et al., 2014; Silva et al., 2017). This color is represented by a combination of the strong influence of chroma red (positive values of a*) and relatively low brightness values (L*). But, although a* values strongly influenced the reddish color of the evaluated woods, the yellow tone (positive b* values) was also crucial to determinate the woods' final colors. High values of the hue of the color (h*, calculated from a* and b* relation) confirms a strong presence of yellow pigmentation, which gives a coloring mean content from pink-gray to pinkish gray. The evaluated tropical woods showed a medium level of saturation (C).

Saturation (C) is directly influenced by the chromatic parameters a* and b*, thus the increasing of red or yellow tones will also increase saturation values (Atayde et al., 2011). Wood species with red tones could be grouped next to each other in a L* x C* diagram (Figure 1). In general, according to the classification suggested by Camargos & Gonçalez (2001), the wood species with higher average values of a* showed a colorimetric rating for pink, red or brown shades. This characteristic can be related to the chemical composition of wood since the extractives on the surface of the material tend to significantly influence their shades. Mori et al. (2004) found that the polyphenol content is positively correlated to the wood color. Thus, the higher the polyphenol content, the greater the red wood tonality.

Table 4. Classification of colors of the woods of tropical species.

Tabela 4. Classificação das cores das madeiras tropicais avaliadas.

Specie	**Color***
Apeiba echinata Gaernt.	Greyish pink
Apuleia leiocarpa (Vogel) J.F.Macbr.	Greyish pink
Caraipa sp	Greyish pink
Copaifera sp.	Greyish pink
Diplotropis sp	Greyish pink
Dipteryx odorata (Aublet) Willd.	Yellowish olive
Erisma uncinatum Warm.	Yellowish olive
Goupia glabra Aubl.	Reddish brown/ Pink
Hymenaea courbaril L.	Light yellow/ Brown olive
Hymenolobium petraeum Ducke	Light yellow/ Brown olive
Jacaranda copaia (Aubl.) D. Don.	Pinkish gray
Vochysia sp.	Pinkish gray
Mezilaurus itauba Taub. ex Mez.	Pinkish gray
Sclerolobium sp.	Pinkish gray
Trattinnickia sp.	Pinkish gray
Ocotea sp.	Olive
Parkia sp.	Olive
Qualea sp.	Olive

*Colorimetric standards suggested by Camargos & Gonçalez (2001).

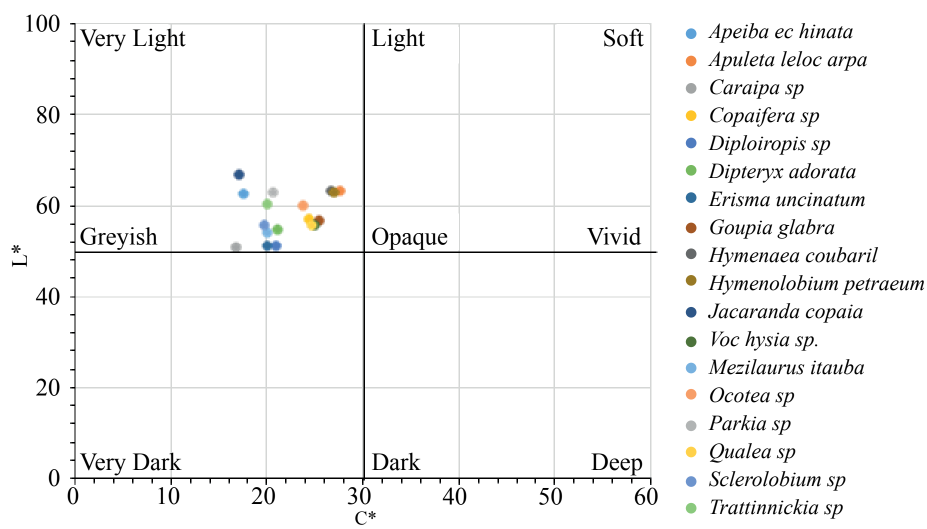

Figure 1. Chromaticity diagram L* x C* of wood from 18 Brazilian tropical species

Figura 1. Diagrama colorimétrico L* x C* para as madeiras das 18 espécies tropicais avaliadas

Moreover, light color timbers, less influenced by a* than b* parameter (e.g. *Apeiba echinata* and *Jacaranda copaia*) tended to show higher gray tone on the surface. This behavior also could be observed on hue (h). Lower influence of red chroma in tropical woods presented higher hue values, which means the presence of a greater influence of yellow tones in the wood coloration. The default wood color can vary in shades ranging from light beige to dark brown, almost black. In these variations, woods with yellow tones, reddish, purple and orange can be observed (Mori et al., 2005).

Due to the different colorimetric parameters reported by Silva et al. (2017), there was also a different color nomenclature adopted. The only species analyzed in both studies grouped at the same color name was *Erisma uncinatum* wood (Yellowish olive). The color of *Apuleia leiocarpa* and *Mezilaurus itauba* wood also didn't follow the pattern observed by Barreto & Pastore (2009). The authors reported a yellow and dark reddish-brown color, respectively. on the other hand, Silva et al. (2007) classified *Mezilaurus itauba* wood as yellowish brown, a color different from both the reddish brown and the pinkish gray. *Hymenaea courbaril* wood color was considered reddish brown by Costa et al. (2011) in contrast to the light yellow observed in this study.

4 Conclusion

- The tropical wood commercialized in the northern region of Mato Grosso, Brazil, tend to be light color. The local market could group the 18 different species processed in 6 groups based on the color similarities.

- The groups would not distinguish flatsawn or quartersawn boards, as it wasn't observed statistically difference between colors from tangential or radial planes.

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