VOL X

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PESQUISA E INOVAÇÃO NAS CIÊNCIAS QUE ALIMENTAM O MUNDO

EDUARDO EUGÊNIO SPERS
(Organizador)

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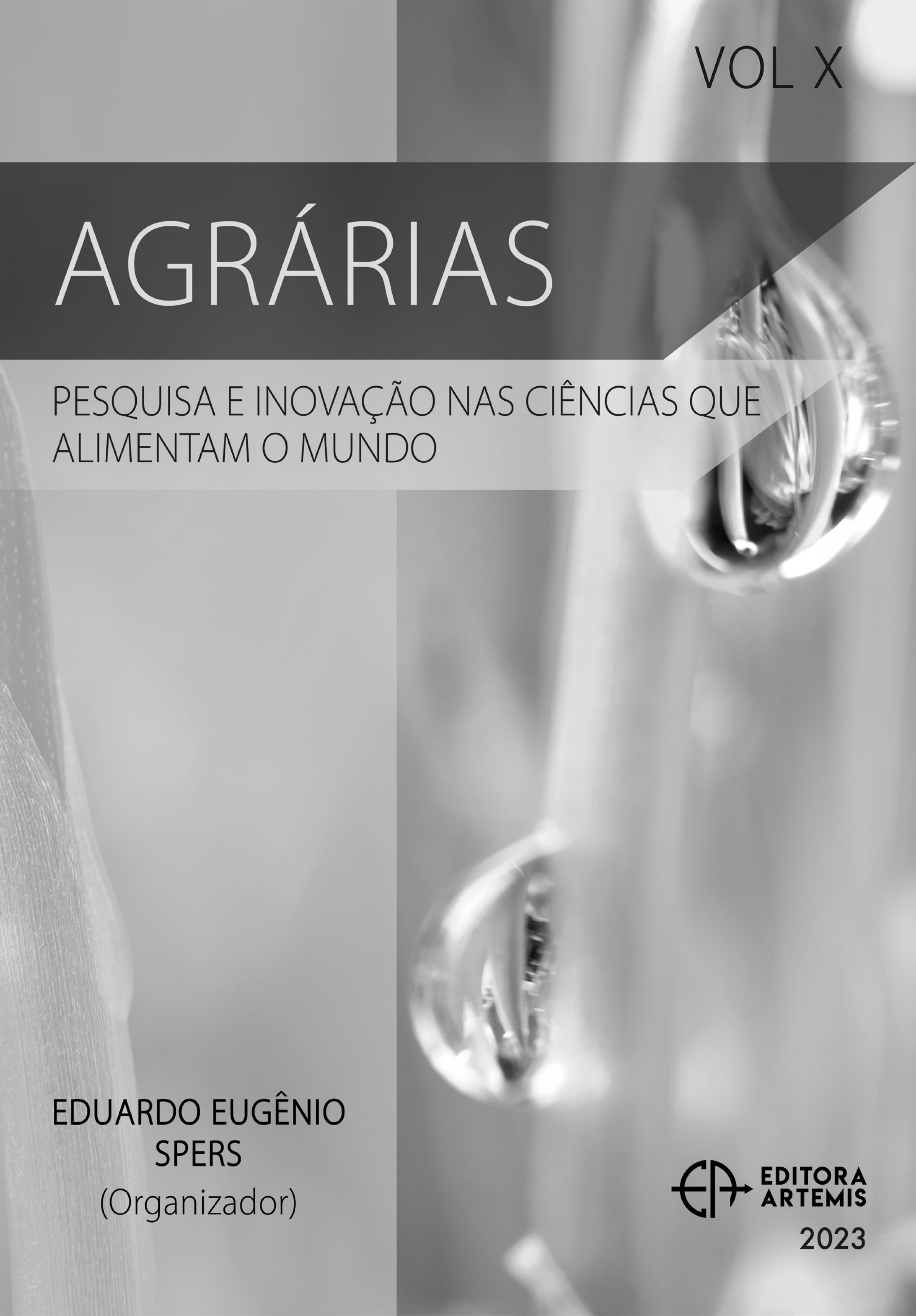

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APRESENTAÇÃO

As Ciências Agrárias são um campo de estudo multidisciplinar por excelência, e um dos mais profícuos em termos de pesquisas e aprimoramento técnico. A demanda mundial por alimentos e a crescente degradação ambiental impulsionam a busca constante por soluções sustentáveis de produção e por medidas visando à preservação e recuperação dos recursos naturais.

A obra **Agrárias: Pesquisa e Inovação nas Ciências que Alimentam o Mundo** compila pesquisas atuais e extremamente relevantes, apresentadas em linguagem científica de fácil entendimento. Na coletânea, o leitor encontrará textos que tratam dos sistemas produtivos em seus diversos aspectos, além de estudos que exploram diferentes perspectivas ou abordagens sobre a planta, o meio ambiente, o animal, o homem e a sociedade no ambiente rural.

É uma obra que fornece dados, informações e resultados de pesquisas tanto para pesquisadores e atuantes nas diversas áreas das Ciências Agrárias, como para o leitor que tenha a curiosidade de entender e expandir seus conhecimentos.

Este Volume X traz 14 trabalhos de estudiosos de diversos países, divididos em dois eixos temáticos: *Produtividade e eficiência na produção vegetal* e *Sustentabilidade e reaproveitamento produtivo.*

Desejo a todos uma ótima leitura!

Eduardo Eugênio Spers

SUMÁRIO

SUSTENTABILIDADE E REAPROVEITAMENTO PRODUTIVO

CAPÍTULO 3

COLORIMETRIC CHARACTERISATION OF TROPICAL WOODS

Data de submissão: 15/11/2023
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ABSTRACT: This study aimed to characterise the calorimetry of 28 tropical wood species in the CIELab colour space. Employing a Minolta CM-2500d spectrophotometer, chromatic axes L* (Luminosity), a* (green-red), and b* (blue-yellow) were determined in xylarium samples, with six measurements per sample. The obtained values underwent an analysis of variance (ANOVA), a comparison of means using the LSD method (α=0.05) and cluster analysis by the average method. The observed and the average values of the chromatic axes were represented in the CIELab system using the Spectra Magic® software. Group representations of average values were done using the SigmaPlot program. The ANOVA showed significant differences ($p \leq 0.05$) in the wood colour of the species in each of the chromatic axes, which allowed the formation of 7 similar groups with an explained variance ratio of 90.1%. Within the wood samples, variations were observed in the luminosity (L*, 24.6 – 81.2), in the a* axis (2.7 – 19) tending towards red, and in the b* axis (3.1 – 32.3) that tends towards yellow. The sapwood of the studied species has light colours due to its high luminosity with a tendency towards yellow on the b* axis, such as the wood of *Bursera simaruba* (L*, 79.66; b*, 21.49) and *Zuelania guidonia* (L*, 77.22; b*, 28.58). In contrast, the heartwood of *Cordia dodecandra* (L*,30.49; a*,4.89) and *S. cubensis* (L*, 27.01; a*, 8.07) shows dark reddish colours with low luminosity. Colour quantification allows for a more objective and measurable characterisation of the wood, facilitating the grouping of similar colours among tropical species.

KEYWORDS: Colour. CIELab system. Heartwood. Sapwood.

1 INTRODUCTION

Colorimetry is defined as the science and technology used to quantify and describe human perception of colour (Choudhury, 2014). Colour is perceived by the human eye in the wavelength range of visible light, which spans approximately 380 nm to 740 nm, when light strikes an object or material. Depending on the material, some wavelengths can be absorbed while others are reflected, creating the basic colour impression. The human eye's perception of colour is based on the sum of reflected wavelengths, which determines the perceived colour of the material. Furthermore, in visual observation of an object, three factors influence the recognition of its appearance and colour: the light source, the object itself, and the human observer (Choudhury, 2014).

Colour in wood is further recognised based on the reflected wavelength of visible light, surface roughness, the internal structure of the specific piece of wood and its refractive properties (Meints et al., 2017).

Wood colour characterisation is used to identify, classify, and quantitatively describe the surfaces of various types of wood. This process involves considering aspects such as texture, design, colour changes due to finishes, humidity, discolouration, and other aesthetic characteristics (Hon & Minemura, 2001; Meints *et al*., 2017). In addition, colour studies have been carried out to evaluate, characterise and classify the wood of different species quantitatively using the CIELab system (Silva *et al.*, 2015; Meints *et al*., 2017; Silva *et al*., 2017; Sousa *et al*., 2019).

In Mexico, various tropical woods are marketed and prized for their colour. However, until now, the description of the colour of these woods has been done qualitatively or comparatively through the use of Munsell colour boards designed for plant tissues or soils (Rebollar and Quintanar, 2000). Therefore, it is essential to quantify the colour of the wood to assess its commercial viability, especially in applications of high economic value, such as the manufacture of decorative panels, parquet, furniture, marquetry and fine joinery. Due to the relevance of this aspect in the market, this study aims to determine the colourimetry properties of 28 types of tropical woods using the CIELab colour system.

2 MATERIALS AND METHODS

Wood samples, measuring 1 cm x 6 cm x 15 cm, were selected from 28 different species of tropical woods sourced from the xylarium of the National Research Institute of Forestry, Agriculture and Livestock (INIFAP). Heartwood species included *Achras zapota* L. - Sapotaceae (Chicozapote), *Astronium graveolens* Jacq. - Anacardiaceae (Jobillo), *Budica buceras L.* - Combretaceae (Pukté), *Calophyllum brasilense* Camb. - Guttiferae (Barí), *Cedrela odorata* L. - Meliaceae (Cedro rojo), *Cordia alliodora Ruiz & Pav.* - Boraginaceae (Bojón), *Cordia dodecandra* D.C. - Boraginaceae (Siricote), *Enterolobium cyclocarpum* (Jacq.) Griseb. - Leguminosae (Guanacaste), *Guaicum sanctum* L. - Zygophyllaceae (Guayacán), *Krugiodendron ferrum* (Vahl) Urb. - Rhamnaceae (Chintok), *Lysiloma latisiliquum* (L.) Benth. - Leguminosae (Tzalam), *Maclura tinctoria* (L.) Steud. - Moraceae

(Mora), *Metopium brownei* (Jacq.) Urban - Anacardiaceae (Chechen), *Piscidia piscipula* (L.) Sarg. - Leguminosae (Jabin), *Pithecolobium brevifolium* Benth. - Leguminosae (Chucum), *Platymiscium yucatanum Standl. - Leguminosae (Granadillo), Swartzia cubensis* (Britton & Wilson) Standl. - Leguminosae (K'atalox), *Sweetia panamensis* Benth. - Leguminosae (Cencerro) and *Swietenia macrophylla King.* - Meliaceae (Caoba). Samples with sapwood were from *Blepharidium mexicanum* Standl. - Rubiaceae (Popistle), *Bursera simaruba* (L.) Sarg. - Burseraceae (Chaca), *Guatteria anomala* R.E.Fr. - Annonaceae (Zopo), *Phoebe aff.* effusa Meisn. - Lauraceae (Aguacatillo), *Simarouba glauca* DC. - Simaroubaceae (Pasa'ak), *Tabebuia rosea* DC. - Bignonaceae (Maculis), *Vitex gaumeri* Greenm. - Verbrenaceae (Yax-nic), *Vochysia hondurensis* Sprague - Vochysiaceae (Palo de agua) and *Zuelania guidonia* (Sw.) Britt. et Millsp. - Flacourtinaceae (Trementino).

For each species, three samples were taken and prepared by sanding them with 150 and 220-grit sandpaper to remove any dust or stains and enhance the colour of the wood. Then, six colour measurements were made on each sample using a Minolta CM-2500d spectrophotometer (Konica Minolta). These measurements were made in a wavelength range of 400 to 700 nm, under a standard D65 light source, with an observation angle of 10° and a field of view of 8 mm.

The resulting colour values for each type of wood were subjected to an analysis of variance (ANOVA), followed by a comparison of means using the LSD method (α = 0.05) and a multivariate analysis of groups using the average grouping method. The SAS program was used in the analyses (SAS, 2000).

Finally, the observed colour data and their average were plotted in the CIELab colour space (ISO 11664:2008), using the L*, a*, b* (ISO/CIE, 2019) values using Spectra Magic® software. Cluster graphical visualisation of the L*, a* and b* average values for each species was generated using the SigmaPlot program (Systat, 2011).

3 RESULTS AND DISCUSSION

In the CIELab* system, quantitative colourimetry converts sensory impressions into the L*, a* and b* colour axes. These axes define, describe, and characterise the colour intensity of materials (ISO/CIE, 2019). The colour axis a* ranges from green (-a*) to red (a*), while the colour axis b* extends from blue (-b*) to yellow (b*). On the other hand, the luminosity axis (L*) varies from 0 (black) to 100 (white). Therefore, it is possible to separate the colours of objects into bright and dark colours by comparing their luminosities (Konica Minolta, 2003). Luminosity increases to a value of 100 and decreases to 0. The point where the a* and b* axes intersect (L*=50) corresponds to a pure, balanced, neutral grey colour.

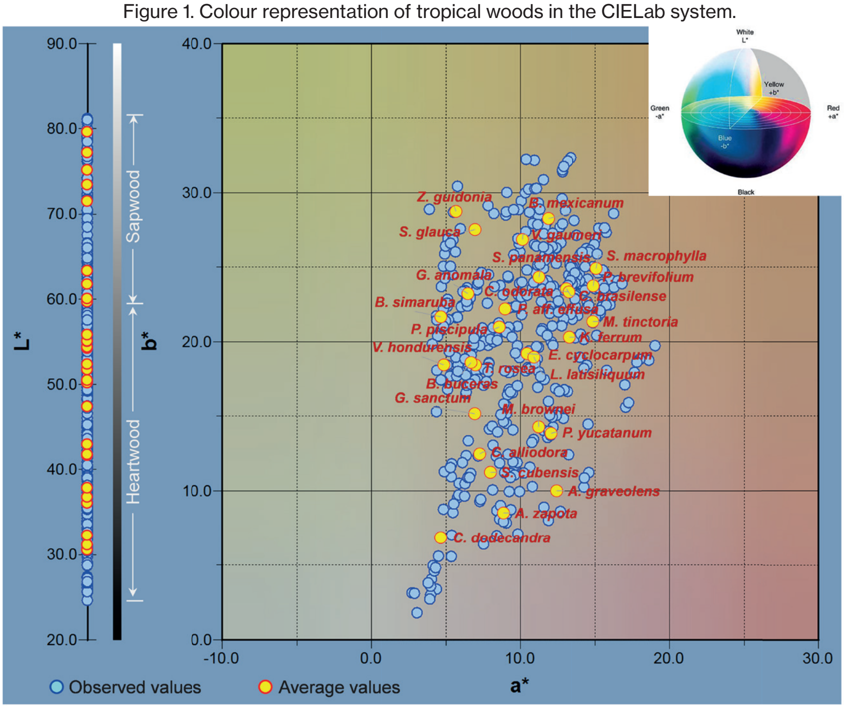
This study observes variations in the three chromatic axes among the tropical woods. The luminosity (L*) varies from 24.6 to 81.2; the a* axis tends to be red and fluctuates between 2.7 and 19.0, while the b* axis tends to be yellow and is between 3.1 and 32.3 (Figure 1, Table 1).

The analysis of variance indicated significant differences ($p \leq 0.05$) in each of the chromatic axes for the wood of the species studied (Table 1).

The average sapwood values of *B. simaruba* (79.7) and *Z. guidonia* (77.2). exhibit light colours with high luminosities. In contrast, the heartwood of *C. dodecandra* (30.5) and *A. zapota* (31.1) shows dark colours with low luminosities (Table 1). These woods have extreme luminosity values.

On the other hand, the wood of *S. macrophylla, C. odorata*, S. panamensis*, P. brevifolium*, *E. cyclocarpum, P. piscipula*, *S. cubensis, B. buceras* and *L. latisiliquum* have luminosities around grey (L*=50±5). While the wood luminosity of *P. aff. effusa*, *C. brasilense, T. rosea, V. hondurensis*, *S. glauca, B. mexicanum*, *V. gaumeri* and *G. anomala* tends to light colours (L*, 55.8-71.5), in contrast, the luminosity of the wood of *C. alliodora, M. brownei, K. ferrum, P. yucatanum, G. sanctum, A. graveolens* and *M. tinctoria* tends towards dark colours (L*, 32.2-42.9).

Figure 1. Colour representation of tropical woods in the CIELab system.



On average, the colour values on the a* axis of the wood of the studied species range from grey to red. Wood species that have near-grey values include *B. simaruba* (4.8), *C. dodecandra* (4.9), and *V. hondurensis* (5.0), while those with near-red values include *P. brevifolium* (14.9), *M. tinctoria* (15.0), and *S. macrophylla* (15.1). Some woods, such as *Z. guidonia (5.8), G. anomala* (6.6), *B. buceras* (6.8) and *S. glauca* (7.0), tend towards shades of grey. In contrast, other woods, such as those of *K. ferrum* (13.4), *C. brasilense* (13.1), *C. odorata* (13.0) and *A. graveolens* (12.8), tend toward red hues. The rest of the woods have intermediate values between 7.1 and 12.3.

Regarding the b* axis, the average values of the different woods show a wide range of colours, ranging from shades close to grey (7.0) to yellow-orange tones (28.6). These extreme colour values correspond to the wood of *C. dodecandra* and *Z. guidonia.* The woods of *A. zapota* (8.8) and *A. graveolens* (10.2) have values close to the wood of *C. dodecandra*, while the wood of *S. cubensis* (27.3), *S. glauca* (27.4) and *B. mexicanum* (28.1) more closely resemble the values of *Z. guidonia.* The other wood species have chromatic values ranging from 12.5 to 26.7.

Table 1. Average values of the chromatic L*, a*, b* axes.

Species	L	a*	b*
Achras zapota (Chicozapote - H)	31.1 ± 1.5 n	9.2 ± 0.8 g h	8.8 ± 1.2 p
Astronium graveolens (Jobillo - H)	32.2 ± 1.9 n	12.8 ± 1.7 b c	10.2 ± 2.2 p o
Blepharidium mexicanum (Popistle - S)	60.1 ± 3.0 f	11.9 ± 1.0 e c d	28.1 ± 2.4 a b
Bucida buceras (Pukté - H)	55.0 ± 2.5 g h	6.8 ± 0.4 l k j	18.5 ± 1.5 k
Bursera simaruba (Chaca - S)	79.7 ± 1.0 a	4.8 ± 0.4 m	21.5 ± 0.9 g f h
Calophyllum brasilense (Barí - H)	55.8 ± 2.3 g	13.1 ± 1.1 b c	23.4 ± 2.0 c d e
Cedrela odorata (Cedro rojo - H)	54.4 ± 5.4 g h i	13.0 ± 1.5 b c	22.7 ± 2.9 g f d e
Cordia alliodora (Bojón - H)	36.0 ± 2.8 m	7.4 ± 1.2 i k j	12.5 ± 2.4 n m
Cordia dodecandra (Siricote - H)	30.5 ± 4.9 n	4.9 ± 1.2 m	7.0 ± 3.2 q
Enterolobium cyclocarpum (Guanacaste - H)	47.4 ± 1.9 k	10.5 ± 1.1 f	19.2 ± 1.7 j k i
Guaicum sanctum (Guayacán - H)	41.8 ± 6.3 l	7.1 ± 1.9 k j	15.4 ± 3.0 l
Guatteria anomala (Zopo - S)	71.5 ± 1.3 d	6.6 ± 0.5 l k	23.1 ± 0.8 c f d e
Krugiodendron ferrum (Chintok - H)	41.7 ± 4.0 l	13.4 ± 1.3 b	20.4 ± 2.1 j h i
Lysiloma latisiliquum (Tzalam - H)	52.4 ± 1.4 j h i	11.0 ± 0.5 e f	18.8 ± 0.8 j k
Maclura tinctoria (Mora - H)	43.0 ± 0.6 l	15.0 ± 0.6 a	21.5 ± 1.1 g f h
Metopium brownei (Chechén - H)	37.8 ± 3.6 m	11.3 ± 1.4 e f d	14.3 ± 2.5 l
Phoebe aff. effusa (Aguacatillo - S)	63.3 ± 1.4 e	9.0 ± 1.1 g h	22.1 ± 2.0 g f h e
Piscidia piscipula (Jabín - H)	51.7 ± 3.3 j i	8.7 ± 1.3 i h	20.9 ± 1.9 g h i
Pithecolobium brevifolium (Chucum - H)	50.2 ± 0.8 j k	14.9 ± 0.7 a	23.6 ± 0.8 c d e

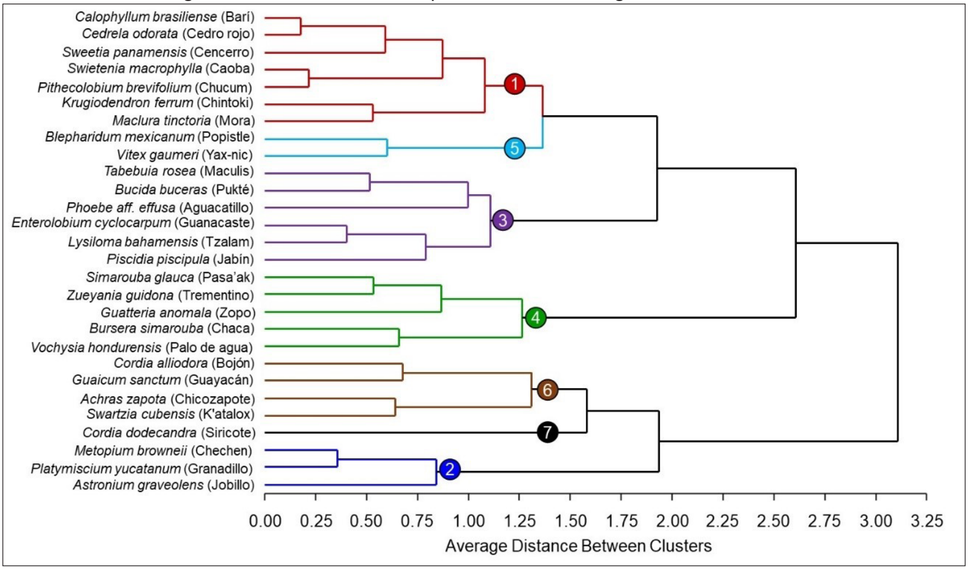
Species	L	a*	b*
***Platymiscium yucatanum* (Granadillo - H)**	37.1 ± 2.0 m	12.5 ± 3.7 b c d	14.2 ± 3.0 l m
***Simarouba glauca* (Pasa'ak - S)**	73.4 ± 6.3 c d	7.0 ± 2.3 l k j	27.4 ± 2.5 a b
***Swartzia cubensis* (K'atalox - H)**	27.0 ± 3.2 o	8.1 ± 1.2 i h j	11.3 ± 2.6 n o
***Sweetia panamensis* (Cencerro - H)**	54.2 ± 1.3 g h i	11.3 ± 0.4 e f d	24.2 ± 1.0 c d
***Swietenia macrophylla* (Caoba - H)**	50.5 ± 5.0 j	15.1 ± 1.1 a	24.8 ± 1.8 c
***Tabebuia rosea* (Maculis - S)**	61.8 ± 2.6 e f	7.1 ± 0.9 k j	18.3 ± 0.9 k
***Vitex gaumeri* (Yax-nic - S)**	59.7 ± 0.6 f	10.2 ± 0.7 g f	26.7 ± 1.2 b
***Vochysia hondurensis* (Palo de agua - S)**	75.2 ± 1.7 c b	5.0 ± 0.5 m	18.3 ± 0.8 k
***Zuelania guidonia* (Trementino - S)**	77.2 ± 1.9 a b	5.8 ± 1.3 l m	28.6 ± 1.3 a

H: Heartwood, S: Sapwood.

The colour differences are distinct and significant for the wood of each species in the chromatic axes (Table 1). For example, *B. simaruba* wood has the highest value on the L* axis (79.7), but the lowest value on the a* axis (4.8), with an average value on the b* axis (21.5). In addition, the wood of some species has similar values in each axe, suggesting the possibility of grouping them by employing a cluster analysis when considering the values of the three chromatic axes.

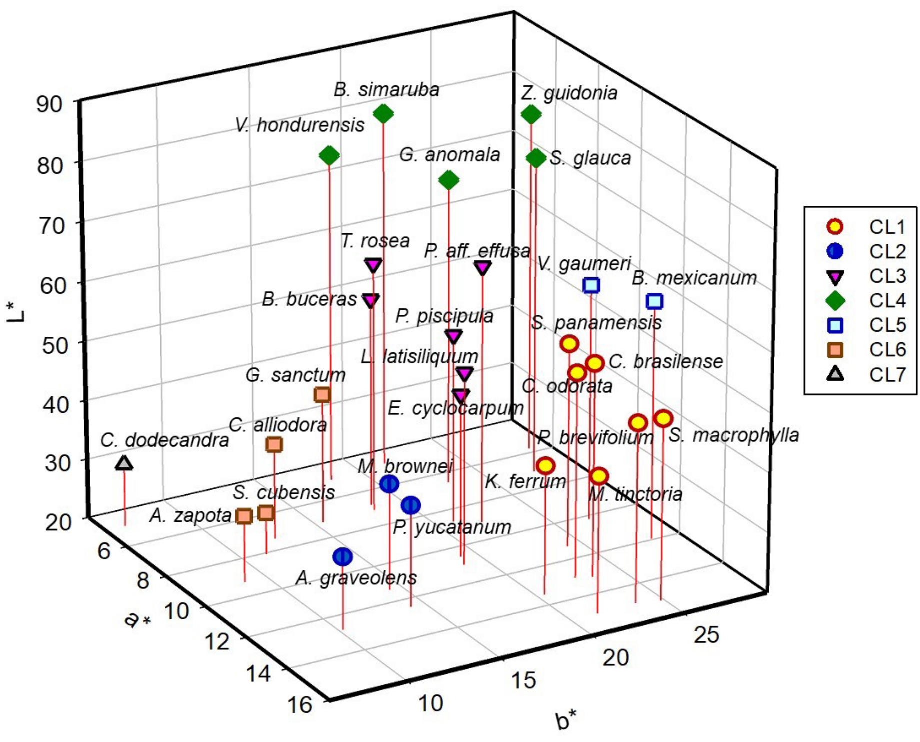
In the cluster analysis of the L*a*b chromatic values using the average method, it was observed that the wood colour of the studied species can be divided into seven groups (Figure 2). These groups explain a significant percentage of variance, reaching 90.1%.

Figure 2. Colour clusters of tropical woods according to the values L*a*b*.



In group 7, *C. dodecandra* wood stands out, characterised by low values in the three chromatic axes (Figure 3). In contrast, group 4, includes the wood of *B. simaruba*, *V. hondurensis*, *S. glauca*, *G. anomala* and *Z. Guidonia* with luminosity values higher than 71 and a tendency towards yellow because it corresponds to sapwood. Group 1, composed of *C. brasilense*, *S. macrophylla*, *C. odorata*, *S. panamensis*, *K. ferrum*, *P. brevifolium* and *M. tinctoria*, shows values that tend towards red on the a* axis and yellow on the b* axis, with intermediate luminosities. The wood of *A. graveolens*, *M. brownie* and *P. yucatanum* are part of group 2 because they have low values in luminosity and in the b* axis, with intermediate values in a* axis. Intermediate values on all three axes characterise group 3, which includes the wood of *B. buceras*, *E. cyclocarpum*, *L. latisiliquum*, *P. aff. effusa*, *P. piscipula* and *T. rosea*. Group 5 shows the highest values on the b* axis, which tend towards the yellow colour and includes the wood of *B. mexicanum* and *V. gaumeri*. Finally, group 6 consist of the wood of *A. zapota*, *C. alliodora*, *G. sanctum* and *S. cubensis*, which shows low values in all three chromatic axes.

Figure 3. Coordinates and colour values L*a*b*.



Although no quantitative studies have been conducted on the colour of wood species in Mexico, studies carried out on tropical woods by Silva *et al.* (2015, 2017) and Sousa *et al*. (2019) indicate that the quantification of colour in the CIELab system eliminates subjectivity in the appreciation of wood colour.

Therefore, colour quantification allows characterisation and classification into similar colour groups based on the values of the chromatic axes, which coincides with the approach of this study on the colour of tropical woods.

4 CONCLUSIONS

The colour of tropical woods varies according to their Lab* colour values. Sapwood exhibits lighter colours with luminosities above 60, while heartwood exhibits darker colours with luminosities below 60. At the high-light end are the sapwood wood of *B. simaruba* and *Z. guidonia*, and at the low-light end are the heartwood of *C. dodecandra* and *S. cubensis*.

Tropical woods show colours distributed on the positive axes from grey to yellow (b*) and to red (a*). Sapwood tends towards the yellow colour, while heartwood tends towards the red colour.

The chromatic values of the colour made it possible to classify tropical woods into seven distinctive groups.

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SOBRE O ORGANIZADOR

EDUARDO EUGENIO SPERS realizou pós-doutorado na Wageningen University (WUR), Holanda, e especialização no IGIA, França. Possui doutorado em Administração pela Universidade de São Paulo (USP). Foi Professor do Programa de Mestrado e Doutorado em Administração e do Mestrado Profissional em Comportamento do Consumidor da ESPM. Líder do tema Teoria, Epistemologia e Métodos de Pesquisa em Marketing na Associação Nacional de Pós-Graduação e Pesquisa em Administração (ANPAD). Participou de diversos projetos de consultoria e pesquisa coordenados pelo PENSA e Markestrat. É Professor Titular no Departamento de Economia, Administração e Sociologia, docente do Mestrado em Administração e Coordenador do Grupo de Extensão MarkEsalq no campus da USP/Esalq. Proferiu palestras em diversos eventos acadêmicos e profissionais, com diversos artigos publicados em periódicos nacionais e internacionais, livros e capítulos de livros sobre agronegócios, com foco no marketing e no comportamento do produtor rural e do consumidor de alimentos.

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