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ANATOMICAL TRAITS OF 'LOUROS' WOOD FROM THE BRAZILIAN AMAZON FOR WOOD IDENTIFICATION

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This study aimed to describe anatomical characteristics of wood known as 'louros' from the Brazilian Amazon. The species is also known in Portuguese as preciosa, louro preto, louro pimenta, louro rosa, itauba, itauba amarela, louro branco and louro vermelho. Wood samples were collected in the extractivist communities of Paraíso and Arimum, located in the Verde Para Sempre Extractivist Reserve in Pará State, Brazil. All evaluated wood had diffuse porosity, simple perforate plate, alternate intervessel pits and non-storied rays. The anatomical characteristics indicated that louro branco had lower average ray frequency values (1.23), while preciosa, itauba and itauba amarela had higher mean ray frequency (6.70, 6.43 and 6.60), respectively. Samples of louro vermelho and louro branco had higher values for ray height (1994.36 and 5579.81) and width (511.21 and 506.40). Regarding vessel dimensions and frequency, itauba and itauba amarela had higher vessel frequency (11.43 and 11.83). Overall, strong uniformity of wood structure was observed at macroscopic and microscopic levels in the evaluated species. However, there were some slight differences. The anatomical characteristics, effective for discrimination, were axial parenchyma type, presence of septate fibres, type and grouping of vessels, presence of oil cells and starch.

Keywords: Wood identification, vessel dimensions, ray dimensions, Lauraceae, Proteaceae

INTRODUCTION

In the Amazon region, wood exploitation for industrial processes is one of the principal economic activities, directly related to abundant supply of a diverse range of species (Soares et al. 2014). However, wood is a material with great variability, mainly tropical arboreal species in the Amazon region. In forest inventories, identification based on popular names is common, which can result in mistakes, since a single species can have a great number of vernacular names. Therefore, correct identification of species is necessary for subsequent species classification of wood (Coradin & Camargo 2002, Candian & Sales 2009).

Another risk factor of incorrect identification of forest species is illegal commerce, which contributes to the overexploitation of species and deforestation of the Amazon region (Soares et al. 2017). In response, Extractivist Reserves (RESEX) have been created to combat illegal deforestation, protect regions with high biological value and satisfy local demand of traditional communities through sustainable use of natural resources (Veríssimo et al. 2011).

Among tropical trees, the Lauraceae and Proteaceae families are important in Pará State, where they are popularly known as 'louro'. This group of trees has several common names, such as louro pimenta, louro preto, louro vermelho, louro branco, louro rosa, itauba, itauba-amarela and preciosa (SEMAS-PA 2016). The Lauraceae family has approximately 52 genera and 3,000 species, distributed in pantropical regions (Rohwer 1993, Flora do Brasil 2020a). Trees of this family have high economic importance, with emphasis on the genera *Ocotea* sp., *Nectandra* sp., *Mezilaurus* sp. and *Aniba* sp., whose wood is widely marketed for its quality for cabinetry, civil construction and boat building, besides some medicinal applications (Gottieb 1972, Ribeiro et al. 1999). The Lauraceae family is one of the taxonomic groups with greatest difficulty of distinction, even at the genus level, because they have strong morphological uniformity (Caiafa & Martins 2007).

The Proteaceae family has approximately 80 genera and more than 1,750 species of trees and shrubs (Weston & Barker 2006). In Brazil, trees of this family can be found in the Amazon and Atlantic Forest fragments, with a total of 33 species (Flora do Brasil 2020b). In relation to wood, the genera with greatest importance are *Roupala* sp. and *Euplassa* sp. (Paula & Costa 2011).

The process of wood identification is complex, involving macroscopic and microscopic analysis. For macroscopic identification, simpler instruments are applied in comparison to microscopic distinction, making practical identification relatively fast. Macroscopic characteristics can be grouped into organoleptic and anatomical. The former encompasses wood color, brightness, odor, taste, grain, texture and density, while the latter entails aspects related to growth rings, shape and dimensions of cellular elements, such as vessels and axial parenchyma (Botosso 2011). In general, macroscopic identification techniques can only identify wood at the genus level (Gasson 2011). Therefore, precise identification of wood species depends on its microscopic characteristics, since macroscopic data can be highly variable (Bernal el al. 2011). The woods of tropical species are very similar in terms of macroscopic and microscopic anatomical characteristics. Among the most common characters are parenchymal similarities, diffuse porosity and coarse texture (Hoadley 1990).

Although macroscopic identification allows distinguishing most commercial wood species in Brazil, it is restrictive when there is a need for botanical recognition at the species level, principally with wood species from botanical groups with higher complexity or structural similarity. So, in microscopic analysis, aspects such as presence and shape of pits, cell wall ornamentation, ray cell composition, cell dimensions and presence of inorganic substances (crystals and silica), among other traits, can be considered for correct identification and also to determine adequate final application (Botosso 2011).

Because of the socioeconomic and ecological importance of the Brazilian Amazon, and of the species of Lauraceae and Proteaceae family, the aim of this study is to evaluate the macroscopic and microscopic description of the anatomical traits of wood from the 'louros' group, contributing information to better distinguish the species of this group.

MATERIALS AND METHODS

The study was conducted in a sustainable forest management area (AMFS), belonging to two extractivist communities, Paraíso and Arimum. Both communities are in the Verde Para Sempre Extractivist Reserve, located at 01°55' S and 52°56' W, with a total area of 1,289,362.78 hectares, in the municipality of Porto de Moz, Pará State. Paraíso has an authorised volume of yearly wood exploitation of 2,198.64 m^3 (7/2017 authorisation) and Arimum has permission to extract 4,740.74 m^3 (9/2016 authorisation).

The study was approved by the Ministry of the Environment (MMA) and Chico Mendes Institute (ICMBio), No. 64485-1, registered in the Authorization and Biodiversity Information System (SISBIO). All species analysed are registered in the National System for Genetic Heritage Management (SisGen) under code A1D7BF7.

The species in this study were collected in two forest censuses carried out in Annual Production Units (UPA-2016 and UPA-2017). The trees were selected based on the availability of each legal exploitation area between August 23 and 25, 2018. The procedure for the analyses was based on the following steps: 1) specimen (tree) selection, 2) felling the tree and removal of a 5 cm thick wooden disk 10 cm above the cut point, 3) removal of a 5 cm wide central strip from the wooden disk, which included the pith region and 4) cutting of wood cubes from this strip, with dimensions 2.5 × 2.5 × 2.5 cm.

The material was transported to Federal University of Paraná (UFPR), where identification was performed in the Wood Anatomy and Quality Laboratory. All samples were identified to genus level due to the great similarity between species within the families (Table 1). A total of 101 wooden cubes were used in the study, without separation of heartwood and sapwood.

Table 1 Wood samples of the Lauraceae and Proteaceae families collected in Paraíso and Arimum

Common name	Code	Scientific name	Family	Community	Specimens	Wooden cubes
Preciosa	PR	*Aniba* sp.	Lauraceae	Paraiso	1	11
Louro preto	LP	*Nectandra* sp.	Lauraceae	Arimum	1	12
Louro pimenta	LPI	*Ocotea* sp.	Lauraceae	Arimum	1	11
Louro rosa	LR	*Ocotea* sp.	Lauraceae	Paraiso	1	13
Itauba	IT	*Mezilaurus* sp.	Lauraceae	Arimum	1	27
Itauba amarela	ITA	*Mezilaurus* sp.	Lauraceae	Paraiso	1	8
Louro branco	LB	*Euplassa* sp.	Proteaceae	Arimum	1	11
Louro vermelho	LV	*Roupala* sp.	Proteaceae	Arimum	1	8
Total samples					8	101

Anatomical characterisation of wood

The anatomical description of the wood samples was based on the recommendations of the International Association of Wood Anatomists (IAWA 1989) for commercial wood in Brazil (Coradin et al. 2011). In order to standardise the surfaces, samples for macroscopic description were polished with sandpaper (No. 80, 600 and 1500). Images were obtained with a stereomicroscope, and processed by Axio Vision software. General description of wood was carried out in function of color, brightness, odor, presence of growth rings, visibility and type of axial parenchyma, visibility of rays and vessels, distribution of vessels and obstructions.

For microscopic evaluation, samples measuring 1.5 cm in the radial, tangential and transversal directions were prepared. The samples were boiled in water for 3–6 hours per day, for two weeks in function of its hardness. Histological sections with 25 m were obtained with a microtome. Color was based on acridine, chrysoidine and astra blue staining. Permanent slides were prepared for evaluating the following structural aspects: i) ray frequency, ii) ray height, iii) ray width in cells (in micrometers), iv) vessel frequency and v) tangential vessel diameter. For the *Euplassa* and *Roupala* genera, only multisseriate rays were measured (height and width).

Dissociated material was produced by the method of Franklin (1945). Images were obtained with a stereomicroscope coupled to a camera and processed with the Axio Vision software to measure microscopic features.

To detect the presence of starch, Lugol's iodine was applied in accordance to usual plant anatomy techniques described by Jansen (1962). Wood sections were cut and placed in distilled water with 3 drops of Lugol, and after 3 minutes the samples were washed with distilled water and temporary slides were prepared for microscopic evaluation.

Statistical analysis

Analysis of variance (ANOVA) was performed with the data on anatomical dimensions in a completely randomised design using ExpDes.pt package (Ferreira et al. 2018). The structural aspects evaluated were rays per millimeter, ray width (µm), ray height (µm), vessels per square millimeter and vessel diameter (µm). Means were compared by the Tukey test ($\alpha = 0.05$).

Principal component analysis (PCA) was applied to evaluate the influence of anatomical characteristics for material grouping with the FactoMineR package, and the results were extracted with the FactoInvestigate package (Lê et al. 2008, Kassambara & Mundt 2017, Thuleau & Husson 2020). A biplot graph was constructed to verify the relationship of PCA samples and the contribution of each variable to the principal components. All analyses were performed with R (version 3.4.3).

RESULTS AND DISCUSSION

After analysis, eight different trees were identified, from six genera and two families, i.e., *Aniba, Nectandra, Ocotea* and *Mezilaurus*, from the Lauraceae family, and *Euplassa* and *Roupala* from the Proteaceae family (Figure 1). The trees were: one *Aniba* sp. (PR, preciosa), one *Nectandra* sp. (LP, louro preto), two *Ocotea* sp. (LPI, louro pimento and LR, louro rosa), one *Roupala* sp. (LV, louro vermelho), one *Euplassa* sp. (LB, louro branco) and two *Mezilaurus* sp. (IT, itauba and ITA, itauba amarela). All samples were identified only at the genus level because anatomical characteristics were too similar to permit secure distinction at species level.

Samples were distributed in three groups based on heartwood color (Figure 1), dark gray (*Nectandra* sp. and *Ocotea* sp.), brownish-red (*Aniba* sp. and *Mezilaurus* sp.) and brownish-yellow (*Euplassa* sp. and *Roupala* sp.).

The mean values of each anatomical characteristic (Table 2) corroborated the similarity of wood inside the genus.

It was possible to notice that the mean values of the anatomical traits indicated that LB (*Euplassa* sp). had lower ray frequency, and PR (*Aniba* sp). and the genus *Mezilaurus* had higher ray frequency values. Samples from LV (*Roupala* sp). and LB (*Euplassa* sp). had higher values for ray height and width. Also, *Euplassa* had higher values of ray height.

With respect to vessel dimensions and frequency, the genus *Mezilaurus* had higher vessel frequency, while for tangential vessel diameter, greater values were found in LP (*Nectandra* sp.) and LB (*Euplassa* sp.).

Wood anatomical description and comparison of Lauraceae family

All evaluated wood samples had diffuse porosity, simple perforate plate, alternate intervessel pits and non-storied rays.

Preciosa (PR) versus louro preto (LP)

As shown in Figure 2, wood from the genus *Aniba* sp. (PR, preciosa) and *Nectandra* sp. (LP, louro preto) had distinct macroscopic traits. *Aniba* sp. had brownish-red heartwood, agreeable odor and taste, vessels visible to the naked eye and obstructed by tyloses, axial parenchyma indistinct at 10 x magnification, scarce paratracheal, and rays invisible at 10 x magnification. *Nectandra* sp. had dark grey heartwood, indistinct odor and taste, vessels visible to the naked eye, with diffuse porosity, vessels obstructed by tyloses and oil resin, axial parenchyma visible at 10 x magnification, paratracheal vasicentric and lozenge-aliform confluent, and rays visible at 10 x magnification, not storied.

Microscopic anatomical traits differed. *Aniba* sp. (Figure 2 A–D) had few growth rings, distinct

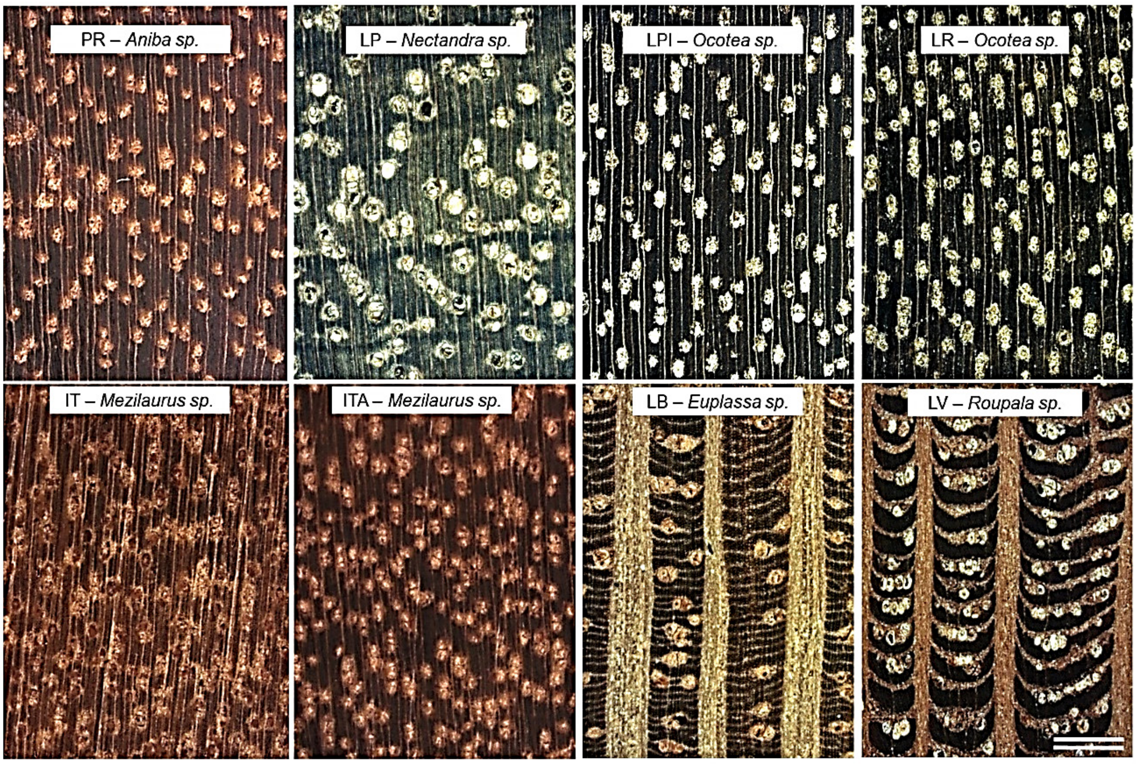

Figure 1 Macroscopic images of 'louros' wood, scale bar = 1000 μm

Table 2 Minimum, mean and maximum values of cell dimensions from wood popularly known as 'louro', collected in the Paraíso and Arimum communities, Para State, Brazil

Scientific name	Wooden cubes		Rays per millimeter	Ray width (µm)	Ray height (µm)	Vessels per square millimeter	Vessel diameter (µm)
PR *Aniba* sp.	11	Min	5	15	210	5	75
		Mean	6.70e	32.43a	490.96a	7.60c	109.93ab
		Max	12	50	780	13	160
LP *Nectandra* sp.	12	Min	3	22.78	74.22	2	178.47
		Mean	4.86c	33.70a	308.801a	3.76a	246.82e
		Max	7	48.6	604.79	6	314.28
LPI *Ocotea* sp.	11	Min	4	17.37	176.65	3	50
		Mean	6.00de	32.67a	376.29a	6.03b	127.51b
		Max	8	56.36	812.84	10	223.96
LR *Ocotea* sp.	13	Min	3	24.84	142.55	3	129.25
		Mean	5.5cd	38.87a	427.43a	7.40bc	169.68c
		Max	8	55.12	777.13	10	216.25
IT *Mezilaurus* sp.	27	Min	5	18	250	6	90
		Mean	6.43e	28.76a	471.30a	11.43d	122.70ab
		Max	9	62	700	16	150
ITA *Mezilaurus* sp.	8	Min	4	20	250	6	60
		Mean	6.60e	40.40a	492.33a	11.83d	103.56a
		Max	9	51	930	16	140
LB *Euplassa* sp.	11	Min	1	273.55	2351.26	3	126.81
		Mean	1.23a	506.40b	5579.81c	4.40a	199.82d
		Max	2	891.38	9879.38	7	259.08
LV *Roupala* sp.	8	Min	2	16.87	59.09	2	93.93
		Mean	2.43b	511.21b	1994.36b	4.43a	163.85c
		Max	3	776.38	4456.56	10	251.65

Same letter in each anatomical characteristic indicates no difference between species based on the Tukey test at $\alpha = 0.05$, Min = minimum, Max = maximum

with thick-walled fibres, solitary vessels in radial multiples of 2–3, tyloses present, vessel elements with short appendages, simple perforate plate, alternate intervessel pits, large vessel-ray pits, scanty axial parenchyma or vasicentric, heterogeneous rays, with body ray cell procumbent and one row of upright or square marginal cells, uniseriate and biseriate, thick-walled fibres, non-septate, and oil cells in axial and radial parenchyma. *Nectandra* sp. (Figure 2 E–I) had distinct growth rings separated by thick-walled fibres, solitary vessels in radial multiples of 2–4, vessel elements with or without short or medium appendages, simple perforate plate, alternate intervessel pits, vessel rays pits with distinct border, larger than intervessel in size and shape, vasicentric axial parenchyma, occasionally scanty or confluent, heterogeneous rays with procumbent body cells and upright and square marginal cells, bi/triseriate, thick-walled fibre, septate, and oil cells predominant in radial parenchyma, occasionally in axial parenchyma.

Louro pimenta (LPI) versus louro rosa (LR)

As shown in Figure 3, both are from the genus *Ocotea* sp., and are very similar in anatomical traits, i.e., heartwood and sapwood were distinct by color, dark gray to black heartwood; vessels visible to the naked eye and obstructed by tyloses, axial parenchyma indistinct at 10 × magnification, scarce paratracheal, rays visible at 10 × magnification on transversal surface, and visible to the naked eye on tangential surface.

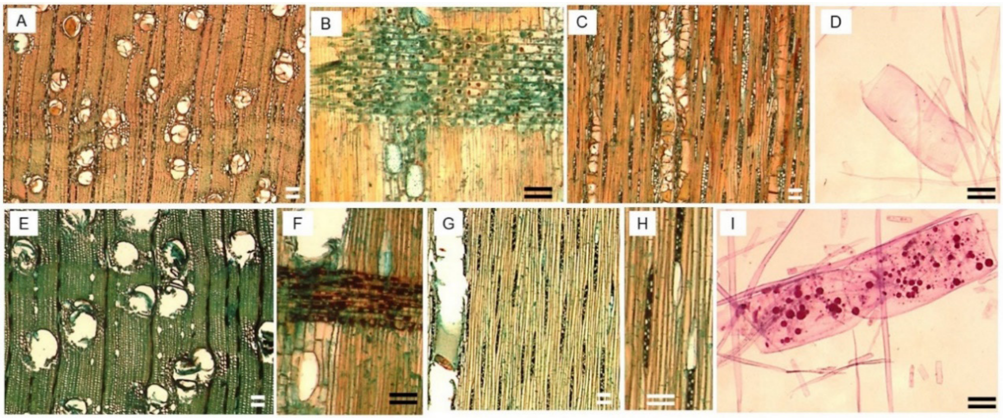

Figure 2 Microscopic images of *Aniba* sp. (A–D) and *Nectandra* sp. (E–I), transversal section (A, E), radial section (B, F), tangential section (C, G, H) and dissociated material (D, I), scale bar = 100 µm

Odor and taste were different, imperceptible for louro rosa and peppery for louro pimenta.

Microscopic traits were also very similar. In both samples, growth rings were distinguished by fibres, diffuse porosity, tyloses present, simple perforate plate, septate fibres, heterogeneous rays, with procumbent body cells and marginal square and upright cells, not storied. The LPI (Figure 3 A–D) had wide and narrow vessel elements, both with and without appendages, solitary and radial multiples of 2–3, alternate intervessel pits, vessel-ray pits with distinct borders, similar to intervessel pits in size and shape, scanty and vasicentric axial parenchyma, oil cells present in axial and radial parenchyma. The LR (Figure 3 E–H) had wide and narrow vessel elements, with short or long appendages, solitary and radial multiples of 2–4, alternate intervessel pits, vessel-ray pits with distinct borders, greater than intervessel pits in size and shape, scanty and vasicentric axial parenchyma, and oil cells present principally in axial parenchyma.

Itauba (IT) versus itauba amarela (ITA)

As shown in Figure 4, both are from the genus *Mezilaurus* sp. with brownish-red or brownish-yellow heartwood, pleasant and slightly sweet odor, imperceptible taste, vessels distinct to the naked eye, obstructed by tyloses, axial parenchyma indistinct with 10 x magnification; rays visible to the naked eye on transversal and radial surface.

At the microscopic level, both wood samples had indistinct growth rings or sometimes limited by thicker fibre regions, diffused porosity,

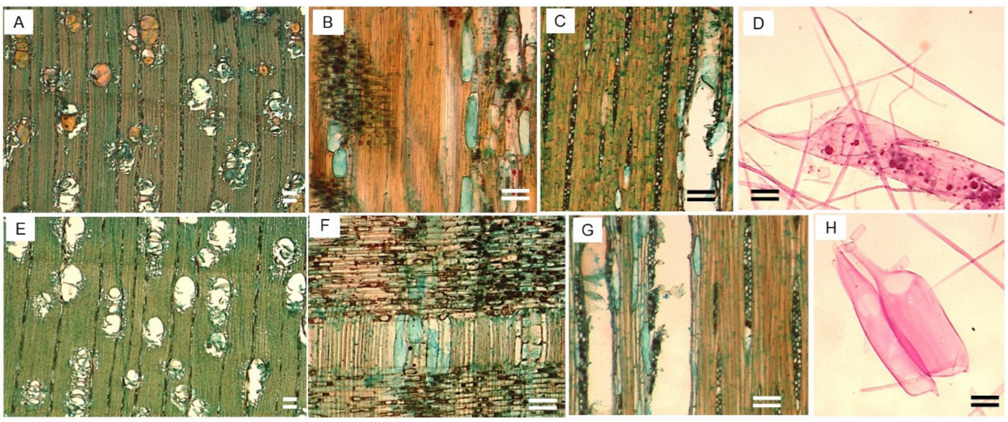

Figure 3 Microscopic images of *Ocotea* sp., LPI (A–D) and *Ocotea* sp., LR (E–H), transversal section (A, E), radial section (B, F), tangential section (C, G) and dissociated material (D, H), scale bar = 100 µm

abundant vessels, small and medium sized, solitary and in radial multiples of 2–3, tyloses present, simple perforate plate, alternate and large intervessel pits, vessel-ray pits similar to intervessel with distinct borders, scanty and vasicentric axial parenchyma, heterogeneous rays, body ray cells procumbent with upright and square marginal cells, biseriate, and oil cells in radial and axial parenchyma in IT (Figure 4 A–D) and predominant in axial parenchyma in ITA (Figure 4 E–H).

When comparing the wood anatomical structures of Lauraceae family, several similar anatomical characteristics were found between samples. Similar findings was reported by Richter (1981) for the same botanical family. The studied species had diffuse porosity, simple perforate plate, alternate intervessel pits, small variation in vessel-ray pits, and vessels with and without appendages. In tropical America, Africa and Asia, diffuse porosity is present in 97% of wood species, in the form of simple perforate plates, representing 87% of species and alternate intervessel pits, corresponding to 94% of wood species (Wheeler et al. 2007).

Distinct growth rings were identified in the genera *Nectandra* and *Ocotea*, which is very common in Lauraceae (Coster 1927). Soffiatti et al. (2016) reported distinct growth rings for *Ocotea puberula* and commented that some genus in the family can have indistinct or weakly distinct growth rings. Growth ring formation in tropical regions is associated, in most situations, with variations in cambial activity and seasonality (Worbes 1989). Thus, in many tropical species, growth rings correspond to rainy and dry seasons (Callado et al. 2013). However, Alves and Angyalossy-Alfonso (2000) reported that this parameter cannot be applied for species separation because it is strongly influenced by environmental conditions.

Most species of the Lauraceae family had paratracheal axial parenchyma, scarce and/or vasicentric. The genera *Nectandra* and *Ocotea* had this characteristic associated with septate fibres. According to Wheeler et al. (2007), septate fibres are common in tropical regions, more in the Southern than the Northern hemisphere. In a study of various Brazilian species (n = 491), Alves and Angyalossy-Alfonso (2002) described high frequency of axial parenchyma associated with septate fibres, and also reported that 56% of samples with septate fibres were from the country's North and Northeast regions. Soffiatti et al. (2016), evaluating wood anatomical traits of 17 Atlantic Forest species from South Brazil, reported the presence of vasicentric parenchyma in *Ocotea puberula* and *Roupala montana*.

In tropical regions, the presence of axial parenchyma is abundant and is associated with the occurrence of septate fibres, which enhance the mobilisation and storage of metabolites, being a possible adaptation to environments where photosynthetic rates are high (Wheeler & Baas 1991, Alves & Angyalossy-Alfonso 2002). These traits were confirmed in this study.

The samples from the Lauraceae family had oil cells associated with axial and radial parenchyma, corroborating other studies describing their presence connected to rays,

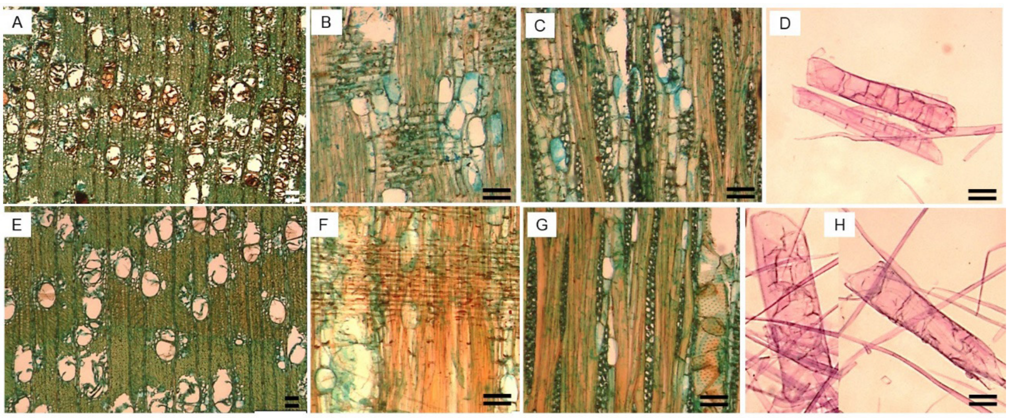

Figure 4 Microscopic images of *Mezilaurus* sp., IT (A–D) and *Mezilaurus* sp., ITA (E–H), transversal section (A, E), radial section (B, F) and tangential section (C, G) and dissociated material (D, H), scale bar = 100 μm

axial parenchyma or between fibres (Singh et al. 2015). Longui et al. (2014) described oil cells associated with rays in *Ocotea curucutuensis*. Richter (1981) observed that the location, arrangement and content of oil cells in the Lauraceae family have low taxonomic significance.

Wood anatomical description and comparison of the Proteaceae family

As with wood samples from the Lauraceae family, wood samples from the Proteaceae family also had diffuse porosity, simple perforate plate, alternate intervessel pits and non-storied rays.

Louro branco (LB) versus louro vermelho (LV)

As shown in Figure 5, *Euplassa* sp. (LB, louro branco) and *Roupala* sp. (LV, louro vermelho) had some similar macroscopic traits, such as brownish-yellow heartwood, indistinct odor and taste, vessels visible to the naked eye, obstructed by tyloses, rays visible to the naked eye in transversal and tangential sections, not storied, axial parenchyma visible to the naked eye, narrow lines in *Euplassa* sp. and wide bands in *Roupala* sp.

Microscopic traits were also slightly different. *Euplassa* sp. (Figure 5 A–D) had solitary vessels, tangential multiples of 2–4, clusters present, vessel elements with or without large appendages, alternate intervessel pits, vessel-ray pits with distinct borders larger than intervessel pits, axial parenchyma in narrow bands or undulated lines up to three cells wide, heterogeneous rays, with procumbent, square and upright cells mixed through the ray, fibre thick walled, not septate. Starch was observed in axial and radial parenchyma. *Roupala* sp. (Figure 5 E–H) had solitary vessels, tangential multiples of 2–3 with some clusters present, vessel elements with appendages on both sides, short and long, alternate intervessel pits, vessel-ray pits with distinct borders larger than intervessel pits, axial parenchyma in bands up to six cells wide, heterogeneous rays, with body cells procumbent and marginal square or upright, and thick-walled fibres, not septate.

Considering the anatomical traits of the Proteaceae family, Chattaway (1948) indicated the importance of large rays and tangential pattern formed in the transversal sections by the vessels and axial parenchyma. Evaluating specifically samples of *Euplassa* sp., we observed multiple vessels in tangential arrangement, axial parenchyma in fine bands or lines up to three cells wide, fibres not septate, among others, similar to characteristics described in literature for species of the same genus. Detienne and Jacquet (1983) studied *Euplassa pinnata* and Brandes et al. (2020) studied *Euplassa cantareirae*, commenting on the presence of silica bodies in ray cells. Sonsin et al. (2014) found similar traits in the wood of *Roupala montana*, with the only difference, in relation to the current study, being the number of axial parenchyma cells.

Regarding the qualitative traits of the wood of the Proteaceae family, most traits were similar in LB (*Euplassa* sp.) and LV (*Roupala* sp.). Two principal differences were

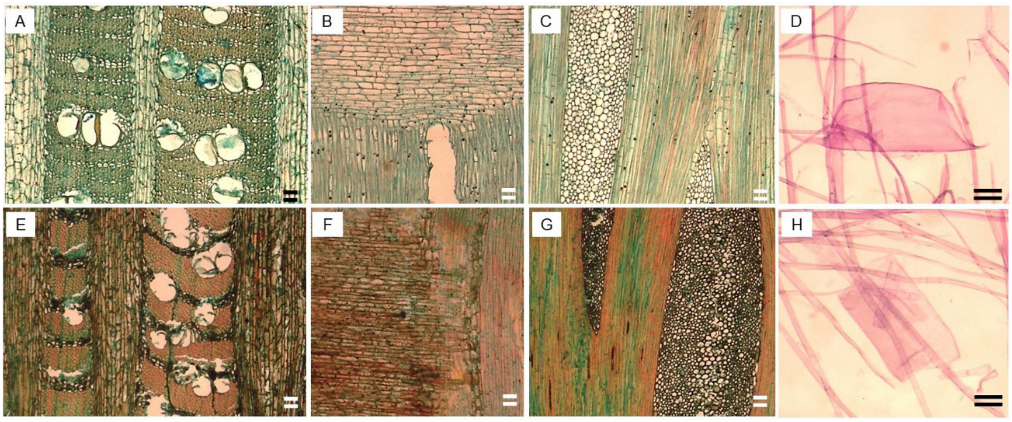

Figure 5 Microscopic images of *Euplassa* sp. (A–D) and *Roupala* sp. (E–H), transversal section (A, E), radial section (B, F) and tangential section (C, G) and dissociated material (D, H), scale bar = 100 µm

verified, i.e., the presence of starch in axial and radial parenchyma in *Euplassa* and the number of cells per strand in the axial parenchyma (in *Roupala,* one to six cells and in *Euplassa,* one to two cells). Some other authors have also described wood of these genera. Chattaway (1948) and Mennega (1966) described similar anatomical traits, such as indistinct growth rings, simple perforate plate, solitary vessels and multiples in tangential arrangement, and heterogeneous rays with procumbent and square cells. Mennega (1966) commented that wood of the *Euplassa* genus has intervessel pits, more circular internally, and axial parenchyma in arched bands, with width of 1–2 cells. Chattaway (1948) described the *Roupala* genus as having wood with parenchyma in arched bands with 4 or more cells. The presence of starch in *Euplassa* wood was not reported previously in literature.

Principal component analysis

Principal component analysis was performed to verify the existence of any patterns in microscopic traits that can allow the discrimination of wood from the 'louros' group. The first two principal components were retained for inferences because they had eigenvalues (λ_i) higher than 1, and expressed approximately 79.94% of the total variation of standardised data (Figure 6).

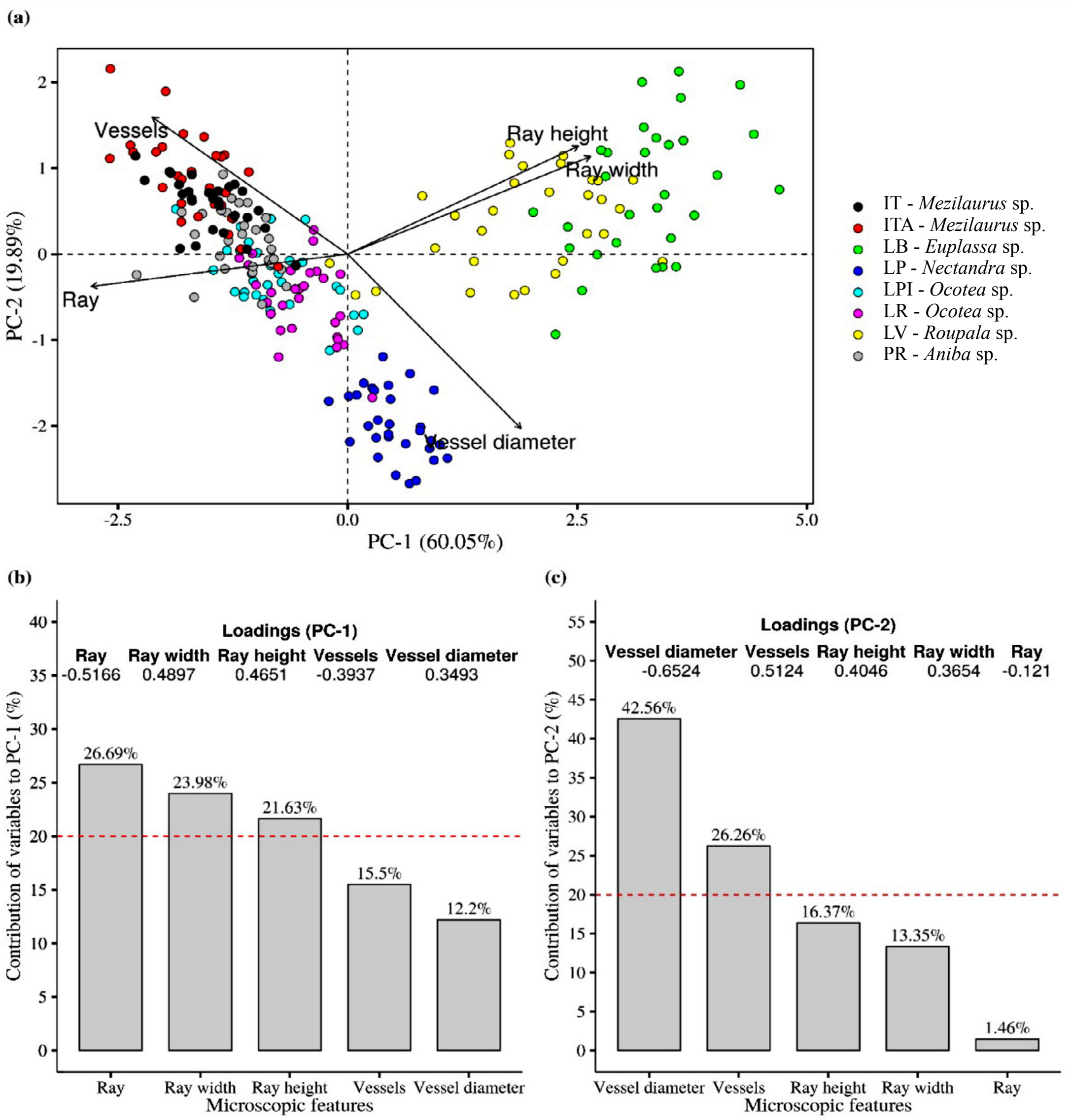

Figure 6 (a) Score graph of PCA based on microscopic traits of wood from 'louros' group, (b) and (c) percentage contribution and loading of each PC, ray = rays per millimeter, ray height (µm), ray width (µm), vessels = vessels per square millimeter, vessel diameter (µm)

Percentage contribution and loading value for each anatomical trait (Figure 6B, 6C) indicated that ray traits (frequency, width and height) had more importance in variance explained by PC-1. On the other hand, vessel traits (diameter and frequency) were more influential in PC-2.

PCA demonstrated that the microscopic traits of LV (*Roupala* sp.) and LB (*Euplassa* sp.) were strongly characterised by larger ray width and height, and lower ray and vessel frequency. Samples of LP (*Nectandra* sp.) had high values for tangential vessel diameter and low values vessel frequency. Samples of other genera [IT and ITA (*Mezilaurus*), LPI and LR (*Ocotea*), and PR (*Aniba*)] were visually close in the PCA graph of Figure 6, sharing higher values for ray and vessel frequency, and lower values for other anatomical traits.

CONCLUSIONS

Pronounced uniformity of wood structural characteristics was observed at the macroscopic and microscopic levels in the evaluated species from the 'louros' group. However, some slightly differences were noted. The most effective anatomical traits for sample discrimination were axial parenchyma type, presence of septate fibres, type and grouping of vessels, and the presence of oil cells and starch.

The difficult distinction of wood of the 'louros' group partly explains the illegal/irregular exploitation and mistaken identification of wood species in commerce, resulting in financial losses to buyers and great harm to biodiversity.

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