Rodriguésia 71: e03322018. 2020
http://rodriguesia.jbrj.gov.br
DOI: http://dx.doi.org/10.1590/2175-7860202071083

Original Paper
Technological properties of woods used in boat's production in the Southeast of Pará, Brazil

Marcelo Mendes Braga Júnior[1], *Thayrine Silva Matos*[1], *Gabriele Melo de Andrade*[1], *Pâmela da Silva Ferreira*[1], *Marta César Freire Silva*[2], *Fernanda Ilkiu Borges de Souza*[2] & *Luiz Eduardo de Lima Melo*[1,3,4]

Abstract
The aim of this study was to identify, anatomically characterize, and determine some of the physical properties of wood species that are used for boat production in the southeast region of the state of Pará in Brazil. The samples were collected during visits to shipyards in the region, then it was identified at the specie level and technologically characterized. Eight species belonging to four distinct botanical families were identified. All identified species had presented some type of deposition in its vessels and 87% of them had had medium density (0.40 to 0.75 g.cm^{-3}). The species with higher frequency of occurrence and that had more parts used for boat production were *Caryocar villosum* and *Apuleia leiocarpa*. It was observed two different group arrangements of species, "piquiá" (*Caryocar villosum* and *Alexa grandiflora*) and "tatajuba" (*Bagassa guianensis* and *Enterolobium schomburgkii*). It was also identified the illegal commercialization of "castanheira's" wood (*Bertholletia excelsa*). The results can indicate anatomical and physical similarities in woods used in boat production and can contribute as a component of a database in wood anatomy of specie used for boat production in the Amazon region, besides to subside practices that contribute to an effective supervision of the logging market in the region.
Key words: shipbuilding, Amazon timbers, anatomical features.

Resumo
O objetivo deste trabalho foi identificar, caracterizar anatomicamente e determinar algumas propriedades físicas de espécies madeireiras utilizadas na produção de embarcações na região Sudeste do Estado do Pará, Brasil. A madeira foi coletada durante visitas em estaleiros da região, em seguida identificadas em nível de espécie e caracterizadas tecnologicamente. Oito espécies, pertencentes a quatro famílias botânicas distintas foram identificadas. Todas as espécies identificadas apresentaram algum tipo de deposição de substâncias nos vasos e 87% apresentaram média densidade (0.40 to 0.75 g.cm^{-3}). As espécies com maior frequência de ocorrência nos estaleiros e que eram utilizadas em mais estruturas construtivas das embarcações foram *Caryocar villosum* e *Apuleia leiocarpa*. Foi observado dois arranjos de diferentes grupos de espécies, "piquia" (*Caryocar villosum* e *Alexa grandiflora*) e "tatajuba" (*Bagassa guianensis* e *Enterolobium schomburgkii*). Também foi identificada a comercialização ilegal da madeira de "castanheira" (*Bertholletia excelsa*). Os resultados indicam similaridades anatômicas e físicas nas madeiras utilizadas na produção de embarcações, que podem contribuir como componente de um banco de dados em anatomia de madeira das espécies utilizadas na produção de embarcações na Amazônia, além de subsidiar práticas que contribuam com a fiscalização mais efetiva do mercado madeireiro na região.
Palavras chave: construção naval, madeiras da Amazônia, características anatômicas.

[1] Universidade do Estado do Pará, Campus VIII, Depto.Tecnologia e Recursos Naturais, Av. Hiléia s/n, 68502-100, Marabá, PA, Brasil.
[2] Embrapa Amazônia Oriental, Travessa Doutor Enéas Pinheiro s/n, 66095-903, Belém, PA, Brasil
[3] ORCID: <https://orcid.org/0000-0001-5321-4772>
4 Author for correspondence: luizeduardo.limamelo@gmail.com

Introduction

The wood is a versatile raw material that arouses interests due to its various properties that enables numerous uses. Considering its potential for construction and building structures, the wood is one of many forest products utilized around the world mainly because it presents a very favorable relationship between resistance and basic density, in comparison to other construction materials, wood reaches higher resistance with lower density which makes it able to be used with more efficiency in structures that carries much more than its own weight (Ramage *et al*. 2017).

The utilization of wood in naval construction is very primitive, before the use of steel in shipbuilding industry, timber was widely used for building watercrafts such as boats and ships. Timber was applied in different parts of the boats, these in turn were designed, projected and manufactured according to the waterway characteristics (Tripati *et al*. 2005; Pommier *et al*. 2016).

As reported by the Institute of National Historic and Artistic Patrimony (IPHAN, acronym in Brazilian Portuguese) (2009) greatest part of small boats in Brazil take advance of wood as a raw material. In the Amazon region, these handmade watercrafts are the means of transportation and subsistence for a significant proportion of the population, they are frequently hand manufactured by regional producers that uses mainly wood as a constructive material. Each selected specie is used according to their empirical knowledge to build components for the boats' structure, however the lack of specialized technical knowledge leads to improper use of the wood, which may cause trouble both for the producers and for the consumers. It can be frequently observed the inadequate use of the timber due to mistakes committed during specie's identification, this may compromise the life cycle of the boat and add to loss in biodiversity once it contributes to the disappearance of certain forest species that suffers from high exploitation pressure due to its commercial value.

The appropriate features for using woods as a raw material in shipbuilding varies in accordance to the environmental conditions of the navigation place (Melo Junior & Barros 2017). Meanwhile, the naval carpentry industry demands understandment of the wood's technological characteristics. Wood's chemical, physical and mechanical properties, are sometimes, inferences of its anatomical characteristics (Baldin *et al*. 2018) thus, the knowledge of these characteristics can be the basis for optimizing the boat's production process, as just like a basic step for testing new species to be used in this productive process.

In this context, the traditional anatomical identification technics of wood are of fundamental importance to understand the distribution of species that are used and commercialized by popular names, which are often wrongly applied, because it provides subsidy for the appropriated and suitable usage of this raw material according to its specific technological properties (Gasson 2011; Muñiz *et al*. 2016), as well as it improves forest biodiversity conservation. It also enables the introduction of new woody species with potential to replace those commonly employed in the market, and by having high exploitation demands they generally end up by having a reduction in population on its areas of occurrence and even enter the list of endangered species.

The lack of technological knowledge is pointed out as one of the main bottlenecks for the socioeconomic development of the sector of boat production in the state of the Pará. The city of Marabá, which represents the economical and political center of the southeast mesoregion of the state (Pena *et al.* 2014), is also known for being the mesoregion that more contributes to the illegal deforestation of the Amazonian forest (INPE 2016) for the accomplishment of this type of work.

Thereby, this research had as its objectives, the identification, anatomical characterization and determination of some physical properties of wood species that are used for building boats in the mesoregion of Marabá - Pará. Moreover to indicate wood's ideal characteristics to be used for the naval industry, providing a rationally and sustainable use of these woods, and information on the anatomy of woody species that are used for boat production in the Amazon, and also on species protected by the Brazilian legislation that has been wrongly used for this purpose, which contributes to the conservation of the biome biodiversity.

Material and Methods

The survey of selected sites for the visits and for the collection of wood samples was placed on information obtained from fishermen and riverside population that lives in the region. They gave us the location of shipyards based in the city, since these enterprises are not registered in any municipal authority of control and supervision. There are in the area two shipyards, being both responsible for the construction of the largest number of boats used in the region, this number although reduced,

represents the activity which is mostly empiric, of family heritage, and is running the risk of coming to an end because of the difficulty of disseminating and passing on the popular knowledge of handmade's boat construction to new generations. The visited shipyards are located in the urban perimeter of the city of Marabá, state of Pará, Brazil, under the address: Transmangueira street, next to the Tocantins River (05°21'54''S and 49°07'24''W).

During the visits to the shipyards we collected samples of woods that were being used for boat construction. The enterprises' owners provided us the popular names by which each wood is commercialized, this was done as a way to verify possible mistakes made in specie's identification. For identification and posterior registration, at least 15 wood samples were cut for each specie, with the help of a hacksaw and a chisel, by each popular name provided by the owner. The wood samples were cut off of batches of wood stored in the yard of the shipyards.

The anatomical identification of the collected wood had the following workflow: (i) confection of the wood samples, properly orientated and defect free, with dimensions of 2 × 2 × 3 cm (tangential, radial and longitudinal directions, respectively); (ii) polishing of the transversal surface with slide microtool knife, to enhance the anatomic characteristics (iii) polishing of the transversal, longitudinal and tangential surfaces, with sandpaper with granulometry of 400 to 2500; (iv) surface cleaning with chamois paper; (v) analysis of its macroscopic anatomical structure using a special 10× magnifying glass and with a binocular stereomicroscope and (vi) identification of the species using an anatomical identification key from the IPT Manual of Wood Identification (Mainieri 1983; Corandin *et al*. 2010; Zenid & Ceccantini 2012) (vii) lastly, confirmation of the identification made by comparing the species with standard samples from a xylotheque belonging to the Northern Agronomic Institute (IAN, acronym in Brazilian Portuguese) - Oriental EMBRAPA, state of Pará. The scientific nomenclature was adopted in accordance to the BFG (2018). The identification of protected species was made based on the consultation of the "Official National List of Endangered Flora Species" (MMA 2014) and also referred to the Red List of the flora of Pará (COEMA-PA 2007). It was taken macrographic photos of the transversal plane of the woods identified in this study, with the help of a digital portable stereomicroscope branded "DinoLite AM4013ZT4".

For the microscopic anatomical characterization, the samples used in the anatomical identification were reduced to the dimension of 2 cm^3 and softened by cooking it in a solution of water and glycerin in the proportion of 4:1. Posteriorly, transversal, tangential longitudinal and radial longitudinal cuts were made in a slide microtome (Leitz 1208), with thickness varying from 16 to 20 µm. In the sequence, the histologic cuts were clarified in sodium hypochlorite 60%, colored with hydroalcoholic safranin 50% (Sass 1940), dehydrated (Johansen 1940; Sass 1940) and then used in the confection of permanent slides with synthetic resin. For measuring the dissociated anatomic elements, it was prepared a macerating solution in accordance with a method proposed by Franklin (1945), lately colored with aqueous safranin 1% used to make semi-permanent slides with glycerin 50% (Strasburger 1924). All anatomical characterization, measurement technics and terminology, followed the protocol proposed by the IAWA Committee (IAWA Committee 1989). For those parameters 30 measurements were made. Counts or measurements were made to: Vessel per square millimeter (VF), Tangential diameter of vessel lumina (TDV), Vessel element length (VEL), Rays per millimeter (RF), Ray width (RW), Ray height (RH), Fiber length (FL), Fiber diameter (FD), Fiber lumina diameter (FLD), Fiber wall thickness (FWT). All anatomical measurements were made by using a light microscope ZEISS Primo Star HAL/LED, coupled to a digital camera Opton microscopio and a software to analyze the images (Image-Pro Express 6.0).

From the microscopic anatomical characteristics it was obtained the confirmation of the genus and species identified by macroscopy analyses, then confirmed by using specialized literature and the InsideWood (onwards 2004) website database.

15 wood samples for each specie were used to determine the wood's physical properties. The wood's basic density was determined by following the procedures established in the NBR 11941/2003 (Brazillian Association of Technical Norms - ABNT 2003 - Acronym in Brazilian Portuguese). For the linear and volumetric contractions, it was used a procedure stablished in the NBR 7190/1997 (Brazillian Association of Technical Norms - ABNT 1997).

As to evaluate the anatomical and physical quantitative characteristics, it was applied a descriptive statistic test. The results are presented as mean values, standard deviation and units.

Results

In Table 1 there are presented the names of the identified species used as raw material in building boats, followed by the popular names given by the shipyard owners and botanic family.

The anatomical characteristics of the species identified in this work are briefly described in Tables 2 (quantitative characteristics) and 3 (qualitative characteristics) and illustrated in Figures 1 to 4.

Table 4 shows the physical properties results for the species identified in this study.

From the anatomical characterization of the wood samples it was possible to successfully identify eight forest species of which timber is used in boats production. Among all identified species, *Caryocar villosum* and *Apuleia leiocarpa* stood out because they were found in higher frequency in shipyards and also because they could be used in different parts of the boats, depending on the needs. Gums and other depositions in heartwood vessels as well as prismatic crystals and in the parenchyma cells of *A. leiocarpa* were observed with more frequency (Fig. 1a-b,e,f), while tyloses in vessels of *C. villosum* were seen more frequently (Fig. 1a,b,e,f).

It was also observed that some popular names were erroneously applied to some species, the specie *Dinizia excelsa* was marketed with an erroneous popular name of "jatatobá" (Tab. 1). The more serious fact is in the stacking of different species, whose woods are commercialized by the same popular names (Tab. 1). In that way, the anatomical differentiation of these species was made.

The main erroneous grouping refers to the commercialization of the timber of "piquiá", which was anatomically identified as two different species: *Caryocar villosum*, specie belonging to a botanic family named Caryocaraceae and *Alexa grandiflora* which belongs to the Fabaceae botanic family. Both woods from these species when observed to the naked eye, have similar organoleptic characteristics on the longitudinal sides, such as color and texture, nonetheless in a simple macroscopic evaluation of the transversal and longitudinal sides, with a 10× magnifying glass as well as a microscopic study of the timber, it is possible to identify these wood species (Tabs. 2; 3). *C. villosum* has an only visible axial parenchyma by using a 10× magnifying glass, apotraqueal diffuse and diffuse in aggregates with vessels totally obstructed by tyloses, presented both in transversal and longitudinal sides (Fig. 5a,c,e). *A. grandiflora* has an axial parenchyma visible to the naked eye, paratracheal aliform losangular; or confluent in short oblique stretches and in thin marginal lines, vessels unobstructed or partially obstructed with resinous oils (Fig. 5b,d,f).

Bagassa guianensis and *Enterolobium schomburgkii* were also found in the shipyards by the same popular name of "tatajuba", though they are not only different species from different genus, they also belong to different botanic families. *B. guianensis* belongs to a botanic family named Moraceae and *E. schomburgkii* is attached to the Fabaceae botanic family. It is possible that the mistakes made in the commercialization of the timber of these two species is due to the similarities in its colors and basic density. Those mistakes would not occur if a brief comparison of the macroscopic anatomical structure of the woods was made, whereas they are from two very distinct genus (Tab. 2; 3). *B. guianensis* has an usually indistinct axial parenchyma, even with a 10x magnifying glass, classified as scarce, vessels are predominantly solitary with obstructions caused by tyloses, anyhow they are visible to the naked eye (Fig. 6a,c,e). *E. schomburgkii* has an axial parenchyma well contrasted to the naked eye, paratracheal aliform losangular forming short confluences and also can be vasicentric, the vessels are partially obstructed by a yellow substance and resinous oil (Fig. 6b,d,f).

Discussion

The anatomical characteristics of the described woods have some similarities, except for *Apuleia leiocarpa* (Fig. 1a,b,c,e,f,g), the vessel frequency can be classified according to Mainieri (1983) as few (up to 3 per mm^2) or as few in number (4 to 7 per mm^2), it was also observed that the tangential diameter of vessel lumina was large, classified according to IAWA (1989), as ≥ 200 µm. All species had an average fiber length of 900 to 1600 µm with fiber wall thickness classified as thin to thick. Likewise, all species have presented tyloses and/or any other deposition obstructing the vessel lumen. The evaluated physical properties have also shown similarities between the species, like 87.5% of them has, according to IAWA (1989), a medium value of basic density (0.40 to 0.75 $g.cm^{-3}$), and 62.5% has shown, in accordance to Durlo & Marchiori (1992), an excellent (1.2 to 1.5) or normal (1.5 to 2) coefficient of anisotropy. Melo Junior and Barros (2017) studying the wood used in the shipbuilding

Table 1 – Popular names of species identified, followed by their scientific names and botanic family.

Popular name given by the shipyard owners	Wood samples	Identified Species	Family
jatobá	15	*Dinizia excelsa* Ducke	Fabaceae
castanheira	18	*Bertholletia excelsa* H.B.K.	Lecythidaceae
cedroarana	15	*Cedrelinga cateniformis* Ducke	Fabaceae
tatajuba	15	*Bagassa guianensis* Aubl.	Moraceae
	15	*Enterolobium schomburgkii* (Benth.) Benth	Fabaceae
amarelão	20	*Apuleia leiocarpa* (J. Vogel) J. F.Macbr.	Fabaceae
piquiá	15	*Alexa grandiflora* Ducke	Fabaceae
	20	*Caryocar villosum* (Aubl.) Pers.	Caryocaraceae
popular name not provided	15	*Caryocar villosum* (Aubl.) Pers.	Caryocaraceae

Table 2 - Quantitative anatomical description of the eight species identified in boats production in Marabá, State of Pará, Brazil. GR – Growth rings; PP – Perforated plates; IP – Intervessel pits; RVP – Vessel-ray pitting; AP – Axial parenchyma; RC – Ray composition: A – body ray cells procumbent with one row of upright and/or square and/or square marginal cells, B – body ray cells procumbent with mostly 2-4 rows of upright and/or square marginal cells, C – All ray cells procumbent, D – Rays with procumbent, square and upright cells mixed throughout the ray; SS –Storied structure; TL/OD – Tylose or any other deposition; MI – Mineral inclusions: A – Prismatic crystals, B – Druses, C – Silica.

Specie	GR	PP	IP	RVP	AP	RC	SS	TL/OD	MI
Alexa grandiflora	√	Simple	Alternates	Distinct areolas	Aliform, some confluences and thin marginal lines	A	Absent	Occasionally resin oil	A
Apuleia leiocarpa	√	Simple	Alternates	Distinct areolas	Aliform, confluent with at most three cells wide and thin marginal lines	A	Present	Resin oil	A/B
Bagassa guianensis	√	Simple	Alternates	Reduced areolas w/ rounded punctures	Vasicentric scarse	B	Absent	Tylose	A
Bertholletia excelsa	√	Simple	Alternates	Distinct areolas	Scalariform, thin marginal strips	A	Absent	Resin oil	A
Caryocar villosum	√	Simple	Alternates	Reduced areolas w/ irregular arrangement	Apotraqueal diffuse and diffuse in aggregates	B	Absent	Tylose	A
Cedrelinga cateniformis	-	Simple	Alternates	Distinct areolas	Vasicentric and occasionally aliform confluent	C	Absent	Occasionally resin oil	-
Dinizia Excelsa	√	Simple	Alternates	Distinct areolas	Losangular aliform with short confluences and marginal parenchyma	C	Absent	Resin oil	-
Enterolobium schomburgkii	√	Simple	Alternates	Distinct areolas	Aliform axial parenchyma with occasional confluence and occasionally vasicentric	D	Absent	Resin oil	A

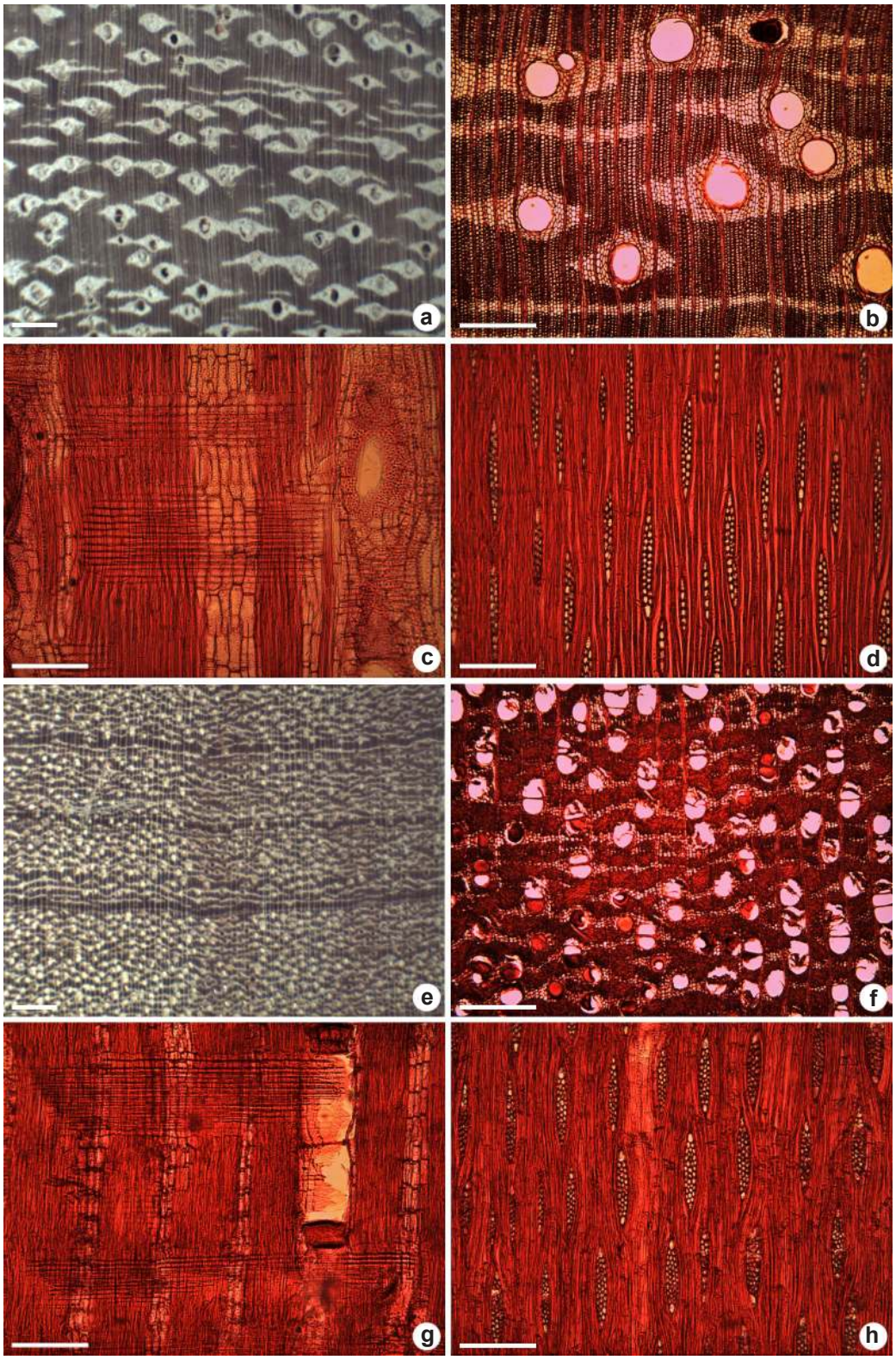

Figure 1 – a-d. *Alexa grandiflora*; e-h. *Apuleia leiocarpa* – a,e. Macroscopy 10× magnification; b,f. bright-field microscopy: transverse section; c,g. radial section; d,h. tangential section of the wood. Scale bar: a,e. 1 mm; b,f. 500 µm; c,d,g,h. 200 µm.

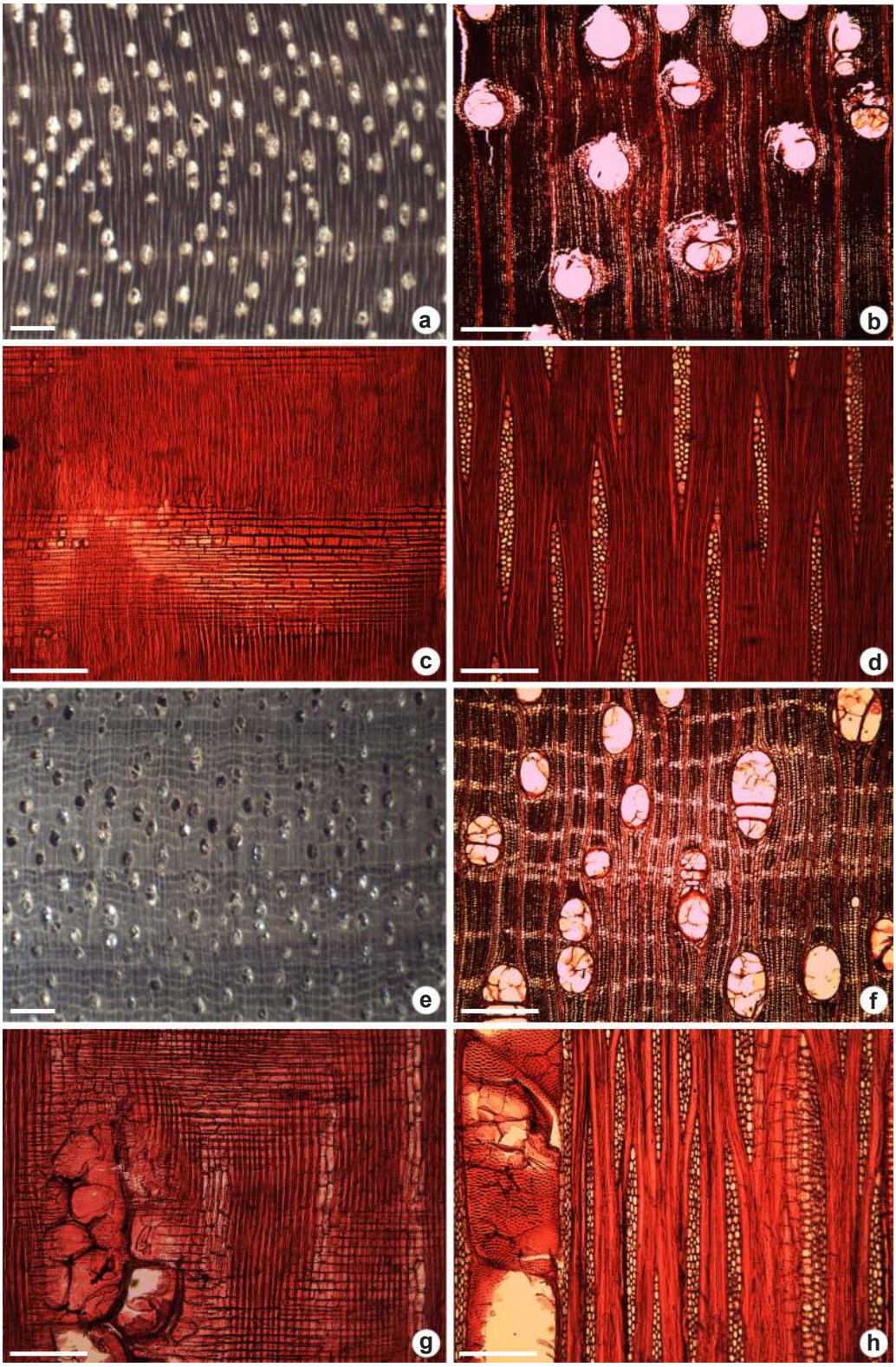

Figure 2 – a-d. *Bagassa guianensis*; e-h. *Bertholletia excelsa* – a,e. Macroscopy 10× magnification; b,f. bright-field microscopy: transverse section; c,g. radial section; d,h. tangential section of the wood. Scale bar: a,e. 1 mm; b,f. 500 µm; c,d,g,h. 200 µm.

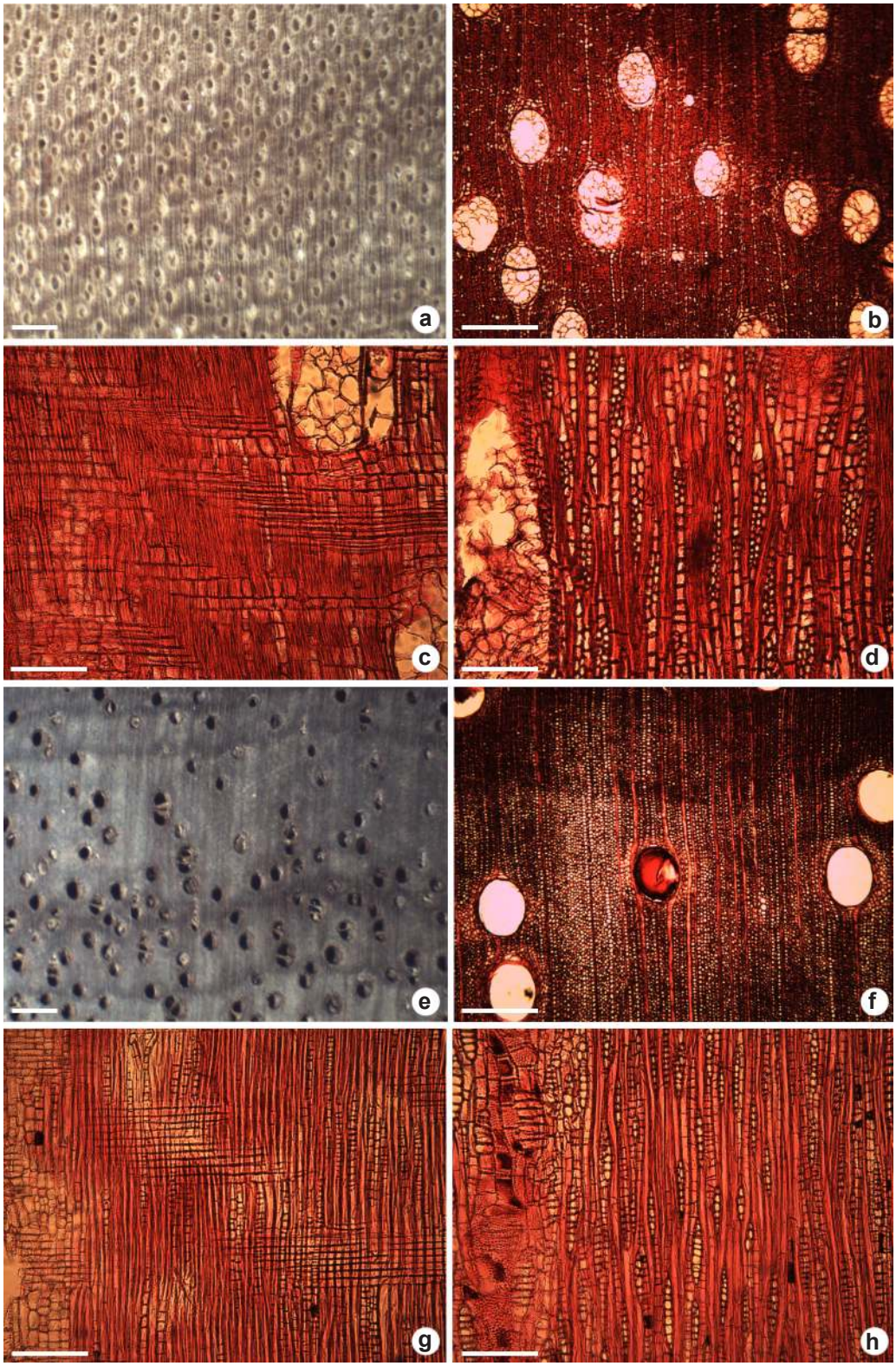

Figure 3 – a-d. *Caryocar villosum*; e-h. *Cedrelinga cateniformis* – a,e. Macroscopy 10× magnification; b,f. bright-field microscopy: transverse section; c,g. radial section; d,h. tangential section of the wood. Scale bar: a,e. 1 mm; b,f. 500 µm; c,d,g,h. 200 µm.

Table 3 – Mean values and standard deviation, in parenthesis, of the evaluated anatomical characteristics. VEL – Vessel element length (μm); TDV – Tangential diameter of vessel lumina (μm); VF – Vessel frequency (per mm^2); RF – Ray frequency (per mm); RW – Ray width (μm); RH – Ray height (μm); FL – Fiber length (μm); FD - Fiber diameter (μm); FLD – Fiber lumina diameter (μm); FWT – Fiber wall thickness (μm).

Specie	VEL	TDV	VF	RF	RW	RH	FL	FD	FLD	FWT
Alexa grandiflora	406,48 (80,78)	274,65 (32,53)	3,30 (2,14)	6,70 (1,29)	28,23 (5,44)	325,48 (45,45)	1370,69 (167,98)	17,42 (5,40)	9,07 (4,85)	4,18 (0,82)
Apuleia leiocarpa	470,41 (163,71)	126,43 (16,62)	14,77 (3,71)	5,97 (0,96)	31,52 (5,11)	203,36 (14,60)	1232,16 (180,58)	16,79 (4,58)	16,79 (4,58)	4,05 (0,73)
Bagassa guianensis	493,48 (162,26)	219,69 (42,90)	3,67 (1,65)	4,47 (0,57)	43,61 (6,74)	481,58 (82,39)	1226,96 (165,59)	17,49 (4,76)	9,17 (4,34)	4,16 (0,78)
Bertholletia excelsa	481,24 (151,04)	269,25 (49,93)	3,60 (1,98)	8,13 (1,59)	36,74 (9,57)	874,14 (250,76)	1247,08 (164,27)	17,41 (4,85)	9,09 (4,36)	4,16 (0,79)
Caryocar villosum	514,47 (180,55)	257,74 (40,74)	3,63 (1,52)	10,43 (1,65)	21,56 (5,91)	658,35 (215,32)	1201,24 (152,25)	18,01 (5,08)	9,64 (4,63)	4,18 (0,86)
Cedrelinga cateniformis	504,78 (179,71)	323,38 (29,92)	2,30 (0,99)	9,90 (2,28)	20,35 (3,77)	200,21 (37,70)	1211,78 (187,47)	18,73 (4,89)	10,15 (4,50)	4,29 (0,81)
Dinizia excelsa	433,22 (101,25)	236,63 (34,09)	4,50 (1,17)	5,27 (1,34)	37,29 (7,64)	328,13 (34,44)	1267,89 (145,19)	18,79 (4,71)	10,24 (4,49)	4,28 (0,82)
Enterolobium schomburgkii	471,67 (101,53)	213,98 (28,72)	2,43 (0,90)	6,27 (1,23)	43,55 (6,31)	330,09 (58,40)	1282,71 (117,07)	18,19 (5,04)	9,70 (4,59)	4,25 (0,84)

Table 4 – Mean values and standard deviation, in parenthesis, of the evaluated physical properties. ε_v: Volumetric contraction (%); ε_t: Tangential contraction (%); ε_r: Radial contraction (%); T/R: Anisotropic coefficient; ρ_{bas}: Basic density (g/cm^3).

Specie	ρ_{bas}	ε_r	ε_t	ε_v	T/R
Alexa grandiflora	0,66 (0,02)	4,24 (0,34)	9,29 (1,30)	16,25 (2,33)	2,21 (0,41)
Apuleia leiocarpa	0,64 (0,03)	4,21 (1,13)	6,16 (0,34)	11,99 (3,01)	1,67 (0,91)
Bagassa guianensis	0,69 (0,05)	5,66 (1,50)	6,61 (1,13)	18,27 (7,09)	1,19 (0,11)
Bertholletia excelsa	0,55 (0,03)	4,72 (0,41)	10,27 (0,51)	18,73 (3,87)	2,40 (0,63)
Caryocar villosum	0,59 (0,02)	14,12 (8,57)	15,53 (8,16)	34,18 (6,96)	1,51 (0,99)
Cedrelinga cateniformis	0,46 (0,02)	3,00 (2,29)	5,61 (1,39)	9,97 (4,89)	2,46 (1,22)
Dinizia excelsa	0,97 (0,01)	5,55 (1,51)	7,30 (1,43)	16,63 (5,30)	1,42 (0,56)
Enterolobium schomburgkii	0,74 (0,04)	4,78 (0,88)	9,20 (1,46)	19,61 (3,69)	1,93 (0,12)

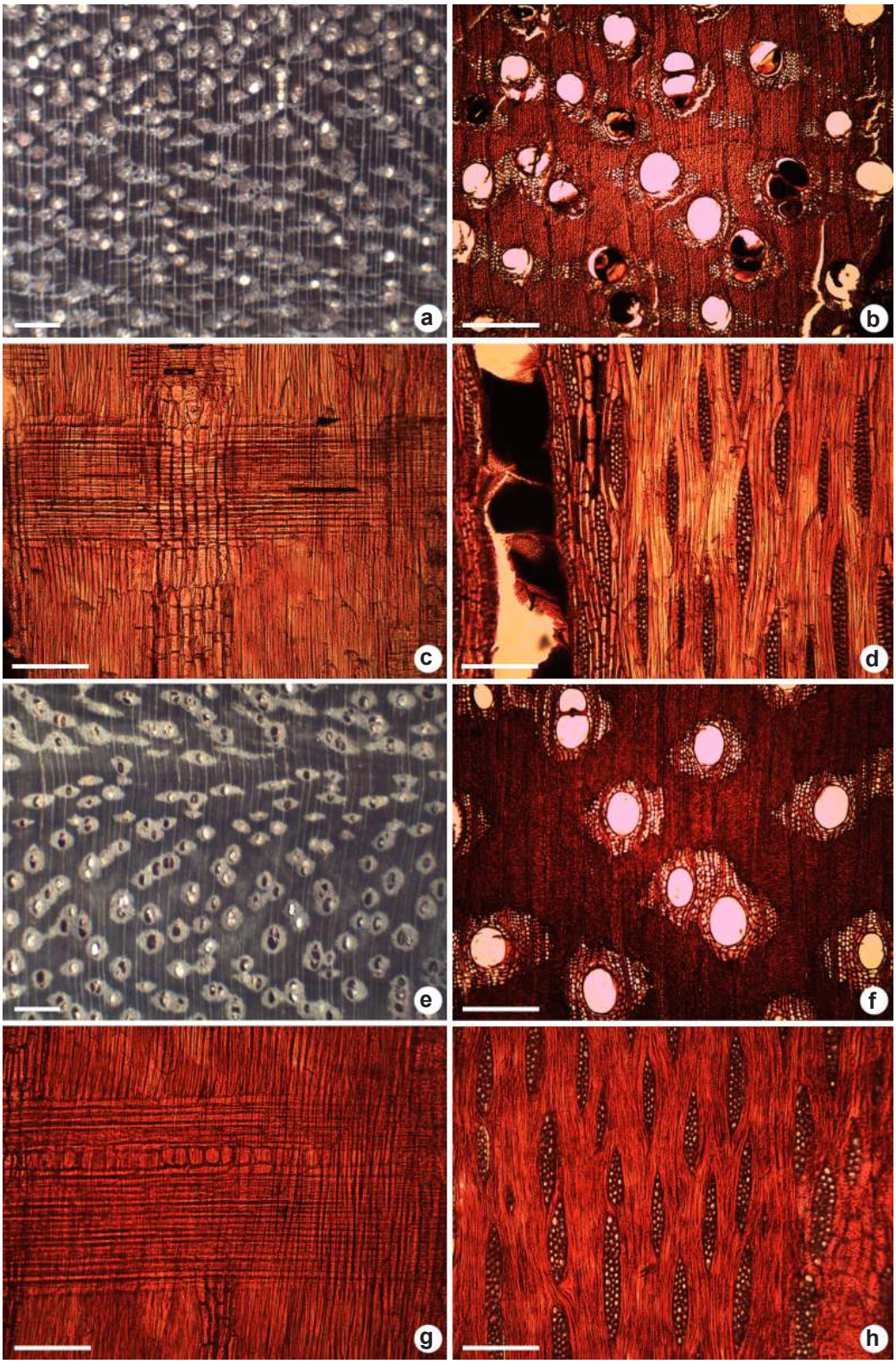

Figure 4 – a-d. *Dinizia excelsa*; e-h. *Enterolobium schomburgkii* – a,e. Macroscopy 10× magnification; b,f. bright-field microscopy: transverse section; c,g. radial section; d,h. tangential section of the wood. Scale bar: a,e. 1 mm; b,f. 500 µm; c,d,g,h. 200 µm.

of "whaling canoes" in the Santa Catarina coast, Brazil, observed that 80% of the identified species presented medium density wood (0.53–0.65 g.cm $^{-3}$), a result similar to that observed in this study.

The similarities in the values observed for some anatomical parameters and some physical properties between the different species, indicates that the choice of the best timber for naval construction, which is currently made based on empirical knowledge, actually has technological justification given to the common properties of these species.

According to Sen *et al*. (2009) and Muller (2010) hardwood's timber are more durable in the marine environment in comparison to softwoods, specially timber of the heartwood region, due to

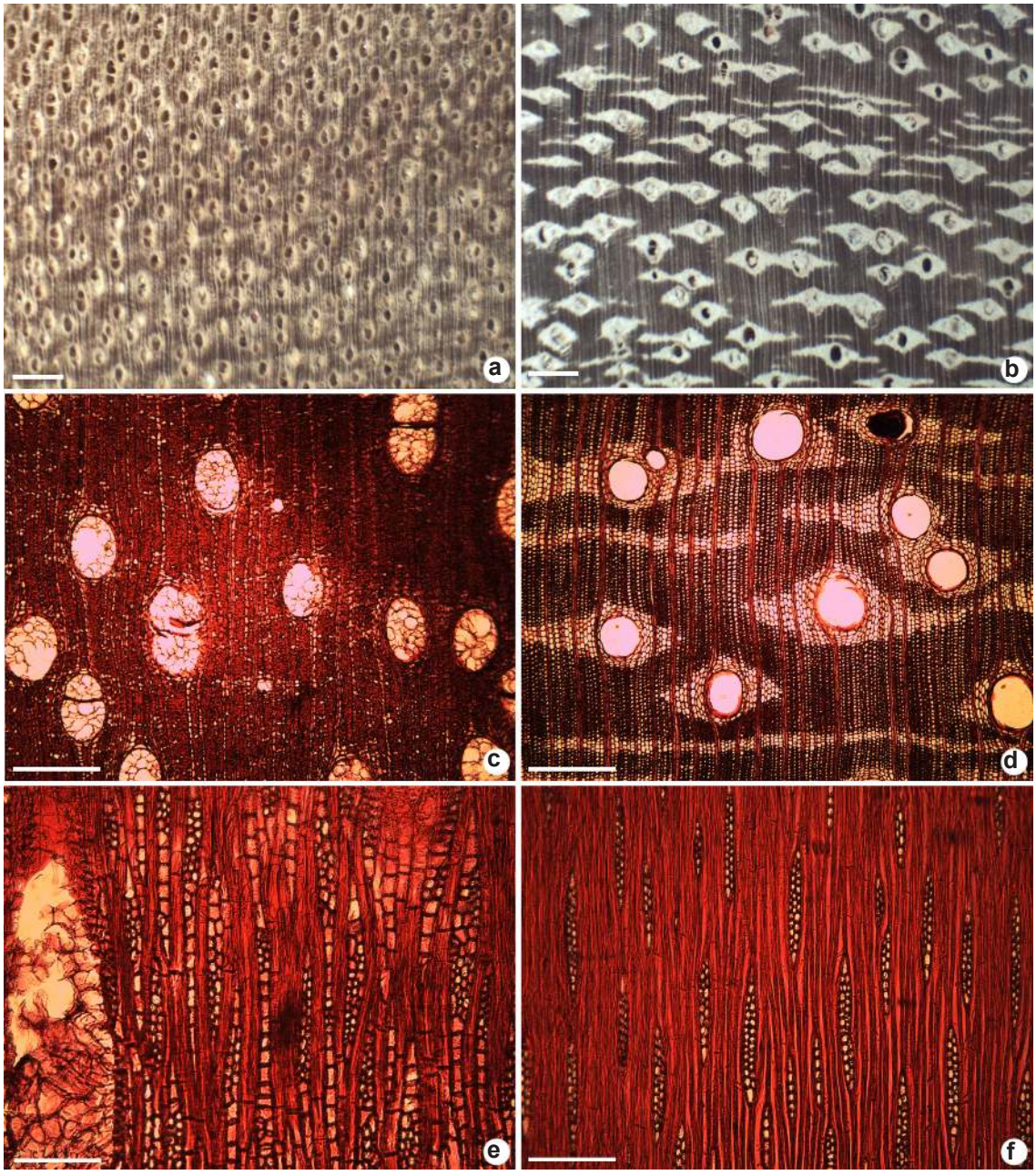

Figure 5 - Comparative images of the species: a,c,e. *Caryocar villosum*; c,d,f. *Alexa grandiflora*. Both marketed as "piquiá". Scale bar: a,b. 1 mm; c,d. 500 µm; e,f. 200 µm.

the presence of several different natural substances such as resinous materials, gummy depositions, oils, alkaloids, silica, etc. Recently, the anatomical analyses of shipwrecks found in the west central coast of India, have indicated that the wood of "teca" (*Tectona grandis* L.f.) has been largely used by Indians and others shipbuilders, mainly due to specifical timber properties, such as moderate basic density, high mechanical resistance, high dimensional stability and few defects during drying wood; to contain silica and resinous oils, conferring resistance to the attack by marine xylophages like "turu" (*Teredo navalis*) and also because it has high resistance to decomposition in terrestrial conditions (Tripati *et al*. 2005, 2016a, 2016b). Maineri & Chimelo (1989) point out that

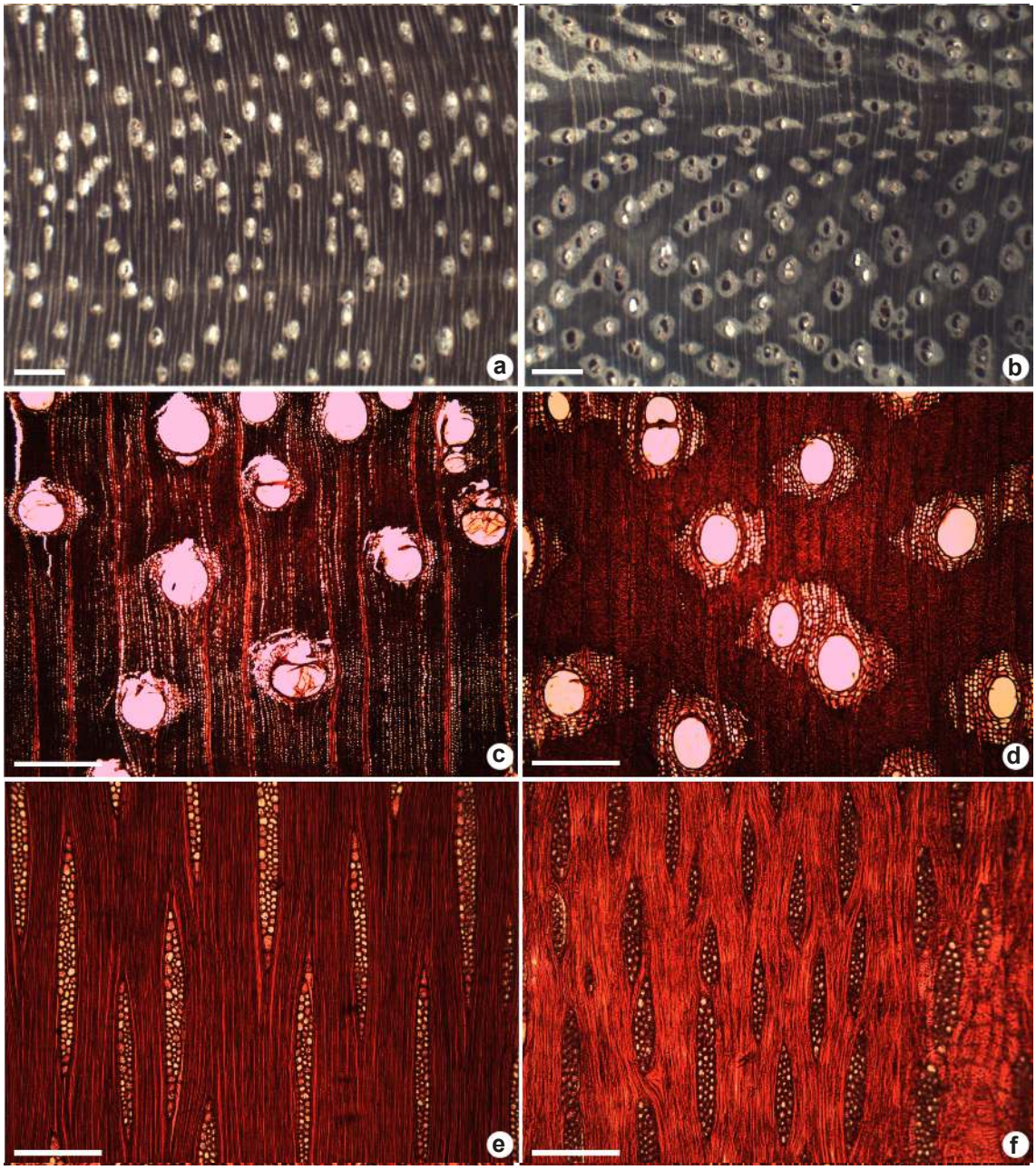

Figure 6 – Comparative macroscopic images of: a,c,e. *Bagassa guianensis* species; b,d,f. *Enterolobium schomburgkii*. Both marketed as "tatajuba". Scale bar: a,b. 1 mm; c,d. 500 µm; e,f. 200 µm.

the woods of *C. villosum* and *A. leiocarpa*, used more frequently on the se regional boats, have good resistance to attacks by xylophages' organisms, being preferably indicated for naval construction, mainly for structural parts of the boats that are in contact with water, thus being more susceptible to attack by aquatic xylophages.

Among the wood species identified in this study, attention is drawn to *Bertholletia excelsa* H.B.K. for being found on the "Official National List of Endangered Plant Species" of the Brazilian Ministry of the Environment (MMA 2014) and on the Red List of the Flora of Pará (COEMA-PA 2007) categorized as vulnerable in the evaluation of risk of extinction, besides all that, the specie is protected by federal law (Decree 5.975/2006), thus cutting it is prohibited by law. It is known that the deforestation in the Amazon Rainforest has increased between 2015 and 2016, and the state of Pará stands out for having presented the largest deforested area (3025 km^2) and one of the largest percentage increases (41%) between the years of 2015 and 2016 (INPE 2016). The confirmation of the use of *B. excelsa*'s wood in the production of boats in the region where this study took place also contributes to the aggravation of this scenario, because it is linked to the illegal commercialization of native wood.

According to Ferreira *et al*. (2004) the appropriate trade name for *Dinizia excelsa* is "angelim-vermelho". The utilization of erroneous names for the wood of different species as being the same can bring damages and losses to the final product. Depending on the technical specification of the part of the boat to which the wood is going to be used, it could compromise all the boat's structure. Some differences are pointed to the values of basic density and coefficient of anisotropy (Tab. 4), these differences can decrease the durability and quality of the final product, once that the basic density relates primarily to the workability in wood and, accentuated variations of the coefficient of anisotropy can ease the appearance of cracks, warping and twisting.

Conclusion

Eight species were identified as a raw material used for boat production in the region of Marabá- Pará *(Dinizia excelsa*, *Bertholletia excelsa*, *Cedrelinga cateniformis*, *Bagassa guianensis*, *Enterolobium schomburgkii*, *Apuleia leiocarpa*, *Alexa grandiflora*, *Caryocar villosum*). The most used species were *Caryocar villosum* and *Apuleia leiocarpa,* each one was used in almost 30% of the constructive structures of the boats. The usage of *Bertholletia excelsa*'s wood for this purpose called our attention, mainly because of the illegal timber trade in the region and the prohibition of cutting of this specie.

Most of the wood used in the production of boats has some anatomical and physical similarities such as, vessels ranging from few to few numerous (3–7 per mm^2) with average diameter ≥ 200 μm; medium length fibers (900–1600 μm) and fiber wall thickness thin to thick-walled. For basic density, 87.5% presented medium density (0.40 to 0.75 $g.cm^{-3}$) and 62.5% presented anisotropic coefficient of medium to normal (1.2 to 2). Therefore, it suggests that these values indicate the quality of the wood for utilization in naval construction.

The results indicate anatomical and physical similarities in the woods used for boat production. Further, the obtained results can contribute as components for a database of the anatomy of wood species that are used for boat production in the Amazon region, besides subsidizing practices that contribute to a more effective control of the timber market in the region, as well as to promote better use of the raw material.

References

ABNT - Associação Brasileira de Normas Técnicas (1997) NBR 7190. Projeto de estruturas de madeira. ABNT, Rio de Janeiro. 107p.

ABNT - Associação Brasileira de Normas Técnicas (2003) NBR 11941. Determinação da densidade básica da madeira. ABNT, Brasília. 6p.

Baldin T, Talgatti M, Marchiori JNC & Silveira AG (2018) Previsões tecnológicas na madeira de quatro folhosas neotropicais: uma análise sob enfoque anatômico. Nativa 6: 107-112.

BFG - The Brazil Flora Group (2018) Brazilian Flora 2020: innovation and collaboration to meet Target 1 of the Global Strategy for Plant Conservation (GSPC). Rodriguésia 69: 1513-1527.

Brazil - Decreto nº 5.975 de 30 de novembro de 2006 (2006) Regula a exploração de florestas e de formações sucessoras compreende o regime de manejo florestal sustentável e o regime de supressão de florestas e formações sucessoras para uso alternativo do solo. Brasília.

Conselho Estadual de Meio Ambiente, Pará. RESOLUÇÃO - COEMA nº 54 de 24 de outubro de 2007 (2007) Homologa a lista de espécies da flora e da fauna ameaçadas no estado do Pará. Belém.

Corandin VPR, Camargo JAA, Pastore TCM & Cristo AG (2010) Madeiras comerciais do Brasil: chave interativa de identificação baseada em caracteres gerais e macroscópicos. Serviço Florestal Brasileiro,

Laboratório de Produtos Florestais, Brasília. Available at <www.florestal.gov.br> Access on 15 January 2017.

Durlo MA & Marchiori JNC (1992) Tecnologia da madeira: retratibilidade. Série técnica n. 10. UFSM CEPEF FETAC, Santa Maria. 33p.

Ferreira GC, Hopkins MJG & Secco RS (2004) Contribuição ao conhecimento taxonômico das espécies de Leguminosae comercializadas no Estado do Pará, como Angelim. Acta Amazonica 34: 219-232.

Franklin GL (1945) Preparation of thin sections of synthetic resin and wood: resin composites, and a new macerating method for wood. Nature 155: 5.

Gasson P (2011) How precise can wood identification be? Wood anatomy's role in support of the legal timber trade, especially cites. IAWA Journal 32 : 137-154.

InsideWood 2004-onwards (2004) InsideWood 2004-onwards. Available at <http://insidewood.lib.ncsu.edu/search>. Access on 20 February 2017.

Instituto do Patrimônio Histórico e Artístico Nacional - IPHAN (2009) Cadastramento e diagnóstico de embarcações tradicionais brasileiras**.** Santa Catarina: baleeiras. IPHAN, Brasília. 340p.

Instituto Nacional de Pesquisas Espaciais - INPE (2016) Projeto de monitoramento do desmatamento na Amazônia Legal por satélite (PRODES). São Paulo. Available at <http://www.inpe.br/noticias/noticia.php?Cod_Noticia=4344>. Access on 3 February 2017.

International Association of Wood Anatomists - IAWA Committee (1989) List of microscope features for hardwood identification. IAWA bulletin 10: 234-332.

Johansen DA (1940) Plant Microtechnique. Vol. 1. McGraw-Hill Book Company, New York. 523p.

Mainieri C (1983) Manual de identificação das principais madeiras comerciais brasileiras. Companhia de Promoção de Pesquisa Científica e Tecnológica do Estado de São Paulo, São Paulo. 241p.

Mainieri C & Chimelo JP (1989) Fichas de características de madeiras brasileiras. Companhia de Promoção de Pesquisa Científica e Tecnológica do Estado de São Paulo, São Paulo. 2040p.

Melo Júnior JCF & Barros CF (2017) Madeiras históricas na carpintaria naval de canoas baleeiras da costa catarinense. Rodriguésia 68: 1241-1255.

Ministério do Meio Ambiente - MMA (2014) Portaria n.º 443, de 17 de dezembro de 2014. Available at <http://www.mma.gov.br>. Access on 12 December 2016.

Müller J (2010) Tree species used in historical shipbuilding and their risk of being attacked by Teredinidae. Skyllis journal 10: 1-6.

Muñiz IB de, Carneiro EC, Batista FRR, Schardosin FZ & Nisgosk S (2016) Wood and charcoal identification of five species from the miscellaneous group known in brazil as "angelim" by near-ir and wood anatomy. Maderas. Ciencia y tecnologia 18: 505-522.

Pena HWA, Alburquerque LO & Lemos SMM (2014) Análise da dinâmica da estrutura produtiva do município de Marabá, Amazônia-Brasil. Observatorio de la Economía Latinoamericana 194: 1-33.

Pommier R, Grimaud G, Prinçaud M, Perry N & Sonnemann G (2016) Comparative environmental life cycle assessment of materials in wooden boat ecodesign. The International Journal Of Life Cycle Assessment 21: 265-275.

Ramage MH, Burridge H, Busse-Wicher M, Fereday G, Reynolds T, Shah DU, Wu G, Yu L, Fleming P, Densley-Tingley D, Allwood J, Dupree P, Linden PF & Scherman O (2017) The wood from the trees: the use of timber in construction. Renewable and Sustainable Energy Reviews 68: 333-359.

Sass JE (1940) Elements of botanical microtechnique. McGraw-Hill Book Company, New York. 222p.

Sen S, Sivrikaya H & Yalçin M (2009) Natural durability of heartwoods from European and tropical Africa trees exposed to marine conditions. African Journal Biotechnology 8: 4425-4432.

Strasburger E (1924) Handbook of pratical botany**.** 8ª ed. George Allen e Nonviirn Ltd., Iowa. 533p.

Tripati S, Shukla SR, Shashikala S & Sardar A (2016a) Role of teak and other hardwoods in shipbuilding as evidenced from literature and shipwrecks. Current science 111: 1262-1268.

Tripati S, Shukla SR, Shashikala S & Sardar A (2016b) Teak (Tectona grandis L.f.): a preferred timber for shipbuilding in India as evidenced from shipwrecks. Current science 110: 2160-2165.

Tripati S, Sujatha M, Rao RV & Rao KS (2005) Use of timber in shipbuilding industry: Identification and analysis of timber from shipwrecks off Goa coast, India. Current Science 89: 1022-1027.

Zenid GJ & Ceccantini GCT (2012) Identificação macroscópica de madeiras. Instituto de Pesquisa Tecnológicas, São Paulo. 22p.

Editor de área: Dr. João Paulo Basso-Alves
Artigo recebido em 19/11/2018. Aceito para publicação em 20/02/2019
This is an open-access article distributed under the terms of the Creative Commons Attribution License.