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WOOD ANATOMICAL STRUCTURE AND DENSITY OF *Tachigali aubl* SPECIES OCCURRING IN THE SOUTHEASTERN PERUVIAN AMAZON FOREST

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Resumo

Estrutura anatômica da madeira e densidade das espécies de Tachigali aubl presentes na floresta amazônica do sudeste do Peru. As florestas tropicais são submetidas à elevada perda de biodiversidade, apesar da sua importância. No entanto, os estudos tecnológicos da madeira das espécies nativas ainda são insuficientes. Conhecer as informações tecnológicas da madeira de mais espécies é fundamental, para incorporar espécies não tradicionais na lista de espécies comerciais e reduzir o impacto dessas espécies. As técnicas de coleta de amostras não destrutivas do lenho do tronco das árvores são baratas e rápidas e podem fornecer esse conhecimento. Aqui avaliaram-se as propriedades tecnológicas da madeira de três espécies florestais do gênero Tachigali no sudeste da Amazônia do Peru: *T. alba*, *T. chrysaloides* e *T. vasquezii*, usando a técnica de coleta não destrutiva com sonda de Pressler. Foi feita a caracterização anatômica e a determinação das propriedades físicas das madeiras e foram agrupadas de acordo com essas informações tecnológicas visando determinar os usos mais adequados. Os resultados mostram que as três espécies apresentaram parênquima paratraqueal vasicêntrico, com densidade básica que variou de 0,49 a 0,77 g/cm^3; finalmente, com base na Análise de Componentes Principais, permitiu-nos caracterizar dois grupos e determinar a sua utilização mais adequada. A aplicação de metodologias não destrutivas em outras espécies poderá ampliar o conhecimento tecnológico da madeira das espécies nativas de forma rápida e econômica. Esse tipo de informação é de vital importância para apoiar o manejo florestal de florestas tropicais e aumentar a lista de espécies comerciais.
Palavras-chave: Fabaceae, espécies nativas peruanas, anatomia da madeira, propriedades físicas, sonda de Pressler.

Abstract

Tropical forests are subject to high biodiversity loss, despite their importance. However, technological studies of wood from native species are still insufficient. Knowing the technological information of the wood of more species is essential to incorporation non-traditional species into the list of commercial species and reduce the impact of these species. The techniques for collecting non-destructive wood samples from tree trunks are cheap and fast and can provide this knowledge. Here, the technological properties of the wood of three forest species of the genus Tachigali in the southeastern Amazon of Peru have been evaluated: *T. alba*, *T. chrysaloides* and *T. vasquezii*, using the non-destructive collection technique with a Pressler probe. Anatomical characterization and the determination of the physical properties of the woods were carried out and they were grouped according to this technical information to determine the most appropriate uses. The results show that the three species presented vasicentric paratracheal parenchyma, with basic density ranging from 0.49 to 0.77 g/cm^3; finally, based on Principal Component Analysis, it allowed us to characterize two groups and determine their most appropriate use. The application of non-destructive methodologies in other species will be able to expand the technological knowledge of native species wood quickly and economically. This type of information is vitally important to support the forest management of tropical forests and increase the list of commercial species.
Keywords: Fabaceae, native Peruvian species, wood anatomy, physical properties, Pressler probe.

INTRODUCTION

The forest management of the current commercial species that occurs in primary forests is complex, due to many factors such as low population density, relatively slow growth, high mortality rates of seeds and seedlings. Their regeneration is scarce in tropical forests (ZIMMERMAN; JORMOS, 2012), which makes us see the need to guide technological investigations of the woods of forest species that grow in secondary forests, however, in both primary and secondary forests, we know few of native forest species, for example at a technological level: the anatomy of the wood, the physical, mechanical, chemical properties, etc., important requirements from the industrial sector to be able to include them as alternatives to the most used species (BAWA;SEIDLER, 1998).

To the aforementioned, it is added that in tropical forests it is difficult to collect samples of native trees. This is due to many factors, such as accessibility, transport of the samples, economic aspects of the species to be studied if they are commercial or not, the permits based on the forest law of each country. That is why new methodologies and techniques are required to help in the sampling of timber material where you can collect technological information of the woods such as macroscopic and microscopic anatomy and physical properties in the short or medium term, non-destructive techniques are known that can help us in this objective (ISHIGURI *et al.*, 2012). One of these techniques is the use of a core borer that can extract wood nuclei in the cortex-medulla direction and thereby analyze anatomical aspects, physical properties, and even some mechanical properties (ISHIGURI *et al.*, 2012; ISHIGURI; MAKINO, *et al.*, 2011; ISHIGURI; MATSUMOTO, *et al.*, 2011; MARCELO-PEÑA *et al.*, 2020), showing values similar to traditional techniques.

On the other hand, the botanical family Fabaceae includes among some of its genera *Tachigali* Aubl., which comprises 102 forest species, this genus currently includes the former genus *Sclerolobium*, included for various botanical aspects and also for the anatomy of the wood (MACEDO *et al.*, 2014; MOTA *et al.*, 2017). The *Tachigali* genus has fast-growing species with high biomass production, it can be used for the recovery of areas degraded by the rapid formation of litter, in reforestation and energy production projects, however, it presents few anatomical studies (REIS *et al.*, 2011). This richness of 84 species in tropical forests is complex and difficult to identify and therefore in some places their forest management is not authorized due to incorrect identifications (BRITO JUNIOR *et al.*, 2021).

Regarding the species of the genus *Tachigali*, in the Peruvian Amazon, the 2019 statistics show only the species *T. setifera*, *T. chrysaloides*, and *Tachigali* sp., as commercially exploited (SERFOR, 2020), however, this genus presents several commercially exploited species, but due to the problems of identification of their woods, they are identified and declared erroneously, which urges that the technical knowledge of the wood helps in these processes and helps the good forest management of the native species of Peru.

An evaluation of the technological properties of three forest species of the genus *Tachigali* in the southeastern Amazon of Peru is present. For this was carried out an anatomical analysis at the macroscopic and microscopic level, also, was determine the physical properties of the three species; These studies were conducted using fast and inexpensive non-destructive methods. Specifically, we address the following questions: (i) What are the anatomical characteristics of the three species? (ii) What are the physical properties of these species? (iii) Is it possible to group these species according to their technological characteristics, which allows determining their most appropriate use? We address these questions using three native species of the genus *Tachigali* of the Fabaceae family.

MATERIAL AND METHODS

Study area

We sampled native trees from the site located in the humid tropical zone in southeastern Peru, in the Madre de Dios region, which covers an area of primary natural forest of (~ 2 522 141 ha), a region located on the tri-border of the country, borders Brazil (Acre) and Bolivia (Pando). The site is specifically located in the province of Tambopata and belongs to the National Amazonian University of Madre de Dios, which is an area of ~ 430 ha called "Fundo El Bosque" (12'27S 69'08W), intended for research and conservation of biodiversity, the area is a relict forest and is a high terrace forest, located at 250 meters above sea level, with a dry season from July to August with an average annual temperature of 25 ° C and average annual rainfall of 2200 at 2400 mm (ARAUJO *et al.*, 2011; MALHI *et al.*, 2002; PORTAL *et al.*, 2020).

Species selection and field collection

Three species of the genus *Tachigali* belonging to the Fabaceae family were selected, which currently have very little technological information on wood, the species were: *T. alba*, *T. chrysaloides*, and *T. vasquezii*, performing a simple random probability sampling, taking into account the phytosanitary aspects. Three trees were selected per species previously botanically identified, the collection was non-destructive using the Pressler hole (5.1x400 mm diameter x length), collecting two rays (samples) in the bark-pith direction per tree (Fig. 1), at breast height (1.30m).

The samples were stored and coded in plastic straws, the coding of each sample in the straws was to guarantee the order of the material collected, for example, TV02R1, which means *Tachigali vasquezii* species, tree number 02, and sample R1. Sampling was done with the aid of an increment borers equipment (Pressler borers). The sampling area was treated against fungi and xylophagous insects with an agricultural hormonal healing paste, it aims to assist the healing process of the tree. Also, in order not to leave the generated gap open, liquid silicone was used to seal the gap so that the tree is not exposed (supplementary document).

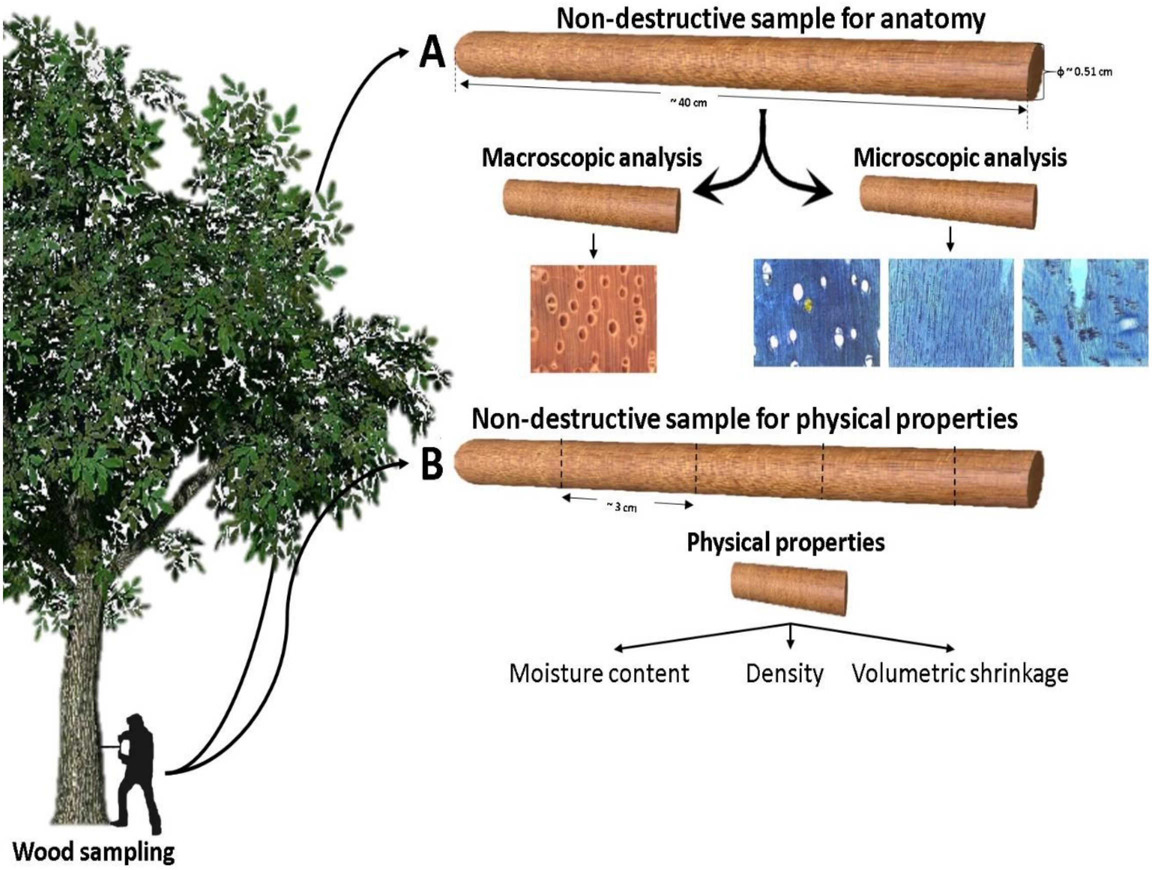

Figure 1. Scheme of the collection phase of the material of the three species of the genus *Tachigali*, using the Pressler borers (non-destructive method). (A) Sample and steps for anatomical analysis and (B) Sample and physical properties analyzed.

Figura 1. Esquema da fase de coleta do material das três espécies do gênero *Tachigali*, utilizzando trado de Pressler (método não destrutivo). (A) Amostra e etapas para análise anatômica e (B) Amostra e propriedades físicas analisadas.

Laboratory phase

The processing of the samples was as follows: of the two samples collected per tree, one of the samples (A) was used for anatomical study, dividing this sample into two sub-samples (A.1 and A.2), the first subsample was used for macroscopic characteristics and the second subsample was used for microscopic characteristics; the other sample (B) was used for the determination of physical properties.

Organoleptic and macroscopic description

The organoleptic characteristics were determined in the sub-sample of wood (A.1) of each tree, the organoleptic characteristics were determined, later, the subsample was glued on wooden support with synthetic glue, with the cross-section up; Once dry, the samples were sanded and polished with a grading of sandpaper (100 to 1000 grain/cm^2), this procedure was carried out to facilitate the observation of the cross-section of the wood.

With the sanded and polished sample, the wood of the three species of the genus *Tachigali* was described, with the help of a 10x magnifying glass and with a stereoscope microscope following the standard (COPANT 1974), where the COPANT standard was used for the descriptions of the characteristics general, organoleptic, and macroscopic of the three species of the genus *Tachigali*. Organoleptic characteristics (odor, color, sapwood-heartwood transition, flavor, texture) and macroscopic characteristics (vessels: visibility, type; growth rings, parenchyma, rays, inclusions) were determined.

Microscopic description

The wood sub-sample (A.2) was divided into three sub-samples (A.2.1, A.2.2, and A.2.3), then it was placed in a plastic container disinfected with distilled water in order to soften the samples and placed in the laboratory refrigerator to keep them fresh. Subsequently, the three sub-samples were glued on a wooden block with synthetic instant glue, previously identifying each section: transverse, tangential, and radial, this to obtain with the help of the microtome the microscopic histological samples of the evaluated woods.

After obtaining the histological samples, material was dehydrated with different percentages of alcohol then, later, colored with toluene blue, followed by fixing the dye (xylol), and the sheets were mounted with the help of liquid glycerin since they were made semi-permanent slides for later microscopic analysis (ISHIGURI *et al*., 2012).

Measurements were obtained of vessel diameter, the number of vessels per mm^2, height and width of rays in microns, rays cells (height and width) with the Pro Plus Image software. The described procedure is based on IAWA (1989).

Physical properties

The other sample (B) in the field phase that was collected from each tree, was used to obtain information on the physical properties of the wood. Sample was segmented into test tubes of 0.51 cm in diameter by 3 cm long, on the same day of collection of the samples of the three species of *Tachigali* in the “Fundo El Bosque”. All the samples were taken to the Wood Properties Laboratory of the Wood Technology Pilot Plant of the Universidad Nacional de Madre de Dios – UNAMAD to determine the initial weight of the sub-samples and the initial volume, to later place them in the kiln. This process was carried out quickly to prevent the samples from losing moisture, it is worth mentioning that the laboratories are located one kilometer from the collection area.

The physical properties that were determined were: moisture content (Standard NTP 251.010), basic density (Standard NTP 251.011), normal density, anhydrous density, and volumetric shrinkage (Standard NTP 251.012). The tests were carried out according to the methodology of ISHIGURI *et al*., 2012 and ISHIGURI; MAKINO, *et al*., 2011).

The volume of the samples was determined by the water displacement or immersion method. The weight was determined with a precision balance of ± 0.01 grams, then the test tubes were conditioned in the kiln and following the protocol it was gradually increased temperature range from 30 ° to 103 ° ± 02 ° C, with increments of 10 ° C per day. During the time that the specimens were dried in the kiln, the provisions of the NTP were followed, the weight of each specimen was checked daily, always placing them in the desiccator provided with silica gel. When the specimens reached their constant weight, the final volume was determined by the same method mentioned above and the following formulas were applied:

a). Determination of Moisture Content (NTP 251.010: 2016).

$$\text{MC}\ (\%) = \frac{wh - wod}{wod} * 100 \quad \textbf{(1)}$$

Where:
wh = Weight of the humidity test specimen (g).
wod = Weight of the oven-dry specimen (g)

b) Determination of Basic Density (NTP 251.011: 2016)

$$\text{DB} = \frac{m}{Vs}\ g/cm^3 \quad \textbf{(2)}$$

c) Determination of Volumetric Shrinkage (NTP 251.012: 2016)

$$\text{CV}\ (\%) = \frac{Vs - Vo}{Vs} * 100 \quad \textbf{(3)}$$

Next, a Tukey analysis was carried out using the RStudio statistical software to see if there are differences between species based on their physical properties (R Core Team, 2019).

Grouping of species

The grouping of the three species of the genus of *Tachigali* by means of the microscopic characteristics and the physical properties of the woods was carried out by means of a multivariate statistical analysis (Principal Component Analysis "PCA"), by means of the RStudio software where a dissimilarity analysis was carried out using the standardized Euclidean distance, because the variables have different units, where each of the values was subtracted by the average of the variable and divided by its respective standard deviation. Finally, the data were analyzed using a PCA, considering the first two components for presenting higher values that respond to the analysis.

RESULTS

Tachigali alba Ducke.

Organoleptic characteristics: in air-dry conditions, there is no abrupt change from sapwood to heartwood. The sapwood and heartwood are creamy yellowish (5 YR 7/8). Distinct growth rings, the limit of the growth rings is characterized by the variation in density that occurs due to the presence of fibrous areas, regularly. Non-distinctive smell and taste, thick texture, high gloss.

Macroscopic Description: diffuse porosity wood. Vessels visible to the naked eye, large and not very abundant, mostly solitary and few radial multiples of 2, 3 to 4, round in shape, occasionally obstructed by gums. Axial parenchyma paratracheal vasicentric (Fig. 2). Rays visible to the naked eye, medium and few, not stratified. Gums and other deposits in heartwood vessels.

Microscopic description: vessel elements with about 5 (± 1.59) vessels / mm^2 classified as few, radial arrangement, circular to oval contour; mean tangential diameter of 162 (± 23.87) µm classified as a medium; simple perforation plate, intervessel pits alternate, not vestured, polygonal outline; Radiovessels pits similar to intervessels ones in shape and size. Axial parenchyma paratracheal vasicentric. Rays about 7 (± 1.35)/mm, homocellular, constituted exclusively by procumbent cells, exclusively uniseriate, width on average 10 (± 4.21) µm; the average height of 167 (± 60.84) µm; high average cell number of 12 (± 5.11) cells (Tab. 1); without stratification. Presence of prismatic crystals in the cells of the axial parenchyma in a rhomboid shape.

Tachigali chrysaloides van del Werff

Organoleptic characteristics: in air-dry conditions, there is no abrupt change from sapwood to heartwood. The sapwood and heartwood are creamy pinks (2.5 YR 6/8). Distinct growth rings, the limit of the growth rings is characterized by the variation in density that occurs due to the presence of fibrous areas, regularly. Non-distinctive smell and taste, thick texture, high gloss.

Macroscopic Description: diffuse porosity wood. Vessels visible to the naked eye, large and not very abundant, mostly solitary and few radial multiples of 2 to 4, round in shape, occasionally obstructed by gums. Abundant axial parenchyma paratracheal vasicentric (Fig. 2). Rays visible to the naked eye, medium and few, not stratified. Gums inclusions.

Microscopic description: vessels elements with about 4 (± 1.84) vessels/mm^2 classified as few, radial arrangement, circular to oval contour; average tangential diameter of 258 (± 33.87) µm classified as large; simple perforation plate, intervessel pits alternate, not vestured, polygonal outline; Radiovessels pits similar to intervessels ones in shape and size. Axial parenchyma paratracheal vasicentric. Rays close to 3 (± 1.43)/mm, homocellular, constituted exclusively by procumbent cells, exclusively uniseriate, width on average 36 (± 6.11) µm; the average height of 317 (± 73.17) µm; high average cell number of 7 (± 2.17) cells (Tab. 1); without stratification. Presence of prismatic crystals in the cells of the axial parenchyma in a rhomboid shape.

Tachigali vasquezii Pipoly.

Organoleptic characteristics: in air-dry conditions, there is no abrupt change from sapwood to heartwood. The sapwood and heartwood are creamy pinks (7.5 YR 6/6). Distinct growth rings, the limit of the growth rings is characterized by the variation in density that occurs due to the presence of fibrous areas, with a very dark color, in a regular way. Non-distinctive smell and taste, thick texture, high gloss.

Macroscopic Description: diffuse porosity wood. Vessels visible to the naked eye, large and not very abundant, mostly solitary and few radial multiples of 2 to 5, round in shape, occasionally obstructed by gums. Axial parenchyma paratracheal vasicentric (Fig. 2). Rays visible with a 10x magnifying glass, medium to fine and few, not stratified. Gums inclusions.

Microscopic description: vessel elements with about 7 (± 1.90) vessels/mm^2 classified as few, radial arrangement, circular to oval contour; mean tangential diameter of 62 (± 12.52) µm classified as small; simple perforation plate, intervessel pits alternate, not vestured, polygonal outline; Radiovessels pits similar to intervessels ones in shape and size. Axial parenchyma paratracheal vasicentric. Rays close to 5 (± 1.59)/mm, homocellular, constituted exclusively by procumbent cells, exclusively uniseriate, width on average 13 (± 2.07) µm; height on average of 138 (± 37.34) µm; high average cell number of 10 (± 3.98) (Tab. 1); without stratification. Presence of prismatic crystals in the cells of the axial parenchyma in a rhomboid shape.

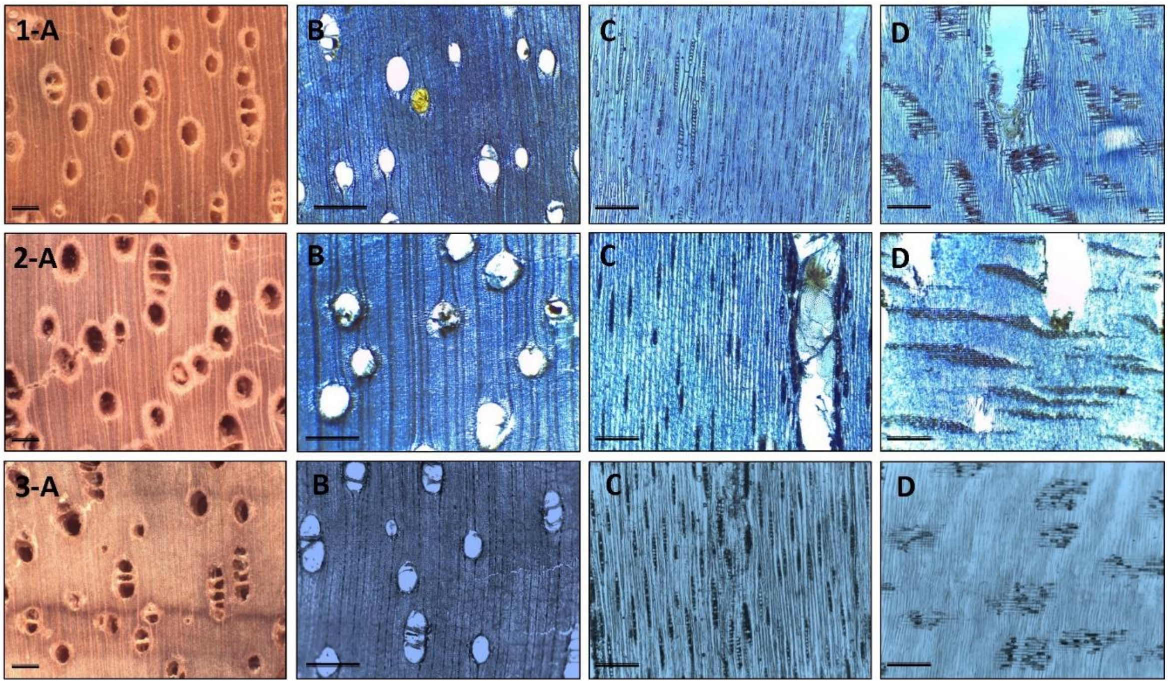

Figure 2. Anatomical characteristics of (1) *Tachigali alba*, (2) *Tachigali chrysaloides*, (3) *Tachigali vasquezii*; (A) Macroscopic cross-section (Scale bar = 20 mm), (B) Microscopic cross-section (Scale bar = 500 µm), (C) Microscopic tangential section (Scale bar = 200 µm), (D) Microscopic radial section (Scale bar = 200 µm).

Figura 2. Características anatômicas de (1) *Tachigali alba*, (2) *Tachigali chrysaloides*, (3) *Tachigali vasquezii*; (A) Seção transversal macroscópica (Barra de escala = 20 mm), (B) Seção transversal microscópica (Barra de escala = 500 µm), (C) Seção tangencial microscópica (Barra de escala = 200 µm), (D) Seção radial microscópica (Barra de escala = 200 µm).

Table 1. Quantitative wood anatomical characteristics of the wood of the species of the genus *Tachigali*. Min: minimum, Max: Maximum, SD: standard deviation.

Tabela 1. Características anatômicas quantitativas do lenho das espécies do gênero *Tachigali*. Min: mínimo, Max: Máximo, SD: desvio padrão.

Variables	Statistic	*Tachigali alba*	*Tachigali chrysaloides*	*Tachigali vasquezii*
Vessel diameter (µm)	Min.	104.39	192.65	28.95
	Max.	197	322.87	79.40
	Average	162	258	62
	SD	23.87	33.87	12.52
Vessels per square millimeter	Min.	3	1	2
	Max.	3	8	10
	Average	5	4	7
	SD	1.59	1.84	1.9
Rays height (µm)	Min.	82.91	154.34	80.49
	Max.	291.61	486.69	207.59
	Average	167	317	138
	SD	60.84	73.17	37.34
Rays width (µm)	Min.	6.7	26.02	9.81
	Max.	20.77	48.15	18.63
	Average	10	36	13
	SD	4.21	6.11	2.07

Rays height (cell number)	Min.	5	3	5
	Max.	23	11	20
	Average	12	7	10
	SD	5.11	2.17	3.98
Rays width (cell number)	Min.	1	1	1
	Max.	1	1	1
	Average	1	1	1
	SD	(0)(0)	(0)(0)	(0)(0)
Rays per linear millimeter	Min.	4	1	3
	Max.	9	6	9
	Average	7	3	5
	SD	1.35	1.43	1.59

Regarding the physical properties, the average values, ranges (minimum and maximum), coefficient of variation, and the Tukey test of the three species of the genus *Tachigali* (Tab. 2) are presented.

Table 2. Average values of the physical properties of the three species of the genus *Tachigali*.
Tabela 2. Valores médios das propriedades físicas das três espécies do gênero *Tachigali*.

Variables	Statistic	*Tachigali alba*	*Tachigali chrysaloides*	*Tachigali vasquezii*
Moisture content (%)	Average	25.54 b	59.83 a	61.02 a
	SD	6.16	20.50	16.20
	C.V	24.00	29.11	24.11
Basic density (g/cm^3)	Average	0.77 a	0.49 b	0.50 b
	SD	0.08	0.12	0.08
	C.V	10.46	24.79	15.75
Normal density (g/cm^3)	Average	0.97 a	0.81 a	0.84 a
	SD	0.10	0.24	0.25
	C.V	10.00	29.66	29.57
Anhydrous Density (g/cm^3)	Average	0.86 a	0.54 b	0.56 b
	SD	0.08	0.13	0.09
	C.V	9.90	23.29	15.65
Volumetric Shrinkage (%)	Average	9.99 a	10.36 a	10.64 a
	SD	2.23	3.88	3.67
	C.V	22.38	37.42	34.48

The means followed by the same letter do not differ statistically from each other, according to the Tukey test (p> 0.05).

Based on the analysis of multivariate statistical analysis (Principal Component Analysis), two groups were identified based on anatomical characteristics and physical properties (Tab. 1 and Tab. 2) by means of their similarity. The results showed that the species *T. chrysaloides* and *T. vasquezii* constitute group 1 and that these species show a similar basic density. Group 1 is separated from the species *T. alba* that forms group 2, which stands out for presenting a higher basic density (Fig. 3), where components 1 and 2 represent 51.29%, assuming them as satisfactory (supplementary document).

The grouping according to the anatomical characteristics and physical properties, allowed us to characterize the groups and determine their most appropriate use: Group 1, according to the classification of Peruvian woods, are species of medium basic density, (basic density between 0.41 to 0.60 g/cm^3), the woods that belong to this group, are characterized by their good behavior when working with carpentry machines, regular in terms of their shrinkage properties, mechanical resistance, and durability. Their durability can be improved, because the woods of this group have good behavior in the retention and penetration of chemical products (ACEVEDO; CHAVESTA, 1991; ARÓSTEGUI, 1982). The most suitable uses of group 1 are packaging, moldings, canopies, carpentry in general, veneer sheets, construction, chipboards, partitions, beams, joists, sports equipment.

Group 2, according to the Peruvian wood classification, is a species with a very high basic density (basic density greater than 0.75 g / cm^3), the woods belonging to group V are characterized by having very good mechanical resistance and high natural durability (ACEVEDO; CHAVESTA, 1991; ARÓSTEGUI, 1982). The most suitable uses of group 2 are doors, windows, furniture in general, linings for ceilings, frame covers, rollers, baseboards, veneer sheets, parquet and floors, structural constructions.

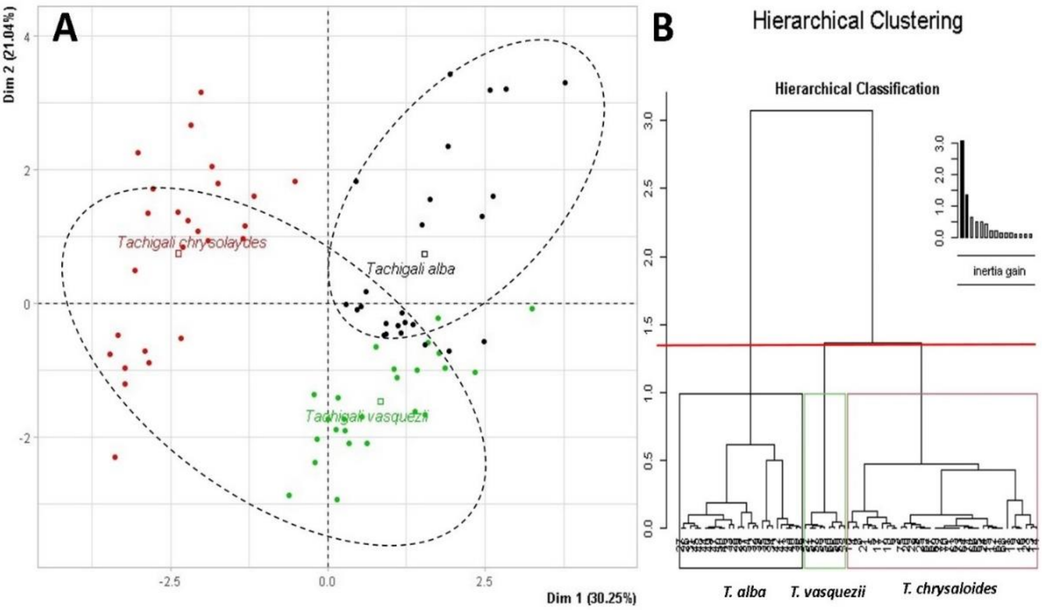

Figure 3. A) Principal Component Analysis (PCA) of the anatomical characteristics and physical properties of wood in the constitution of groups of species. B) Dendrogram of similarity (Euclidean distance) in relation to microscopic anatomy and physical properties of the three species of the genus *Tachigali*.

Figura 3. A) Análise de Componentes Principais (PCA) das características anatômicas e propriedades físicas da madeira na constituição de grupos de espécies. B) Dendrograma de similaridade (distância euclidiana) em relação à anatomia microscópica e propriedades físicas das três espécies do gênero *Tachigali*.

DISCUSSION

The anatomy and physical properties of three species of the genus *Tachigali* were characterized by non-destructive collection techniques. Regarding the growth rings of the species of the genus *Tachigali*, the scientific literature shows that they are frequently characterized by the fact that the rings are different and the type of marking is due to the variation in the density of latewood fibers with thick and flattened walls (BRIENEN; ZUIDEMA, 2005; MACEDO et al., 2014). In addition, Brienen and Zuidema (2005), points out about the growth rings of the species *T. vasquezii*, which are clear to unclear approaching the center of the slices, studying this species in dendrochronology. These descriptions coincide with the three species of *Tachigali* studied in the Peruvian Amazon.

Regarding the parenchymal tissue, it is found in various studies of the *Tachigali* species that one of the most frequent types of parenchyma in these species is the vasicentric paratracheal type (BRITO JUNIOR *et al.*, 2021; MACEDO *et al.*, 2014; REIS *et al.*, 2011), where the three species studied present this type of parenchyma, being abundant and prominent in the cross-section. Of course, there are some other types of parenchyma that the species of the genus *Tachigali* present, such as: unilateral (*T. froesii*, *T. melanocarpa*), aliform and confluent in short and long sections (*T. aurea*), and even absent or extremely rare (*T subvelutina*) (DE FARIA *et al.*, 2020; REIS *et al.*, 2011). Regarding the rays, there is also an outstanding characteristic in the species of this genus, most of the studies show that the *Tachigali* species present predominantly uniseriate rays (BRITO JUNIOR *et al.*, 2021; DE FARIA *et al.*, 2020; MACEDO *et al.*, 2014; REIS *et al.*, 2011), as in the case of the three studied species that are uniseriate; however some species can be uniseriate and biseriate such as *T. denudata*, *T. paratyensis* (MACEDO *et al.*, 2014).

On the technique used in this research, there are several investigations where the wood is analyzed at a microscopic level through small cores of wood extracted with non-destructive instruments (ARAGÃO *et al.*, 2019;

ISHIGURI *et al*., 2012; MARCELO-PEÑA *et al*., 2020). And regarding the physical properties of this method, there are studies mainly in Indonesia using small blocks of wood extracted with core borer, where the radial variation of the basic density (pith-bark) and even mechanical properties such as resistance was determined to compression parallel to grain in the same variation, using the Faractometer II equipment (ISHIGURI *et al*., 2012; ISHIGURI; MAKINO, *et al*., 2011; ISHIGURI; MATSUMOTO, *et al*., 2011).

The information on the technological characterization of the woods of the genus *Tachigali* is still insipient, for this reason, the information was extracted from the Global wood density database with 13 species of *Tachigali* (ZANNE *et al*., 2009), Silva *et al*. (2019) with 01 species (*T. vulgaris*) and the 03 *Tachigali* species studied; where the average basic density of the 17 species of the genus *Tachigali* is 0.57g/cm^3 and varies from 0.41 to 0.77 g/cm^3, qualitatively classifying these species as a medium to very high basic density (supplementary document).

CONCLUSIONS

In conclusion, we determined the technological properties of three native species of the genus Tachigali in the southeastern Amazon of Peru, applying non-destructive techniques.

- Regarding the anatomy at the macroscopic level, the three species are similar, highlighting the presence of vasicentric paratracheal type parenchyma and exclusively uniseriate rays, at the microscopic level there are differences in the diameter of the vessels and the width of the rays.
- Regarding the physical properties, the basic density had a variation from 0.49 to 0.77 g/cm3, where T. chysaloides presented the lowest density and T alba the highest density.
- Finally, the technological characteristics of the three species allowed them to be grouped using Principal Component Analysis into two groups and allowed their most appropriate use to be determined.
- We suggest that researchers can apply this relatively practical and economical methodology compared to traditional analyzes that can generate technological information on more native tropical species in the medium to short term.

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REFERENCES

ACEVEDO, M.; CHAVESTA, M. **Informe sobre fichas tecnológicas de la madera y asignación a grupos tecnológicos**. Proyecto Dantas. 1991, 6 p.

ARAGÃO, J.; GROENENDIJK, P.; LISI, C. S. Dendrochronological potential of four neotropical dry-forest tree species: Climate-growth correlations in northeast Brazil. **Dendrochronologia**, v. 53, p. 5 - 16, 2019. DOI: https://doi.org/10.1016/j.dendro.2018.10.011

ARAUJO, A.; PARADA, A.; TERÁN, J.; BAKER, T.; FELDPAUSCH, T.; PHILLIPS, O.; BRIENEN, R. Necromasa de los bosques de Madre de Dios, Perú; una comparación entre bosques de tierra firme y de bajíos. **Revista Peruana de Biología**, v. 18, n. 1, p. 113 - 118, 2011. DOI: https://doi.org/10.15381/rpb.v18i1.155

ARÓSTEGUI, A. Recopilación y análisis de estudios tecnológicos de maderas peruanas. PNUD-FAO. 1982, 57 p.

BAWA, K. S.; SEIDLER, R. Natural Forest Management and Conservation of Biodiversity in Tropical Forests. **Conservation Biology**, v. 12, n. 1, p. 46 - 55, 1998.

BRIENEN, R. W.; ZUIDEMA, P. A. Relating tree growth to rainfall in Bolivian rain forests: A test for six species using tree ring analysis. **Oecologia**, v. 146, n. 1, p. 1 - 12, 2005. DOI: https://doi.org/10.1007/s00442-005-0160-y

BRITO JUNIOR, J. F; SCCOTI, M. S. V.; BIAZATTI, S. C.; PEREIRA, B. L. C. Anatomical characterization of wood for identification of the *Tachigali* Aubl. Species. **Revista Ibero-Americana de Ciências Ambientais**, v. 12, n. 3, p. 38 - 46, 2021. DOI: https://doi.org/10.6008/CBPC2179-6858.2021.003.0004

COPANT. **Maderas: Método para la descripción de las características generales, macroscópicas y microscópicas de las maderas angiospermas y dicotiledóneas: Anteproyecto de Norma**. COPANT 30: 1 – 019, 1974, 25 p.

DE FARIA, M. C. G.; SILVA-NETO, C.; LIMA, P. A. F.; CHAGAS, M. P.; TOMAZELLO, M.; SETTE, C. R. Brazilian cerrado species: Wood characteristics. **Bioscience Journal**, v. 36, n. 4, p. 1335 - 1352, july/aug. 2020. DOI: https://doi.org/10.14393/BJ-v36n4a2020-48044

IAWA. COMMITTEE. **List of microscopic features of hardwood identification**. Netherlands: IAWA Bulletin**,** 3 ed. 1989, 219 - 332 p.

ISHIGURI, F.;MAKINO, K.; WAHYUDI, I.; TAKASHIMA, Y.; IIZUKA, K.; YOKOTA, S.; YOSHIZAWA, N. Stress wave velocity, basic density, and compressive strength in 34-year-old *Pinus merkusii* planted in Indonesia. **Journal of Wood Science**, v. 57, n. 6, p. 526 - 531, 2011. DOI: https://doi.org/10.1007/s10086-011-1208-8

ISHIGURI, F.;MATSUMOTO, K.; KUWANO, M.; OHNO, H.; KAMEYAMA, Y.; IIZUKA, K.; YOKOTA, S.; YOSHIZAWA, N. Relationship between compressive strength of core samples measured by Fractometer and compressive properties of full size short columns in sugi (*Cryptomeria japonica* D. Don). **Bull. Utsunomiya Univ. For.**, v. 47, p. 35 - 40, 2011.

ISHIGURI, F.; TAKEUCHI, M.; MAKINO, K.; WAHYUDI, I.; TAKASHIMA, Y.; IIZUKA, K.; YOKOTA, S.; YOSHIZAWA, N. Cell Morphology and wood properties of *Shorea acuminatissima* Planted in Indonesia. **IAWA Journal**, v. 33, n. 1, p. 25 - 38, 2012. DOI: https://doi.org/10.1163/22941932-90000077

MACEDO, T. M.; BARROS, C. F.; LIMA, H. C.; COSTA, C. G. Wood anatomy of seven species of *Tachigali* (Caesalpinioideae–Leguminosae). **IAWA Journal**, v. 35, n. 1, p. 19 - 30, 2014. DOI: https://doi.org/10.1163/22941932-00000044

MALHI, Y.; PHILLIPS, O. L.; LLOYD, J.; BAKER, T.; WRIGHT, J.; ALMEIDA, S.; ARROYO, L.; FREDERIKSEN, T.; GRACE, J.; HIGUCHI, N.; KILLEEN, T.; LAURANCE, W. F.; LEAÑO, C.; LEWIS, S.; MEIR, P.; MONTEAGUDO, A.; NEILL, D.; VARGAS, P. N.; PANFIL, S. N.; VINCETI, B. An international network to monitor the structure, composition and dynamics of Amazonian forests (RAINFOR). **Journal of Vegetation Science**, v. 13, n. 3, p. 439 - 450, 2002. DOI: https://doi.org/10.1658/1100-9233(2002)013[0439:AINTMT]2.0.CO;2

MARCELO-PEÑA, J.; ROIG, F.; GOODWIN, Z.; TOMAZELLO, M. Characterizing growth rings in the trees of Perú: A wood anatomical overview for potential applications in dendroecological-related fields. **Dendrochronologia**, v. 62, p. 1 - 13, 2020. DOI: https://doi.org/10.1016/j.dendro.2020.125728

MOTA, G.; SARTORI, C.; MIRANDA, I.; QUILHÓ, T.; MORI, F.; PEREIRA, H. Bark anatomy, chemical composition and ethanol-water extract composition of *Anadenanthera peregrina* and *Anadenanthera colubrina*. **PLOS ONE**, v. 12, n. 12, p. 1 - 14, dez. 2017. DOI: https://doi.org/10.1371/journal.pone.0189263

PORTAL, L.; CARDOZO, J.; SANTOS, L.; SAAVEDRA, G.; HUAMÁN, B. Dendrocronología de *Jacaranda copaia* que contiene registro ENSO en Madre de Dios, Perú. **Nativa**, v. 8, n. 4, p. 572 - 578, 2020. DOI; https://doi.org/10.31413/nativa.v8i4.10082

R CORE TEAM. *R:* A language and environment for statistical computing. R Founda- tion for Statistical Computing [Vienna: R Foundation for Statistical Computing]. http://www.R-project.org. 2019.

REIS, A.; MARQUES, P.; OLIVEIRA, A.; BRAGA, P. Anatomia do xilema secundário de sete espécies do gênero *Tachigali* Aubl. (Fabaceae), disponíveis na Xiloteca Walter A. Egler, do Museu Paraense Emílio Goeldi, Pará, Brasil The anatomy of the secondary xylem of seven species of the Tachigali Aubl. Type. From the Walter A. Egler wood collection of the Museu Paraense Emílio Goeldi, Pará, Brazil. **Boletim do Museo Paraense Emílio Goeldi. Ciencias Naturais.** v. 6, n. 3, p. 319 - 333, 2011.

SERFOR. (2020). *Anuario Forestal y de Fauna Silvestre 2019*. 132 p.

SILVA, M.; DA SILVA, M.; BUFALINO, L.; DE ASSIS, M.; GONÇALVES, D.; TRUGILHO, P.; PROTÁSIO, T. Variations in productivity and wood properties of Amazonian tachi-branco trees planted at different spacings for bioenergy purposes. **Journal of Forestry Research**. p. 1 - 14, 2019. DOI: https://doi.org/10.1007/s11676-019-01068-8

ZANNE, A. E.; LOPEZ-GONZALEZ, G.; COOMES, D. A.; ILIC, J.; JANSEN, S.; LEWIS, S. L.; MILLER, R. B.; SWENSON, N. G.; WIEMANN, M. C.; CHAVE, J. Global Wood Density Database. Dryad Digital Repository. 2009. DOI: https://doi.org/10.5061/dryad.234

ZIMMERMAN, B.; JORMOS, C. F. Prospects for sustainable logging in tropical forests. **BioScience**, v. 62, n. 5, p. 479 - 487, 2012. DOI: https://doi.org/10.1525/bio.2012.62.5.9