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ANATOMY AND IDENTIFICATION OF CHARCOAL MARKETED IN THE REGION OF PAPANDUVA, SANTA CATARINA, SOUTHERN BRAZIL.

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Resumo

Anatomia e identificação do carvão vegetal comercializado na região de Papanduva - Santa Catarina. Este trabalho teve por objetivo identificar e descrever anatomicamente as espécies comercializadas na forma de carvão na região de Papanduva – SC, sul do Brasil, a fim de fornecer informações técnicas para auxiliar na identificação de espécies pertencentes ao bioma Mata Atlântica. Foram adquiridas embalagens de 3 a 10 kg de carvão vegetal, realizada uma pré-seleção das peças com maior similaridade, obtidas imagens macro e microscópicas para posterior descrição dos elementos anatômicos componentes e identificação do material. Verificou-se adulteração do conteúdo de algumas embalagens de carvão vegetal analisadas, contendo tanto gêneros do grupo das angiospermas, como gimnospermas. Foram encontradas amostras, em ordem decrescente de frequência, dos gêneros *Eucalyptus/Corymbia, Ocotea/Nectandra, Acacia, Pinus, Araucaria, Alchornea, Casearia, Cedrela, Eugenia, Hieronyma, Ilex, Schinus* e *Zanthoxyllum.* Nas gimnospermas, foi possível ver a distinção dos anéis de crescimento, com a diferente espessura da parede dos traqueoides e os canais resiníferos do pinus. Nas angiospermas, a porosidade difusa foi a mais frequente, destacando-se com porosidade em anel semiporoso o gênero *Cedrela*. A presença de tilos foi predominante nos gêneros *Eucalyptus/Corymbia*; as fibras septadas foram características dos gêneros *Ocotea/Nectandra.* A placa de perfuração simples e pontoações intervasculares alternas foi predominante, com exceção no gênero *Ilex* com placa de perfuração escalariforme e pontoações opostas. A presença de canal secretor foi observada apenas no gênero *Zanthoxyllum.* Observou-se a predominância de eucalipto proveniente de florestas plantadas, mas a presença de araucária, espécie na lista das ameaçadas de extinção, mostra a importância da fiscalização e conscientização dos produtores e comerciantes locais.
Palavras-chave: carbonização, Mata Atlântica, espécies nativas, estrutura anatômica.

Abstract

The objective of this paper was identifed anatomically and describe wood species marketed as charcoal in the region of Papanduva, SC, southern Brazil, to provide technical information to help in identification of species from the Atlantic Forest biome. Packages of 3 to 10 kg of charcoal were purchased, a pre-selection from more similar pieces was performed, macro and microscopic images were obtained for posterior anatomical description and material identification. Mislabeling was found in some charcoal packages, including genus, from both angiosperm and gymnosperm groups. Samples were found in decreasing frequency order, from the genera *Eucalyptus/Corymbia, Ocotea/Nectandra, Acacia, Pinus, Araucaria, Alchornea, Casearia, Cedrela, Eugenia, Hieronyma, Ilex, Schinus* and *Zanthoxyllum.* In gymnosperms, it was possible to verify growth rings distinct, with differences in cell wall thickness of tracheid and resin canals in pinus. In angiosperms, diffuse porosity was more frequent, with highlight to semiring porous in genus *Cedrela*. The presence of tyloses was predominant in genus *Eucalyptus/Corymbia*; septate fibers were characteristics for genus *Ocotea/Nectandra.* Simple perforate plate and alternate intervessel pits were predominant, with exception of genus *Ilex* with scalariform perforation plate and opposite intervessel pits. Secretory canals were observed in genus *Zanthoxyllum.* The predominance of eucalyptus from planted forests was observed, but the presence of araucaria, which is on the list of endangered species, indicated the importance of better supervision and training for awareness of producers and local traders.
Keywords: carbonization, Mata Atlântica, native species, anatomical structure.

INTRODUCTION

Brazil is the world's principal charcoal producer, accounting for 12% of global production in 2019, with the state of Minas Gerais being the main consumer region, mainly for production iron and steel. The state has more than 40% of charcoal producing companies in the country (IBÁ, 2020). In 2019, charcoal consumption rose by 3.7% in relation to the previous year, reaching 5.3 million tons. The use of products from renewable sources increased from 4.9 to 5.1 million tons in 2019 in relation to prior year (IBÁ, 2020).

Besides the iron and steel industry, charcoal is used for heating and cooking (PEDROSO *et al.*, 2018; OLIVEIRA *et al.*, 2019). In 2019, these household uses were responsible by consuming approximately 11% of total production, corresponding to 6,197 tons (IBÁ, 2020). In Santa Catarina state, average household consumption

is 48.6 kg person^{-1} year^{-1} (PASSOS *et al.*, 2016), with a strong correlation with barbecuing (r = 0.77), which together with the number of people in each household were the principal variables associated with consumption of charcoal for cooking (OLIVEIRA *et al.*, 2019).

Industrial production of charcoal in Brazil mainly uses eucalyptus wood from planted forests, but unfortunately, studies have documented many situations of charcoal made from wood of native species not authorized for this purpose being sold as eucalyptus (GONÇALVES *et al.*, 2018). Such misrepresentation is facilitated because carbonization makes species identification more difficult (STÜPP *et al.*, 2021), but it is possible using the Anthracology. This technique is multidisciplinary and enables identification of charcoal species based on the anatomical traits of wood that are still identifiable after carbonization (PRIOR; GASSON, 1993), allowing taxonomic determination (KIM; HANNA, 2006). Also is an important tool for the purpose of deterring illegal production or commerce of charcoal produced with native/endangered species (CARVALHO *et al.*, 2017).

From the environmental standpoint, charcoal production from planted forests is considered clean and renewable, because it presents a positive value of carbon balance, in contrast to charcoal produced from native forests, which has a negative carbon balance (GONÇALVES; SCHEEL-YBERT, 2012). Illegal production of charcoal affects the Amazon, Pantanal, Cerrado, Caatinga and Atlantic Forest biomes, with the last two being of greatest concern for many years (REPÓRTER BRASIL; PAPEL SOCIAL, 2012).

The Atlantic Forest biome is considered one of the 34 hotspots of biodiversity in the world, rich in diversity and with high level of endemism (CANEI *et al.*, 2018), making conservation of the remaining areas a global priority (OMACHI *et al.*, 2018). This biome is extremely fragmented, with only 12% of the original area remaining, the majority composed of forest fragment areas smaller than 50 hectares (RIBEIRO *et al.*, 2009; RUSCA *et al.*, 2017), mainly in Brazil's South and Southeast regions in different degradation stages (CANEI *et al.*, 2018).

Data from the Brazilian Institute of Geography and Statistics (IBGE, 2020) referring to the number of silviculture products, indicated that Santa Catarina state produced 12,056 tons of charcoal from *Eucalyptus* sp., 23 tons from *Pinus* sp. and zero tons of legal charcoal from other species. In function of exposed above, the aim of this study was to describe and identify anatomically samples of charcoal sold in the region of Papanduva, Santa Catarina state, and also to detect the presence of mislabeled material.

MATERIAL AND METHODS

The study was performed in the municipality of Papanduva (latitude 26º22'13"S and longitude 50º08'40"W), in northern region of Santa Catarina state, micro-region of Canoinhas, southern Brazil. The charcoal samples were purchased from local stores, with various brands and identifications of wood species. Seven packages from 3 to 10 kg were purchased and designated A, B, C, D, E, F and G. Detailed information from packages are in Table 1. In each sample package, the number of charcoal pieces was counted to verify percentage of each genus/species if material was mislabeled.

Table 1. Information from evaluated charcoal packages.
Tabela 1. Informações nas embalagens de carvão estudadas.

Sample	Weight (kg)	Species described in packages	Material origin and Package region	Register in an environmental inspection body	
				State	National
A	5	Forest species	Santa Catarina	No	No
B	3	*Acacia mearnsii* de Wild	Rio Grande do Sul	Yes	Yes
C	4	*Eucalyptus* spp.	Paraná	Yes	Yes
D	10	Forest species	Santa Catarina	No	No
E	5	*Eucalyptus* spp.	Santa Catarina	Yes	Yes
F	3	*Eucalyptus* spp.	Santa Catarina	Yes	Yes
G	5	*Eucalyptus* spp.	Santa Catarina	Yes	Yes

Analysis was performed in the Wood Anatomy and Quality Laboratory of Federal University of Paraná (LANAQM/UFPR), in Curitiba, Paraná state. The pieced in each package were evaluated macroscopically and pieces with similarity were grouped for posterior analysis. After that, the piece was broken manually or with a chisel to expose the three anatomical surfaces (transversal, longitudinal radial, and longitudinal tangential) for image acquisition, anatomical description and identification.

Images were obtained with Zeiss Discovery V12 stereomicroscope with magnifications of 10x, 25x, 50x, 75x and 100x. Detailed images were obtained with a Hitachi TM-1000 tabletop scanning electron microscope

with direct observation of samples, without coating. Material was described based on recommendation of International Association of Wood Anatomists (IAWA, 1989) and identification was performed by comparing the samples with wood anatomical descriptions present in the Inside Wood database as well as in Marchiori *et al.* (2009, 2010, 2011), Santos and Marchiori (2011) and also with samples from the charcoal collection of LANAQM (anatomic details at CARVALHO *et al.*, 2017; GONÇALVES *et al.*, 2018; STÜPP *et al.*, 2021). Material was identified only to the genus level and percentage of misrepresentation was computed.

RESULTS

The results indicated that some samples had different material from that described on the packages (Table 2), being observed 13 genera including native and exotic species.

Table 2. Genera observed in charcoal samples marketed in Papanduva, SC.
Tabela 2. Gêneros observados nas amostras de carvão vegetal comercializadas na região de Papanduva - SC.

Sample	Description in package	Adulterated content	Percentage of misrepresentation (%)	Genus observed
A	Forest species	-	-	*Cedrela*, *Eucalyptus/Corymbia*, *Pinus*, *Zanthoxylum*
B	*Acacia mearnsii* de Wild	Yes	75.9	*Acacia*, *Eucalyptus/Corymbia*
C	*Eucalyptus* spp.	Yes	100	*Alchornea*, *Casearia*, *Eugenia*, *Ilex*, *Ocotea/Nectandra*, *Schinus*
D	Forest species	-	-	*Araucaria angustifolia*, *Hieronyma*, *Ocotea/Nectandra*
E	*Eucalyptus* spp.	No	-	*Eucalyptus/Corymbia*
F	*Eucalyptus* spp.	No	-	*Eucalyptus/Corymbia*
G	*Eucalyptus* spp.	No	-	*Eucalyptus/Corymbia*

A total of 13 genera were identified (Figure 1), with some variations in genus *Eucalyptus/Corymbia* and *Ocotea/Nectandra* related to different species. Two genera of gymnosperms, *Pinus* sp. and *Araucaria angustifolia*, and 11 genera of angiosperms were identified, two being exotic (*Acacia* and *Eucalyptus/Corymbia*) and nine being native (*Alchornea* sp., *Casearia* sp., *Cedrela* sp., *Eugenia* sp., *Hieronyma* sp., *Ilex* sp., *Ocotea/Nectandra* spp., *Schinus* sp., and *Zanthoxylum* sp.) A total of 12 botanic families were identified: Anacardiaceae, Aquifoliaceae Araucariaceae, Euphorbiaceae, Fabaceae, Lauraceae, Meliaceae, Myrtaceae, Pinaceae, Phyllanthaceae, Rutaceae and Salicaceae.

Anatomical descriptions

1 - Scientific name: *Pinus* sp. (Figure 2a-d) - Pinaceae
Vernacular name: Pinus
Growth rings: distinct, with gradual transition from earlywood to latewood (Figure 2a-b). **Tracheid pits:** uniseriate, biseriate alternate. **Resin canals:** axial with normal distribution (Figure 2a-b). **Axial parenchyma:** associated with resin canals. **Rays:** heterogeneous with presence of tracheid rays with indentures (Figure 2c); uniseriate and fusiform (Figure 2d).

2 – Scientific name: *Araucaria angustifolia* (Figure 2e-h) - Araucariaceae
Vernacular name: Araucária
Growth rings: distinct, with gradual transition from earlywood to latewood (Figure 2e-f). **Tracheid pits:** uniseriate, biseriate alternate. **Resin canals:** absent. **Axial parenchyma:** absent. **Rays:** homogeneous (Figure 2g) and uniseriate (Figure 2h).

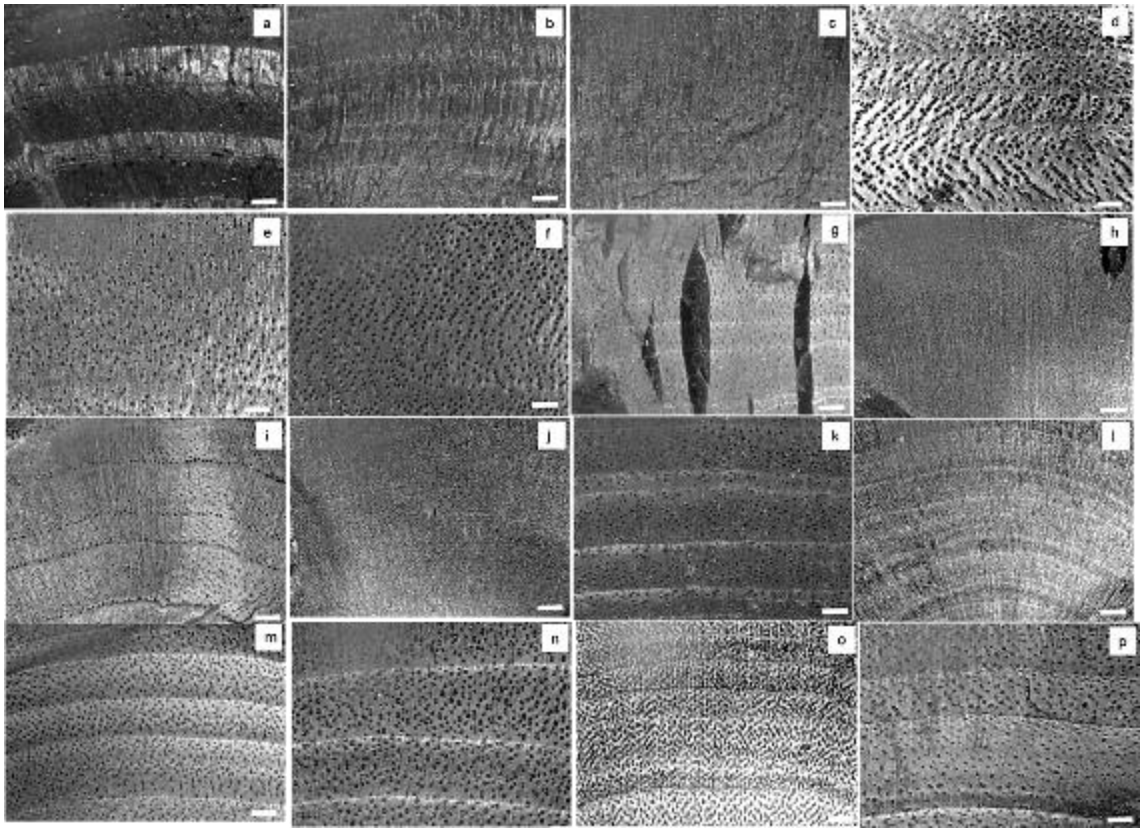

Figure 1. Stereomicroscopic images of transversal surface of a) *Pinus* sp.; b) *Araucaria angustifolia*; c) *Acacia* sp.; d-f) *Eucalyptus/Corymbia* spp.; g) *Alchornea* sp., h) *Casearia* sp., i) *Cedrela* sp., j) *Eugenia* sp., k) *Hieronyma* sp., l) *Ilex* sp., m-n) *Ocotea/Nectandra* spp.; o) *Schinus* sp., p) *Zanthoxylum* sp. Scale bar = 1000 µm.

Figura 1. Imagens em estereomicroscópio da superfície transversal de a) *Pinus* sp.; b) *Araucaria angustifolia*; c) *Acacia* sp.; d-f) *Eucalyptus/Corymbia* spp.; g) *Alchornea* sp., h) *Casearia* sp., i) *Cedrela* sp., j) *Eugenia* sp., k) *Hieronyma* sp., l) *Ilex* sp., m-n) *Ocotea/Nectandra* spp.; o) *Schinus* sp., p) *Zanthoxylum* sp. Barra de escala = 1000 µm.

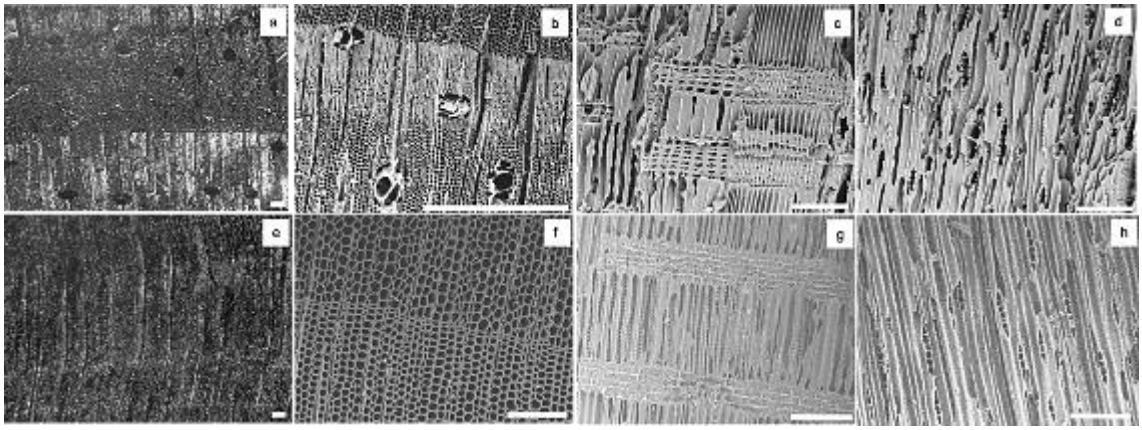

Figure 2. Stereomicroscopic (a, e) and SEM images (b-d, f-h) of charcoal from *Pinus* sp. (a-d) and *Araucaria angustifolia* (e-h). Transversal (a,b,e,f), radial (c,g), and tangential surface (d,h). Scale bar: 200 µm.

Figura 2. Imagens em estereomicroscópio (a, e) e MEV (b-d, f-h) do carvão de *Pinus* sp. (a-d) e *Araucaria angustifolia* (e-h). Superfície transversal (a,b,e,f), radial (c,g) e tangencial (d,h). Barra de escala: 200 µm.

3 – Scientific Name: *Acacia* sp. (Figure 3a-d) – Fabaceae.
Vernacular name: Acácia.
Growth rings: indistinct or distinguished by fiber wall thickness (Figure 3a-b). **Vessels:** diffuse porosity; solitary vessels or in radial multiples of 2-5 (Figure 3b); tyloses common; simple perforate plate (Figure 3c); intervessel pits alternate (Figure 3d). **Axial parenchyma:** scanty, unilateral, vasicentric and confluent (Figure 3b). **Rays:** homogeneous, all cell procumbent (Figure 3c), uni and multiseriate (2-3), not storied (Figure 3d). **Fibers:** thin to thick-walled, non-septate. **Mineral inclusion:** prismatic crystals present in axial and radial parenchyma.

4 – Scientific Name: *Eucalyptus/Corymbia* spp. (Figure 3e-h) – Myrtaceae.
Vernacular name: eucaliptus
Growth rings: indistinct or distinguished by fiber wall thickness (Figure 3e-f). **Vessels:** diffuse porosity; solitary vessels predominant, radial multiples of 2-3 present (Figure 3f); diagonal arrangement (Figure 3e-f); tyloses present; simple perforate plate (Figure 3g); alternate intervessel pits (Figure 3h). **Axial parenchyma:** diffuse, unilateral, vasicentric, confluent and lozenge aliform (Figure 3f). **Rays:** predominant homogeneous, with procumbent cells, occasionally one row of square marginal cells (Figure 3g); uniseriate predominant, biseriate locally present, not storied (Figure 3h). **Fibers:** thin to thick-walled, non-septate. **Mineral inclusion:** prismatic crystals present in axial parenchyma.

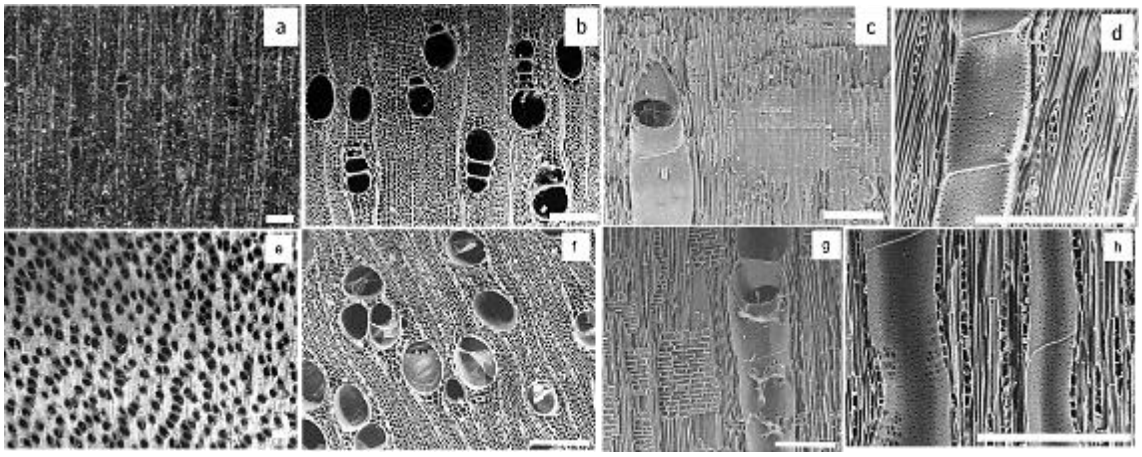

Figure 3. Stereomicroscopic (a, e) and SEM images (b-d, f-h) of charcoal from *Acacia* sp. (a-d) and *Eucalyptus/Corymbia* spp. (e-h). Transversal (a,b,e,f), radial (c,g), and tangential surface (d,h). Scale bar: 200 µm.
Figura 3. Imagens em estereomicroscópio (a, e) e MEV (b-d, f-h) do carvão de *Acacia* sp. (a-d) e *Eucalyptus/Corymbia* spp. (e-h). Superfície transversal (a,b,e,f), radial (c,g) e tangencial (d,h). Barra de escala: 200 µm.

5 – Scientific Name: *Alchornea* sp. (Figure 4a-e) – Euphorbiaceae
Vernacular name: tapiá
Growth rings: few, distinguished by fiber wall thickness (Figure 4a). **Vessels:** diffuse porosity; solitary and radial multiples of 2-4 (Figure 4b), gum deposits present; simple perforate plate (Figure 4d); intervessel pits alternate (figure 4e). **Axial parenchyma:** scanty, unilateral and vasicentric. **Rays:** heterogeneous, body ray cells procumbent with one row of square marginal cells (Figure 4c), uniseriate, not storied (Figure 4e). **Fibers:** thin-walled, non-septate. **Mineral inclusion:** prismatic crystals present in ray or axial parenchyma cells.

6 – Scientific Name: *Casearia* sp. (Figure 4f-i) – Salicaceae
Vernacular name: guaçatonga
Growth rings: few, distinguished by fiber wall thickness (Figure 4f). **Vessels:** diffuse porosity; solitary vessels and radial multiples of 2-3, cluster present (Figure 4g), gum present; simple perforate plate (Figure 4h); intervessel pits alternate (Figure 4i). **Axial parenchyma:** scanty, unilateral. **Rays:** heterogeneous, with procumbent, square and upright cells mixed throughout the ray (Figure 4h); multiseriate (2-3), not storied (Figure 4i). **Fibers:** thin to thick-walled, non-septate. **Mineral inclusion:** crystals presents in rays and axial parenchyma.

7 – Scientific Name: *Cedrela* sp. (Figure 4j-m) – Meliaceae
Vernacular name: cedar
Growth rings: distinguished by semi-ring-porous and axial parenchyma (Figure 4j). **Vessels:** semi-ring-porous, solitary and in radial multiples of 2-3 (Figure 4k); simple perforate plate (Figure 4l); alternate intervessel pits

(Figure 4m). **Axial parenchyma:** marginal, scanty, unilateral and vasicentric. **Rays:** heterogeneous, with body ray cells procumbent and 2-4 rows of upright and/or square marginal cells (Figure 4l); uni and multiseriate (2-3), not storied (Figure 4m). **Fibers:** thin wall, non-septate. **Mineral inclusion:** prismatic crystals present in radial parenchyma.

8 – Scientific Name: *Eugenia* sp. (Figure 4n-q) – Myrtaceae.
Vernacular name: uvaia, guamirim
Growth rings: few, distinguished by fiber cell wall (Figure 4n). **Vessels:** diffuse porosity; solitary vessels predominant, eventually radial multiples 2-3 (Figure 4o); simple perforate plate (Figure 4p); intervessel pits alternate (Figure 4q). **Axial parenchyma:** diffuse-in-aggregates. **Rays:** heterogeneous, with body ray cells procumbent and 1-2 rows of upright and/or square marginal cells (Figure 4p); uni and multiseriate (2-3), not storied (Figure 4q). **Fibers:** thick wall, non-septate. **Mineral inclusion:** prismatic crystals present in axial parenchyma (Figure 4o-p).

9 – Scientific Name: *Hieronyma* sp. (Figure 4r-u) – Phyllanthaceae.
Vernacular name: licurana
Growth rings: distinguished by fiber cell wall (Figure 4r). **Vessels:** diffuse porosity; solitary and radial multiples of 2-3 (Figure 4s); simple perforate plate (Figure 4t); intervessel pits alternate (Figure 4u). **Axial parenchyma:** diffuse. **Rays:** heterogeneous, with procumbent, square and upright cells mixed throughout the ray (Figure 4t); uni and biseriate, not storied (Figure 4u). **Fibers:** thin to thick wall, non-septate.

10 – Scientific Name: *Ilex* sp. (Figure 4v-z) – Aquifoliaceae.
Vernacular name: caúna.
Growth rings: distinguished by axial parenchyma (Figure 4v). **Vessels:** diffuse porosity; solitary and radial multiples of 2-3, cluster present (Figure 4w); scalariform perforate plate (Figure 4x, z); intervessel pits opposite (Figure 4z). **Axial parenchyma:** marginal. **Rays:** heterogeneous, body ray cell procumbent with square/upright marginal cells (Figure 4y); multiseriate, not storied (Figure 4y). **Fibers:** thin to thick wall, non-septate.

11 – Scientific Name: *Ocotea/Nectandra* spp. (Figure 5a-h) – Lauraceae.
Vernacular name: cinnamon
Growth rings: distinguished by fiber wall thickness. (Figure 5a-c). **Vessels:** diffuse porosity; solitary and radial multiples from 2-5 (Figure 5b-c); tyloses present; simple perforate plate (Figure 5e); alternate intervessel pits (Figure 5e). **Axial parenchyma:** scanty, unilateral and vasicentric. **Rays:** heterogeneous, body ray cell procumbent with one or two square/upright marginal cells (Figure 5d-e); uni or multiseriate (2-3), not storied (Figure 5f-h). **Fibers:** thin to thick-walled, septate. **Oil cells:** present in ray margin or associated with axial parenchyma (Figure 5b-d,f,g). **Mineral inclusion:** prismatic crystals in radial or axial parenchyma (Figure 5b).

12 – Scientific Name: *Schinus* sp. (Figure 5i-m) – Anacardiaceae
Vernacular name: aroeira
Growth rings: distinguished by vessel frequency and fiber wall thickness. (Figure 5i-j). **Vessels:** diffuse porosity; solitary and radial multiples from 2-5 (Figure 5j), some clusters; tyloses present; simple perforate plate (Figure 5k); alternate intervessel pits (Figure 5m). **Axial parenchyma:** scanty, unilateral and vasicentric. **Rays:** heterogeneous, body ray cell procumbent with one or two square/upright marginal cells (Figure 5k); uni or multiseriate (2-5), not storied (Figure 5l). **Fibers:** thin to thick-walled, non-septate. **Mineral inclusion:** prismatic crystals in radial parenchyma.

13 – Scientific Name: *Zanthoxylum* sp. (Figure 5n-r) – Rutaceae
Vernacular name: mamica de cadela.
Growth rings: distinguished by fiber wall thickness and marginal parenchyma (Figure 5n). **Vessels:** diffuse porosity; solitary and radial multiples from 2-3 (Figure 5o); tyloses present; simple perforate plate (Figure 5p); alternate intervessel pits (Figure 5r). **Axial parenchyma:** marginal, scanty, unilateral and vasicentric. **Rays:** heterogeneous, body ray cell procumbent with one row of square marginal cells (Figure 5p); uni or multiseriate (2-3), not storied (Figure 5q,r). **Fibers:** thin to thick-walled, non-septate. **Intercellular canals** present in marginal parenchyma lines (Figure 5q).

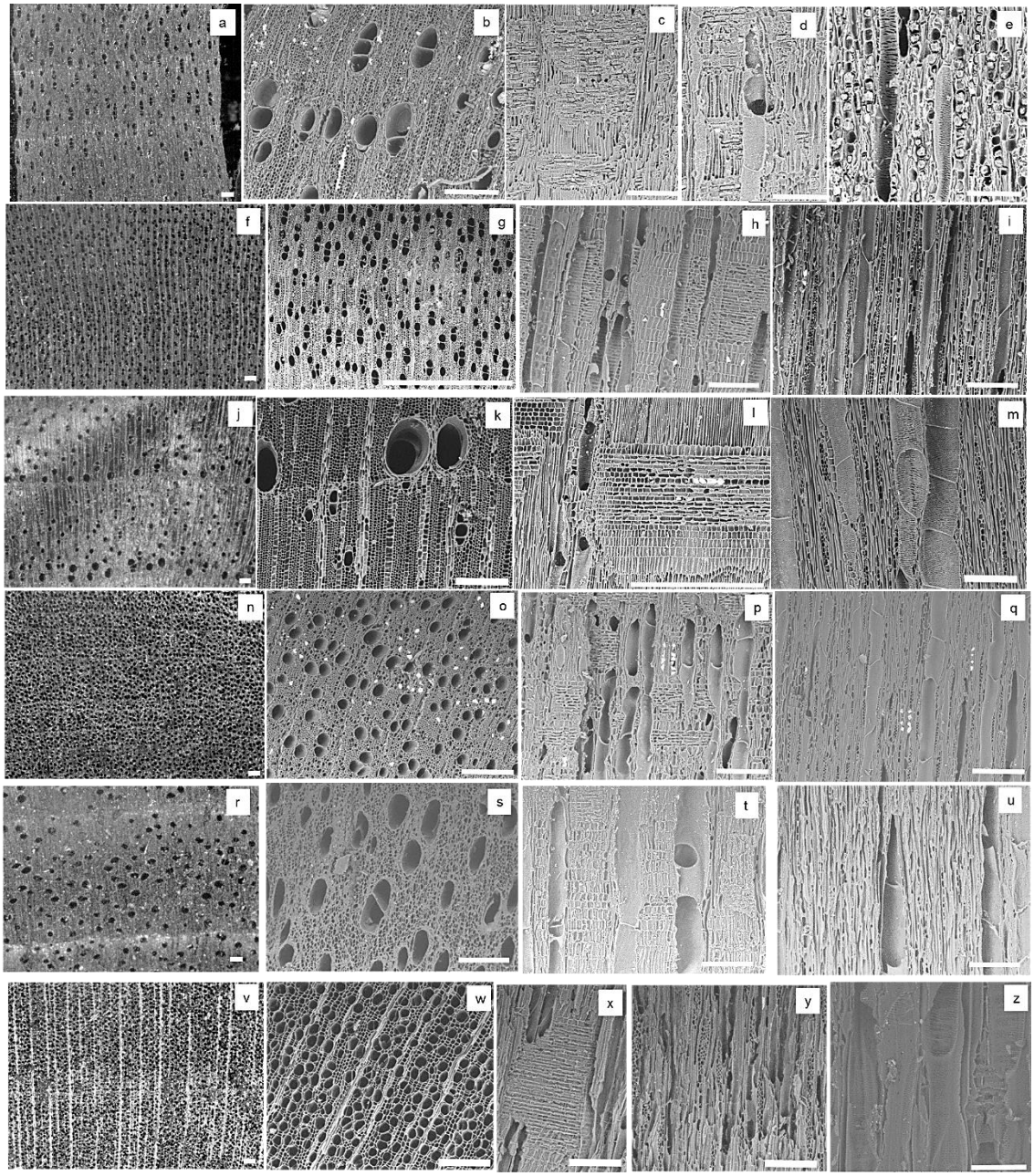

Figure 4. S. Stereomicroscopic (a,f,j,n,r,v) and SEM (b-e, g-i, k-m, o-q, s-u, x-z) images of charcoal from *Alchornea* sp. (a-e), *Casearia* sp. (f-i), *Cedrela* sp. (j-m), *Eugenia* sp. (n-q), *Hieronyma* sp. (r-u), *Ilex* sp. (v-z). Transversal (a,b,f,g,j,k,n,o,r,s,v,w), radial (c,d,h,i,p,t,x), and tangential surface (e,i,m,q,u,y,z). Scale bar: 200 μm.

Figura 4. Imagens em estereomicroscópio (a,f,j,n,r,v) e MEV (b-e, g-i, k-m, o-q, s-u, x-z) do carvão de *Alchornea* sp. (a-e), *Casearia* sp. (f-i), *Cedrela* sp. (j-m), *Eugenia* sp. (n-q), *Hieronyma* sp. (r-u), *Ilex* sp. (v-z). Superfície transversal (a,b,f,g,j,k,n,o,r,s,v,w), radial (c,d,h,i,p,t,x) e tangencial (e,i,m,q,u,y,z). Barra de escala: 200 μm.

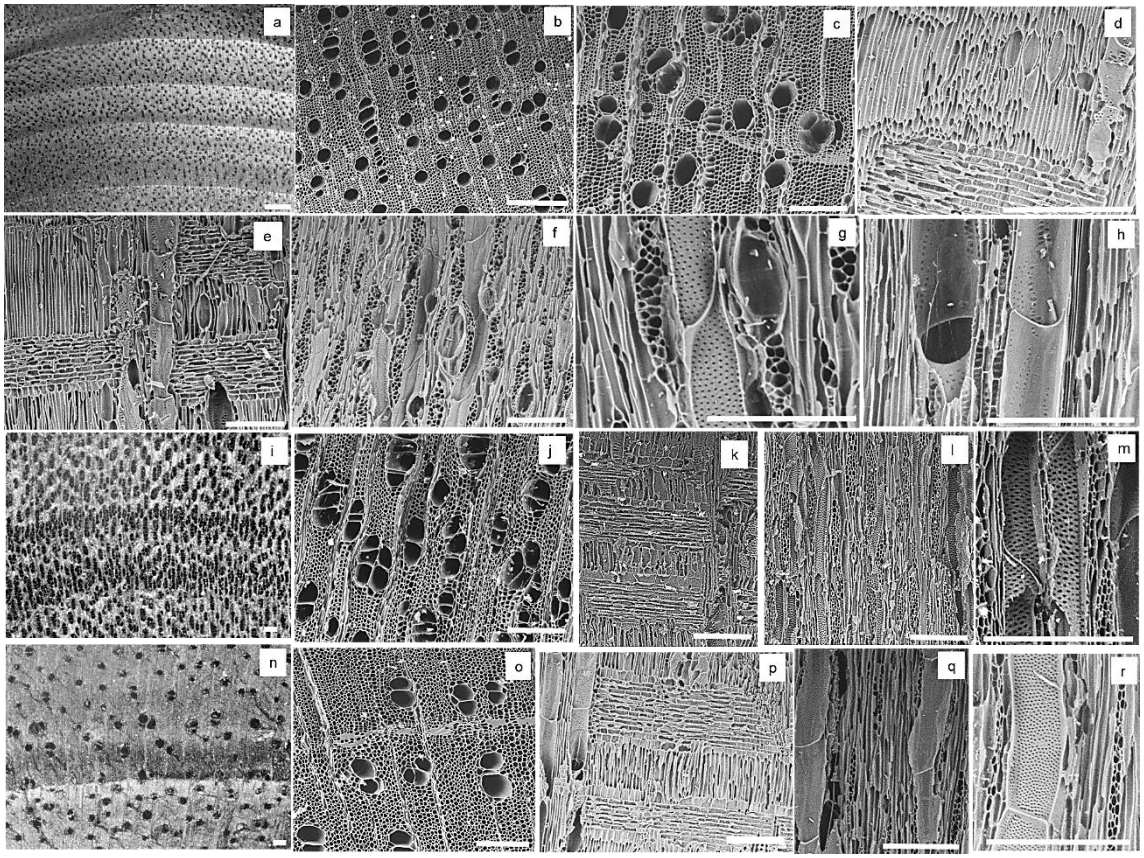

Figure 5. Stereomicroscopic (a,i,n) and SEM (b-h, j-m, o-r) images of charcoal from *Ocotea/Nectandra* sp. (a-h), *Schinus* sp.(i-m)), *Zanthoxyllum* (n-r). Transversal (a,b,c,i,j,n,o), radial (d,e,k,p), and tangential surface (f-h,i,m,q,r). Scale bar: 100 μm (b) 200 μm (a, c-r).

Figura 5. Imagens em estereomicroscópio (a,i,n) e MEV (b-h, j-m, o-r) do carvão de *Ocotea/Nectandra* sp. (a-h), *Schinus* sp.(i-m)), *Zanthoxyllum* (n-r). Superfície transversal (a,b,c,i,j,n,o), radial (d,e,k,p) e tangencial (f-h,i,m,q,r). Barra de escala: 200 μm. BARRA DE ESCALA = 300 μm (d) 200 μm (a-c, e-r).

DISCUSSION

Charcoal samples had the same qualitative anatomical characteristics as the wood, so samples can be discriminated after carbonization (PERDIGÃO *et al.*, 2020). In this study, it was possible to verify that in some packages, the content described on the label was not in accordance with the material identified inside (Table 2). Of the seven packages evaluated (A-G), five stated the wood came from planted forests, of two species (*Eucalyptus/Corymbia* spp. and *Acacia* sp.), and two identified the contents as native forest species. Only three (E, F, G) were in accordance with the label, containing 100% charcoal from *Eucalyptus/Corymbia* spp. Package B, described as *Acacia* sp., had 24.1% *Acacia* and 75.9% *Eucalyptus/Corymbia* charcoal, although there was no unstated inclusion of native species. Package C, described as eucalyptus, consisted of 100% native species, 40.7% of samples from *Ocotea/Nectandra* spp., and 59.3% distributed in the genera *Ilex*, *Casearia*, *Schinus*, *Eugenia* and *Alchornea*. The principal anatomical characteristics that differentiate *Eucalyptus/Corymbia* from native species was the predominance of solitary vessel in diagonal arrangement, presence of tyloses and homogeneous rays (Figure 3). All species in the package C had heterogeneous rays, and some other special features as scalariform perforation plate in *Ilex* (Figure 4) and oil cells in *Ocotea/Nectandra* (Figure 5).

Of the two packages described as containing forest species (A, D), one had 100% native species (D), with charcoal samples from *Ocotea/Nectandra* spp. (67.2%), *Hieronyma* sp (20.4%) and *Araucaria angustifolia* (12.4%). The other package (A), mostly contained charcoal from *Pinus* sp. (77.6%), with the presence of the native genera *Zanthoxylum* (11.2%), *Cedrela* (8.3%) and planted material from *Eucalyptus/Corymbia* (2.9%). *Araucaria angustifolia* and species of the genus *Ocotea/Nectandra* are among the principal components of Araucaria forest (Mixed Ombrophilous Forest - MOF) stands in the Atlantic Forest biome. A member of Araucariaceae family, *Araucaria angustifolia* is the only species of the genus with natural occurrence in Brazil, and both *Araucaria*, *Ocotea/Nectandra* and *Cedrela* are or have species in vulnerable category of the list of threatened species of the

International Union for Nature Conservation (IUCN), so policies for preservation and recuperation are extremely important, along with awareness of all those involved in the production chain, traders and local producers.

Among the botanical families identified in charcoal samples, Lauraceae and Myrtaceae are described by Gasper *et al.* (2013) as having the greatest richness in species occurrence in MOF stands of the Catarinense Planalto (Santa Catarina Highlands) region. Of all the samples evaluated, 66.44% were from planted forests and 33.56% from MOF native species, which were differentiated from *Eucalyptus/Corymbia* and *Pinus* by anatomical characteristics of each genus, permitting identification of illegal commerce. The presence of axial parenchyma, paratracheal vasicentric and sometimes confluent, solitary vessels with small diameter, diagonal arrangement, and mostly uniseriate rays facilitated distinction between eucalyptus and native species (PERDIGÃO *et al.*, 2020). It is important to emphasize that within a genus, some different anatomical characteristics can be observed, due to ecological factors, intraspecific variation and wood age (SOUZA-PINTO; SCHEEL-YBERT, 2021).

Some other macro characteristics were observed. Pieces from the gymnosperm group (araucaria and pinus) had greater tendency to rupture (also the case of eucalyptus samples). In general, ruptures occurred in radial position, in function of wood species or the carbonization process. The prolonged high temperature increases the pressure exerted by the liquid content inside the wood, resulting in cell wall collapse, increased pore volume and formation of fissures and ruptures. These factors reduce the average sizes of the charcoal pieces and increase the number of fine pieces in the packages (ASSIS *et al.*, 2016). Packages with higher percentage of native species and pinus had greater content of fines and smaller pieces. On the other hand, pieces described as eucalyptus had larger and denser pieces that were less friable.

In some samples vitrification was observed, which occurs in function of cell fusion after carbonization. It can be identified by the contrast between bright coloration and darker tones of gray. Also, the presence of fungi was detected in many samples, suggesting the use of wood after long storage or from dead trees.

CONCLUSIONS

- Charcoal anatomic investigation revealed that carbonization did not significantly change the anatomical structure and arrangement, making it possible to distinguish species. Some misrepresentations were observed in the package labels describing the material, including mixture of species from angiosperm and gymnosperm groups.
- We found samples from the following genera, in decreasing frequency: *Eucalyptus/Corymbia*, *Ocotea/Nectandra*, *Acacia*, *Pinus*, *Araucaria*, *Alchornea*, *Casearia*, *Cedrela*, *Eugenia*, *Hieronyma*, *Ilex*, *Schinus* and *Zanthoxyllum.* The predominance of eucalyptus from planted forest was observed, but the presence of the genus *Araucaria*, present on the list of endangered species, indicated the importance of supervision and awareness of local producers and traders.

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