Chemical Evaluation of Two Tropical Wood Species for Use as Grilling Planks

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This research evaluated the possible use of tropical hardwood species (*Myrocarpus frondosus* and *Ocotea porosa*) for grilling plank production. Physical, chemical, and organoleptic properties were evaluated and compared with properties of a well-used wood species for grilling planks, western red cedar (*Thuja plicata*). For chemical analysis, one technique was used: hydrodistillation. Normality tests and analyses of variance (ANOVA) were used for the comparisons between *Thuja plicata* and tropical hardwoods. The results of the organoleptic, chemical, and statistical analyses demonstrated the possibility of using *Myrocarpus frondosus and Ocotea porosa* in grilling plank production.

Keywords: Grilling plank; Apparent density; Brazilian tropical hardwood; Chemical analysis

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INTRODUCTION

Humans have used wood since antiquity for shelters, agricultural implements, and tools. Its use has increased, as it is used in the furniture and food industries (Lahr *et al*. 2016; Christoforo *et al*. 2019; Sthapit 2019). In the food industry, conventional smoking is used to preserve food. This technique enhances the organoleptic process, augmenting the flavor, color, and smell of food (Ledesma *et al*. 2017).

An alternative means of smoking food is the use of grilling planks. In this process, food is in contact with wood planks, which add to the food complex flavors and moisture. In this case, smoking does not aim to improve the food's lifetime but improves its taste and smell. A grilling plank works as a smoker, as the porous wood surface absorbs moisture and then, when taken to a barbecue or heated oven, releases it with an aromatic smoke (Zoschke 2016). The use of wood grilling planks originated with the Native Americans of the Pacific coast, who used western red cedar (*Thuja plicata*) wood planks to prepare foods. These foods, such as salmon and vegetables, are tastier, have a soft flavor, and are not burned. In Europe, wood grilling planks have become widely used in restaurants to enhance flavor and smell (Zoschke 2016; Ledesma *et al*. 2017).

Brazil has the greatest number of wood species in the world (8715 wood species) and a large vegetal cover, being 52% of Brazilian territory (Beech *et al*. 2017; IBÁ 2017). This amount of wood species and vegetal cover includes a unique diversity of aromatic hardwood trees, such as the Anacardiaceae, Annonaceae, and Meliaceae families. The families Cupressaceae, Abietaceae, and Betulaceae are aromatic softwoods. Considering the diversity of chemical components present in these families, it is easy to select wood species with potential for grilling plank production (Lorenzi 1998; Márquez 2004).

To expand the use of Brazilian tropical woods as grilling planks and to advance the food industry, this study examined the chemical and physical characteristics of *Myrocarpus frondosus* Allemão and *Ocotea porosa* wood species and compared their properties with those of *Thuja plicata*, one of the first wood species used to produce grilling planks.

EXPERIMENTAL

The wood species *Thuja plicata*, *Myrocarpus frondosus* Allemão, and *Ocotea porosa* were harvested and stored in homogeneous batches at an equilibrium moisture content of 12%, following the method of Brazilian Standard ABNT NBR 7190 (1997). The batches were deposited at the Wood and Timber Structures Laboratory (LaMEM), University of São Paulo, São Carlos, São Paulo, Brazil.

For the analysis of the organoleptic properties of the wood species, sensory analyses were performed to check the smell, color, taste, grain, and texture, following the parameters described in the literature (Zenid 2019). The wood smell, the main characteristic to be analyzed, was evaluated in three conditions: *in natura*, after immersion in cold water for 60 min, and during use on a heat source (190 °C), to identify smell changes as would occur with their use as grilling planks. Five male LaMEM employees (ages ranging between 30 years and 60 years) qualified the smell of each species using a hedonic scale: bad, poor, fair, good, or excellent.

Evaluation of apparent density (ρ_{ap}) followed the method of the Brazilian standard ABNT NBR 7190 (1997).

For chemical analysis, wood samples were obtained according to TAPPI T 257 cm-85 (1985) and TAPPI T 264 cm-97 (1997). The wood was crushed with mill equipment (Wiley SL-31, Piracicaba, Brazil) to reach small particles passing a 30 mesh. The total extractives were evaluated according to TAPPI T 204 (1997). After extractives were removed, the samples were washed with distilled water and dried in an oven at 100 °C ± 2 °C for 24 h. The extractive content was calculated by mass difference. The resulting extractive-free wood was used to determine Klason lignin content by a modified Klason method (Gomide and Demuner 1986), by the sum of insoluble and soluble lignins. The holocellulose content was determined by the difference between lignin content, ash content, and extractive-free wood mass (Tjeerdsma and Militz 2005). For each chemical analysis, 12 specimens were used, considering hydrodistillation method.

For chemical composition analysis by gas chromatography, one technique was used: hydrodistillation. For the extraction of essential oil from wood species, hydrodistillation was performed, using a graduated Clevenger apparatus protected by aluminum foil. Twenty grams of dry wood of each species was used, ground to 40 mesh weight, with 500 mL of distilled water. All chemical analyses were performed using gas chromatography-mass spectrometry (GC-MS) (Shimadzu GC-2010AF Plus with TQ8040 sequential mass spectrometer detector, Kyoto, Japan), with a capillary column (Rtx-5ms, 30 m × 0.25 mm × 0.25 µm, Restek, Bellefonte, USA).

After qualitative exploratory analysis by GC-MS, the extraction method to be used to obtain a broader chemical profile of the volatile compounds was defined. Extraction was performed with 250 mg of sample moistened with 200 µL of ultra-pure water for 30 min under constant agitation at 80 °C. Then, 1000 µL of the volatile compounds were analyzed by GC-MS (Spectrometer TQ8040 detector), with heating from 40 °C to 120 °C at a rate of 15 °C/min and from 125 °C to 160 °C at a rate of 1 °C/min, remaining at 160 °C for 2 min. The aforementioned capillary columns were used.

To investigate differences in the wood species based on the experimental results for density, contact angle, and percentages of components (extractives, lignin, and ash), an analysis of variance (ANOVA) was performed, with a 5% significance level. Equivalence of averages was the null hypothesis, and non-equivalence (of at least two) was the alternative hypothesis. A p-value equal to or greater than the level of significance (0.05) implies acceptance of the null hypothesis, which is refuted otherwise. To validate the ANOVA, the set of values should be evaluated if present a normal distribution, and the homogeneity of the variances of the groups was investigated, with the aid of the Anderson-Darling (AD) test, considered at the 5% significance level.

RESULTS AND DISCUSSION

Evaluation of Organoleptic Properties of Wood Species

Tables 1 and 2 present the organoleptic properties of the Brazilian tropical hardwoods and their smells in different conditions of grilling planks.

Table 1. Organoleptic Properties of Brazilian Tropical Hardwoods

Wood Species	Color	Texture	Taste	Grain
Myrocarpus frondosus	Dark pinkish brown	Medium to thin	Imperceptible	Wavy and irregular
Ocotea porosa	Dark brown	Medium	Bitter	Direct to reverse

Table 2. Smell in Different Conditions

Wood Species	Natural	Wet	After Heat Source
Myrocarpus frondosus	Excellent	Good	Good
Ocotea porosa	Excellent	Good	Good

Physical and Chemical Properties of Wood Species

Table 3 presents the mean values of physical and chemical properties of the wood species and their coefficients of variation (CV).

As shown in Table 3, the apparent densities of *Myrocarpus frondosus* and *Ocotea porosa* were higher than that of *Thuja plicata*. Both *Myrocarpus frondosus* and *Ocotea porosa* woods presented contact angles less than 90° and less than the reference value of *Thuja plicata* (68.54°), indicating that the surfaces were more wettable than the surface of the reference wood (*Thuja plicata*) (Wu and Baghdachi 2015). It is also important to consider natural characteristics of the wood, such as chemical composition and surface roughness (Adamson and Gast 1997).

Table 3. Physical and Chemical Properties of Wood Species

Property	Wood Species		
	Myrocarpus frondosus	*Ocotea porosa*	*Thuja plicata*
ρ_{ap} (g/cm³) (CV - %)	0.88 (1.32%)	0.66 (3.83%)	0.46 (2.17%)
Mean angle (°) (CV - %)	56.75 (15.54%)	58.75 (2.71%)	68.54 (6.10%)
Extractives (%) (CV - %)	11.99 (6.41%)	16.91 (2.85%)	7.25 (3.66%)
Soluble lignin (%) (CV - %)	3.19 (0.35%)	1.91 (23.07%)	0.27 (3.27%)
Insoluble lignin (%) (CV - %)	30.97 (0.98%)	43.93 (2.88%)	34.16 (0.74%)
Ashes (%) (CV - %)	0.74 (1.00%)	0.22 (12.54%)	0.20 (8.67%)
Holocellulose (%) (CV - %)	53.11 (4.31%)	37.03 (6.57%)	58.12 (1.29%)

Ocotea porosa had the greatest extractive content, indicating more effects on flavor on dishes after wood use as grilling plank. *Myrocarpus frondosus* presented a higher value compared to *Thuja plicata*, affecting food flavor. For information of the chemical compositions of the wood species, the lignin, ash, and holocellulose contents were determined. *Thuja plicata* wood had a holocellulose value of 58.12%, close to that of *Myrocarpus frondosus*. For *Ocotea porosa*, the elevated lignin content led to minor holocellulose content (less than 50%). It is important to highlight that ash and extractive contents may vary due to edaphoclimatic factors (Zau *et al*. 2014).

The result of Anderson-Darling normality test for all analysis presented a p-value greater than 0.05, *i.e*., the results of tropical hardwoods compared with the reference wood species (*Thuja plicata*) presented a normal distribution, validating the ANOVA results.

Tables 4 to 9 display the results of the ANOVA, comparing the tropical wood species in apparent density, contact angle, and contents of extractives, soluble lignin, insoluble lignin, and ash content.

Table 4. Relation between Apparent Densities

Wood Species	p-value
Thuja plicata × *Myrocarpus frondosus*	0.0000
Thuja plicata × *Ocotea porosa*	0.0000

Table 5. Relation between Mean Values of Contact Angle for Wettability

Wood Species	p-value
Thuja plicata × *Myrocarpus frondosus*	0.4201
Thuja plicata × *Ocotea porosa*	0.5838

Table 6. Relation between Extractive Contents

Wood Species	p-value
Thuja plicata × *Myrocarpus frondosus*	0.0000
Thuja plicata × *Ocotea porosa*	0.0000

Table 7. Relation between Soluble Lignin Contents

Wood Species	p-value
Thuja plicata × *Myrocarpus frondosus*	0.0000
Thuja plicata × *Ocotea porosa*	0.0000

Table 8. Relation between Insoluble Lignin Contents

Wood Species	p-value
Thuja plicata × *Myrocarpus frondosus*	0.0001
Thuja plicata × *Ocotea porosa*	0.0000

Table 9. Relation between Ash Contents

Wood Species	p-value
Thuja plicata × *Myrocarpus rondosus*	0.0000
Thuja plicata × *Ocotea porosa*	0.6213

As shown in Table 4, there was a significant difference between the apparent densities of *Myrocarpus frondosus*, *Ocotea porosa*, and *Thuja plicata*. For values of mean contact angle (Table 5), both wood species presented values close to the *Thuja plicata* value. For extractive content, insoluble lignin, and soluble lignin values (Tables 6 to 8), *Myrocarpus frondosus* and *Ocotea porosa* values were significantly different from the reference values (*Thuja plicata*). The ash content of *Myrocarpus frondosus* was significantly different from that of *Thuja plicata*, which did not differ significantly from that of *Ocotea porosa*. The GC-MS results are presented in Tables 10, 11, and 12.

Table 10. Compounds Detected in *Myrocarpus frondosus* Essential Oils Extracted by Hydrodistillation

Compound [b]	I.R. [a]
1,1-dimethyl 3-chloropropane	807
4-methyl-2-pentanol	811
5-methoxy-2-pentanone	1008
Nerolidol	1655

(a) Kovats indexes (KI) on capillary column; (b) compounds listed in evolution order in capillary column; I.R. (infrared spectra interpretation);

Table 11. Compounds Detected in *Ocotea porosa* Essential Oils Extracted by Hydrodistillation

Compound [b]	I.R. [a]	Compound [b]	I.R. [a]	Compound [b]	I.R. [a]
1,1-dimethyl-3-chloropropanol	807	Guaiol	1695	Hinesol	1730
4-methyl-2-pentanol	811	Ledol	1700	τ-cadinol	1736
5-methoxy-2-pentanone	1008	Isoshyobunone	1705	1-Naphthalenol	1740
Eucalyptol	1038	Cubenol	1711	Nerolidol	1746
α-copaene	1474	γ-eudesmol	1715	α-Cadinol	1748
Naftalene	1612	Cubedol	1723	Selina-3,7(11)-diene	1750
Trans-calamenene	1620	α-acorenol	1726	β-bisabolol	1766
α-calacorene	1639			Naphthalene	1768

(a) Kovats indexes (KI) on capillary column; (b) compounds listed in evolution order in capillary column; I.R. (infrared spectra interpretation);

Table 12. Compounds Detected in *Thuja plicata* Essential Oils Extracted by Hydrodistillation, Soxhlet, and Headspace

Compound [b]	I.R. [a]	Compound [b]	I.R. [a]	Compound [b]	I.R. [a]
1,1-dimethyl-3-chloropropanol	807	Terpinen-4-ol	1274	Bicyclo[3.1.1]heptane-2-methanol	1340
2-pentanol	811	α-Terpineol	1284	3-caren-10-al	1361
Norbornane	954	Myrtenol	1297	Cyclohexene-carboxaldehyde	1374
o-cymene	1029	Carvone	1309	Phenol, 2-ethyl-4,5-dimethyl-	1398
2,7,7-trimethylbicyclo [2.2.1]heptan-2-ol	1218	2-methyl-3-phenylpropanal	1337	Benzoic acid, 2,4,5-trimethyl-	1420
Endo-borneol	1263	Furadane	1514	Acetovanillone acetate	1426
Nerolidol	1656			Benzoic acid, 4-(1-methylethyl)-	1477

(a) Kovats indexes (KI) on capillary column; (b) compounds listed in evolution order in capillary column; I.R. (infrared spectra interpretation of chemical compound);

As shown in Table 10, from the *Myrocarpus frondosus* extraction by hydrodistillation, it was possible to identify four compounds.

The results of the GC-MS tests presented in Table 11 showed that the species *Ocotea porosa* contained compounds identified in all the extraction techniques used. From hydrodistillation for *Ocotea porosa*, 23 compounds were identified, the majority of them, in decreasing order: guaiol (100%), ledol (24.69%), and τ-cadinol (50.92%).

The results of the GC-MS tests presented in Table 12 showed that, through hydrodistillation for *Myrocarpus frondosus*, 20 compounds were identified, the most of them being, in decreasing order: myrtenol (100%), α-terpineol (49.76%), and terpinen-4-ol (26.24%).

The percentages presented represent chemical content of each compound. The higher content stands out for higher percentage (100%) and so decreasing for other contents.

Nerolidol was present in all wood species. Nerolidol is allowed by the United States Food and Drug Administration (FDA) to be used in the food industry as a food flavoring agent. Then, it supports the possible use of tropical wood species as grilling planks in the food industry, which can improve foods' preparations (Chan *et al*. 2016; Ušjak *et al*. 2017; Azzi *et al*. 2018).

Also, otherwise *Thuja plicata*, *Myrocarpus frondosus*, and *Ocotea porosa* did not contain, according chemical analysis, toxic volatile chemical compounds such thujone, which is toxic for human being even at low levels (SCE 2002). This absence enables their use as grilling planks, with similar apparent density of a well-known wood specie already used for grilling planks and satisfactory organoleptic properties for use on planks. Also, a lower apparent density for *Myrocarpus frondosus* and *Ocotea porosa* contributes a good impregnation process during plank manufacture and lower weight, reducing costs along productive process and transportation.

CONCLUSIONS

1. Chemical analysis supported the possible use of *Myrocarpus frondosus* and *Ocotea porosa* tropical hardwoods for production of grilling planks. They have elevated amounts of extractives, which are important for organoleptic properties, such as taste and smell.
2. Apparent density of *Myrocarpus frondosus* and *Ocotea porosa* were close to the reference value of *Thuja plicata* wood specie, being interesting the wood species with lower apparent density.
3. Gas chromatography indicated the presence of nerolidol, used as a flavoring agent in several foods, in all wood species and the absence of the compound thujone, which is toxic for humans. In addition, organoleptic properties were satisfactory supporting the use of *Myrocarpus frondosus* and *Ocotea porosa* wood species for grilling plank production.

REFERENCES CITED

ABNT NBR 7190 (1997). "Projeto de estruturas de madeira," Associação Brasileira de Normas Técnicas, Rio de Janeiro, Brazil.

Adamson, A. W., and Gast, A. P. (1997). *Physical Chemistry of Surfaces*, 6th Ed., John Wiley & Sons, Inc., New York, NY, USA.

Azzi, J., Auezova, L., Danjou, P.-E., Fourmentin, S., and Greige-Gerges, H. (2018). "First evaluation of drug-in-cyclodextrin-in-liposomes as an encapsulating system for nerolidol," *Food Chemistry* 255, 399-404. DOI: 10.1016/j.foodchem.2018.02.055

Beech, E., Rivers, M., Oldfield, S., and Smith, P. P. (2017). "GlobalTreeSearch: The first complete global database of tree species and country distributions," *Journal of Sustainable Forestry* 36(5), 454-489. DOI: 10.1080/10549811.2017.1310049

Chan, W.-K., Tan, L. T.-H., Chan, K.-G., Lee, L.-H., and Goh, B.-H. (2016). "Nerolidol: A sesquiterpene alcohol with multi-faceted pharmacological and biological activities," *Molecules* 21(5). DOI: 10.3390/molecules21050529

Christoforo, A. L., Aquino, V. B. d. M., Wolenski, A. R. V, Araujo, V. A. D., and Lahr, F. A. R. (2019). "Evaluation of the *Peltophorum vogelianum* Benth. wood species for structural use," *Engenharia Agrícola* 39(6), 763-768. DOI: 10.1590/1809-4430-eng.agric.v39n6p763-768/2019

Gomide, J. L., and Demuner, B. J. (1986). "Determinação do teor de lignina em material lenhoso: Método Klason modificado," *O Papel*, 47(8), 36-38.

IBÁ (2017). *Relatório 2017*, Indústria Brasileira de Árvores (IBÁ), Brasilia, Brazil.

Lahr, F. A. R., Arroyo, F. N., Almeida, T. H. d., Almeida Filho, F. M. d., Mendes, I. S., and Christoforo, A. L. (2016). "Full characterization of *Erisma uncinatum* Warm Wood Specie," *International Journal of Materials Engineering*, 6(5) 147-150. DOI: 10.5923/j.ijme.20160605.01

Ledesma, E., Rendueles, M., and Díaz, M. (2017). "Smoked food," in: *Current Developments in Biotechnology and Bioengineering: Food and Beverages Industry*, A. Pandey, M. Á. Sanromán, G. Du, C. R. Soccol, and C.-G. Dussap (eds.), Elsevier, Amsterdam, The Netherlands, pp. 201-243. DOI: 10.1016/B978-0-444-63666-9.00008-X

Lorenzi, H. (1998). *Árvores Brasileiras: Manual de Identificação e Cultivo de Plantas Arbóreas Nativas do Brasil*, Plantarum, São Paulo, Brazil.

Márquez, M. D. R. (2004). *Plantas Aromaticas: Tratado de Aromaterapia Científica*, Kier, Buenos Aires, Argentina.

SCE. (2002) "Opinion of the Scientific Committee on Food on Thujone" [Internet]. *European Comission*. Brussels, Belgium; Available from: http://ec.europa.eu/food/fs/sc/scf/out120_en.pdf

Sthapit, E. (2019). "Memories of gastronomic experiences, savoured positive emotions and savouring processes," *Scandinavian Journal of Hospitality and Tourism* 19(2), 115-139. DOI: 10.1080/15022250.2017.1402702

TAPPI T 204 (1997). "Solvent extractives of wood and pulp," TAPPI Press, Atlanta, GA, USA.

TAPPI T 257 cm-85 (1985). "Sampling and preparing wood for analysis," TAPPI Press, Atlanta, GA, USA.

TAPPI T 264 cm-97 (1997). "Preparation of wood for chemical analysis," TAPPI Press, Atlanta, GA, USA.

Tjeerdsma, B. F., and Militz, H. (2005). "Chemical changes in hydrothermal treated wood: FTIR analysis of combined hydrothermal and dry heat-treated wood," *Holz als Roh- und Werkstoff* 63(2), 102-111. DOI: 10.1007/s00107-004-0532-8

Ušjak, L., Petrović, S., Drobac, M., Soković, M., Stanojković, T., Ćirić, A., and Niketić, M. (2017). "Edible wild plant *Heracleum pyrenaicum* subsp. *orsinii* as a potential new source of bioactive essential oils," *Journal of Food Science and Technology* 54(8), 2193-2202. DOI: 10.1007/s13197-017-2610-z

Wu, L., and Baghdachi, J. (eds.) (2015). *Functional Polymer Coatings: Principles, Methods, and Applications*, John Wiley & Sons, Inc., Hoboken, NJ, USA. DOI: 10.1002/9781118883051

Zau, M. D. L., Vasconcelos, R. P. d., Giacon, V. M., and Lahr, F. A. R. (2014). "Avaliação das propriedades química, física e mecânica de painéis aglomerados produzidos com resíduo de madeira da Amazônia - Cumaru (*Dipteryx odorata*) e resina poliuretana à base de óleo de mamona," *Polímeros* 24(6), 726-732. DOI: 10.1590/0104-1428.1594

Zenid, G. J. (2019). *Identificação e Grupamento das Madeiras Serradas Empregadas na Construção Civil Habitacional na Cidade de São Paulo*, Master's Dissertation, Universidade de São Paulo, Piracicaba, Brazil. DOI: 10.11606/D.11.2019.tde-20191218-140415

Zoschke, H. (2016). "Grillen & BBQ, Sonstiges," (http://pepperworld.com/mit-der-grillplanke-grillen-wie-die-profis-teil-1), Accessed 6 Jan 2021.

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