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Physico-Chemical Characterization of Tropical Wood Species for Use and Production of Grilling Planks

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The objective of this research is to evaluate the possibility of use of tropical hardwood species (*Amburana cearensis* and *Cedrella fissilis*) for grilling plank production. Physical, chemical and organoleptic properties were evaluated and compared with properties of a well-used wood specie for grilling plank across Europe and USA, Western Red Cedar (*Thuja plicata*). For chemical analysis, three techniques were used: hydro distillation, soxhlet and head space. Normality test and analysis of variance (ANOVA) were used for the comparison between *Thuja plicata* and tropical hardwoods. The results of organoleptic, chemical and statistical analysis demonstrated the possibility of use of *Amburana cearensis* and *Cedrella fissilis* on grilling plank production, with no volatile compound present in these species being toxic, low apparent density and Nerolidol presence, chemical compound used as flavoring agent, enabling their use as grilling planks.

Keywords: *grilling plank, apparent density, Brazilian tropical hardwood, chemical analysis.*

1. Introduction

For many ages, wood has been used for several purposes on human life, since agricultural implements, shelters and tools. Also, it is used nowadays for furniture, civil construction for structural and non-structural purpose, paper and pulp industry, sports equipment and food industry[1-3].

For an appropriate use of wood on food industry, flavor and ingredients industry have developed many advances on flavors, smells and enzymes in order to develop new products and new production process[3-6].

Considering food industry, one of the most used process is the conventional smoking. It is characterized by food exposure to smoke and their derivatives to conserve food. In present time, smoking process is highlighted due the organoleptic characteristic inherent to the smoking process, such as flavor, color and smell[7].

Another form to smoke food is using grilling planks. In this process, food is in contact with wood planks, adding to the food complex flavors and humid texture. Smoking, in this case, do not aim to improve food lifetime, but improve their taste and smell at their consumption. Grilling plank works as a smoker as the porous surface of the wood absorbs moisture and then, when taken to a barbecue or heated oven, releases it together with an aromatic smoke. Food is cooked slowly and, as a result, becomes tastier, has a pleasant aroma and is less susceptible to loss of nutrients[8].

The use of grilling planks has become a popular method to smoke several meals and finalize many dishes, such salmon, fish and vegetables, not cooked directly on fire. Native americans from Pacific coast realized that dishes cooked on Western Red Cedar (*Thuja plicata*) wood planks were tastier, soft flavor and not burned when consumed. Also, on

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Europe, it has become very used on restaurants considering the benefits for flavor and smell[7,8].

However, the existence of the compound thujone, a terpene and related to a menthol, which occurs naturally in plants, trees (bark and leaves), in the essential oil of *Thuja plicata* (Western red cedar), cedar white and other herbs such as *Arthemisia absinthium* (wormwood). In extremely high doses, thujone is dangerous and can cause seizures. Thujone-induced seizures are epileptiform in character and are preceded by general vasodilation, a drop in artery pressure, decreasing heart rate and increasing respiratory amplitude[9].

Brazil owns the largest number of wood species in the world (8715 wood species) and a large vegetal cover, being 52% of Brazilian territory[10,11]. This amount of wood species and vegetal cover displays a unique diversity of aromatic trees from hardwoods group, such as Anacardiaceae, Anonaceae, Fabaceae, Lamiaceae, Araceae, Meliaceae families. For sotfwoods, the families Cupressaceae, Abietaceae and Betulaceae are considered aromatic plants. Considering the diversity of chemical components present on these families, it is eased the selection of wood species with potential for grilling planks production[12,13].

Aiming to contribute to the development of food industry and the use of grilling planks made of Brazilian native wood species, the present research presents the physical and chemical characterization of *Amburana cerarensis* Smith. and *Cedrella fissilis* Vell. wood species and compare their properties with *Thuja plicata* wood specie, one of the pioneer wood specie used to produce grilling planks in the world.

2. Materials and Methods

The wood species *Thuja plicata*, *Amburana cearensis* and *Cedrella fissilis* were harvested and stored in homogeneous batches on equilibrium moisture of 12%, following the disposed on Brazilian Standard ABNT NBR 7190[14]. The batches were deposited on Wood and Timber Structures Laboratory (LaMEM), University of São Paulo, São Carlos, São Paulo, Brazil.

For the analysis of organoleptic properties of wood species, sensory analysis were performed to check smell, color, taste, grain and texture, following the parameters described on the literature[15]. For wood smell evaluation, main characteristic to be analyzed, three steps were performed: (i) *in natura*, (ii) after immersion on cold water for 60 minutes; (iii) during use on heat source (190°C), identifying smell changes as with their use as grilling planks. Five LaMEM employees of male sex and ages ranging between 30 and 60 years, qualified the smell of each specie using the hedonic scale: bad, poor, fair, good or excellent. Figure 1 presents the heat source used.

For evaluation of apparent density (ρ_{ap}) and the measure of contact angle and surface angle by the sessile drop method followed the disposed on the Brazilian Standard ABNT NBR 7190, using specimens of 5 cm x 3 cm x 2 cm, with the major dimension on the longitudinal direction of the fibers. For each test, 12 specimens were used for each wood specie.

For sessile drop method, it was used a KSV Cam 200 goniometer, which photographs the drops immediately after contact with the sample surface. The pattern used for time lapse between photographs: (i) in the interval between 0 and 5 seconds, 50 photos, one photo every 48 ms and (ii) in the interval 0 to 30 seconds, one photo every second. The 3 µl volume was standardized for all solvent drops used on the wood surface. The solvents used were water, diiodomethane, formamide and ethylene glycol. Using the KSV contact angle measurement system program, the wettability graph was produced and the 0,5 s time was defined as the standard for calculating the contact angle with the surface of each sample.

For chemical analysis, the samples of wood were obtained according TAPPI Standard[16,17]. The wood was crushed mill equipment type Willey SL-31 to reach small particles passing a 30 mesh. The total extractive were evaluated by standard TAPPI 204 cm-97[16], checking the volume of extractives on the samples. These samples were extracted in two phases in a soxhlet with a mix hexane/ethanol for 8 hours (1:1 v/v); water for 8 hours and boiling distilled water for 30 minutes. After extractives remove, the samples were washed with distilled water and dried in oven at 100 °C ± 2 °C for 24 hours. The extractive content was calculated by mass difference. The resulting extractive-free wood was used to determine Klason lignin content by modified Klason method[18], by the sum of insoluble and soluble lignin. The holocellulose

Figure 1. Heat source used for sensory analysis.

content was determined by difference between lignin content and extractive-free wood mass[19]. Figure 2 illustrates the soxhlet extractor.

The ash content of the wood was obtained after calcination of the crucible. The material resulting from the filtration of the soluble lignin was taken to the oven for drying. 1,00 g of the sample was removed, which was crushed, dried and placed in a crucible, the mass of which was disregarded for calculation purposes. The crucible with the sample was subjected to calcination, exposing the material to 525 °C in a muffle furnace, for the period of 4 hours, with a heating rate of 100 $°C.h^{-1}$. The calculation of the ash content of the wood was determined by the amount of inorganic material in the sample after its calcination, that is, complete burning of the material. To calculate the percentage of ash in the material, the quotient between the mass of the residual material and the initially dry mass is made, multiplying the result by 100.

Also, for chemical composition analysis by gas chromatography, three techniques were used: hydro distillation, soxhlet and head space. For the extraction of essential oil from wood species, hydro distillation was performed, using a graduated Clevenger apparatus protected by aluminum foil. 20 g dry wood of each species were used, ground to 40 mesh weight, and 500 ml of distilled water.

The collection of essential oil extracted from each species was performed after 2.5 hours of boiling, using a graduated pipette. After collecting the samples, they were placed in hermetically sealed tubes, protected by aluminum foil and stored in a refrigerated place. The extractions were carried out in triplicates by species. The extracted essential oils were analyzed by GC-MS (Shimadzu gas chromatograph GC 2010AF Plus with TQ8040 Sequential Mass Spectrometer detector), with capillary column Rtx-5ms 30m x 0.25 mm x 0.25 µm RESTEK. The method used was heating rates 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 minutes.

Soxhlet extraction was carried out after establishing what would be the best solvent for the extraction of the species' essential oil. In the first stage, a mix of the five wood species was prepared with 30 g dry of each species and mixed uniformly for extraction. For extraction, three usual solvents were chosen: ether, ethyl acetate and ethanol. Each extraction was performed in a soxhlet extraction apparatus with a 500 ml flat-bottomed flask, using 10 g of the species mix, wrapped in filter paper, with 150 ml of the respective extraction solvent. After 4 hours of extraction, the extract was removed and the solvent was removed under reduced pressure. The flat-bottomed flasks were placed in the chapel to reduce the solvent and the samples were then transferred to capped flasks and sealed. The extracts were analyzed by GC-MS (Shimadzu gas chromatographic GC 2010AF Plus with TQ8040 Sequential Mass Spectrometer detector), With capillary column Rtx-5ms 30m x 0.25mm x 0.25 µm; RESTEK Split mode 10. Figure 3 shows the gas chromatographic detector.

For head space analysis, it was initially necessary to carry out exploratory tests to define which parameters would be used for the best extraction. The tested parameters were: variation of the sample mass (250 mg and 500 mg), extraction time (20 minutes and 40 minutes), variation of heating temperature (60 °C and 80 °C), wet sample (addition of 200 µl of ultra-pure water) and dry sample. The extracts were analyzed by GC-MS (Shimadzu gas chromatographic GC 2010AF Plus with TQ8040 Sequential Mass Spectrometer detector), With capillary column Rtx-5ms 30m x 0.25mm x 0.25 µm; RESTEK Split mode 10.

After qualitative exploratory analysis by GC-MS, the extraction method to be used in order to obtain a broader chemical profile of volatile compounds was defined. Extraction was performed with 250 mg of sample moistened with 200 µl of ultra-pure water, for 30 minutes, under constant agitation at 80 °C. Then, 1000 µl of the volatile compounds were analyzed by GC-MS (Shimadzu GC 2010AF Plus gas chromatograph with Sequential Mass Spectrometer TQ8030 detector), with heating rate 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 minutes, capillary column Rtx-5ms 30 mx 0.25 mm x 0.25 um; RESTEK.

Chemical analysis was well decribed above in order to enhance the comprehension of fully chemical characterization of wood species. Also, if in a barbecue test there was wood carbonization, it could be explained by the low ash content.

Figure 2. Soxhlet extractor.

Figure 3. Chromatographic gas detector.

Since this low content would indicate low inorganic content and high energy release.

To investigate wood species, based on the results obtained experimentally for density, contact angle and percentages of extractives, lignin and ash, analysis of variance (ANOVA) was performed, considered at the level of 5% significance, consisting of the equivalence averages as a null hypothesis and non-equivalence (at least two) as an alternative hypothesis. By formulating the hypotheses, P-value equal to or greater than the level of significance (0.05) implies accepting the null hypothesis, refuting it otherwise.

To validate ANOVA, the normality in the distribution of the values of the properties considered and the homogeneity of the variances of the groups were investigated, with the aid of the Anderson-Darling [AD] test, considered at the 5% significance level. For the formulation of the tests, P-value greater than 5% implies that the responses come from populations with normal distribution and that the variances of the groups are equivalent, thus validating the ANOVA model.

When ANOVA between species was found to be significant, the Tukey multiple comparison test (contrast test) was used next, making it possible to group the levels of the investigated factor and thus compare each species of tropical wood with the species of the genus *Thuja*.

3. Results and Discussions

3.1 Evaluation of organoleptic properties of wood species

On Tables 1 and 2, organoleptic properties of Brazilian tropical hardwoods and aromatic degrees on different uses as grilling planks, with results on hedonic scale: bad, poor, fair, good or excellent.

Physical and Chemical Results of Wood Species

Table 3 presents the mean values of physical and chemical for wood species characterization and coefficient of variation (Cv).

Observing the values of apparent density on Table 3, *Amburana cearensis* and *Cedrella fissilis* density are close to the reference value of apparent density of *Thuja plicata*. For the value of contact angle, *Amburana cearensis* wood presented a value above 90°, indicating the surface is less wettable than the reference wood (*Thuja plicata*)[20]. *Cedrella fissilis* presented the lowest value of contact angle, being the surface more wettable. Also, it is important consider natural characteristics of wood, such chemical composition and surface rugosity[21].

Considering the values of extractive content, *Amburana cearensis* wood presented an elevated value, indicating a more pronounced flavor on wood after use. *Cedrella*

Table 1. Organoleptic properties of Brazilian tropical hardwoods.

Wood Specie	Color	Texture	Taste	Grain
Amburana cearensis	Reddish brown	Smooth	Sweet	Straight and Irregular
Cedrella fissilis	Beige pink	Coarse	Imperceptible	Straight

Table 2. Smell on Different conditions.

Wood Specie	Natural	Wet	After Heat Source
Amburana cearensis	Excellent	Excellent	Excellent
Cedrella fissilis	Good	Good	Good

Table 3. Physical and Chemical results for Wood Species.

Properties	Wood Species		
	Amburana cearensis	*Cedrella fissilis*	*Thuja plicata*
ρ_{ap} (g/cm^3)	0.56	0.50	0.46
Cv (%)	4.72	6.98	2.17
Mean Angle	95.81	43.37	68.54
Cv (%)	12.94	18.96	6.10
Extractives (%)	19.70	5.20	7.25
Cv (%)	0.51	15.04	3.66
Soluble Lignin (%)	1.62	0.84	0.27
Cv (%)	2.03	5.27	3.27
Insoluble Lignin (%)	31.39	29.25	34.16
Cv (%)	0.57	0.87	0.74
Ashes (%)	0.97	0.76	0.20
Cv (%)	3.75	4.84	8.67
Holocellulose (%)	46.32	63.95	58.12
Cv (%)	2.34	1.57	1.29

fissilis presented a lower value compared to *Thuja plicata*. For chemical composition of wood species, checking lignin, ashes and holocellulose contents. *Thuja plicata* wood presented a value for holocellulose of 58.12%, close to the obtained for *Cedrella fissilis*. For *Amburana cearensis*, the elevated value of lignin content led to minor holocellulose content, below 50% value. It is important highlight that ashes and extractives content may vary due edaphoclimatic factor[22].

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

For the comparison of the wood species, Tables 4 to 9 displays the results for ANOVA comparing the results of tropical wood species for apparent density, contact angle, extractive, soluble lignin, insoluble lignin and ashes content.

Observing the Table 4, there is significant difference between the apparent density of *Amburana cearensis* and *Thuja plicata*. For *Cedrella fissilis,* the difference is not significant. For values of mean contact angle and extractive content, both wood species presented values significantly different from *Thuja plicata*.

Considering the values of soluble lignin, the value of *Amburana cearensis* were significantly differently from *Thuja plicata*, which not occurred for *Cedrella fissilis*. For insoluble lignin and ashes content, there were significantly difference between bot wood species and *Thuja plicata*.

The results of gas chromatography tests CG-MS are presented on Tables 10, 11 and 12.

The results of the CG-MS assays presented in Table 10 show that, based on the hydrodistillation extraction of the species *Amburana cearensis*, it was possible to identify 10 compounds, with the majority compounds, of greater relative area, being, in decreasing order: Nerolidol (100%), followed by trans-calamenene (28.48%) and 2-Hexanol (16.21%). Through soxhlet extraction, it was possible to identify a greater number of compounds (15), the majority of which are in decreasing order: ButylatedHydroxytoluene (100%), Cinnamic acid (88.07%) and Nerolidol (87.64%). The major compound identified through headspace extraction was 1-Propyne (100%); the seven other compounds identified had a relative area below 10%.

It can also be observed that there was a difference in the identified compounds depending on the extraction technique used. Comparing the hydrodistillation and soxhlet techniques, 4 common compounds were identified: Nerolidol, Butylated Hydroxytoluen, α-Muurolene and α-Calacorene. In the headspace extraction, no compound in common with those of the other techniques was identified.

The results of the CG-MS assays shown in Table 11 show that, from the hydrodistillation extraction of *Cedrela fissillis*, it was possible to identify 12 compounds. The major compounds detected by hydrodistillation are, in decreasing order: Nerolidol (100%), τ-Cadinol (53.58%) and α-Cadinol (45.47%). In soxhlet extraction, 16 compounds were identified, the major ones, in decreasing order: Nerolidol (100%), Butylated Hydroxytoluene (48.49%) and τ-Cadinol (47.36%). Through headspace extraction, the largest number of compounds (24) was identified, the major ones being, in decreasing order: δ-Cadinene (100%), α-Copaene (71.24%) eα- Calacorene (48.07%). It is worth noting that the Nerolidol compound was the major component in both hydrodistillation and soxhlet extraction, but it was not identified in headspace extraction.

Some compounds appear in all extractions. They are: α- Copaene, α-Calacorene, τ-Cadinol and α-Cadinol. The compounds Aromadendrene, δ-Cadinene, α-Cedrene and Cadalene are only identified in soxhlet and headspace extractions.

The results of the CG-MS tests presented in Table 12 show that, through hydrodistillation, 19 compounds were identified, the majority of them being, in decreasing order: Myrtenol (100%), α-terpineol (49.76%) and Terpinen -4-ol (26.24%). In soxhlet extraction, only seven compounds were identified, with Cuminicacid (100%) being the majority. The other compounds presented very low relative area. It is also possible to identify the Nerolidol component in soxhlet extraction, which was not found in any of the other techniques. Finally, in headspace extraction, 25 compounds were identified, the three major ones, in decreasing order: 1-brine (100%), Myrtenol (69%) and Camphene (67.07%).

The compounds identified simultaneously in all extraction techniques were: Mirtenol, α-terpineol and carvone. Between

Table 4. Relation between apparent densities.

Wood Species	p-value
Thuja plicata x *Amburana cearensis*	0.0016
Thuja plicata x *Cedrella fissilis*	0.1579

Table 5. Relation between mean value for contact angle for wettability.

Wood Species	p-value
Thuja plicata x *Amburana cearensis*	0.0127
Thuja plicata x *Cedrella fissilis*	0.0207

Table 6. Relation between extractive content.

Wood Species	p-value
Thuja plicata x *Amburana cearensis*	0.0000
Thuja plicata x *Cedrella fissilis*	0.0072

Table 7. Relation between soluble lignin content.

Wood Species	p-value
Thuja plicata x *Amburana cearensis*	0.0001
Thuja plicata x *Cedrella fissilis*	0.0527

Table 8. Relation between insoluble lignin content.

Wood Species	p-value
Thuja plicata x *Amburana cearensis*	0.0003
Thuja plicata x *Cedrella fissilis*	0.0000

Table 9. Relation between ashes content.

Wood Species	p-value
Thuja plicata x *Amburana cearensis*	0.0000
Thuja plicata x *Cedrella fissilis*	0.0072

Table 10. Compounds detected in *Amburana cearensis* essential oils extracted by hydrodistillation, soxhlet and headspace.

Hydrodistillation		Soxhlet		Headspace	
Compound[b]	I.R.[a]	Compound[b]	I.R. a	Compound[b]	I.R. a
1,1-Dimetil-3-cloropropanol	809	4-metil-2-pentanol	811	1-Propyne	60
2-Hexanol	812	hexanoic acid	981	2-Nitro-1- propanol	70
α-Curcumeno	1578	2-metoxi-fenol	1091	Ethyl Acetate	96
α-Muurolene	1600	Nonanal	1107	4-methyl-3-Pentenal	733
Butylated Hydroxytoluene	1610	octanoic acid	1255	4,4-Dimethyl-2-cyclopenten-1- one	777
γ-Muurolene	1612	nonanoic acid	1378	Octane	798
trans- calamenene	1620	Benzodihydropyrone	1485	Hexanal	803
α-Calacorene	1638	cinnamic acid	1537	1,4-cineol (SI)	1018
E-Nerolidol	1658	α-Muurolene	1599		
Ledol	1700	Butylated Hydroxytoluene	1610		
		trans-calamenene	1620		
		α-Calacorene	1638		
		Nerolidol	1658		
		isovalinic acid	1665		
		α-Cubebeno	1722		

[a] Kovats indexes (KI) on capilar column Rtx-5 MS. [b] Compounds listed on evolution order on capillary column Rtx-5 MS.

Table 11. Compounds detected in *Cedrella fissilis* essential oils extracted by hydrodistillation, soxhlet and headspace.

Hydrodistillation		Soxhlet		Headspace	
Compound[b]	I.R.[a]	Compound[b]	I.R. [a]	Compound[b]	I.R.[a]
1,1-dimetil-3-cloropropanol	807	α-Cubebene	1466	1,4-Cineole	1018
4-metil-2- Pentanol	811	α-Copaene	1474	δ-EIemene	1430
5-Metoxi-2-Pentanona	1008	Aromadendrene, dehydro-	1504	α-Cubebene	1442
α-Copaene	1474	α-Bergamotene	1528	Y-langene	1460
Naphthalene	1620	Butylated Hydroxytoluene	1610	α -Copaene	1471
α-Calacorene	1639	δ-Cadinene	1618	β-Elemene	1488
Nerolidol	1658	α-Calacorene	1639	Aromadendrene, dehydro-	1504
Copaene	1723	Nerolidol	1658	α-Santalene	1515
τ-Cadinol	1736	Ledol	-	α-Bergamotene	1528
1-Naphthalenol	1726	Caryophyllene oxide	1696	α-Guaiene	1535
α-Cadinol	1748	α-Cedrene	1720	Epi-β-Santalene	1540
Naphthalene	1768	1-Naphthalenol	1726	Humulene	1548
		τ-Cadinol	1736	Alloaromadendrene	1556
		δ-Cedrol	1738	α-Guaiene	1584
		α-Cadinol	1745	Ledene	1591
		Cadalene	1765	α-Muurolene	1597
				γ-Muurolene	1609
				δ-Cadinene	1618
				α-Calacorene	1636
				α-Cedrene	1720
				τ-Cadinol	1733
				δ-Cedrol	1738
				α-Cadinol	1745
				Cadalene	1765

[a] Kovats indexes (KI) on capilar column Rtx-5 MS.[b] Compounds listed on evolution order on capillary column Rtx-5 MS.

Table 12. Compounds detected in *Thuja plicata* essential oils extracted by hydrodistillation, soxhlet and headspace.

Hydrodistillation		Soxhlet		Headspace	
Compound[b]	I.R.[a]	Compound[b]	I.R.[a]	Compound[b]	I.R.[a]
1,1-dimethyl-3-cloropropanol	807	4-Terpineol	1177	1-Propyne	60
2-Pentanol	811	p-Cymen-8-ol	1183	Acetonitrile	70
Norbornane	954	α-Terpineol	1189	2-Bornene	906
o-Cymene	1029	Myrtenol	1297	α-Pinene	937
2,7,7-trimethylbicyclo [2.2.1]heptan-2-ol	1218	Carvone	1307	Camphene	951
endo-Borneol	1263	Cuminicacid	1398	β-Cymene	974
		Nerolidol	1656		
Terpinen-4-ol	1274			3-Carene	1013
α-Terpineol	1284			1,4-Cineole	1018
Myrtenol	1297			o-Cymene	1027
Carvone	1309			D-Limonene	1032
2-Methyl-3-phenylpropanal	1337			Eucalyptol	1037
Bicyclo[3.1.1]heptane-2-methanol,	1340			o-Isopropenyltoluene	1086
3-Caren-10-al	1361			p-Cymenene	1094
Cyclohexene-carboxaldehyde	1374			β-Linalool	1107
Phenol, 2-ethyl-4,5-dimethyl-	1398			exo-2,7,7-trimethylbicyclo [2.2.1]heptan-2-ol	1218
Benzoicacid, 2,4,5-trimethyl-	1420			L-Pinocarveol	1233
Acetovanillone acetate	1426			endo-Borneol	1261
Benzoicacid, 4-(1-methylethyl)	1477			cis-Verbenol	1264
Furadane	1514			Terpinen-4-ol	1271
				Ocimenol	1281
				α-Terpineol	1286
				Myrtenol	1294
				Carvone	1307
				Isothymolmethylether	1333
				3-Caren-10-al	1359

[a] Kovats indexes (KI) on capilar column Rtx-5 MS. [b] Compounds listed on evolution order on capillary column Rtx-5 MS.

hydrodistillation and headspace, two more common compounds were found: Terpinen-4-ol and o-Cymene.

It is important highlight that different chemical compounds were found for each extraction method (hydrodestillation, soxlet and headspace) due to effectiveness of each method. Sohxlet and hydrodistillation are more similar in the essential oil extraction method, which differentiates them from headspace. Thus, the capillary column ends up identifying different compounds.

One component present in all wood species is Nerolidol. This substance is allowed by the United States Food and Drugs Administration (FDA) to be used on food industry as food flavoring agent. Then, it enhances the possibility the use of tropical wood species as grilling planks on food industry, improving dishes preparation[23-25].

Also, otherwise *Thuja plicata*, *Amburana cearensis* and *Cedrella fissilis* did not presented, according chemical analysis, toxic volatile chemical compounds such Thujone, toxic for human being even at low levels[9], enabling 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 *Amburana cearensis* and *Cedrella fissilis* contributes a good impregnation process during plank manufacture and lower weight, reducing costs along productive process and transportation.

It is important highlight this research is original, with no precedent work treating the production of grilling planks using tropical hardwoods, analyzing organoleptic and chemical properties.

4. Conclusions

The results of the present research enable us to conclude:

- Apparent density of *Amburana cearensis* and *Cedrella fissilis* were close to the reference value of *Thuja plicata* wood specie, being interesting the wood species with lower apparent density;

- Chemical analysis indicated the possibility the use of tropical hardwoods for grilling planks production, with elevated amount of extractive content, important for organoleptic properties, such taste and smell;

- From gas chromatography results, the presence of Nerolidol, used as flavoring agent on several foods, on all wood species and the nonexistence of Thujone chemical compound, toxic for humans, and organoleptic properties were satisfactory, indicating the possibility of use of *Amburana cearensis* and *Cedrella fissilis* wood species for grilling plank production.

5. References

1. Christoforo AL, Aquino VBM, Wolenski ARV, Araujo VAD, Lahr FAR. Evaluation of the *Peltophorum vogelianum* Benth. wood species for structural use. Eng Agric. 2019;39(6):763-8. http://dx.doi.org/10.1590/1809-4430-eng.agric.v39n6p763-768/2019.
2. Lahr FAR, Arroyo FN, Almeida TH, Almeida FM Fo, Mendes IS, Christoforo AL. Full characterization of *Erisma uncinatum* Warm Wood Specie. Int J Mater Eng. 2016;6(5):147-50. http://dx.doi.org/10.5923/j.ijme.20160605.01.
3. Sthapit E. Memories of gastronomic experiences, savoured positive emotions and savouring processes. Scand J Hosp Tour. 2019;19(2):115-39. http://dx.doi.org/10.1080/15022250.2017.1402702.
4. Bilal M, Iqbal HMN. State-of-the-art strategies and applied perspectives of enzyme biocatalysis in food sector: current status and future trends. Crit Rev Food Sci Nutr. 2020;60(12):2052-66. http://dx.doi.org/10.1080/10408398.2019.1627284.
5. Soares JF, Prá VD, Kempka AP, Prestes RC, Tres MV, Kuhn RC, et al. Cellulases for food applications. In: Gupta VK, editor. New and future developments in microbial biotechnology and bioengineering. Amsterdam: Elsevier; 2016. p. 201-8. http://dx.doi.org/10.1016/B978-0-444-63507-5.00018-6.
6. Ben Akacha N, Gargouri M. Microbial and enzymatic technologies used for the production of natural aroma compounds: synthesis, recovery modeling, and bioprocesses. Food Bioprod Process. 2015;94:675-706. http://dx.doi.org/10.1016/j.fbp.2014.09.011.
7. Ledesma E, Rendueles M, Díaz M. Smoked food. In: Larroche C, Sanroman M, Du G, Pandey A, editors. Current developments in biotechnology and bioengineering. Amsterdam: Elsevier; 2017. p. 201-43. http://dx.doi.org/10.1016/B978-0-444-63666-9.00008-X.
8. Zoschke H. Grillen & BBQ, Sonstiges [Internet]. 2016 [cited 2021 Jan 6]. Available from: http://pepperworld.com/mit-der-grillplanke-grillen-wie-die-profis-teil-1
9. European Commission. Opinion of the Scientific Committee on Food on Thujone [Internet]. Brussels: European Comission; 2002. [cited 2021 Jan 6]. Available from: http://ec.europa.eu/food/fs/sc/scf/out120_en.pdf
10. Beech E, Rivers M, Oldfield S, Smith PP. GlobalTreeSearch: the first complete global database of tree species and country distributions. J Sustain For. 2017;36(5):454-89. http://dx.doi.org/10.1080/10549811.2017.1310049.
11. IBÁ: Indústria Brasileira de Árvores. Relatório IBÁ [Internet]. Brasília; 2017. 80 p. [cited 2021 Jan 6]. Available from: http://iba.org/images/shared/Biblioteca/IBA_RelatorioAnual2017.pdf
12. Marquéz MDR. Plantas aromáticas: tratado de aromaterapia cientifica. 1. ed. Buenos Aires: Kier; 2004. 224 p.
13. Lorenzi H. Árvores brasileiras: manual de identificação de plantas arbóreas nativas do Brasil. 2. ed. Nova Odessa: Plantarum; 1998.
14. ABNT: Associação Brasileira de Normas Técnicas . NBR 7190: projeto de estruturas de madeira. Rio de Janeiro: ABNT; 1997. 107 p.
15. Zenid GJ. Identificação e grupamento das madeiras serradas empregadas na construção civil habitacional na cidade de São Paulo [dissertação]. Piracicaba: Universidade de São Paulo; 2019 [cited 2021 Jan 6]. Available from: https://teses.usp.br/teses/disponiveis/11/11149/tde-20191218-140415/
16. TAPPI: Technical Association of the Pulp and Paper Industry. Test methods: T 264 cm- 97: preparation of wood for chemical analysis. Atlanta: TAPPI Press; 1997.
17. TAPPI: Technical Association of the Pulp and Paper Industry. TAPPI test methods: T 257 cm-85: sampling and preparing wood for analysis. Atlanta: TAPPI Press; 1985.
18. Gomide JL, Memuner BJ. Determinação do teor de lignina em material lenhoso: método Klason modificado. O Papel. 1986;47(8):36-8.
19. Tjeerdsma BF, Militz H. Chemical changes in hydrothermal treated wood: FTIR analysis of combined hydrothermal and dry heat-treated wood. Holz Roh- Werkst. 2005;63(2):102-11. http://dx.doi.org/10.1007/s00107-004-0532-8.
20. Wu L, Baghdachi J, editors. Functional polymer coatings. 1st ed. Hoboken: John Wiley & Sons; 2015. 352 p. http://dx.doi.org/10.1002/9781118883051.
21. Adamson AW, Gast AP. Physical chemistry of surfaces. Hoboken: John Wiley & Sons; 1997. 808 p.
22. Zau MDL, Vasconcelos RP, Giacon VM, Lahr FAR. 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. 2014;24(6):726-32. http://dx.doi.org/10.1590/0104-1428.1594.
23. Chan WK, Tan LTH, Chan KG, Lee LH, Goh BH. Nerolidol: a sesquiterpene alcohol with multi-faceted pharmacological and biological activities. Molecules. 2016;21(5):529. http://dx.doi.org/10.3390/molecules21050529.
24. Ušjak L, Petrović S, Drobac M, Soković M, Stanojković T, Ćirić A, et al. Edible wild plant Heracleum pyrenaicum subsp. orsinii as a potential new source of bioactive essential oils. J Food Sci Technol. 2017;54(8):2193-202. http://dx.doi.org/10.1007/s13197-017-2610-z.
25. Azzi J, Auezova L, Danjou PE, Fourmentin S, Greige-Gerges H. First evaluation of drug-in-cyclodextrin-in-liposomes as an encapsulating system for nerolidol. Food Chem. 2018;255:399-404. http://dx.doi.org/10.1016/j.foodchem.2018.02.055.