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Radial variation in extractives content of Amazonian wood *Alexa grandiflora*

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Abstract
The extractives are organic constituents present in small quantities in the wood, but affects various characteristics such as color, smell, specific gravity and durability. The extractive content may vary within the tree, however for Amazon woods this knowledge is little reported. The present study reports the variation of extractive content in radial direction of *Alexa grandiflora* Ducke wood from the Tapajos National Forest. The samples were collected from discs of three trees in five different positions of each disc in the radial direction. The extraction was conducted in cold-water, hot-water and ethanol/toluene solvent. The amount of extractives differ between positions. The extractives content decrease in radial direction, with a higher occurrence near the pith, followed by the heartwood and in less quantity in the sapwood.
Keywords: within-tree variation, soluble extractives, hot-water extractives, Melancieira.

Introduction

The extractives are considered non-structural organic constituents of wood, usually representing a small portion of this (Petersen 1984; Fengel e Wegener 1989; Rowell 2005). It content and composition may vary among species or within-tree of same species (Silvério 2008; Goulart et al. 2012; Hsing 2013; Mori et al. 2009; Yang 2011). This variability might be higher in old-grown trees, like the most commercial Amazon woods, specifically from the pith to the bark.

According to Santos (2008) such wood components form, among others, in response of injuries or due to a defense mechanism and, even presenting low levels related to other structural constituents, can influence the use of wood for certain purposes due to the effects in some wood characteristics as color, smell and mechanical strength (Sjostrom 1993; Pettersen 1984; Rowell 2005).

Some wood physical properties, such as density, equilibrium moisture content and swelling/shrinkage are also affected by the extractives (Jankowsky 1979; Bodig e Jayne 1982; Chagas et al. 2014; Soares et al. 2015). In addition, the extractives also influence in the natural resistance against termites and fungi (Pettersen 1984; Suprapti 2010; Syofuna et al. 2012; Luchtemberg 2013). So, it is important to know how this content varies within-tree, allowing to define woods or parts thereof more suitable for exterior applications, for example. The use of woods with low natural durability will requires higher costs, repositions and, consequently, a more native forestry resources (Paes et al. 2013).

The *Alexa grandiflora* Ducke, popularly known as melancieira, presents wood with a basic density of 660 kg.m^{-3} and a light yellow coloring. The wood have a great workability and it can be used to furniture manufacturing (Gomes et al. 2012). In addition, it is one of the most abundant species in Amazonian region (Salomão et al. 2007; Côrrea et al. 2015). The studies on its chemical characteristics can support the substitution of the species overly harvest and which, in some cases, are in a extinction process.

According to Hsing (2013), wood is a heterogeneous material which has great variations in its chemical, physical and anatomical compositions due to factors such as age, genetic material and environmental conditions. These variations within-tree may occur both towards the basis to top and toward the pith to bark. Considering the importance of extractives and considering the heterogeneous wood characteristics, it is necessary others studies about the presented species, studies which aim evaluate chemical properties of these species, making possible relate them with indications of a proper final use.

The present study reports the extractives content of *Alexa grandiflora* Ducke wood, and the radial distribution in different position from the pith to the bark.

Materials and methods

Study area

The studied material were collected in the Tapajós National Forest (FNT), which is located among the coordinates 2º45 and 4º10’S and 54º45’ and 55º30’W, Belterra, Pará, Brazil. The local vegetation is classified as dense tropical rain forest, with predominance of large trees (Veloso et al. 1991).

Sampling procedure

Three trees of *Alexa grandiflora* Ducke (melancieira) with DBH>50cm were randomly selected from primary forest and botanically identified by Brazilian Agricultural Research Corporation (EMBRAPA). One disc were cut from each tree at two meters of basis height.

Samples of five positions (0%, 25%, 50%, 75% and 100%) in a radial direction from pith (0%) to bark (100%) were used, with three repetitions from each position, results in fifteen samples per tree. The samples were pulverized and the fraction the passed through a 40-mesh screen but retained on a 60-mesh screen was conditioned at 20ºC and 65% relative humidity.

Extractives content determination and data analysis

The samples were extracted in a soxhlet apparatus according to standards of American Society for Testing and Materials (ASTM) in hot water (100 to 105°C) for three hours and in cold water (23 ±2°C) for 48 hours, with 4 to 6 cycles per hour (ASTM, 2013b). For determination of total extractives content was considered all the extractives soluble in ethanol/ toluene (1:2) for 08 hours (ASTM, 2013a).

For the evaluation and comparison of data, it were realized normality and homogeneity tests where, after positive, it was made the analysis of variance (ANOVA) and the Scott-Knott average comparison test were performed to verify the significance among the five positions.

Results and discussion

We observe a highest concentration of extractives in region close to the pith (0%) for all solvents (Tab.1). The

extractives content varied according to the type of used solvent, presenting average values of 4.76, 5.96 and 8.42% for extraction in cold water, in hot water and in alcohol/ toluene, respectively (1:2).
The contents were higher than observed by Zanuncio et al. (2014), using the same methodology, for wood extractives of six species of *Eucalyptus* and *Corymbia,* finding average values of 4.13% for cold water extraction, and 7.96% for total extraction (1:2).

Table 1. Averages of extractives content obtained for the analyzed positions.

Position	AF (%)	AQ (%)	ET (%)
0%	6.20±3.17a	10.14±0.52a	13.08±1.30a
25%	5.65±1.02a	7.36±2.27b	10.06±0.43b
50%	5.40±1.07a	5.21±1.27c	7.04±0.78c
75%	4.74±1.65a	4.84±1.85c	6.50±0.30c
100%	1.78±0.42b	2.25±0.74d	5.44±1.11d
Average	4.76	5.96	8.42
CV (%)	36.58	24.87	10.34

The averages followed by the same letter in the same column do not differ among themselves by the Scott-Knott ($p \leq 0.05$) test. Where AF= extractives in cold water, DP = standard deviation; AQ = extractives in hot water; ET = ethanol: toluene (1:2); CV = vary coefficient.

For the positions from 0 to 75% for cold water extraction there was no significant difference, highlighting that they correspond to the heartwood region of *Alexa grandiflora* and the 100% position correspond to sapwood region according to visual classification. Cold water extraction can remove inorganic salts, sugars, low molecular weight polysaccharides, cycloses, cyclitois, and some phenolic substances (Sarto and Sansigolo, 2010).

For the hot water extraction, it was observed a significant variation in relation to the samples position, varying from 2.25 to 10.14%, with an average of 5.96, being higher than 4.31% observed by Morais et al. (2005) for hot water extraction in *Pinus oocarpa* wood.

It was noted that the greater values were observed in the regions closer to the pith. The difference can be related to the radial variation in the deposition of starch in wood, since, according to Oliveira et al. (2005), the hot water, besides extracting soluble compounds in cold water, extracts starch.

For alcohol/toluene extraction (1:2), it was observed a similar behavior of the hot water extraction, with greater values in the pith region. However, the magnitude of extractives content was considerably higher reaching 13.08%. The total extraction includes all extractives soluble in these solvents, include polyphenols, fatty acids, fats, resins, ethers, waxes, unsaponifiable substances, pigments and others substances (Oliveira et al., 2005; Sarto e Sansigolo, 2010; ASTM 2013).

Silvério et al. (2006), when comparing the use of ethanol/toluene (1:2) and others solvents in the determination of extractive in eucalyptus wood, observed the higher efficiency of this solvent for different types of extractive and for the required time for its removal. This fact can be explained by the alcohol polarity, which is determinant in solubilization of determined chemical compounds present in wood (Sjöström and Alén, 2013). Moreover, Jardim et al. (2017) explains the effectiveness in combining a polar solvent with an apolar one, in this case the alcohol/ toluene, in the quantification of the extractives of biomass.

In the studies realized by Paes et al. (2013) and Brito et al. (2014), it was verified that the quantity of substances extracted were greater in the heartwood when compared to the sapwood region, such difference that could be elucidated by the higher occurrence of these substances in the heartwood. Moreira et al. (2016) state that the heartwood creates a condition of extractive deposits due of its loss of transport capacity.

Santos (2008) cites that, generally, the occurrence of extractives in wood is greater in the bark followed by the heartwood, and it can be considered negligible in the sapwood region. However, it is verified in the present study that the quantities of extractives obtained for the position inherent to sapwood region cannot be considered negligible, with extractives occurring above 5% depending on the solvent used.

A decrease in extractives concentration in wood radial direction of *Alexa grandiflora* Ducke was observed (Fig.2). Vidaurre et al. (2011) observed a decrease tendency in extractives content with age increase and a highest content of extractives in juvenile wood when compared to mature wood of *Pinus radiata*. Trugilho et al. (1996) affirm that exists a tendency of stabilization in the values of total extractives with tree's age for *Eucalyptus saligna* wood.

Albino et al. (2012) observed opposite behavior for *Eucalyptus grandis* wood at 18-year-old, with an increase in extractive content in the radial direction, from 6.10% to 8.84%. Reis et al. (2012) cited the wood variability can be explained by several factors, such as weather, soil, site, genetic factors, silvicultural treatments and mainly by the wood chemical and anatomical structure. For Castro et al. (2015) that this fact can be related to the material origin and Santana and Okino (2007) also attribute this to the age of collected trees. Therefore, the difference of extractives content behavior observed in this present study and Albino et al. (2012) can be related to some of the aforementioned factors, showing that the amount of extractives can be quiet variable among species.

The *Alexa grandiflora* wood's presented values close to those observe for others Amazonian species. Bila (2014) and Kobylarz (2016) observe values of total extractives of 8.36% and 8.16% for *Inga paraensis* and *Eschweilera coriaceae*. Santana and Okino (2007) observed averages ranged from 0,6% to 17,3% for different amazon species.
Thus, it is verified that most efficient method for the extractives quantification for the studied species was the alcohol/toluene extraction, due to the percentage quantity of extracted compounds. According to Sarto and Sansigolo (2010), the above mentioned solvent is able to solubilize, waxes, greases, resins, oils and others compounds, whereas water solubilizes only saults, simple carbohydrate, low molecular weight polysaccharides and some phenolic substances.

Conclusion

The extractives content differs significantly between positions towards radial direction. The highest content of extractives in *Alexa grandiflora* wood is located close to the pith, followed by the heartwood and, in lower amount, the sapwood.

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