INFLUENCE OF VAPORIZATION AND IMPREGNATION OF SILVER NANOPARTICLES ON THE DRYING RATE OF *Eucalyptus pellita* F. MUELL.

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Resumo

Influência da vaporização e de impregnação de nanopartículas de prata na taxa de secagem da madeira de Eucalyptus pellita F. Muell. O objetivo deste estudo foi avaliar o efeito da vaporização e da impregnação de nanopartículas de prata nas propriedades da madeira de *Eucalyptus pellita*. Para tanto, amostras de três regiões radiais da madeira, oriundas de três árvores, foram separadas em madeiras vaporizadas durante 12 e 24 h e madeiras imersas em solução de nanopartículas de prata com e sem aplicação prévia de vácuo (750 mmHg). Análises anatômicas, físicas e químicas da madeira foram realizadas a fim de avaliar o efeito dos tratamentos. A taxa de secagem da madeira foi determinada em faixas de umidade antes e após o ponto de saturação das fibras (PSF). Em geral, os tratamentos não modificaram as características anatômicas, densidade e permeabilidade da madeira nas três regiões radiais; contudo, a vaporização por 24h reduziu o teor de extrativos totais na madeira. Esses resultados contribuíram para que ganhos na taxa de secagem antes e após o ponto de saturação das fibras fossem obtidos. O efeito da impregnação de nanopartículas com vácuo e os dois períodos de vaporização resultaram nas maiores taxas de secagem, sendo que o tempo de 24h de vaporização obteve as melhores médias entre todos os tratamentos. A vaporização por 24h e a impregnação de nanoparticulas apresentaram efeitos positivos na taxa de secagem.
Palavras-chave: secagem da madeira, nanotecnologia, permeabilidade da madeira.

Abstract

The aim of this study was to evaluate the effect of vaporization and impregnation of silver nanoparticles on the *Eucalyptus pellita* wood properties. For that, samples of three radial regions of the wood from three trees were vaporized for 12 and 24 hours and later on, they were immersed in solution of silver nanoparticles with and without application of vacuum (750 mm.Hg). Anatomical, physical and chemical analyzes of the wood were carried out in order to evaluate the effect of the treatments. The drying rate of the wood was determined in moisture bands before and after the fiber saturation point. Generally, the treatments did not modify the anatomical characteristics, permeability, and wood density in the three radial regions; however, the vaporization for 24h reduced the total extractive content in the wood. These results contributed in obtaining gains in the drying rate before and after the fiber saturation point. The effect of impregnation of nanoparticles with vacuum preceded by two periods of vaporization resulted in higher drying rates and the time of 24h stood out, resulting in the best averages among all treatments. The impregnation of nanoparticles had positive effects on the drying rate.
Keywords: wood drying, nanotechnology, wood permeability.

INTRODUCTION

During the drying process it is necessary to minimize the undesirable effects to the factors related to the wood, such as the thermal diffusivity, the related physical properties with the dimensional movement, the drying tensions, density and wood permeability (TARMIAN *et al*., 2012; LUIS *et al*., 2017).

Drying rate is an important variable in wood behavior control during the drying process. In general, eucalyptus wood presents low permeability which is responsible for the significant humidity gradient and consequently tension formation that complicates its drying process (ELEOTÉRIO *et al.*, 2014; REZENDE *et al.*, 2015). According to Bal and Bektas (2012), vaporization is a treatment possibility that modifies wood hygroscopic properties. The application of elevated temperatures initially causes carbohydrates degradation, mainly hemicelluloses and amorphus regions of cellulose chains (LUÍS *et al*., 2017), and by extended periods and higher temperatures. It modifies completely the wood permeability due to the appearance of microcracks in cellular wall (CALONEGO *et al*., 2014).

Vapor treatment allows drying process optimization due to permeability increase, resulting from pits and vessels clearance (ALEXIOU *et al.*, 1990). In such a way, the permeability is directly related to anatomical structures (BARAÚNA *et al*. , 2014), as well as with the balance of the water entrance and exit from the wood and the easiness of preservative fluid penetration (BREADS *et al.*, 2013; GAO *et al*., 2015).

The wood impregnation with silver nanoparticles has revealed a worthwhile process, promoting alterations in wood characteristics internally and superficially, providing, in some cases, improvements in durability as well as physical and mechanical properties (DASHTI *et al*., 2012; TAGHIYARI *et al*., 2012; MONTAZER, ALIMOHAMMADI, 2012; TAGHIYARI *et al.*, 2014; TAGHIYARI *et al*., 2015; GAO *et al*., 2015).

Regarding what was exposed, it was evaluated the hypothesis that vaporization and impregnation of wood with silver nanoparticles promote modifications in the drying process, influenced by the material chemistry and anatomy. Thus, the objective of this experiment was to evaluate the wood technological behavior of *Eucalyptus pellita* F. Muell. treated previously with vapor and impregnated with silver (Ag) nanoparticles.

MATERIAL AND METHODS

Delineation, collection and preparation of the material

For the acquisition of wood samples, three 22-year-old trees of *Pellita Eucalyptus* had been cutted, planted 3 x 2m of spacing in a population located in the campus of the Rural Federal University of Rio De Janeiro - UFRRJ in Seropédica, state of Rio de Janeiro, Brazil (Lat 22.7604°, Lon 43.7078°). Samples of these trees were deposited in the xylotheque of the Forest Institute of the Rural Federal University of Rio de Janeiro, under the registration number: 7711, 7712 and 7713. After the cutting, the first log of each tree, with 4.5 m of length, was conducted to the primary cut with the assistance of vertical band saw in order to obtain planks with 3 inch radial thickness. After that, they were parted in pieces with the following dimentions: 33 x 2.5 x 5 cm (length x thickness x width), enclosing three radial positions from the pith towards the vascular cambium, denominated: Heartwood/Sapwood Transition Zone (HST), Intermediate Heartwood (ITH) and Internal Heartwood (INH)

The samples of each region were distributerd in three groups: 1) No treatment samples; 2) samples treated only with nanoparticles; and 3) samples treated only with vapor (Table 1), totalizing 5 treatments per radial position. Vaporizarion was applied in the wood pieces in two constant periods with 12h and 24h of duration.

Tabela 1. Delineamento experimental aplicado para as três regiões radias da madeira: Transição Cerne/Alburno (TCA), Cerne Intermediário (CIT) e Cerne Interno (CIN).

Table 1. Experimental design applied to the three radiated regions of the wood: Heartwood/Sapwood Transition (HST), Intermediate Heartwood (ITH) and Internal Heartwood (INH).

Radial position	Vaporization (h)	Impregnation with Nano Ag	Vacuum Application	Code
External (HST) Intermediate (ITH) Internal (INH)	N	N	-	Control Sample
	N	Y	Y	WV
	N	Y	N	NV
	12	N	-	Vap12
	24	N	-	Vap24

Nano Ag (silver nanoparticles); N = no; Y = yes; WV = nanoparticles impregnation with vacuum; NV = nanoparticles impregnation without vacuum; Vap12 = wood vaporization for 12h; Vap24 = wood vaporizarion for 24h.

Vaporization and impregnation of nanopartículas

Initially, the wood was vaporized using an horizontal autoclave with capacity of 0.18 m³ approximately, providing temperature and pressure control. The maximum temperature applicated was 98°C ± 2 and the relative humidity was 90% ± 5 proceeding from vapor generation through a boiler with the capacity of 12 Kg vapor/hour.

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The sample impregnation with silver nanoparticles (NPs) was performed through simple immersion, using an acrylic chamber with 45 x 40 x 50 cm of dimention. The wood immersion in destilled water with silver NPs in suspension (22 ppm) occurred with and without initial vacuum application of 750 mmHg for five minutes. This solution consisted by silver NPs with size between 5 and 20 nm, which characterizes as colloid with exceptional stability and purity, i. e., without surfactants presence, avoiding precipitates formation. The wood remained submerged in the solution for 30 min.

Anatomical analyses

For the anatomical analyses, a sample of 2 cm of thickness was removed from the extremity of each treatment parts. Later, this sample was cutted in 1 x 1 cm blocks for observation in Scanning Electron Microscope (SEM), aiming at the verification of nanoparticles impregnation and vascular contents and the obtention of transversal histological cuts in slide microtome.

Semi-permanent blades were prepared to the measurement of the tangential diameter of the vessels through digital images captured by a monochromatic camera connected to the trilocular microscope.1 The used procedures followed the International Association of Wood Anatomy Committee (IAWA) (1989) recomendations.

At first, the frequency of the vessels (tissue.mm^{-2}) also followed the methodology proposed by IAWA (1989). For that, digitalized images from the transversal face of cilindrical samples were used, being prepared to the air permeability test.

Chemical analyses

For the determination of total extratives content, the procedures described by Abreu *et al*. (2006) were used, following an eluotropic sequence with the solvents: cyclohexane, acetate and methanol. Each extraction was performed during six hours. After each extraction the solution was placed in a rotary evaporator (Rotavapor) so it was possible, using vacuum and heat, to concentrate and weigh the extracted portion in each type of solvent. The contents of lignin (soluble and insoluble in acid), uronic acid, acetyl group and carbohydrates (xylan, mannan, galactan, arabinan and glucan) were determined according to the procedures proposed by Tappi T222 (2000), Scott (1995), Solar *et al*. (1987) and Wallis *et al*. (1996). Additionally, chemical analyses were performed in the vaporized and without treatment samples.

Wood drying rate

After vaporization and nanoparticle impregnation treatment, all samples went through a drying process in climatized room with temperature at 20°C ± 2 and relative humidity at 65% ± 5. During the drying process, at each 2 hours the mass and respective dimentions (width, thickness and length) of all samples were measured. This process was used in order to register water mass loss and it was 54 days long until the obtention of 15% humidity.

According to the water mass loss registered after each 24 hours, it was determined the wood drying rate with the following equation:

$$Dr = \frac{Mwater}{t.A}$$

in which: Dr = drying rate for a determined humidity interval (kg/cm^2.h), Mwater = water mass removed from wood (kg), t = drying time (h), A = evaporation area (cm²).

The wood drying rate in each treatment was calculated using the area of a prism to the humidity intervals varying from saturated until 30%, from saturated until 15%, and from 30% until 15% humidity, according to the formula:

$$TA = 2(a.b + a.c + b.c)$$

in which: TA = total area (cm²); a, b and c = prismatic sample faces' measures (cm).

Wood density and permeability

After the drying process, the prismatic samples were lathed in order to obtain cylindrical pieces with 2.0 cm of diameter. Then, they were sectioned in 5.0 cm to obtain the sample to density and permeability test.

The volume of cylindrical samples was obtained through Mercury (Hg) imertion in order to determine the aparent density (15%) of all samples already in balance and, after the permeability test, the basic density through the gravimetric method was performed. Mercury temperature was measured after each eight weighing with a digital thermometer (±0,2°C).

To the permeability test the same dimentions described by other authors were adopted (BARAÚNA *et al.*, 2014; TAGHIYARI *et al.*, 2012; TAGHIYARI *et al.* 2015). To the final dimentipons, the samples had their longitudinal face waterproofed with maritime varnish with polyurethane base (two applications). Four flow meters

linked in series in the following scales and sequences were used to determine the wood permeability regarding atmospheric air: 0.04 to 0.5 LPM (Liters per Minute); 0.2 to 2.5 LPM; 0.4 to 5.0 LPM and 2.0 to 25.0 LPM. Then, in one of the flow meters series extremities it was connected a vacuum pump, and on the other extremity the samples were connected. The following equation was used for the determination of air wood permeability:

$$Kg = \frac{\text{Q. L. Pi}}{\text{A. }\Delta\text{P. Pa}}$$

in which, Kg = gas permeability ($cm^3/cm.atm.s$), Q = gas flow volume that travels the species (cm^3/s), L = length of sample (cm); Pi = entrance pressure, the one from the environment (atm); A = transversal section area (cm^2); ΔP = pressure difference (atm); Pa = average pressure in the sample (atm).

Statistical analyses

For the anatomical, chemical, density and drying rate variables, being accepted residues statistical requirements of normality (Shapiro-Wilk, at 5% of significace) and homogeneity of variance (Bartlett, at 5% of significace), methods of parametrical analyses (ANOVA) with completly randomized design were adopted, considering: three radial positions; two vaporization periods (12 and 24 hours); and two nanoparticles impregnation levels (with and without vacuum impregnation). Tukey test was used for comparison of the averages at 95% level of reliability, all the times that nullity hypothesis was rejected. The statistical analysis used for permeability was the non parametric test of Kruskal-Wallis (95% probability) for the comparison of the average stages, due to the fact that the data did not follow a normal distribution (teste de Lillefors). After this test, the analysis by Dunn test was carried out in order to compare averages (95% probability).

RESULTS

Anatomical and chemical analyses

Diameter, area and vessels analyses did not present significant differences (at 95% probability) between three radial regions, highlighting that statistically anatomical elements morphology did not modify in the radial direction of the wood and with vaporization use. At first, carbohydrates' content reduced with vaporization period increasing, as well as total extractives' content, which resulted in a total percentage increase of lignin in the samples (Table 2).

Tabela 2. Análises anatômicas e químicas para as três regiões radias da madeira: Transição Cerne/Alburno (TCA), Cerne Intermediário (CIT) e Cerne Interno (CIN), submetidas a diferentes períodos de vaporização.

Table 2. Anatomical and chemical analyzes for the three radiated positions of the wood: Heartwood/Sapwood Transition (HST), Intermediate Heartwood (ITH) and Internal Heartwood (INH), submitted to different periods of vaporization.

Radial position	Vapor (h)	VD	VF	Total lignin (%)	Uro	Ace	Ara	Gal	Gli	Xil	Man	Total Extractives
HST	Control	128.2^{ns}	9^{ns}	36.63	3.01	1.5	0.1	1.2	43.0	8.8	1.1	6.91^{Ab}
	12h	129.5	11	36.74	3.00	1.3	0.1	1.0	42.9	8.4	0.8	7.11^{A}
	24h	131.7	10	38.51	2.88	1.1	0.1	1.0	41.6	7.8	0.6	5.36^{B}
ITH	Control	126.1^{ns}	10^{ns}	35.50	2.81	1.2	0.2	1.1	42.7	8.7	1.1	11.0^{Aa}
	12h	131.4	10	36.06	2.70	1.1	0.1	0.9	42.5	8.4	1.0	8.37^{B}
	24h	128.2	10	36.74	2.57	0.8	0.1	0.9	43.5	8.1	0.6	7.3^{B}
INH	Control	123.4^{ns}	9^{ns}	33.44	3.20	0.9	0.2	1.7	45.0	9.7	0.5	9.32^{Aa}
	12h	124.6	10	34.52	3.30	0.9	0.1	1.4	43.7	8.6	0.4	9.57^{A}
	24h	120.5	9	36.62	3.04	0.6	0.1	1.3	42.5	7.9	0.3	6.35^{B}

VD = vessels diameter (μm); VF= vessels frequency ($n^o.mm^{-2}$); Uro = uronic acids; Ace = acetyl group; Ara = arabinan; Gal = galactan; Gli = glucan; Xil = xylan; Man = mannan; Extra T = total extractives; ^{ns}: It express that there was not significative difference; ($^{A\,B}$) Averages followed by equal capital letters indicate that there was not difference between vaporization period in each radial position, at 5% of significance; (^{a,b}) Averages followed by equal lower-case letter indicate that there was not difference between positions to control sample, at 5% of significance.

The total extractives content average for wood was 9.07%. A significant increase of contents was observed, when analyzing extractives content in pith towards the vascular cambium direction, because of the heartwood presence in the most interior wood parts. The vaporization caused a significant reduction in total extractives' content. In vaporized wood for 12h only the intermediate heartwood (ITH) region presented reduction, while vaporization for 24h resulted in an average decreasing of 29,31% in total extractives' content.

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Air permeability and density

Wood basic density in the three radial regions did not differ statistically, even when submitted to vaporization and nanoparticles impregnation. Density varied between 0.843 to 0.857 g/cm^3. The results obtained to air permeability (k) of *E. pellitta* wood showed a variation between the radial position. The heartwood regions (INH and ITH) present values significantly inferior to the portions that contain sapwood (Table 3). Wood permeability in sapwood region was about 15 times superior to internal heartwood (INH) region. This denotes that capillary contents affect significantly fluids' and gases' flow.

Tabela 3. Densidade básica e permeabilidade ao ar nas três regiões radiais.
Table 3. Basic density and air permeability in the three radial regions.

Treatment	Basic density (g/cm^3)			Air permeability (K)		
	HST	ITH	INH	HST	ITH	INH
Control	0.857 (0.22)	0.831 (0.02)	0.827 (0.05)	458.983*	50.128	30.989
NV	0.834 (0.13)	0.827 (0.04)	0.825 (0.06)	448.803*	30.958	36.848
WV	0.843 (0.09)	0.828 (0.03)	0.824 (0.06)	449.645*	71.727	27.462
12h	0.842 (0.20)	0.828 (0.03)	0.824 (0.11)	469.473*	31.372	22.748
24h	0.843 (0.15)	0.826 (0.04)	0.825 (0.03)	478.594*	16.894	28.352

NV = nanoparticles with vacuum application; WV = nanoparticles without vacuum application; HST = Heartwood/Sapwood Transition Zone, ITH = Intermediate Heartwood; INH = Internal Heartwood. ( ): Variation coefficient, *: it expreess difference at 5% of significance between wood radial positions.

However, even with reduction of extractive content and carbohydrates caused by vapor application, there was not significant increase in air flow in vaporized wood in relation to the non-vaporized one. The treatments with nanoparticles impregnations did not improve air longitudinal permeability.

The radial profile of *E. pellita* wood permeability presents a natural tendency, once the heartwood region present vascular cells with the lumen obstructed by thyllos, as well as by extractives (Figure 1).

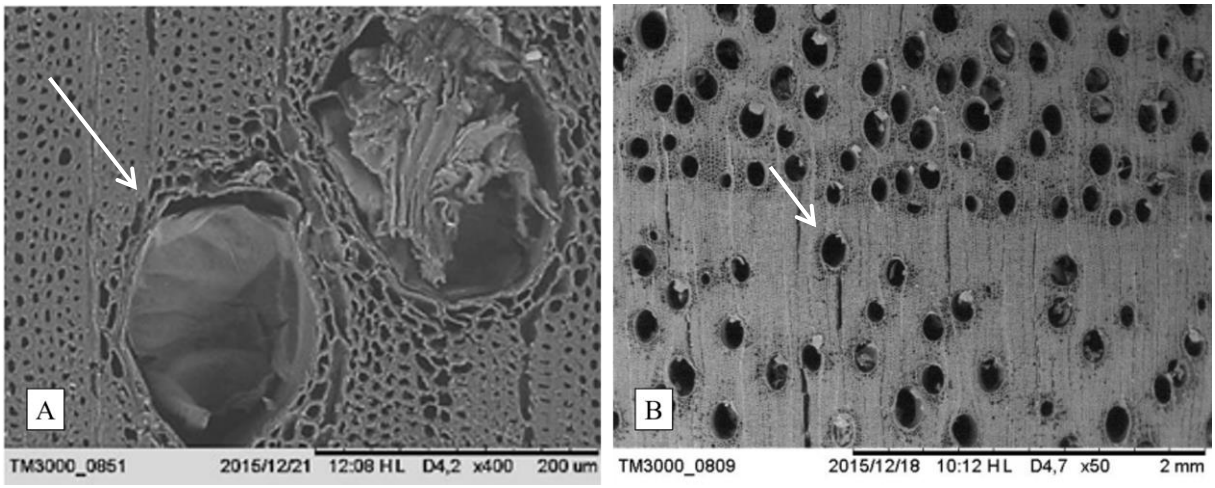

Figura 1. Obstrução dos vasos (indicada por setas) do cerne por tiloses (A) e vasos desobstruídos na região de transição entre o cerne e o alburno (TCA) (B).
Figure 1. Obstruction of the heartwood vessels (indicated by arrows) by tyloses (A) and unobstructed vessel in the transition region between heartwood and sapwood (HST) (B).

Drying rate

Drying rate in wood without treatment was 0.382 kg/cm^2.h.(10 $^{-4}$), presenting a difference between humidity range saturated-30% (free water) and 30-15% (hygroscopic water). After the treatments' application, hygroscopic water and free exits presented higher influence of vaporization and nanoparticles impregnation, respectively (Table 4). Therefore, the highest drying rate in heartwood/sapwood transition zone radial position (HST), that is, in samples containing sapwood portions.

Tabela 4. Taxa de secagem das três regiões radiais em todos os tratamentos e nas fases de capilaridade e difusão (kg/cm^2.h.(10^{-4})).

Table 4. Drying rate of the three radial regions in all treatments and in the capillary and diffusion phases ($kg/cm^2.h.(10^{-4})$).

Treatments		Humidity range (Radial positions' average)		Radial position (Saturated - 15%)			Total (Saturated - 15%)
		Saturated - 30%	30% - 15%	HST	ITH	INH	
Vapor	WV	0.806 [b] (0.29)	0.307 [c] (0.06)	0.417 [c] (0.10)	0.351 [b] (0.05)	0.378 [b] (0.06)	0.382[c] (0.08)
	12h	0.806 [b] (0.38)	0.369 [b] (0.09)	0.504 [b] (0.17)	0.435 [a] (0.11)	0.425 [b] (0.10)	0.455[b] (0.13)
	24h	0.974 [a] (0.37)	0.411 [a] (0.09)	0.615 [a] (0.11)	0.438 [a] (0.07)	0.498 [a] (0.11)	0.515[a] (0.12)
Nano	WN	0.806 [b] (0.29)	0.307 [b] (0.06)	0.417 [b] (0.10)	0.351 [ns] (0.05)	0.378 [a] (0.06)	0.382[b] (0.08)
	NVac	0.674 [b] (0.13)	0.337 [b] (0.07)	0.438 [b] (0.11)	0.377 [ns] (0.06)	0.376 [b] (0.05)	0.397[b] (0.08)
	WVac	1.152 [a] (0.11)	0.403 [a] (0.11)	0.657 [a] (0.13)	0.439 [ns] (0.12)	0.479 [a] (0.12)	0.525[a] (0.15)
Interaction		ns	ns	ns	ns	ns	ns

WV = without vapor; WN = without nanoparticles; Nvac = without vacuum application; Wvac = with vacuum aplication; HST = Heartwood/Sapwood Transition Zone; ITH = Intermediate Heartwood; INH = Internal Heartwood; Saturated -30% = capilarity fase; 30% - 15% = diffusion fase; ( ) = variation coefficient; ns = not significant at 5% of significance; ([a,b]) Averages followed by equal letters indicate that there was no difference between treatments at 5% of significance.

Wood vaporization for 24h was more efficient than 12h period in total drying rate (saturated at 15%), also in capilarity and diffusion. However, silver nanoparticles incorporation in wood with previous vacuum application resulted in higher increase in drying rate because of the benefits before and after saturation point of fibers. It was possible to observe nanoparticles' deposition location, after previous vacuum application, in the surface of vessels walls as well as inside fibers' walls ultrastructure (Figure 2).

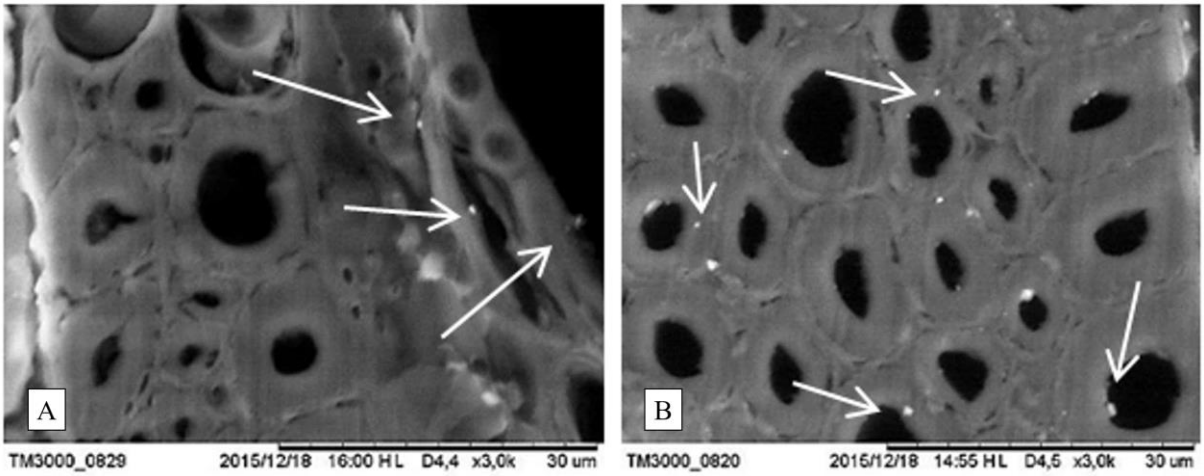

Figura 2.Deposição de nanopartículas de Ag (indicadas por setas) observada em microscópio eletrônico de varredura. (A) Impregnadas na parede do vaso. (B) Impregnadas na parede das fibras.

Figure 2. Deposition of Ag nanoparticles (indicated by arrows) observed in a scanning electron microscope. (A) Impregnated in the vessel wall. (B) Impregnated in the wall of the fibers.

DISCUTION

In all vapor treatments the sugar content reduced. This effect can be explained by molecular mass loss that occurs in hemicellulose polymer when vapor is directed towards the wood (PERSSON; JÖNSSON, 2017).

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One of the reactions responsible for this molecular mass loss is the acetylation that occurs in acetyl group present in the ramifications of hemicelluloses' chains, transforming them in acetyl group monomer and defragmenting hemicelluloses' chains (JOHNSON *et al*., 2017) due to the easy access promoted by amorphous regions of the cellulose chain (CALONEGO *et al*., 2014). Therefore, vapor application modifies wood chemical composition. The presence of volatile extractives in *E. pellita* wood contributed to total extractives content reduction, due to a possible leaching and/or degradation of these components during the process of vaporization (DASHTI *et al.*, 2012; TAGHYARI *et al.*, 2014). Carbohydrates and extractives content reduction also interefe in hygroscopic properties of wood cell wall (BAL; BEKTAS, 2012; CALONEGO *et al*., 2014). Vascular cambium direction permeability increase can be explained, mainly, by the distinct characteristics between heartwood and sapwood, that is, reduction of extractives content and absence of thyllos in sapwood. Thus, there is an inverse relation between extractives content and wood drying rate due to the obstruction of vessels by starch and resins (DASHTI *et al.*, 2012; PAES *et al.*, 2013).

E. pellita wood drying rate presented an increase after vapor treatment for 24h. Similar results were obtained by Rezende *et al.* (2015) in planks of *E. grandis* submetted to vaporization (90°C and 100% of relative humisity for 3h), which promoted significant increase in drying rate for the studied species. Drying rate increase can be directly related to the permeability increase and to the diffusivity parameters of wood (DASHTI *et al.*, 2012). Vapor pre-treatment, depending on the period, can cause modifications in cell wall ultrastructure (JHONSON *et al.*, 2017) and this type of modification can interfere in hygroscopic water exit rate (CALONEGO *et al.*, 2014). Hence, temperature increase in wood treatments has direct influence in adsorption capacity of cell wall; due to the inactivation or neutralization of adsorption sites (hydroxyl groups) found in the wall, resulting from cellulose and hemicellulose chains rearrangement as well as migration and/or extractives loss (BAL; BEKTAS, 2012). These chemical rearrangements promoted by vaporization modify positively, reducing water exit access quantity, denotating significant effect in water movement by diffusion.

Moreover, it was possible to note nanoparticle presence on the cell wall (Figure 3), since they can adhere on the wall surface or even penetrate it (MONTAZER; ALIMOHAMMADI, 2012). The significant air permeability increase obtained by nanoparticles depends on the impregnation method. The process of empty-cell is an effective method due to the forced clearance that the pressure causes in the vessels (TAGHIYARI *et al.*, 2014; TAGHIYARI *et al*., 2015). The drying rate increase after silver nanoparticle immersion also was observed by Lotfizadeh *et al.* (2012) in *Populus nigra wood*. Besides, Taghiyari and Layeghi (2012) verified that silver nanoparticles impregnation and thermical treatments reduced water adsorption capacity in *P. nigra, P. deltoides and Fagus orientalis* wood. This result, according to the authors, occurred due to the silver low hygroscopicity and carbohydrates content reduction by thermical treatment (TAGHIYARI *et* al., 2015; JHONSON *et al*., 2017).

CONCLUSIONS

- Vapor wood treatment for 24 hours period reduces total extractives content of wood contributing to the increase of drying rate;
- In wood that present thyllos, heartwood permeability does not modify in vaporization processes;
- Physical properties (basic density and permeability) of *E. pellita* wood are not affected significantly by vaporization and silver nanoparticles impregnation;
- 24 hours vaporization and silver nanoparticles incorporation with previous vacuum application contribute to the significant drying rate increase in *E. pellita* wood, before as well as after fibers' saturation point.

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