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Articles

Influence of sodium chloride concentration on the dimensional stability of *Eucalyptus* wood

Influência da concentração de cloreto de sódio na estabilidade dimensional da madeira de *Eucalyptus*

Lorran de Sousa Arantes[I], Ianca Oliveira Borges[I], Paulo Ricardo Gherardi Hein[I], Bárbara Maria Ribeiro Guimarães de Oliveira[I], Leonardo Seibert Kuhn[I], Daniella Dutra Carneiro[I], Larissa Nara Nascimento de Miranda[I], Hekiciellen Pamella Nunes do Vale[I], Lourival Marin Mendes[I], José Benedito Guimarães Júnior[I]

[I]Federal University of Lavras, Lavras, MG, Brazil

ABSTRACT

Evaluated the influence of the concentration of sodium chloride in the dimensional stability of *Eucalyptus urophylla* x *Eucalyptus grandis*. It was used 90 samples, which were saturated in beakers containing distilled water (control) and sodium chloride solution concentrations of 2.5% and 10%. Once saturated, the samples were dried until constant mass. The dimensions of the samples were determined for calculate the swelling and radial and tangential contractions. Woods of *Eucalyptus urophylla* x *Eucalyptus grandis* impregnated with sodium chloride solution at concentrations of 2.5 and 10% obtained tangential swelling values similar to those of the control. For radial swelling, wood impregnated with sodium chloride solution at a concentration of 2.5% reached lower values. The concentration of sodium chloride solution influenced the tangential and radial contraction of *Eucalyptus urophylla* x *Eucalyptus grandis* woods, as lower values were found for woods impregnated with sodium chloride solution at concentrations of 10 and 2.5%.

Keywords: Dryin; Moisture; Soluble salts

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RESUMO

Avaliou-se a influência da concentração de cloreto de sódio na estabilidade dimensional da madeira de *Eucalyptus urophylla* x *Eucalyptus grandis*. Foram utilizados 90 corpos de prova, na qual foram saturados em béqueres contendo água destilada (controle) e solução de cloreto de sódio com concentrações de 2,5% e 10%. Depois de saturados, os corpos de prova foram submetidos à secagem até atingirem massa constante. As dimensões dos corpos de prova foram determinadas para cálculo dos inchamentos e contrações radiais e tangenciais. Madeiras de *Eucalyptus urophylla* x *Eucalyptus grandis* impregnadas com solução de cloreto de sódio nas concentrações de 2,5 e 10% obtiveram valores de inchamento tangencial semelhantes ao do controle. Para o inchamento radial, as madeiras impregnadas com solução de cloreto de sódio na concentração de 2,5% atingiram menores valores. A concentração da solução de cloreto de sódio influenciou a contração tangencial e radial das madeiras de *Eucalyptus urophylla* x *Eucalyptus grandis*, pois menores valores foram encontrados para as madeiras impregnadas com solução de cloreto de sódio nas concentrações de 10 e 2,5%.

Palavras-chave: Secagem; Umidade; Sais solúveis

1 INTRODUCTION

One of the important characteristics of wood for application in solid products is its dimensional stability, which is related to its ability to adsorb or dissolve water according to the relative humidity of the environment (Glass; Zelinka, 2010; Oliveira; Tomazello; Fiedler, 2010). The dimensional variations caused by the contraction and swelling of the wood, according to Durlo and Marchiori (1992), together with anisotropy, they constitute undesirable characteristics of wood, limiting its use for various purposes or even requiring specific techniques of use.

The dimensional stability of wood can be improved by reducing its hygroscopicity through thermal degradation of its more hydrophilic components, such as hemicelluloses. This process may also involve the breakdown of cellulose, the formation of new chemical bonds, or the impregnation of cell walls with saline solutions (Kollmann; Côté, 1968). Yang *et al*. (2022) modified poplar wood with furfuryl alcohol and polyethylene glycol, which resulted in improved dimensional stability. Wang *et al*. (2021) impregnated poplar wood with polymeric resin synthesized from glycidyl methacrylate resin, resulting in better mechanical properties and dimensional stability. Ermeydan, Babacan and Tomak (2021) chemically modified Scots pine with the ε-caprolactone copolymer and found a reduction in hygroscopicity, significantly improving dimensional stability and corrosion resistance.

To alleviate the dimensional instability of wood, research by Kollmann (1959) investigated the use of alkaline and acid solutions and observed that the swelling of wood was smaller than that resulting from the adsorption of pure water. The study by Stamm (1977) demonstrated that concentrated solutions of salts and sugars can be used to reduce swelling and contraction of wood. These solutions include manganese chloride, sodium chloride, barium chloride, magnesium chloride, lithium chloride, sucrose, glucose and fructose. According to Kollmann and Côté (1968), the stability of wood treated with salts occurs due to the reaction of these compounds with the components of the cell wall, forming a complex that prevents the absorption of water by the wood, since its structure is already saturated with salts.

The study of Arantes *et al*. (2017) verified that wood *Eucalyptus urophylla* x *Eucalyptus grandis* treated with preservative salts (CCA-C) showed higher radial and tangential swelling values compared to untreated wood, and the presence of salts did not affect their contraction. Chemical and physical methods can alleviate the undesirable effects of wood's dimensional stability, however these methods still present some challenges such as high cost and toxicity of the reagents used.

The wood of *Eucalyptus* is widely used in the rural sector as posts, stakes and in rural constructions. Due to its high anisotropy and dimensional instability, it is important to better understand the behavior of *Eucalyptus* wood under certain conditions of use (Arantes *et al*., 2017), mainly in arid and semi-arid regions that are characterized by having saline and sodic soils. Therefore, there is a need to carry out studies that verify the influence of saline solution impregnation on the dimensional stability of *Eucalyptus* wood, in order to improve its use and application.

Sodium chloride (NaCl) is a non-toxic salt that has a low cost and can reduce the dimensional stability of wood, as demonstrated by Paes *et al*. (2015). However, there is no information in the literature on how the concentration of sodium chloride can affect the dimensional stability of wood. Therefore, this study aimed to analyze the effect of different concentrations of sodium chloride on the dimensional stability of *Eucalyptus urophylla* x *Eucalyptus grandis* wood.

2 MATERIALS AND METHODS

In this work, 90 specimens from sapwood were used, with nominal dimensions of 2.0 cm x 2.0 cm x 2.0 cm (tangential x radial x longitudinal) of *Eucalyptus urophylla* x *Eucalyptus grandis* wood aged 5 years age.

2.1 Wood characterizations

The wood was physically and chemically characterized according to the analysis and standards presented in Table 1.

Table 1 – Analyzes and standards carried out for the physical and chemical characterization of *Eucalyptus urophylla* x *Eucalyptus grandis*

Analysis	Standards
Basic density	NBR 11941 (ABNT, 2003)
Total extractives	NBR 14853 (ABNT, 2010)
Insoluble lignin	NBR 7989 (ABNT, 2010)
Cellulose	Kennedy, Phillips e Willians (1987)
Ashes	NBR 13999 (ABNT, 2017)

Source: Authors (2023)

The hemicellulose content was quantified by the difference between the holocellulose and cellulose contents.

2.2 Saline impregnation

The specimens were stored in a climate-controlled chamber (temperature of 25°C and RH of 60%), with a humidity, before saline impregnation, of 12.22% b.s. The saturation of the specimens was carried out in beakers containing 1 liter of distilled water (control) and sodium chloride solution with concentrations of 2.5% (2.5 g of salt for 100 g of water) and 10% (10 g of salt to 100 g of water) for 72 hours.

2.3 Dimensional stability

Before saturation and after impregnation, the specimens had their radial and tangential dimensions measured with a digital caliper (0.01 mm precision) to determine linear swelling. After being saturated, the specimens were dried in the open air for 2 days and then placed in an oven at 103 °C until they reached constant mass. The dimensions of the specimens were determined to calculate the radial and tangential contractions. The calculations of radial and tangential contractions were made in accordance with the recommendations of NBR 7190 (ABNT, 1997). The anisotropic swelling and contraction coefficients were obtained by the quotient of the tangential and radial dimensional variations.

2.4 Statistical analysis

To evaluate the effect of sodium chloride concentration on the dimensional stability of wood, the means of wood impregnated with sodium chloride and the control were compared using analysis of variance followed by the Scott-Knott test (p-value < 0 .05). The analyzes were carried out using the SPSS statistical program (IBM corp., version 21).

3 RESULTS AND DISCUSSIONS

3.1 Wood characterization

The basic density found for *Eucalyptus urophylla* x *Eucalyptus grandis* (Table 2) was higher in relation to the values found by Braz *et al*. (2014) and Medeiros *et al*. (2016). Basic density is considered one of the main physical properties of wood as it is an easily determined variable and a strong indicator of wood quality. In practice, it serves as a reference for the classification of wood (Gonçalves *et al*., 2009). This property is directly related to several parameters, including retractability, workability, natural durability and mechanical properties (Dias *et al*., 2018).

Table 2 – Average values of basic density and chemical components of *Eucalyptus urophylla* x *Eucalyptus grandis*

Analysis	Averages	Standard deviation
Extractives (%)	7.04	1.36
Lignin (%)	25.61	5.34
Cellulose (%)	41.69	1.53
Hemicellulose (%)	24.68	0.07
Ashes (%)	0.98	0.04
Basic density (g/cm^3)	0.471	0.05

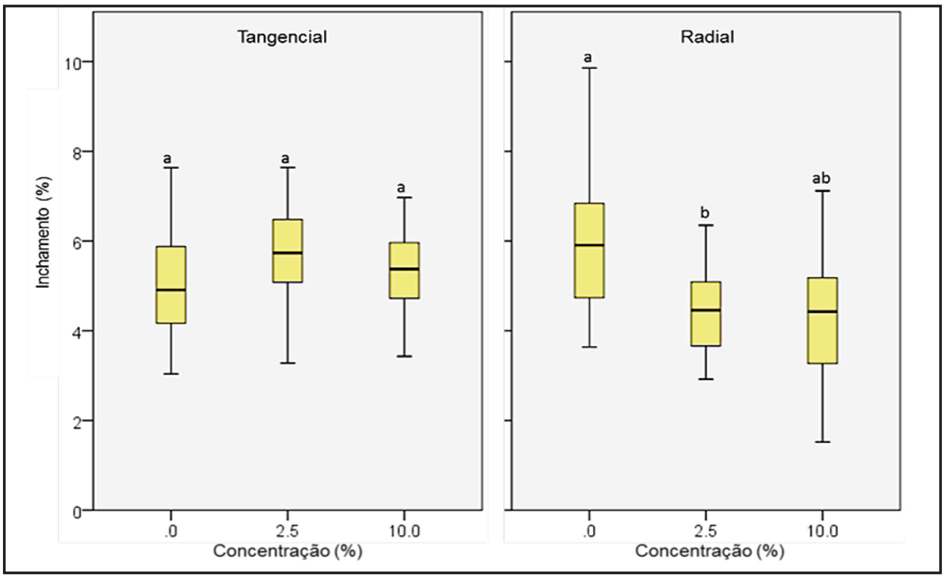
Source: Authors (2023)

The average values of extractives, lignin, cellulose, hemicellulose and ash found in this work are close to those found by Medeiros *et al*. (2016) for *Eucalyptus urophylla* x *Eucalyptus grandis*. The chemical composition of wood also directly affects its dimensional stability, as the polysaccharides present in the structure of hemicelluloses and cellulose have hydroxyls that interact with water, resulting in greater or lesser swelling and contraction. Extractives also influence the dimensional stability of wood, as a high amount of extractives reduces wood swelling, since extractives occupy the empty spaces of the wood's plant cells (Paes *et al*., 2013).

3.2 Dimensional stability

Wood impregnated with sodium chloride solution at concentrations of 2.5 and 10% provided tangential swelling similar to that of the control (Figure 1). The wood impregnated at concentrations of 2.5 and 10% reached 5.76 and 5.41% of tangential swelling, respectively, while for the control there was a tangential swelling of 5.85%.

Figure 1 – Tangential and radial swelling of *Eucalyptus urophylla* x *Eucalyptus grandis* wood impregnated with different concentrations of sodium chloride



Source: Authors (2023)

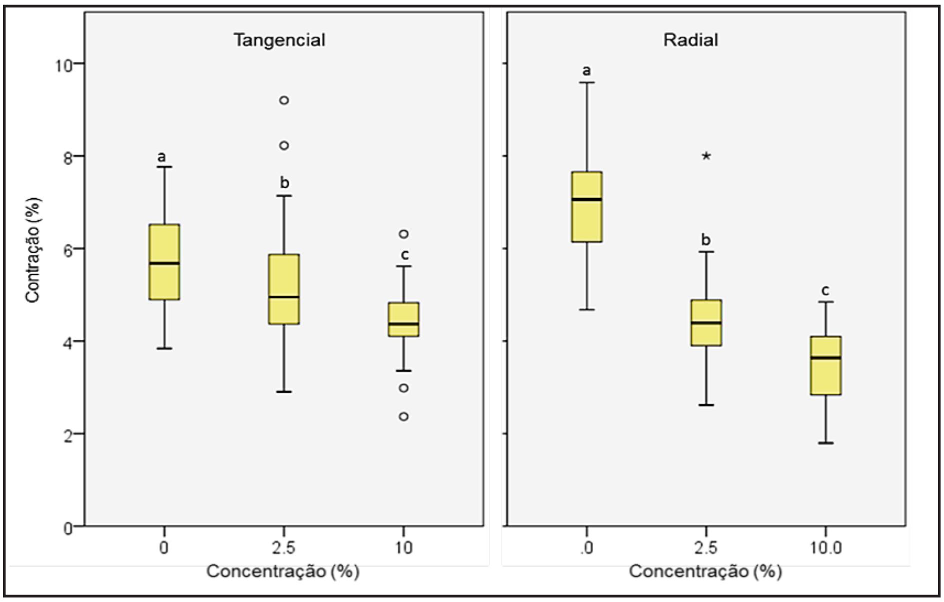
In radial swelling, less swelling was obtained for Eucalyptus urophylla x Eucalyptus grandis wood for those impregnated with sodium chloride solution at a concentration of 2.5%, in which they reached an average value of 4.30% (Figure 1). For wood impregnated with sodium chloride solution at a concentration of 10%, there was a radial swelling similar to that of the control.

The study by Paes *et al*. (2015), evaluated the influence of saline solutions with a concentration of 5% on the dimensional stability of *Corymbia torelliana* and *Eucalyptus cloeziana* wood. The results showed that Corymbia torelliana wood impregnated with lithium chloride solution presented lower radial and tangential swelling values. As for *Eucalyptus cloeziana* wood, samples impregnated with lithium chloride, sodium carbonate, magnesium sulfate, zinc sulfate and copper II sulfate showed lower radial and tangential swelling compared to samples immersed in distilled water (control). This indicates that saline solutions may be effective in reducing wood swelling.

According to Kollmann (1968), impregnating wood with salts results in less swelling of the wood due to moisture retention by the salts. This minimizes the phenomenon of adsorption of water molecules in the submicroscopic spaces of the micelles. The stability of wood impregnated with salts occurs due to the reaction of these compounds with the constituents of the cell wall, forming a complex. This prevents the wood from adsorbing water, since its structure is already saturated with salts (Paes *et al*., 2013).

Regarding the radial and tangential contraction values of *Eucalyptus urophylla* x *Eucalyptus grandis* wood, it was observed that the concentration of the sodium chloride solution had an influence on the results (Figure 2). It was found that the lowest tangential contraction was obtained in wood impregnated with a sodium chloride solution at a concentration of 10%, reaching a contraction of 4.41%. Wood impregnated with a sodium chloride solution at a concentration of 2.5% also showed lower tangential shrinkage compared to the control.

Figure 2 – Tangential and radial contraction of *Eucalyptus urophylla* x *Eucalyptus grandis* wood impregnated with different concentrations of sodium chloride



Source: Authors (2023)

For radial contraction, a result similar to that found for tangential contraction was observed, where wood impregnated with sodium chloride solution at concentrations of 2.5 and 10% achieved 4.50 and 3.44% contraction, and the control obtained a radial contraction of 5.70% (Figure 2).

The study carried out by Paes *et al*. (2015) found no significant differences in the tangential and radial contractions of *Corymbia torelliana* wood impregnated with saline solutions, such as sodium chloride, lithium chloride, sodium carbonate, sodium sulfate, magnesium, zinc sulfate and copper II sulfate, all at a concentration of 5%, compared to wood immersed in distilled water (control). However, the results were similar for *Eucalyptus cloeziana* wood, where the samples impregnated with saline solutions showed radial and tangential contractions similar to the control, except for the samples impregnated with sodium chloride, which showed a smaller tangential contraction in relation to the control.

The improvement in dimensional stability observed in this work may be related to the reaction of sodium chloride with the OH groups of hemicelluloses and cellulose, forming new compounds and reducing the hygroscopicity of the wood. The hydroxyl groups of cellulose and hemicellulose can react or interact with chemicals, and reduce the hygroscopicity of wood (Klitzke, 2007).

Regarding the anisotropic coefficient, it can be seen from Table 3 that wood impregnated with sodium chloride at a concentration of 10% obtained the lowest value of anisotropic coefficient in swelling. Regarding contraction, the lowest anisotropic coefficient was found for wood impregnated with sodium chloride at a concentration of 2.5%.

Table 3 - Anisotropic coefficient of *Eucalyptus urophylla* x *Eucalyptus grandis* wood impregnated with different concentrations of sodium chloride

Concentration (%)	Anisotropic coefficient	
	Swelling (T/R)	Contraction (T/R)
Control	1.19 (0.20*)	1.27 (0.51)
2.5	1.38 (0.08)	1.19 (0.12)
10	1.10 (0.23)	1.34 (0.31)

Source: Authors (2023)

In where: *Standard deviation.

The anisotropy coefficient is the parameter that represents the variation in the transverse direction, resulting from the dimensional balance in the radial and tangential directions, and is used to classify the quality of the material (Bozi; Mascarenhas; Melo, 2021; Tomasi *et al*., 2013). According to Klitzke (2007), wood with an anisotropy coefficient of less than 1.5 is considered stable and is generally intended for uses that do not allow warping, cracking and twisting, such as windows, doors, floors and furniture. With an anisotropic coefficient between 1.6 and 1.9, wood is considered normal and recommended for civil construction.

4 CONCLUSIONS

Eucalyptus urophylla x *Eucalyptus grandis* wood impregnated with sodium chloride solution at concentrations of 2.5 and 10% obtained tangential swelling values similar to those of the control. For radial swelling, wood impregnated with sodium chloride solution at a concentration of 2.5% achieved lower values.

The concentration of the sodium chloride solution influenced the tangential and radial contraction of *Eucalyptus urophylla* x *Eucalyptus grandis* wood, as lower values were found for wood impregnated with sodium chloride solution at concentrations of 10 and 2.5%.

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Authorship Contribution

1 Lorran de Sousa Arantes

Forest Engineer, Master in Wood Science and Technology and PhD in Biomaterials Engineering

https://orcid.org/0000-0002-4473-2292 • lorran.arantes@ufla.br

Contribuition: Conceptualization; Investigation; Methodology; Writing – review & editing

2 Ianca Oliveira Borges:

Environmental Engineering, Master's in Biomaterials and PhD student in Biomaterials Engineering

https://orcid.org/0000-0003-4370-4705 • iancaborges@hotmail.com

Contribuition: Resources, Formal analysis; Visualization; Writing – review & editing

3 Paulo Ricardo Gherardi Hein

Forest Engineer, Master in Wood Science and Technology and PhD in Mechanical and Civil Engineering

https://orcid.org/0000-0002-9152-6803 • paulo.hein@ufla.br

Contribuition: Resources; Supervision; Validation; Visualization

4 Bárbara Maria Ribeiro Guimarães de Oliveira

Agronomist, Master in Wood Science and Technology and PhD in Biomaterials Engineering

https://orcid.org/0000-0001-5509-7098 • bmrg2115@yahoo.com.br

Contribuition: Validation; Visualization; Writing – original draft

5 Leonardo Seibert Kuhn

Forest Engineer, Master in Wood Science and Technology and PhD student in Wood Science and Technology

https://orcid.org/0000-0002-5424-9077 • leonardo.s.kuhn@gmail.com

Contribuition: Validation; Visualization; Writing – original draft

6 Daniella Dutra Carneiro

Civil Engineering, Master student in Biomaterials Engineering
https://orcid.org/0000-0002-1828-6989 • danielladclaranjal@hotmail.com
Contribuition: Validation; Visualization; Writing – original draft

7 Larissa Nara Nascimento de Miranda

Forest Engineer, Master student in Wood Science and Technology
https://orcid.org/0009-0008-4854-9816 • larissanara8@gmail.com
Contribuition: Validation; Visualization; Writing – original draft

8 Hekiciellen Pamella Nunes do Vale

Civil engineering, Master in Biomaterials Engineering and PhD student in Biomaterials Engineering
https://orcid.org/0009-0002-6204-0289 • hekiciellen@gmail.com
Contribuition: Validation; Visualization; Writing – original draft

9 Lourival Marin Mendes

Forest Engineer, Master in Forest Sciences and PhD in Forest Sciences
https://orcid.org/0000-0001-8713-405X • lourival@ufla.br
Contribuition: Supervision; Validation; Visualization

10 José Benedito Guimarães Júnior

Forest Engineer, Master and PhD in Wood Science and Technology
https://orcid.org/0000-0002-9066-1069 • jose.guimaraes@ufla.br
Contribuition: Supervision; Validation; Visualization

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