

NATURAL DURABILITY AND CHEMICAL COMPOSITION OF *Liquidambar* sp. WOOD

Thaís Pereira Freitas^{1*}, Juarez Benigno Paes², José Tarcísio da Silva Oliveira³, Walter Torezani Neto Boschetti⁴,
Déborah Nava Soratto⁵, Márcia Silva de Jesus⁶

^{1*}Federal University of Viçosa - UFV, Department of Forest Engineering, Viçosa, Minas Gerais, Brazil -thais_pfreitas@yahoo.com.br

²Federal University of Espírito Santo - UFES, Department of Forest and Wood Sciences, Jerônimo Monteiro, ES, Brazil - jbp2@uol.com.br

³Federal University of Espírito Santo - UFES, Department of Forestry and Wood Sciences, Jerônimo Monteiro, ES, Brazil -
jtsilva@npd.ufes.br

⁴Federal University of Viçosa - UFV, Department of Forest Engineering, Viçosa, Minas Gerais, Brazil - walterboschetti@hotmail.com

⁵Federal University of Mato Grosso do Sul - UFMS, Chapadão do Sul Campus, Chapadão do Sul, Mato Grosso do Sul, Brazil -
deborahsoratto@gmail.com

⁶Federal University of Viçosa - UFV, Department of Forest Engineering, Viçosa, Minas Gerais, Brazil -eng-marcia@hotmail.com

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Resumo

Durabilidade natural e composição química da madeira de Liquidambar sp. A madeira é um material de origem biológica e por causa de sua composição química está sujeita ao ataque de vários organismos que a utilizam como fonte de alimento. Assim, este estudo teve como objetivo avaliar a durabilidade natural e a composição química da madeira de *Liquidambar* sp. Foram realizados os ensaios de apodrecimento acelerado em laboratório, ao utilizar cultura pura do fungo *Postia placenta*, causador da podridão parda, e de alimentação forçada ao cupim *Nasutitermes corniger*. Após os ensaios biológicos, as amostras foram secas em estufa a 103 ± 2°C, até atingirem massas constante e posteriormente pesadas, para se avaliar a porcentagem de perda de massa. Também foram determinados os teores de extrativos, lignina (solúvel, insolúvel e total) e holocelulose. A madeira em estudo obteve perdas de massa de 37,79% e 23,37%, quando submetida à ação do fungo e cupins, respectivamente, e um teor médio de extrativos igual a 4,13%. Conclui-se que a madeira de *Liquidambar* sp. apresentou resistência moderada ao ataque do fungo de podridão parda e foi pouco resistente à ação do cupim testado.

Palavras-chave: Resistência Natural; Fungo e Cupim Ilófagos; Ensaios Biológicos.

Abstract

Wood is a material of biological origin and because of its chemical composition it is subject to attack by various organisms that use it as a food source. Thus, this study aimed to evaluate the natural durability and chemical composition of the *Liquidambar* sp. wood. Accelerated rot tests were carried out in the laboratory, using pure culture of the fungus *Postia placenta*, which causes brown rot, and forced termite feeding *Nasutitermes corniger*. After biological tests, the samples were dried in an oven at 103 ± 2°C, until they reached constant masses and later weighed, to evaluate the percentage of mass loss. The levels of extractives, lignin (soluble, insoluble and total) and holocellulose were also determined. The wood under study had mass losses of 37.79% and 23.37%, when submitted to the action of the fungus and termites, respectively, and an average extract content equal to 4.13%. It is concluded that the *Liquidambar* sp. wood presented moderate resistance to the attack of the brown rot fungus and was little resistant to the action of the tested termite.

Keywords: Natural Resistance; Illophagous Fungus and Termite; Biological Tests.

INTRODUCTION

Over the past few years, the main species used in Brazil by the large-scale timber industries come from trees of the genus *Eucalyptus* and *Pinus*, which represent 72 and 21%, respectively, of the total area of reforested areas in the country, as data from the Brazilian Tree Industry - IBÁ (2017), with excellent use of its wood. However, species of the genus *Liquidambar* can be another alternative for use by Brazilian industry, mainly in the southern region of the country, presenting good growth and excellent quality wood for several uses, such as sawn wood, laminates and plywood, cooperage, fuel, cellulose and paper and boxes (Mattos *et al.*, 2001; Lingbeck *et al.*, 2015).

The genus *Liquidambar* is the best known of the Altingiaceae family, being constituted by four intercontinental species in the temperate zone of the Northern Hemisphere. Two species are found in East Asia (*L. formosana* and *L. acalycina*), one in Western Asia (*L. orientalis*) and the other is found in North America (*L. styraciflua*) (Ickert-Bond *et al.*, 2005), and have great potential for reforestation due to its straight shaft and the good quality of its wood, which is quite homogeneous, with little variation in its properties along the tree trunk.

The wood has average values of basic density between 0.48 gm^{-3} (Freitas *et al.*, 2015) and 0.52 gm^{-3} (Mattos *et al.*, 2001).

Despite the favorable dendrological and technological characteristics, wood of the genus *Liquidambar* without treatment can present low natural durability (Clausen, 2010). The heterogeneity of forest species results in variations in their vulnerability to attack by xylophagous organisms, which in this case, is mainly caused by differences in anatomical arrangement and chemical composition, such as the levels of nutritive substances (sugars and starch) in wood and the presence of toxic substances in the extracts present in the heartwood (Melo, 2013; Carvalho *et al.*, 2015).

Wood is subject to the action of biodeteriorating agents, including biological, physical and chemical agents, causing harm and consequently damage (Carvalho *et al.*, 2015), and no species of wood, not even those of recognized durability natural, it is able to resist these agents indefinitely, since wood is a material of an organic nature and subject to the next stage of the natural sequence of any living being; deterioration and decomposition.

In this context, it is verified the importance of knowledge of the natural resistance of wood for the recommendation of its most appropriate use, avoiding expenses with replacement of parts and reducing the impacts on the environment. Thus, this study aimed to evaluate the natural durability and chemical composition of the *Liquidambar* sp. wood.

MATERIAL AND METHODS

Study material and evaluation of the biological resistance of wood

The wood of *Liquidambar* sp. used in this study came from a plantation with spacing of $3.0 \times 3.0 \text{ m}$, aged 8 years, located in the municipality of Guaçuí, Espírito Santo. Three trees were obtained with average values of commercial height and diameter at breast height (DBH), taken 1.30 m from the ground, 15.7 m and 23.3 cm, respectively.

Tests of accelerated rotting in the laboratory and forced termite feeding were carried out. The execution of the accelerated rot test followed the specifications of the *American Society for Testing and Materials* - ASTM D-2017 (2008). Twenty specimens with dimensions of $2.5 \times 2.5 \times 0.9 \text{ cm}$ were used, and 12 samples of *Pinus* sp. with the same dimensions as a comparison standard. Pure culture of the fungus *Postia placenta* (Fr.) M. Larsen et Lombard causing brown rot was used. The test was kept in an air-conditioned room ($25 \pm 2^\circ\text{C}$ and $75 \pm 5\%$ relative humidity), for 98 days. After such period, the specimens were dried and the loss of mass was evaluated when comparing the values obtained with those mentioned in the standard.

In the termite feed test *Nasutitermes corniger* Motsch, the specifications of ASTM D-3345 (2008) were followed with some modifications suggested by Paes *et al.* (2013), regarding the maintenance of the colony, capture of insects and conducting the experiment. According to the recommendations, the termite colony used in the experiment was collected in the municipality of Jerônimo Monteiro - ES.

Twenty defect free specimens with dimensions of $2.54 \times 2.54 \times 0.64 \text{ cm}$ and 20 samples of *Pinus* sp. were used as the comparison standard. The samples were exposed to the action of termites for 28 days, in an air-conditioned room, under the same conditions of the accelerated rot test.

After the test, the samples were dried in an oven at $103 \pm 2^\circ\text{C}$, until they reached constant mass and then weighed to assess the percentage loss in mass. The biological resistance of *Liquidambar* sp. depending on the loss of mass, the wear and tear caused by termites (note), the mortality of termites and the number of days for the death of insects in each flask. The mass loss was corrected by means of the operational mass loss samples, as indicated in ASTM D-2017 (2008), and the wear score was the average obtained by five evaluators.

Chemical composition of wood

For the chemical characterization of the wood, two opposite wedges of discs were removed at the height of the DBH of each tree, and the analyzes were performed in duplicates. The wedges were reduced in chips. These were homogenized, air dried and transformed into sawdust in a Willey mill, according to *Technical Association of the Pulp and Paper Industry* (TAPPI - T 257 om - 92, 1992). The sawdust was classified in sieves so that the analyzes were carried out only in the fraction of sufficient granulometry to pass through a 40 mesh (0.42mm opening), however, they were retained in a 60 mesh (0, 25mm).

The extractives analysis was performed according to TAPPI 264 om-88 (1992), with an extraction sequence in ethanol: toluene solution (1: 2) for 5 hours, ethanol for 4 hours, both in a "Soxhlet" extractor, and in hot water for 1 hour.

After removing the extractives, 0.3 g of the sample was weighed, which was subjected to hydrolysis with sulfuric acid for 60 minutes ($30.0 \pm 1.0^\circ\text{C}$), autoclaved for 60 minutes and filtered. When considering the retained solid as insoluble lignin, which was determined by mass difference (Gomide and Demuner, 1986), the remaining liquid from the filtration of insoluble lignin was analyzed in a UV spectrophotometer, to determine soluble lignin

(Goldshimid, 1971). The total lignin content consisted of the sum of the soluble and insoluble fractions and the holocellulose was determined by the difference between the initial mass and the amount of extractives and total lignin.

RESULTS

The wood of *Liquidambar* sp., When submitted to the action of the fungus *Postia placenta* (brown rot) had a mass loss of 37.79% (variation coefficient of 56.25%), being classified as of moderate resistance (ASTM D-2017, 2008) and showed better resistance to attack by xylophagous fungi, when compared to that of *Pinus* sp., Which was non-resistant to attack, having lost 48.93% (coefficient of variation of 13.34%) of the original mass.

The values of mass loss caused by termites *Nasutitermes corniger*, mortality and time elapsed for the death of insects in the forced feeding test are shown in Table 1. For the test of forced feeding caused by termites *Nasutitermes corniger*, it was noticed that the wood of *Liquidambar* sp. presented much higher values for mass loss, when compared to *Pinus* sp., which was practically not attacked.

Tabela 1. Perda de massa, desgaste, mortalidade e tempo para a morte dos cupins em contato com as madeiras de *Liquidambar* sp. e *Pinus* sp.

Table 1. Mass loss, wear, mortality and time to termite death in contact with the woods of *Liquidambar* sp. and *Pinus* sp.

Assessed Features	<i>Liquidambar</i> sp.	<i>Pinus</i> sp.
Mass loss (%)	23,37 (7,13)	4,70 (19,78)
Wear (Note)	3,73 (22,97)	9,19 (2,85)
Mortality (%)	40	100
Time (days)	28	17

Values in parentheses are coefficients of variation.

The wear (wood consumption) caused by termites in the wood samples of *Liquidambar* sp. during the forced feeding test can be seen in Figure 1.



Figura 1. Corpos de prova da madeira de *Liquidambar* sp. atacados após ensaio de alimentação forçada com cupins *Nasutitermes corniger*

Figure 1 Samples of the wood from *Liquidambar* sp. attacked after termite forced feeding test *Nasutitermes corniger*.

The average values of extractives content, lignin (soluble, insoluble and total) and holocellulose, obtained by chemical analysis are shown in Table 2.

Tabela 2. Valores médios da análise química da madeira de *Liquidambar* sp.
Table 2. Average values of the chemical analysis of the wood of *Liquidambar* sp.

Extractives (%)	Soluble Lignin (%)	Insoluble Lignin (%)	Total Lignin (%)	Holocellulose (%)
4,13 (9,30)	3,30 (2,36)	24,96 (2,59)	28,26 (2,50)	67,61 (0,55)

Values in parentheses are coefficients of variation.

DISCUSSION

Behavior similar to that observed in this study for the resistance of liquidambar wood to attack by xylophagous fungi was found by Terzi *et al.* (2012) when studying the biological performance of untreated heartwood from *Liquidambar orientalis*, who found mass loss percentages equal to 50.66; 40.2 and 37.08% for fungi *Trametes palustris*, *Gloeophyllum trabeum* and *Trametes versicolor*, respectively, and classified it as non-resistant (*Palustrine*) or moderately resistant (*Gloeophyllum trabeum* *Trametes versicolor*), although the heartwood has a reddish color, which is generally associated with the presence of extracts and woods with high natural durability.

When grouping some species of wood, native and exotic from North America, due to natural resistance to fungal deterioration, Clausen (2010) also classified liquidambar wood (*Liquidambar styraciflua*) as little resistant or non-resistant to attack by xylophages' organisms.

The high resistance to biological deterioration of some wood species is generally explained based on the properties of their chemical components, since it is a consensus that there is a close relationship between the extractive content and the natural durability of the wood. However, this relationship is not a rule. Paes *et al.* (2016) when studying the effect of extractives content on the natural resistance of five woods to attack by xylophagous termites, found that the content of extractives in the wood does not necessarily correspond to its natural durability, and may present a weak correlation between these variables, depending on composition, type of extract and location in the cell.

According to Gonçalves *et al.* (2013), another factor that can confer natural durability is the presence of inert elements in the wood, such as silica and other mineral incursions (ashes), which can cause damage to the insects' jaws, making it difficult to access the food source, and, therefore, increasing resistance to attack by xylophagous organisms.

For wear, lower grades indicate higher consumption of wood, according to ASTM D-3345 (2008), which is generally consistent with the values of mass loss (Table 1). The wood of *Liquidambar* sp. obtained an average score of 3.73, intense attack (Figure 1), while the *Pinus* sp. obtained an average score of 9.19 and superficial attack, according to ASTM D - 3345 (2008).

In the wood of *Pinus* sp., After 17 days, all individuals had already died, that is, total mortality, while in *Liquidambar* sp., Even after 28 days had passed (deadline for the end of the test according to ASTM D - 3345 (2008), only 40% of individuals died, that is, moderate mortality rate). Based on these values, it was found that this species did not show resistance to termite attack *Nasutitermes corniger*. This being evaluated based on the loss of mass, wear (note), mortality and survival time of insects.

A mass loss of 16.04% for *Liquidambar orientalis* wood subjected to the termite forced feeding test *Reticulitermes flavipes* was obtained by Terzi *et al.* (2012), who found greater loss of mass for the *Pinus slyvestris* wood (25.87%) used as a control. However, Lepage *et al.* (2017) cite that termites of the genus *Nasutitermes* consume little of the wood of *Pinus* sp. due to terpenes and terpenoids in it. Thus, the difference in the consumption of *Pinus* sp. by the termite species mentioned and the one used in this research.

The lower natural durability of liquidambar wood may be related to the chemical characteristics of this species. Another factor to be considered is the age of the trees used, containing a good proportion of younger wood and little heartwood. This, in addition to the nature and the concentration of extractives present in the wood, may have been the cause of moderate termite mortality, since the species had an average extract content equal to 4.13%.

However, the natural durability depends not only on the quantity or class of extracts, as already mentioned, but also on their location in the wood. Thus, extracts in the cell fire contribute less to the biological resistance of the wood than those in the cell wall.

For wood from *Liquidambar styraciflua* aged 16, Mattos *et al.* (2001) found percentages equal to 7.4; 21.6 and 71.0% for the levels of extracts, total lignin and holocellulose, respectively, having been similar to those obtained in the present study. Thus, based on the results obtained and those found in the literature, the studied wood should not be used, without treatment (chemical or thermal), in direct contact with the soil or in places with a high incidence of termites of the genus *Nasutitermes*.

CONCLUSIONS

- The wood of *Liquidambar* sp. presented moderate resistance to the attack of the fungus *Postia placenta* (brown rot).
- The damage caused by termites *Nasutitermes corniger* to the wood of *Liquidambar* sp. it was intense, presenting a moderate mortality rate, and, therefore, this species behaved little resistant to the action of these insects.
- The number of extractives obtained in ethanol: toluene proved not to be sufficient to guarantee the wood's resistance to the xylophagous organisms tested.

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