

RESISTANCE OF THERMALLY MODIFIED *Eucalyptus grandis* W. Hill ex Maiden WOOD TO DETERIORATION BY DRY-WOOD TERMITES (*Cryptotermes* sp.)

RESISTÊNCIA DA MADEIRA MODIFICADA TERMICAMENTE DE *Eucalyptus grandis* W. Hill ex Maiden AO TÉRMITA DE MADEIRA SECA *Cryptotermes* sp.

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ABSTRACT

There are currently in operation five major European industrial processes for wood thermal modification. They improve wood's dimensional stability and decay resistance, but are not efficient against termites attack. In fact, there is little research about the effect of thermal modification on wood resistance to termites, whether subterranean or dry-wood termites. The aim of this study was to evaluate the effect of the Brazilian process of thermal modification (VAP HolzSysteme®) on the resistance of *Eucalyptus grandis* wood to attack by *Cryptotermes* sp. dry-wood termites. Five treatments were tested: untreated eucalypt wood, thermally modified eucalypt wood at three final temperatures (140, 160 and 180 °C) and pine wood (control). The attack was evaluated in terms of mass loss, mean score of wear grades, number of holes and termites mortality, according to a Brazilian method proposed by the Technological Research Institute of São Paulo. Similarly to the European processes of thermal modification, the Brazilian VAP HolzSysteme® was not effective to improve wood resistance to dry-wood termites attack, at least in the evaluated conditions.

Keywords: thermal modification process; VAP HolzSysteme®; termites attack.

RESUMO

Existem atualmente cinco principais processos de modificação térmica em operação na Europa, que aumentam a estabilidade dimensional e a resistência da madeira à biodeterioração, porém, não são eficientes contra o ataque de térmitas. Na verdade, existe pouca pesquisa a respeito do efeito da modificação térmica da madeira na resistência à biodeterioração por térmitas, sejam subterrâneas ou de madeira seca. O objetivo desta pesquisa foi avaliar o efeito do processo brasileiro de modificação térmica VAP HolzSysteme® na resistência da madeira de *Eucalyptus grandis* ao ataque de térmitas de madeira seca *Cryptotermes* sp. Para tanto, foram testados cinco tratamentos: madeira não tratada de eucalipto, madeira de eucalipto modificada termicamente a três temperaturas finais (140, 160 e 180°C) e madeira de pinus

INTRODUCTION

Brazilian forest plantations are composed of 71.8% *Eucalyptus* spp., 20.5% *Pinus* spp., 2.1% *Acacia* spp. and 7.7% of other species (mainly *Acacia* spp., *Hevea* spp. and *Tectona grandis*), resulting in a total area of 7,7 millions of hectares. The area

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(controle). O ataque foi avaliado em termos de perda de massa, escore médio das notas do desgaste, número de orifícios e mortalidade dos térmitas, de acordo com o método proposto pelo Instituto de Pesquisas Tecnológicas de São Paulo. Semelhante aos processos europeus de modificação térmica, o processo brasileiro VAP HolzSysteme® também não foi eficaz para melhorar a resistência da madeira de eucalipto ao ataque dos térmitas de madeira seca, pelo menos nas condições avaliadas.

Palavras-chave: processo de modificação térmica; VAP HolzSysteme®; ataque de térmitas.

planted with eucalyptus has been increasing steadily in recent years, a pattern expected to continue for the next foreseeable future (INDÚSTRIA BRASILEIRA DE ÁRVORES, 2015).

Among the many eucalypt species, *Eucalyptus grandis* Hill. ex Maiden is the most often planted in Brazil, because of its fast growth and good adaptation to regional variations. Its wood has multipurpose use, from firewood and charcoal production to pulp to make paper, making this species one of the most important in Brazil's wood industry.

However, the use of juvenile wood of *Eucalyptus grandis* as lumber, such as in furniture, for example, is limited by its poor dimensional stability (SILVA et al., 2006; BATISTA et al., 2010) and low natural durability (OLIVEIRA, 1998; SILVA et al., 2004). But according to some authors (ESTEVEZ; PEREIRA, 2009; HILL, 2006; XIE et al., 2002), it has long been known that thermal modification processes lead to chemical changes in wood's structure, which improves its dimensional stability and resistance against attack by xylophages. Successful results have been reported in the literature of thermal modification processes to improve the dimensional stability of eucalypt wood (BRITO et al., 2006; ESTEVES et al., 2007a, 2007b; BATISTA et al., 2011; CALONEGO et al., 2012).

Another advantage of thermal modification, regarding increased xylophages attack resistance, is that this process does not use toxic chemical products, which are potentially harmful to human beings and domestic animals. This is an advantage in relation to the common preservative products used in industry. Preserved wood also faces a series of problems of waste reuse, handling and disposal in nature, which thermally modified wood does not have (HILL, 2006).

It is widely known that thermally modified wood has its decay resistance increased (ESTEVEZ; PEREIRA, 2009; HILL, 2006; XIE et al., 2002), but more research has been done about attack by fungi

than other xylophagous organisms (KAMDEM et al., 2002; CALONEGO et al., 2010; CAO et al., 2011; BAZYAR, 2012; DUBEY et al., 2012; MOHAREB et al., 2012). Hence, there are few studies about the resistance of thermally modified wood to termites attack (MOMOHARA et al., 2003; MBURU et al., 2007), and least have involved dry-wood termites (PESSOA et al., 2006).

Dry-wood termites do not multiply as rapidly as subterranean ones and have some differences in colony life and habits. However, the ability of dry-wood termites to live in dry wood without outside moisture or contact with the ground makes them a definite menace in the regions where they occur. Their destruction is not rapid, but they can thoroughly riddle timbers with their tunneling if allowed to work undisturbed for many years (CLAUSEN, 2010). Thus, dry-wood termites are a major wood pest and methods to prevent infestation must be studied.

Some European industrial thermal modification processes have been shown effective to increase wood decay resistance, but the same cannot be said about termites attack (FINNISH THERMOWOOD ASSOCIATION, 2003; PLATOWOOD, 2013; RETIWOOD, 2013). The reason is that the mechanism of termite's degradation is mechanical, due to their highly developed mouthparts, unlike the enzymatic fungal mechanism, which does not recognize the chemical modifications imparted to wood (hygroscopicity reduction, new extractives generation, modification of cell wall polymers and hemicelluloses reduction) (HAKKOU et al., 2006; LEKOUNOUGOU et al., 2009).

Thermally modified wood by the Brazilian process VAP HolzSysteme® has been produced by the company TW Brazil since 2006, when it started its researches about the application of saturated steam, allied to an efficient system of oxygen elimination, to modify the properties of wood. More details about the process can be found in Batista et al. (2015).

The aim of this study was to evaluate the effect of the Brazilian process of thermal modification (VAP HolzSysteme®) on the resistance of *Eucalyptus grandis* wood to attack by *Cryptotermes* sp. dry-wood termites.

MATERIAL AND METHODS

Material and treatments

The *Eucalyptus grandis* wood used in this study was from an 18 year-old stand (from seeds) planted in Telêmaco Borba city, Paraná state, southern Brazil. Five trees were felled and only the first logs (three meters) were used, which were broken down according to Figure 1. For this work only the “A” boards were used, corresponding to juvenile corewood. The wood was thermally modified according to the Brazilian industrial process VAP HolzSysteme®, in three batches, each one with a different final cycle temperature: 140, 160 and 180 °C. The exact schedule is proprietary information. We analyzed five treatments: untreated and thermally modified (140, 160 and 180 °C) *Eucalyptus grandis* wood, and pine wood (*Pinus* sp.) as control (because this species has low natural durability).

Exposure to termites

The test was performed according to a Brazilian method proposed by the Instituto de Pesquisas Tecnológicas de São Paulo (Technological

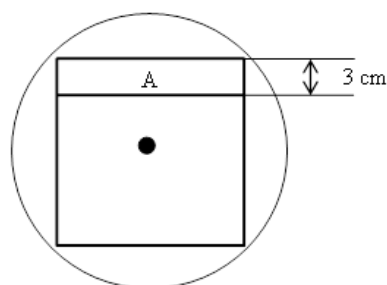


FIGURE 1: Scheme of the transversal section of a log, having the pith in the center, showing the boards which were used in this study (A).

FIGURA 1: Representação da seção transversal de uma tora, tendo a medula ao centro, mostrando as peças utilizadas no estudo (A).

Research Institute of São Paulo), named Ensaio acelerado de laboratório da resistência natural ou de madeira preservada ao ataque de térmitas do gênero *Cryptotermes* - fam. Kalotermitidae (Accelerated laboratory testing of natural or preserved wood resistance to termites attack of the genus *Cryptotermes*, fam. Kalotermitidae) (IPT, 1980).

Each treatment involved 10 specimens measuring 6 x 23 x 70 mm (tangential, radial and longitudinal), which were oven dried at 103 ± 2 °C for 48 hours before determination of initial anhydrous mass (m_0). Then the specimens were mounted laterally in pairs, forming sets of five by treatment, and received a glass sleeve of 35 mm diameter and 80 mm height, which was fixed with melted paraffin. Inside the glass sleeve, 40 termites were introduced (39 workers and one soldier). The dry-wood termites of the genus *Cryptotermes* sp. were collected few days before the test, from internally infested furniture, in order not to use weak insects.

After mounting, the pairs of samples were put in Petri dishes and placed in a climatic chamber (27 ± 1 °C and $70 \pm 4\%$ relative humidity), in the dark, where they remained during the 45 days of testing. Figure 2 depicts four pairs of mounted specimens, representing some of the treatments.

Attack evaluation

At the end of the test, the specimens were evaluated for termites mortality (%), number of holes and wear grading (IPT, 1980), and the latter

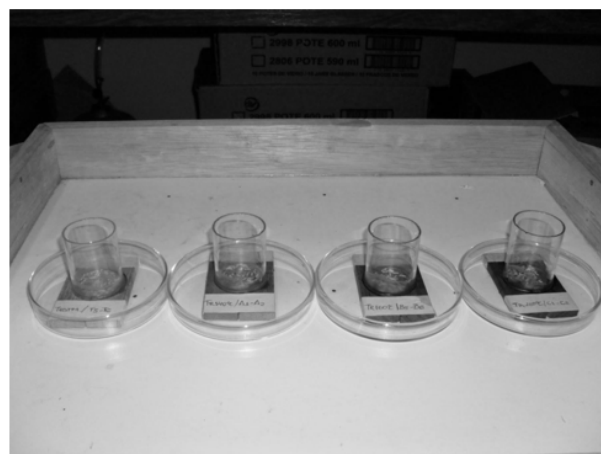


FIGURE 2: Examples of specimens ready for testing of dry-wood termites attack.

FIGURA 2: Amostras preparadas para o ensaio de deterioração por térmitas de madeira seca.

is presented on Table 1. Regarding holes, we only considered those that crossed the top and bottom faces of the specimens, as recommended by the standard used.

TABLE 1: Wear qualitative evaluation of wood specimens after dry-wood termites attack.

TABELA 1: Avaliação qualitativa do desgaste causado pelo ataque de térmitas de madeira seca.

Wear	Grade
Sound	0
Light	1
Moderate	2
Heavy	3
Failure	4

Additionally, the mass loss was calculated at the end of the test. The specimens were oven dried and had the final anhydrous mass (m_1) determined as in the initial procedure, and mass loss (ML) was calculated according to Equation 1.

(1)

In which m_0 is the initial oven dried mass of each specimen (in $ML = 100 \times (m_0 - m_1) / m_0$ n dried mass after termites attack (in grams).

Statistical analysis

Statistical analysis was performed only for mass loss and wear grades data, according to a completely randomized design, with 95% confidence level for all tests.

Mass loss

The effect of the treatments was checked by applying analysis of variance (ANOVA), with Bartlett's test used for its validation, which verifies a basic premise for the realization of ANOVA, the homogeneity of variances among treatments (RIBEIRO JUNIOR, 2001). In cases of homogeneous variances, ANOVA was applied, while in cases of statistically significant difference between means, Tukey's multiple range test was used to determine which means were different.

If at least one of the variances was not statistically equal, the Kruskal-Wallis H-test was applied, which provides a non-parametric method for ANOVA, for classification of a criterion or

experiments with one factor, where generalizations can be made (SPIEGEL, 1994). In this test, the original data of all treatments are increasingly ordered and receive scores, giving a mean score per treatment instead of an overall mean. Where at least one median was not statistically equal (p -value < 0.05), the Box-and-Whisker Plot graph was used to identify which were different.

Wear grades

As the grades are discrete data, the analysis was performed using the Kruskal-Wallis H-test, as described before.

RESULTS AND DISCUSSION

Table 2 presents the results of the test of attack by *Cryptotermes* sp. dry-wood termites.

Eucalyptus grandis wood has been classified as having low to moderate natural durability to dry-wood termites attack (SILVA et al., 2004; IPT, 2016), as well as the most likely to suffer this attack among eucalyptus species marketed in Brazil (OLIVEIRA, 1998).

Silva et al. (2004), for example, classified *Eucalyptus grandis* wood as being just as susceptible as *Pinus elliottii* wood when exposed to attack by *Cryptotermes brevis*. However, according to the results of Table 2, untreated *Eucalyptus grandis* wood had satisfactory durability to attack by *Cryptotermes* sp., contrary to the literature, mainly regarding the small average mass loss, less than 1%.

Regarding mass losses by treatment, Bartlett's test showed that the variances were homogeneous, enabling the application of ANOVA. According to the F-test result, the means of the different treatments were not statistically different, indicating that the effect of the thermal modification process on *Eucalyptus grandis* wood resistance to dry-wood termite attack was nil.

What may have contributed to the lack of difference of the means was the high coefficients of variation, indicating heterogeneity in the attack of the specimens of same treatment, due to the complex interaction between wood and termites. In this case, mass loss was not a proper test for evaluating the effect of thermal modification process, because the lowest mean (140 °C, 0.58%) was just over half of the largest one (pine wood, 1.15%), and both did not

TABLE 2: Results of the test of *Cryptotermes* sp. attack.TABELA 2: Resultados do ensaio de deterioração por *Cryptotermes* sp.

Treatments	Mass Loss (%)	Mean score of wear grades	Holes	Termites mortality (%)
Untreated <i>Eucalyptus grandis</i> wood	0.82 (81%)	31	6	77.25
<i>Eucalyptus grandis</i> thermally modified wood at 140 °C	0.58 (102%)	21	2	76.75
<i>Eucalyptus grandis</i> thermally modified wood at 160 °C	0.94 (81%)	25	7	83.25
<i>Eucalyptus grandis</i> thermally modified wood at 180 °C	1.05 (63%)	32	10	80.50
Pine wood - control	1.15 (50%)	17	0	100.00
Bartlett's test	1.02 ^{ns}	-	-	-
ANOVA – F-test	1.12 ^{ns}	-	-	-
H-test	-	8.16 ^{ns}	-	-

Where in: Numbers in parentheses correspond to the coefficient of variation. ns: not statistically significant (95% confidence level).

differ statistically.

It is noteworthy that the mass loss means were low, proportional to termites mortality, which was high, indicating the presence of toxic substances in the samples of *Eucalyptus grandis* (untreated and thermally modified) and pine. This result contradicts those from the literature (OLIVEIRA, 1998; SILVA et al., 2004; IPT, 2013). The method used (IPT, 1980) does not indicate performing mass loss analysis, but we used this analysis adapted from the ASTM D 2017 (2005) standard for rot-fungi decay resistance.

Also noteworthy is the 100% termites mortality for pine wood, suggesting that this wood species is not part of the normal diet of dry-wood termites evaluated. Although the method used (IPT, 1980) does not assume a qualitative classification of termites mortality (but indicates this information must be reported), according to the criteria of ASTM D 3345 (2008), termites mortality in treatments with *Eucalyptus grandis* wood was classified as “high”. So, if mortality was “high”, one would expect little deterioration, and small mass loss, which in fact occurred.

Dry-wood termites were not able to make holes in pine wood, while the number of holes in the treatment at 180 °C was the highest (10 holes). This finding highlights the inability of dry-wood termites to digest pine wood. Among *Eucalyptus grandis* treatments, the samples at 140°C were less perforated, with only two holes, followed by untreated wood (six holes) and those at 160 °C (seven holes). However, *Eucalyptus grandis*,

in general, presented fewer holes than what was reported by Oliveira (1998), 15 holes.

According to the method used (IPT, 1980), less worn specimens get lower grades, so the lower the mean score of grades (Table 2), the lower the wear caused by dry-wood termites attack. Figure 3 shows the joint analysis of trend lines of mass loss and mean score of wear grades, by treatment. The results of mass loss were multiplied by 10 for better visualization of its trend line.

For *Eucalyptus grandis* wood the mass loss behavior was identical to the mean score of wear grades, wherein there was a fall in the 140 °C treatment compared to the untreated, after which there was a constant increase until the treatment at 180 °C. Pine wood was the only treatment with different behavior, in which the highest mean of

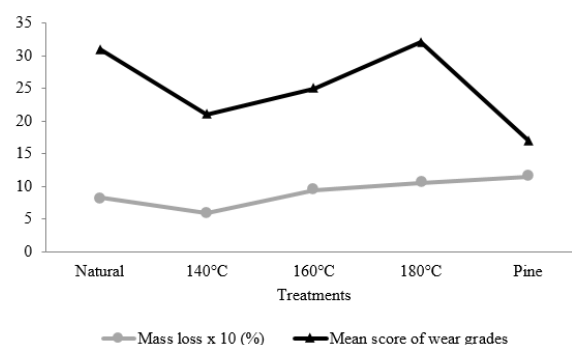


FIGURE 3: Trend lines of mass loss and mean score of wear grades, by treatment.

FIGURA 3: Linhas de tendência da perda de massa e escore médio do desgaste, por tratamento.

mass loss accompanied the lowest mean score of wear grades. This can be explained by the different foraging pattern of termites in pine in relation to *Eucalyptus grandis*, in which they were unable to penetrate the wood, although only degrading the surface of the specimens. As the presence of holes and tunnels implies worse grades, *Eucalyptus grandis* wood received such downgrades despite the lower mass loss. The criteria of wear grading recommended by the standard used (IPT, 1980) must also be considered on the results found for *Pinus* sp.

The results obtained were similar to those of Pessoa et al. (2006), who found that even at 200 °C, the effect of thermal modification was nil on the resistance of *Eucalyptus grandis* wood to dry-wood termites attack. Just as the European processes (FINNISH THERMOWOOD ASSOCIATION, 2003; PLATOWOOD, 2013; RETIWOOD, 2013), the Brazilian (VAP HolzSysteme®) did not increase the wood resistance to dry-wood termites attack.

We did not perform any comparison between wood chemistry and termites attack, because the deterioration caused by termites is mechanical rather than chemical, such as that caused by fungi. Moreover, the results indicate that the effect of thermal modification was nil on the resistance to termites attack, indicating that the chemical change (ESTEVEZ; PEREIRA, 2009; HILL, 2006; XIE et al., 2002) imparted by the process was not able to change the insects' feeding behavior.

CONCLUSIONS

Like the European processes of thermal modification, the Brazilian VAP HolzSysteme® was not effective to improve wood resistance to dry-wood termites attack, at least in the evaluated conditions.

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