Original Article

Natural Resistance of Seven Amazon Woods to Xylophagous Termite *Nasutitermes octopilis* (Banks)

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ABSTRACT

Some Amazonian woods are considered highly resistant to the attack of microorganisms; however, which ones present the highest resistance is unknown. This study aimed to evaluate the natural resistance of seven woods to xylophagous termite *Nasutitermes octopilis* through a no-choice feeding assay. The following wood species were assessed: *Dinizia excelsa*, *Manilkara huberi*, *Dipteryx odorata*, *Bagassa guianensis*, *Astronium lecointei*, *Caryocar villosum*, and *Hymenolobium petraeum* (Ducke). To this end, five timber samples from the middle heart at breast height of each plant with dimensions of 2.54 × 2.54 × 0.64 cm (longitudinal × radial × tangential) were collected from sawmills in the municipality of Altamira, Pará state, Brazil, submitted to termite action under laboratory conditions, and had their mass loss and wear assessed, with five replicates. *A. lecointei* showed the lowest resistance, whereas *C. villosum* and *D. odorata* presented the highest resistance.

Keywords: biodeterioration, xylophagous termites, no-choice feeding assay, Amazonian wood.

1. INTRODUCTION

Timber is one of the main products of construction, and lumber is used in the manufacture of furniture, bridges, boats and crafts, as well as in civil construction (Rodrigues & Brito, 2011). The native wood species from Amazon are the most sought and commercialized worldwide because of their quality and mechanical resistance, which ensure construction integrity and, consequently, the safety of individuals for a longer time (Stallbaun et al., 2017). However, because timber is a biological material, little is known about the biological resistance of Amazonian woods to different degrading organisms.

In Brazil, research on termite attack is scarce, and according to Gonçalves et al. (2013), most studies address dry wood termites. The genus *Nasutitermes* comprises most of the species of termites in the planet, and it is the most diverse and complex due to its adaptability to feeding and dwelling and its longevity compared with those of other insects of this order. Xylophagous termites are the best known as they are more commonly visualized and combated, mainly because they are considered pests by humans and present urban and rural distribution. Currently, there are approximately 2,882 species of termites cataloged worldwide, with 562 of them occurring in the Neotropical region (Constantino, 2015). Termites (Isoptera) can be classified according to their eating habit in xylophages, humivores, reapers, and intermediates (Ferreira et al., 2011).

Several researchers have conducted studies to assess wood resistance to termite attack using choice and no-choice feeding assays. Paes (2002) investigated the natural resistance of *Corymbia maculata* and only observed light wear, the author considered this wood as highly resistant; Paes & Vital (2000) studied five species of *Eucalyptus* and found that termites degraded the less dense species; Silva et al. (2004) verified that *Eucalyptus grandis* presents low resistance regardless of the age of wood. However, Paes et al. (2007b) assessed seven native, exotic woods and observed no correlation between biological resistance and wood density.

Rodrigues & Brito (2011) studied *Pinus elliottii*, *Eucalyptus urophylla*, and *Corymbia citriodora* and verified that *Pinus* timber presents higher resistance to *Coptotermes gestroi*; Gonçalves et al. (2013) investigated 10 Amazonian species and observed that the higher the density and the lower the extractive and ash contents, the higher the termite mortality; Stallbaun et al. (2017) evaluated the resistance of *Sclerolobium paniculatum* and classified its timber as highly resistant.

It is also worth noting the relevant contribution of the studies on the effects of natural extractives and thermal modification tests to assess wood resistance conducted by Paes et al. (2010, 2013, 2016), who evaluated the efficiency of Candeia (*Eremanthus*) tree oil, the effects of natural extractives, and heat treatment in various woods, and by Pereira et al. (2015), who tested the efficiency of burned oil against termite attack as a preservative in Amazonian woods.

Nevertheless, the contributions to Amazonian woods in these areas are still incipient, as in the cases of Angelim-vermelho, Angelim-pedra, Brazilian Teak, Bulletwood, Brazilian Tigerwood, Pequi, and Tatajuba, the main timbers marketed in the state of Pará, considering their good mechanical strength, high density, and use as structural parts in civil construction. In 2015, a volume of 457,145,2673 m³ of these woods were legally marketed, with cubic meter value ranging from $ 257.40 to $ 716.10 (Pará, 2017).

In the Amazon region, the biological behavior of these termites is unknown. In addition, these woods are used without considering biological degradation – either by fungi or termites –, and this information is empirical and should be recognized by the science and technology of wood, thus generating technical-scientific information. In this context, the present study aimed to assess the natural resistance of the wood of seven forest species to the attack of xylophagous termite *Nasutitermes octopilis* under laboratory conditions through no-choice feeding assays.

2. MATERIAL AND METHODS

2.1. Selection of woods and preparation of specimens

The following wood species were selected: Angelim vermelho (*Dinizia excelsa* Ducke), Bulletwood (*Manilkara huberi* Ducke Stand), Brazilian Teak (*Dipteryx odorata* Aubl), Tatajuba (*Bagassa guianensis* Aubl), Pequi (*Caryocar villosum* Aubl.), Brazilian

Tigerwood (*Astronium lecointei* Ducke), and Angelim pedra (*Hymenolobium petraeum* Ducke). The selection criterion was commercialization in the civil construction market for the purposes of permanent structures such as roofs and beams, in the municipality of Altamira, Pará state. Timber samples were collected at sawmills at the time of processing, with five samples per species and five replicates.

Test specimens with dimensions of $2.54 \times 2.54 \times 0.64$ cm (longitudinal × radial × tangencial), composed only of heartwood, were prepared according to the American Society for Testing and Materials – ASTM D-3345 (ASTM, 2005b) norm. The specimens were oven dried (103 ± 2 °C) until constant mass was reached. After that, the mass of each sample was measured according to the ASTM D-1413 (ASTM, 2005a) norm and the values were used to calculate the mass loss of test specimens submitted to termite attack. In addition to the timber of native forest wood species, samples of *Pinus* sp. were used as standard comparison according to the ASTM D-3345 (ASTM, 2005b) norm. Basic density values were determined according to the ABNT NBR 7190/1997 norms, using a mean for each species (ABNT, 1997).

2.2. Colony collection and capture of termites

A termite colony was collected at a sawmill in the municipality of Altamira from ceiling beams located approximately 5 m above the ground. After collection, the colony was arranged in a water tank (250 L), which was supported on four bricks placed in plastic trays containing water to prevent the termites from escaping, according to the methodology described in Paes et al. (2013).

Termites were captured from the tank using square pieces of cardboard (20 × 20 cm), moistened with distilled water to attract the insects and placed at the bottom of the tank, according to the recommendations by Paes et al. (2013). Collection of the termites occurred approximately 48 h after their migration from the colony to the cardboard pieces.

The cardboard pieces were disassembled on a tray and the termites transported to a 10-liter bucket containing 20 paper towels. Ten of these paper towels were moistened with distilled water, slightly kneaded, and placed at the bottom of the bucket, whereas the other 10 dry towels were used as a cover, as described

in the ASTM D-3345 (2005b) norm. After 7 h, the insects settled between the towels, with the weaker termites remaining on the dry towels and the more vigorous termites remaining on the moist towels. The dry paper towels were removed and discarded, whereas the moist ones were taken to the laboratory for collection of the termites.

2.3. Preparation of the assay assembling flasks

The no-choice feeding assay was assembled in 500 mL plastic flasks, washed and sterilized (80% ethanol), to which 200 g of sterilized sand and distilled water were added to saturation point and kept at rest for 12 h, according to the ASTM D-3345 (ASTM, 2005b) norm.

A specimen was then placed in each flask and buried in the sand up to half its length, embedded to the side so that it was visible for analysis from the outside of the flask. For each wood, five replicates were used in five randomized blocks (25 jars with sand and samples of timber and termites per species). The same procedure was adopted for the control.

N. octopolis termites (1 ± 0.05 g) were weighed and added to the flask. Necessarily, 90% of the termites used were workers, because this class of individuals is responsible for the wood wear. After addition of the insects, the flasks were covered with thin cloth, as recommended by Paes et al. (2007a).

In addition, five flasks without wood samples (water, sand and termites only) were used to evaluate termite vitality. The flasks remained at temperature and relative humidity conditions of 27 ± 2 °C and $75 \pm 5\%$, respectively, for four weeks, as described in the ASTM D-3345 (ASTM, 2005b) norm.

2.4. Statistical analysis

Determinations of the ASTM D-3345 (ASTM, 2005b) norm were used as parameter to assess the mass loss and wear of wood (Table 1). The experiment was conducted in a randomized design, and the blocks represented the specimens of each forest wood species. The Lilliefors test was performed to verify the normality of data; as the data did not present normality, they were transformed into percentage and the Tukey's test was then applied for analysis of variances at 5% significance level ($p > 0.05$).

Table 1. Evaluation of wood wear and termite mortality.

Wood wear	Grade
Sound, allowing superficial scarification	10
Light attack	9
Moderate attack, with penetration	7
Heavy attack	4
Failure, with rupture of the specimens	0
Termite mortality	**(%)**
Low	0-33
Moderate	34-66
High	67-99
Total	100

Source: Modified from ASTM D-3345 (ASTM, 2005b).

Table 2. Mean values of wood wear and termite mortality according to species.

Species	Wear grade	Termite mortality
Pinus sp. (Control)	7	100
Dipteryx odorata	10	100
Dinizia. excelsa	10	100
H. petraeum	10	100
A. lecointei	7	50
M. huberi	9	100
B. guianensis	9	100
C. villosum	10	100

3. RESULTS AND DISCUSSION

Among the species evaluated regarding wood wear, Brazilian Tigerwood (*Astronium lecointei* Ducke) presented the lowest grade (7) (Table 2), characterized by moderate termite attack. The other assessed species presented light attack or remained sound. These results can be associated with the chemical composition of wood, because those that presented higher wear grades have higher natural extractive contents. As reported by several authors (Supriana, 1985; Rodrigues & Brito, 2011; Paes et al., 2013), depending on the type and concentration of these compounds combined with high density, wood may present higher biological resistance.

Loureiro et al. (1997, 2000) classified Angelim-vermelho (*Dinizia excelsa* Ducke) wood as of high density (0.83 gcm⁻³), a value lower than that found in this study (1.05 gcm⁻³), and resistant to attack by xylophagous organisms; however, the authors did not identify such organisms. This wood species also presents low permeability, which assists with its natural resistance. Ferreira & Hopkins (2004) associated density with thickness of the fiber wall, that is, the thicker the fiber wall, the denser the wood. Regarding the Angelim-pedra species, Paula & Alves (1997) and Ferreira & Hopkins (2004) reported that this wood presents density > 1 gcm⁻³; however, Vasconcellos et al. (2001) mentioned a value of 0.72 gcm⁻³, similar to that found in this study, showing the variation in wood density, which may influence biological resistance.

Gonçalves et al. (2013) classified the wood of Angelim-pedra as of moderate wear grade to the attack of *Cryptotermes brevis*; however, the present study demonstrated that this wood is resistant to the attack of *N. octopilis*, as it can be verified in Table 2. The high resistance can be explained by the chemical composition of this wood: 31.77% lignin, 11.52% extractives, 0.56% ash, 56.15% holocellulose, 47.36% cellulose, 5.90% xylose, 1.40% mannose, 1.02% glucuronic acid, and 0.40 galactose, according to Castro et al. (2015); these authors also found 1.08% tannins. Colodette et al. (2015) and Febrianto et al. (2015) reported that extractives can influence the physical properties, and that certain phenolic components can inhibit the attack of fungi and insects.

As for Bulletwood (*Manilkara huberi* Ducke Stand), density of 0.83 gcm⁻³ was observed in the present study; however, Santos (1987), Paula & Alves (1997), and Pereira (2013) found a density value > 1 g cm⁻³. Brazilian Teak (*Dipteryx odorata* Aubl) presented density of 1.07 gcm⁻³, a result similar to those observed by Santos (1987) and Pereira (2013). Tatajuba (*Bagassa guianensis*) showed density of 0.79 gcm⁻³, the same value obtained by Santos (1987) and Pereira (2013), who described this wood as resistant to termite attack.

At the end of the assays, it was possible to verify complete termite mortality in all tested wood species, except for Brazilian Tigerwood (*Astronium lecointei* Ducke) (Table 2), which presented moderate wear grade in relation to the attack of *N. octoplis*, according to the parameters shown in Table 1. Abreu & Silva (2000) showed that high-density native species tend to contain more lignin and, consequently, more natural extractives such as quinones, terpenoids and polyphenols. These

extractives, which act as natural defenses preventing the microorganisms present in the intestines of termites from fully digesting the cellulose, are the possible cause of the high mortality rate of insects, a fact also observed by Stallbaun et al. (2017).

Brazilian Tigerwood timber samples, as shown in Table 2, presented considerable susceptibility to termite attack compared with that of *Pinus* sp., which was used as control due to its low wear grade according to the ASTM D-3345 (ASTM, 2005b) norm. This finding can be explained by the quite selective feeding habits of these termites, which attack more avidly species they have more contact with, as reported by Stallbaun et al. (2017), suggesting that this situation occurred in the present study, because the colony obtained for the experiment came from a sawmill in a region where Brazilian Tigerwood timber is more abundantly stored and commercialized.

Another explanation may be the preference of termites for a particular wood. According to Lima & Costa-Leonardo (2007), these insects present different feeding habits, and this difference can occur between and within (imagoes and soldiers) groups, in addition to be an important factor for the evolution of the species.

The mass loss observed in the experiment indicates that the woods assayed are naturally resistant to termites of the tested species, except for the Brazilian Tigerwood timber samples, which presented the highest percentage of mass loss (Table 3). According

Table 3. Mean values of basic density and mass loss according to species.

Species	Basic density (gcm⁻³)	Dry mass (g)	Final mass (g)	Mean values of mass loss (%)
Pinus sp. (Control)	0.54	56.45	48.04	14.90 c
D. odorata	1.11	114.88	112.95	1.67 a
D. excelsa	0.60	62.42	60.86	2.5 a
H. petraeum	0.65	67.57	62.71	7.19b
A. lecointei	0.61	62.78	55.14	12.16c
M. huberi	0.58	59.85	55.75	6.85 b
B. guianensis	0.76	78.71	76.46	2.85 b
C. villosum	0.49	50.91	50.17	1.45 a

Means followed by the same letter do not differ statistically by the Tukey's test (*p* > 0.05).

to Stallbaun et al. (2017), high-density woods tend to decrease the fragmentation ability of termites, thus inhibiting their consumption. Nevertheless, it is consensus that, in order for natural resistance to be assessed, not only must the wood density and the amount of chemical extractives be evaluated, but also the chemical class of such extractives and their effects on different organisms (Paes et al., 2007a; Stangerlin et al., 2013; Marcondes et al., 2013). Alencar et al. (2011) did not find any correlation between mass loss and density for Sabiá (*Mimosa caesalpiniifolia*) wood, but found a difference between phenotypes (with or without aculei) and position of the wood in the pith-to-bark direction.

4. CONCLUSION

Dipteryx odorata (Brazilian Teak), *Dinizia excelsa* (Angelim-vermelho), *Manilkara huberi* (Bulletwood), *Bagassa guianensis* (Tatajuba), *Caryocar villosum* (Pequi), and *Hymenolobium petraeum* (Angelim-pedra) showed resistance to termite attack.

Pequi (*Caryocar villosum*) can be considered the most suitable wood for use in civil construction because it presents biological resistance (total termite mortality and absence of wood wear) and low mass loss after *N. octopilis* termite attack.

Brazilian Tigerwood (*A. lecointei* Ducke) presented the lowest wear grade and mortality rate and the highest mass loss.

Study of the chemical composition (cellulose, hemicellulose, predominant lignin type: syringyl or guaiacyl) and extractives of the wood of the species addressed in this study is recommended because of the termite mortality rate and the lifestyle of *Nasutitermes octoplis* termites.

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