REVISTA CONTRIBUCIONES A LAS CIENCIAS SOCIALES

Relationship of extractive content, ash and basic density of wood to the attack of termites *Nasutitermes* sp.

Relação do teor de extrativos, cinzas e densidade básica da madeira com o ataque de cupins *Nasutitermes* sp.

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ABSTRACT
An important characteristic for the use of wood is its natural resistance. The objective of the research was to evaluate the natural resistance of the species Plathymenia reticulata, Kielmeyera speciosa and Casearia sp. to the attack of Nasutitermes sp termites and relate it to the content of extractives, ash and basic wood density. The basic density was determined in accordance with NBR 11941 (ABNT 2003) and the extractive and ash contents in accordance with TAPPI T 204 and TAPPI T 211 standards, respectively. The food preference test was performed using the Completely Randomized Design (DIC) method. As a result, P. reticulata showed statistical difference in the basic density in relation to the other species that did not differ among themselves, and the ashes did not present a significant difference between the species, at the 5% level of significance. P. reticulata obtained 0.33% of mass loss, 24.54% of extractive and basic density of 780 kg m-³, in addition to presenting the highest ash content of 2.06%. It is concluded that this is the most resistant species, in relation to its chemical and physical constituents. K. speciosa showed the lowest resistance, followed by Casearia sp., having no relationship with the extractive content.

Keywords: térmites, chemical properties, natural resistance, degradation, food preference.

RESUMO
Uma caraterística importante para o uso da madeira é a sua resistência natural. O objetivo da pesquisa foi avaliar a resistência natural das espécies Plathymenia reticulata, Kielmeyera speciosa e Casearia sp. ao ataque de cupins Nasutitermes sp e relacioná-la com o teor de extrativos, cinzas e densidade básica da madeira. A densidade básica foi determinada de acordo com a NBR 11941 (ABNT 2003) e os teores de extrativos e cinzas de acordo com as normas TAPPI T 204 e TAPPI T 211, respetivamente. O teste de preferência alimentar foi realizado pelo método de Delineamento Inteiramente Casualizado (DIC). Como resultado, a P. reticulata apresentou diferença estatística na densidade básica em relação às demais espécies que não diferiram entre si, e as cinzas não apresentaram diferença significativa entre as espécies, ao nível de 5% de significância. A P. reticulata obteve 0,33% de perda de massa, 24,54% de extrativos e densidade básica de 780 kg m-³, além de apresentar o maior teor de cinzas de 2,06%. Conclui-se que esta é a espécie mais resistente, em relação aos seus constituintes químicos e físicos. A K. speciosa apresentou a menor resistência, seguida da Casearia sp. não tendo relação com o teor de extrativos.

Palavras-chave: térmitas, propriedades químicas, resistência natural, degradação, preferência alimentar.

1 INTRODUCTION

The raw material wood can be used in different ways, whether for civil construction, charcoal, pulp and paper, packaging, posts, pallets and furniture (Carvalho et al., 2018). It has three main macromolecular elements that make up the cell wall: lignin, cellulose and hemicellulose; and the minority and low molecular weight components: extractives and mineral substances (Lima et al., 2007), which are related to the natural resistance capacity of wood against xylophages.

Although extractives have low levels compared to other wood components, they are responsible for odor, color, rotting durability, natural resistance to xylophages and taste, and may be reserve and/or protective substances (Paes et al., 2016). In addition, the amount of compounds and the composition of the extractives depend on factors such as species, region of origin, age, etc. (Klock et al., 2013; Paes et al., 2016).

Regarding biotic factors, especially xylophagous organisms, termites are the most common, considered as pests by humans, with extensive occurrence in urban and rural areas. These insects belong to the suborder Isoptera (Order Blattodea), with approximately 3,166 species in the world, 661 of which occur in the Neotropical region (Krishna et al., 2013; Constantino, 2017). The genus *Nasutitermes* sp. stands out for being the most numerous, with 254 species, 114 of which in the Neotropical region that feed on dry, wet or partially decomposed wood (He et al., 2013; Krishna et al., 2013; Paes et al., 2013).

Some studies that analyze factors on the maintenance of the physical structure of wood, such as the work by Paes et al. (2013), have shown an antagonistic relationship between ash content and the presence of direct termite attack. According to the authors, this is explained by the presence of abrasive substances in the ash that cause potential damage to the jaws of xylophages (Paes et al., 2013; Gonçalves et al., 2013).

Another important characteristic that stands out is the basic density of the woody material, being one of the main parameters for evaluating the quality of the wood and defining its final use, since many properties of wood depend on this physical characteristic (Oliveira, 2014).

The species *Plathymenia reticulata*, belongs to the Fabaceae family, has a wide occurrence in Brazil, extending from Amapá to Paraná, being present in the Atlantic Forest, Cerrado, Caatinga and Pantanal. It is popularly known as mahogany and consists of chemical components such as tannins and flavonoids. Tannins are water-soluble phenolic elements that can prevent the action of insects, bacteria and fungi (Fernandes, 2002). Sawn or round wood of this species is widely used in furniture, panels, doors, naval construction, internal use, posts, bodies, stakes, supports and posts (Carvalho, 2008). According to Jenrich (1989), the wood of this species is quite durable even when used as a fence post, because it is very resistant to termites.

The genus *Kielmeyera Mart*. is native to South America and comprises approximately 47 species, of which 45 are native to Brazil (Barros, 2002). The species *Kielmeyera speciosa* is popularly called Pau-Santo and belongs to the *Calophyllaceae* family. It is present in the Cerrado biome, with geographic distribution in the Center-West and Southeast regions of Brazil (Bittrich, 2012), occurring from Rio Branco to São Paulo, being more constant in the Center-West (Rizzini 1963; Saddi 1982, 1984, 1996). It is used in folk medicine as a tonic and emollient and in woodworking (Silva-Júnior, 2012).

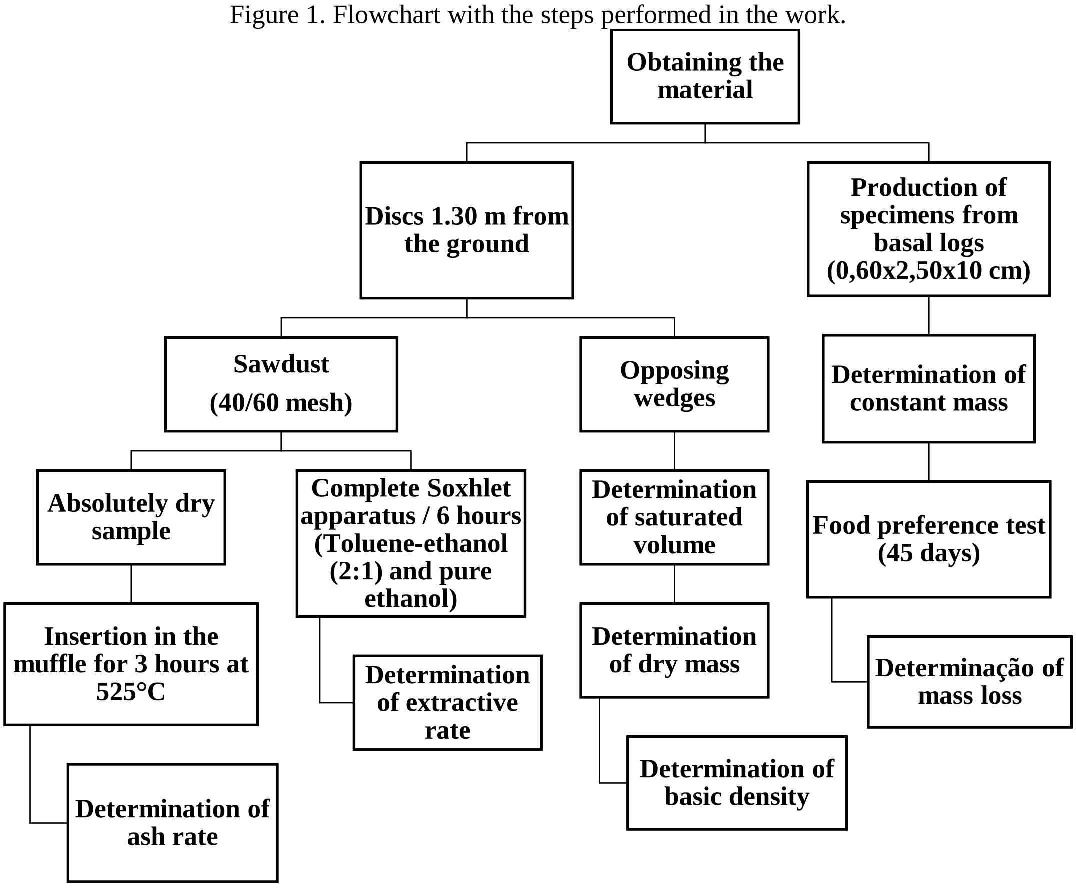
The genus *Casearia* comprises approximately 160 species spread across the tropics and subtropics (Breteler, 2008), with about 70 of them present in Brazil (Maistro et al., 2004). Furthermore, it is widely distributed occurring from Mexico to Argentina (Marquete et al., 2016). In Brazil, species of this genus grow in the formations of dense ombrophilous forest (Amazonian and Atlantic Forest), semi deciduous seasonal forest, deciduous seasonal forest, savannah (Cerrado), steppe savannah (Caatinga), vegetation with marine influence (Restinga), ombrophilous forest mixed (Araucária Forest), gallery forest, secondary vegetation, at altitudes ranging from sea level to 1800 meters (Marquete et al., 2007; Marquete et al., 2010). Considered the wood from *Casearia decandra* Jacq. useful in joinery and carpentry, and can also be used for civil construction, lathes, clubs, floorboards, firewood and charcoal (Marquete et al., 2010).

In light of the above, the present study aims to evaluate the natural resistance of the species *Plathymenia reticulata*, *Kielmeyera speciosa* and *Casearia* sp. to the attack of *Nasutitermes* sp., and to relate with the contents of total extractives, ash and basic density of the wood.

2 METHODOLOGY

Figure 1 shows the flowchart with the steps performed in the work, which are described below.

Figure 1. Flowchart with the steps performed in the work.



Source: From the authors (2023).

2.1 FEEDSTOCK

The experiments were carried out at the Laboratory of Energy Production and Sawmill, of the Institute of Agricultural Sciences, campus of the Federal University of Minas Gerais, Montes Claros – MG, Brazil. Three native species were used: *Plathymenia reticulata* and *Kielmeyera speciosa* collected in Carbonita, MG, Brazil, at the coordinates of 17°33'12.97"S and 43°7'48.23"W and 17°32'35.60"S and 43° 8' 44.48"W, respectively, with vegetation type Cerrado sensu stricto (Santos et al., 2010) and the species *Casearia* sp. collected in Conceição do Mato Dentro, MG, Brazil, at the coordinates of 18°55'27.92"S and 43°24 '46.75"W, with phytophysiognomy of semideciduous seasonal forest (FES), (Veloso et al., 1991). These were located at altitudes of 818, 880 and 701 meters, respectively. Both cities are classified as having a tropical climate (Aw) according to the Köppen climate classification (Martins et al., 2018).

For the analyses, discs of Diameter at Breast Height (1.30 m from the ground) of each species were used, cut into four wedges, two opposite wedges used to determine the basic density and the others for chemical analysis. Samples of the basal logs were also prepared for the analysis of food preference of soil termites *Nasutitermes* sp.

The forest species used in this research were extracted from protected regions, with permission of only two trees per species. Thus, the forestry company is not allowed to take more samples, through strict control of the preservation areas. Furthermore, with the constant evaluation of the species dispersion index and with the mild situation of the same, we obtained a quantity of raw material that does not compromise the biodiversity of the property.

2.2 TOTAL EXTRACTIVES CONTENT

The total extractive content was determined through samples of the wood core, ground and sieved, using the fraction that passed through the 40 mesh sieve and was retained in the 60 mesh, followed by two grams of sawdust and three replications for each species. For the isolation of the extractives, the solvents Toluene-alcohol (2:1) and pure alcohol were used, with extraction carried out in a complete Soxhlet apparatus for 6 hours, according to the TAPPI T 204 cm-97 standard (Technical Association of the Pulp and Paper Industry 1997a).

2.3 ASH CONTENT

The determination of the ash content was carried out according to the TAPPI T 211 cm-93 standard (Technical Association of the Pulp and Paper Industry 1997b). In which, from the material retained on the 60 mesh sieve and previously dried in an oven, each repetition, with two grams of sawdust, was conditioned in a muffle furnace at 525 °C for 3 hours.

2.4 BASIC DENSITY

The basic density was calculated using the water displacement method, according to NBR 11941 (ABNT 2003), which is based on the ratio between the dry mass of wood and its saturated volume. Sample saturation was obtained by immersing them in water until reaching constant volume. Dry mass was obtained by weighing, after drying the sample in a forced air circulation oven at 103 ± 2°C.

2.5 FOOD PREFERENCE TEST

The food preference test was carried out in a PVC box with a capacity of 500 liters, composed of a layer of ± 10 cm of wet sand, containing the termite colony. The 45 samples, divided into 3 treatments, were buried approximately 2/3 of their length, randomly, in the sand.

The termite colony was collected near the area where the experiment was installed in the Energy Production Laboratory and Sawmill, later they were placed in the box on a metal grid measuring 30 x 40 x 5 cm above the sand layer.

The specimens were exposed to the action of termites for 45 days in an acclimatized room (27 ± 2 °C and 75 ± 5% of relative humidity) according to the standards of Paes et al. (2013). At the end of the experiment, the samples were dried in an oven at 103 ± 2 °C to evaluate the loss of mass.

Table 1. Classification of mass loss in a xylophagous fungi resistance test (ASTM D-2017 2008).

Weight loss (%)	Residual Mass (%)	Resistance Class
0-10	76-89	highly resistant
11-24	90-100	Resistant
25-44	56-75	moderately tough
≥45	≤55	not resistant

Source: From the authors (2023).

2.6 STATISTICAL ANALYSIS

All data analyzes were processed and interpreted by the Software R Core Team (2019). The statistical evaluation followed the Completely Randomized Design (CRD) and to obtain homogeneity and normality, the mass loss data were transformed into Log. For all data, Tukey's test was applied at 5% significance.

3 RESULTS AND DISCUSSIONS

The values of mass loss and extractive content were different among all forest species (Table 2). *P. reticulata* showed a statistical difference in basic density, in relation to the other species that do not differ among themselves. On the other hand, the ash did not obtain a significant difference between the three species, being all analyzed at 5% of significance. Statistical analysis indicated that *P. reticulata* was more resistant to termite attack with 0.33% mass loss, presenting 24.54% of total extractive and density of 780 kg.m³, statistically different and superior to the other species, and also showing the highest ash content of 2.06%, which did not differ between species. As a result, *P. reticulata* suffered less mass loss, followed by *Casearia* sp. and *K. speciosa*.

Table 2. Mass Loss Result (%), Ash (%), Basic Density (kg m-³) and Total Extractives (%) of *Plathymenia reticulata*, *Kielmeyera speciosa* and *Casearia* sp.

Species	Weight loss (%)	ashes (%)	base density (kg m³)	Total extracts (%)
Plathymenia reticulata	0,33c	2,06a	780a	24,54a
Kielmeyera speciosa	59,94a	0,65a	570b	5,53b
Casearia sp	5,29b	0,62a	605b	4,37c

Source: From the authors (2023).

The lower deterioration of *P. reticulata* can be explained by the presence of a high content of extractives, ash and higher basic density. The ash is usually harmful to the jaws of termites, while the density and extractives usually confer greater resistance to the wood, a situation that did not occur to the other species, which had a great preference for feeding by insects. However, according to authors such as Paes et al. (2013) and Paes et al. (2016), the relationship of wood strength does not depend exclusively on the quantitative factors of the extractives that make up the wood, but on the types and location of the organic extractives in the woody cell.

Similar results to those obtained for *P. reticulata* (Table 2), were presented in the work by Gama et al. (2020) with the species *Copaifera arenicola* (Fabaceae), in which an average of 20.18% of extractives along the tree and 1.93% of ash were found. A similar value was also found by Franzen (2018) in *Copaifera sp.*, with 25.09% of extractive in ethanol/toluene. Conversely, Pereira et al. (2019) found extractive content of 7.3% and 0.45% ash for wood of Pterogyne nitens (Fabaceae) in ethanol/toluene, and Paes et al. (2013) found a total extractive of 13.59% and ashes of 2.18% for *Amburana cearensis* (Allem.) A.C.Sm. (Fabaceae). However, in this work, extractive contents were not linked to attack resistance. On the other hand, species with higher ash content were the least attacked. Also highlighting the existing differences between age, region, species and genus of trees in the influence of their chemical compounds.

Regarding the mineral components of wood, the content is usually small, formed mainly by mineral oxides, such as calcium, magnesium, phosphorus, silicon and potassium oxides, among others. According to Tsoumis (1991), the ash content is rarely greater than 1% of the dry weight of the woods. As per Brand et al. (2013), the increase in ash content is related to the increase in volatile content. Batista (2020) observed in his work that *Auxemma oncocalyx* and *Mimosa caesalpiniifolia* exhibited higher ash contents in their constitutions with 4.84% and 3.11%, respectively.

Extractives may differ even between species as it depends on the extraction method used (Rowell et al., 2005). The natural durability of wood is usually given by extractives soluble in 1% NaOH, as some of these are terpenes and phenols, which are considered protective materials for wood (Mendoza, 2017). Phenolic substances are also removed in acetone and water (Jansson et al., 2009), pointing out the differences in the amount and composition of the total extractives of the studied species. In the work of Batista (2020), *Mimosa tenuiflora* and *Mimosa caesalpiniifolia* exhibited higher extractive contents in their constitutions, with 14.62% and 14.92%, respectively.

The results showed that *Auxemma oncocalyx* with 4.84% of ash and 10.42% of extractives was one of the most susceptible species to deterioration in biotic and/or abiotic actions during the 365 days of the test, while *Mimosa tenuiflora* with 0.90% ash and 14.62% extractives and *Mimosa caesalpiniifolia* with 3.11% ash and 14.92% extractives stood out as one of the highly resistant (Batista, 2020).

The basic density in the present study for *P. reticulata* was 780 kg m^{-3}, whereas Machado Neto (2015) described in his study the value of 520 kg m^{-3} of basic density for the same species. Likewise, with species from the same family, Pereira et al. (2019) had 641 kg m^{-3} for *Pterogyne nitens.* The difference between densities can be explained by the fact that the basic density is variable in several ways, between botanical species, between trees of the same species, between individuals of the same clone and along the trunk of the same tree (Couto et al., 2012).

For *Casearia* sp., results similar to those obtained in the present study (Table 2) were found by Costa et al. (2014) for *Casearia sylvestris,* with 6.09% extractive, 1.92% ash content and 625 kg m^{-3} of basic density. Also, in the work by Missio et al. (2017), the basic density found for *Casearia obliqua* was 670 kg m-³, and for *Casearia decandra* was 650 kg m-³. For ash, analyzes performed with Cerrado wood found variations between 0.15% (*Enterolobium gummiferum*) and 2.73% (*Erytroxylum suberosum*), (Vale et al., 2002).

Regarding *K. speciosa*, the results were similar to those of Martins (2012) for *Kielmeyera coriacea* Mart. & Zucc, where the ash content was 0.70% and the total extractive was 5%. In a study carried out by Vale et al. (2002), *K. speciosa* resulted in 580 kg m-³ of basic density.In the work by Carli et al. (2012) with *Calophyllum brasiliensis* Cambess found an average lignin content, with extractives of 31.38%, 1.28% ash and 700 kg m-³ of basic density.

Testing the anti-termite potential of the heartwood and bark with the extractive and chemical compounds isolated from *Madhuca utilis* Ridl. HJ Lam and *Neobalanocarpus heimii* Rei PS Ashton, Kadir et al. (2014) found that, in general, extracts from the bark and heartwood of *N. heimii* were more toxic than extracts from *M. utilis* at any concentration tested. For this purpose, Siramon et al. (2007) pointed out that the composition of essential oils and wood extractives vary significantly depending on the geographical origin, time of extraction and procedure.

Analyzing the better performance of the extracts of *N. heimii*, they concluded that it is due to the presence of greater amounts of oxygenated compounds (96.5% in the bark and 99.7% in the heartwood) compared to extracts of *M. utilis* (17% in the bark and 23.5% in the heartwood). In another study, Watanabe et al. (2005) also reported that oxygenated compounds from white cypress pine (*Calitris glaucophylla*) were termite repellent. Another factor mentioned by Pandey et al. (2012) is the presence of alcohol, acetate and aldehyde groups being toxic compounds for the termite *Odontotermes assamensis* Holmgren.

In an analysis of the natural resistance of *Bambusa vulgaris* to termite and beetle attack, Sadiku et al. (2021) found that the higher the lignin content of bamboo, the lower its resistance to attack, in contrast to the literature that reports bamboo as more resistant to termite attack compared to wood (Syafii et al., 1988). However, the level of consumption by termites and beetles may be due to the higher amount of starch that makes the species more susceptible to insect attacks, as well as the extractive and lignin components that may not be toxic enough to prevent consumption by termites. (Grace et al., 1988; Sulthoni, 1988).

Furthermore, the correlation between wood density and consumption by termites and beetles, respectively, was low or weak (R 2 =0.109 and 0.366). Thus, Sadiku et al. (2021) found that increasing culm density does not guarantee that bamboo consumption will decrease, contradicting a study that showed density as influencing the termite's ability to mechanically fragment wood with its jaws (Owoyemi et al., 2014). Thus, the use of the density factor alone, in most cases, is not enough to determine the durability of bamboo or wood (Roszaini et al., 2017).

Thus, in the present study, it was possible to observe that only *Plathymenia reticulata* had a correlation between chemical compounds and mass loss. And that the natural resistance of the other species was not related to the content of existing extractives, proving that not always the most resistant woods had the highest extractives contents in the wood.

4 CONCLUSIONS

The species *P. reticulata* proved to be more resistant to the attack of the termite *Nasutitermes* sp., being related to the high amount of extractive, ash and basic density, 24.54%, 2.06% and 780 Kg m^{-3} respectively.

K. speciosa was statistically equal to *Casearia* sp. in ash content and basic density, the latter having a smaller amount, giving its low resistance. However, it was the species most attacked by the termite, with a higher extractive content compared to *Casearia* sp. stating that resistance is not only related to the amount of extractives, but also to the type available.

K. speciosa was the species with the lowest natural resistance and there was no relationship between extractives and weight loss. On the other hand, *P. reticulata* presented high resistance to the attack of the xylophage and has a relationship between the chemical and physical properties of the wood.

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