

Biodeterioration of wood from two fast-growing eucalypts exposed to field test



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ABSTRACT

This study aimed to evaluate changes in the chemical composition and mechanical properties of static bending of wood from two fast-growing eucalypt species (blue gum and lemon-scented gum) after exposure for one year in a field test. To achieve this, decayed untreated wood (after 1 yr of exposure in the field test) was characterised by chemical analysis, thermogravimetric analysis, and infrared spectroscopy, and was compared with control samples. Mass loss and modulus of elasticity (MOE) and modulus of rupture (MOR) as a function of the exposure time were evaluated. The main findings showed that lignin and carbohydrate content of the two decayed woods decreased after exposure in the field test. Mass loss increased with increasing time of exposure, while MOE and MOR decreased for both woods. Nevertheless, blue gum wood was more susceptible to decay.

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1. Introduction

Natural biodegradable materials are widely used in constructions that are exposed to degradation processes with chemical, environmental or microbial origins. The rate of material deterioration is directly dependent on the exact environment to which the material will be exposed. Among biodegradable materials, wood is considered durable in relation to the ability to maintain its structural properties under the action of weathering, although attacks by xylophages have to be taken into account.

Lemon-scented gum (*Corymbia citriodora*) and blue gum (*Eucalyptus saligna*) are Australian eucalypts and their wood is highly regarded for its durability. Australian Standard 5604 (2005) classifies these species as Class 2 and 3, respectively, which means they can be expected to have a service life of 15–25 yr in-ground. In Brazil, eucalypt heartwood can suffer severe decay (Zeni et al., 2005; Araújo et al., 2012). Many factors aggravate that situation; examples are geographical location, in which tropical climatic conditions (temperature

and humidity) make the presence of fungi and termites abundant; use of wood from fast-growing plantations and young trees; and low toxicity of extractives from young trees when compared to extractives in mature trees (Silva, 2002; Goulart et al., 2012).

Field tests are one of the most important ways to understand the process of degradation of in-service wood and have been used in many previous studies, such as those done by Palanti et al. (2011), Cookson (2012), Magalhães et al. (2012), Meyer et al. (2014), and Brischke et al. (2014). Moreover, field tests are an alternative to ensure more realistic conditions (Meyer et al., 2014) such as climatic conditions and microflora of the soil, both characteristics that can influence the durability of wood in-ground contact (Brischke et al., 2014).

Evaluation of decayed wood exposed in field tests, laboratory tests, and weathering tests can be performed using different techniques. Usually, visual ratings by local specific standards for evaluation of decayed wood are used (Ali et al., 2011; Palanti et al., 2011; Cookson, 2012). However, these criteria are subjective and depend on the perception capacity of the referee. Another common technique applied to evaluate the decay resistance of wood is the analysis of loss in physical and mechanical properties (Humar et al., 2006; Simsek et al., 2010; Ali et al., 2011).

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In recent years, techniques such as infrared spectroscopy and thermogravimetric analysis have been applied to evaluate the degradation of lignocellulosic materials by xylophagous organisms. Many studies have observed that modification of intensity of main bands at $800\text{--}1800\text{ cm}^{-1}$ - fingerprint of wood (Pandey, 1999) - qualitatively indicates the degradation of wood components by the action of weathering or decay (Mohebbi, 2005; Naumann et al., 2012; Tomak et al., 2013). Additionally, thermogravimetric analysis has been shown to be a good tool for the evaluation of wood deterioration, mainly when the type of rot (white or brown, for example) is known (Popescu et al., 2010; Alfredsen et al., 2012). This technique uses the thermogravimetric curve of wood components to estimate and quantify the loss caused by weathering or decay.

In this context, the present study aimed to evaluate changes in the chemical and mechanical properties at static bending of two eucalypt woods from a fast-growing Brazilian forest population after 1 yr of exposure in service.

2. Materials and methods

2.1. Selection and preparation of the material

Blue gum (*E. saligna*) and lemon-scented gum (*Corymbia citriodora*) were the selected eucalypt species. For each species, twelve 20-yr-old trees from a fast-growing forest population with planting spacing of $3 \times 2\text{ m}$ were used in order to cut the wood samples. To achieve this, the first two logs measuring 2.8 m in length with a diameter at breast height of $\sim 35\text{ cm}$ were cut from each tree (Fig. 1).

All the logs presented differences between heartwood and sapwood; about 65% of the cross-cut section area was heartwood and just $\sim 3.4\text{ cm}$ was sapwood. Logs were sawn in a band saw using tangential cutting in order to obtain a central plank measuring 8 cm in thickness, and then the planks were cut into boards without sapwood.

From these boards, 68 defect-free heartwood stakes measuring $2 \times 2 \times 31\text{ cm}$ (thickness, width, and length, respectively) were randomly prepared for each species, and were kept in a climate chamber under controlled conditions (temperature, $20\text{ }^{\circ}\text{C}$; relative humidity, 65%) to reach the equilibrium moisture content ($\sim 12\%$). The specific gravities of blue gum and lemon-scented gum wood are 0.79 and 1.02 g cm^{-3} , respectively.

2.2. Installation and characterisation of the field tests

The field tests were carried out in two sites with different types of vegetation. The stakes were placed at an outdoor site dominated by

low vegetation (out of the shade) and inside a forest of *Acacia mearnsii* (6 yr old) with planting spacing of $3 \times 2\text{ m}$. Both sites are located in southern Brazil ($31^{\circ}58'18''\text{S}$ and $52^{\circ}63'55''\text{W}$), 245 m above sea level. The Köppen classification of the climate region is Cfa.

Wood stakes were randomly distributed and placed at 1 m distances between the stakes to either side in a vertical position with half of their length grounded, totalling 64 m^2 of the experimental area. Stakes were collected at eight different times: after 45, 90, 135, 180, 225, 270, 315, and 360 days of exposure. Four stakes per wood, per site, were collected for each species and cleaned with a brush; an additional four stakes were used as controls. The stakes were then placed in a climate chamber ($20\text{ }^{\circ}\text{C}$ and 65% RH) until constant mass was achieved.

2.3. Chemical characterisation

The quantitative chemical analyses of the decayed and the control samples were performed using wood removed from the critical zone (Magalhães et al., 2012). That region was chosen because it is the part more affected by decay due to the presence of oxygen and humidity, which contributes to the growth of the xylophagous organisms.

After mechanical tests, the critical zone of the stakes from the eighth collection were separated, milled in a knife mill (Wiley type), and homogenised. Milled samples were kept in a climate chamber at $70\text{ }^{\circ}\text{C}$ to eliminate the excess moisture. Finally, all the milled samples were classified according to the particle size; 40–60 mesh was used for the chemical characterisation by TAPPI standards and below 60 mesh was used for ATR-IR and TGA analysis.

Ethanol-toluene extractives content (T204 cm-97), Klason lignin (T222 om-98), and $\text{NaOH}_{(1\%)}\text{ solubility}$ (T212 om-02) were determined by TAPPI standards. Hollocellulose content was measured as described by Wise et al. (1946). All chemical quantification was performed in triplicate.

2.4. ATR-IR spectroscopy

Decayed samples grading below 60 mesh were prepared. Attenuated total reflectance infrared spectroscopy (ATR-IR) tests were performed using a spectrometer, Shimadzu model Prestige 21, equipped with a ZnSe crystal with mirrors of 45° (PIKE Technologies, Madison, WI, USA). The equipment was configured to measure in absorbance mode; resolution of 4 cm^{-1} and 12 scans in the spectral region $700\text{--}4000\text{ cm}^{-1}$. Representation of the spectra was

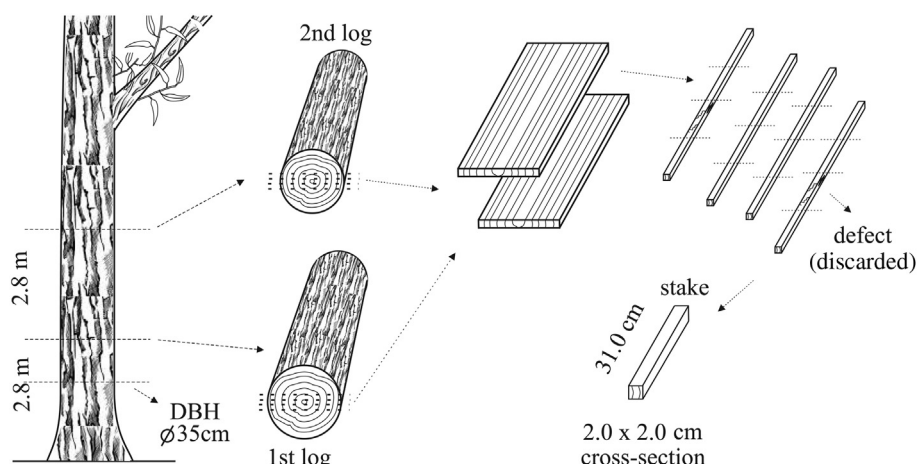


Fig. 1. Schematic of preparation of the eucalypt wood stakes.

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