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Wood quality of guanandi (*Calophyllum brasiliense* Camb.) after thermorectification

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ABSTRACT

The scarcity of native forests and the national code that protects them have been making it difficult to obtain wood considered lawful, making it necessary to discover new species or practices that make reforestation wood an alternative to reduce the pressure on native forests. The objective of this study was to analyze the behavior of Guanandi wood (*Calophyllum brasiliense* Camb.), regarding its physical properties when subjected to thermorectification and to compare it to natural wood. In this work, basal log boards were obtained from five 13-year-old trees, which were subjected to high temperatures, 140, 160, 180, 200 and 220°C, and their physical properties were analyzed, such as basic specific mass, apparent specific mass at 12% humidity, loss of mass of the heat-resistant boards, swelling, as well as the presence of surface and/or top warpings and cracks. The results showed that the loss of mass, the basic density and the anisotropy coefficient increased with the increase in temperature, even in relation to natural wood. The density at 12% and the linear and volumetric dimensions decreased with the increase in temperature, even in relation to natural wood. Temperatures of 180, 200 and 220°C, in general, caused defects such as cracks in the direction of the spinal cord and pipes, which were not present in the lower temperatures or in the control.

Keywords: Heat treatment, Dimensional stability, Wood defects.

INTRODUCTION

The Guanandi, a species of neotropical occurrence, stands out in several biomes from Mexico to the state of Santa Catarina do Brasil (POLITO et al., 1982; REITZ et al., 1978).

Phenotypically, the Guanandi tree has a straight and cylindrical trunk with a diameter and height, respectively, up to 60 cm and 30 meters, as well as a rounded and dense crown. Its leaves are opposite, symmetrical, glabrous and leathery, with dimensions of 5 to 15 cm long by 3 to 7 cm wide. The flowers are white, cluster inflorescence and the fruits are globose drupes and oilseed pulp. The outer bark is thick, up to 40 mm thick and dark brown or brown in color, while the inner skin is pink, bitter, aromatic, and acidic. The wood has a slightly glossy surface that is rough to the touch, with a medium to coarse texture and irregular grain (crisscross). As for the color, its sapwood is pinkish-beige and the heartwood varies from pinkish-brown tending to brown. The smell and taste are imperceptible (CARVALHO, 1994)

Guanandi wood, despite being little used in Brazil in contrast to its popularity in other countries in South America and the Caribbean, has great potential for use, offering a variety of products. It is suitable

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for construction, including rafters, slats, skirting boards, moldings, boards, and packaging, as well as broomsticks and tools, shipbuilding masts, joinery, carpentry, sleepers, posts, bridges, posts, plates, and decorative slats (KILLEAN et al., 1993; CARVALHO, 1996).

Depending on the origin, the bulk density of Guanandi wood varies from mild to moderately dense (0.45 to 0.65 g.m-3) from 12% to 15% moisture content (MAINIERI; CHIMELO, 1989; JANKOWSKY et al., 1990), while the basic range varies little from 0.49 to 0.51 $^{g.cm-3}$ (AROSTEGUI, 1982; JANKOWSKY et al., 1990).

With the growing demand for renewable materials and clean technologies, the heat treatment of lignocellulite materials stands out, which causes structural transformations in wood when exposed to heat. This process, known as thermorectification (BRITO, 1997), has been widely studied and described in the literature. Generally, wood is subjected to temperatures close to 200ºC for several hours (RAPP, 2001; WASKETT; SELMES, 2001; ROUSSET et al., 2004; METSÄ-KORTELAINEN et al., 2005).

Heat treatment is common all over the world and is already carried out commercially: in Finland as "ThermoWood® Process"; in France, "Retification®" and "Le Bois Perdure®"; in the Netherlands, "Plato-Process®" and finally in Germany as "Oil-Heat-Treatment®" (MILITZ, 2002; RAPP, 2001). The main differences between these treatments are: maximum temperature applied and the use or not of an inert atmosphere.

Temperature range selection is a crucial step in heat treatment. For hardwoods, such as *Eucalyptus grandis*, for example, temperatures of 120ºC, 140ºC, 160ºC, 180ºC and 200ºC were tested, with the best results observed in the higher temperature ranges (Pessoa et al., 2006).

Heat treatment improves the physical properties of wood, increasing its market acceptance and allowing it to compete with hardwoods. This improvement opens up new possibilities of use for Guanandi wood, overcoming the possible limitations of its natural properties, when used as a raw material for various purposes, most of them being related to its hygroscopic characteristics in combination with its anisotropy of contraction and swelling, in addition to the density related to the variation of moisture of the wood (JOHANSSON, 2005). Thus, Guanandi wood gains relevance for contributing to the maintenance of the environment as a renewable material, associated with a clean energy mode such as thermorectification.

OBJECTIVE

The objective of this work was to evaluate the effect of thermorectification on the physical properties of Guanandi wood in terms of: basic specific mass, apparent specific mass at 12% humidity, mass loss, dimensional variation, warping, surface and/or top cracks, as well as to relate these properties with some diameter classes.

METHODOLOGY

The material used in this study is trees of the species Guanandi (*Calophyllum brasiliense* Camb.), from the Primavera Farm, located in the municipality of Adrianópolis, northern Paraná. Seedlings were planted with seedlings in a spacing of 4.0 x 2.5 m. When the trees were sampled, they were 13 years old and had average diameters ranging from 10 to 20 cm. These trees were divided into 5 classes of diameters: 10-12, 12-14, 14-16, 16-18 and 18-20 cm, and one tree from each class was randomly collected.

From these trees, basal logs of 2.5 m in length were removed, which were unfolded in order to obtain boards centered in relation to the medulla, oriented in relation to the anatomical planes, with a thickness of 3 cm. After unfolding, the planks were sent for drying in a climatized chamber to the equilibrium of 12% and then flattened to a thickness of 2.5 cm. From each of the boards, six 40 cm long pieces were removed, one of which was the control and the others received thermorectification treatments. Afterwards, all the pieces had their tops sealed with silicone rubber, which resists high temperatures, and returned to the air-conditioned chamber.

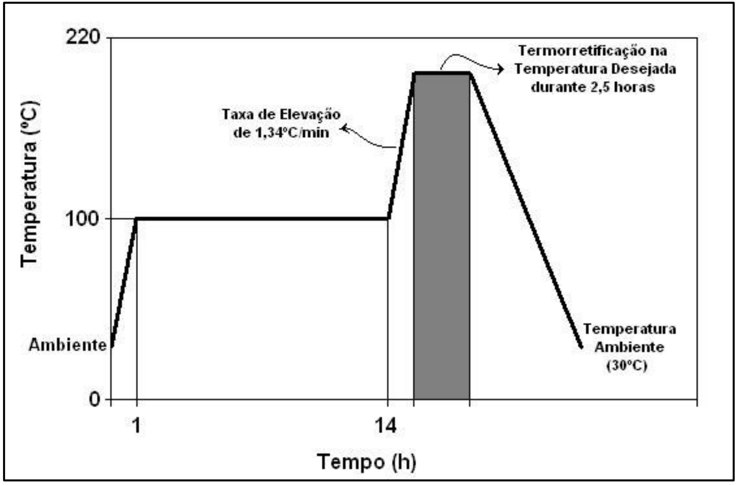
Before the application of each treatment, each piece was weighed and placed in a drying oven with pre-regulated forced air circulation with an initial temperature of 35°C, gradually increasing the temperature until it reached 103 ±2°C, which remained heated for 14 hours, in order to reduce its moisture content to about 3% and avoid possible problems of water vapor expansion and cell wall rupture.

After this period, each treatment, except for the control, was subjected to a temperature rise rate of 1.34 °C/min., according to the recommendations of Rousset et al. (2004), until the final temperatures, i.e., 140, 160, 180, 200 and 220°C, according to the thermorectification program outlined by Calonego (2009) in Figure 1.

The wood remained at each thermorectification temperature for 2.5 hours, taking into account the statement given by Bhuiyan et al. (2001), that after the first hour of thermorectification the crystallization of cellulose occurs.

After each thermorectification treatment, the kiln was turned off and the wooden pieces remained inside in natural cooling until they reached room temperature, then the pieces were weighed again to calculate mass loss.

Figure 1. Example of a time and temperature program that was adopted in wood thermorectification (CALONEGO, 2009).



After the treatments, the mass loss was determined using Equation 1.

$$Pm = [(M1 - M2) / M1].100 \qquad (1)$$

Where: Pm = mass loss, %; M1 = mass of the specimen before treatment, g; M2 = mass of the workpiece after treatment.

For the determination of the dimensional variation, through the linear and volumetric stability, as well as for the determination of the basic and apparent densities, specimens were taken from each piece and each treatment, spaced about 4 cm from the medulla, with a dimension of 2 cm x 3 cm x 5 cm, with the largest lateral edge oriented in the longitudinal direction and the smallest in the tangential and radial directions. respectively, according to the ABNT NBR 7190 standard (ABNT, 1997).

The specimens were placed in an air-conditioned chamber up to 12% equilibrium, then their tangential, radial and longitudinal dimensions were weighed and measured with a digital caliper to determine the apparent specific mass (Equations 2 and 3).

$$Pu = Mu / Vu \qquad (2)$$

$$Vu = Dt . Dr . Dl \qquad (3)$$

Where: ρu = apparent specific mass at 12% humidity, $^{g.cm-3}$; Mu = mass of specimens at 12% moisture, g; Vu = specimen volume at 12% humidity, cm3; Dt = tangential dimension of the specimens at 12% humidity, cm; Dr = radial dimension of the specimens at 12% humidity, cm; Dl = longitudinal dimension of the specimens at 12% humidity, cm.

Then, the specimens were placed in a pre-regulated drying oven with an initial temperature of 35 °C and gradually increasing the temperature until it reached 103 ±2 °C and were kept in this condition until they reached a constant weight.

From the dry specimens, with the purpose of determining the maximum swelling of the wood, they were measured again with the aid of a digital caliper and weighed with the aid of a precision electronic scale.

Soon after, all the material was submerged in water for several days, until the fibers were completely saturated. Then, with the wood saturated, each specimen was measured again and the linear and volumetric swellings were determined, as well as the respective shrinkage coefficients of the control wood and the heat shrinkage between 140 and 220 °C, by applying Equations (4), (5) and (6), respectively.

$$\alpha L = [(Dsat - Ds) / Ds].100 \tag{4}$$

$$\alpha V = [(Vsat - Vs) / Vs].100 \tag{5}$$

$$Q = \Delta\alpha L / \Delta u \rightarrow Q = (Dsat - Ds).\ Msat / [Ds.(Msat - Ms)] \tag{6}$$

Where: αL = linear swelling, %; αV = volumetric swelling, %; Q = retractability coefficient, dimensionless; Dsat = linear dimension of the specimen in the saturated condition, cm; Ds = linear dimension of the specimen in the dry condition at 103 ±2°C, cm; Vsat = specimen volume in the saturated condition, cm^3; Vs = specimen volume in the dry condition at 103 ±2°C, cm^3; Msat = mass of the specimen in the saturated condition, g; Ms = specimen mass in the dry condition at 103 ±2°C, g.

The ratio between tangential and radial contractions, called anisotropy factor or coefficient, usually ranges from 1.5 to 2.5, and has become a very important index in studies of wood dimensional variation, because the higher this ratio, the greater the tendency to wood splitting and warping. For uses that involve dimensional stability of the wood, the most recommended is the one with the lowest anisotropy coefficient (OLIVEIRA; SILVA, 2003). According to Moreschi (2009), woods with an anisotropy coefficient greater than two have limited application in the manufacture of furniture, doors, windows and musical instruments.

The determination of the apparent density at 12% humidity of each specimen was performed using the stereometric method (Equation 7).

$$Pa = M12\% / V12\% \tag{7}$$

Where: ρa = apparent specific mass of the specimen at 12% humidity, $^{\text{g.cm-3}}$; M12% = specimen mass at 12% moisture, g; V12% = specimen volume at 12% moisture, cm3.

The basic density of the wood of each specimen was determined by the hydrostatic balance method, according to the ABTCP M 14/70 standard (ABTCP, 1968). By this standard, the basic density was then calculated by the quotient between the dry mass and the difference between the saturated and immersed masses of each specimen (Equations 8 and 9).

$$\mathit{Phantom\ Assassin} = \mathrm{MS/Vsat} \tag{8}$$

$$\mathrm{Vsat} = \mathrm{Msst} - \mathrm{Mi} \tag{9}$$

Where: ρb = basic specific mass of the specimen, $^{g.cm-3}$; Ms = dry mass of the specimen at 103 ±2°C, g; Vsat = saturated specimen volume, cm^3; Msat = saturated mass of the specimen, g; Mi = immersed mass of the specimen, g.

Defects such as cracks and warping were observed in the parts after the application of each treatment.

DEVELOPMENT/RESULTS

Although the work has not yet been fully concluded, as a statistical analysis of the results obtained is still needed, Table 1 shows a preview of the mean results obtained.

Table 1 – Physical characterization of natural wood and thermorectified wood from Guanandi. Da = Apparent density at 12%; Db = Basic density; Pm = Mass loss; It = Tangential swelling; Ir = Radial swelling; Il = Longitudinal swelling; Iv = Volumetric swelling; Ca = Anisotropy coefficient.

	Of g.cm^{-3}	Db g.cm^{-3}	Pm g	It %	And %	The %	Iv %	Ca
Natural	0,561	0,455	-	6,72	3,54	0,44	10,98	1,9
140 °C	0,544	0,465	36,45	6,73	3,21	0,50	10,71	2,1
160 °C	0,548	0,460	44,34	6,99	3,67	0,43	11,39	1,9
180 °C	0,529	0,446	46,28	6,90	3,14	0,38	10,67	2,2
200 °C	0.534	0,468	52,93	5,96	2,56	0,32	9,02	2,3
220 °C	0.518	0,471	56,26	3,72	2,09	0,22	6,12	1,8

FINAL THOUGHTS

Based on the results obtained so far, the following can be considered:

The mass loss was linearly greater with the increase in temperature.

The bulk density at 12% humidity decreased with increasing temperature and in relation to natural wood.

The basic density increased with increasing temperature and in relation to natural wood, with the exception of treatment at 180°C.

In the tangential direction, swelling increased with increasing temperature up to 180 °C and then decreased to temperatures of 200 and 220 °C relative to natural wood.

In the radial direction, the swelling decreased with the increase in temperature compared to natural wood, with the exception of the 160 °C treatment which was higher, even for natural wood.

In the longitudinal direction, the swelling decreased with increasing temperature, with the exception of the 140 ºC treatment, which was higher, including for natural wood.

As for volumetric swelling, it decreased with the increase in temperature, with the exception of the 160°C treatment, which was higher, even for natural wood.

The anisotropy coefficient was good for temperatures of 160 and 220 °C, including natural wood, and bad for other temperatures.

The thermorectified parts at temperatures of 180, 200 and 220°C, in general, presented defects such as cracks in the direction of the spinal cord and pipes, which were not present at the lower temperatures or in the control.

In general, it was possible to characterize the natural wood of Guanandi in terms of the physical properties determined, including a good anisotropy coefficient, as well as to analyze it in the face of thermorectification, which showed that higher temperatures increase its basic density and decrease the apparent density to 12% of humidity.

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