ACCELERATED LABORATORY TEST OF THREE AMAZONIAN WOOD SPECIES CALLED TAUARI, EXPOSED TO WHITE- AND BROWN-ROT FUNGI AND COLOR RESPONSE ACCORDING TO CIE *L* A* B** SYSTEM

ENSAIO ACELERADO DE LABORATÓRIO DE TRÊS ESPÉCIES DE MADEIRAS DA AMAZÔNIA CHAMADAS DE TAUARI, EXPOSTAS AOS FUNGOS DE PODRIDÃO-BRANCA E PARDA E RESPOSTA COLORIMÉTRICA DE ACORDO COM O SISTEMA CIE *L* A* B**

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ABSTRACT

The purposes of this study were to: evaluate de natural durability of three species of tauari (*Couratari guianensis* Aublet*, Couratari oblongifolia* Ducke & R.Knuth and *Couratari stellata* A.C.Smith), report the colorimetric parameters according to CIE *L*a*b** 1976 system and also show the appearance of control and attacked wood blocks. Two brown-rot [*Gloeophyllum trabeum* (Persoon ex Fries) Murril. and *Lentinus lepideus* Fr.] and two white-rot [*Trametes versicolor* (Linnaeus ex Fries) Pilat and *Ganoderma applanatum* (Pers. ex Wallr.)] fungi were used. Tauari wood was classed as "moderately resistant" to "resistant" when exposed to *Gloeophyllum trabeum, Trametes versicolor* and *Ganoderma applanatum* fungi. All extractives' contents of attacked samples decreased when compared with the control (sound wood), except *Couratari stellata* exposed to *Ganoderma applanatum*. Conversely, all ash contents increased when compared with the control, except *Couratari stellata* exposed to *Gloeophyllum trabeum*. All attacked wood blocks and wood meal samples were darker, except wood meal from *Couratari stellata* exposed to *Trametes versicolor*, and redder than the control. The $\Delta E*$ mean value in attacked wood blocks and wood meal samples attained 29.5 and 14.3, respectively.

Keywords: natural durability; extractives; ashes; *Couratari* sp.; colorimetry.

RESUMO

Os objetivos deste estudo foram: avaliar a durabilidade natural de três espécies de tauari (*Couratari guianensis* Aublet, *Couratari oblongifolia* Ducke & Knuth R. e *Couratari stellata* A.C.Smith), relatar os parâmetros colorimétricos de acordo com o sistema CIE *L * a * b ** 1976 assim como mostrar

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a aparência dos blocos de madeira antes e após o ataque. Dois fungos de podridão-parda [*Gloeophyllum trabeum* (Persoon ex Fries) Murril. e *Lentinus lepideus* Fr.] e dois de podridão-branca [*Trametes versicolor* (Linnaeus ex Fries) Pilat e *Ganoderma applanatum* (Pers. ex Wallr.)] foram utilizados. A madeira de tauari foi classificada como "moderadamente resistente" a "resistente" quando exposta aos fungos *Gloeophyllum trabeum*, *Trametes versicolor* e *Ganoderma applanatum*. O conteúdo de extrativos das amostras atacadas diminuiu quando comparado com o controle, exceto *Couratari stellata* expostos a *Ganoderma applanatum*. Por outro lado, os conteúdos de cinzas aumentaram quando comparados com o controle, exceto para a madeira de *Couratari stellata* exposto ao *Gloeophyllum trabeum*. Todos os blocos de madeira atacados e as serragens tornaram-se mais escuras, exceto para a serragem de *Couratari stellata* exposto ao fungo *Trametes versicolor*, e mais vermelho do que a amostra sem ataque. O ∆E * médio do bloco de madeira e serragem, atacados, atingiram 29,5 e 14,3, respectivamente.

Palavras-chave: durabilidade natural, extrativos; cinzas; *Couratari* sp.; colorimetria.

INTRODUCTION

Wood holds a special place in the traditional culture because of its impressive range of attractive qualities, including aesthetic appearance, low density, low thermal expansion, and desirable mechanical strength. Among these properties, color is of considerable importance in wood used for decorative purposes (CHANG and CHENG, 2001).

The family Lecythidaceae is composed of medium size trees, occurring in tropical rain forests, especially in the neotropical region. The stands predominate in low lands and preferably occupy the canopy, although *Couratari guianensis* Aublet and *Couratari stellata* A.C.Smith are emerging species (MORI and PRANCE, 1979). This family comprises approximately 400 genera and 22 species, distributed in all over the tropics.

According to Bernal et al (2011) "Tauari" is a tropical timber very commonly harvested (commercialized and exported) in the Amazon Basin due to its good physical and mechanical properties and easy workability. However, woods from several species and different origin are grouped under the name "tauari" and marketable lots are usually composed of a mixture of species. So, a species called by one name in a region might not be the same in another; moreover, one common name might be used in multiple regions but referring to different species. Also grouping of several species under same name results in an overexploitation of this "individual pseudospecies" inventories, Therefore a logger company could harvest a species that surpasses its capacity to natural regeneration. According to the literature there are 18 plant species called "tauari" within four Neotropical genera belonging to the Lecythidaceae: *Allantoma* (3 spp.), *Cariniana* (4

spp.), *Couratari* (9 spp.) and *Eschweilera* (2 spp.). They reported that wood colour was very useful and helped to separate *Couratari* (white, yellowish or grayish) from *Allantoma* and *Cariniana* (pink, reddish or brownish).

The main natural diversity of the genus *Couratari* occurs in the Central Amazon, with 53% of their species. The group named tauari includes *Couratari guianensis*, *Couratari oblongifolia*, and *Couratari stellata*, which are among the more marketable wood species. Work carried out by the Brazilian Institute of Forestry Development - IBDF (1981, 1988), Fedalto et al. (1989), and Souza et al. (1997) presented macroscopic and microscopic descriptions, data of physical and mechanical properties, general characteristics and end uses. More information, fast and free, about these species may be retrieved from the Database of Brazilian Woods (http://sistemas.florestal.gov.br/madeirasdobrasil/), Garzón (2004), and Procópio and Secco (2008).

Natural durability, or alternatively decay resistance, is defined as the ability of wood to resist biological degradation. It is generally low in the sapwood and high in the heartwood of some species (EATON and HALE, 1993). Heartwood formation is associated with cell death, the disappearance of storage material and an increase in extractive content (BAMBER, 1976). Heartwood extractives comprise terpenoids, tropolones, flavonoids, stilbenes, and other aromatic compounds (SCHEFFER and COWLING, 1966). Extractives can protect wood from decay, add color and odor, specific grain pattern and enhance strength properties. Extractives may also inhibit setting of concrete, glues and finishes, cause problems in papermaking, contribute to corrosion of metals in contact with wood, present

health hazards and affect wood color stability to light (ROWE and CONNER, 1979).

The tristimulus spectrocolorimetry technique was developed for color quality control and finds application in paints, textiles, and plastic (BILLMEYER and SATZMAN, 1981).

According to Nelson and Heather (1970), probably the color of dark-colored wood is largely controlled by extractives absorbed on and within cell walls, while textural properties (e.g. lumen diameter and wall thickness distribution) probably significantly affect the color of light-colored woods. The color of wood depends on chemical components interacting with light, i.e. the presence or absence of extractives (HON and MINEMURA, 2001). Furthermore, for the amount of heartwood extractives, there is a huge variability within and among trees, across sites, species, provenances and tree age (GIERLINGER et al., 2004; WINDEISEN et al., 2002)

There are several intrinsic factors of the wood contributing for the formation of the gross features such as figure and the color, such as the anatomical elements (BURGER and RICHTER, 1991), and still there are the chemical factors that influence the natural durability and the extractives forming chromophores compounds.

According to Janin (1988), the color of wood, mainly of heartwood, comes from gradual deposit of the degeneration of protoplasmic vegetal cell along time and from chemical substances that are found inside the fiber wall, wooden rays that selectively absorb the light in different spectral wavelengths.

The changes in wood color is more frequently measured by the CIE $L*a*b*$ system, in accordance with the axial variation $\Delta a*$ and $\Delta b*$, which correspond to the pair of color coordinates red-green and yellow-blue, respectively, and the luminosity $\Delta L*$ (MAZET et al., 1993). The luminance, which is the lightness or intensity of the color, defines the gray scale where "0" is black and "100" is white, also refers to the darkness of the wood, where darker wood usually have lower luminance than light-colored wood. Purity is related to hue and is the amount in the total color of an object. This parameter is used to characterize the color of an object both quantitatively and objectively in a physical sense.

Nishino et al. (1998), studying the colorimetry of 97 wood species from French Guiana, reported values of 69.83, 6.99, 25.63, 26.57 and 74.76 to *Couratari guianensis* Aubl., respectively, for *L*, a*, b*, C* and *h**, in the radial surface, while for the tangential the values were respectively 70.53, 6.81, 24.57, 25.49 and 74.50.

With the aim of supplying more technical data information of the well marketed tauari species, the present work evaluates the natural resistance of the *Couratari guianensis, Couratari oblongifolia,* and *Couratari stellata* species exposed to brown-rot *Gloeophyllum trabeum* and *Lentinus lepideus* fungi and the white-rot *Trametes versicolor* and *Ganoderma applanatum.* It also reports alcohol-toluene extractive, ash, and color characteristics in wood meal and blocks.

MATERIAL AND METHODS

The material used was collected in Santarém- PA, and the voucher has been deposited in FPBw - Xylarium from Setor de Anatomia e Morfologia Florestal LPF/SFB according to the following numbers 000467 (*Couratari oblongifolia* Ducke & R.Knuth.), 001135 (Couratari guianensis *Aublet.*) and 001132 (*Couratari stellata* A.C.Smith).

The material in wood disc-shaped or wedges-shaped was used to prepare 2.5 x 2.5 x 0.9 cm wood blocks. Accelerated laboratory test was conducted according to ASTM D 2017-05 (2005) which establishes that specimen should be conditioned, before and after fungi attack in an air-forced at (50 ± 1°C), weighed, sterilized and submitted to fungus attack, in controlled environment at (27± 1)°C temperature and (70 ± 4)% relative humidity.

The brown-rot *Gloeophyllum trabeum* (Persoon ex Fries) Murril. and *Lentinus lepideus* Fr. fungi and the white-rot *Trametes versicolor* (Linnaeus ex Fries) Pilat and *Ganoderma applanatum* (Pers. ex Wallr.) fungi were used. The wooden feeder used was *Cecropia* sp. for white-rot fungi and *Pinus* sp. for brown-rot.

The experimental design is shown in Table 1, consisted of three wood species, four types of fungi, with 12 samples per treatment, totaling 180 specimens. It was also conducted a blank treatment plus 36 samples as reference blocks.

The mean value of colorimetric parameters were submitted to an analysis of variance (ANOVA), and to the Tukey test at 5% of significance level to evaluate the differences between color parameters of the control and attacked samples, pairwise. Further, stepwise regression analysis was conducted using color parameters and weight loss as predictors. The

TABLE 1:   Numbers of wood samples used in the bioassay test.
TABELA 1: Número de amostras de madeira utilizadas no bioensaio.

| Wood species | Number of wood samples | | | | |
	Gloeophyllum trabeum	*Lentinus lepideus*	*Trametes versicolor*	*Ganoderma applanatum*	Control (blank)
Couratari oblongifolia	12	12	12	12	12
Couratari guianensis	12	12	12	12	12
Couratari stellata	12	12	12	12	12
Reference blocks	9	9	9	9	-

software used was the Statistical Program for Social Science (SPSS), version 13.0 for Windows.

The wood susceptibility to fungi attack was evaluated throughout the percentage of weight loss - WL, before and after exposure to decay, and reported as resistance classes according to ASTM D 2017-05 (2005).

Illustrations

The cross section photomacrography of the wood blocks, in stabilized condition, to control and attacked specimens was made using the binocular microscope Olympus BH2 and the stereo digital camera Olympus SZ4. Preview binning 2, exposure time of 5 milisec and 0.67 magnifying lenz were used. None surface processing was applied to the samples, except for the control to illustrate and show details of the transversal surface, which was smoothed by using a sequence of 150, 320 and 400 grit sandpaper.

Spectrocolorimetry

Percent reflectance data were collected at 10 nm intervals over the visible light spectrum (400 to 700 nm) by using a spectrophotometer Datacolor International Microflash 200D equipped with a diffuse reflectance integrator sphere. Spectral curves with resolution of 3 nm were obtained. The illuminant was D65 daylight type (xenon light), as required by Commission Internationale de Enluminure (CIE) in 1976. When measuring, a 10° standard observer and a 6 mm sensor head diameter were used, with the specular component included. Before measuring the color parameters, the equipment was calibrated following the supplier recommendations. Three measures for each sample were made and averaged as mean values.

The color variations were calculated as the difference between the samples, either woods blocks or wood meal, and the reference. To evaluate the effect of the fungi attack in the color parameters, in both surfaces of the wood blocks, the parameters $a*$ and $b*$ were calculated as the difference between each of the attacked block and the paired control.

For wood meal the effects of extractives withdrawal and also fungi attack were evaluated. In the first case, the color variations were calculated as the difference between control wood meals extractive-free minus unextracted. The effects of fungi were calculated between attacked wood meals minus control, both unextracted, using equations described in a previous study reported by Okino et al. (2009).

To avoid possible alteration in the color, samples were kept in darkness to reduce photo-induced or other alteration. The wood blocks were prior stabilized and oven-dried at 50°C. Then, the color parameters were measured before and after fungal attack. The same procedure was applied to the wood meal, after the preparation process.

General analysis

As to the methodology, two different faces were adopted to measure the color, referred now as the upper and the lower surfaces of the attacked specimens. After conditioning, the colorimetric parameters of the wood blocks were measured before and after fungal attack.

The sample preparation for the chemical analysis was conducted according to TAPPI T 264 om-82 (TAPPI, 1996a) with few modifications. Only the surfaces degraded by fungi were removed from the wood blocks and screened. It was collected the material that passed the 42 mesh sieve and was retained on the 80 mesh, resulting in the wood meal

sample. This material was conditioned at room temperature reaching 6% to 9% moisture content.

The extractive contents in alcohol-toluene (1:2, v/v) were gravimetrically determined, in control and attacked samples, according to TAPPI T 204 om-88 (TAPPI, 1996b).

Ash content was obtained according to TAPPI T 211 om-93 (TAPPI, 1996c) for control and attacked wood meal samples.

RESULTS AND DISCUSSIONS

The used *Couratari guianensis* Aublet. species had medium basic specific mass (0.52 g/cm³); yellowish to yellowish-gray heartwood indistinct from sapwood; imperceptible smell. *Couratari oblongifolia* Ducke & R.Knuth. wood had medium basic specific mass (0.49 g/cm³); whitish-yellow heartwood indistinct from sapwood; characteristic smell. *Couratari stellata* A.C.Sm. wood had medium basic specific mass (0.65 g/cm³); yellow-pale heartwood indistinct from sapwood; imperceptible smell (FEDALTO et al., 1989; IBDF, 1981).

Table 2 shows the mean values of percentage weight loss, to the three tauari woods exposed to fungi, in the accelerate laboratory test.

According to the data listed in Table 2, *Couratari stellata* was the least susceptible wood against the attack of the three out of four fungi and ranked as "resistant class". The resistance classes determined to tauari varied from "moderately

resistant" to "resistant" when exposed to *Gloeophyllum trabeum, Trametes versicolor* and *Ganoderma applanatum*, and "highly resistant" to *Lentinus lepideus*.

According to Kartal and Green III (2003), all three wood species were below the weigh loss limit of 25% to be classified as "resistant" according to the ASTM D 2017-05 standard (Figure 1). The ANOVA, taking into account only the wood species, showed that *Couratari stellata* suffered the lowest weight loss (15.7%). The analysis by type of fungus alone shows that *Gloeophyllum trabeum* and *Trametes versicolor* provoked the higher wood decay, above the 25% limit, and was not significantly different. Also, there is a tendency to an inverse correlation between basic specific mass and the percentage of weight loss.

Special care must be taken if the wood of tauari will be exposed to environments under fluctuations and prone to the attack of *Gloeophyllum trabeum* or *Trametes versicolor*.

Figure 2 shows that the color of control sample (*Couratari oblongifolia*) is lighter than *Couratari guianensis* and *Couratari stellata*. Figures 3 and 4 show that specimens exposed to the white-rot *Trametes versicolor* fungus were clearer in color than the brown-rot *Gloeophyllum trabeum*. In Figure 4a the *Couratari oblongifolia* wood blocks attacked by *Gloeophyllum trabeum*, besides great wood color changes, showed clean and larger pores, whereas *Couratari guianensis* (4b) and *Couratari stellata* (4c) showed protuberant areas and cracks

TABLE 2:   Percentage weight loss of tauari wood species exposed to brown-rot and white-rot fungi, after 12 weeks in accelerated laboratory test.

TABELA 2: Porcentagem de perda de peso das espécies de tauari expostos aos fungos de podridão-parda e de podridão-branca, após 12 semanas de ensaio acelerado de laboratório.

Species	Brown-rot percentage weight loss[a]			
	Gloeophyllum trabeum	Resistance class [b]	*Lentinus lepideus*	Resistance class
Couratari oblongifolia	34.58 (9.85)[c]	MR	6.31 (0.24)	HR
Couratari guianensis	25.01(5.17)	MR	1.93 (1.28)	HR
Couratari stellata	21.04 (4.53)	R	0.93 (0.59)	HR
	White-rot percentage weight loss[a]			
	Trametes versicolor	Resistance class	*Ganoderma applanatum*	Resistance class
Couratari oblongifolia	32.34 (9.71)	MR	19.36 (4.02)	R
Couratari guianensis	28.44 (6.83)	MR	26.94 (4.09)	MR
Couratari stellata	18.46 (4.19)	R	16.74 (2.60)	R

Where in: [a]Mean values of 12 samples per fungus. [b]HR = highly resistant, MR = moderately resistant and R = resistant. [c]Values in parentheses are standard deviations.
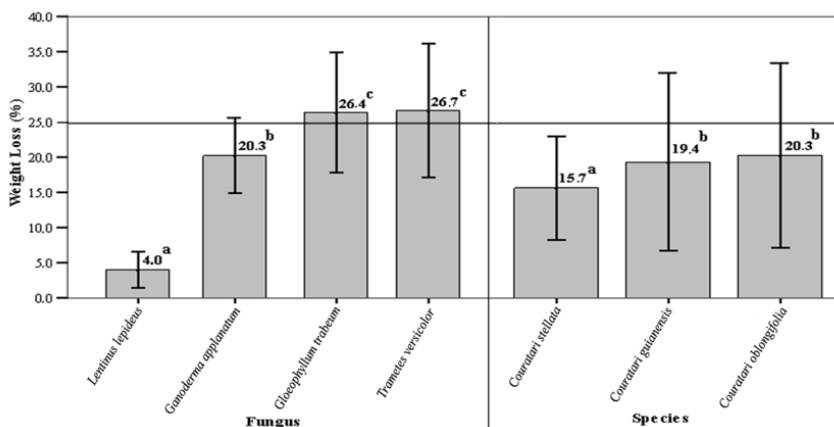
FIGURE 1: Mean values of weight loss by fungus type (each value represents the means of 36 replications) and by wood species (each value represents the means of 48 replications). Specimens with weight loss of ≤ 25% is classified as resistant (Bars represent means of weight loss, and error bars represent standard deviations). Letters represent homogeneous groups in the Tukey test at 5% significance level.

FIGURA 1: Valores médios de perda de peso por tipo de fungo (cada valor representa a média de 36 repetições) e por espécies de madeira (cada valor representa a média de 48 repetições). As amostras com perda de peso ≤ 25% é classificada como resistentes (Barras representam perda de peso médio, e barras de erros representam os desvios padrão). Letras representam grupos homogêneos no teste de Tukey a nível de significância de 5%.

near the pores.

According to Bernal et al. (2011) the vessels in *Couratari stellata* are wider than in *Couratari guianensis*, as shown in Figures 2a and 2c. Their SEM micrography study showed silica grains in body ray cells in the irregular form, so it may have affected positively in decay resistance as observed in the lower weight loss percentage.

The morphology of decay exhibits different pattern of structural and ultrastructural changes along the decay process. Levin and Castro (1998) reported that hyphae colonize the lumen of vessel elements, fibres and parenchyma cells causing cell wall thinning and erosion. Hyphal penetration was mainly through pits, whose inner apertures were enlarged enzymatically, this is, large holes in the wood were evident during biodeterioration. It is known that decay is not uniform, and practically unaltered tissues coexist with seriously damaged ones.

In general the white-rot fungus degrades the lignin polymer, leaving almost intact the hemicelluloses and cellulose resulting in the whitish surface of the wood. On the other hand, the brown-rot fungus attacks the polysaccharides leaving the lignin modified, thus darkening the surface of the wood.

Results in Table 3 show that *Couratari stellata* presented the lower extractives and ash contents. Generally, there is an inverse correlation between extractives content and weight loss. This discrepancy may be partially explained not by the amount of the extractives, but mainly by the chemical structure, where dual synergism plays a fundamental role in inhibiting fungi attack. *Couratari oblongifolia* and *Couratari guianensis* showed similar amounts of extractives and ash contents. Attacked samples showed lower extractive content values than control, except for *Couratari stellata* exposed to *Ganoderma applanatum*. It is not a common behavior, once the cleavage of the cell wall wood polymers constituents into small fragments takes place, remaining a modified lignin residuum and increasing solubility of the "extractive" component of wood (McGINNES and ROSEN, 1984). It is known that carbohydrate polymer is source of nourishment of xilophagon organisms, it is a possible explaining the decline in the extractive content of the attacked samples. The extractives content in tauari wood is in accordance with that one described in the literature for tropical hardwoods. Santana and Okino (2007) reported
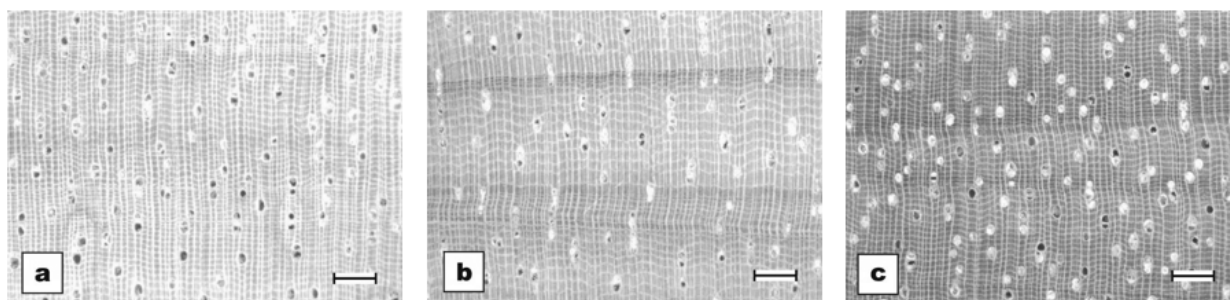
FIGURE 2: Photomacrography of transversal section of the control hardwood samples a: *Couratari oblongifolia*; b: *Couratari guianensis* and c: *Couratari stellata*. Scale bars = 1000μm.

FIGURA 2: Fotomacrografia da seção transversal das amostras controles de madeira a: *Couratari oblongifolia*; b: *Couratari guianensis* e c: *Couratari stellata*. Barra de escala = 1000μm.
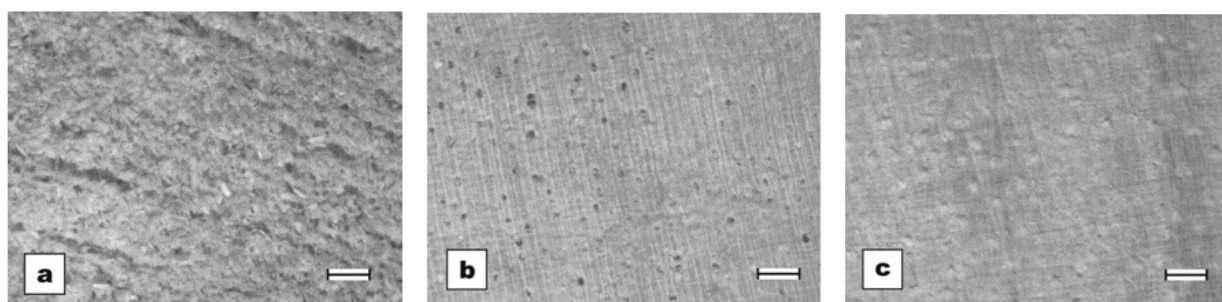

FIGURE 3: Photomacrography of transversal section of hardwood attacked by *Trametes versicolor*. a: *Couratari oblongifolia*; b: *Couratari guianensis* and c: *Couratari stellata*. Scale bars = 1000μm.

FIGURA 3: Fotomacrografia da seção transversal da madeira de tauari atacada por *Trametes versicolor*. a: *Couratari oblongifolia*; b: *Couratari guianensis* e c: *Couratari stellata*. Barra de escala = 1000μm.

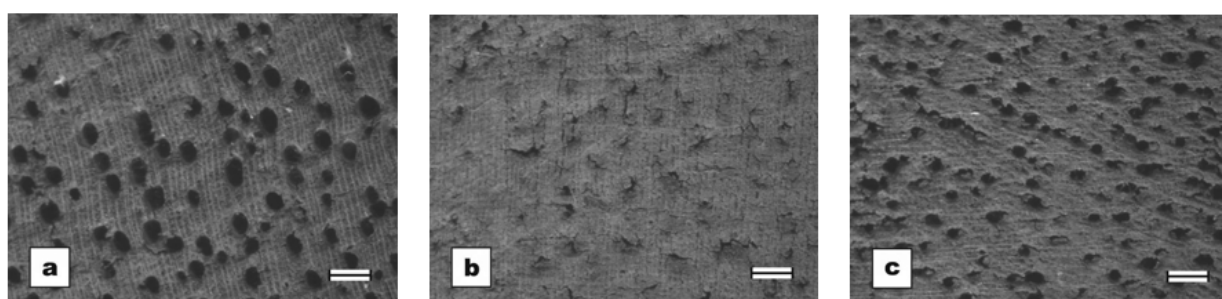FIGURE 4: Photomacrography of transversal section of hardwood attacked by *Gloeophyllum trabeum*. a: *Couratari oblongifolia*; b: *Couratari guianensis* and c: *Couratari stellata*. Scale bars = 1000μm.

FIGURA 4: Fotomacrografia da seção transversal de madeira de tauari atacada por *Gloeophyllum trabeum*. a: *Couratari oblongifolia*; b: *Couratari guianensis* e c: *Couratari stellata*. Barra de escala = 1000μm.

TABLE 3:   Percentage of moisture content, extractives in ethanol-toluene and ashes in control and attacked tauari wood samples.

TABELA 3:   Percentagem média de umidade, extrativos em etanol-tolueno e cinzas em madeiras de tauari-controle e atacadas por fungos.

Percentage[a]	Control	Attacked by fungi			
		Gloeophyllum trabeum	Lentinus lepideus	Trametes versicolor	Ganoderma applanatum
Couratari oblongifolia					
Moisture content	8.18 (0.02)[b]	7.00 (0.16)	6.61 (0.09)	7.16 (0.10)	6.64 (0.06)
Extractives	3.17 (0.06)	2.26 (0.04)	1.65 (0.21)	2.43 (0.05)	2.17 (0.04)
Ash	0.52 (0.02)	0.63 (0.04)	0.55 (0.00)	0.60 (0.03)	0.54 (0.01)
Couratari guianensis					
Moisture content	8.49 (0.04)	6.13 (0.01)	6.69 (0.40)	7.04 (0.04)	7.47 (0.31)
Extractives	3.24 (0.12)	2.40 (0.10)	1.72 (0.03)	2.09 (0.22)	2.72 (0.08)
Ash	0.52 (0.01)	0.58 (0.09)	0.57 (0.01)	0.59 (0.02)	0.57 (0.08)
Couratari stellata					
Moisture content	7.59 (0.04)	6.58 (0.25)	6.45 (0.17)	7.18 (0.01)	5.80 (0.10)
Extractives	1.70 (0.11)	1.57 (0.10)	1.25 (0.13)	1.27 (0.18)	1.89 (0.13)
Ash	0.34 (0.05)	0.25 (0.08)	0.48 (0.02)	0.50 (0.01)	0.56 (0.02)

Where in: [a] Mean values of two repetitions. [b] Values in parentheses are standard deviations.

the extractives' content of *Couratari multiflora* (Sm.) Eyma, *Couratari* sp. and *Couratari stellata* A.C.Sm., of 1.1%, 1.4% and 1.0%, respectively, quite below that one obtained in this study, while for ashes the contents were 2.0%, 1.6% and 1.8%, respectively. Although the last species is the same one used in this study, the material was from a different site, tree, age and place of harvesting, explaining possible deviation in extractives' and ash contents.

The ash contents of the attacked samples increased when compared to control, except for *Couratari stellata* exposed to *Gloeophyllum trabeum*. Green III et al. (1997) reported a significant increment in the amount of iron, aluminum, magnesium, manganese and copper in southern pine wood inoculated with four brown-rot fungi, and maple inoculated with *Trametes versicolor*. Since the wood ashes are formed by oxides of these metals, a proportional increment of the ash content was expected.

Table 4 list the mean values of color parameters due to fungi effects and wood species, either in upper and lower surface of the wood blocks.

In Table 4, statistical analysis was applied to observe the effects of fungi and also the wood species.

Statistically there was some correlation

($R^2 = 0.767$) between weight loss - WL and a^* (after fungi exposure) and ΔE^* as given by Eq. 1.

$$WL = -12.861 + 0.533\Delta E^*_{upper} + 0.265\Delta E^*_{lower} + (0.243\ a^*_{lower} + 1.105\ a^*_{upper})_{attacked}$$
Equation 1

If by any means ΔE^* of tauari can be estimated, this equation can be used to estimate the percent weight loss of the attacked sample. The correlation ($R = 0.239$) between weight loss and the parameters a^*, b^* and L^* of the control samples was very low, so it is not a good estimate of the weight loss. This low correlation may be partially explained because wood is highly anisotropic or else the area of measurement was very restrict.

The colorimetric parameters did not vary extensively between upper or lower surfaces. The direct contact of the sample with soil did not restrain fungus settlement, so there was no need to worry about which sample surface is to be measured.

Camargos (1999) stated that chromatic coordinates fit the first quadrant for major reported tropical hardwood species, which were corroborated in this study. He classified the wood color of *Couratari oblongifolia* as yellow-whitish and the *Couratari guianensis* and *Couratari stellata* as gray-yellowish. In this study, once lightness mean values were higher than 54 woods are considered as light color. Silva et al. (2007) reported to *Couratari*

TABLE 4:   Effect of fungi and wood species in colorimetric parameters of tauari woods block exposed to brown-rot and white-rot fungi, after 12 weeks in accelerated laboratory test.

TABELA 4: Efeito dos fungos e espécies de madeira nos parâmetros colorimétricos de blocos de madeira de tauari expostos aos fungos de podridão-parda e podridão-branca, após 12 semanas em ensaio acelerado de laboratório.

CIE $L^*a^*b^*$	L^*	a^*	b^*	L^*	a^*	b^*	ΔL^*	Δa^*	Δb^*	ΔE^*
	Control			Attacked			Color variations			
Upper surface wood blocks [a]										
Gloeophyllum trabeum	65.5[A]	6.3[A]	21.0[A]	36.3[A]	10.1[B]	21.5[A]	-29.3[A]	3.8[A]	0.5[A]	29.5[C]
Lentinus lepideus	68.2[A]	5.5[A]	21.0[A]	57.6[B]	7.9[A]	24.3[B]	-10.6[B]	2.4[A]	3.3[A]	11.4[A]
Trametes versicolor	67.4[A]	5.4[A]	20.3[A]	59.2[B]	13.8[C]	37.5[C]	-8.1[B]	8.3[B]	17.2[B]	20.7[B]
Ganoderma applanatum	66.3[A]	5.8[A]	20.1[A]	55.3[B]	15.0[C]	36.8[C]	-11.0[B]	9.2[B]	16.8[B]	22.1[B]
Lower surface wood blocks										
Gloeophyllum trabeum	66.4[A]	5.8[A]	21.7[A]	37.5[A]	9.8[B]	21.0[A]	-28.9[A]	4.0[B]	-0.7[A]	29.2[C]
Lentinus lepideus	68.4[A]	5.4[A]	21.2[A]	59.4[B]	7.0[A]	23.2[A]	-9.0[B]	1.6[A]	2.0[B]	9.4[A]
Trametes versicolor	67.2[A]	5.4[A]	20.0[A]	63.3[B]	12.0[C]	35.1[B]	-3.9[C]	6.5[C]	15.1[C]	17.0[B]
Ganoderma applanatum	68.1[A]	5.2[A]	19.7[A]	61.2[B]	13.6[D]	37.5[B]	-6.9[BC]	8.3[D]	17.8[D]	20.8[B]
Upper surface wood blocks [b]										
	L^*	a^*	b^*	L^*	a^*	b^*	ΔL^*	Da^*	Db^*	ΔE^*
Couratari oblongifolia	70.4[C]	5.9[A]	23.0[A]	55.9[A]	12.0[A]	32.0[A]	-14.4[A]	6.0[A]	9.0[A]	18.0[A]
Couratari guianensis	67.0[B]	5.8[A]	19.6[A]	53.2[A]	11.7[A]	30.3[A]	-13.8[A]	5.9[A]	10.7[A]	18.4[A]
Couratari stellata	61.7[A]	5.3[A]	17.6[A]	50.0[A]	12.1[A]	29.9[A]	-11.7[A]	6.9[A]	12.3[A]	18.3[A]
Lower surface wood blocks										
Couratari oblongifolia	70.7[C]	5.7[B]	23.1[A]	58.8[C]	10.7[A]	31.2[A]	-11.9[A]	5.0[A]	8.1[A]	15.2[A]
Couratari guianensis	67.3[B]	5.6[A]	19.7[AB]	56.5[B]	10.1[A]	28.3[A]	-10.8[A]	4.5[A]	8.6[A]	14.5[A]
Couratari stellata	63.2[A]	4.9[A]	17.4[A]	54.4[A]	11.3[A]	30.1[A]	-8.8[A]	6.4[A]	12.7[A]	16.7[A]

Where in: [a] Mean values of 36 measurements (12 for each of the three wood specimens). [b] Mean values of 48 measurements (12 for each fungus). Capital letters represent homogeneous group in the Tukey test at 5% significance level. Chromaticity coordinates a^* = (along the X axis red to green) and b^* = (along the Y axis yellow to blue); L^* = lightness; $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ is the color difference, where $\Delta L^*, \Delta a^*, \Delta b^*$ is given by measured value of the attacked sample minus measured value of non-attacked sample.

sp. the color parameters L^*, a^*, b^* of 50.4, 5.7 and 15.6, respectively. These values are similar to those found in *Couratari stellata* wood. Although it belongs to the same genera, the color suffers influences of samples, site, age and anatomical characteristics. Souza (1997) reported for *Couratari* sp. indistinct heartwood and yellowish-white to light yellowish-brown sapwood, as characterized by the Munsel color chart. Gonçalez et al. (2006) reported for wood of tauari (*Allantoma lineata*) the following values 57.7, 7.2 and 14.4 to L^*, a^* and b^*, respectively, classifying it as clear wood, gray-pinkish color.

No statistical significant difference was observed in the color parameters of the control samples at 5% significance level. The effects of brown-rot and white-rot fungi in the results of Δa^* and Δb^* increases in the upper surface, showing two homogeneous groups, while in the lower surface there were two to three homogeneous groups. The ΔE^* mean value also showed that white-rot fungi belong to an intermediate group, and each brown-rot fungus fit the extreme sub-set.

Color differences (ΔE^*) were higher in all samples attacked by brown-rot *Gloeophyllum trabeum* fungus, reaching up to 29.5, decreasing in the following sequence *Ganoderma applanatum, Trametes versicolor* and *Lentinus lepideus*. The ΔE^* values of brown-rot fungi specimens were mainly caused by variation in the mean values of lightness (ΔL^*), whereas to white-rot fungi were dominantly caused by variation in Δb^*. Specimens attacked by

Gloeophyllum trabeum fungus indicated a color change towards reddish, while both specimens attacked by *Trametes versicolor* and *Ganoderma applanatum* fungi indicated a color change towards yellowish. This same trend can also be observed in Figures 3 and 4.

Wood blocks attacked by both fungi types, wether in upper or lower surfaces, showed the highest perception levels (ΔE^*), surpassing the maximum class range reported by Cui et al. (2004), which is 6.0 - 12.0 as very appreciable, although their study was carried out only in weathered wood samples. Nelson et al. (1969) evaluated black walnut and suggested that differences of 3.5% in luminance, 4 nm in dominant wavelength and 5% in purity would be visually detectable by a normal observer. Some of this changes occurred in tauari sample, allowing visible color differences under naked eyes.

Mean values of yellow and red hue increased considerably when compared to control samples. These changes may be attributed to lignin oxidation besides others compounds plus exposure of the specimens at high moisture and longer time. Extractives should have an important role in color changes as reported by Ishiguri et al. (2003), since their constituents can also be chemically changed. As reported by Chang et al. (2000) and Chang and Cheng (2001), specimens exposed under high moisture conditions had the color darkened and eventually turned to brownish black, this effect may also strengthened the *Gloeophyllum trabeum* decay pattern in this study.

Despite brown-rot or white-rot, both fungi decreased the lightness of the samples, that is, all attacked samples were darker than the control. This trend was also reported by Ferraz et al. (2007), who evaluated *Eucalyptus grandis* wood chips biotreated by *Ceriporiopsis subvermispora*, where final lightness of the biopulps was always slightly lower than the control pulps. However, the cause for the darkening observed in biopulps remains unclear. They also commented that aspen wood, biotreated

TABLE 5:   Color parameters in wood meal of tauari exposed to brown-rot and white-rot fungi, after 12 weeks in accelerated laboratory test.

TABELA 5:   Parâmetros colorimétricos em serragem de madeira de tauari expostos aos fungos de podridão-parda e de podridão-branca, após 12 semanas em ensaio acelerado de laboratório.

Sample	Colorimetric parameters[a] of wood meal								
	Effect of extractives withdrawal								
	Unextracted			Extractive-free			Color variations		
Control	L^*	a^*	b^*	L^*	a^*	b^*	ΔL^*	Δa^*	Δb^*	ΔE^*
Couratari oblongifolia	53.6	8.1	25.9	55.5	9.2	27.3	2.0	1.1	1.4	2.7
Couratari guianensis	51.0	9.2	24.5	51.3	9.7	25.8	0.3	0.5	1.2	1.6
Couratari stellata	51.1	8.4	24.4	50.4	8.3	24.7	-0.7	-0.1	0.3	0.8

	Effect of fungus in color parameters								
	Couratari oblongifolia			*Couratari guianensis*			*Couratari stellata*		
Attacked by	L^*	a^*	b^*	L^*	a^*	b^*	L^*	a^*	b^*
Gloeophyllum trabeum	44.4	7.7	22.3	41.6	8.4	21.7	37.4	7.9	20.6
Lentinus lepideus	48.5	7.7	23.6	48.2	8.0	22.9	50.2	6.9	23.3
Trametes versicolor	49.4	10.1	28.5	48.5	9.7	26.7	53.2	8.7	28.1
Ganoderma applanatum	49.1	10.1	28.1	45.1	10.0	26.0	49.9	8.6	27.0

	Couratari oblongifolia				*Couratari guianensis*				*Couratari stellata*			
Attacked by	ΔL^*	Δa^*	Δb^*	ΔE^*	ΔL^*	Δa^*	Δb^*	ΔE^*	ΔL^*	Δa^*	Δb^*	ΔE^*
Gloeophyllum trabeum	-9.2	-0.4	-3.6	9.9	-9.3	-0.8	-2.9	9.8	-13.8	-0.5	-3.8	14.3
Lentinus lepideus	-5.1	-0.4	-2.3	5.6	-2.7	-1.2	-1.7	3.4	-0.9	-1.5	-1.1	2.1
Trametes versicolor	-4.2	2.0	2.6	5.3	-2.5	0.5	2.1	3.3	2.1	0.3	3.7	4.3
Ganoderma applanatum	-4.4	2.0	2.2	5.3	-5.9	0.8	1.5	6.1	-1.2	0.2	2.5	2.8

Where in: [a] Mean values of 3 repetitions.

by *Phanerochaete chrysosporium* followed by refiner mechanical pulping the biopulps were darker than control pulps.

After 12 weeks of exposure, no statistical difference of color parameters among the wood species was observed.

The results of the color parameters of the wood meal taking into account the effects of the extractives withdrawal and fungi exposure are presented in Table 5.

Unextracted wood samples of *Couratari oblongifolia* are brighter more yellowish than *Couratari guianensis* and *Couratari stellata*, thus matching the pattern of the control blocks in Figure 2. From these colorimetric mean values the tauari wood color was quantitatively specified, although the differences among them were quite small.

The ethanol-toluene (1:3, v/v) extracting process caused an increment in L^*, a^* and b^* mean values and consequently in ΔE^* parameters for wood of *Couratari oblongifolia* and *Couratari guianensis*. Even in comminuted form, the *Couratari oblongifolia* samples showed to be brighter and with higher color difference ($\Delta E^* = 2.7$). The withdrawal of the extractives from *Couratari stellata* samples caused darkening, but this phenomenon is not discrepant. McGinnes and Dingeldein (1971) found that acetone extraction significantly lightened the redcedar (*Juniperus virginiana* L.) heartwood samples, conversely to water extraction. McGinnes Jr. (1975) reported that redcedar samples were least affected by the extraction procedure, with slight darkening of samples in the violet-blue zones of the spectrum. Also Dellus et al. (1997a) applied various treatments to the Douglas fir heartwood, and in the case of extracted wood powder by acetone/water, a good extractant for polyphenols, the red tint of heartwood (a* value) was not affected by this extraction and the lightness (L*) value did not increase. This show that even with these solvents (DELLUS et al., 1997b) a major fraction remains bound to the matrix. Extraction with the same aqueous solvent but at a higher temperature similarly failed to significantly increase the lightness of Douglas fir heartwood (ZIMMER and WEGENER, 1992).

All mean values of attacked wood meal showed a decrease in ΔL^*, except for *Couratari stellata* sample exposed to *Trametes versicolor*. All mean values Δa^* and Δb^* increased when exposed to the white-rot fungi, conversely to the brown-rot for Δa^* and Δb^*. This behavior is well known by means of fungi biochemistry. Major samples were classified as appreciable (3.0 - 6.0) in terms of ΔE^*, according to Cui et al. (2004), while samples exposed to *Gloeophyllum trabeum* fungus attained the highest ΔE^* from ca. 10 to 14.

The lightness of the control wood meal was lower than the wood block, while a^* and b^* mean values were higher. The difference in the color measurement between wood meal and wood blocks was clear, with preference to the second form, due to no additional sample preparation and also due to higher total color difference.

Although extra care was taken to get these measurements, still some diffuse light beam may have been lost. Future recommendation is the use of a wood meal in pellet form, although this type works well as unextracted lignocellulosic material (more cohesion) than extractive-free. The acquisition of an integrator sphere equipped with smaller aperture is also well recommended.

CONCLUSIONS

The tauari wood species *Couratari oblongifolia* and *Couratari guianensis* were ranked as "resistant" to "moderately resistant" when exposed to the *Gloeophyllum trabeum*, *Trametes versicolor* and *Ganoderma applanatum* fungi.

The wood of *Couratari stellata* showed the lowest extractives and ash contents. Almost all extractives' content of attacked wood samples showed a lower value than the control, conversely to almost all ash contents.

All studied specimens altered its color significantly under this experimental condition.

Wood blocks of *Couratari oblongifolia* were the lighter, and *Couratari stellata* the darker. Colorimetric parameter responses of the attacked wood blocks matched the patterns of white- or brown-rot fungus.

The attacked wood blocks showed high perception, in term of ΔE^* levels, when exposed to *Gloeophyllum trabeum*. *Ganoderma applanatum* and *Trametes versicolor* showed no statistical difference in ΔE^* parameter.

The color parameters of the three wood species exposed to fungi were not statistically different.

Wood blocks showed higher total color differences than wood meal, involving less sample preparation.

The best correlation was obtained between

weight loss and ΔE^* and a^*.

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REFERENCES

AMERICAN SOCIETY FOR TESTING AND MATERIALS - ASTM D 2017-05. *Standard method of accelerated laboratory test of natural decay resistance of woods*: Annual Book of ASTM Standard. Philadelphia, v. 0410: 5 p, 2005.

BAMBER, R. K. Heartwood, its function and formation. Wood Sci. Technol, New York, v. 10, p. 1-8, 1976.

BERNAL, R. A. et al. Wood anatomy of Lecythidaceae species called "Tauari". **IAWA Journal**, Leiden, v. 32, n. 1, p. 97-112, 2011.

BILLMEYER, F. W.; SATZMAN Jr. M. **Principles of colour technology.** New York: John Wiley, 1981.

BURGER, L. M.; RICHTER, H. G. **Anatomia da Madeira.** São Paulo: Nobel, 1991. 154 p.

CAMARGOS, J. A. A. **Colorimetria quantitativa aplicada na elaboração de uma tabela de cores para madeiras tropicais**. 1999. 99 f. Dissertação (Mestrado em Ciência Florestal) Universidade de Brasília, Brasília, 1999.

CHANG, S.-T. et al. Environmental effects on the color of sugi (*Cryptomeria japonica* D. Don) heartwood. J. **Wood Sci.**, Japan, v. 46, p. 390-394, 2000.

CHANG, S.-T.; CHENG , S.-S. 2001. Effects of environmental factors on the color of sugi (*Cryptomeria japonica* D. Don) yellowish heartwood. **Holzforschung**, Berlin, v. 5, n. 5, p. 459-463, 2001.

CUI, W. et al. Diffuse reflectance infrared Fourier transform spectroscopy (DRIFT) and color changes of artificial weathered wood. **Wood and Fiber Science**, Madison, v. 46, p. 289-290, 2004.

DELLUS, V. et al. Polyphenols and colour of Douglas fir heartewood. **Holzforschung**, Berlin, v. 51, n. 4, p. 291-295, 1997a.

DELLUS, V.et al. Douglas fir polyphenols and heartwood formation. **Phytochemistry**, New York,

v. 45, n. 8, p. 1573-1578, 1997b.

EATON, R. A.; HALE, M. D. C. **Wood:** decay, pests and protection. Chapman & Hall. London, 1993. 546 p.

FEDALTO, L. et al. **Madeiras da Amazônia**. Descrição do lenho de 40 espécies ocorrentes na Floresta Nacional de Tapajós**.** Brasília: IBAMA/DIRPED-LPF, 1989.

FERRAZ, A. et al. Technological advances and mechanistic basis for fungal biopulping. **Enzyme and Microbial Technology**, New York, v. 43, n. 2, p. 178-185, 2007.

GARZÓN, S. B. R. **Estudo anatômico comparativo do lenho das espécies de Lecythidaceae denominadas "tauari".** 2004, 65 f. Dissertação (Mestrado em Botânica) – Universidade de Brasília, Brasília, 2004.

GIERLINGER, N. et al. Colour of larch heartwood and relationships to extractives and brown-rot decay resistance. **Trees**, California, v. 18, p. 102-108, 2004.

GONÇALEZ, J. C. et al. Caracterização das propriedades físicas e colorimétricas de duas espécies florestais para a indústria moveleira. In: CONGRESSO BRASILEIRO DE INDUSTRIALIZAÇÃO DA MADEIRA E PRODUTOS DE BASE FLORESTAL - CBIM, 2., 2006, Pinhais, PR. **Anais...** CBIM: Paraná, 2006.

GREEN III, F. et al. Detection of increased metal cations after wood decay using Chromeazurol - S. IRG/WP/97-20112. International Research Group on Wood Preservation, Vancouver. 1997.

HON, D.N.-S.; MINEMURA, N. **Wood and cellulosic chemistry**. New York: Marcel Dekker, 2001, 914 p.

INSTITUTO BRASILEIRO DE DESENVOLVIMENTO FLORESTAL - IBDF. **Madeiras da Amazônia:** características e utilização. Floresta Nacional do Tapajós. Brasília: CNPq/DE-LPF, 1981. v. 1

INSTITUTO BRASILEIRO DE DESENVOLVIMENTO FLORESTAL. **Madeiras da Amazônia :** características e utilização. Estação experimental de Curuá-Una. Brasília: IBDF/DPq-LPF, 1988. v. 2.

ISHIGURI, F. et al. Extractives relating to heartwood color changes in sugi (*Cryptomeria japonica*) by a combination of smoke-heating and UV radiation exposure. **J. Wood Sci.,** Japan, v. 49, p. 135-139, 2003.

JANIN, G. 1988. La measure de la couleur du bois. Intérêts agronomique, technologique et

économique. In: Mesure instrumentation – controle – automatisme (MICA). Sèminaire couleurs et lumière, MICA, Montréal.

KARTAL, S. N.; GREEN III, F. Decay and termite resistance of medium density fiberboard (MDF) made from different wood species. **International Biodeterioration & Biodegradation**, Birminghan, v. 51, p. 29-35, 2003.

LEVIN, L., CASTRO, M. A. Anatomical study of the decay caused by the white-rot fungus *Trametes trogii* (Aphyllophorales) in wood of *Salix* and *Populus*. **IAWA Journal**, Leiden, v.19, n. 2, p. 169-180, 1998.

MAZET, J. F. et al. Modification de couleur du bois de chênes européens exposés à lumière solaire. **Ann. For. Sci.,** Lês Ulis, v. 50, p. 119-146, 1993.

McGINNES Jr, E. A.; DINGELDEIN, T. W. Effect of light, extraction, and storage on color and tackiness of clear-finished eastern redcedar. **Forest Products Journal**, Madison, v. 21, n. 1, p. 53-60, 1971.

McGINNES Jr, E. A. Influence of incandescent and fluorescent light on the color of unfinished heartwood of black walnut and eastern redcedar. **Wood Science**, Madison, v. 7, n. 4, p. 270-279, 1975.

McGINNES Jr, E. A.; ROSEN, H. N. Macroscopic and microscopic analyses of color changes of wood pressure steam-dried above atmospheric pressure. **Wood and Fiber Science**, Madison, v. 16, n. 1, p. 48-56, 1984.

MORI, S.; PRANCE, G. Lecythidaceae. Part I. **Flora Neotropica**, New York, v. 21, n. 1, 1979. 270 p.

NELSON, N. D. et al. Relationships of black walnut wood color to soil properties and site. **Wood Fiber**, Madison, v. 1, n. 1, p. 29-37, 1969.

NELSON, N. D.; HEATHER, W. A Quantitative colour values of the heartwood of various Australian species. **Australian Forestry Journal**, Yarralumla, v. 33, n. 4, p. 275-280, 1970.

NISHINO, Y. et al. Colorimetry of wood specimens from French Guiana. **J. Wood Sci.**, Japan, v. 44, p. 3-8, 1998.

OKINO, E. Y. A. et al. Color variation of rubberwood clones and cypress infected by *Gloeophyllum striatum* and *Phanerochaete chrysosporium*. **International Biodeterioration & Biodegradation**, Birminghan, v. 63, p. 41-45, 2009.

PROCÓPIO, L. C.; SECCO, R. S. A importância da identificação botânica nos inventários florestais: o exemplo do "tauari" (*Couratari* spp. e *Cariniana* spp. - Lecythidaceae) em duas áreas manejadas no estado do Pará. **Acta Amazônica**, Manaus, v. 38, n. 1, p. 31-44, 2008.

ROWE, J. W.; CONNER, A. H. **Extractives in eastern hardwoods - A review**. General Technical Report FPL 18, Forest Products Laboratory, Forest Service, U. S. Department of Agriculture, Madison, Wisconsin. 1979, 67 p.

SANTANA, M. E.; OKINO, E. Y. A. Chemical composition of 36 Brazilian Amazon forest wood species. **Holzforschung**, Berlin, v. 61, n. 5, p. 469-477, 2007.

SCHEFFER, T.C.; E.B. COWLING. Natural resistance to microbial deterioration. **Ann Rev Phytopathol**, Palo Alto, v. 4, p. 147-170, 1966.

SILVA, J. O. et al. Resistência ao intemperismo artificial de cinco madeiras tropicais e de dois produtos de acabamento. **Ciência Florestal**, Santa Maria, v. 17, n. 1, p. 17-23, 2007.

SOUZA, M. H. **Madeiras tropicais brasileiras**. Brasília: IBAMA/LPF, 1997. 152 p.

TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY - TAPPI TEST METHODS 1996a. Preparation of wood for chemical analysis. T 264 om-82. 1996 TAPPI test methods. Atlanta, TAPPI press, v. 1.

TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY - TAPPI TEST METHODS 1996b. Solvent extractives of wood. T 204 om-88. TAPPI test methods. Atlanta, T APPI press, v. 1.

TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY - TAPPI TEST METHODS 1996c. Ash in wood, pulp, paper and paperboard: combustion at 525°C. T 211 om-93. TAPPI test methods. Atlanta, TAPPI press, v. 1.

WINDEISEN, E. et al. Investigation of the correlation between extractives content and natural durability in 20 cultivated larch trees. **Holz als Roh- und Werkstoff**, Berlin, v. 60, p. 373-374, 2002.

ZIMMER, B.; WEGENER, G. Extraktion von Douglasienholz zur Entfernung gefärbter Kernholzbestandteile. **Holz als Roh- und Werkstoff**, Berlin, v. 50, p. 294-295, 1992.