

The effect of oleoresin tapping on physical and chemical properties of *Pinus elliottii* woodEfeito da extração de resina nas propriedades físicas e químicas da madeira de *Pinus elliottii*André Luiz Missio¹, Bruno Dufau Mattos², Pedro Henrique G. Cademartori³,
Tainise Vergara Lourençon³, Jalel Labidi⁴ e Darci Alberto Gatto⁵**Resumo**

O objetivo desse estudo foi avaliar os efeitos da extração, pelo método de estrias na casca, nas propriedades físicas e químicas da madeira de *Pinus elliottii*. Amostras foram confeccionadas a partir de tábuas com e sem a presença de bolsas de resina. Todas as tábuas foram selecionadas de árvores que sofreram o processo de resinagem de 10-12 vezes. A resina foi caracterizada por GC/MS e a caracterização física e química da madeira foi realizada por testes de absorção de água, molhabilidade dinâmica, análises termogravimétricas, composição química e espectros ATR-IR. Entre os principais compostos encontrados na resina de pinus, α e β -pineno apresentaram o maior valor percentual e são considerados produtos de elevado valor comercial. Em relação a qualidade da madeira, propriedades relacionadas a absorção de água e molhabilidade apresentaram decréscimos devido a presença da resina na madeira. Por outro lado, a estabilidade térmica das amostras diminuiu com a presença da resina na madeira.

Palavras-chave: óleo essencial, GC/MS, avaliação térmica, molhabilidade, práticas silviculturais.

Abstract

The aim of this study was to evaluate the effect of tapping by bark streak method on the physical and chemical properties of wood. Pine wood samples were made from boards with and without the presence of oleoresin pockets. All the boards were selected from trees that were tapped 10-12 times for the oleoresin extraction. The oleoresin was characterized by GC/MS, and the physical and chemical characterization of wood was performed by water absorption tests, dynamic wettability, thermogravimetric analyzes, chemical composition and ATR-IR spectroscopy. Among the main compounds found in the pine oleoresin, α and β -pinene had the highest percentage and are considered products with high commercial value. Regarding wood quality, properties related to water absorption and wettability all decreased due to the large presence of oleoresin. On the other hand, thermal stability of the wood samples decreased with the presence of oleoresin.

Keywords: Essential oil, GC/MS, thermal evaluation, wettability, silvicultural practice.

INTRODUCTION

The genus *Pinus* consists in approximately 600 species, which are typically used for production of pulp and paper and in sawing processes. They represent 23.4% of planted forests in Brazil (ABRAF, 2013), where slash pine (*Pinus elliottii*) and loblolly pine (*Pinus taeda*) were introduced

in the 50s and presented the best adaptation to Brazilian climatic conditions, thus contributing to them becoming a fast-growing renewable source.

Resin is an important product obtained from these species through many tapping methods such as bark streak, which is performed using chemical stimulants to avoid cicatrization and to allow for long-term extraction. Brazilian oleoresin

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production in 2012-2013 was over 96 million tonnes, with an average price in May/13 of ~US\$750 per tonne (ARES, 2013), placing Brazil as the second producer of oleoresin, only behind China.

Oleoresin is a mixture of terpenoids, gum rosin (diterpenes, C₂₀) and turpentine (monoterpene, C₁₀ and sesquiterpene, C₁₅) (BOHLMANN ; KEELING, 2008). Most of the rosin is used as intermediate chemicals products, including synthetic rubber, adhesives and coatings (STUBBS et al., 1984). On the other hand, turpentine has been used as a solvent or cleaning agent for inks, varnishes and in the pharmaceutical industry (FAO, 1995; RODRIGUES-CORRÊA et al., 2012). Turpentine can be separated into α - and β -pinene, in which α -pinene is used for synthetic oils, insecticides (STUBBS et al., 1984), flavour and fragrance ingredients, while β -pinene is used in pharmaceutical products (KELKAR et al., 2006).

Regarding wood quality, the process of oleoresin tapping does not cause any damage to the material if is done correctly, i.e., only the bark is removed (FAO, 1995). On the other hand, incorrect processes can change the wood structure due to the formation of large oleoresin pockets and, consequently, the accumulation of oleoresin. Considering that industries in Brazil use a high proportion of pine trees as raw material, such as *P. elliottii*, the evaluation of wood originated from fast-growing forest populations that tap trees to obtain oleoresin are important because the quality of the products generated could be significantly affected by the several variations in the properties of the raw material.

Correlations of silvicultural management with wood properties – such as early-latewood proportion, density, fibre length (IKONEN et al., 2008) and tracheid properties (MÄKINEN ; HYNENEN, 2012) are very important, mainly for valorization of fast-growing forests in tropical countries. Lately, studies have investigated the oleoresin yield when related to silvicultural practices (ESHETE et al., 2012; RODRÍGUEZ-GARCÍA et al., 2014). Nevertheless, the effect of oleoresin tapping as a silvicultural practice on the wood properties was poorly discussed.

In the last ten years, much research has emphasized the importance of physicochemical characterization as a means to assess the quality of materials of forest origin (ESTEVES et al., 2011; DUBEY et al., 2012; JELLE, 2012; CADEMARTORI et al., 2013; CADEMARTORI et al., 2014; CONTE et al., 2014; MATTOS et al., 2014).

Evaluation of physical properties of wood is an excellent alternative to obtain more information about, surface wettability, water uptake and thermal stability, which contribute towards the best technological use of this material (NGUYEN et al., 2013; PRIES et al., 2013). These properties can provide useful information for technical applications such as painting, waterborne treatments, to prevent “gumming up” in sawmill, and others. On the other hand, chemical characterization of wood (quantification and qualification of wood components) helps one to understand physical properties and results in more satisfactory conclusions related to the technological properties of wood (WANG et al., 2007; HUANG et al., 2012; CADEMARTORI et al., 2013).

Therefore, this work aims to characterize the influence of oleoresin tapping by the bark streak method on the some properties of juvenile and mature *Pinus elliottii* Engelm. wood, to improve the utilization of its wood. The juvenile and mature pine wood were separately studied due to the very different properties of each one.

MATERIAL AND METHODS

Raw Material

Pine wood (*Pinus elliottii* Engelm.) was obtained from a homogeneous population of 7.200 ha located in the southern coast region of São José do Norte, Rio Grande do Sul– Brazil (32°01'22.21"S 52°01'51.81"). The trees (28-32 years old) were planted in a 2 x 2 m spacing without forest management. The process of oleoresin tapping by the bark streak method was performed 10-12 times before harvesting. The tapping process was done once a year (started during winter and finished in the summer period).

Logs measuring 3 m were cut and sawed in order to obtain tangential and radial boards with 25 mm of thickness. These boards were separated in two parts: with and without a large presence of oleoresin pockets due to the tapping of trees (Figure 1).

Samples with a large presence of oleoresin measuring 10 x 10 x 200 mm (thickness, width and length) were cut from close to the pith and were identified as juvenile resinous wood (JRW), while samples with the same size were cut from close to the bark and were identified as mature resinous wood (MRW). Similarly, samples without the presence of oleoresin measuring 10 x 10 x 200 mm (thickness, width and length)

were cut and were identified as juvenile wood (JW) and mature wood (MW).

GC/MS characterization of oleoresin

The oleoresin was obtained by hydrodistillation with Clevenger type extractor for 4 h (4h was necessary to obtain sufficient sample). The oleoresin was separated by density difference, collected with a micro pipette and kept at 4 °C, until GC-MS analyse.

The oleoresin was dissolved in ethyl acetate and injected in a GC-MS Agilent equipped with a capillary column HP-5MS ((5%-phenyl)-methylpolysiloxane, 60 m × 0.32 mm). Helium was used as the carrier gas. The oven programme started at 60°C and was kept for 10 min at this temperature; programmed at 220°C with a heating rate of 4°C min⁻¹ and kept for 10 min at this temperature, and finally heated at 280°C with a heating rate of 1°C min⁻¹. The injector temperature was 280°C.

Oleoresin compounds were identified using retention indices, mass spectra, peak matching library search and database of NIST 08. Main oleoresin compounds were determined as the percentage of peak area relative to the total peak area from GC/MS analyses of the whole extracts.

Chemical characterization

Chemical quantification of wood

The chemical quantification of wood was performed in triplicate for each type of pine wood. Wood samples were milled (TAPPI, 1996) in a Knife mill (40 mesh) for the chemical analyzes. Ethanol-toluene extractives (TAPPI, 1997), Klason lignin (TAPPI, 1998a), hot water soluble (TAPPI, 1993) and NaOH1% soluble (TAPPI, 1998b) were determined.

Infrared spectroscopy (ATR-IR)

Infrared spectroscopy (ATR-IR) spectra of milled wood samples and oleoresin were determined using a Nicolet Nexus 570 equipment with direct transmittance at a resolution of 4 cm⁻¹ for 32 scans in the range from 700 cm⁻¹ to 4000 cm⁻¹. The alignment of the light equipment and the background spectra were collected before all the tests, and each spectra was generated from an average of three spectra.

Thermogravimetric analyzes (TGA)

Thermal analyzes was performed using wood samples and oleoresin extracted as described in section 2.2. Thermo-gravimetric analyzes (TGA) was carried out using a DTG-60 Shimadzu

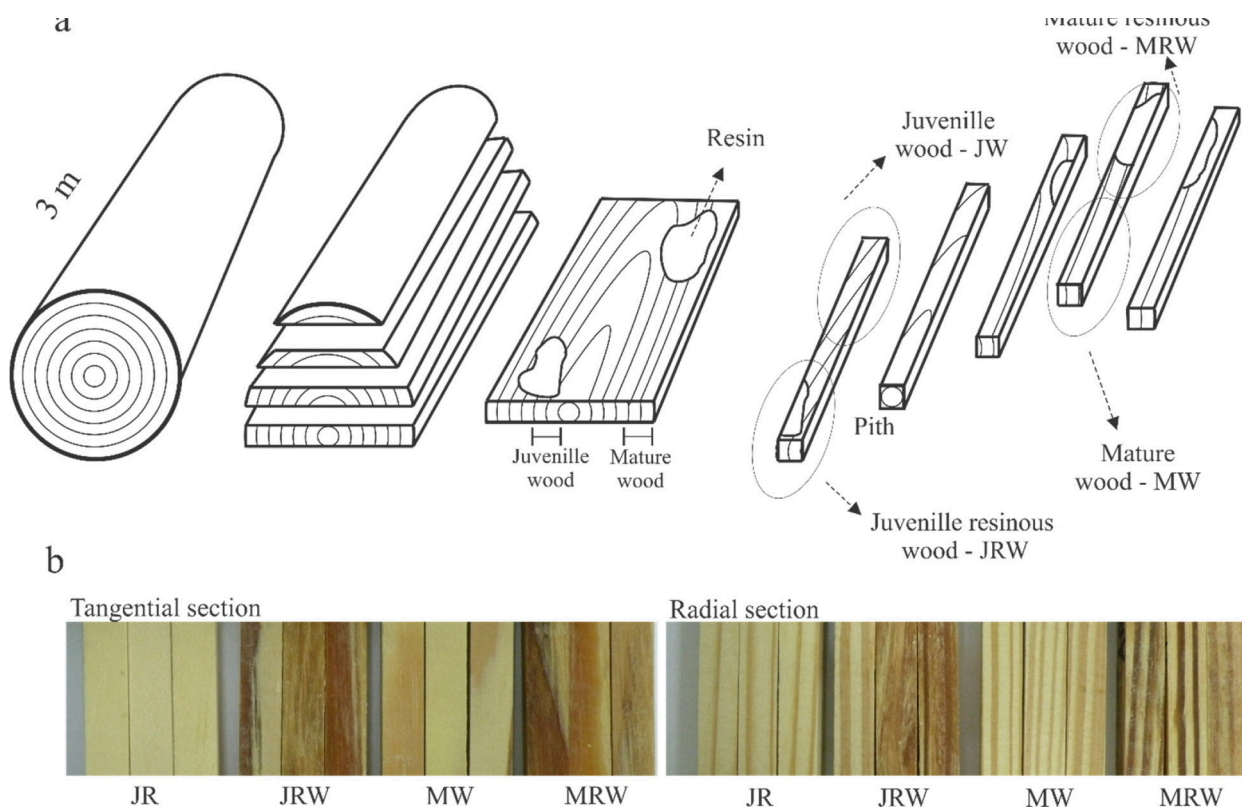


Figure 1. Summarized diagram of the samples preparation (a) and visual appearance of the samples with and without resin (b).

Figura 1. Diagrama resumido do preparo das amostras (a) e aparência visual das amostras com e sem resina (b).

equipment in a dynamic nitrogen atmosphere (gas flow of 50 ml min⁻¹) at 25-600 °C with a heating rate of 10 °C min⁻¹, in which 5-6 mg of each sample was kept in a platinum pan.

Water uptake tests and contact angle

Water absorption (WA), water absorption rate (RA) and contact angle were determined using 15 samples measuring 10 x 10 x 30 mm (thickness, width and length) for each type of wood.

For WA and RA tests, samples were dried in an oven at 103±2 °C until reaching constant weight and, subsequently, samples were immersed in distilled water to obtain the saturation point. Weight of samples was measured after 1, 2, 3, 4, 8, 24, 48, 72 and 96h of immersion. WA and RA were measured by Equations 1 and 2.

$$WA = \frac{(w_f - w_i)}{w_i} \cdot 100 \quad (1)$$

$$RA = \frac{(w_f - w_i)}{t_f - t_i} \quad (2)$$

Where w_f is the sample weight after immersion in a different time; w_i is the dry weight; t_f is the measurement time of w_f and t_i the measurement time of w_i .

Dynamic wettability of pine wood samples (same dimensions) was measured using a Dataphysics OCA goniometer (sessile droplet method). Wood samples were kept in a climatic chamber at 25 °C and 50% relative humidity in order to stabilize the moisture content.

Distilled water droplets (5 µL) were disposed in three distinct points of longitudinal radial and longitudinal tangential sections in each of the five samples per type of wood to determine the contact angle. Measurements were performed at 5, 25, 45, 65 and 85 s after the contact between the droplet and sample surface.

RESULTS AND DISCUSSION

Oleoresin characterization

Results summarized in Table 1 and Figure 2 show the main products obtained from pine oleoresin. The main compound was dehydroabietic acid with 15.38% of total. According to Silvestre e Gandini (2008), dehydroabietic acid is the most frequent and abundant diterpenoid compound found in oleoresins.

The compounds α and β -pinene are the main components of gum turpentine oil (GRAIKOU

et al., 2012; RODRIGUES-CORRÊA et al., 2012), and were some of the most abundant compounds found in oleoresin in this work. α and β -pinene are highly appreciated in chemical industries, such as flavour and fragrances industries, pharmaceuticals, insecticides and repellents, solvents and antimicrobial (ZULAICA-VILLAGOMEZ et al., 2005; MERCIER et al., 2009; SILVA et al., 2012). These compounds can be found in several other species of pine such as *P. brutia*, *P. pinea*, *P. nigra*, *P. halepensis* and *P. sylvestris* (USTUN et al., 2012). Into wood, both pinenes acts as a natural antifungal agent (CHANG et al., 2008; MATAN et al., 2012; CHENG et al., 2013).

A small amount of other compounds in pine oleoresin was observed. Likewise, others studies (ARRABAL et al., 2002; DOB et al., 2005; GRAIKOU et al., 2012) analysed oleoresin from pine species and observed a low percentage of these compounds, which is the typical behavior of oleoresin from this type of raw material and usually comprehend ~1% of the total composition of the products.

Rodrigues-Corrêa et al. (2012) affirmed that these compounds with small content present in oleoresin have a high added value, are used as food additives (myrtenol and aromadendrene), and could be used for alternative applications such as polymer explosives (camphene) and cosmetics and household cleaners (borneol).

The acids found in small quantity (octadecanoic acid, pimelic acid, abietic acid, palustric acid) are used for many value-added purposes such as materials of candle fire, soap, grease, synthetic detergent and softener (GOODGER et al., 2007).

Chemical characterization of wood

High content of ethanol:toluene extracted material with the presence of oleoresin (JRW and MRW) was observed (Table 2).

The high amount of material obtained after extraction in ethanol:toluene reflected in lower amounts of Klason lignin (insoluble). In addition, hot water extraction significantly removed a high fraction of the oleoresin from JRW and MRW samples. Hot water extraction is a process similar to hydrodistillation, which is one of the methods used for the extraction of oleoresin from pine woods. Graikou et al. (2012) obtained a range of monoterpenes and sesquiterpenes using the hydrodistillation method.

Table 1. Main compounds of the oleoresin from pine wood.**Tabela 1.** Componentes principais da oleoresina da madeira de pinus.

Retention time (min)	Compound	% of total	Chemical structure (Figure 2)
8.63	α pinene	6.33	1
9.46	Camphene	0.15	2
11.26	β pinene	8.15	3
14.33	β -phellandrene	0.60	4
18.68	Fencholexo	0.12	5
19.30	α -Campholenal	0.12	6
19.83	10-Pinen-3-ol	0.54	7
21.04	Borneol	0.16	8
22.37	Myrtenol	0.49	9
22.47	Estragole	0.11	10
22.91	Verbenone	0.17	11
51.59	Aromadendrene	0.61	12
55.42	Octadecanoic acid	0.19	13
55.91	Pimaric acid	4.70	14
57.30	Abietic acid	5.37	15
57.60	Palustric acid	4.51	16
59.07	Dehydroabietic acid	15.38	17

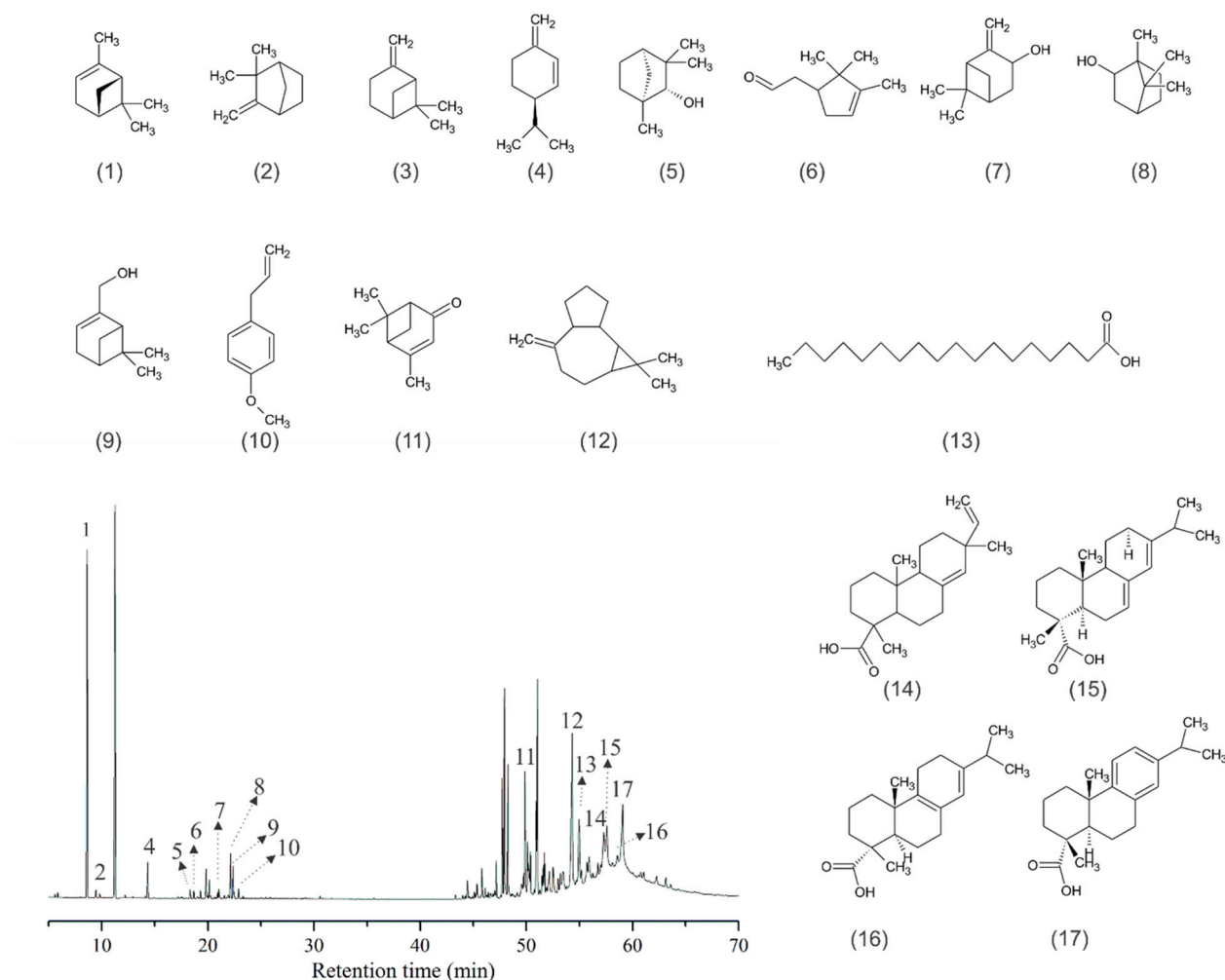
**Figure 2.** Chromatogram and chemical structure of the main compounds identified in pine oleoresin (see Table 1).**Figura 2.** Cromatograma e estruturas químicas dos principais compostos identificados na resina de pinus (veja Tabela 1).

Table 2. Chemical quantification (%) of the type of pine wood.**Tabela 2.** Quantificação química dos tipos de madeira de *Pinus*.

Samples	Etanol:toluene Extract	Klason lignin	Solubility hot water	Solubility NaOH(1%)
JW	9.3 ± 0.17	25.23 ± 0.27	5.98 ± 0.02	16.02 ± 0.04
JRW	35.72 ± 0.40	17.73 ± 0.07	20.80 ± 1.06	55.07 ± 1.26
MW	1.76 ± 0.36	28.11 ± 0.19	2.04 ± 0.09	11.64 ± 0.69
MRW	14.61 ± 0.62	23.96 ± 0.72	23.99 ± 0.35	46.80 ± 1.12

Average ± deviation standard; JW = juvenile wood; JRW = juvenile resinous wood; MW = mature wood; MRW = mature resinous wood.

The high percentage of soluble material in NaOH_{1%} found in JRW and MRW showed that a fraction of oleoresin was extracted by weak alkali solution. JW and MW presented 16.02 and 11.64% of soluble material in NaOH_{1%} with up to 4 times lower to resinous samples.

Figure 3 shows the infrared spectra obtained for JW, MW, JRW, MRW and oleoresin extracted samples. Peak at 1508 cm⁻¹ (aromatic skeletal in lignin) and at 1272 cm⁻¹ (guaiacil ring) were found with similar intensity for all types of woods – indicating that even with significant differences in lignin content is difficult to track these changes by infrared. Nevertheless, peaks at 892 cm⁻¹ (C-H deformation in cellulose), 1022 cm⁻¹ (C-O stretch), 1157 cm⁻¹ (C-O-C vibration), and 1376 cm⁻¹ (C-H deformation in cellulose and hemicelluloses) were observed.

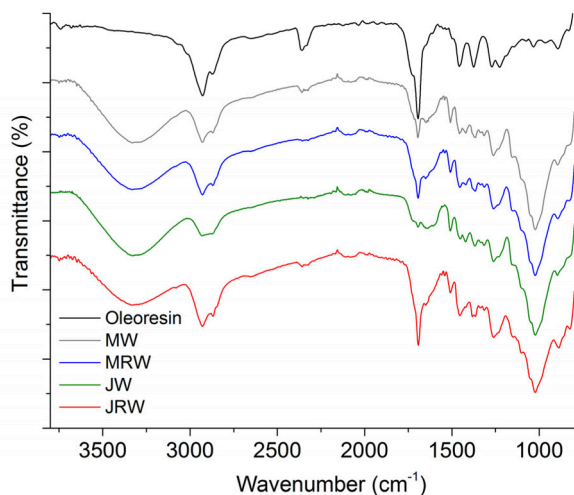


Figure 3. Infrared spectra for pine wood samples and extracted oleoresin. JW = juvenile wood; JRW = juvenile resinous wood; MW = mature wood; MRW = mature resinous wood.

Figura 3. Espectros infravermelhos para as amostras e da resina extraída. JW = lenho juvenil; JRW = lenho juvenil resinado; MW = lenho adulto; MRW = lenho adulto resinado.

A characteristic peak at 1729 cm⁻¹, related to carbonyl bonds in free fatty and resin acids (SUN; SUN, 2001), was observed in the oleoresin spectra. The peak at 1690 cm⁻¹, corresponding to

C=C stretching vibration, is attribute to presence of terpenes in the oleoresin composition, as seen in the GC-MS analyzes. This peak was observed in spectra for all types of wood. Two intense peaks (2927 and 2860 cm⁻¹) that are related to methylene and methyl stretching frequencies were observed, as previously reported by Sun e Sun (2001). Furthermore, a peak at 2927 cm⁻¹ may be related to the presence of aliphatic group types of triglycerides or fatty acids (CARON, 2010). The tracking of all these peaks, related to chemical structures of the oleoresin, can be a good tool for rapid screening of rosined woods in automated systems sawmill.

Higher presence of oleoresin in pine wood, can make it difficult the alkali pulping processes due to the extensive occurrence of pitch in the equipment. On the other hand, with previous hydrodistillation of wood, is possible obtained oleoresin and subsequently cellulose, such as an integrated biorefinery process.

Thermogravimetric analyzes (TGA)

Figure 4 shows the thermograms (TG) and derivatives (DTG) of all types of wood and oleoresin extracted. Loss of water in wood samples occurs at ~100°C, which was not observed in oleoresin due to their hydrophobic character.

The peak at 280°C (Table 3) is referred to the major thermal degradation of the oleoresin, and corresponds to 70% of the weight loss of oleoresin. Another peak at 310-425°C was observed and represents ~22% of the weight loss. Thermograms of all types of woods showed that the intensity of the first peak at 217-260°C was influenced by the presence of oleoresin in the samples (Table 3). Presence of oleoresin both in juvenile and mature wood decreased the thermal stability of these woods, which can be seen due to the difference in T_i (Figure 4b) when compared JW/MW with JRW/JMW. Samples with high percentage of oleoresin (JRW and MRW) present the thermogram onset temperature (T_i) close to T_i for the oleoresin extracted.

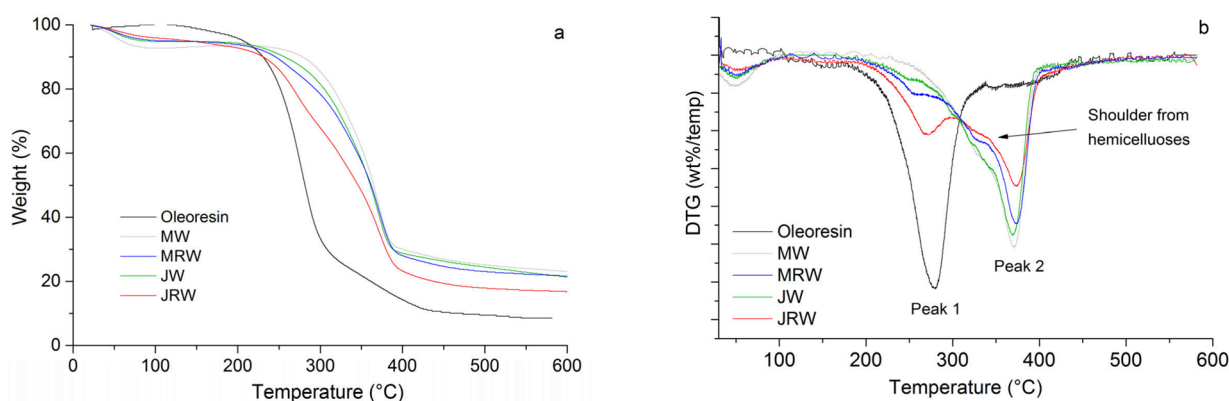


Figure 4. Thermogravimetric curves for the types of wood and extracted resin. JW = juvenile wood; JRW = juvenile resinous wood; MW = mature wood; MRW = mature resinous wood.

Figura 4. Curvas termogravimétricas para os quatro tipos de madeira e extrato da resina. JW = lenho juvenil; JRW = lenho juvenil resinado; MW = lenho adulto; MRW = lenho adulto resinado.

Table 3. Thermal degradation temperatures, T shoulder, DTG peaks and % residue at 600°C for the type of wood study and oleoresin.

Tabela 3. Temperaturas de degradação térmica, T shoulder, picos DTG e % de resíduo em 600°C para os tipos de madeiras estudadas e oleoresina.

Sample	Ti (°C)	3% wt. loss	T shoulder (°C)	Peak 1 (°C)	Peak 2 (°C)	Residue at 600°C (%)
Resin	184	-	-	280	-	8.5
JW	245	323	248	365	21.3	
JRW	217	320	270	375	16.7	
MW	260	326	-	368	23.1	
MRW	225	325	255	373	21.7	

JW = juvenile wood; JRW = juvenile resinous wood; MW = mature wood; MRW = mature resinous wood.

The second stage of thermal degradation of wood ($\sim 320^\circ\text{C}$) is related to the hemicelluloses content, which was also observed by Poletto et al. (2012) for the same species. Oleoresin did not interfere in the maximum temperature of hemicelluloses degradation (T shoulder, Figure 4b).

Poletto et al. (2012) suggested that the appearance of this shoulder is due to the similarity of thermal degradation of amorphous cellulose and hemicelluloses, which hinders the identification of the degradation temperature of each component.

The main degradation of cellulose in the wood samples with resin pockets (JRW and MRW) occurred in a temperature slightly higher than the samples without the presence of oleoresin (Peak 2, Table 3). As observed in Figure 3b, the intensity of the peak of cellulose degradation showed inverse behavior in relation to the intensity of peak 1 (thermal degradation of the oleoresin), which is related to the chemical quantification. An increase in the percentage of oleoresin tends to decrease the percentage of other wood components.

The higher thermal reactivity of hemicelluloses is in its chemical composition and structure, which presents amorphous chains

that are easier to hydrolyze. On the other hand, cellulose is a long polymer formed by glucose units, in which its crystalline regions improve the thermal stability of wood (YANG et al., 2005; AKGÜL et al., 2007).

A peak related to the thermal degradation of lignin was not observed. According to Yang et al. (2005) the thermal degradation of lignin is slow and occurs between $100\text{-}900^\circ\text{C}$, although only 40 wt % of lignin is lost at a very slow rate ($<0.15 \text{ wt } \%^\circ\text{C}^{-1}$) from room temperature to 700°C .

These associated facts explain the values found for residues at 600°C (Table 3), in which wood with more Klason lignin content (Table 2) presented higher residues content at 600°C and higher formation of charcoal. On the other hand, residues at 600°C of oleoresin samples are lower than those found in all types of pine wood because oleoresin does not have lignin in its composition.

In sawing processes, the pitch pockets can cause "gum up" in the equipment, mainly due to the small thermal stability of oleoresin. On the other hand, the thermal behavior of oleoresin tends to improve the production of pellets for bioenergy from pine wood (FILBAKK et al., 2011).

Water uptake tests and contact angle

Figure 5 shows the short-term behavior of water absorption (%) and absorption rate for wood samples. Samples with the presence of oleoresin pockets (JRW and MRW) presented low water absorption than samples without oleoresin pockets (JW and MW). A similar behavior was observed in the water absorption rate (%), in which JRW and MRW showed significantly lower indices than those found for JW and MW.

First, water flows into the piece of wood depend on the permeability of the material (SIVERTSEN; FLÆTE, 2012) and the content of polysaccharides present in wood (ASHORI; NOURBAKHSI, 2010). Therefore, incrustations in wood resulting from the accumulation of oleoresin hinders the penetration and diffusion of water, and limits the access to carbohydrates in the wood cell wall.

Juvenile samples without oleoresin pockets (JW) showed the highest absorption of water. The rate of water absorption of wood with oleoresin pockets (JRW and MRW) was approximately ten times lower than JW and MW. This fact is related to the hydrophobic nature of the pitch (CIESLA, 2009), which is an oleoresin component that acts as a water repellent.

As seen in Figure 6, kinetics of contact angle in tangential and radial sections showed different behavior as a function of the type of wood. JW samples showed the more wetting. Although both contact angle of MW and JW decreased as a function of the time, JW tends to have higher droplet absorption in relation to values found

in MW. Percentage of decrease of contact angle of MW in both anatomical sections was ~42% while JW decreased ~63% in radial section and ~81% in tangential section.

This behavior can be explained by anatomical and chemical characteristics of juvenile wood. Zobel and Buijtenen (1989) reported that juvenile wood have higher lumen diameter and a higher proportion of holocellulose. Higher lumen diameter in juvenile wood may have improved absorption and spread of the droplet, resulting in a low contact angle. High levels of holocellulose result in higher amounts of polysaccharides in the chemical structure of juvenile wood and, consequently, in higher absorption and spread of the droplet due to the affinity between hemicelluloses and water.

Large presence of oleoresin in the JRW and MRW leads to create a very hydrophobic surface (no absorption), meanwhile MW and mainly JW showed an instantaneous absorption. On the other hand, droplet volume of JRW and MRW remains nearly the same (constant as a function of the time), which indicated the hydrophobic character of these materials. The presence of low molecular weight compounds on the wood surface that form a monolayer or multilayer structure of low surface energy decreases the wettability of the material (BACK, 1991).

From a practical point of view, changes on water absorption of wood imply in positive and negative applications. The pine wood from tapped trees that presenting significant proportion of pitch pockets tends to shows higher dimensional stability and higher decay

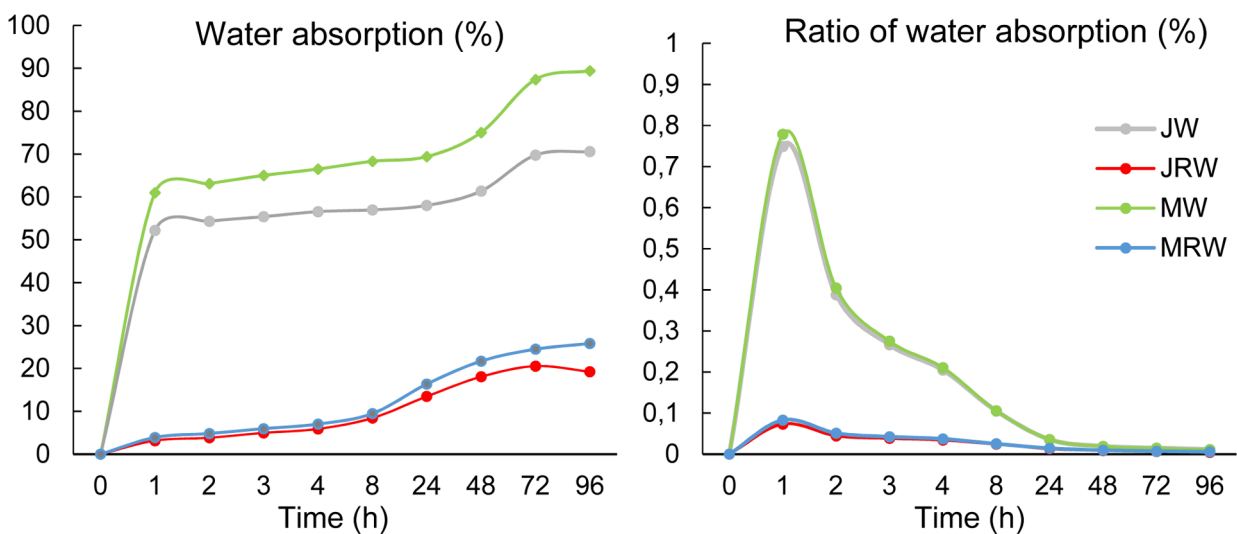


Figure 5. Short-term behavior of water uptake in pine wood samples. JW = juvenile wood; JRW = juvenile resinous wood; MW = mature wood; MRW = mature resinous wood.

Figura 5. Comportamento da absorção de água em curto período nas amostras de pinus. JW = lenho juvenil; JRW = lenho juvenil resinado; MW = lenho adulto; MRW = lenho adulto resinado.

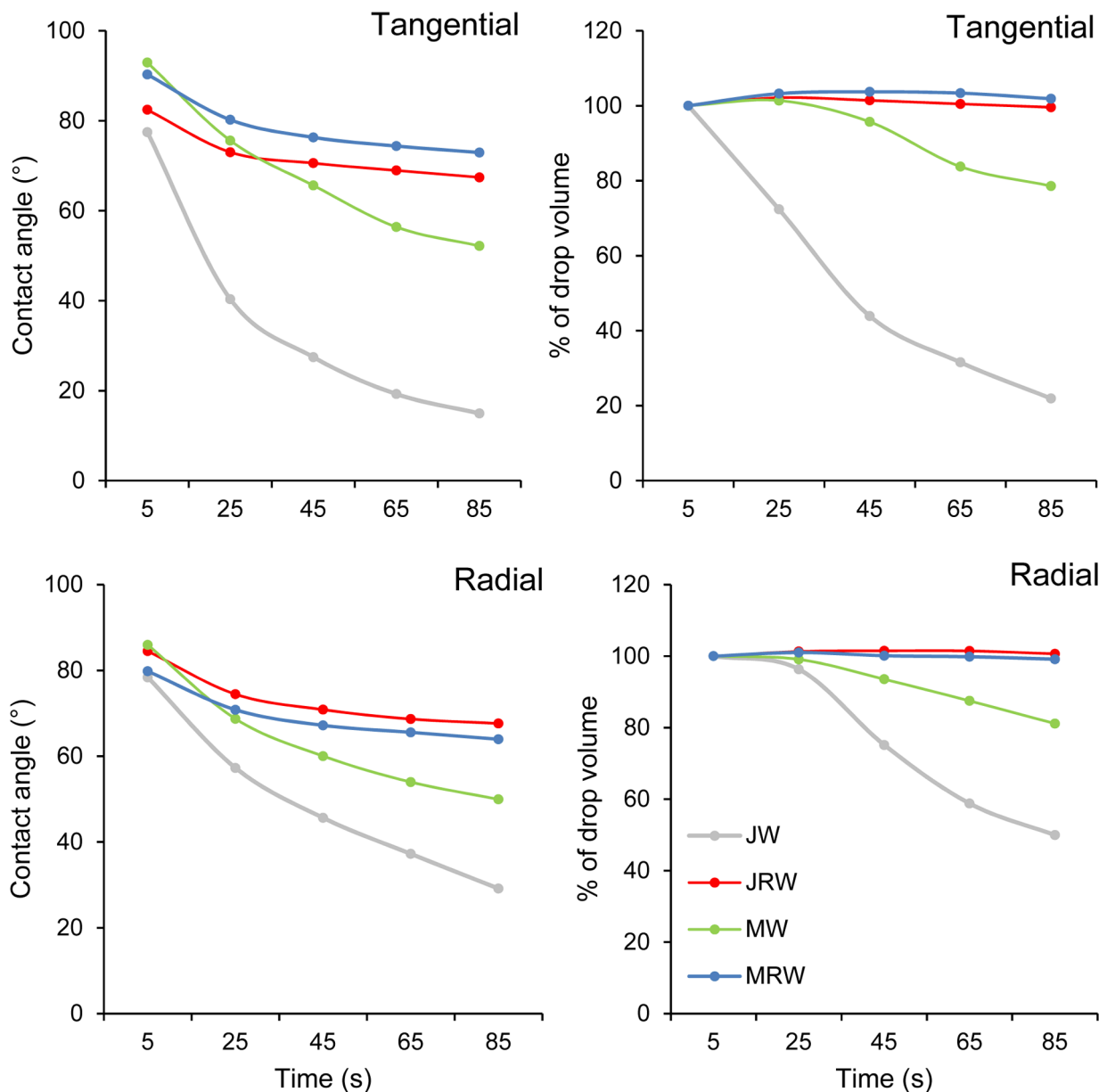


Figure 6. Wettability behavior of pine wood. JW = juvenile wood; JRW = juvenile resinous wood; MW = mature wood; MRW = mature resinous wood.

Figura 6. Comportamento da molhabilidade na madeira de pinus. JW = lenho juvenil; JRW = lenho juvenil resinado; MW = lenho adulto; MRW = lenho adulto resinado.

resistance due to their hydrophobic character. On the other hand, waterborne treatments – designated to high-risk applications – can present some difficulties due to the incrustations of oleoresin.

CONCLUSIONS

The properties related to water absorption and wettability all decreased with increase of the presence of oleoresin. On the other hand, the thermal stability of the samples decreased with the presence of oleoresin. Many technological techniques can be affected by presence of

oleoresin in wood, such as sawmilling, waterborne treatments, pulp, and others.

A considerable variation in wood properties and incrustations located on boards may make the material extremely heterogeneous, limiting its uses.

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