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# INFLUENCE OF CLONE HARVESTING AGE OF *Eucalyptus grandis* AND HYBRIDS OF *Eucalyptus grandis x Eucalyptus urophylla* IN THE WOOD CHEMICAL COMPOSITION AND IN KRAFT PULPABILITY

## INFLUÊNCIA DA IDADE DE CORTE DE CLONES DE *Eucalyptus grandis* E HÍBRIDOS DE *Eucalyptus grandis x Eucalyptus urophylla* NA COMPOSIÇÃO QUÍMICA DA MADEIRA E POLPAÇÃO KRAFT

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### ABSTRACT

The recent efforts on the quality of the wood used in pulp and paper mills has focused in many points, among them the influence of the raw material chemical characteristics in the production process and final product quality. Considering the current demand for younger trees, the effect of the wood harvesting age in the chemical composition and in the process variables becomes a very important fact for the industries of this sector. So, the objective of this study was to characterize Brazilian eucalypt clones, *Eucalyptus grandis* and *Eucalyptus urograndis*, both in different harvesting ages (1 to 8 years-old), for their chemical composition and kraft pulping parameters. Both chemical compositions of wood samples showed significant statistical variations due to the alteration of their harvesting ages. The glucan content, as well as cellulose content, basic density, and extractives tended to rise with the increase of harvesting age; while xylan and the other carbohydrate contents that compose the hemicelluloses tended to decline with the increase of the harvesting age, as well as uronic acids, acetyl groups, lignin, ashes, and S:G ratio. The 5 year-old wood samples showed the greatest pulping yield results for kappa number 17, and the yield at kappa number 17 showed strong correlation with glucan content.
**Keywords:** wood quality; chemical pulping; eucalypt.

### RESUMO

Os recentes esforços na melhoria da qualidade da madeira para o abastecimento das fábricas de celulose e papel têm focado em muitos pontos, dentre estes, a influência das características químicas da matéria-prima no processo produtivo e na qualidade do produto final. Considerando a atual demanda por árvores mais jovens, o efeito da idade de corte da madeira na composição química e nas variáveis de processo, torna-se uma questão importante para as indústrias do setor. Em função disto, o objetivo do presente estudo foi caracterizar clones de eucalipto, *Eucalyptus grandis* e híbridos *Eucalyptus urograndis*, ambos em diferentes idades de corte (1 a 8 anos) quanto às suas composições químicas e parâmetros de polpação kraft. Ambas as composições químicas das madeiras mostraram variações estatísticas significativas devido

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às suas diferentes idades de corte. O teor de glicanas, assim como o teor de celulose, densidade básica e extrativos, aumentaram com o aumento da idade de corte das árvores, enquanto o teor de xilanas e demais carboidratos que compõem as hemicelulose, tenderam a diminuir com o aumento da idade de corte, assim como os ácidos urônicos, grupos acetila, lignina, cinzas e relação S:G da lignina da madeira. As amostras com 5 anos de idade mostraram o melhor rendimento na polpação kraft para número kappa 17, e este rendimento (número kappa 17) mostrou forte correlação com o teor de glicanas.
**Palavras-chave:** qualidade da madeira; polpação química; eucalipto.

## INTRODUCTION

Brazil is considered a world power in bleached eucalypt kraft pulp production. The determining factors for this success are the strong investment in research and development, wide availability of areas for the planting of forests, and favorable soil-climatic conditions for the cultivation of eucalypt plantations (COUTO; NICHOLAS; WRIGHT, 2011; STEFANO, 2008).

The conventional methods for assessing wood quality for pulp production include density and pulpability assessments (RAMIREZ et al., 2009). Density has been the most prominent assessment and considered the main parameter for it is a very complex trait, resulting from the combination of several factors, including the chemical composition and morphology of wood fibers (MATYAS; PESZLEN, 1997). This property is influenced by the conditions of tree growths, climate, soil, spacing, and harvesting age (CARVALHO, 1997). Recent studies, conducted with commercial eucalypt used in Asia mills (*Eucalyptus camaldulensis)*, showed good correlation between wood chemical composition/physical properties and harvesting age, as increasing basic density or decreasing pentosan content while increasing the harvesting age. However, the tree harvesting ages did not affect lignin, holocellulose, and ash contents in those studies (LUANGSAARD et al., 2010; PISUTTIPICHED et al., 2003).

More recently, as a criteria for superior clone selections, the fine wood chemistry has also been considered, especially regarded to its cellulose, hemicelluloses, extractives, and lignin contents, as well as lignin syringyl/guaiacyl ratio (S:G). These chemical parameters are usually related to the output quantitative aspects and the chemical consumptions during the pulping and bleaching processes (PEREIRA et al., 2009; WALLIS; WEARNE; WRIGHT, 1996).

The objective of this study was to characterize two Brazilian clones, *Eucalyptus grandis* and hybrids of *Eucalyptus grandis* and *Eucalyptus urophylla* at different harvesting ages (1, 3, 5, 6, 7, and 8 years old), for chemical composition and kraft pulping parameters.

## MATERIALS AND METHODS

### Materials

This study used two Brazilian wood clones, *Eucalyptus grandis* (clone A) and a hybrid of *Eucalyptus grandis* and *Eucalyptus urophylla*, called *Eucalyptus urograndis* (clone B). Both woods were selected purposefully in sites located in Ipatinga area (Minas Gerais state, Brazil), with similar characteristics, such as soil conditions (Oxisol - Typic Hapludox with loamy texture), relief (undulating hillside), precipitation index (95 $mm.year^{-1}$), and altitude (850 m).

### Methods

The material was received at the Pulp and Paper Laboratory (Federal University of Viçosa), in logs of approximately 50 cm cut from the diameter at 1.3 m height, and also 25, 50, 75, and 100% of the commercial height. Clones A and B harvest was performed at harvesting ages 1, 3, 5, 6, and 7 years-old, and 1, 3, 5, 7, and 8 years old, respectively. Five trees were used for each age. The logs were chipped and processed in the laboratory. Chips from a variety of eucalypt woods were prepared in a pilot scale chipper.

The wood chips for chemical analysis were sent to a Willey mill and processed in sawdust, where it was classified on 40 and 60 mesh screens. The sawdust obtained from each sample was stored in hermetically sealed containers and their moisture contents were determined. All chemical analysis was performed in duplicate.

For the graphical analysis, it was used the average results of five samples (five trees) of each harvesting age. The chemical analysis results of the group containing five trees of each harvesting age, for both studied clones, were submitted to a Tukey statistical test at 5% probability, and the divergent values were not used in the calculation of the averages for each harvesting age.

The kraft cooking was performed in a rotary digester, electrically heated and equipped with a thermometer and a manometer. The cooking time and temperature were monitored by electronic controller coupled at the computer. The alkali charge of liquors used in cooking was determined through a curve aiming to kappa number 17.0 ± 0.5 and sulfidity 30%. The cooking temperature was 170°C, the time to temperature was 90 minutes and the time at temperature was 50 minutes.

After the cooking, chips were discharged into the pulp washer with stainless steel screen of 150 mesh and washed thoroughly with water at room temperature. The individualization of the fibers was done in a "hidrapulper" laboratory of 25 liters of capacity, at a 0.6% consistency approximately. The pulp screening was performed in a Voith laboratory debugger equipped with plate with apertures of 0.2 mm. The pulp was washed with excess water and then dewatered in a centrifuge to 30% of consistency.

The analytical procedures used for the analysis of wood, pulp and liquor were: chip classifications - Scan 40:94 (SCANDINAVIAN PULP, PAPER AND BOARD TESTING COMMITTEE, 2004); density - Tappi T258 om-94 TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY, 2002); total extractive - Tappi T204 cm-97 (TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY, 2002); Acid insoluble lignin (GOLDSCHIMID, 1971); Acid soluble lignin (GOMIDE; DEMUNER, 1986); carbohydrate content (WALLIS; WEARNE; WRIGHT, 1996); uronic acids (SCOTT, 1979); acetyl groups (SOLÁR et al., 1987); lignin syringyl/guaiacyl ratio (LIN; DENCE, 1992); ash content - Tappi T211 om-93 (TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY, 2002); pulping yield (gravimetric method); kappa number - Tappi T236 om-99 (TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY, 2002); viscosity - Tappi T230 om-99 (TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY, 2002); hexenuronic acid content (VUORINEN et al., 1996); forming handsheet - Tappi T205 sp-95 (TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY, 2002).

Statistical analyses were performed using analysis of variance and F statistical test at 5% of probability. After that, it was used Tukey's statistical test to show the statistical difference among the averages. In the end, the MATLAB software was used in order to cluster the groups of trees with the same wood chemistry correspondences.

## RESULTS AND DISCUSSION

### Chemical composition of wood

#### *Carbohydrate*

Glucan, the major wood carbohydrate and the exclusive sugar component of cellulose, had its levels increased between 1 and 6 years old, with values between 40.4% and 46.8%, and a decline from the last harvesting age for the clone A (Figure 1.I). For clone B, the percentage of glucan was 39.2% and 47.3% at harvesting ages 1 and 7 years old, respectively. It was possible to fit quadratic regression equations correlating glucan content with clones A and B harvesting ages, with coefficients of determination ($R^2$) of 98.2% and 94.4%, respectively.

One possible explanation for the increasing of glucan content with harvesting age is that the trees are predominantly composed by cellulose. This component increases with a higher rate than the others. One of the cellulose polymer functions is structural, so in order to keep the trees growing they need to synthesize a large amount of glucans, to produce enough cellulose (KASMANI, et al., 2011). That result is in accordance to literature, where pinus wood cellulose content increased until 25 years old (BERROCAL et al., 2004).

Xylan content, the eucalypt trees main hemicellulose (MIRANDA; PEREIRA, 2002), was negatively correlated with the increasing in harvesting age for both clones (Figure 1.II), endorsing results showed in previously studies (PISUTTIPICHED et al., 2003). For clone A, the values obtained for harvesting ages 1 and 7 years old were 13.2% and 10.9%, respectively; while for clone B, the values obtained for harvesting ages 1 and 8 years old were 12.5% and 9.9%, respectively. The quadratic regression models,

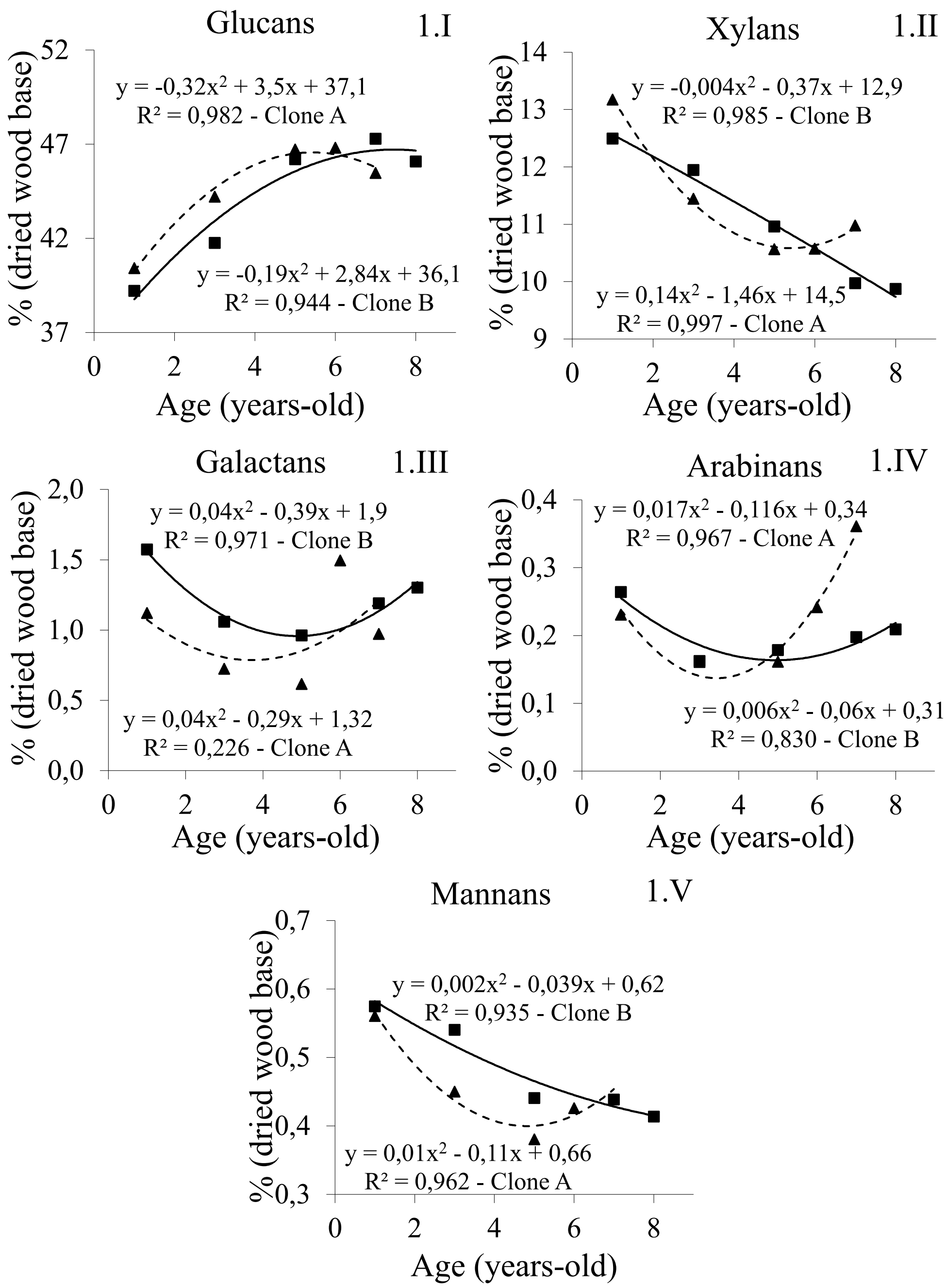


FIGURE 1: Effect of wood harvesting age on carbohydrate content (I - glucans, II – xylans, III – galactans, IV – arabinans e V – mannans). The dotted line represents clone A behavior, while solid line represents clone B behavior.

FIGURA 1: Efeito da idade de corte da madeira no teor de carboidratos (I – glicanas, II – xilanas, III – galactanas, IV - arabinanas, V – mananas). A linha pontilhada representa o comportamento do clone A enquanto a linha contínua o do clone B.

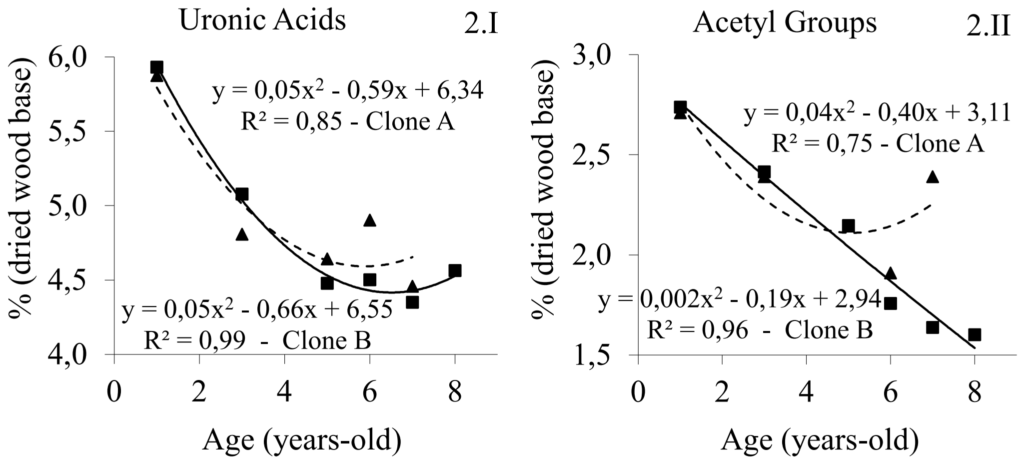


FIGURE 2: Effect of wood harvesting age on uronic acids (I) and acetyl groups (II) content. The dotted line represents clone A behavior, while solid line represents clone B behavior.

FIGURA 2: Efeito da idade de corte da madeira no teor de ácidos urônicos (I) e grupos acetila (II). A linha pontilhada representa o comportamento do clone A enquanto a linha contínua o do clone B.

correlating xylan contents and harvesting ages, had: $R^2$ = 99.6% and 98.4% for clones A and B, respectively.

Galactans, arabinans, and mannans are hemicelluloses sugars of less importance for eucalypt tress (MIRANDA; PEREIRA, 2002). These sugars also correlate with harvesting age (Figure 1.III, 1.IV and 1.V, respectively); however, the correlation was too low to galactans (clone A). Generally, there was a tendency to decrease galactans, arabinans, and mannans contents when increasing harvesting age up to 5 years old, with subsequent stabilization, as verified in some studies using different woods (BERROCAL et al., 2004).

The total uronic acids and acetyl group contents (Figure 2), both hemicelluloses components, also showed negative correlation with harvesting age, especially for clone B. These two components followed the same trend of xylan, which made sense as they are hemicellulose structural components. Uronic acid percentage (Figure 2.I) for clone A varied from 5.87 to 4.46%, from 1 to 7 years old, respectively. For clone B, it was highly correlated, and its content varied from 5.93 to 4.35%, from 1 to 7 years old, respectively. The Acetyl groups percentage (Figure 2.II) showed the same tendency, nevertheless the correlation levels were lower. Especially for clone A, the measure at harvesting age of 7 years old was very high, and entirely

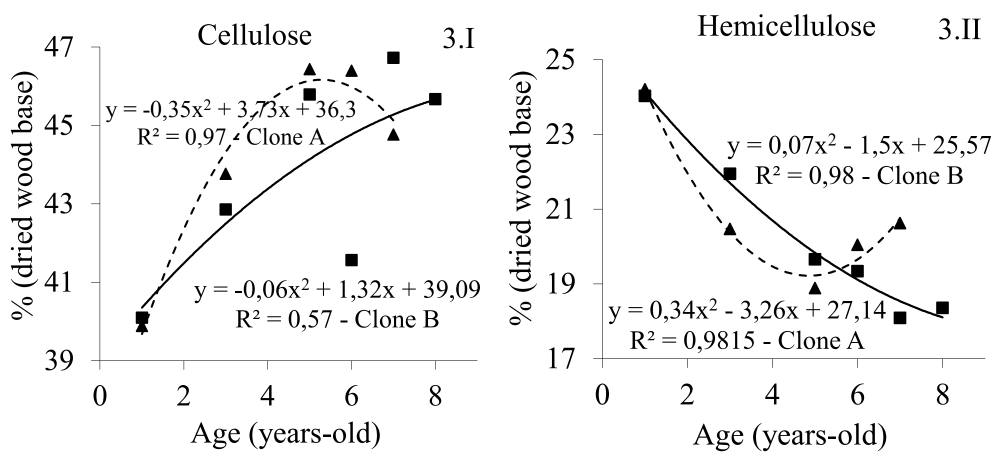


FIGURE 3: Effect of wood harvesting age on cellulose (I) and hemicellulose (II) content. The dotted line represents clone A behavior, while solid line represents clone B behavior.

FIGURA 3: Efeito da idade de corte da madeira no teor de celulose e hemicelulose. A linha pontilhada representa o comportamento do clone A enquanto a linha contínua o do clone B.

out of the trend. For clone B, the values varied from 2.74% for the harvesting age of 1 year to 1.58% for the harvesting age of 7 years-old.

To achieve the cellulose content of eucalypt pulp for each sample, one mannose equivalent was subtracted from the content of the glucans, as has been reported in previous literature (SIXTA, 2006), known that glucomannan hemicelluloses have a glucose:mannose ratio approximately of 1:1. The hemicelluloses content was obtained by summing xylans, galactans, arabinans, and mannans, plus the equivalent of mannans, as glucans, uronic acids, and acetyl groups.

The influence of the harvesting age on the cellulose content (Figure 3.I) showed the same tendency as observed for glucan contents, which was expected for cellulose is formed exclusively by glucans. The cellulose contents of clone A were 39.9 and 46.4% for harvesting ages 1 and 6 years old, respectively; and clone B had values of 40.1 and 46.7% for woods of 1 and 7 years old, respectively, as shown in the previously literature (BERROCAL et al., 2004).

It was observed a strong correlation between harvesting age and hemicellulose content (Figure 3.II). For clone A, the levels were 24% and 19% for woods at harvesting age of 1 and 5 years old, respectively; and for clone B, they were 24% and 18% for harvesting age of 1 and 7 years old, respectively.

***Lignin***

The lignin, which is the second largest wood constituent, had its total amount determined by the sum of two fractions: soluble and insoluble in acid. A good correlation between the lignin amount and samples harvesting age was found for the two clones studied. This correlation tended to decline with increasing harvesting age. As illustrated in Figure 4.I, the lignin content varied from 31.6% to 28.7% for clone A, and 31.6% to 28.8% for clone B. The fact that the lignin content decreased with the harvesting age was expected, because the youngest species tend to have a higher proportion of juvenile wood, which is richer in lignin than the mature wood (BERROCAL et al., 2004; TRUGILHO; LIMA; MENDES, 1996).

Another important feature observed was the lignin quality, i.e. the relationship between the amount of units derived from sinapilic alcohols (syringyl lignin) and coniferyl alcohols (guaiacyl lignin) called S:G ratio (Figure 4.II). This variable showed a good correlation with harvesting age for clone A, although trees with 6 years old have deviated from the trend, varying from 3.0 to 2.1. For clone B, the correlation between the S:G ratio and harvesting age was very weak and the values were higher (3.2) for trees with minimum 1 year old and 2.5 for trees 8 years old. For pulp and paper application, it is desirable material with high S:G ratio due syringyl lignin is more reactive than guaicyl lignin, so it is easier to be removed from de chemical

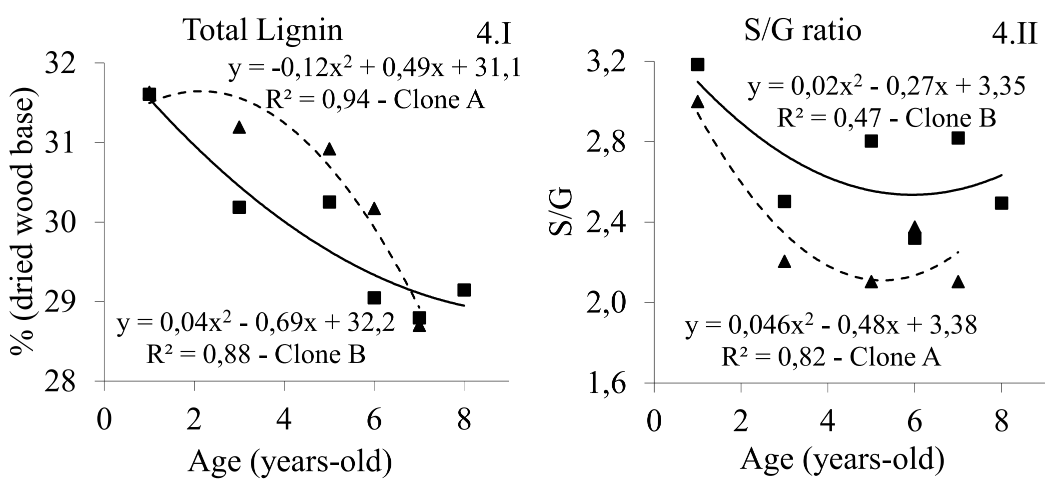


FIGURE 4: Effect of wood harvesting age on total lignin content (I) and S:G lignin ratio (II). The dotted line represents clone A behavior, while solid line represents clone B behavior.

FIGURA 4: Efeito da idade de corte da madeira no teor de lignina (I) e na relação S:G da lignina (II). A linha pontilhada representa o comportamento do clone A enquanto a linha contínua o do clone B.

process (GOMIDE et al., 2005; VENTORIM et al., 2014).

***Extractives and ashes***

Acetone and dichloromethane are considered very selective solvents and provide good extraction yield, without harming the environment, as opposed to other solvents previously used (ether, benzene, and toluene). Thus, the extractive content was obtained by subjecting the samples to extraction, using the solvents above mentioned, and the results were expressed by the sum of acetone and dichloromethane, as total extractives (BARROS, 2003).

The extractive content, in accordance with previous studies (LUANGSAARD et al., 2010; SIXTA, 2006), tended to decrease with the increasing of harvesting age up to 5 years-old, and an elevation of its content was observed after this age (Figure 5.I). For clone A, the percentages varied from 0.98% to 2.58%, for wood harvesting age of 1 and 7 years old, respectively. For clone B the variation was from 1.30 to 2.32% for wood harvesting age of 1 and 8 years old, respectively. This change in the declining trend is due to a process known as cernification, which is a deposition of extractives with consequent heartwood formation. Considering this study results, it became clear that the cernification process is intensified in harvesting age of 5 years old for those woods. For both clones, the correlation between harvesting age and extractives content was significant.

The ash content, which corresponds to the wood inorganic materials, was correlated with the age from both clones, as illustrated in Figure 5.II.

The ash content tended to decrease with the advance of harvesting age, showing values of 0.50% at 1 year old, and reaching a minimum at 8 years old with 0.12% (clone B). Younger trees require larger amounts of minerals, because they are in a growing phase where the metabolism is accelerated, thereby justifying the highest ash content. These results are in accordance with other studies (PISUTTIPICHED et al., 2003).

**Statistical analysis**

The wood chemical composition variance analysis showed significant statistical differences to samples tested by Test F. Table 1 shows the averages compared by Tukey's test at 5% of probability. Considering the significant difference observed for various parameters evaluated among different harvesting ages, it is concluded that the wood harvesting age is an important parameter to be considered in wood quality programs for pulp and paper production.

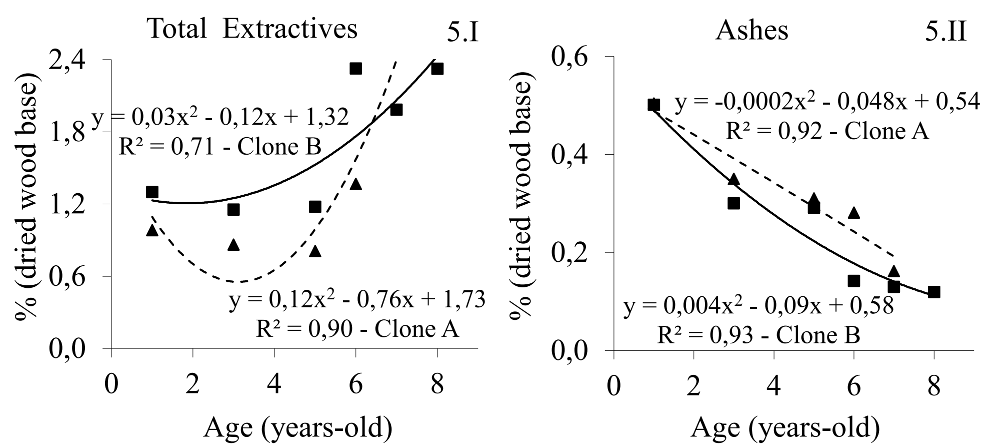


FIGURE 5: Effect of wood harvesting age on total extractives (I) and ashes (II) content. The dotted line represents clone A behavior, while solid line represents clone B behavior.

FIGURA 5: Efeito da idade de corte da madeira no teor total de extrativos (I) e cinzas (II). A linha pontilhada representa o comportamento do clone A enquanto a linha contínua o do clone B.

Using MATLAB program, it was performed a principal component analysis (PCA). Based on this statistical analysis, it was possible to clearly differentiate the wood that had given all the chemical components and the lignin S:G ratio. This distinction was recognized by simple visual analysis. However, this happened only for the results obtained for clone A. For clone B, due to the greater dispersion of the results, it was not possible to obtain the same samples separation by harvesting age. For clone A, using only two principal components, it could explain 77.1% (47.31+29.80) of the variation due to the wood harvesting age, while for clone B this value was 73.6% (54.79+18.80). The PCA graphs are shown in Figure 6.

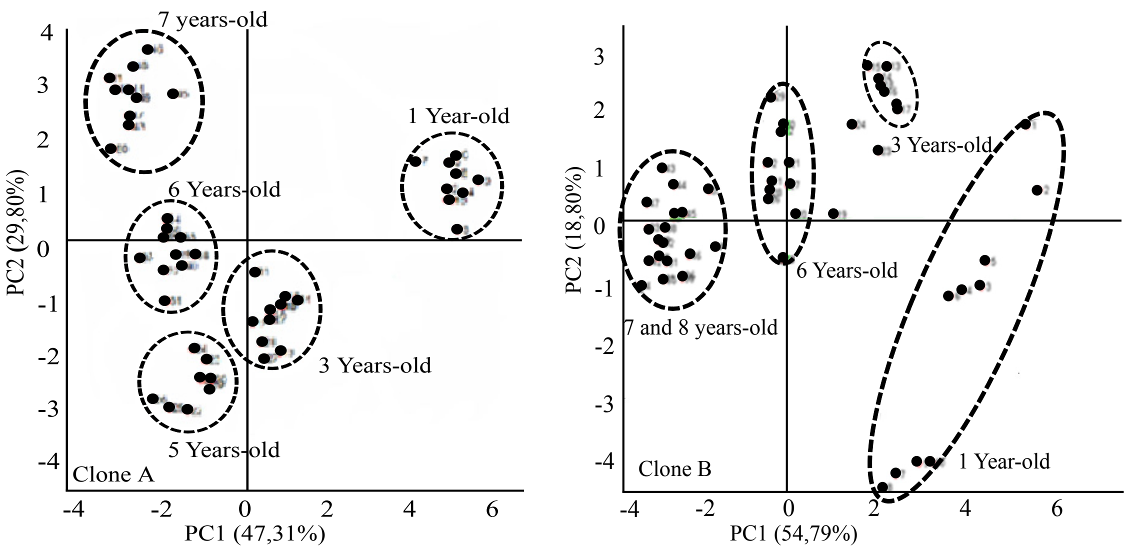


FIGURE 6: Principal component analysis of wood chemistry composition for clones A and B.
FIGURA 6: Análise do componente principal da constituição química da madeira para os clones A e B.

**Basic density**

The results shown in Figure 7 indicate a good and positive correlation between density and wood harvesting age; the results also show that the correlation was slightly weaker for clone A. This correlation is remarkable, because this parameter can be considered a key to the selection and evaluation of eucalypt clones. Based on basic densities between 460 and 480 kg.m$^{-3}$, as suitable for the manufacture of pulp and considering all the results, it appears that 6-year old (clone A) and 5-year old (clone B) clones could already be harvested for use in the process. However, the assessment based only on basic density is not enough, and the inclusion of additional wood quality parameters (wood chemistry), is necessary for a better conclusion. The same behavior was observed in previous studies (BERROCAL et al., 2004; PISUTTIPICHED et al., 2003).

**Kraft pulping**

Ideally, the performance of kraft pulping should be measured at a fixed value of kappa number. For eucalypt, a kappa number value of about 17.0 ± 0.5 has been considered adequate. For this study, a sample was selected from a 7-year old clone B (industrial situation), and the cooking was performed by varying the alkaline charge, in order to determine the dosage of active alkali (AA) required to obtain a kappa number 17.0 ± 0.5. This active alkali dosage was used for the cooking of all samples, except for clone A at harvesting ages of 1 and 7 years-old, which required higher active alkali dosages, i.e., 19.5% and 18.0% AA, respectively (Table 2).

The pulp yield at kappa number 17 (RD17) was calculated according to the equation below, which in the kappa number range of 14-21 provides a 0.5% decline in yield in every unit of kappa number

T ABLE 1: Statistical test of the wood chemical compounds content for available clones.
TABELA 1: Teste estatístico para composição química da madeira dos clones avaliados.

| Clone | Age (years) | Glucans (%) | Xylans (%) | Galactans (%) | Arabinan (%) | Mannans (%) | Uronic acids (%) | Acetyl (%) |
|---|---|---|---|---|---|---|---|---|
| A | 1 | 40.4 a | 13.2 a | 1.1 a | 0.23 a | 0.56 a | 5.87 a | 2.71 a |
| | 3 | 44.2 b | 11.4 b | 0.7 b | 0.16 b | 0.45 ab | 4.81 b | 2.39 b |
| | 5 | 46.7 c | 10.6 c | 0.6 c | 0.16 b | 0.38 b | 4.64 b | 2.14 c |
| | 6 | 46.8 c | 10.7 c | 1.5 d | 0.24 a | 0.43 b | 4.90 b | 1.91 d |
| | 7 | 45.5 d | 11.0 d | 1.0 e | 0.36 c | 0.70 c | 4.46 b | 2.39 b |
| B | 1 | 39.2 a | 12.5 a | 1.4 a | 0.26 a | 0.57 a | 5.93 a | 2.74 a |
| | 3 | 41.8 b | 11.9 b | 1.1 ab | 0.16 bc | 0.54 ab | 5.08 b | 2.41 b |
| | 5 | 46.2 c | 11.0 c | 1.0 b | 0.18 c | 0.44 bc | 4.48 c | 2.15 c |
| | 7 | 47.3 d | 10.0 d | 1.2 ab | 0.20 cd | 0.44 bc | 4.35 c | 1.64 d |
| | 8 | 46.1 c | 9.9 d | 1.3 ab | 0.21 d | 0.41 c | 4.56 bc | 1.60 d |

| Clone | Age (years) | Lignin (%) | Ashes (%) | Cellulose (%) | Hemicellulose (%) | Extractives (%) | S/G ratio |
|---|---|---|---|---|---|---|---|
| A | 1 | 31.6 a | 0.50 a | 39.9 a | 24.2 a | 0.98 a | 3.0 a |
| | 3 | 31.2 b | 0.35 b | 43.8 b | 20.5 b | 0.86 a | 2.2 bc |
| | 5 | 30.9 b | 0.31 bc | 46.4 c | 18.9 c | 0.81 a | 2.1 c |
| | 6 | 30.2 c | 0.28 c | 46.4 c | 20.1 b | 1.37 b | 2.4 b |
| | 7 | 28.7 d | 0.16 d | 44.8 b | 20.6 b | 2.58 c | 2.1 c |
| B | 1 | 31.6 a | 0.50 a | 38.5 a | 23.6 a | 1.30 a | 3.2 a |
| | 3 | 30.2 b | 0.30 b | 41.1 b | 22.0 b | 1.15 a | 2.5 b |
| | 5 | 30.3 b | 0.29 b | 45.8 c | 19.7 c | 1.18 a | 2.8 c |
| | 7 | 28.8 c | 0.14 c | 46.7 d | 18.1 d | 1.98 b | 2.8 c |
| | 8 | 29.1 d | 0.12 c | 45.7 c | 18.4 d | 2.32 b | 2.5 b |

Where in: Means followed by the same letter (in the same column), within each chemical component and clone do not differ by Tukey's test at 5 % of probability.

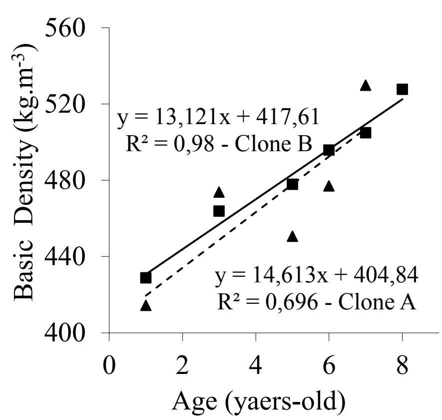


FIGURE 7: Effect of wood harvesting age on basic density wood. The dotted line represents clone A behavior, while solid line represents clone B behavior.
FIGURA 7: Efeito da idade da madeira na densidade básica. A linha pontilhada representa o comportamento do clone A enquanto a linha contínua o do clone B.

decreased in eucalypt kraft cooking of: RD = RD17 + 0.5 * (17 - measured kappa) (COLODETTE; GOMES; MAGATON, 2005). The calculated yield on the kappa number 17 (RD17) showed an increasing trend with the increase of harvesting age up to 5-year old, followed by a drop for the older harvesting ages (Table 2). There were no clear trends observed regarding the effect of harvesting age on Hexa's content, viscosity, and brightness of the pulps.

The RD17 correlated strongly and negatively with hemicellulose content (Figure 8.II), and also correlated strongly but positively with cellulose content for both clones (Figure 8.I). The correlations between RD17 and cellulose and hemicellulose contents were expected. Cellulose is a wood polysaccharide, and resistant to alkali, while the eucalypt wood main hemicellulose (the xylans) is essentially soluble in alkali (SIXTA, 2006). One of the reasons why the load rise decreases the alkaline cooking yield is exactly the dissolution of a higher xylan amount.

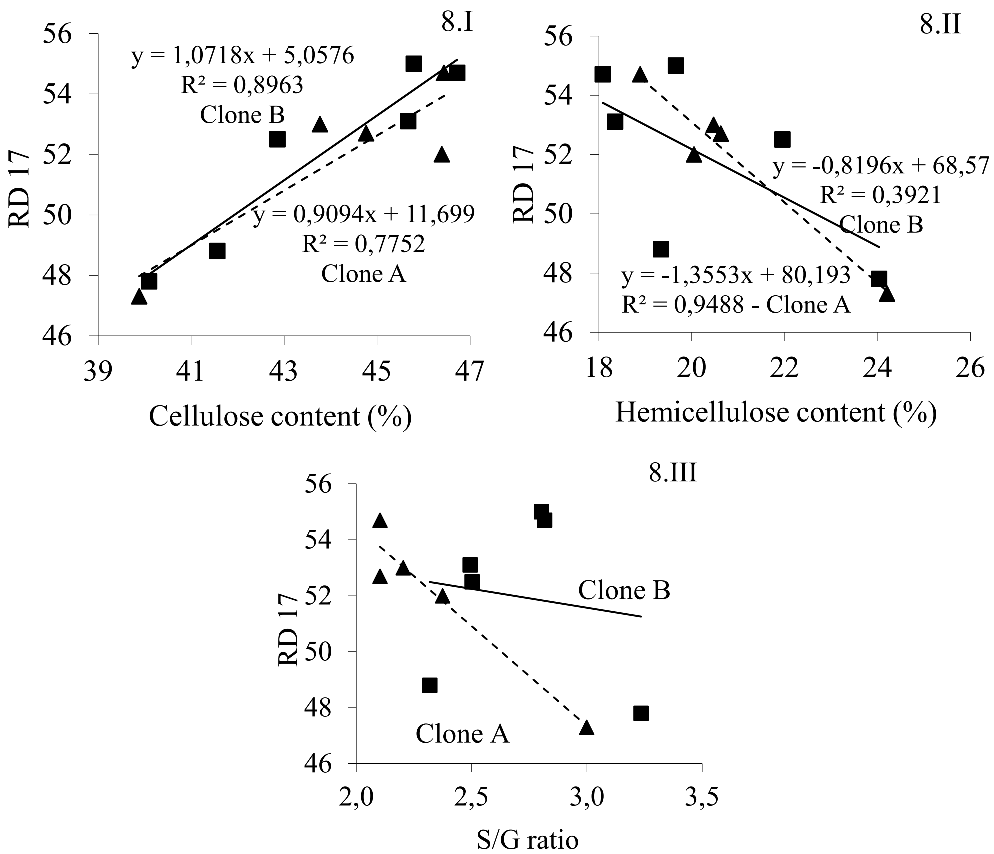


FIGURE 8: Correlation between yield in kappa number 17 and cellulose content (I), hemicellulose content (II), and lignin S:G ratio (III) for clones A and B. The dotted line represents clone A behavior, while solid line represents clone B behavior.

FIGURA 8: Correlação entre rendimento para número kappa 17 e teor de celulose (I), hemicelulose (II) e relação S:G da lignina (III). A linha pontilhada representa o comportamento do clone A enquanto a linha contínua o do clone B.

TABLE 2: Kraft pulping parameters.
TABELA 2: Parâmetros da polpação kraft.

| Clone | Age (years) | AA (%) | Kappa Number | Mensured Yeild | $RD_{17}$ | HexA's (mmol.kg$^{-1}$) | Viscosity (cP) | Brigthness (%ISO) |
|---|---|---|---|---|---|---|---|---|
| A | 1 | 19,5 | 17,2 | 47,4 | 47,3 | 63,0 | 41,4 | 37,8 |
| | 3 | 17,0 | 15,9 | 52,5 | 53,0 | 53,0 | 50,4 | 38,4 |
| | 5 | 17,0 | 15,4 | 53,9 | 54,7 | 54,1 | 47,2 | 41,3 |
| | 6 | 17,0 | 18,6 | 52,6 | 51,2 | 51,5 | 43,0 | 35,7 |
| | 7 | 18,0 | 17,5 | 53,1 | 52,7 | 56,7 | 45,9 | 32,9 |
| B | 1 | 17,0 | 19,1 | 49,0 | 47,8 | 48,8 | 60,7 | 33,7 |
| | 3 | 17,0 | 15,7 | 51,9 | 52,5 | 50,9 | 55,4 | 36,8 |
| | 5 | 17,0 | 13,8 | 53,5 | 55,0 | 49,9 | 48,6 | 38,8 |
| | 7 | 17,0 | 16,2 | 54,5 | 54,7 | 51,3 | 51,7 | 35,4 |
| | 8 | 17,0 | 19,0 | 52,9 | 53,1 | 51,1 | 54,7 | 30,6 |

## CONCLUSIONS

The chemical composition of eucalypt wood for the available clones suffered significant statistical influence of wood harvesting age that had to be taken.

The glucan contents, and consequently the cellulose and extractive contents, tended to increase with the tree maturing ages for both clones.

The xylan contents, as well as other components of hemicelluloses, tended to decrease with advancing of the wood harvesting age.

A comprehensive analysis of carbohydrates and groups that compose the fibrous material of eucalypt wood can be more useful when handled as cellulose and hemicellulose only, as opposed to treated separately; as the final product obtained in the pulping and bleaching processes is composed basically of cellulose and hemicellulose. Accordingly, the excellent correlations among harvesting age and cellulose and hemicelluloses contents imply that these variables are reliable parameters for the knowledge of the raw material that arrives at the factory.

The pulp yield, calculated for kappa number 17, was correlated with the cellulose content of the evaluated wood, and the highest results for this parameter were reached by woods harvested at 5 years old (for both clones).

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