Technological Characterization of the New Generation of Brazilian *Eucalyptus* Clones for Kraft Pulp Production

José Lívio Gomide, Jorge Luiz Colodette, Rubens Chaves de Oliveira, Cláudio Mudado Silva

Abstract – Detailed wood chemical analyses were carried out to establish wood quality of the latest generation of *Eucalyptus* clones used for pulp production by the major Brazilian kraft pulp mills. Laboratory simulation of a modern continuous digester technique was used for pulping. Results demonstrated the high quality of *Eucalyptus* clones being planted in Brazil for kraft pulp production.

Key words: carbohydrates, clone, *Eucalyptus*, kraft pulp, lignin.

1. INTRODUCTION

The objective of this study was to analyze the technological quality of the latest generation of Eucalyptus clones used by the major Brazilian bleached kraft pulp mills. This objective included a more detailed wood quality characterization than usually carried out at Brazilian pulp mills. The major Brazilian eucalypts pulp producers were invited to participate in this study by providing wood samples of the eucalyptus clone they considered as one of their best. Ten major companies agreed to participate in this study and the clones they provided were identified as clones A to J, for confidentiality reasons.

2. EXPERIMENTAL

Sample Preparation

Three trees of the same clone with average plantation height and diameter at breast height (DHB) were obtained from each company. All clones were collected at harvest age (5 to 7 years old). The trees were cut into 50cm long bolts obtained at the base and at 25, 50, 75 and 100% of the commercial height of the tree (height up to six cm diameter). The fifteen bolts from each clone were mixed and chipped in a laboratory chipper having two classifying screens (40x40 and 5x5cm). Additional manual chip classification was carried out to eliminate pieces of bark and knots. The chips were well mixed in a spherical 260 liter mixer for at least 10 minutes. After classification and homogenization the chips were air dried for uniform moisture content and to avoid microorganism attack and finally were stored in air tight polyethylene bags.

Wood Chemical Analysis

A chip sample of each clone was milled in a Wiley mill, classified by 40 and 60 mesh screens and then conditioned at 25°C and 50% humidity. The analysis performed on the wood samples were: basic density (ABTCP M14-70), extractives in alcohol/toluene and dichloromethane (Tappi T204 cm-97), acid insoluble Klason lignin (5), acid soluble Klason lignin (3), carbohydrates (Tappi T249 cm-00, modified), uronic acids (2), hexenuronic acids (11), syringyl and guaiacyl lignin (7), and acetyl groups (9).

Fiber Analysis

Pulp fiber analyses were carried by mounting slides of fibers stained with astra blue. Fiber width and wall thickness were determined using an optical microscope at 40x magnification and fiber length using a 10x magnifying lens. Microscope images were digitalized and dimensions were measured using the program Image-Pro Plus version 3.2. Fiber coarseness and the number of fibers per gram were quantified using a Galai CIS-100 automatic analyzer.

Continuous Cooking Simulation

A Continuous Digester Simulation System (CDSS) belonging to the Pulp and Paper Laboratory of the Federal University of Viçosa was used (Figure 1) to simulate continuous cooking in the laboratory. The system consists of a six liter capacity batch digester, equipped with a recirculation pump, heat exchanger, and computer monitored electronic controller time and temperature. The digester is coupled to a set of electrically heated accumulator vessels that have individually connections to the digester. The system is heated and pressurized and permits use of different cooking liquors in the accumulator vessels as well as digester liquor displacement by the accumulator vessel liquors to simulate the different cooking zones in a continuous digester. The continuous cooking simulation included use of a chip impregnation vessel, low temperature cooking and divided alkali charges. The continuous cooking conditions used were: 800 grams oven dry chips; sulfidity = 25%; effective alkali (EA) charge established experimentally to reach kappa 18±0.5; vaporization zone of 20 min at 1.5 atm.; impregnation zone with 60% of total EA, liquor to wood (L/W) ratio of 5/1, for 60 min at 135°C; cooking zone: 40% of total EA, a L/W of 4/1, for 150 min at 155°C; washing zone with a decrease in temperature from 155° to 95°C over 30 min.

After completing the cook the chips were removed from the digester by vacuum suction and defibered in a 20 L capacity laboratory hydrapulper at 0.6% consistency. After each cook, pulp screened yield, kappa number, viscosity, residual alkali and hexenuronic acids content were determined.

3. RESULTS AND DISCUSION

Silvicultural Characteristics of Eucalyptus Clones

Brazil has presented an enviable evolution in *Eucalyptus* forest productivity over the past decades, reaching the highest annual average increment (AAI) levels in the world. The *Eucalyptus* clones analyzed in this study demonstrate the high productivity of the major Brazilian companies, with two clones reaching AAI equal to or greater than 50m^3/ha/year and 80% of the clones presenting increments above 40m^3/ha/year (Table 1). Only one clone (F) presented an AAI below 35 m^3/ha/year.

Fiber Dimensions

The clones analyzed presented average fiber lengths of 0.99mm, varying only from 0.95 to 1.07mm, as shown in Table 2. This small variability may be explained by the measurement technique that consisted in using an optical microscope to measure only whole fibers, excluding fiber pieces or very short fibers. Fibers also presented little variability in fiber width, with an average of 18.2µm for all clones. The fibers presented lumen diameter and wall thickness values typically observed in Brazilian *Eucalyptus* woods, but with higher coefficients of variation than found for fiber length, explained by the smaller values of these latter two dimensions.

An understanding of the anatomical characteristics of pulp fiber elements permits predicting paper properties. Paper quality is influenced by fiber morphological characteristics and by the quantity of fibers per unit of mass. An important fiber characteristic for high bulk writing paper and tissue is cell wall thickness, which is also correlated to pulp coarseness. In general, for a given tree species, pulps produced from fibers with thicker cell walls tend to produce pulps of greater coarseness and papers of higher apparent bulk. These characteristics can contribute favorably to tissue softness and to opacity of writing papers. Opacity can be improved using pulp with a higher number of fibers per gram, due to the higher number of optical surfaces that disperse light in the paper structure. Shorter fibers improve sheet formation while longer fibers favor tear strength. The dimensions variability presented in Table 2 demonstrate that the clones may possibly behave differently during the sheet forming process as well as present different paper properties.

Basic Density of *Eucalyptus* Wood Clones

Basic densities of *Eucalyptus* clones are presented in Table 3. Studies carried out with eucalypt clones (6) have demonstrated advantages of wood with lower basic density. These advantages are the lower alkaline charges necessary during pulping, resulting in higher yields and pulp viscosities, and also in lower solids load to the recovery cycle. The use of higher density wood requires stronger alkali charge to achieve greater diffusion of the cooking ions into the chips to obtain the kappa target, considering that in industrial operations attempts are made to control cooking time and temperature with minimal variability. Use of low density woods will however result in high specific wood consumption, which constitutes a significant disadvantage principally when the company possesses a limited raw material supply. On the other hand, studies carried out with different *Eucalyptus* species did not find well defined correlations between basic wood density and alkali charge or process yield (8). Wood density represents the sum of diverse wood characteristics and it is not always possible to establish perfect correlations between pulp production results and this wood characteristic. Currently, projects for expansion of mill production capacity and for greenfield mills in Brazil consider use of eucalypts wood with density close to or somewhat higher than 500 kg/m^3.

In this study, only 40% of the woods presented basic density above 500 kg/m^3 and densities of the remaining clones varied from 465 to 490 kg/m^3. These results indicate that Brazilian companies have prioritized basic densities near 500 kg/m^3 in clone selection, with a tendency for slightly lower densities.

Extractives and Lignin Content of *Eucalyptus* Wood Clones

The woods analyzed in this study presented considerable variability in extractives and lignin contents, as shown in Table 3. The alcohol/toluene soluble extractives varied from 1.76 to 4.13%. The clones with higher extractives contents will present lower pulp yields, with up to 4% yield losses due exclusively to extractives removal. Hydrophobic extractives soluble in dichloromethane (DCM) which are a potential source of pitch also presented considerable variation, from 0.06 to 0.50%. Although Brazilian companies have invested much time and effort in studying hydrophobic extractives, measures to minimize the action of pitch deposits have been merely palliative, consisting in using additives, such as talc, to combat their harmful effects. Selection of clones with low potential pitch forming extractives contents should be prioritized by Brazilian bleached eucalypt kraft pulp producers.

The *Eucalyptus* clones analyzed presented lignin contents that varied from 27.5 to 31.7%. These values demonstrate that, even though a hardwood, some eucalypt clones planted in Brazil have lignin contents above 30%, a level more characteristic of softwoods. The content of lignin with chemical structures that are more susceptible to degradation and solubilization, determined as soluble Klason lignin, varied from 3.1 to 5.1%. This type of lignin may be more easily removed during alkaline kraft cooking. Eucalypt wood lignins presented characteristically higher levels of syringyl structures than guaiacyl structures, as shown in Table 4. Syringyl lignin structures are more easily degraded by kraft cooking liquor since they have a less condensed structure because of the lack of a C5 carbon available for reaction during the polymerization phase of lignin biosynthesis. The syringyl to guaiacyl ratio (S/G) indicates that the frequency of syringyl structures is two to three times greater than that of guaiacyl structures in the eucalypt woods analyzed. Some *Eucalyptus* species, such as *E. globulus,* present higher syringyl contents with an S/G ratio of up to 4.7 (8), which would be a desirable characteristic for eucalypt clones used for kraft pulp production.

Carbohydrate Content of *Eucalyptus* Wood Clones

The composition of the carbohydrate fraction of the *Eucalyptus* clone woods is presented in Table 5. Glucans represented on average 46.6% of the wood weight, while xylans were the dominant hemicellulose fraction, representing 10.8 to 13.2% of the wood weight. The other carbohydrates, including galactans, mannans and arabinans, each constituted less than 1% of the wood weight. The arabinans were the smallest wood carbohydrate fraction, representing on average only 0.2% of the wood. Besides the basic monomeric xylose units, the side chain uronic acid and acetyl groups connected to basic chain were also quantified. The uronic acids, including glucuronic and galacturonic acids, represented a significant fraction of the wood, on average about 4% of the wood weight. The importance of these xylan groups is related to the alkali they consume during pulping with consequent hydrolysis and solubilization as well as their transformation to hexenuronic acids, which are undesirable in the bleaching operation. The content of acetyl groups on xylan chains was quite constant, varying only from 2.6 to 3.1%. The presence of acetyl groups in xylans is a technological disadvantage since and besides consuming alkali during kraft cooking they represent a yield loss since they are completely hydrolyzed and solubilized during the cook (4). The *Eucalyptus* clones presented a high frequency of acetyl groups on the xylan chains, on average more than six acetyl groups for every ten xylose units. A global analysis of the *Eucalyptus* woods showed (Table 6) that the hemicellulose content, including the side chain groups, represented from 18.6 to 23.2% of the wood weight with an average of 21%. The cellulose content of the woods also presented considerable variation, ranging from 43.9 to 49.7% of the wood weight.

Pulping Characteristics of *Eucalyptus* Wood Clones

The technological characteristics of the *Eucalyptus* clones were determined by simulating a modern pulp kraft production technology in the laboratory. The technology selected consisted in using an impregnation vessel, maximum cooking temperature significantly lower than the conventional techniques and divided alkali charges. These conditions afforded a more selective delignification, thus maximizing pulp quality. The results of pulp production using the ten clones are presented in Table 7.

The clones analyzed constituted a representative sample of the best *Eucalyptus* clones currently used in Brazil for pulp production and the results obtained demonstrate that a significant variation exists in wood quality. The pulps from all clones presented kappa numbers within the pre-established limits of 18±0.5, which permitted comparative analyses of pulping characteristics.

The alkali charge necessary to produce kappa 18 pulps varied extensively, from 13.7 to 19.0%. High alkali demands are undesirable since they result in higher yield losses, more intense degradation of carbohydrate chains, overload of the recovery boiler and increase in production costs.

Use of different alkali charges resulted in pulps with distinct properties and characteristics. One of the clones (B) presented a screened yield of 57.6%, an exceptionally high value for eucalypts typically used industrially in Brazil. This high yield may be explained by favorable wood characteristics that included low basic density, extractives lignin, uronic acids and acetyl group contents combined with high cellulose content and S/G ratios. It should be noted that clone B´s relatively low basic density (465 kg/m^3) would result in high wood specific consumption, even with the high pulp yield. On the other hand, clone H presented a 49.3% yield that would be considered low for forest improvement programs in Brazil. The lower yield of clone H can be explained by the unfavorable wood characteristics, except for basic (482 kg/m^3). In general, in Brazil a 50% yield is established as the lower limit for clone selection and of the ten clones analyzed only one had a yield lower than this limit. The average yield of the ten clones was about 53% and six of the ten clones presented yields above 52%, demonstrating the high quality of *Eucalyptus* clones used in Brazil.

As was found for yield, the pulps presented wide variation in viscosity, reaching almost 220%. Once again, clone B stood out with an exceptionally high viscosity of 129.6 cP. High viscosities can be indicators of good pulp quality, but do not necessarily guarantee high fiber, and consequently pulp, mechanical strength. The lowest viscosity value (59.1 cP) was still sufficiently high to guarantee unbleached eucalypt kraft pulp quality. The high average pulp viscosity (85.6 cP) demonstrated the high quality of the *Eucalyptus* clones used nationally for pulp production.

Modern ECF bleaching technologies have made hexenuronic acids (HexA´s) content of the unbleached hardwood kraft pulp an important parameter to measure. This stems from the reaction of these xylan side chain structures with bleaching chemicals such as chlorine dioxide and ozone. During kraft cooking, part of the uronic acids are transformed to HexA´s. Formation of HexA´s is influenced by wood chemical characteristics and, among other factors, by the alkali charge used in cooking. The HexA´s contents of the kraft pulps are presented in Table 7. The different alkali charges used together with the different uronic acid levels originally present in the wood resulted in significantly different HexA´s contents that varied more than 65%, with values ranging from 34.7 to 57.9 mmol/kg. Correlation analyses was carried out to verify the effect of alkali charge and uronic groups originally present in the pulp on formation of HexA´s (Figures 2 and 3). As seen in Figure 2, the alkali charge used in pulping effected HexA´s formation. Although the correlation was only 77%, it was clearly observed that an increase in alkali charge tended to result in higher formation of pulp HexA´s. On the other hand, the uronic acids groups in the wood presented no correlation with HexA´s formation. A correlation might be expected since HexA´s are formed from uronic acids but this was not observed, possibly because of the great variability in alkali charge used during pulping to achieve the kappa target.

4. CONCLUSIONS

The results obtained in this study demonstrate the high technological quality of *Eucalyptus* clones currently used in Brazil by the major bleached kraft pulp producers. This quality is demonstrated by the high average cooking yield

(52.9%) to kappa 18, with only one clone presenting a yield lower than 50% and one presenting an exceptionally high yield of 57.6%. In the 1980s and 1990s national genetic improvement programs were aimed at selecting clones that provided yields above 50%, an objective that was entirely met as shown in this study. Use of pulp yield as a global quality parameter is perfectly valid, since this technological characteristic is a consequence of various factors, encompassing anatomical and chemical wood characteristics as well as the alkali demand for pulp production.

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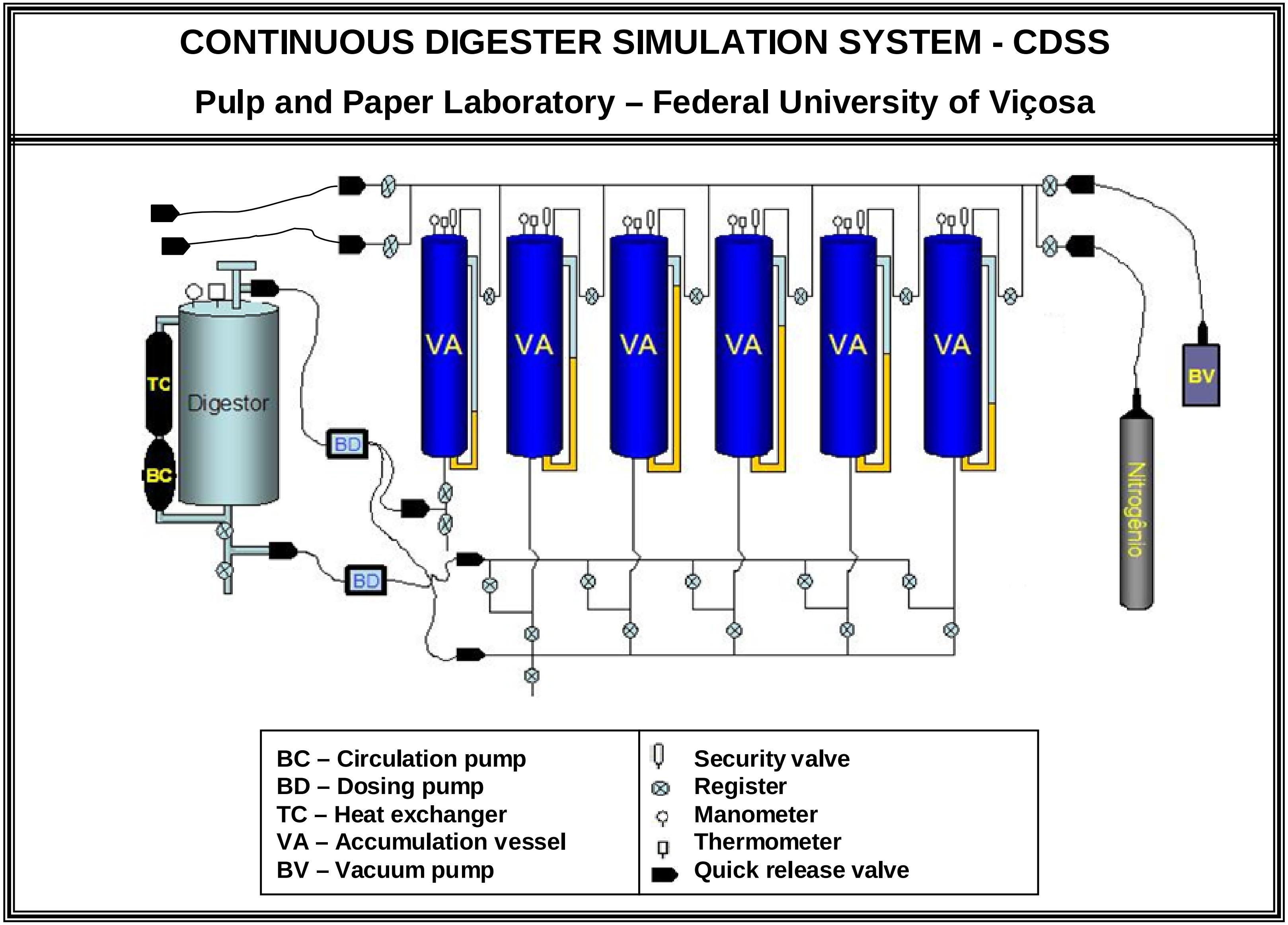

Figure 1 – Continuous Digester Simulation System (CDSS).

Table I – Silvicultural characteristics of *Eucalyptus* clones

Clones	Species	DBH, cm	Height, m	AAI, m^3/ha/year
A	*E.grandis x urophylla*	17.7	26.9	52.9
B	E. *grandis* (híbrido)	17.7	19.6	46.0
C	*E.grandis x urophylla*	20.5	27.8	47.0
D	*E.grandis x urophylla*	20.8	31.2	45.4
E	*E.grandis*	21.4	21.2	33.9
F	*E.grandis x urophylla*	17.0	23.0	40.0
G	*E.grandis x urophylla*	17.3	24.8	43.9
H	*E.grandis*	15.6	21.3	39.5
I	*E.grandis x urophylla*	18.1	29.0	46.1
J	*E.grandis x urophylla*	22.3	28.5	50.0

Table 2 – Dimensional characteristics of *Eucalyptu*s clone fibers

Clones	Length, mm		Width, µm		Lumen diameter, µm		Wall thickness, µm		N° fibers/ gram x 10^{-6}	Coarseness, (mg/100m)
	Average	CV,%	Average	CV,%	Average	CV,%	Average	CV,%	Average	Average
A	0.98	12.7	17.9	17.2	8.1	31.2	4.9	17.1	19.8	6.9
B	1.00	14.1	18.0	16.8	8.5	29.9	4.7	22.6	19.6	6.6
C	1.05	16.7	17.6	13.3	8.4	29.2	4.6	26.6	20.5	6.3
D	1.07	14.3	18.6	16.8	9.0	29.8	4.8	19.6	20.3	6.3
E	0.96	15.6	18.8	16.2	8.8	34.3	5.0	19.3	20.7	6.6
F	1.02	17.9	17.3	15.1	7.5	31.4	4.9	21.3	21.3	6.0
G	0.98	18.1	18.2	17.2	8.4	34.0	4.9	18.9	25.3	5.8
H	0.95	13.6	17.7	17.4	8.0	33.9	4.8	17.9	27.7	5.1
I	0.96	13.8	19.2	18.5	8.9	42.5	5.2	20.5	16.3	8.3
J	0.97	12.8	18.3	17.6	8.4	31.5	5.0	21.5	19.7	7.0

Table 3 – Basic density and chemical composition of *Eucalyptus* clones

Clone	Basic Density, kg/m^3	Solubility Alcohol/Toluene, %	Solubility Diclorومethane, %	Klason Lignin, %		
				Insoluble	Soluble	Total
A	510	4.13	0.18	27.0	3.5	30.5
B	465	1.76	0.10	22.4	5.1	27.5
C	482	2.88	0.14	27.1	3.5	30.6
D	472	1.99	0.06	24.9	3.3	28.2
E	486	3.37	0.20	26.4	3.7	30.1
F	505	2.12	0.40	24.2	3.3	27.5
G	503	3.54	0.50	24.8	4.4	29.2
H	482	3.30	0.38	28.6	3.1	31.7
I	490	3.52	0.40	24.2	3.6	27.8
J	501	3.45	0.13	26.0	3.9	29.9

Table 4 – Syringyl and guaiacyl content of *Eucalyptus* clones

Clones	Syringyl (mmol)	Guaiacyl (mmol)	Syringyl/Guaiacyl Ratio
A	1.82	0.83	2.2
B	2.04	0.81	2.5
C	1.70	0.74	2.3
D	1.88	0.88	2.1
E	1.91	0.77	2.5
F	1.88	0.85	2.2
G	2.19	1.01	2.2
H	1.98	1.00	2.0
I	1.83	0.66	2.8
J	2.26	0.97	2.4

Table 5 – Carbohydrate analysis of *Eucalyptus* clones

Clones	Glucans, %	Xylans, %	Galactans, %	Mannans, %	Arabinans, %	Uronic acids, %	Acetyl groups, %	Acetyl/ 10 xyloses
A	45.0	11.5	0.9	0.6	0.3	3.8	2.9	6.8
B	49.2	13.2	0.8	0.6	0.3	3.2	3.0	6.1
C	47.8	10.8	0.7	0.4	0.1	3.7	2.6	6.5
D	50.0	11.1	0.8	0.3	0.2	4.3	2.6	6.3
E	44.6	12.8	0.5	0.5	0.3	4.4	2.9	6.1
F	47.6	13.1	0.6	0.9	0.2	4.6	3.0	6.2
G	45.7	11.6	0.8	0.6	0.3	4.7	3.1	7.2
H	44.5	11.8	0.7	0.6	0.1	3.9	2.8	6.4
I	46.5	13.2	0.6	0.7	0.3	3.9	2.9	5.9
J	44.8	12.7	0.6	0.7	0.3	4.3	2.7	5.7

Table 6 – Cellulose and hemicellulose contents of *Eucalyptus* clones

Clones	Cellulose, %	Hemicelluloses, %	Holocellulose, %
A	44.4	20.5	64.9
B	48.6	21.6	70.2
C	47.4	18.6	66.0
D	49.7	19.6	69.3
E	44.1	21.9	66.0
F	46.7	23.2	69.9
G	45.0	21.8	66.8
H	43.9	20.6	64.5
I	45.8	22.4	68.2
J	44.1	22.0	66.1

Table 7 – Kraft pulping of *Eucalyptus* clones

Clone	Effective alkali, %	Kappa Number	Screened Yield, %	Viscosity, cP	HexA´s, mmol/kg
A	18.5	17.8	50.2	59.1	54.0
B	13.7	17.7	57.6	129.6	34.7
C	16.0	18.0	53.4	76.1	44.9
D	15.5	18.0	55.4	80.8	50.7
E	17.5	18.5	50.8	71.7	57.9
F	15.0	17.8	54.5	99.9	51.7
G	15.5	18.3	52.3	108.0	43.1
H	19.0	18.0	49.3	60.4	54.5
I	15.8	17.8	54.3	98.7	46.6
J	17.0	18.2	51.1	71.8	48.5

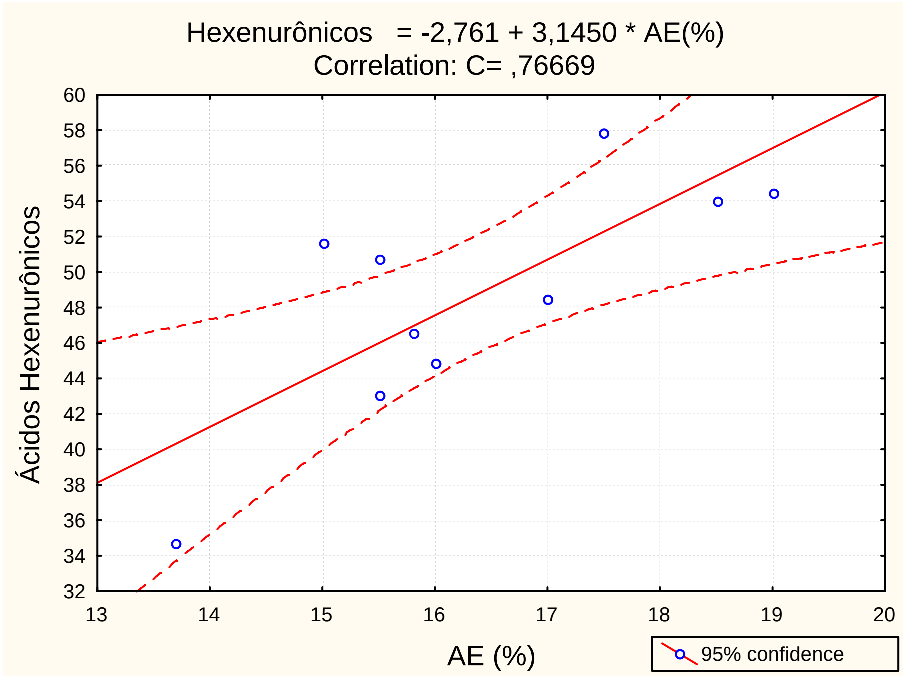

Figure 2- Correlation between hexenuronic acids and effective alkali.

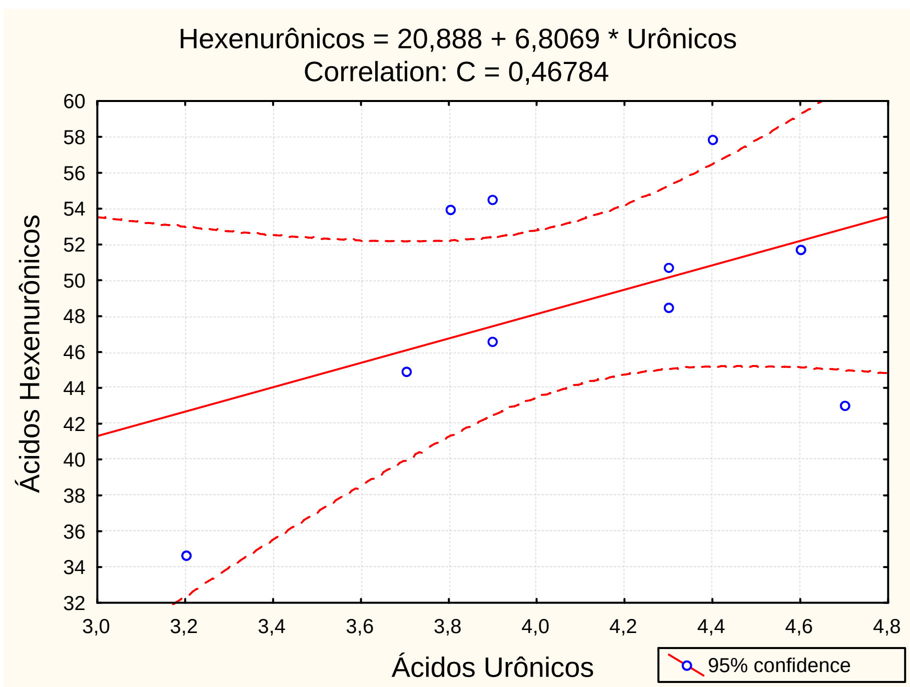

Figure 3 – Correlation between hexenuronic and uronic acids.

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Technological Characterization of the New Generation of Brazilian Eucalyptus Clones

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Tappi Pulping Conference – Philadelphia, August 28-31/2005.

Introduction

- Brazil has attained very high eucalypt forest growth
  Annual Average Increment (AAI): 40-60m^3/Ha/year

Introduction

This Paper Main Target ⇨ A survey

"Analyze Brazilian Eucalyptus Technological Characteristics for Kraft Pulp Manufacture"

Introduction

- Tem major Brazilian Pulp Mills were invited
- Each mill provided one of their best Eucalyptus clones
- Confidentiality reasons ⇨ Clones codified as A to J

Sample Preparation

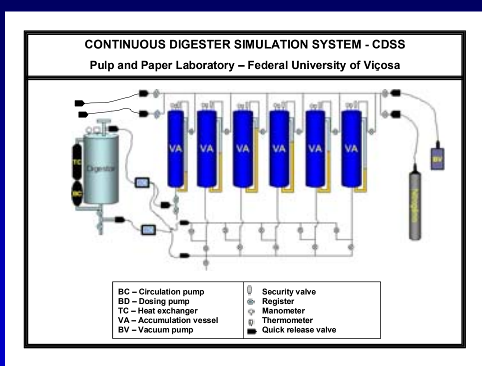
- Each clone: 3 trees (average height and DBH)
  - Five bolts each tree (0, 25, 50, 75, 100% height)
- Chips classification: 40x40 and 15x15mm screens
  - Pieces of bark and knots removed
- Mixture chips: spherical rotating 260 liters mixer
- Air drying (moisture uniformity, microorganism attack)
- Chips storage: polyethylene bags

Chips Analysis

- Wood Basic Density: ABTCP Standard
- Extractives: TAPPI Standards
- Klason Lignin (Gomide 1986, Goldschmid 1971)
- Carbohydrate Analysis (TAPPI Standard)
- Uronic Acids (Englyst & Cummings, 1984)
- Hexenuronic Acids (Vourinen, 1966)
- Syringyl & Guaiacyl (Lin, 1992)
- Acethyl Groups (Sola, 1987)
- Fiber Dimensions: Microscope and Image-Pro Plus digitalization
- Fiber coarseness and # fiber/gram: Galai CIS-100 analyzer

Laboratory Cooking Simulation

- Continuous Digester Simulation System (CDSS)
  - 7 liters digester
    - circulating pump
    - heat exchanger
    - time & temperature computer control
    - Accumulator tanks



Laboratory Cooking Simulation

- Pulping Conditions:
  - •Chips: 800 grams
  - •Sulfidity: 25%
  - •EA charge: established for kappa 18±0.5
  - •Vaporization: 20min, 1.5 atm
  - •Impregnation Zone: 60%EA, L/W 5/1, 60min, 135°C
  - •Cooking Zone: 40% EA, L/W 4/1, 150min, 155°C
  - •Washing Zone: 155 to 95°C in 30min

Results

Silvicultural Characteristics Eucalyptus Clones

Clones	DBH, cm	Height, m	AAI, m^3/ha/year
A	17.7	26.9	52.9
B	17.7	19.6	46.0
C	20.5	27.8	47.0
D	20.8	31.2	45.4
E	21.4	21.2	33.9
F	17.0	23.0	40.0
G	17.3	24.8	43.9
H	15.6	21.3	39.5
I	18.1	29.0	46.1
J	22.3	28.5	50.0
Variation	15.6-22.3	19.6-31.2	33.9-52.9

Brazilian Eucalyptus Forests

- High productivity of Eucalyptus Forest (AAI)
  - •Two companies: > 50m^3/Ha/year
  - •70% companies: > 40m^3/Ha/year
  - •Only one clone: < 35m^3/Ha/year

Fiber Dimensional Characteristics

Clones	Length, mm	Width, µm	Lumen, µm	Fiber Wall, µm	# Fiber/g 10^6	Coarseness mg/100m
A	0.98	17.9	8.1	4.9	19.8	6.9
B	1.00	18.0	8.5	4.7	19.6	6.6
C	1.05	17.6	8.4	4.6	20.5	6.3
D	1.07	18.6	9.0	4.8	20.3	6.3
E	0.96	18.8	8.8	5.0	20.7	6.6
F	1.02	17.3	7.5	4.9	21.3	6.0
G	0.98	18.2	8.4	4.9	25.3	5.8
H	0.95	17.7	8.0	4.8	27.7	5.1
I	0.96	19.2	8.9	5.2	16.3	8.3
J	0.97	18.3	8.4	5.0	19.7	7.0
Variation	0.95-1.07	17.3-19.2	7.5-9.0	4.6-5.2	16.3-27.7	5.1-8.3

Fiber Dimensions

- Average Fiber Dimensions Typical for *Eucalyptus*
  - •Length: 0.99mm
  - •Diameter: 18.2mm
  - •Lumen diameter: 8.4µm
  - •Wall thichness: 8.9 µm
  - •Number fibers/gram: 16.6-27.7 million
  - •Coarseness: 5.1-8.3 mg/100m
- Variability: clones for tissue or P&W grades

Basic Density – Chemical Composition

Clones	Density Kg/m^3	Alc/Tol %	DCM %	Lignin,% Insoluble	Lignin,% Soluble	Lignin,% Total
A	510	4.13	0.18	27.0	3.5	30.5
B	465	1.76	0.10	22.4	5.1	27.5
C	482	2.88	0.14	27.1	3.5	30.6
D	472	1.99	0.06	24.9	3.3	28.2
E	486	3.37	0.20	26.4	3.7	30.1
F	505	2.12	0.40	24.2	3.3	27.5
G	503	3.54	0.50	24.8	4.4	29.2
H	482	3.30	0.38	28.6	3.1	31.7
I	490	3.52	0.40	24.2	3.6	27.8
J	501	3.45	0.13	26.0	3.9	29.9
Variation	465-510	1.76-4.13	0.06-0.50	22.4-28.6	3.1-5.1	27.5-31.7

Wood Basic Density

Lower density ⇨ less alkali: higher yield

higher viscosity

Eucalyptus clones ⇨ 40% above 500 Kg/m^3

60% 465-490 Kg/m^3

Prioritize density close 500 Kg/m^3

Brazil (mill expansion, greenfield) ⇨ ≥ 500 Kg/m^3

Extractives

- Considerable variability:

  Alc/Toluene ⇒ 1.76 – 4.143%

  DCM (pitch) ⟹ 0.06 - 0.50%

Lignin

Brazilian Eucalyptus ⇒ higher lignin than Northern HW

Lignin: 27.5 - 31.7%

Syringyl / Guaiacyl = 2-3

Syringyl and Guiacyl Content

Clones	Syringyl, mmol	Guaiacyl, mmol	S/G
A	1.18	0.83	2.2
B	2.04	0.81	2.5
C	1.17	0.74	2.3
D	1.88	0.88	2.1
E	1.91	0.77	2.5
F	1.88	0.85	2.2
G	2.19	1.01	2.2
H	1.98	1.00	2.0
I	1.83	0.66	2.8
J	2.26	0.97	2.4
Variation	1.17-2.26	0.66-1.01	2.0-2.8

Carbohydrate Composition

Clones	Glucans %	Xylans %	Galactans %	Mannans %	Arabinans %
A	45.0	11.5	0.9	0.6	0.3
B	49.2	13.2	0.8	0.6	0.3
C	47.8	10.8	0.7	0.4	0.1
D	50.0	11.1	0.8	0.3	0.2
E	44.6	12.8	0.5	0.5	0.3
F	47.6	13.1	0.6	0.9	0.2
G	45.7	11.6	0.8	0.6	0.3
H	44.5	11.8	0.7	0.6	0.1
I	46.5	13.2	0.6	0.7	0.3
J	44.8	12.7	0.6	0.7	0.3
variation	44.5-50.0	10.8-13.2	0.5-0.9	0.3-0.7	0.1-0.3

Carbohydrates

- Glucans: 44.5 – 50.0%
- Xylans: 16.6 - 21.0%
- Galactanns, Mannans, Arabinans: 0.1 – 0.9%
- Hemicelluloses: 17.5 – 22.9%

Uronic & Acetyl Groups

Clones	Uronic Acids,%	Acetyl Group,%	Acetyl / 10Xiloses
A	3.8	2.9	6.8
B	3.2	3.0	6.1
C	3.7	2.6	6.5
D	4.3	2.6	6.3
E	4.4	2.9	6.1
F	4.6	3.0	6.2
G	4.7	3.1	7.2
H	3.9	2.8	6.4
I	3.9	2.9	5.9
J	4.3	2.7	5.7
Variation	3.2-4.7	2.6-3.1	5.7-7.2

Kraft Pulping of Eucalyptus Clones*

Clones	EA, %	Screened Yield, %	Viscosity, cP	HexA's mmol/Kg
A	18.5	50.2	59.1	54.0
B	13.7	57.6	129.6	34.7
C	16.0	53.4	76.1	44.9
D	15.5	55.4	80.8	50.7
E	17.5	50.8	71.7	57.9
F	15.0	54.5	99.9	51.7
G	15.5	52.3	108.0	43.1
H	19.0	49.3	60.4	54.5
I	15.8	54.3	98.7	46.6
J	17.0	51.1	71.8	48.5
Variation	13.7-19.0	49.3-57.6	59.1-129.6	34.7-57.9

*Kappa: 17.7-18.5

Pulping Characteristics

- •Alkali demand: 13.7–19.0%
- •One clone exceptionally high yield: 57.6%
  - low: Db, extractives, lignin, uronic acids, acetyl
  - high: cellulose, high S/G
- •90% clones more than 50% yield
- •Average yield: 53%
- •60% clones above 52% yield

Tank you very much

for your attention !!