THE INFLUENCE OF THE VARIABILITY OF LIGNIN CHARACTERISTICS OF EUCALYPT SPECIES ON THE DELIGNIFICATION RATE OF WOOD PULPING PROCESS.

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Abstract

The variability of the lignin in eucalypt species from commercial and experimental forests was evaluated. The objective was to contribute to the optimization of delignification and pulp bleaching processes.

The evaluation considered the wood quality and cooking process data of approximately seven hundred (700) eucalypt trees of *Eucalyptus grandis*, *Eucalyptus urophylla* and *Eucalyptus pellita*, as well as data from natural and controlled pollination hybrids of these species. As part of this work, syringyl / guaiacyl ratio and its impact in the kraft process were also evaluated.

The results indicated that knowledge of lignin content and lignin characteristics of eucalypt species constitutes a powerful tool for use in yield optimization of the kraft cooking process (increased from 51,5 to 58 %) and in the improvement of TCF pulp bleaching (20 % reduction in hydrogen peroxide consumption). In addition, the content and characteristics of wood lignin showed good heritability, which is highly desirable when applied to genetic tree improvement.

Key Words: lignin, variability, eucalyptus, delignification, pulping, Aracruz Celulose

Introduction:

Variability is one of the most important factors of success in tree improvement strategies. Beyond its power to help in the selection of the best genetic material for propagation, it also helps to maintain the biodiversity, which is necessary to protect environmental health (1). That is one of the reasons Aracruz Celulose S. A., a pulp company located in mideastern Brazil, has invested many years in research and management of its eucalyptus forests, located in the states of Espírito Santo and southern Bahia, about 3000 km from the Amazon rain forest.

The total 203,000 hectares of Aracruz lands, include 132,000 hectares of eucalypt plantations, of which 83,000 are in Espírito Santo State and 49,000 in Bahia State. These areas correspond to 1.8 % and 0.08% of the territories of these states, respectively. Of the remaining area, 56,000 hectares are occupied by natural reserves, maintained as permanent preservation areas. These 56,000 hectares correspond to 27% of the total area of the Company. Therefore each 2.4 hectares planted with eucalypt, Aracruz preserves 1 hectare of natural reserves, including sandbanks, brushwood, swamps and regeneration areas. The remaining 15,000 hectares are occupied by infra-structure (roads, residential area, mill, port etc.)

To enrich the natural reserves, Aracruz maintains a production program for native species. In the last three years, more than 1.8 million seedlings of 250 different native species from Atlantic Forest and associated ecosystems have been planted.

The mosaic form of its plantations is one of the company's visiting cards. A large number of eucalypt species, from different origins, mostly clones selected based on forest, process and product quality criteria are planted, in very close contact with natural reserves. Forest heterogeneity is thus increased by interspersing the eucalypt plantations with preservation areas containing different types of native vegetation. This design permits visits of birds, insects and small animals to the eucalypt plantations, resulting in advantages such as biological control by biodiversity, thus reducing the need for human intervention to a reasonable minimum.

Of the 53 species planted by Aracruz *E. grandis* and *E. urophylla,* originally from Australia and Indonesia, dominate. The most important tree selection parameters in use are silvicultural performance, forest productivity, kraft process yield, wood density and pulp quality. The selection process has led to the development of one principal species, known world-wide as UROGRANDIS, which has adapted quite well to the different sites and environmental conditions of Aracruz's plantations. Despite this adaptation, the tree selection program continues to include an evaluation of other species, such as *E. pellita*, *E. tereticornis*, *E. resinifera* etc.

Throughout the 27 years of existence of Aracruz's plantations, tree improvement development has focused on optimization, first of productivity, then of wood quality. The evaluation of other species and hybrids has led the company to analyse lignin content as a factor in productivity, since it is responsible not only for the sustainability of trees but also for the main production cost at pulp mills. Therefore, Aracruz has invested some years of research in understanding the variability of lignin content and quality of its eucalypt plantations (2).

Another extremely important parameter for plantation improvement strategies is heritability, since it indicates the degree of confiability to select for superior genotypes. The importance of heritabilily has been very well described by ZOBEL (3) but not much related to eucalypt species. A few works describe the estimation of heritability to wood density and fiber length, but other important characteristics have not been well described (4).

The purpose of this work was to correlate lignin content and chemical characteristics with the kraft pulping process, and, in combination with heritability data, use this information to guide new improvement strategies.

<u>Material and Methods:</u>

The following genetic material were considered in this experiment:

- 152 trees, hybrids of *E. grandis* x *E. urophylla*
- 28 trees of *E. grandis*
- 26 trees of *E. urophylla*
- 25 trees of *E. pellita*
- 365 trees of 15 UROGRANDIS clones, planted in 3 different and most representative sites
- at least 1 tree of each hybrid (obtained by controlled pollination): *E. grandis x E. pellita, E. grandis x E. saligna, E. grandis x E. torelliana, E. grandis x E. citriodora* and *E. grandis x E. alba*
- 301 trees of miscellaneous clones and species

Whole trees were cut and chipped in an industrial chipper. Klason lignin was determined according to Tappi T222 os-74 method (5). Chips were cooked to a constant kappa 20, in MK digesters equipped with recirculation and liquor heating systems. Alkali charge was varied in each sample. TCF bleaching was performed in a Mark III mixer, in the following sequence: O - Q - EPO - Q - P. Methoxyl content was obtained by FTIR, according to FAIX (6). Guaiacyl / Syringyl ratio was calculated as described by PEREIRA et alii (2). Heritability was estimated according to BERTOLUCCI, DEMUNER & LATORRACA (7).

Results and Discussion:

A - Variability of Lignin:

Tables 1 refer to the variation of lignin in pure *E. grandis,* pure *E. urophylla*, natural hybrids of *E. grandis* and *E. urophylla,* hybrids obtained by controlled pollination, *E. pellita* and a miscellanea of other trees, representative of Aracruz eucalypt plantations.

The results reveal the existence of a **high variability** in the amount of lignin in more than 700 trees. From a pulp production point of view, the main practical result of this broad lignin variability is its impact on chemical consumption during cooking, as can be seen by the broad variability in alkali charge, to reach kappa number 20, as well as in digester yield.

From a tree improvement point of view, the wide variation of lignin and pulping parameters indicates a good possibility for gains in the tree selection process, since the genetic gains are a function of the heritable variability among the genotypes under evaluation.

The results for *E. pellita* reveal a quite different from those obtained for the species mentioned previously. A **low** lignin variability can be observed, however alkali charge and yield **variation where high**. Such results suggest the presence of other factors affecting the cooking process. A high wood density with negative effect on chip impregnation and a high extractives content may explain these differences among species. **Inserir dados / estudos.**

B - Lignin impact on kraft cooking

Although the results of these tables cannot be considered solely as an effect of lignin (since there are other physical and chemical wood characteristics, such as chip impregnation facility, amount of extractives, etc.), they confirm the existence of a broad variation of lignin content in Aracruz's genetic material, as well as in alkali charge and digester yield.

A simulation of the Aracruz kraft process was performed considering, in a first run, the large variation in lignin amount. The simulation was done as follows: alkali charge was related to the amount of lignin and later the same was done for alkali charge and yield (Figure 1). From both graphs, specific points were defined for data acquisition: the average amount of lignin in Aracruz genetic material (29.5 %), an intermediate amount of lignin (27.0 %) and a minimum amount of lignin (25 %). These points were used to identify the corresponding values of alkali charge in Figure 1. The values obtained were used as inputs for a computer program which simulates Aracruz's process to calculate the corresponding values of cooking yield. The computer simulation generated values for the amount of solids to the recovery system, the wood consumption from the alkali charge values (including recovery, screenings, washing and bleaching processes, including losses, make-ups, balances, etc.) to obtain the results listed in Table 2.

Table 1: Variability of lignin in species representative of Aracruz Plantation

E. grandis

Parameters	n	Average	Minimum	Maximum	Coefficient of Variation, %
Lignin content [1], %	28	28.7	26.9	31.4	4.2
Alkali Charge, % as NaOH	28	14.8	13.0	17.5	6.5
Yield, %	28	50.5	47.9	54.3	3.2

E. urophylla

Parameters	n	Average	Minimum	Maximum	Coefficient of Variation, %
Lignin content, %	26	28.3	26.5	31.4	4.3
Alkali Charge, % as NaOH	26	12.7	11.7	14.5	4.9
Yield, %	26	54.6	51.0	57.6	3.1

UROGRANDIS

Parameters	n [2]	Average	Minimum	Maximum	Coefficient of Variation, %
Lignin content, %	365	29.4	25.6	34.7	4.7
Alkali Charge, % as NaOH	365	13.9	12.6	17.5	5.7
Yield, %	365	52.0	45.5	55.8	3.7

HYBRIDS [3] OBTAINED BY CONTROLLED POLLINATION

Parameters	n	Average	Minimum	Maximum	Coefficient of Variation, %
Lignin content, %	9	29.0	27.9	30.8	4.1
Alkali Charge, % as NaOH	9	14.7	13.5	16.5	6.3
Yield, %	9	49.6	47.4	51.9	2.2

MISCELLANEOUS [5]

Parameters	n	Average	Minimum	Maximum	Coefficient of Variation, %
Lignin content, %	301	29.5	25.4	35.2	5.0
Alkali Charge, % as NaOH	301	14.2	11.6	17.5	7.3
Yield, %	301	51.2	44.1	58.6	4.5

E. pellita

Parameters	n	Average	Minimum	Maximum	Coefficient of Variation, %
Lignin content, %	25	32.19	30.20	34.20	3.6
Alkali Charge, % as NaOH	25	16.09	14.7	17.20	4.5
Yield, %	25	46.94	44.1	52.50	3.5

Obs:
(1) Lignin content, corresponding to soluble + insoluble in sulfuric acid
(2) n: number of data, corresponding to 152 trees from 15 clones
(3) *E. grandis* x E. saligna, *E. grandis* x *E. torelliana*, *E. grandis* x *E. citriodora* , *E. grandis* x *E. alba* and *E. grandis* x *E. pellita*
(4) n: obtained from 5 different hybrids
(5) matrices, clones with different ages, sites, etc.

Figure 1. Behavior of Lignin Content versus Alkali Charge and Yield in Aracruz's Process

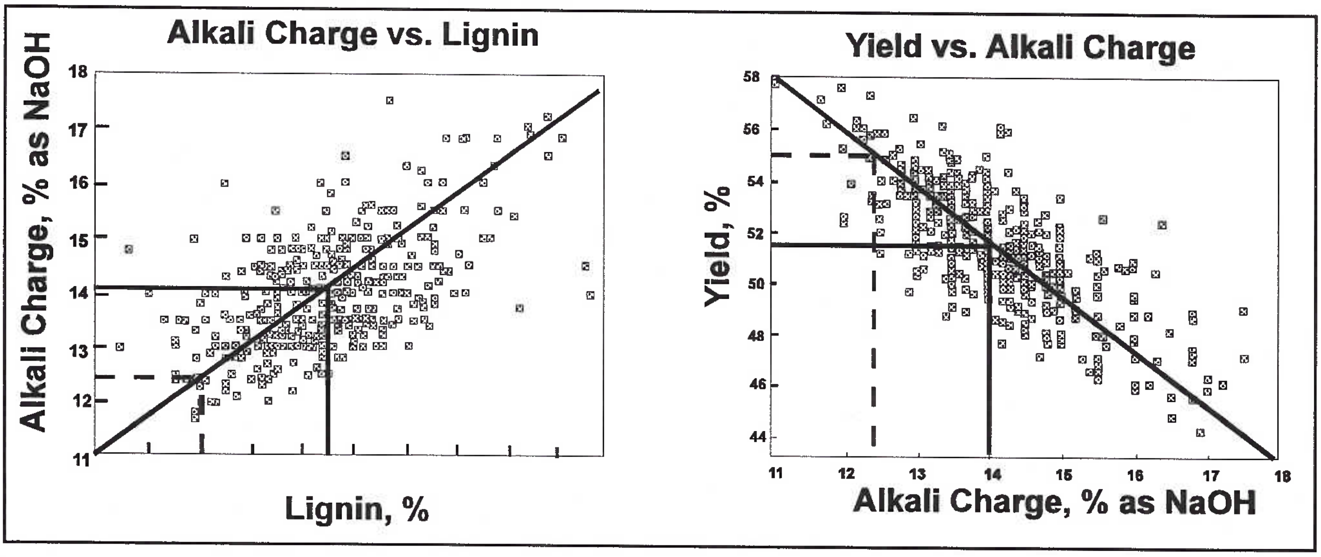


Table 2: ARACRUZ PROCESS SIMULATION X LIGNIN CONTENT

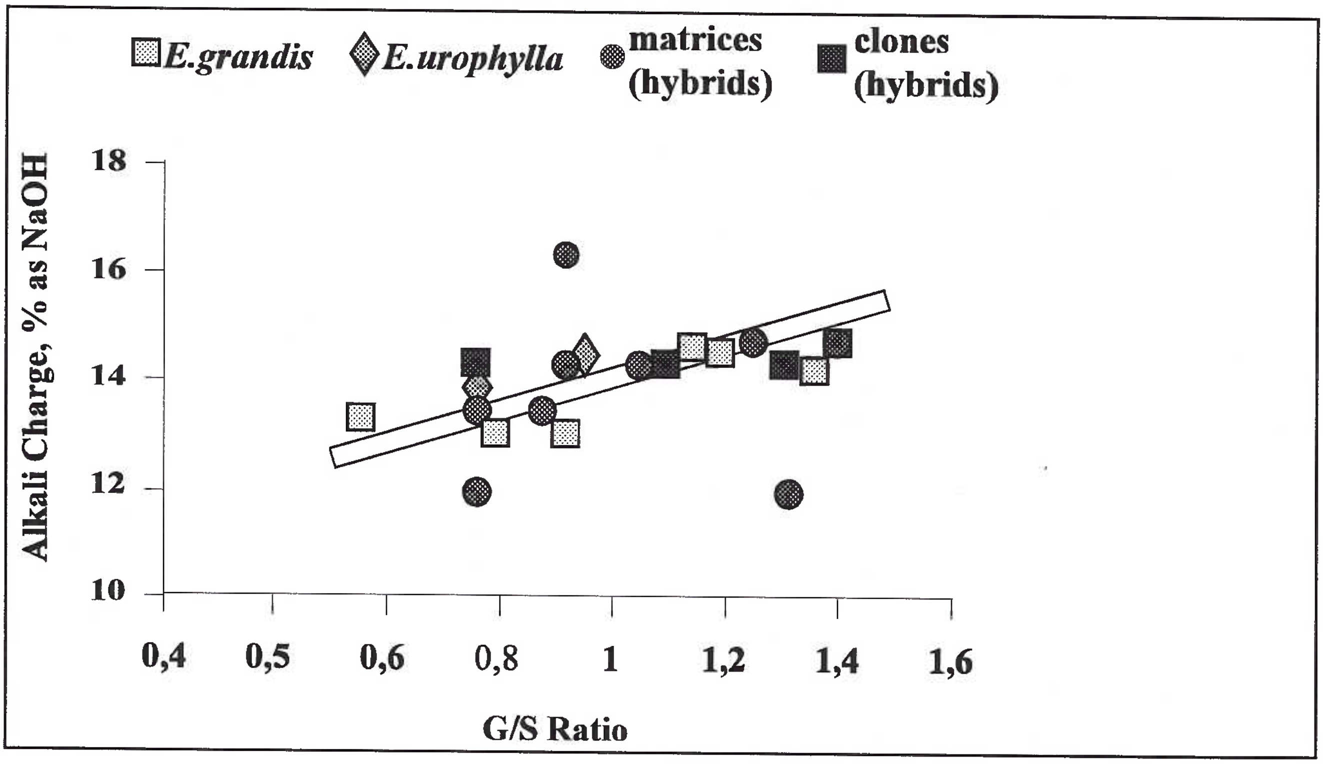
Parameters	29,5 % lignin	27 % lignin	25 % lignin
Alkali Charge, % as NaOH	14.0	12.5	11.0
Yield, %	51.5	55.0	58.0
Wood Consumption, m^3 under bark / admt *	3.74	3.50	3.32

Obs: * Average Wood Basic Density: 500 Kg/m^3 ; estimate for Kappa 20

As shown in Table 2, varying the amount of wood lignin results in impressive decreases in wood consumption and yield gains, which directly impact the environmental performance as well as production costs savings.

The guaiacyl / syringyl (G/S) ratio has been described as one of the most important parameters for determining the facility of lignin extraction (8, 9, 10, 11). The presence of syringyl lignin produces more soluble sub products in contact with kraft cooking liquor which leads to cost competitive pulp production and lower bleaching agent consumption. As seen in Figure 2 the lower the guaiacyl / syringyl ratio, the lower the alkali charge necessary to reach kappa 20 in pulping. This tendency is the same as was observed for lignin content (Figure 1).

Figure 2. Behavior of G / S Ratio versus Alkali Charge in Aracruz's Process



The amount and quality of lignin in relation to the performance of TCF bleaching was evaluated. The results, which can be observed in Table 3, reflect savings in hydrogen peroxide for wood with low lignin content. The same can be seen by examining the amount of syringyl, more H_2O_2 can be saved at lower G/S values.

Table 3: S/G RATIO AND PEROXIDE CONSUMPTION

S/G Ratio	Lignin, %	Alkali Charge, %	Yield, %	Wood Consumption, **	Solids, Kg/adt	H_2O_2 Kg/adt (@)
1.27	28.7	14.4	50.9	3.86	1578	65
0.91	28.8	12.9	53.8	3.67	1479	52

Obs.: * as NaOH; production: 2900 adt / day ; ** m^3 under bark / admt * ; @: TCF bleaching, 88% ISO

The importance of heritabilily could also be tested during this experiment. Above 80% one can consider that the heritability is high, confirming that the phenotypic variance can be fixed though selection, especially for characteristics related to wood and pulp. The estimated heritability of both parameters lignin amount and syringyl / guaiacyl ratio were 82.0 and 86.0 % respectively, in a broad sense method.

Conclusions:

The obtained values for alkali charge and yield, related to the lignin content and quality demonstrate the possibility of using these parameters as selection criteria in our tree improvement program. Aracruz has decided to invest in reducing lignin content and in increasing syringyl content in its lignin. The goals are to use genetic and biotechnological manipulation of lignin amount and quality to achieve lower production costs and, consequently, a better environmental performance.

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