Eucalyptus wood quality and its impact on kraft pulp production and use

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ABSTRACT: This paper summarizes the authors' research findings over the last five years on eucalyptus wood properties and their impact on process efficiency and pulp use, addressing the influence of species and harvesting age. Efficient production of kraft pulp is achieved with eucalyptus wood having reasonably high density, low extractives and lignin contents, high lignin S/G ratio, and high xylan and uronic acid contents. Woods containing large amounts of lignin tend to possess lignin with low S/G ratios and are hard to process. Age significantly affects the chemistry and morphology of wood and its behavior in kraft pulping and pulp use. Wood density, extractives content, and fiber coarseness increase with age. Eucalyptus hemicelluloses are composed mainly of a xylan unusually rich in uronic acids, which is reasonably stable in kraft pulping. The xylans retained in the kraft pulp substantially improve its refinability. The increase in wood age and density increases fiber coarseness, which negatively affects pulp refinability, but increases pulp drainability.

Application: This work identifies the most significant parameters affecting eucalyptus wood quality. Low-cost pulp producers should focus on woods of high specific gravity that are easy to cook (low effective alkali demand) and have high xylan and uronic acid contents. Although high-specific-gravity woods may penalize pulp refinability, they are very desirable for improving pulp drainability and decreasing specific wood consumption. Poor refinability can be mitigated by selecting woods of high xylan and uronic acid content.

Eucalyptus is becoming the most important fiber source for papermaking worldwide. It is predicted that by 2015, market pulp production will reach 70 million tons, with about 35 million coming from hardwoods and 50% of this coming from eucalyptus. Eucalyptus is the largest single global source of market pulp. The major interest in eucalyptus wood comes from its low production cost in certain regions, mainly because of high forest productivity and high pulping yield. However, more recently the outstanding quality of eucalyptus fibers has been recognized. The use of bleached eucalyptus fibers to manufacture paper grades previously made only with bleached softwoods is growing quickly. The ongoing scientific and technical advances achieved in production of eucalyptus fibers, from forest to product, and the increasing understanding of their applications in various paper grades have made these the preferred fibers worldwide. Unlike mixed-species pulps, single species offer specific benefits and well-defined properties. In this regard, eucalyptus pulp fibers produced from clonal plantations have emerged as the most desirable fibers in the market, not only for the production of tissue and printing and writing papers, but also for the manufacture of "new products."

Brazil is a large producer of bleached eucalyptus market pulp. In 2008, Brazil exported about 8 million tons of eucalyptus fibers, which represented more than 70% of all eucalyptus fibers commercialized globally. The total amount of eucalyptus fibers produced in Brazil, including those used in the domestic market, is more than 11 million tons per year.

Eucalyptus wood-fiber characteristics may vary substantially among the various species and clones as well as with age. By acting on these parameters and the pulping process, it is possible to prepare eucalyptus pulps that are of good quality and suitable for most paper-manufacturing applications.

This study discusses the main wood properties and their impact on specific wood consumption, kraft pulping yield, and pulp use for a variety of eucalyptus wood species. The work summarizes the findings of our research group as well as those of others over the last five years.

EXPERIMENTAL

This work presents a summary of our eucalyptus wood-quality investigative research program over the last five years. It includes many different projects and laboratory procedures that are described in the references cited for each data set presented. Only the methods that have not been presented previously are mentioned here.

Chips from a variety of Eucalyptus woods were prepared in a pilot-scale chipper. We used TAPPI procedures for wood preparation and evaluation (T 257 cm-85, T 264 cm-97, T 222 om-98, T 211 om-93, T 280 pm-99, T 258 om-94, T 249 cm-85, T 205 sp-95, T 220 sp-96, T 410 om-98, T 411 om-97, T 412 om-94, T 414 om-98, T 494 om-96, T 403 om-97, T 460 om-96, T 519 om-96) and for pulp and liquor analyses (T 625 cm-85), except for the following. Insoluble and soluble lignins were measured according to Gomide and Demuner [1] and Goldschmid [2], respectively. The lignin syringyl/guaiacyl ratio was determined by high-performance liquid chromatography

(HPLC) after oxidation of sawdust with nitrobenzene, as described by Lin and Dence [3]. Uronic acid groups were determined using a colorimetric method described by Scott [4]. Xylan contents of wood, pulp, and black liquor were measured by methanolysis-gas chromatography, 1H-NMR, and HPLC, according to procedures described elsewhere [5].

RESULTS AND DISCUSSION

Industrially, wood quality for kraft pulping is assessed by the following main characteristics: density; fiber morphology (coarseness, fiber distribution, and other fiber properties); and lignin, extractives, and xylan contents. More recently, wood uronic acids content and lignin syringyl/guaiacyl (S/G) ratio have been added to this list. It is worth noting that other wood characteristics such as microfibril angle, cellulose crystallinity, crystal structure, cellulose and xylan molecular-weight distribution, non-process elements (minerals), acetyl groups, and others are also important, but they have not been widely used for wood selection in most forest products and pulp and paper companies. In the sections that follow, the main wood characteristics are addressed in connection with eucalyptus kraft pulp production and use.

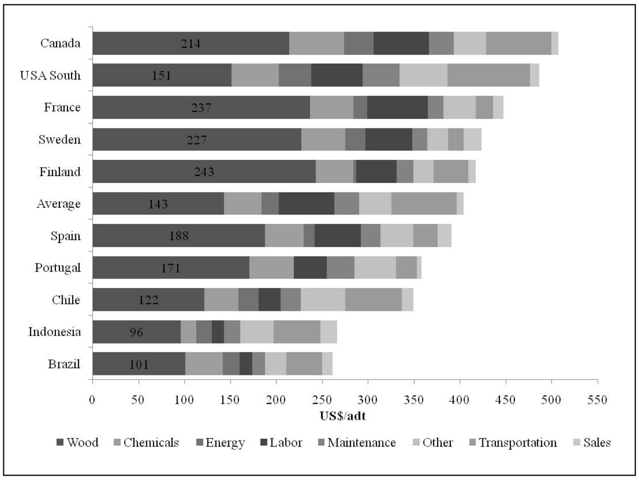
Kraft pulp production

Bleached kraft pulp is usually considered a commodity because the manufacturing process is well known and established. On the manufacturing side, the main focus has been on process efficiency improvements and cost reductions. However, there have been drives toward pulp product differentiation. The ideal wood quality characteristics for low-cost commodity pulp are well known, but they are not necessarily the same as those required for special products.

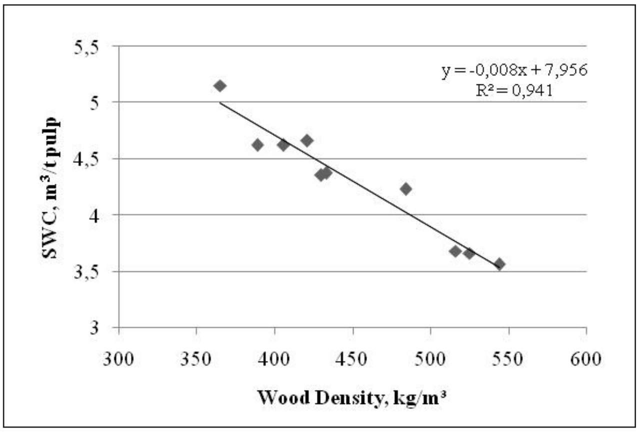
When the focus is on producing low-cost commodity pulp, pulping yield is often used to define wood quality because it combines the effects of various wood characteristics into a single parameter. Although it depends largely on wood, pulping yield cannot be considered a wood characteristic in itself because it is also influenced by pulping technology, kappa-number target, and other process-related issues. Certain wood characteristics, such as density, lignin, extractives, xylan and uronic acids contents, and lignin S/G ratio, significantly affect pulping yield and define so-called wood pulpability. These are thoroughly discussed in the following sections.

Wood density

Density is by far the most significant wood characteristic for kraft pulp use and production. On the use side, wood density affects pulp-fiber coarseness and distribution, which are very important parameters for defining the pulp end use. On the production side, wood density strongly affects process economics because it is the most important factor affecting the so-called specific wood consumption (SWC), i.e., the volume of wood required to make a ton of pulp. Wood is the most significant price component of the pulp manufacturing process [6]. Even for low-cost pulp producers, wood represents at least 40% of the total manufacturing costs (**Fig. 1**). Therefore, a low SWC is of paramount importance for low-cost production.



1. Composition of hardwood fiber production cost in 2006. Source: Wright [6].



2. Effect of wood density on SWC for ten different eucalyptus samples cooked to kappa 17–18. Source: Colodette et al. [7].

Figure 2 shows the significant impact of wood density on SWC for a variety of eucalyptus wood species. The SWC values were calculated from wood densities and pulping yields, with the lowest values obtained for the densest woods and the woods that delivered the highest pulping yields [7]. Unfortunately, there is no clear correlation between wood density and pulping yield (**Fig. 3**), which can be expected because pulping yield is influenced by many other wood characteristics besides density.

Pulping yield (dry weight basis) and wood density may vary from 48% to 56% and from 350 to 650 kg/m^3, respectively, for commercial eucalyptus forest stands. Therefore, it is much easier to decrease SWC by manipulating wood density than pulping yield. For example, a *Eucalyptus grandis* wood sample of 389 kg/m^3 density and 55.9% yield had an SWC of 4.62 m^3/odt, whereas a *Eucalyptus urophylla* sample of 544 kg/m^3 density and 51.7% yield had a much lower SWC (3.56 m^3/odt) (**Table I**). Disregarding possible pulp quality

Characteristic	*E. grandis*	*E. urophylla*
Wood density, kg/m³	389	544
Pulping yield, % on wood	55.9	51.7
SWC, m³/odt pulp*	4.60	3.56

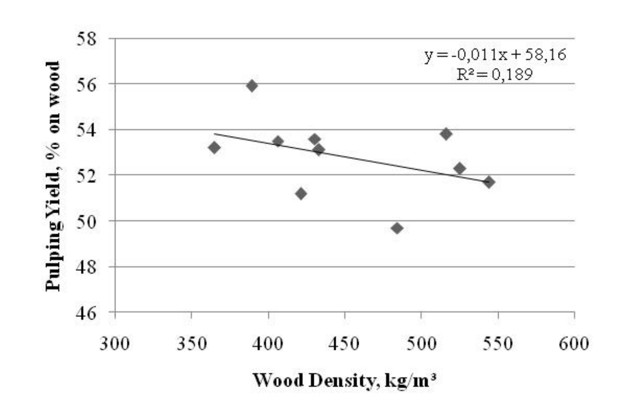
*[1 odt pulp x 100] / [wood density (kg/m³) x pulping yield (% on wood)].

I. Effect of wood density and pulping yield on specific wood consumption (SWC) for* Eucalyptus grandis *and* Eucalyptus urophylla *woods cooked to kappa 17–18. Source: Colodette et al. [7].

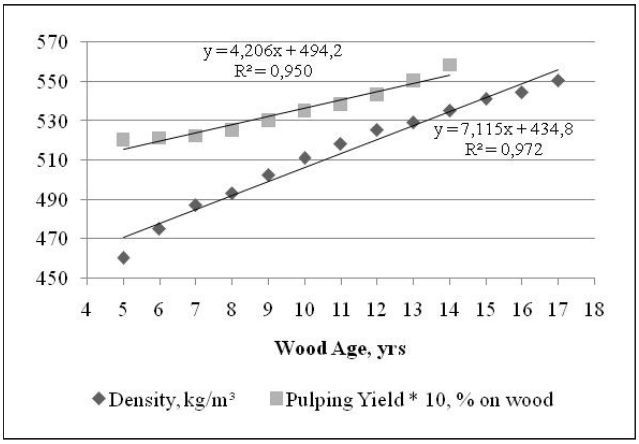
issues, it becomes evident that high-density woods will deliver lower-cost pulps because much less wood volume must be consumed to make a ton of pulp. For pulp mills that are not recovery-boiler limited, *Eucalyptus urophylla* wood will also enable increased throughput because a greater weight of wood can be fed to the digester in a given time.

Eucalyptus urophylla will produce more solids to recovery than *Eucalyptus grandis* because of the larger weight of wood entering the process and the lower fiber-line yield. Therefore, a larger black liquor recovery system is required to process *Eucalyptus urograndis* wood, which can be a problem for old pulp mills.

The example shown in Table I represents a case where the low-density wood has a high pulping yield and vice versa, but this is not always the case. As shown in Fig. 3, no correlation between pulping yield and density was found for ten different eucalyptus woods growing in a tropical climate. However, this is not necessarily the case for all eucalyptus woods. **Figure 4** shows data for *Eucalyptus globulus* from southern Chile, for which pulping yield actually correlates positively with wood density. Of course, this would be the best scenario of all. It can also be seen in Fig. 4 that wood density increases almost linearly with age [8]. Much effort has been expended in tree-improvement programs aimed precisely at producing trees of high density that also deliver high pulping yield. These programs run quite secretively within Brazilian forest companies.



3. Effect of wood density on pulping yield for ten different eucalyptus samples cooked to kappa 17–18. Source: Colodette et al. [7].



4. Effect of wood age on density and pulping yield at kappa 15 for Chilean* Eucalyptus globulus*. Source: Peredo et al. [8].

One of the reasons for the lack of positive correlation between wood density and pulping yield for eucalyptus grown in Brazil may be the premature formation of heartwood in these woods. Heartwood penalizes yield because of its high content of polyphenolic extractives such as flavonoids, stilbenes, and lignans. As trees grow older, they become denser, which should improve pulping yield; but at the same time their extractives content increases, which increases the active alkali demand for pulping the wood to a given kappa number, thus decreasing yield. The results of Backman and De León [11], presented in **Table II**, show this trend for three eucalyptus species from northern Uruguay. The nine-year-old trees, which contained much more extractives than the four-year-old ones, required more effective alkali to achieve the desired kappa number and exhibited lower pulping yields. Unfortunately, there is no clear-cut correlation between wood density and pulping yield for eucalyptus grown in tropical and semitropical areas.

Wood extractives content

Fast-growing eucalyptus trees possess low extractives contents because of their young harvesting age. Therefore, the negative impact of extractives on pulping yield is not very significant, but a reasonable correlation exists between total wood extractives content and pulping yield (**Fig. 5**). The correlation is significant only for the ethanol/toluene extractives fraction, with the minor lipophilic fraction represented by the DCM extractives being of little significance. However, this fraction is quite troublesome for pitch formation. The lipophilic extractives contain significant amounts of saturated and unsaturated fatty acids and steryl esters, which are quite sticky and a major contributor to pitch problems in eucalyptus kraft pulp mills [12,13]. The majority of these pulp mills use talc or some other form of pitch control to operate satisfactorily.

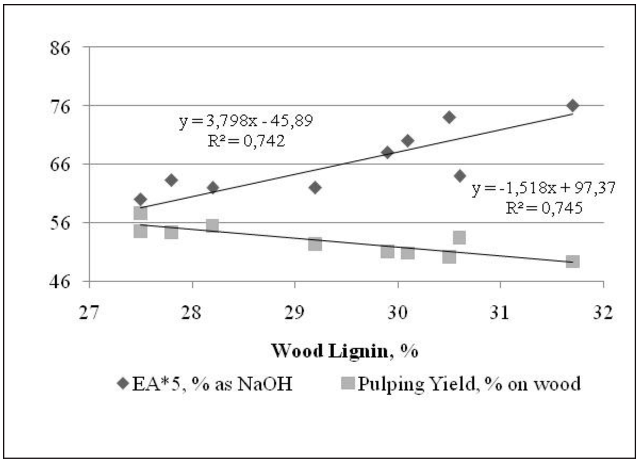
Wood lignin content

From a mass-balance standpoint, wood lignin content should be negatively correlated with kraft pulping yield. However,

Species	*E. grandis*		*E. saligna*		*E. benthamii*	
Age, yr	4	9	4	9	4	9
Extractives, % on wood	0.8	2.9	0.9	3.2	1.0	4.3
Density, kg/m³	445	498	460	509	450	479
Kappa No.	19.7	17.2	21.5	18.5	19.9	17.1
Effective Alkali, % NaOH	16.5	17.0	15.7	17.9	16.3	18.0
Pulping Yield*, % on wood	48.5	47.9	48.5	46.4	47.8	46.6

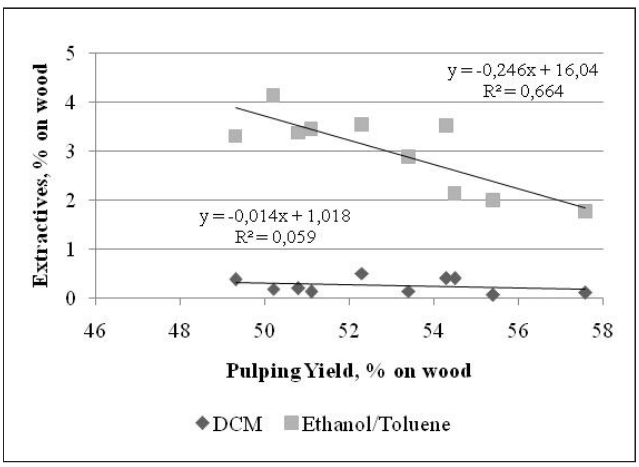
*Pulping conditions: liquor to wood ratio = 4 m³/t, time to temperature=90 min, time at temperature and effective alkali varied to reach kappa target of 18–20, sulfidity = 25%.

II. Effect of age on eucalyptus wood density, extractives content, and pulping yield at kappa 17–21.5. Source: Backman and De León [11].



6. Effect of lignin content on pulping yield and effective alkali demand at kappa 18±0.5 for ten seven-year-old clones. Source: Gomide et al. [9].

this is not always the case. Studies carried out by Gomes et al. [10] with 24 samples of three-year-old trees showed only a slight negative correlation at kappa 17–18. These unexpected results were explained by the observation that young trees contain significant amounts of low-density juvenile wood that also affects yield. However, similar poor correlations have also been found in another study [7] using ten different eucalyptus wood species at harvesting age. Obviously, pulping yield is controlled by many variables other than lignin content. In addition, lignin structure may play an important role in the rate of delignification and in pulping yield. Lignin structural aspects such as S/G ratio, C-4 condensed structures, and hydroxyl-free phenolic group content affect the behavior of lignin during pulping. For example, a reasonably good negative correlation between lignin content and pulping yield (**Fig. 6**) was obtained in a study by Gomide et al. [9] in which selected trees of somewhat similar ages, densities, and lignin S/G ratios were compared. These are the main factors affecting pulping yield besides lignin content, and by keeping them somewhat controlled, it was possible to see the effect of lignin on yield. Figure 6 also shows that lignin content correlates reasonably well with effective alkali demand for kraft pulping to a given kappa target. Lignin is a large consumer of alkali during kraft pulping, and the excess alkali required for removing lignin penalizes yield by also dissolving polysaccharides. Therefore, the ideal scenario is low lignin content which demands less alkali, thus improving pulp yield. Unfortunately, the amount of lignin alone is not sufficient to explain yield behavior. At a minimum, pulping yield must be analyzed in the light of lignin content and S/G ratio, extractives content, and wood density.

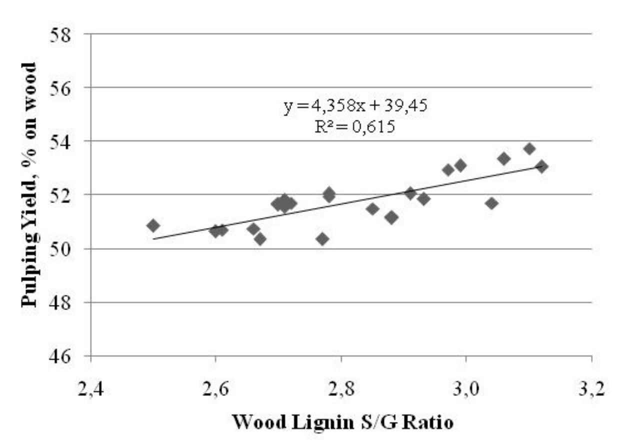


5. Effect of wood ethanol/toluene and DCM extractive contents on pulping yield at kappa 18±0.5 for ten seven-year-old Eucalyptus clones. Source: Gomide et al. [9].

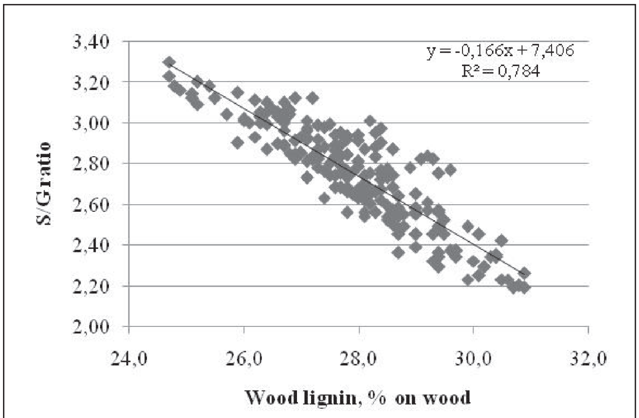
Wood lignin syringyl/guaiacyl (S/G) ratio

In principle, the higher the lignin S/G ratio, the better should be the wood pulpability, because syringyl lignin is more reactive in kraft pulping. Many workers [14–19] have found that the S/G ratio correlates negatively with effective alkali demand and positively with pulping yield. Unfortunately, the eucalyptus wood species grown in Brazil present a rather narrow range of variation (two or three to one) of lignin S/G ratio among clones, and therefore good correlations between this ratio and pulping yield are usually hard to observe. However, the results presented in **Fig. 7** show a reasonably good positive correlation between S/G and pulping yield for 24 three-year-old wood samples. These samples come from six different *Eucalyptus urograndis* clones planted in four different regions of Minas Gerais state, and the results are averages of values for five trees [10]. Much effort has been dedicated to increasing the S/G ratio in eucalyptus wood, both through classical tree-improvement programs and through genetic engineering.

Our studies [20] of 100 trees of three-year-old *Eucalyptus urograndis* have indicated that wood lignin content is inversely correlated with lignin S/G ratio (**Fig. 8**). This work has also shown that lignin with a high S/G ratio contains more



7. Effect of lignin S/G ratio on pulping yield at kappa 17 for twenty-four three-year-old* Eucalyptus urograndis *wood samples. Source: Gomes et al. [10].



8. Relationship between wood lignin content and syringyl/guaiacyl ratio for 100 samples of three-year-old* Eucalyptus urograndis*. Source: Colodette and Gomide [20].

β-O-4 ether bonds. Other investigators have found similar trends for different wood and grass species [21]. Therefore, the ease of cooking and the higher pulping yields observed for woods containing lignin with a high S/G ratio can be explained by their higher content of ether bonds, i.e., of less-condensed lignin, and their concomitant lower lignin contents. A potential negative impact of high-S/G-ratio lignin is a decrease in black liquor heating value. Syringyl lignin is more oxygenated than its guaiacyl counterpart and gives rise to black liquor of lower heating value. However, by accelerating delignification during pulping, the high-S/G-ratio lignin will result in decreased polysaccharide losses, which will have an opposite effect on black liquor heating value, thus counterbalancing the potential losses arising from the higher oxygen content of syringyl units. It has also been proven that eucalyptus woods with high S/G ratios provide kraft pulps that are easier to bleach at a given kappa number. This phenomenon has been explained by the higher content of β-O-4 bonds and lower content of C-4 condensed bonds in the kraft pulp lignin derived from woods containing high S/G ratio lignin [22].

A (Source: Pascoal Neto et al., [22])		
Species	Wood	Kraft Pulp
Eucalyptus globulus	31	16
Eucalyptus urograndis	31	14
Eucalyptus grandis	25	13
B (Source: Magaton [5])		
Eucalyptus dunnii	37	20
Eucalyptus globulus	33	19
Eucalyptus grandis	38	21
Eucalyptus nitens	33	19
Eucalyptus urograndis	35	20
Eucalyptus urophylla	39	21

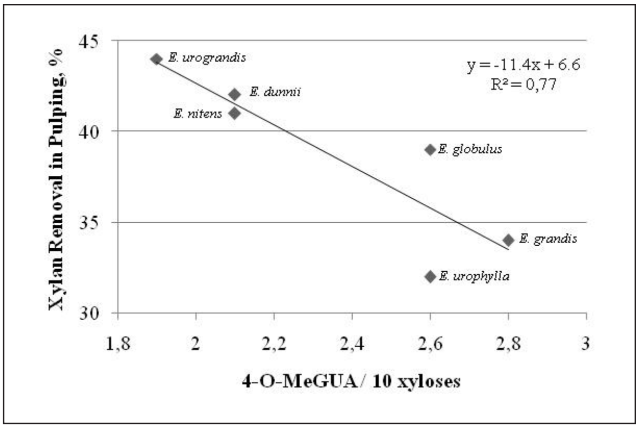
III. Molecular weight (kDa) of xylans in the wood and in the corresponding kraft pulp: A: harvesting-age hardwoods cooked to kappa 16–19; B: harvesting-age eucalyptus clones of various origins cooked to kappa number 17.

Wood Species	**Xylans, % of original wood**		
	Pulp	**Black Liquor**	**Degraded**
Eucalyptus dunnii	51.3	7.3	41.4
Eucalyptus globulus	54.1	7.7	38.2
Eucalyptus grandis	57.3	6.9	35.8
Eucalyptus nitens	52.6	4.0	43.4
Eucalyptus urograndis	49.7	6.2	44.1
Eucalyptus urophylla	58.7	7.5	33.8

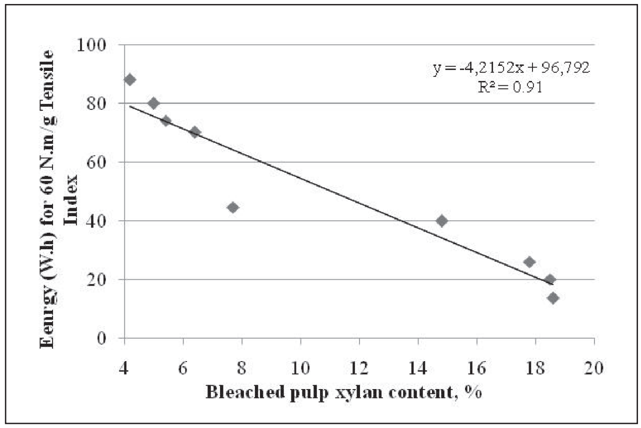
IV. Distribution of eucalyptus-wood xylans after kraft pulping, expressed as a percentage of the original value in wood. Source: Magaton [5].

Wood hemicellulose and uronic acids contents

It has been established that a significant fraction of wood uronic acids are converted into hexenuronic acids during kraft pulping of eucalyptus wood [23–25], and that such conversion stabilizes wood xylan against degradation reactions, thus improving pulp yield [26,27]. In fact, eucalyptus xylans retain about half their molecular weight during kraft pulping [5,22]. The xylan molecular weight in wood and in kraft pulps, shown respectively in **Tables IIIA** and **IIIB**, is a good indication that such polymers resist kraft pulping reasonably well for most of the eucalyptus wood species evaluated. Additional evidence of eucalyptus xylan resistance is presented in **Table IV**. The values of xylan retained in the pulp after kraft pulping are unusually high for most eucalyptus, in the range of 50%–59% of the amount originally present in the wood. The large amounts of 4-O-methylglucuronic acids present in eucalyptus-wood xylans, 1.9–2.8 per ten xylose units as measured by the ^{1}H NMR technique, likely protect chains against peeling reactions and hydrolysis of β(1-4)-glycosidic bonds [5]. The results presented in **Fig. 9**, obtained

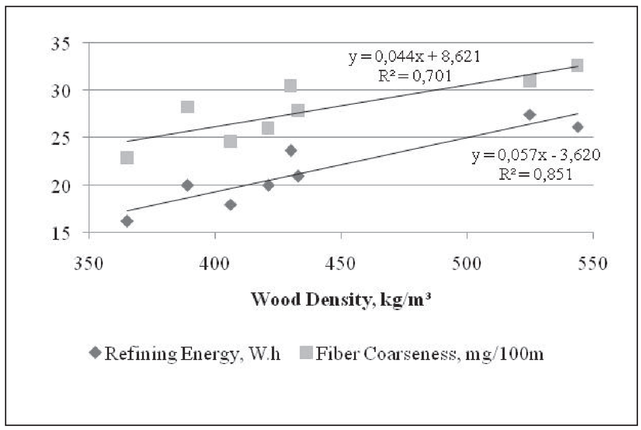


9: Effect of wood 4-O-methylglucuronic acid content on xylan removal during kraft pulping to kappa number 17. Source: Magaton [5].



10. Effect of pulp xylan content on energy demand to achieve 60 N.m/g tensile index for low-density and high-density seven-year-old **Eucalyptus urograndis** *wood samples cooked to kappa 17 (different cooking protocols) and ECF bleached to 90% ISO brightness. Source: Pedrazzi [28].*

from six seven-year-old *Eucalyptus spp* trees, show that wood content of 4-O-methylglucuronic acid correlates negatively with xylan removal during kraft pulping [5]. Therefore, high pulping yields can be anticipated from woods containing large amounts of uronic acids because of their high xylan retention in the pulp. Other reports have indicated that kraft pulps containing significant amounts of hexenuronic acids tend to deliver high pulp yields [26,27]. An interesting observation, presented in Table IV, is that only a small fraction of the eucalyptus wood xylans is actually present in the black liquor. This is not particularly encouraging for process developments aimed at recovering xylans from black liquor.



11. Effect of wood density on bleached pulp fiber coarseness and refinability to 30 ºSR for eight harvesting-age eucalyptus wood samples cooked to kappa 17–18 and ECF bleached to 90% ISO brightness. Source: Colodette et al. [7].

Pulp refinability

Many factors may affect pulp refinability, which can be defined as the amount of energy required to achieve a given degree of drainage. These include fiber chemistry and morphology, wet-end chemistry, and refining technology.

For eucalyptus pulps, hemicellulose content is synonymous with xylan content, given that only the latter resists kraft pulping and ECF bleaching. Pulp xylan content has been shown [28] to decrease energy demand significantly during refining. At 60 N.m/g tensile strength, an increase in pulp xylan content from 13% to 17% decreased energy demand by 40%, which signifies an energy savings of approximately 10% per 1% xylan increase (**Fig. 10**). Xylans facilitate fiber hydration, thus decreasing refining energy, and consequently xylan-rich pulps enable the manufacture of bulkier papers because they require less energy input to achieve a given tensile index.

Fiber morphology includes fiber length and width, cell-wall thickness, and other properties. An easy way to interpret these parameters is through the measurement of pulp fiber coarseness and distribution. Fiber distribution correlates (inversely) fairly well with coarseness for eucalyptus fibers because these fibers exhibit little length variation. Most fiber morphological aspects are strongly correlated with wood density, particularly for woods that present a narrow range of fiber lengths, such as the eucalyptus species grown in Brazil. **Figure 11** shows the significant impact of wood density on fiber coarseness and energy demand during pulp refining to 30 ºSR. It is evident that the high-density woods deliver bleached pulps of high coarseness which are harder to refine to a given degree of drainage.

Pulp use

The main applications of bleached eucalyptus market pulps are for tissue and for printing and writing (P&W) paper grades. The fiber properties required to manufacture these two products are obviously different. While tissue-paper manufacturers prefer pulps with high smoothness, high bulk, and good absorption properties, the P&W paper manufacturers are more interested in pulps with good refinability that produce papers with high tear/tensile index, good formation, and good printability. The desired fiber characteristics for tissue papers include high fiber coarseness, predominance of short fibers, and low xylan content, whereas for P&W papers, the list of desired characteristics is not as clear. Both markets have one similar desire: fibers with high drainability on the paper machine. Unfortunately, this presents a paradox, because pulps with a predominance of short fibers drain poorly on the paper machine, although they make very good P&W papers.

Brazilian eucalyptus-fiber producers have been able to meet these very different fiber-quality demands for tissue and P&W papers because of the wide variety of eucalyptus wood species, hybrids, and clones that they cultivate. Woods of a wide variety of basic densities, fiber distributions, and coarseness values can be produced from eucalyptus by means of the advanced tree-improvement programs in place in most pulp-producing companies. However, it is not easy to control wood-fiber xylan content in the forest. Variations in pulp xylan content can be obtained in the forest by picking the right wood species, but they can more easily be achieved in the pulp manufacturing process by choosing the right pulping technology. Xylans can also be added to pulp fibers after pulping and bleaching.

It is worth noting that pulp fibers especially engineered for the tissue and P&W paper markets in the forest may still present significant variations during use, which means that there are other fiber characteristics beyond the well-known morphological (coarseness, fiber distribution, fines, and other fiber properties) and chemical (xylans, uronic acids, and others) properties which affect the manufacture of such products. Fiber hysteresis and hornification potentials may play a role. Fiber ultrastructure (microfibril angle, crystallinity, crystal structure, and others) and the molecular-weight distribution of the main macromolecules contained in pulp fibers (cellulose and xylans/uronic acids) may also be significant. For example, high xylan content is desirable for the manufacture of P&W paper grades because it decreases the energy demand during refining, but it has been proven that these xylans are advantageous only if they have a sufficiently high molecular weight [29]. Xylans have been considered undesirable for making tissue paper, which requires little refining, because of the inconveniences they present during paper drying on the Yankee cylinder. The intensity of the negative impact may depend upon the xylan molecular-weight distribution.

CONCLUSIONS

In general, we can conclude that high-quality eucalyptus wood for kraft pulping should have a reasonably high density, low extractives and lignin contents, a high lignin S/G ratio, and high xylan and uronic acid contents. Some more specific conclusions include:

- Specific wood consumption is more strongly influenced by wood density than by pulping yield.
- Pulping yield does not correlate well with any one wood property in isolation.
- Woods containing high quantities of lignin tend to possess lignin with low S/G ratios and are harder to process during kraft pulping.
- Age significantly affects wood chemistry and morphology and its behavior in kraft pulping and pulp use.
- Eucalyptus hemicelluloses are composed mainly of a xylan unusually rich in uronic acids which is reasonably stable in kraft pulping.
- Xylans retain about half their molecular weight during kraft pulping.
- The xylans retained in the kraft pulps substantially improve their refinability.
- An increase in wood age and density increases fiber coarseness, which negatively affects pulp refinability, but increases pulp drainability. **TJ**

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INSIGHTS FROM THE AUTHORS

We decided to investigate this topic because wood represents 40%–60% of overall pulp production costs. A careful selection of quality wood is the most effective way of reducing pulp production costs. In addition, proper wood selection is the easiest way to differentiate pulp products.

This research is an important complement to our previous work because it evaluates a wide spectrum of raw materials in considerable details. It adds to this work a study of lignin syringyl/guaiacyl ratios and a very detailed analysis of hemicelluloses by studying their behavior during kraft pulping. Xylan structure and molecular-weight distribution were evaluated for wood, pulp, and black liquor.

The most difficult aspect of this investigation was the isolation of xylans from wood, pulp, and black liquors, because they are strongly linked to lignin and their isolation in the pure state was challenging.

We did not expect to discover that lignin syringyl/guaiacyl ratio is a very important parameter for wood selection, perhaps more important than lignin content itself. The most surprising finding was that xylan molecular weight decreases only by half during kraft pulping, whereas cellulose molecular weight decreases fourfold. In addition, it was found that retention of xylan and molecular weight depends on the gentleness of kraft pulping, and furthermore, that xylan retention is positively influenced by uronic acids content.

Forest products companies can benefit from these findings by selecting woods containing high lignin syringyl/guaiacyl ratios and high levels of xylan and uronic acids. Kraft cooking must be carried out in a gentle way (low temperature and adequate alkali profiling) so that xylans are retained in large quantities and with high molecular weights.

Magaton

Colodette

Gouvêa

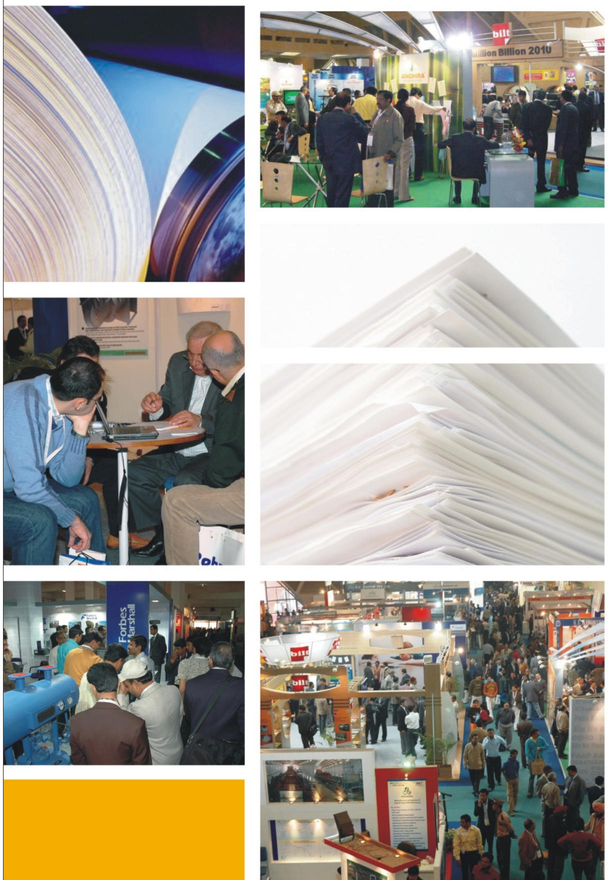
Gomide

Muguet

Pedrazzi

Our next study will focus on fine-tuning wood quality and kraft cooking to retain the maximum possible amounts of xylans in the pulp, thus improving pulp yield and refinability. We propose to achieve that by selecting so-called easy-to-cook woods (low lignin, low extractives, and high lignin syrinyl/guaiacyl ratio) and processing them in a very gentle way.

Magaton, Colodette, Gouvêa, and Gomide are professors; Muguet is a Master's student; and Pedrazzi is a doctoral student in the Forest Engineering Department, Federal University of Viçosa in Viçosa, MG, Brazil. Contact Colodette via email at colodett@ufv.br.



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