Production of printing and writing paper grade pulp of sugar cane bagasse

MARCELA FREITAS ANDRADE, JORGE LUIZ COLODETTE, RUBENS CHAVES DE OLIVEIRA, CAROLINA MARANGON JARDIM, AND HASAN JAMEEL

ABSTRACT: The main goal of this study was to evaluate the potential of depithed bagasse for the production of printing and writing paper. Industrial whole bagasse was separated into two fractions: pith and depithed bagasse. The depithed bagasse was cooked by the soda process to two different degrees of delignification. The resulting pulps were fully bleached by the O-D*-(EP)-D sequence and characterized for their beatability, drainability, and physical-mechanical properties. Bleached soda pulps cooked to kappa 17.5 and 10.8 showed similar refinability and resistance to drainage, but the strength properties (tensile, burst, and tear) were slightly higher for the kappa 17.5 pulp at beating energy consumptions in the range of 2-7 W•h. We concluded that both pulps from depithed sugar cane bagasse would be suitable for the production of printing and writing paper grade pulps, but the higher kappa pulp is more economically attractive given its higher pulping yield, without significantly increasing the bleaching chemical demand.

Application: The work shows the possibility of using a renewable raw material, such as sugar cane bagasse, for the production of pulp for printing and writing paper.

In recent years, there has been an increasing trend toward more efficient use of agro-industrial residues, including sugar cane bagasse. Several processes and products have been reported that use sugar cane bagasse as a raw material. Among the many agricultural fibers used for pulp manufacture, sugar cane bagasse is the one with most promise. The sugar cane (*Saccharum officinarum*) is a perennial grass that originated in Asia, and is well-adapted for growing in most tropical and subtropical climates. Brazil is the largest producer of sugar cane in the world.

In 2011 and 2012, Brazil produced 571 million tons of sugar cane on 8.4 million ha of land, with an average productivity of 68 tons/ha [1]. Wastes from sugar cane agro-industry are produced in large quantities. Each processed sugar cane ton generates about 140 kg of bagasse on a dry weight basis [2]. Approximately 80 million tons of bagasse are generated per year on 8.4 million hectares of land [1]. This wasted material can potentially be used for producing high added value pulp, such as the production of printing and writing pulp grades. Brazil is a leader in the production of significant volumes of packaging, printing and writing, and paperboard grades of paper. In 2011, Brazil was 9th in the world among producers of paper, and in 2012, it produced 10.1 million ton of paper [3].

Sugar cane bagasse is a lignocellulosic material with potential for printing and writing papers production, especially when integrated into biorefinery processes [4,5]. Bagasse is a low-cost raw material and has a high carbohydrate content (51%-78%), which is suitable for papermaking [4-8]. In addition, it provides longer fiber than straw, low refining energy consumption, and good sheet formation, as well as paper smoothness [9]. These are relevant raw material traits for pulp production and other industrial uses. Bagasse pulp is generally comparable to hardwood pulps [10].

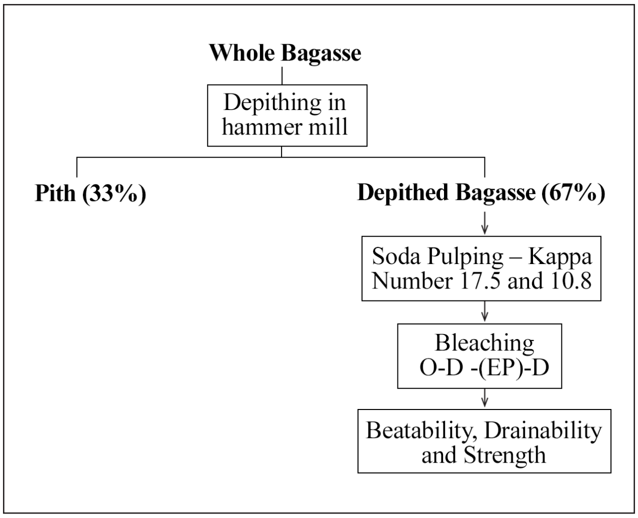
The soda pulping process is widely applied for nonwood material worldwide [11,12]. The amount of sodium hydroxide (NaOH) for cooking depends on the particular fiber raw material being pulped. The cooking temperature used depends on the cooking time and alkali charge. The typical sodium hydroxide charge is around 16% and typical cooking temperature is 140°C-170°C [13-16]. Its main advantage in relation to the traditional kraft process is the absence of sulfur-based chemicals, which minimizes air emissions and facilitates the recovery of pulping chemicals. But the soda process produces lower pulp yield in relation to the kraft process [17].

According to Foelkel [18], the required properties for printing and writing papers are smoothness, opacity, formation, bulk, porosity, printability, strength, and dimensional stability. Those properties can be obtained with short and small diameter fibers, such as eucalyptus and bagasse fibers. The main goal of this study was to evaluate the potential of the depithed bagasse for the production of printing and writing paper pulp at two levels of delignification: kappa 17.5 and 10.8.

EXPERIMENTAL

Working plan

Figure 1 depicts the working plan for the study. The two fractions of sugar cane bagasse (pith and fibers) were separated in a hammer mill. The depithed bagasse fraction (fibers) was soda pulped to two different levels of delignification



1. Working plan for bagasse fractionation.

(kappa 17.5 and 10.8). The resulting brownstock pulps were fully bleached by the O-D*-(EP)-D sequence, and then characterized for their beatability, drainability, and physical-mechanical properties.

Material

About 150 kg of industrial whole bagasse was provided by a Brazilian pulp mill. About 100 kg of the whole bagasse was separated into two fractions (pith and depithed bagasse) by a hammer mill. The pith fraction represented 33%, while the other 67% remained as the depithed bagasse. The pith, depithed bagasse, and whole bagasse were dried to about 85% dryness in a conditioning room (23.0°C ± 1.0°C and 50.0% ± 2.0% humidity) and stored in polyethylene bags for further use. The air-dried samples were ground in a Wiley mill and sieved, and the fraction that passed through a 40 mesh screen but was retained by a 60 mesh screen was collected.

Methods

Soda pulping

Soda pulping of the depithed bagasse was performed with a 7 L capacity laboratory digester equipped with forced circulation and a heat exchanger. Pulping conditions were altered to produce pulps delignified to kappa 17.5 and 10.8. Soda pulping was conducted using the following parameters: 8 L/1 kg ratio of liquor to biomass, 180°C maximum temperature; 60 min to maximum temperature, 20 min at maximum temperature, and 12.5% or 15.0% alkali charge (as % NaOH) to obtain kappa 17.5 or 10.8, respectively.

After cooking, the pulped chips were placed into a stainless steel box with a 150 mesh screen and were washed thoroughly with running water. The washed chips were defiberized using a laboratory hydropulper with a 25 L capacity. The pulp was classified in a laboratory screener equipped with 0.20 mm slotted screen; accepts were centrifuged to a consistency of about 30%, and the resulting dewatered pulp was stored in polythene bags. The following procedures were used for soda pulping analysis: brightness (TAPPI T 452 om-08 “Brightness of pulp, paper, and paperboard [directional reflectance at 457 nm]”), kappa number (TAPPI T 236 om-06 “Kappa number of pulp”), and viscosity (TAPPI T 230 om-08 “Viscosity of pulp [capillary viscometer method]”).

ECF bleaching

The kappa 17.5 and 10.8 brownstocks were fully bleached by the O-D*-(EP)-D_1 sequence, where O is a simple oxygen delignification stage, D* is a hot chlorine dioxide stage, (EP) is alkaline extraction with hydrogen peroxide, and D_1 is a chlorine dioxide bleaching stage. **Table I** lists the conditions used in each bleaching stage. The O stage was carried out in a Mark V mixer/reactor (Quantum Technologies; Akron, OH, USA) with samples of 300 g bone-dry pulp. The desired charges of magnesium sulfate, sodium hydroxide, and oxygen were added

Parameters	Kappa 17.5				Kappa 10.8			
	O	D*	(EP)	D	O	D*	(EP)	D
Consistency, %	10	10	10	10	10	10	10	10
Temperature, °C	105	95	80	80	105	95	80	80
Time, min	70	120	90	120	70	120	90	120
Pressure, kPa	600	-	-	-	600	-	-	-
O_2, kg/o.d. ton	20.0	-	-	-	20.0	-	-	-
ClO_2, as active Cl_2, kg/o.d. ton	-	20.4	-	13.2	-	17.7	-	13.2
H_2O_2, kg/o.d. ton	-	-	5.0	-	-	-	5.0	-
NaOH, kg/o.d. ton	20.0	-	9.0	1.0	15.0	-	9.0	1.0
H_2SO_4, kg/o.d. ton	-	4.0	-	-	-	4.5	-	-
$MgSO_4$, kg/o.d. ton	1.5	-	-	-	1.5	-	-	-

I. Conditions in each bleaching stage of bagasse pulps from soda pulping.

Parameter	TAPPI Test Method	
Forming handsheets	T 205 sp-06	Forming handsheets for physical tests of paper
Apparent specific volume (bulk) and weight	T 220 sp-06	Physical testing of pulp handsheets
PFI beating	T 248 sp-08	Laboratory beating of pulp (PFI mill method)
Burst index	T 403 om-02	Bursting strength of paper
Grammage	T 410 om-08	Grammage of paper and paperboard (weight per unit area)
Tear index	T 414 om-04	Internal tearing resistance of paper (Elmendorf-type method)
Drainage resistance (Schopper)	T 423 cm-07	Folding endurance of paper (Schopper-type tester)
Brightness	T 452 om-08	Brightness of pulp, paper, and paperboard (directional reflectance at 457 nm)
Air resistance	T 460 om-02	Air resistance of paper (Gurley method)
Modulus of elasticity, tensile energy absorption, and tensile index	T 494 om-06	Tensile properties of paper and paperboard (using constant rate of elongation apparatus)
Thickness	T 551 om-06	Thickness of paper and paperboard (soft platen method)
Opacity and light scattering coefficient	T 1214 om-07	Interrelation of reflectance, R_0; reflectivity, R_∞; TAPPI opacity, $C_{0.89}$; scattering, s; and absorption, k

II. TAPPI standard test methods used for PFI pulp beating, handsheet formation, and physico-mechanical handsheet testing.

Kappa No.	Alkali (%)	Rejects (%)	Screened Yield (%)	Total Yield (%)	Brightness (%ISO)	Viscosity (dm³/kg)
17.5	12.5	0.9	49.5	50.4	35.0	947
10.8	15.0	0.4	47.6	48.0	42.5	805
*Soda pulping conditions: liquor/biomass = 8 L/1 kg, maximum temperature = 180°C, time to maximum temperature = 60 min, time at maximum temperature = 20 min.						

III. Results of soda pulping of the depithed bagasse.*

to the reactor, in that order, after the desired temperature was reached. After the total reaction time had elapsed, the system was depressurized and the pulp discharged. The D* and D_1 stages were carried out in polyethylene bags. The bleaching liquor containing chlorine dioxide, water, and sodium hydroxide or sulfuric acid was added to the pulp at room temperature. The application of sodium hydroxide or sulfuric acid was to control the chlorine dioxide reaction pH; the amount used was determined in previous experiments with small samples of the pulp. After hand mixing the chemicals with the pulp in polyethylene bags, the material was heated in a microwave oven to the desired temperature, transferred to a water bath set to the desired reaction temperature, and maintained for the predetermined time. The same procedure was used for the (EP) stage, except the bleaching liquor was comprised of water, sodium hydroxide, and hydrogen peroxide, which were added to the pulp in that order. After each bleaching stage, the residual liquor was extracted for pertinent chemical analysis, and the pulp samples were washed with an equivalent of 9 m³ of distilled warm water per ton of dry pulp. All experiments were run in duplicate. After bleaching, the pulps were characterized for their beatability, drainability, and physical-mechanical properties.

Physico-mechanical tests

The pulps were beaten in a PFI mill capable of measure energy consumption (Wh) at different energy inputs (0, 300, 600, and 1000 revolutions), made into handsheets, and tested for physico-mechanical properties according to TAPPI test methods listed in **Table II**. Test were conducted to measure tensile stresses, tear, burst, air resistance, opacity, light scattering, and ISO.

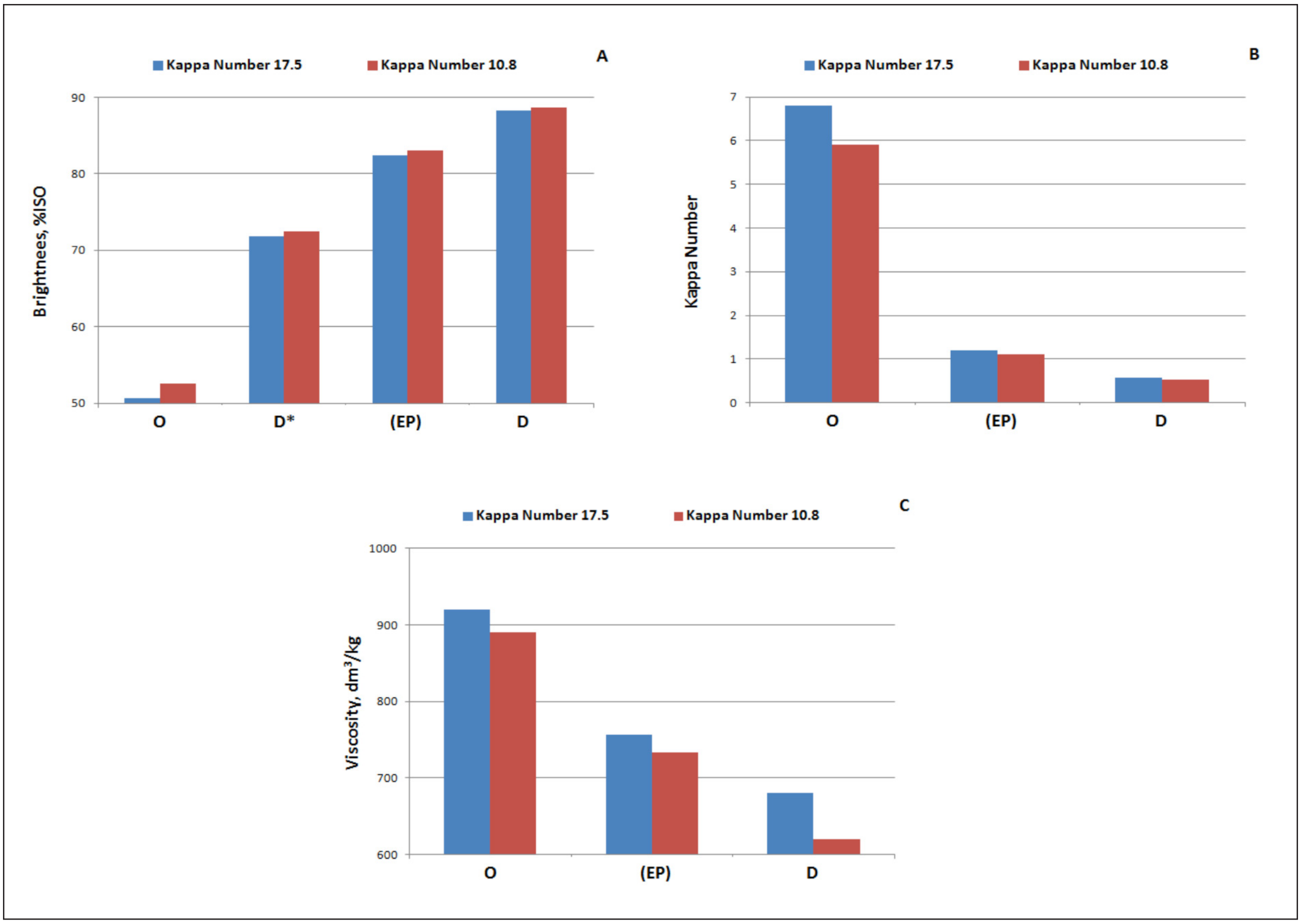
Data analysis

The pulp physico-mechanical properties obtained at different beating levels were analyzed using Excel 5.0, calculating the mean and standard deviation for each level.

RESULTS AND DISCUSSION

Soda pulping

Table III shows the results of soda pulping of the depithed bagasse. The brownstock with a kappa of 17.5 afforded a 49.5% screened yield and a pulp viscosity of 947 dm³/kg, compared with a 47.6% yield and a pulp viscosity of 805 dm³/kg for the 10.8 kappa brownstock. The reject contents were very low in both cases (<1%). The lower kappa number pulp achieved higher unbleached brightness values than the higher kappa number



2. Brightness (A), kappa number (B), and viscosity (C) profile across the O-D*-(EP)-D sequence for pulps of kappa 17.5 and 10.8.

pulp, which can be explained by the higher amount of lignin in higher kappa pulp. The majority of pulp chromophores are from the lignin [19], whereas a small amount arises from the decomposition of carbohydrates [20]. The lower pulp viscosity of the low kappa pulp is explained by the higher alkali charge used during soda pulping. The alkali degrades the carbohydrates by cleaving the chains of cellulose and hemicelluloses, thus affecting the pulp's viscosity. The results obtained in this study for the kappa 17.5 pulp were somewhat similar to those reported by Hamzeh et al. [21], who carried out soda pulping on depithed bagasse to kappa 17.1. Those authors reported values of 15.0% NaOH for the alkali demand, 52.5% screened yield, 1.1% rejects, and 36.0% ISO brightness. Compared to eucalypts, the depithed bagasse is easier to cook to kappa numbers of 17-18. Values of 25% NaOH for the alkali charge, 49.8% screened yield, 0.1% rejects, 33.4% ISO brightness, and 862 cm^3/g viscosity have been reported for the soda pulping of eucalypts [22].

ECF bleaching

The depithed bagasse pulps were bleached by the O-D*-(EP)-D sequence to a target brightness of 88% ISO. The oxygen delignification (O) efficiencies, compared at fixed conditions and similar final reaction pH (10.6-10.8), were higher for the kappa 17.5 pulp (61.1%) than for the kappa 10.8 pulp (45.4%); the post-O brightness values of the pulps were 50.6% and 52.6% ISO, respectively. The oxygen delignification efficiency was calculated on the basis of kappa number before and after the oxygen stage. **Figure 2** shows the brightness, kappa number, and viscosity of the pulps when treated with the O-D*-(EP)-D sequence.

No significant brightness changes were observed between the kappa 17.5 and 10.8 pulps, with the exception of the oxygen delignification stage, where the difference in brightness values was significantly higher than the next stages of bleaching. This occurred because of the initial difference in kappa number values after cooking. The positive effect in the brightness values of the pulps after stage D* was probably a result of the higher kappa factor used in this study (0.30 for both pulps).

The main goal of reinforcing an extraction stage with hydrogen peroxide (EP) is to increase the amount of lignin removed [23], which results in a substantial reduction in kappa number after this stage; post-extracted kappa numbers of 1.2 and 1.1 were obtained for the 17.5 and 10.8 kappa pulps, respectively. The final bleached kappa number values were similar for both pulps studied. The viscosity values decreased over the bleaching stages. The more severe cooking conditions used to obtain pulps with a low kappa number caused a decrease in carbohydrates contents and had a negative

Bleaching parameter	Kappa 17.5	Kappa 10.8
Total active chlorine*, kg/o.d. ton	44.05a	41.35b
Brightness, % ISO	88.3a	88.6a
Post color number	0.24a	0.27a
Viscosity, dm³/kg	680a	620b
Kappa number	0.58a	0.53a
* Total active chlorine (kg/o.d. ton) = ClO_2 (kg/o.d. ton)*2.63 + H_2O_2 (kg/o.d. ton)*2.09. Note: The averages marked with the same letters in each line are not significantly difference by Tukey's test at a 5% significance level.		

IV. Summary results of the bleaching by O-D*-(EP)-D sequence.

influence on viscosity. The significant viscosity losses after the (EP) stage for both pulps were more likely to be caused by the high temperature used in D*, coupled with the low pH (acid hydrolysis of the glycosidic linkages), and by the hydrogen peroxide used in the (EP) stage. The decomposition of hydrogen peroxide in the alkaline conditions generates free radicals, which attack the cellulose fibers, thus reducing the viscosity of the pulp. According to Ventorim, et al. [24], pulps exposed to a hot acid hydrolysis stage (e.g., D*) may experience some carbohydrate degradation, which is dependent on reaction conditions. The final viscosities were 680 dm³/kg for the kappa 17.5 bleached pulp and 620 dm³/kg for the kappa 10.8 bleached pulp.

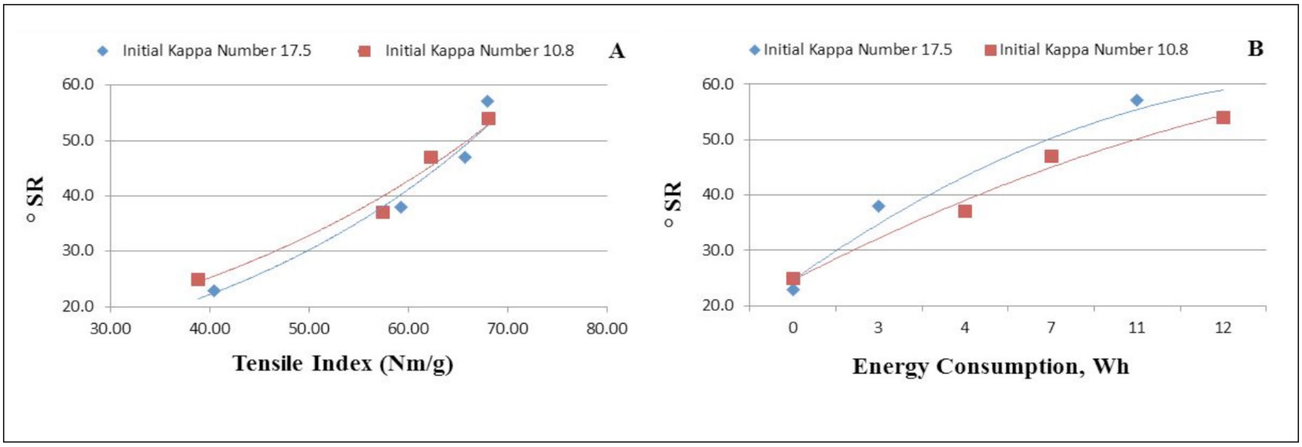
The overall bleaching chemical consumptions for the kappa 17.5 and 10.8 pulps, measured as total active chlorine, were 44.05 kg/o.d. ton pulp and 41.35 kg/o.d. ton pulp, respectively, to achieve a brightness of about 88% ISO (**Table IV**). The post-bleaching color values were in the range of 0.24-0.27 for both bleached pulps, which indicated high brightness stability. Table IV shows the results of the bleaching by O-D*-(EP)-D sequence.

Physico-mechanical tests

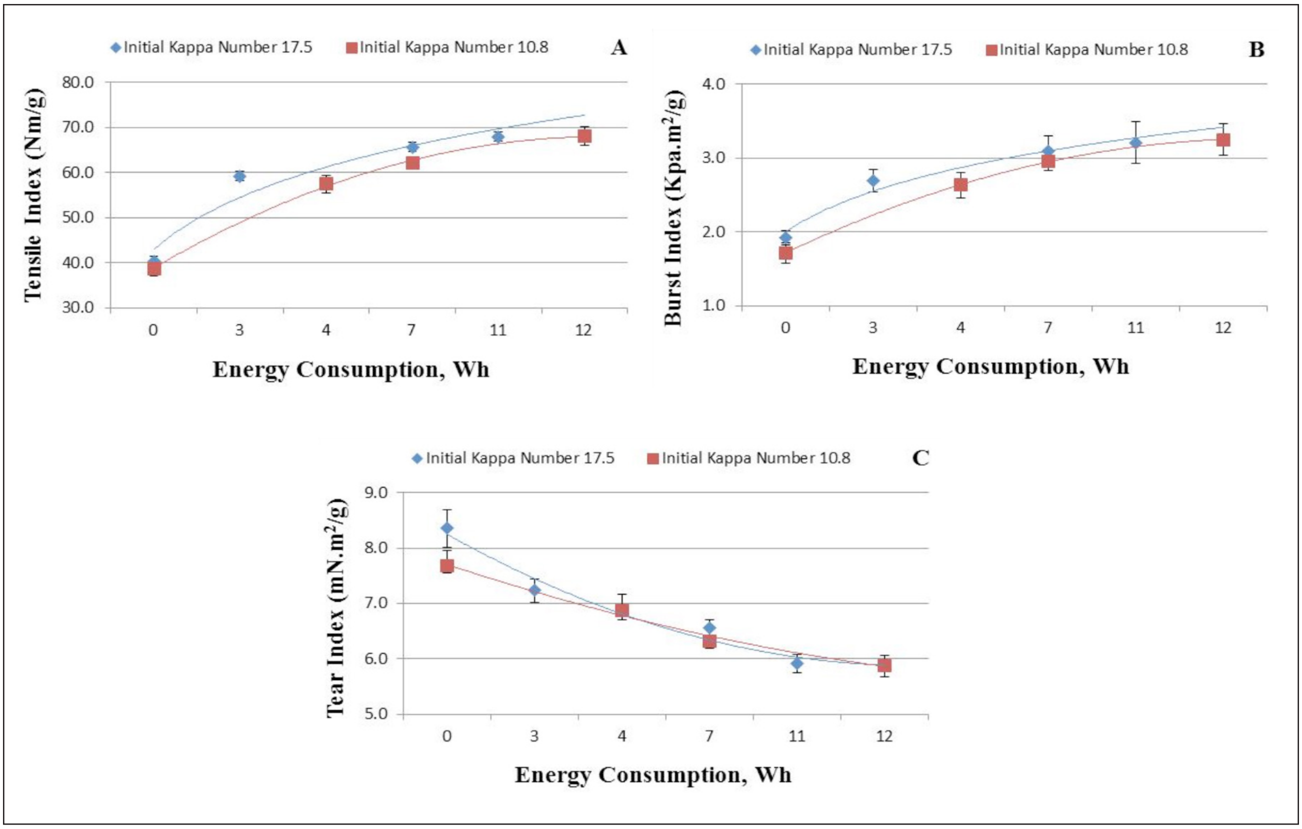
The bleached pulps were beaten using different revolutions in the PFI mill (0, 300, 600, and 1000 rpm) and subjected to physical and mechanical tests to evaluate their potential for the production of printing and writing paper grades. All properties were expressed in relation to the energy consumed during beating, given its contribution to paper production cost. For the development of required pulp properties, beating refining requires substantial energy, about 18% of the total electrical energy required for producing paper from wood [25]. The graphs in **Figs. 3-7** show the experimental data and curves, represented through mean values and standard deviation.

<u>Drainage resistance and beatability</u>

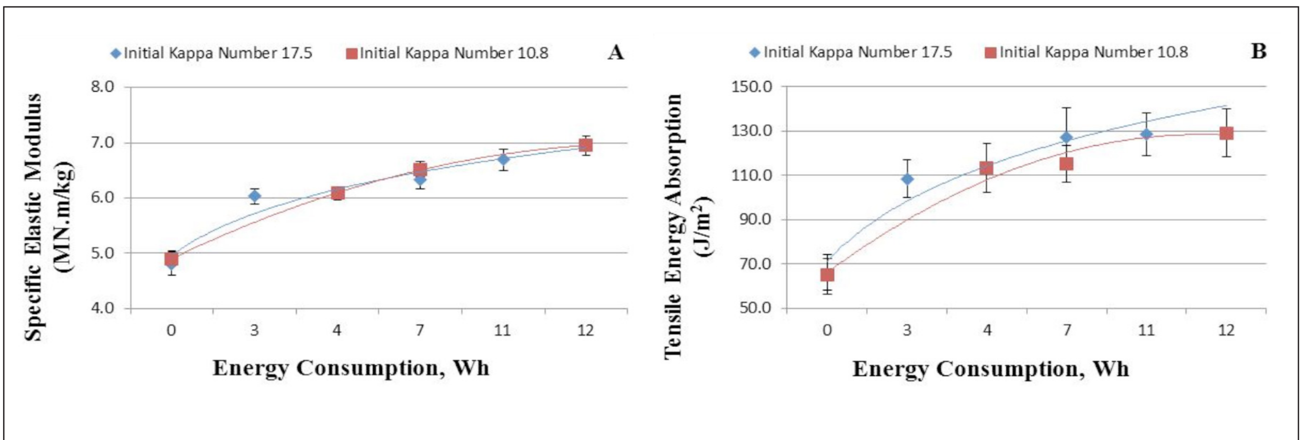
Pulp drainability can be loosely defined as the capacity of the pulp to drain the water from the mat. Because Schopper-Riegler (°SR) is a drainage resistance measure, it gives a conception of pulp drainability. Therefore, once °SR increases, so does the tensile index. Pulp beatability can be loosely defined as the amount of pulp beating energy required to achieve a certain drainage degree. Therefore, the relationship between °SR and energy consumption, for example, gives a direct indication of pulp beatability. The higher the amount of beating energy required to achieve a given °SR, the lower is the pulp's beatability. Figure 3 shows the relations between °SR and tensile index (A) and °SR and energy consumption (B) for the bleached pulps with initial brownstock kappa numbers of 17.5 and 10.8. As anticipated, the resistance to drainage



3. Drainage resistance (A): Schopper-Riegler (oSR) versus tensile index, and beatability (B): oSR versus energy consumption for bleached pulps cooked to two different degrees of delignification (kappa 17.5 and 10.8).



4. Tensile index (A), burst index (B), and tear index (C) versus energy consumption for bleached pulps cooked to two different degrees of delignification (kappa 17.5 and 10.8).



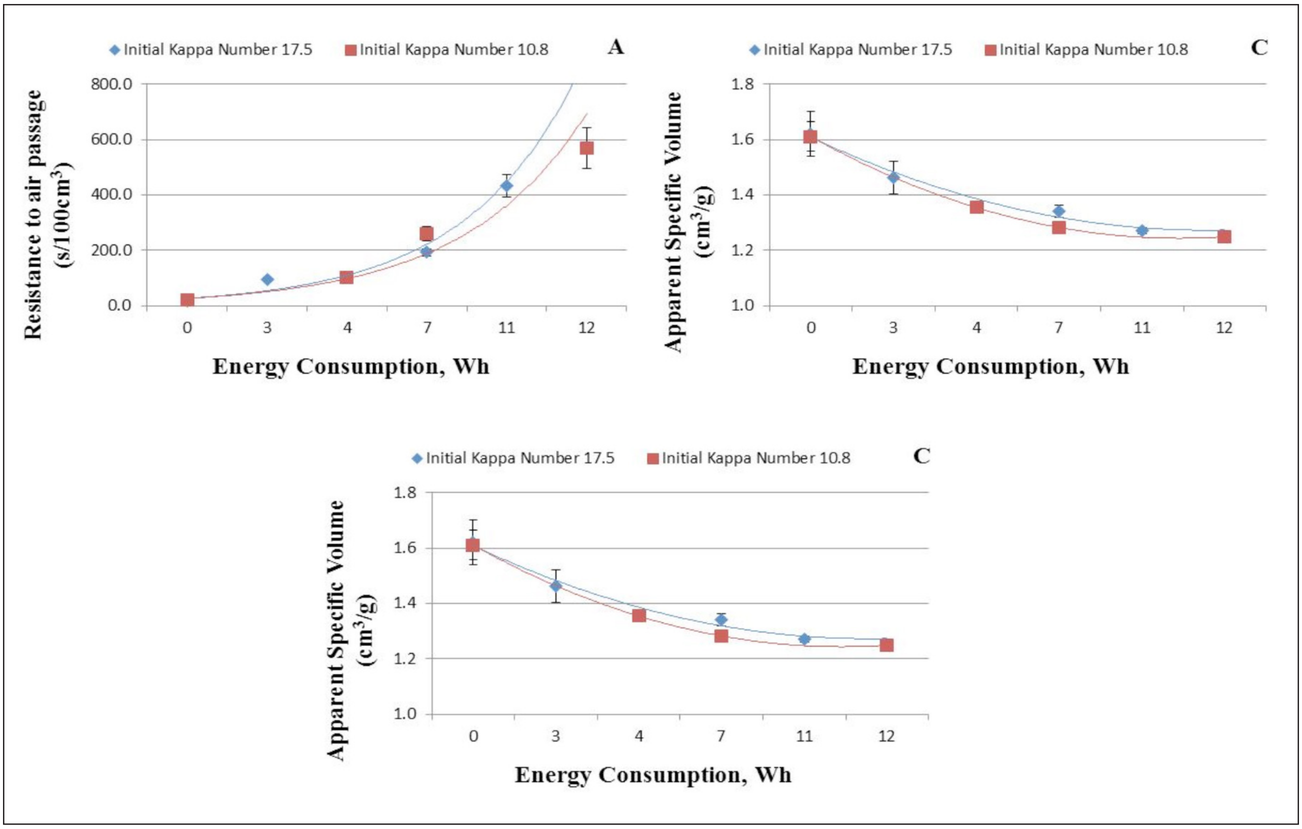
5. Specific elastic modulus (A) and tensile energy absorption (B) versus energy consumption for bleached pulps cooked to two different degrees of delignification (kappa 17.5 and 10.8).

increased with increasing tensile index and the °SR increased with increasing energy consumption. As observed through the curves tendency, the drainage resistance and beatability did not seem to be influenced by the degree of pulping delignification.

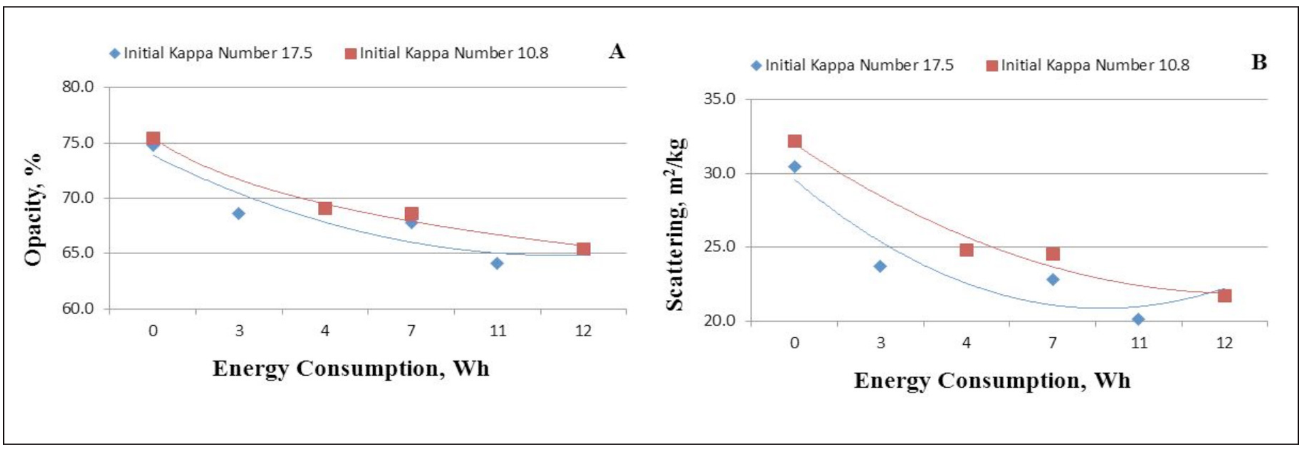
Tensile, burst, and tear indices

In papermaking, strength properties resulting from fiber strength, bonding, and length indicate the paper's resistance to web breaking during printing and converting [26]. Figure 4 shows the relations between tensile, burst, and tear index versus energy consumption for the bleached pulps with initial brownstock kappa numbers of 17.5 and 10.8.

Tensile and burst indices increase with energy consumption. The kappa 17.5 pulp exhibited slightly higher tensile, burst, and tear indices than the kappa 10.8 pulp over the beating energy range examined, especially for tensile index. The more severe cooking conditions used to obtain the



6. Resistance to air passage (A), apparent specific weight (B), and apparent specific volume (C) versus energy consumption for bleached pulps cooked to two different degrees of delignification (kappa 17.5 and 10.8).



7. Opacity (A) and scattering (B) versus energy consumption for bleached pulps cooked to two different degrees of delignification (kappa 17.5 and 10.8).

10.8 kappa pulp probably caused a decrease in pulp's xylan content, which resulted in a negative effect on tensile strength.

<u>Specific elastic modulus and tensile energy absorption</u>

Modulus of elasticity (MOE), also known as specific elastic modulus, is an important property because it represents the capacity of the material to absorb a tensile force without suffering substantial deformation. Higher MOE values provide greater capacity of the material to absorb a certain load without undergoing large deformations. Tensile energy absorption (TEA) represents the durability of the paper when subjected to repetitive use when subjected to tensile or impact forces. Figure 5 shows the relations of MOE and TEA with energy consumption for the two bleached pulps. As observed, through the curves tendencies, the cooking conditions used to obtain different delignification degrees did not have any significant effect on MOE and TEA values at the various beating energy levels.

Sample	Opacity (%)	Mill Revolutions	°SR	Bulk (cm^3/g)	Tensile Index (N•m/g)	Burst Index (kPa•m^2/g)	Tear Index (mN•m^2/g)	Air Resistance (s/100 cm^3)
Depithed bagasse kappa 17.5	68.7	300	38	1.5	59.2	2.7	7.2	86.8
Depithed bagasse kappa 10.8	69.1	300	37	1.4	57.4	2.6	6.9	85.5
Eucalyptus hybrid [28]	70.8	1793	34	1.4	78.0	5.4	10.5	4.6
Eucalyptus hybrid [28]	74.1	1184	34	1.6	66.2	4.6	8.6	3.8
Eucalyptus hybrid [29]	70.7	3000	40	1.2	77.0	4.8	9.0	31.3
Eucalyptus Grandis [30]	72.9	1000	33	1.5	56.5	3.6	9.8	8.9

***V. Selected printing and writing paper grade properties for the depithed bagasse soda pulp of this study (initial kappa 17.5 and 10.8) and of commercial eucalypt kraft pulps and of* Eucalyptus grandis.**

Resistance to air passage, apparent specific weight, and apparent specific volume

Air resistance has an inverse relationship with paper porosity. This property is highly and positively influenced by the amount of pulp refining. Figure 6 shows its behavior as a function of beating energy consumption for the two bleached pulps. The paper sheet resistance to air passage increases with increasing energy consumption because of decreased porosity. The kappa 10.8 pulp showed slightly higher air resistance than that of kappa 17.5 pulp. The 10.8 kappa pulp possessed more collapsible fibers and produced more fines during refining, with consequent increases in the amount of fines and reduced empty spaces, thus decreasing porosity.

Apparent specific weight and volume are important properties for printing and writing paper grade papers because they influence the porosity and opacity of paper. For a given raw material, an increase in apparent specific volume or a decrease in apparent specific weight means an increase in paper opacity and porosity. The apparent specific volume is also known as bulk. The structural characteristics of the fibers also influence the determination of this property. Less collapsible fibers contribute to increased specific volume of papers because of their low conformation capacity. Figure 6 shows the relations of apparent specific weight and apparent specific volume with energy consumption for the two bleached pulps. The apparent specific weight increased and apparent specific volume decreased with refining energy consumption. Specific weight and volume were not significantly affected by the degree of delignification during soda pulping.

Opacity and scattering coefficient

Opacity is defined as the ability of light to pass through a paper sheet. The extent of beating affects opacity. Opacity is important in printing and writing paper grade pulps to prevent images or text printed on one side from being seen through the other side of the sheet. Opacity is a function of paper thickness, amount of filler(s), pulp brightness, and beating degree. Beating makes the paper denser, but excessive beating results in lower opacity [27]. The scattering coefficient is a measure of the ability of the sheet to scatter light. Figure 7 shows the relations between opacity and scattering coefficient versus energy consumption during refining for the two bleached pulps. The opacity and scattering coefficient decreases with increasing refiner energy consumption. The opacity and scattering were not influenced by the degree of pulping delignification.

Potential for production of printing and writing paper grades

To determine the potential of the pulps produced in this study for the production of printing and writing (P&W) paper grades, these pulps were compared with eucalypt pulps that are traditionally used for this application. According to Foelkel [18], tensile and tear indices are important for P&W paper grades. Other important properties of P&W paper grade pulps are opacity, bulk and porosity. **Table V** lists relevant properties for the pulps of this study and of commercial eucalypt P&W paper grade kraft pulps. In general, the bleached pulps derived from depithed bagasse presented acceptable properties; however, they did not measure up to those of traditional eucalypt kraft pulps. Because opacity is one of the most important properties for this paper grade, it was chosen as the property for comparison of the sugar cane bagasse and eucalypt pulps.

The strength properties of the eucalypt kraft pulps, as tensile, burst, and tear indices, were generally higher than those of the depithed bagasse soda pulps (Table V). Although the eucalypt and depithed bagasse raw materials had similar fiber morphology, the fiber viscosities of the eucalypt kraft pulps were higher than those of the bagasse soda pulps. However, the values of bulk (~1.5 cm3/g) and opacity (~70%), which are important properties for printing and writing paper grades, were similar for the eucalypt kraft and bagasse soda pulps. Yet, when comparing the depithed bagasse pulps with eucalypt pulps (*Eucalyptus grandis*), the variations between the physico-mechanical properties values were small. The *E. grandis* pulps had values of 1.5 cm^3/g bulk, 56.5 N•m/g tensile index, 3.6 kPa•m^2/g burst index, and 71.9% opacity.

CONCLUSIONS

- The bleached soda pulps cooked to kappa 17.5 and 10.8 showed similar refineability, resistance to drainage, and strength properties (tensile, burst, and tear).
- Both brownstock pulps obtained from depithed sugar cane bagasse were suitable for the production of printing and writing paper grades; however, the higher kappa brownstock was more economically attractive given its higher pulping yield.
- In general, the bleached pulps derived from depithed bagasse presented acceptable properties; however, these pulps did not measure up against those of traditional eucalypt kraft pulps. **TJ**

LITERATURE CITED

1. Companhia Nacional de Abastecimento (CONAB), "Acompanhamento de safra brasileira: cana-de-açúcar, terceiro levantamento – December 2011." Available [Online] http://www.conab.gov.br/OlalaCMS/uploads/arquivos/11_12_08_11_00_54_08.pdf>[12 June2014].
2. Centro de Tecnologia Canavieira (CTC), 2012. Available [Online] at http://www.ctcanavieira.com.br>[12June2014].
3. Associação Brasileira de Celulose e Papel (BRACELPA), 2013. Available [Online] http://bracelpa.org.br/bra2/index.php>[26June2014].
4. Caraschi, J.C., Campana Filho S.P., and Curvelo, A.A.S., *Polim.: Cienc. Tecnol.* 6(3): 24(1996).
5. Wolf, L.D., "Pré-tratamento organossolve do bagaço da cana-de-açúcar para produção de etanol e obtenção de xilooligômeros," M.S. dissertation, Universidade Federal de São Carlos, São Carlos, Brasil, 2011.
6. Canilha, L., Carvalho, W., Rocha, G.J.M., et al., "Caracterização do bagaço de cana-de-açúcar in natura, extraído com etanol ou ciclohexano/etanol," Associação Brasileira de Química - Seção Regional do Rio Grande do Norte, Natal, Brasil, 2007. Available [Online] at http://www.abq.org.br/cbq/2007/trabalhos/11/11-570-713.htm>[13June2014].
7. De Ramos e Paula, L.E., Trugilho, P.F., Napoli, A., et al., *Cerne* 17(2): 237(2011).
8. Marabezi, K., "Estudo sistemático das reações envolvidas na determinação dos teores de lignina e holocelulose em amostras de bagaço e palha da cana-de-açúcar," M.S. dissertation, Instituto de Química de São Carlos da Universidade de São Paulo, São Carlos, Brasil, 2009.
9. Rajesh, K.S. and Rao Mohan, N.R., *IPPTA J.* 10(3): 151(1998).
10. Casey, J.P., Ed., *Pulp and Paper: Chemistry and Chemical Technology*, 3rd edn., vol. 2, John Wiley & Sons, New York, 1980.
11. Khristova, P., Kordsachia, O., Patt, R., et al., *Ind. Crops Prod.* 23(2): 131(2006).
12. Enayati, A.A., Hamzeh, Y., Mirshokraiei, S.A., et al., *BioResources* 4(1): 245(2009).
13. Mohta, D., Upadhyaya, J.S., Kapoor, S.K., et al., *TAPPI J.* 81(6): 184(1998).
14. Feng, Z. and Alen, R.J., *Appita J.* 54(2): 217(2001).
15. Finell, M. and Nilsson, C., *Ind. Crops Prod.* 19(2): 155(2004).
16. Okayama, T. and Li, B., "Soda-oxygen pulping of rice straw and liquid absorption of resulting hand sheets," *Non-Wood Fiber Pulping Papermaking, [Int. Conf.], 3rd*, International Academic Publisher, Beijing, China, 1996, Vol. 1, p. 177-186.
17. Hedjazi, S., Kordsahia, O., Patt, R., et al., *Ind. Crops Prod.* 62(2): 142(2009).
18. Foelkel, C.E.B., "Eucalypt wood and pulp quality requirements oriented to the manufacture of tissue and printing and writing papers," *Appita Annu. Gen. Conf. Proc., 52nd*, Appita, Bundoora, Australia, 1998, pp. 149-154.
19. Gierer, J., *Sven. Papperstidn.* 73(18): 571-597.
20. Forskahl, I., Popoff, T., and Theander, O., *Carbohydr. Res.* 48(1): 13(1976).
21. Hamzeh, Y., Abyaz, A., Niaraki, M.O.M., et al., *BioResources* 4(4): 1267(2009).
22. Almeida, D.P. and Gomide, J.J., "Estudo do efeito de antraquinona e de surfactante na polpação soda," *ABTCP Annu. Congr., 45th*, Brazilian Pulp and Paper Technical Association, São Paulo, Brazil, 2012.
23. Anderson, J.R., *TAPPI Bleach Plant Operations Short Course Notes*, TAPPI PRESS, Atlanta, GA, USA, 1992, p. 123.
24. Ventorim, G., Colodette, J.L., and Eiras, K.M.M., *O Pap.* 70(8): 39(2009).
25. Bhardwaj, N.K., Bajpai, P., and Bajpai, P.K., *J. Biotechnol.* 51(1): 21(1996).
26. D'Almeida, M.L.O., *Celulose e papel: Tecnologia de fabricação do papel*, 2nd edn., Vol. 2, IPT, São Paulo, Brasil, 1988, p. 403.
27. Gonzáles, I., Boufi, S., Pèlach, M.A., et al., *BioResources* 7(4): 5167(2012).
28. Bassa, A., Bassa, A.G.M.C., Sacon, V.M., et al., "Seleção e caracterização de clones de eucalipto considerando parâmetros silviculturais, tecnológicos e de produto final," *II Int. Colloq. Eucalyptus Pulp*, Universidade Federal de Viçosa, Viçosa, Brasil, 2005.
29. Andrade, M.F., "Estudo comparativo da branqueabilidade de polpas kraft de *Pinus radiata* e de uma mistura de *Eucalyptus globulus e Eucalyptus nitens*," M.S. dissertation, Universidade Federal de Viçosa, Viçosa, Brasil, 2010.
30. Pedrazzi, C., "Influência das xilanas na produção e nas propriedades de polpas de *Eucalyptus grandis e Eucalyptus urograndis*," Ph.D. dissertation, Universidade Federal de Viçosa, Brasil, 2009.
31. Andrade, M.F., Collodette, J.L., and Jameel, H., *TAPPI J.* 13(6): 27(2014).

ABOUT THE AUTHORS

We chose this topic because sugar cane bagasse is a lignocellulosic material with potential for printing and writing papers production. Among the many agricultural fibers used for pulp manufacture, sugar cane bagasse is the one with most promise. This work shows the ideal conditions for the production of pulp from sugar cane.

The most difficult aspect of this research was to thoroughly elucidate the lignin structure from bagasse. To solve this, a complementary study of chemical, morphological, and structural characterization was performed for bagasse [31].

The most interesting surprise was that both brownstock pulps, with different kappa numbers, obtained from depithed sugar cane bagasse were suitable for the production of printing and writing paper grades.

Mills can use the same conditions as those in this study to produce cellulose pulps from sugar cane bagasse without high costs and wastage of chemicals.

The next step will be to produce special cellulose pulps from sugar cane bagasse, such as dissolving pulp production.

Andrade is a Ph.D. candidate, Colodette is professor, Oliveira is professor, and Jardim is post-doctoral student, Pulp and Paper Laboratory, Department of Forestry Engineering, Federal University of Vicosa, Minas Gerais, Brazil. Jameel is professor, Department of Wood and Paper Science, North Carolina State University, Raleigh, NC, USA. Email Andrade at andrade-marcela@hotmail.com.


Andrade


Colodette


Oliveira


Jardim


Jameel