Effect of Sodium Xylenesulphonate Use in Bleached Kraft Pulp from Eucalyptus Wood on the Physical, Optical, and Mechanical Properties

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Sodium xylenesulphonate (SXS) was evaluated in wood chip pretreatment in order to improve the quality and the properties of bleached eucalypt kraft pulp. First, the chips were subjected to pretreatment with SXS, and then the pretreated chips were cooked by the kraft process. The resulting pulp was subjected to oxygen-delignification and then to bleaching. Various bleached pulp properties, such as fiber morphology, physical, optical and mechanical strength, were measured. The pulp from the SXS pretreated chips had higher lignin removal efficiency in oxygen delignification, which resulted in higher bleachability and lower bleach consumption compared with the reference pulp. The physical and optical properties of the pulp from the SXS pretreated chips had higher drainability, capillarity water absorption, specific volume, roughness, and opacity *versus* the reference pulp. These observations indicated that the pretreated pulp has the potential to be used in tissue pulp grades. However, the pulp obtained from the SXS pretreated chips had lower mechanical strength properties than the reference pulp. In sum, SXS chip pretreatment can be used to produce a pulp that has high bleachability and is suitable for tissue grades.

Keywords: Efficiency in pre-delignification; Reagents consumption; Bleachability

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INTRODUCTION

Brazil is the second largest global producer of cellulose, especially for bleached hardwood pulps made from eucalypt species. In 2016, Brazil produced 18.8 million tons of pulp, of which 86.2% was from hardwood species; the *Eucalyptus* genus was predominant (IBÁ 2017). This output represented an 8.0% increase compared with 2015 for this pulp segment. From the total pulp produced in Brazil, 69% is exported; the country is a world leader in bleached hardwood exports. The main destinations of Brazilian exports are the United States, China, and Europe (IBÁ 2017).

In this context of industry growth and constant search for new alternatives, one area of research is wood pretreatments, which make it possible to extract compounds that inhibit the conversion of wood chips into kraft pulp. In particular, the removal of lignin increases the efficiency and reduces the reagents needed for this process.

Sodium xylenesulphonate (SXS) can be applied to remove lignin; in a hydrotropic solution, this compound increases the solubility of poorly soluble substances such as lignin (Andelin *et al.* 1989). Akia and Feyzi (2006) reported that the application of SXS into industrial units is attractive due to its high selectivity, low flammability, and easy recovery by dilution with a polar solvent. However, the use of SXS during pulping and bleaching affects the physical, optical, and mechanical properties of the resulting pulp. Therefore, the goal of this study was to evaluate the effect of sodium xylenesulphonate application on the quality of bleached pulp made from *Eucalyptus grandis* x *Eucalyptus urophylla* wood. The physical, optical, and mechanical properties of pulp were examined.

EXPERIMENTAL

Characterization of the Used Pulp

Wood chips from five clones of *Eucalyptus grandis* x *Eucalyptus urophylla* hybrid were used (five years old) that were harvested from a forest stand located in the city of Telêmaco Borba/PR, (24° 08' 46" S; 50° 31' 57" W). Chips were pretreated with sodium xylenesulphonate (SXS) (90% purity, Fluka Analytical, Saint-Quentin-Fallavier, France) in a rotative autoclave (Regmed, Osasco, Brazil), with a 20-L capacity, containing eight individual stainless steel capsules that were loaded with 70 g of wood chips (dry mass) and the extraction solution, with a solution/wood ratio of 4:1. The treatment conditions were as follows: 12 h treatment time; 30% SXS concentration; and 130 ºC (Vivian *et al.* 2017). After pretreatment, the chips showed a 39.12% reduction of lignin (from 27.12% to 16.51% lignin). After SXS pretreatment, the wood chips (reference and pretreated) were subjected to conventional kraft pulping to obtain a pulp with kappa number 15 ± 0.5; the kraft pulping conditions have been reported by Vivian (2015) and are summarized in Table 1. The resulting pulp parameters are listed in Table 2.

Table 1. Pulping Conditions Used to Produce Pulps with Kappa Number 15 ± 0.5

Parameters	Conditions
Active alkali (% NaOH)	*
Sulfidity (%)	25
Dry mass of chips (g)	70
Liquor/wood ratio	4:1
Maximum temperature (ºC)	166
Heating time (min)	90
Cooking time (min)	60
H-factor	780

*Active alkali was adjusted by experimentation to reach a kappa number 15 ± 0.5 for pretreated and untreated chips.

Table 2. Parameters Obtained from Pulping to Kappa Number 15 ± 0.5

Parameters	Material	
	Reference	Pretreated
Kappa number	15.2	14.9
Active alkali (NaOH basis) (%)	18.1	11.8
Gross / global yield (%)	54.6	30.2*
Screened yield (%)	54.6	30.2
Rejects content (%)	0.0	0.0
Hexenuronic acids ($\mu mol \cdot g^{-1}$)	55.7	8.9
Intrinsic viscosity ($cm^3 \cdot g^{-1}$)	1049	1239
Selectivity	69.2	83.4

*Global yield considers the pretreatment (67.69%) and the pulping yield.

Pre-Delignification with Oxygen and Pulp Bleaching

Pulps obtained from untreated and pretreated chips were pre-delignified with oxygen and bleached by means of an ECF (elemental chlorine free) sequence, (A/D_0)(EOP)D_1P, to obtain ≥ 90 % ISO brightness. The pre-delignification with oxygen was performed in a reactor/mixer (Quantum-Mark) using 200 g (bone dried) pulp. The (EOP) stage was performed at the reactor, and the (A/D_0), D_1 and P stages were performed in plastic bags heated by a thermostatically controlled water bath. The bleaching conditions are summarized in Table 3.

Table 3. Pre-Delignification and ECF Bleaching Conditions

Bleaching conditions	Sequence				
	Pre-O	**(A/D_0)**	**(EOP)**	**D_1**	**P**
Consistency (%)	12	12	10	10	10
Temperature (°C)	90	90+90	85	75	80
Time (min)	60	120+13	60	120	120
Pressure (bar)	5	-	5	-	-
Final pH	10.5 – 11.0	2.5 - 3.0	10.5 - 11.0	3.0 - 3.5	10.5 - 11.0
Bleaching Reagents					
H_2O_2 (kg·t^{-1})	-	-	5	-	3
ClO_2 (kg·t^{-1})	-	KF = 0.2*	-	5**	-
NaOH (kg·t^{-1})	15	-	10	-	5
O_2 (kg·t^{-1})	18	-	4	-	-
H_2SO_4 (kg·t^{-1})	-	6	-	-	-

Pre-O is pre-delignification with oxygen; (A/D_0) is sulfuric acid/chlorine dioxide delignification; (EOP) is alkaline extraction with oxygen and hydrogen peroxide; D_1 is first chlorine dioxide brightening stage; and P is hydrogen peroxide.
*Kappa factor (KF); ClO_2 in D_0 (kg·t^{-1}) = (kappa number after Pre-O x KF x 10) / 2.63.
**defined after the curve of 5 to 10 kg·t^{-1} of ClO_2 to achieve the desired brightness.

Kraft pulp and reagents were manually mixed in polyethylene bags; subsequently the material was transferred to the equipment or water bath, according to the bleaching stage, which was maintained during the preset time at the desired temperature. After the reaction, liquor samples were extracted for pH and residual oxidant measurements. The resulting pulps after each stage were washed with distilled water at room temperature.

After the oxygen delignification stage, the delignification efficiency was determined. These calculations were calculated from the kappa number of the pulps, with and without corrections for hexenuronic acid content, as shown in Eqs. 1 through 4,

$$Ef\,Pre\text{-}O = \frac{K_i - K_d}{K_i} \times 100 \tag{1}$$

$$Ef\,Pre\text{-}O\,(\text{Corrected kappa}) = \frac{K_{Ci} - K_{Cd}}{K_{Ci}} \times 100 \tag{2}$$

$$K_{Ci} = K_i - \frac{H_i}{11.6} \times 100 \tag{3}$$

$$K_{Cd} = K_d - \frac{H_f}{11.6} \times 100 \tag{4}$$

where *Ef Pre-O* is the Pre-O efficiency (%), K_i is the initial kappa number, K_d is the O_2-delignified kappa number, *Ef Pre-O* (corrected kappa number) is the Pre-O efficiency corrected for hexenuronic acids (%), K_{Ci} is the kappa number corresponding to the brownstocks, corrected for hexenuronic acids, K_{Cd} is the kappa number for the O_2-delignified pulp corrected for hexenuronic acids, H_i is the hexenuronic acids content of the brownstock (μmol·g^{-1}), and H_f is the hexenuronic acid content of the O_2-delignified pulp (µmol·g^{-1}).

The equivalent active chlorine consumption and bleachability were determined for the pulps after bleaching,

$$CCA = 2.63 \cdot CD + 2.09 \cdot CP \tag{5}$$

$$Bleachability = \frac{K_i}{CCA} \tag{6}$$

where CCA is the equivalent active chlorine consumption (kg·t^{-1}), CD is the total consumption of chlorine dioxide in D_0 and D_1 (kg·t^{-1}), 2.63 is the conversion factor of chlorine dioxide to active chlorine, CP is the total consumption of hydrogen peroxide in P (kg·t^{-1}), 2.09 is the conversion factor of hydrogen peroxide to active chlorine, and K_i is the initial kappa number of the brownstocks.

Morphology of Fibers from Bleached Pulps

Morphology analyses of the bleached pulps were performed using a Kajaani FiberLab analyzer (Metso Automation), which determines the following fiber characteristics,

$$\text{Fiber average length} = \frac{\sum C_i}{N} \tag{7}$$

$$\text{Fiber average width} = \frac{\sum L_i}{N} \tag{8}$$

$$\text{Coarseness} = \frac{m}{\sum C_i N} \tag{9}$$

$$\text{Fines content in length} = \frac{\sum F_i}{\sum C_i} \tag{10}$$

where C_i is the fiber length (mm), L_i is the fiber width (µm); N is the number of fibers analyzed, m is the mass of the fibers analyzed, and F_i is the length (µm) of the fines, which is defined as material with lengths between 5 and 200 µm.

Table 4. Parameters Determined in the Refined Pulps

Properties	Parameters	Standards
Physical/optical properties	Drainability (Schopper-Riegler)	ISO 5267-1 (1999)
	Apparent density	ISO 534 (2011)
	Specific volume	ISO 534 (2011)
	Air resistance	ISO 5636-5 (2013)
	Opacity	ISO 2470 (2009)
	Klemm Capillarity	ISO 8787 (1986)
	Water retention value	ISO 23714 (2007)
	Roughness Bendtsen	SCAN-P 84 (2002)
Mechanical properties	Tensile index	ISO 1924-3 (2005)
	Burst index	ISO 2758 (2014)
	Tear index	ISO 1974 (2012)

Refining and Physical, Optical, and Mechanical Testing of Bleached Pulps

Bleached pulps were refined in PFI mill, in accordance to NBR 14345 standard (2004), using the equivalent of 30 g (a.d.). Refining was done at 10% of consistency using

0, 750, 1500, and 3000 revolutions. The drainability of the refined pulp was characterized by the Schopper-Riegler test.

After refining the pulps, handsheets of 60 g·m^{-2} were made to evaluate physical, optical, and mechanical properties of the pulps, in sheet forming machine, model SE-032 (company Lorentzen & Wettre), according to the ISO standard. These handsheets were conditioned for a period of 12 h in a room at 23 ± 1 ºC and 50 ± 1% relative humidity (RH). After conditioning, the physical, optical, and mechanical tests were performed on the handsheets; the testing standards used are listed in Table 4.

RESULTS AND DISCUSSION

Pre-Delignification with Oxygen and Pulp Bleaching

The characteristics of the pulps after pre-delignification with oxygen, obtained from pulping processes without pretreatment (reference) and with SXS pretreatment, are listed in Table 5.

Table 5. Pulps Characteristics after Pre-Delignification with Oxygen

Parameters	Material	
	Reference	SXS Pretreated
Kappa number	9.6	6.4
Brightness (% ISO)	48.5	55.5
Hexenuronic acids (µmol·g^{-1})	44.8	5.5
Intrinsic viscosity (cm^3·g^{-1})	932	970

The kappa number of the pretreated pulp was lower after the pre-delignification with oxygen, which reflected more delignification occurred compared with the reference pulp. In addition, the pretreated pulp brightness was higher, which is directly correlated to the amount of lignin remaining in the pulp after pre-O treatment.

The hexenuronic acid content in the pulp obtained from reference chips after the pre-O is similar to that reported by Segura (2012) for pre-O pulp produced from *E. grandis* x *E. urophylla* that had a kappa number of 15 and had a hexenuronic acid content of 49.5 µmol·g^{-1}. The pretreated pulp contained an extremely low amount of hexenuronic acid, which is related to the low content present in the brownstock.

Pulps viscosity was high for the pretreated pulp, keeping the difference observed for this parameter in the pulps after the pulping process, indicating that the efficiency of the delignification process with oxygen is related to the initial characteristics of the pulps.

The efficiency of pre-delignification with oxygen to the pulps regarding the pulping processes with reference chips and those pretreated with SXS can be observed in Fig. 1A.

The efficiency of pre-O for the pretreated pulp was 50% higher than the reference pulp, indicating that the residual lignin in this pulp, even in smaller quantities, shows characteristics that facilitate its removal at this stage of bleaching. Another point to be considered in the evaluation of the pulp delignification efficiency obtained at this stage of the work is the hexenuronic acids content, which was lower in the pretreated pulp.

Hexenuronic acids contribute to the measured kappa number of pulps (Li and Gellerstedt 1997); 11.6 µmol·g^{-1} of hexenuronic acid content in pulp corresponds to 1 kappa unit. The corrected kappa number was calculated for the brownstocks and pre-delignified O pulps, and the delignification efficiency was re-evaluated (Fig. 1B). It was observed that the delignification efficiency of the reference pulp increased, which was attributed to the high levels of hexenuronic acids in the brownstock and pre-O pulp.

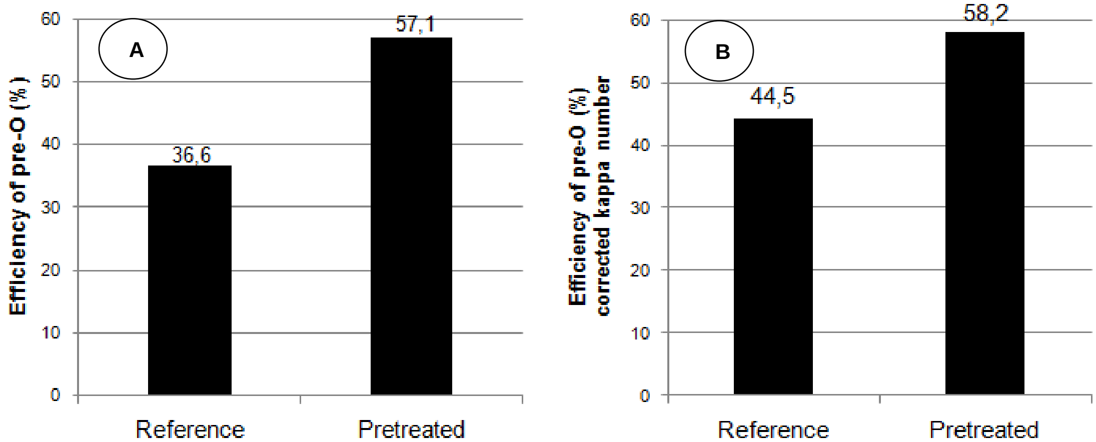

Fig. 1. Delignification efficiency of pre-delignification with oxygen

After the pre-delignification with oxygen, the other bleaching stages were conducted on the pulp (Table 6). The results indicated that the conditions used could easily attain higher than 90% ISO final brightness; these observations indicated that there are possibilities of reducing amount of bleach used.

Table 6. Characteristics of Bleached Pulps and Bleach Consumption with O(A/D_0)(EOP)D_1P

Parameter	Material	
	Reference	**Pretreated**
Final brightness (% ISO)	92.3	92.6
Brightness reversion (% ISO)	1.0	1.3
Final intrinsic viscosity ($cm^3 \cdot g^{-1}$)	755	652
H_2O_2 ($kg \cdot t^{-1}$)	8.0	8.0
ClO_2 ($kg \cdot t^{-1}$)	12.4	9.9
NaOH ($kg \cdot t^{-1}$)	30.0	30.0
O_2 ($kg \cdot t^{-1}$)	22.0	22.0
H_2SO_4 ($kg \cdot t^{-1}$)	6.0	6.0
Equivalent total active chlorine ($kg \cdot t^{-1}$)	49.3	42.8
Bleachability, kappa/total active chlorine	0.308	0.348

The intrinsic viscosity of the reference pulp after bleaching was higher than the pretreated pulp after bleaching; this trend was the opposite observed for the brownstock and pre-O pulp prior to bleaching. This observation may have been a consequence of the bleaching sequence, in which lower bleach charges could have been used, especially in the D_0 and/or D_1 stage. The bleached viscosity values were similar to the Segura (2012) study, 685 $cm^3 \cdot g^{-1}$, for *E. grandis* x *E. urophylla* kraft pulps.

The SXS pretreated pulp consumed the least amount of equivalent active chlorine than the reference pulp. This was due to the (A/D_0) stage, where the chlorine dioxide charge is based on the kappa number entering the (A/D_0) stage (Table 5), which was lower for the

SXS pretreated pulp. It was observed that the bleachability of the SXS pretreated pulp was higher when compared to the reference pulp.

Morphology of Bleached Pulps Fibers

The morphological characteristics of the pulps are shown in Table 7. The values obtained for the fibers morphology in the present study are within the range reported by Foelkel (2007), which mentions fibers lengths ranging from 0.6 to 0.85 mm, coarseness from 4.5 to 11 mg·100 m^{-1}, and fiber population from 12 to 30 million of fibers·g^{-1}.

Table 7. Morphological Characteristics of Bleached Pulps

Parameter	Material	
	Reference	Pretreated
Coarseness (mg·100 m^{-1})	5.83	5.80
Fiber population (10^6 fibers·g^{-1})	21.85	23.56
Average length (mm)	0.69	0.61
Average width (μm)	17.20	16.40
Wall fraction (%)	34.74	39.03
Fines content in length (%)	15.80	17.00

The coarseness is defined as the mass per unit of fiber length, expressed in milligrams per 100 m of fiber (Santos 2005). According to the same author this parameter affects the fibers response in the paper manufacturing and changes several of its structure, resistance and optical properties.

The SXS pretreatment did not affect the coarseness value (5.82 mg·100 m^{-1} (reference) *versus* 5.80 mg·100 m^{-1} (pretreated)). A high coarseness value, according to Foelkel (2009), implies a pulp that has high tear resistance, high specific volume, high porosity, high opacity, rapid water absorption, rapid drainage, rough paper surfaces, low fiber population, and low interfiber bonding.

Menegazzo (2012) reported that the fibers with thicker cell walls (larger wall fraction) are more rigid and harder to collapse; this results in more porous, bulky, rugged and absorbent paper since the amount of interfiber bonding is lower and sheet densification is negatively affected. The SXS pretreated pulp had a higher wall fraction value, which can lead to bulky and absorbent paper.

The fiber population is expressed as the number of fibers (in millions) per gram of pulp; this morphological parameter is inversely related to fiber length. A similar trend was observed as has been observed in earlier studies (Bassa 2006; Menegazzo 2012; Segura 2012), where the shorter the fiber length, the higher is the fiber population value. It was observed that the SXS pretreated pulp had a higher fiber population than the reference pulp, which had a lower fiber length.

The low fiber length observed for the pretreated pulp can negatively affect paper strength properties, which can be attributed to low fiber-to-fiber contact and bonding. The fines content also influences paper properties, such as improving the characteristics related to the resistance to mechanical stresses. The fines are formed during the cooking and the bleaching stages of pulp; the fines are comprised of short fibers, fiber fragments, vessel cells, parenchyma cells, and other xylem cells (Segura 2012).

Refining and Bleached Pulp Properties

The bleached pulps were refined in a PFI mill at four levels (0, 750, 1500, and 3000 revolutions), to assess their physical, optical, and mechanical properties (Figs. 2 and 3).

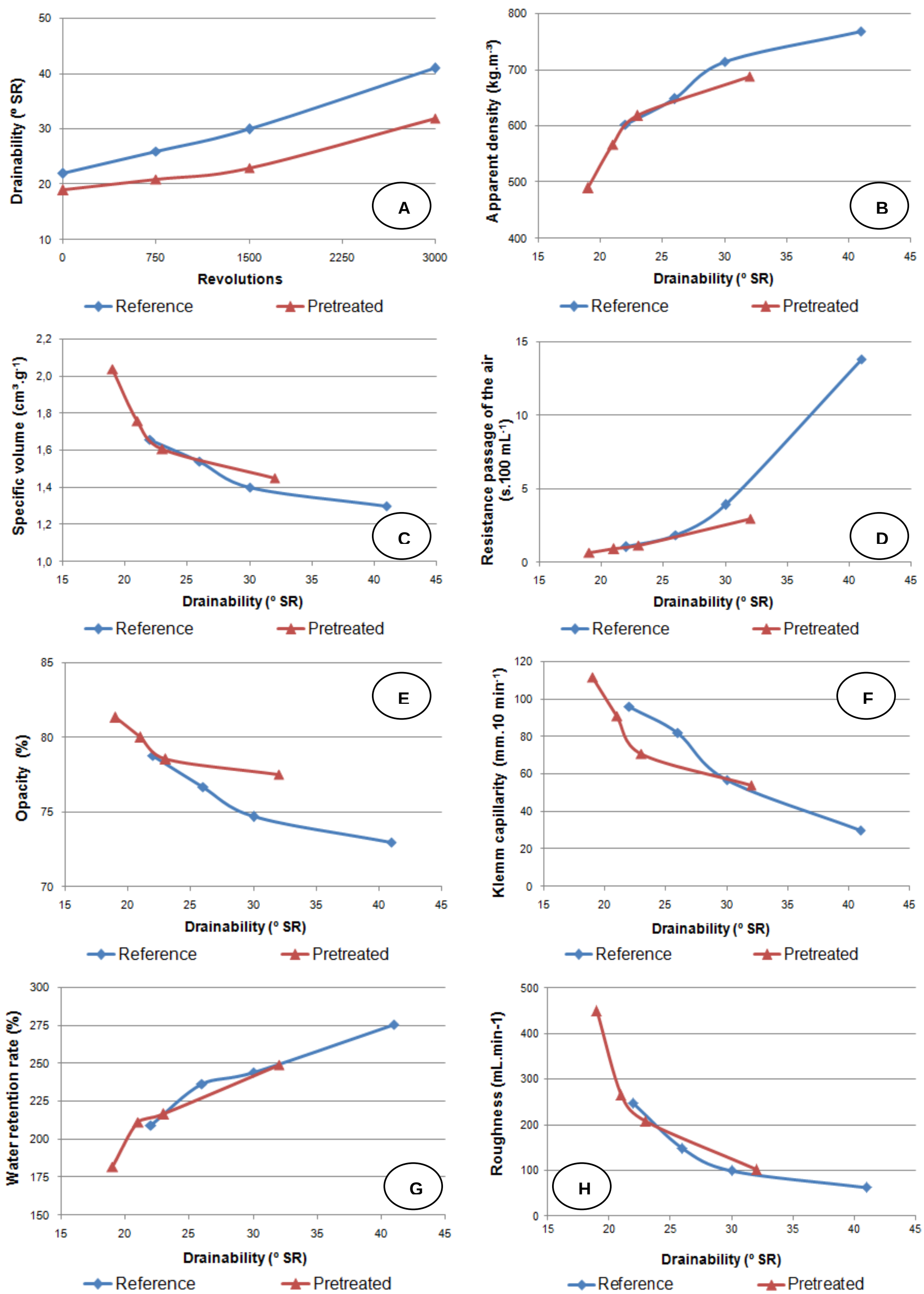

Fig. 2. Physical and optical properties of pulps as a function pulp drainage (°SR)

In Fig. 2A, the drainage of the reference and SXS pretreated pulps can be observed. The Schopper-Riegler (ºSR) value indicates the pulp's drainability. A higher ºSR value indicates slower water draining, which indicates increased pulp fiber fibrillation that results in more interfiber bonding potential.

The pulp from the reference chips had a slower drainability than the pulp from the chips pretreated with SXS. The ºSR value is directly related to other physical-mechanical properties, which is an indirect indicator of fiber-fiber bonding capacity.

According to Bassa (2006) the drainability increases with the refining, being acceptable up to levels that do not affect the paper machine operation, because the pulp drainage easiness positively influences on the paper machine speed.

Figures 2B and 2C show the apparent density and specific volume of pulps, respectively. The reference pulp had a higher apparent density that increased as ºSR value increased. As the fibrillation of the fibers increased as ºSR increased, the density and air resistance of the handsheets increased. The apparent density and the specific volume of the handsheets are inversely proportional to one another. According to Menegazzo (2012), higher specific sheet volume (*i.e.*, lower sheet density) is considered important in tissue manufacturing because it positively affects water absorption and sheet softness. In this regard, the pulp made from the SXS pretreated chips was more suitable for tissue manufacture.

Figure 2D plots the air resistance of handsheets made from pulps from the reference chips and those pretreated with SXS versus °SR value. The air resistance parameter indicates, according to D'Almeida *et al.* (2004), the difficulty of the air in crossing a sheet of paper, and varies according to the number, size, shape, and distribution of pores. Such properties influence the drying, printing, impregnation, and coating of paper (Silva 2011; Segura 2012).

Figure 2D shows that as the Schopper-Riegler increased above 30 ºSR, the air resistance increased more rapidly for the reference pulp in comparison to the SXS pretreated pulp. The interweaving of the fibers increases with the refining level, raising the resistance to air passage of the pulp.

Another important characteristic with hardwood kraft pulps is the opacity (Fig. 2E), which is an important quality parameter for printing and writing grades. Silva (2011) noted as the opacity of paper increases, the transparency of the paper decreases, which is desirable when printing on both sides of the paper. According to Segura (2012), this property is directly related to the fiber count of the pulps; higher fiber counts results in fewer light beams transmitting through the paper handsheet. As noted in Table 7, the SXS pretreated pulp had a higher fiber count and higher opacity versus the reference pulp, which confirms this statement.

Klemm capillarity is shown in Fig. 2F; Segura (2012) indicated that this property is important in the dryer section of paper and tissue manufacturing. The Klemm capillarity value of the SXS pretreated pulp was higher than the reference pulp, which indicated that the pretreated pulp has greater water absorption than the reference pulp.

In Fig. 2G, the water retention value is plotted, which indicates the ability of the kraft pulp to retain water. This quality parameter is important in drying section of paper and tissue manufacturing. The pulp from the reference chips showed the highest water retention value when compared to pretreated chips; the observed trend increased as Schopper-Riegler increased. Lower water retention values were noted for the pulp obtained from SXS pretreated chips, which suggested that a proportion of hemicelluloses were removed during the SXS pretreatment.

In Figure 2H it is possible to observe the roughness versus °SR value. The pulp from SXS pretreated chips is more rugged compared to the reference, reducing with increasing refining, indicating better arrangement of the fibers on the paper surface. The higher roughness of the pretreated pulp may be related to its higher specific volume. Such property is important for printing and writing papers.

In the case of the mechanical strength properties, tensile index obtained from the reference pulp and the pulp from SXS pretreated chips are plotted in Fig. 3A as a function of PFI revolutions. The index in question has great importance in the paper manufacturing, because it indicates the probability of sheet breaking during its production process, as well as its further processing in industrial/commercial scale.

As expected, the tensile index increased as PFI revolutions increased, which was due to higher fibrillation of the pulp fiber that increased fiber-to-fiber bonding. The pulp from the reference chips had a higher tensile index, almost double the value of the pulp made with chips pretreated with SXS. This observation can be explained based on the morphologies of the bleached fibers; the pretreated pulp fibers had a shorter length, and a higher wall volume fraction, which reduced fiber fibrillation and fiber-to-fiber bonding that lead to lower tensile strength.

According to Bassa (2006), the tensile and tear indices of the pulp are highly influenced by fiber length. The tensile index observed for the reference pulp is close to values reported by Segura (2012) for *E. grandis* x *E. urophylla* bleached kraft pulp for the same amount of PFI refining; the SXS pretreated pulp had lower values in comparison to the Segura (2012) study.

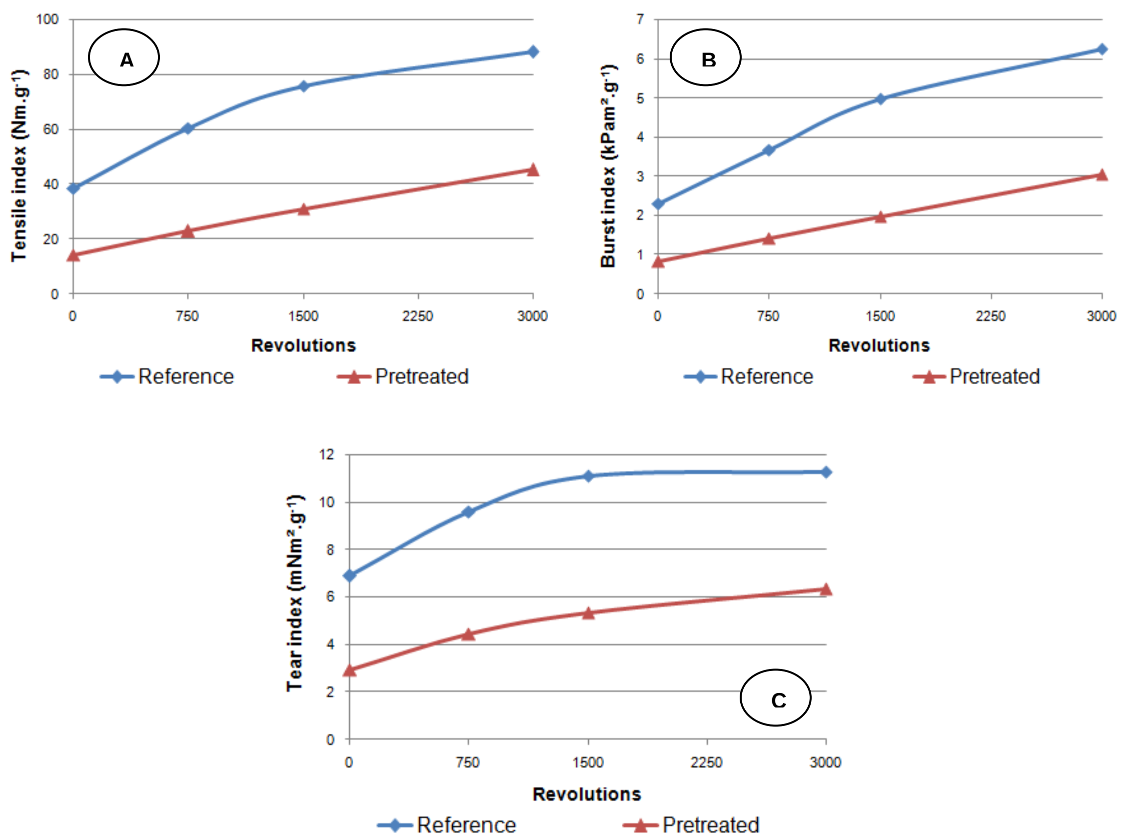

Fig. 3. Development of mechanical properties of pulps as a function of PFI refiner revolutions

Figure 3B plots the values for the burst index of pulps *versus* PFI revolutions. The burst index followed the same trend of other mechanical properties; *i.e.*, as refining revolutions increased, the strength index value increased, with the reference pulp having higher values than the SXS pretreated pulp.

Another important property is the tear index (Fig. 3C), which represents the strength required to propagate a fracture from an initial cut on a sheet of paper (D'Almeida *et al*. 2004). The reference pulp had a higher tear index, which was double the value observed for the SXS pretreated pulp. This strength property is related, among other factors, to the length of the fibers and to the fines content of the pulp.

In general, the pulp obtained from the reference chips had higher paper strength properties, whereas the SXS pretreated pulp had higher optical properties and certain other physical properties (*e.g*., specific volume). From these observations, the paper produced from the reference chips is judged to be more suitable for paper requiring high strength properties, such as the printing and writing grades. The pulp obtained from SXS pretreated chips would be more appropriate for tissue (absorbent/toilet) paper grades since the pulp has good liquid absorption capacity.

CONCLUSIONS

1. Pre-delignification with oxygen is more efficient for the pulp obtained from chips pretreated with sodium xylenesulphonate (SXS).
2. The chips pretreated with SXS increased the bleachability of the eucalypt kraft pulp, which led to a lower amount of bleach being used to reach the targeted brightness level.
3. The chips pretreated with sodium xylenesulphonate did not change appreciably the morphology of the bleached eucalypt fibers.
4. The pulp obtained from chips pretreated with sodium xylenesulphonate had better physical and optical properties, such as pulp drainability, pulp capillarity absorption, paper specific volume, roughness and paper opacity; these characteristic values for the SXS pretreated pulp indicated it has the potential to be used in tissue manufacture.
5. The pulp obtained from chips pretreated with sodium xylenesulphonate had low paper strength properties when compared to the reference pulp. This observation indicated that this pulp should not be used for paper grades where high paper strength is required.
6. Utilization of pretreated pulp may be suitable for dissolving cellulose or nanocellulose production.

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