PRODUCTION OF DISSOLVING GRADE PULP FROM ALFA

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Alfa, also known as *Stipa tenacissimaI* or "halfa", is grown in North Africa and south Spain. Due to its short fiber length, paper made from alfa pulp retains bulk and takes block letters well. In this study alfa was evaluated for bleached pulp production. Two cellulose pulps with different chemical compositions were pulped by a conventional kraft process. One sample was taken from the original alfa material and another from alfa that had been pretreated by diluted acid. The pulp produced from the pretreated alfa was bleached by the elemental-chlorine-free sequences DEPD and DEDP. The yield, Kappa number, brightness, and α- cellulose content of bleached and unbleached pulps were evaluated. The results showed that during the chemical pulping process, treated alfa cooked more easily than the original alfa. The treated alfa pulp also showed very good bleaching, reaching a brightness level of 94.8% ISO with a yield of 93.6% at an α-cellulose content 96.8(%) with a DEDP bleaching sequence, compared to 83.2% ISO brightness level, 92.8% yield, and 95.1% α-cellulose content for bleached pulp with a DEPD bleaching sequence. Therefore, this alfa material could be considered as a worthwhile choice for cellulosic fiber supply.

Keywords: Alfa; Kraft; Dissolving grade Pulp; Bleaching; Chlorine dioxide; Prehydrolysis

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INTRODUCTION

The paper consumption in the world has increased by 50% during the last decade, and the quantitative growth of paper production has been accompanied by a demand for new grades and by technological developments in response to ecological challenges (Lopez et al. 2001, 2003). In this sense, because of the shortage of wood, non-woody materials such as annual plants have received more attention in recent years for producing pulp, paper, paperboard, and cellulose derivatives (Atchison 1993; Ye et al. 2005). Currently, in developing countries, about 60% of cellulose fibers originate from non-wood raw materials such as bagasse (sugar cane fibers), cereal straw, bamboo, reeds, alfa (esparto grass), jute, flax, and sisal (Leminen et al. 1996; Katri 2001).

Alfa (*Stipa tenacissima*) is a hardy perennial grass. This plant is indigenous of the Western Mediterranean, and it grows on the semi arid grounds of North Africa and the southern Spain. Boudy (1950) estimated the esparto-covered surface in hectares at approximately 4.5 million hectares in Algeria, though a more recent report has estimated only 3 million (Ghebalou 2001). In Algeria, the species (*Stipa tenacissima*) grows mainly on the high plateaus in mixture with the sparte (spartumlegium) in an alternation of

vegetation studied by Chifu and Meziani (1995). The yield at havest varies with the density of the alfa coverage of 400 to 2000 kg ha^{-1} (Ramendo 1975).

Alfa fibers have thick walls and are short, normally less than 3 mm in length, with an average length of 1.5 mm. The fiber diameter varies from about 0.005 to 0.015 mm, with an average of about 0.012 mm, giving a length to diameter ratio of 125 (Harche 1982; Akchiche et al. 1987; Hurter 1988). Alfa refines quite quickly, yielding low strength properties, but retains bulk, air permeability, and excellent opacity. Its low fiber coarseness provides the sheet with a good formation, smoothness, and excellent opacity. A particular property of this pulp is its ability to give the sheet a good dimensional stability (El ghazi et al. 1997; Akchiche and Bouregda 2007). The formation, smoothness, and optical characteristics of this pulp makes it suitable for all fine paper grades. Its ability to create a dimensionally stable sheet finds uses in wallpaper base. The pulp also has a low extract conductivity, which finds application in some electrical grades (Harche and Catesson 1985).

Alfa has held its own against the competition with wood pulp for some time because of its favourable papermaking properties. The stock forms well on a paper machine because of free drainage and uniform fiber length, compared with rag or wood pulp. Another important characteristic of papers made from alfa is dimensional stability with changes in moisture content. Alfa contains 65 to 70 % of holocellulose, 18 to 25 % of lignin, 25 to 30 % of pentosans, and 4 to 5 % of mineral matter, and the silicate level is 1 to 2% (Nadji et al. 2006).

The good solubility of this lignin in an alkaline liquid makes it possible to use less active alkali and temperature for kraft or soda cooking (Houacine 1983; Hattali et al. 2004). Kraft processes produce a variety of pulps used mainly for packaging and high-strength papers and board. However, for most printing, for copying, and for some packaging grades, the pulp has to be bleached to remove the small fraction of the lignin remaining after cooking. Use of elemental chlorine in the pulp bleaching process causes the formation of toxic chemicals such as dioxins, furans, and adsorbable organic halides (AOX) in the wastewater (Brunner and Pulliam 1993; Mishra 2001). The characteristics of pulp mill effluents have the potential to be hazardous to both humans and marine life. For this purpose, elemental chlorine-free (ECF) bleaching, based on chlorine dioxide, offers a number of fundamental benefits for the pulp and paper industry over the traditional methods. Chlorine dioxide is a very selective bleaching reagent, preferentially oxidizing lignin in the presence of carbohydrates, thereby preserving pulp quality (Svenson et al. 2006). In addition, ClO_2 generates less chlorinated organics or absorbable chlorinated organic compound (AOX) compared to chlorine (Huggett 1994; Solomon 1996). However, there are issues surrounding the utilization of chlorine dioxide. Based on oxidation equivalents it's more expensive than elemental chlorine. Furthermore, the formation of chlorate and chlorite decrease its oxidation efficiency, further increasing the cost of bleaching (Svenson et al. 2006).

The objective of the study presented here was to compare and evaluate kraft pulping of alfa with and without a prehydrolysis process, and ECF bleaching process of alfa pulp. Yield, Kappa number, cellulose, and viscosity were examined in order to determine the best bleaching conditions of the pulp.

EXPERIMENTAL

Raw Material

The alfa was provided by the pulp and paper mill of Saida, in south Algeria. For pulping, stems of length 60-70 cm were washed with water to remove the residues, dried under the sun, and manually cut up approximately to the size of 3 to 4 cm. This was designated as original alfa (OA). An OA sample was pretreated with 0.75% sulfuric acid solution under the following conditions: solid:liquid ratio equal to 1:5, temperature 120°C, pressure 6 bar, and retention time 120 min (Nguyen et al. 1998). After the reaction, the solid residue was separated, then washed with water until neutral pH. This sample was designated acid pretreated alfa (APA). Characteristics of OA and APA are given in Table 1.

Methods

Kraft pulping

Unbleached pulps were obtained from both OA and APA. For the sulfate pulping reaction, a 5 L stainless steel batch cylindrical pressurized reactor was filled with chips of alfa, in addition to sulfate liquor. A 5:1 liquor to alfa ratio was used with 18% active alkali on chips as Na_2O and 24% sulfidity. The time to reach the max temperature of 145 °C was 90 min, and the duration at 145°C was 150 min (Houacine et al. 1983a; Akchich et al. 2007). Following cooking, the pulp was separated from the black liquor by filtration, washed with distilled water on a sieve of 0.16 mm mesh to remove residual alkali, dried, and screened to separate shives. The pulp obtained from the original alfa material was termed OAP, while that obtained from pretreated alfa was designated APAP. The characteristics of the pulps obtained are given in Table 2.

Pulp bleaching procedure

Alfa pulps free of shives were submitted to an oxidative delignification process. This bleaching process was done in 4 stages, using chlorine dioxide (D), alkali extraction (E), and hydrogen peroxide (P).

Pulp bleaching procedure by chlorine dioxide (D)

The preparation of pure aqueous ClO_2 solutions was carried out by acidification of saturated aqueous $NaClO_2$ with 4 N sulfuric acid and ClO_2 gas absorption in pure refreshed water. The ClO_2 concentration was 8.5 g l^{-1}, with an undetectable level of chlorine.

The alfa screened pulps were loaded into heat-proof polystyrene bags that were subsequently placed in a thermostat regulated bath for the retention time of 2 h, consistency of 10%, pH= 3.5, four temperature levels of 50, 60, 70, and 80 °C, and the chlorine dioxide concentrations used in the different experiments were 0.5, 1, 1.5, 2, 2.5, and 3% of o.d. pulps. After the D stage, pulp was discharged from the reactor and washed with distilled water. Then next step of alkali extraction (E) was carried out using 10% consistency, 70 °C temperature for 60 min, pH > 10, and NaOH concentrations of 1, 1.25, 1.75, 2, 2.5, 2.75, 3.75, and 4% of o.d. pulps.

Pulp bleaching procedure by hydrogen dioxide (P)

The pulp was loaded into heat-proof polystyrene bags that were subsequently placed in a thermostat regulated bath at 70 °C, a consistency of 10%, a NaOH concentration of 1.8%, and sodium silicate ($Na_2SiO_3 \cdot 9H_2O$) 5% relative to the weight of absolutely dry cellulose. The hydrogen peroxide concentrations and retention times for each step used in the different experiments were from 1% to 5% and 30 to 210 min, respectively.

Analyses

After each step, washed and dried pulp was analyzed. Pulp yield expressed on a screened material basis (referred to dry matter) was determined gravimetrically. Moisture content of the pulp was determined as per TAPPI test method T 210 cm-86. The standard method was used to measure the Kappa number (PN-70/P50093). To determine the percentage of lignin content in pulp on the basis of kappa number, a conversion index 0.15 was assumed. Alpha cellulose, the pulp fraction resistant to a treatment in an aqueous solution containing 17.5% sodium hydroxide, was determined by TAPPI method T 203 om-88. The brightness and whiteness of the pulp were measured using Technibrite TB 1c instruments as per TAPPI method T 525 om-02, and T 560 pm-96, respectively. The viscosity of pulp was determined by capillary viscosimetry using TAPPI test method T230 om-99. Chemical oxygen demand (COD) of the effluent generated from bleaching sequences was estimated by an open reflux method (Degremont 2005)

RESULTS AND DISCUSSION

The chemical composition of alfa is shown in Table 1. Cellulose was the major component, followed by hemicelluloses and lignin. The smallest components were extractives and ash. The silicate in the alfa accounted for 2.53% of the mass. According to Han (1998) it was a much higher than the content in wood. The comparative analyses of chemical composition reveal some differences between original and prehydrolyzed alfa. The pretreated alfa was richer in cellulose (60.57% vs. 47.63%), lignin (22.85% vs. 17.71%), silicates (3.56% vs. 2.53%), and ashes (6.63% vs. 5.12%) and poor in hemicelluloses (4.43% vs. 22.15%) and extractible matter (4.22% vs. 6.59%), as compared with original alfa. Hemicelluloses are much more susceptible to attack with dilute acids than cellulose or lignin (McMillan 1994; Grace et al. 1996). This probably occurs because its structure is ramified, and the sugar units are linked by bonds weaker than those of the glucose units in cellulose (Kholkine 1989). Lignin is a cross-linked hydroxylated and methoxylated aromatic macromolecule that gives colour, resistance to biological attack, and structural rigidity to the material cell wall, and because its different units are linked by series of ether and carbon-carbon linkages, it presents considerable resistance to chemical degradation (Nikitin et al. 1978; Chen et al. 2001).

Table 1. Chemical Composition of the Original and Acid-Pretreated Alfa

Component	Composition (% dry weight)	
	OA	APA
Cellulose	47.63	60.57
Hemicelluloses	22.15	4.43
Lignin	17.71	22.85
Silicates	2.53	3.56
Extractable matters	6.59	4.22
Ash	5.12	6.62
Other	0.80	0.31

Cooking

Two alfa chips samples (OA and APA) were chosen for cooking. Chemical properties of the pulps are shown in Table 2. Contents of α-cellulose (an indicator of cellulose purity) approached 86.3% and 93.3% for OA pulps and APA pulps, respectively. These results clearly show that acid pre-hydrolysis was effective in increasing cellulose purity (Day et al. 2007). Hemicelluloses, lignin, and ash contents of pulps of APA, which are indicators of cellulose impurity, were not comparable to those of OA pulps. With the same cooking conditions, the total pulp yield of OA was 43.5% higher than that of APA, which was 36.7%.

The high yield has to be attributed to the possible preservation of a high amount of high-molecular weight xylan (Jahan et al. 2008). This is indicative of the effectiveness of sulfate cooking after acid pre-hydrolysis treatment for increasing cellulose purity. The amount of reject material, defined as the difference between total and screened yields, was much lower in the sulfate pulp of APA. This could be due to a good diffusion of white liquor into the chips and/or to strongly affected structure of chips (Testova 2006).

The Kappa number was included in this study to measure the content of pulps in compounds susceptible to oxidation in bleaching. The best results in terms of Kappa number were found with kraft-processed APA (3.2%), which corresponded to lignin contents of 1.34%. This lower Kappa number contributed to improved optical properties of this pulp (41.3% ISO brightness), which were better than the results determined for kraft pulps produced from original alfa (23.5% ISO brightness). The kraft delignification of pre-hydrolysed chips resulted in a lower content of hemicelluloses (0.15%) than in kraft delignification of original alfa (5.38%). The pulp viscosity was 22.8 cp and 20.6 cp for OAP and APAP respectively. The aforementioned results confirmed the very well known concept that higher Kappa pulps present higher yield and viscosity. Therefore, it can be concluded that kraft pulping of pre-hydrolysed chips may be best in order to produce viscose-grade pulps.

Table 2. Results of Kraft Pulping of OA and APA

Parameters	OAP	APAP
Total yield (%)	43.5	36.7
Rejects (%)	0.88	0.21
α- cellulose (%)	68.4	76.8
Kappa number	18.2	8.6
Klason lignin (%)	2.73	1.3
Hemicelluloses (%)	5.38	0.15
Viscosity (cp)	22.8	20.6
Brightness (% ISO)	23.5	41.3
Ash (%)	1.01	0.08

ECF Bleaching

The experimental conditions selected to bleach pulps were fixed according to literature data and our own experience.

Chlorine Dioxide Delignification

Bleached pulps showed different properties according to the material used, demonstrating that the dilute acid pretreatment before pulping process affected the characteristics of the produced pulps. As show in Table 3, the kappa number (a measure of lignin content) of bleached APA pulp was lower than that of bleached OA pulps. On the other hand, the brightness and α-cellulose content were higher in the bleached APA pulp than in the bleached OA pulps. The presence of extractives in the unbleached OA pulps negatively affected the bleaching process (Mussatto et al. 2008). According to Fengel and Wegener (1989) extractives must be removed prior the lignin isolation to avoid the formation of condensation products with lignin during the pulping process.

The chlorine dioxide oxidation started with different temperatures and concentrations of ClO_2. The results obtained suggest that there is no reason to increase the temperature more than 70 °C. The low Kappa numbers of 7.5 and 3.3, respectively, were achieved at this temperature from OA and APA. In addition, at this temperature the brightness of the both pulps was the highest, 63.6 and 71.3, for the pulps produced from OA and APA, respectively. In this case, the ClO_2 concentration was 3% based on the weight of dried pulp. A higher α-cellulose in pulp was obtained at the same temperature with a ClO_2 concentration of 1.5 - 2%.

Alkali Extraction

This stage achieves extraction of degraded lignin compounds, which would otherwise increase the chemical usage in subsequent bleaching stages, by means of caustic (NaOH) solution. The objective of this step is the removal of chromophores generated during previous steps: chlorinated and oxidized lignin fragments are removed, and this increases the brightness that can be imparted by subsequent bleaching steps, yielding better brightness, opacity, softness, and mechanical properties, with limited removal of polysaccharides (Süss 2006). The experimental results obtained in this extraction process are shown in Table 4. It can be seen that at the same level of alkali

extraction, pulp produced from APA, after E stage, had the lowest Kappa number, highest brightness, and highest contents of α-cellulose compared to pulps produced from OA. With lower amounts of NaOH in interval from 1 to 2 %, Kappa number rapidly decreased and for a given amount beyond 2% stabilised at 1.8 and 0.8 for pulps OA and APA, respectively. On the other hand, brightness and α-cellulose content increased with increasing NaOH. The optimum amount of NaOH was 2% od pulps, for which OA pulps achieved a Kappa number, brightness, and α-cellulose content of 1.9, 68.5%, and 90.6%, respectively. In the case of APA pulps, at 2% level of NaOH based on od pulps, the Kappa number, brightness, and α-cellulose content reached 0.8, 83.6%, and 94.6%, respectively. It was not possible to produce a dissolving grade pulp from paper grade kraft pulp without applying a prehydrolysis stage before pulping (see results Table 4), probably because of the conversion of some hemicelluloses fractions to an alkali-insoluble form.

Table 3. Effect of ClO_2 Consistency and Temperature on the Bleaching Process

ClO_2 consistency, (% dried pulps)	Temper-ature, C°	OAP			APAP		
		Kappa number	Bright-ness, %	α-cellulose, %	Kappa number	Bright-ness, %	α-cellulose, %
0	-	18.2	23.5	68.4	8.6	41.3	76.8
0.5	50	15.3	28.6	83.5	7.3	63.6	87.5
1	50	14.2	32.8	83.5	5.6	66.7	87.0
1.5	50	12.8	37.2	83.6	4.8	68.2	87.2
2	50	10.7	40.8	83.8	4.5	67.4	87.1
2.5	50	9.9	46.7	85.1	4.4	67.3	87.6
3	50	9.6	51.3	85.5	4.1	66.6	87.5
0.5	60	12.7	38.7	83.8	6.7	65.9	88.5
1	60	10.1	45.3	83.9	5.8	66.2	88.7
1.5	60	9.5	50.5	85.0	5.2	68.5	88.2
2	60	8.6	52.1	85.5	4.3	68.7	88.5
2.5	60	8.2	57.4	86.8	3.8	70.1	88.5
3	60	7.9	60.8	86.5	3.8	68.3	88.8
0.5	70	10.3	45.9	86.9	6.2	69.6	89.7
1	70	9.1	50.1	86.6	4.7	71.3	90.1
1.5	70	8.1	53.2	87.4	3.8	71.6	90.7
2	70	7.8	55.2	87.1	3.6	70.8	90.5
2.5	70	7.6	63.5	86.8	3.5	71.2	89.8
3	70	7.5	63.6	85.8	3.3	71.3	89.3
0.5	80	9.3	50.3	85.3	5.5	69.3	89.5
1.	80	8.4	55.8	86.2	4.6	68.9	89.7
1.5	80	7.8	56.3	85.8	4.2	68.6	89.2
2	80	7.9	62.3	85.4	3.8	68.7	89.7
2.5	80	7.7	63.2	84.3	3.7	68.8	88.1
3	80	7.8	63.8	84.4	3.5	68.6	88.3

Time= 120 min, Consistency = 10%, pH =3.5

Table 4. Effect of the NaOH Consistency on the Alkali Extraction Process

NaOH consistency (% dried pulps)	OAP			APAP		
	Kappa number	Brightness (%)	α-cellulose (%)	Kappa number	Brightness (%)	α-cellulose (%)
-	7.9	53.7	87.3	3.6	71.8	90.5
1	5.2	60.5	88.4	2.3	76.8	92.2
1.25	3.6	63.7	88.7	1.1	79.4	93.5
1.75	2.5	66.9	90.2	0.9	81.6	94.2
2	1.9	68.5	90.6	0.8	83.6	94.6
2.5	1.8	69.2	90.8	0.8	84.2	95.1
2.75	1.9	69.6	91.5	0.8	84.7	95.6
3.25	1.9	70.2	91.6	0.8	85.2	95.8
4	1.9	70.6	92.3	0.8	85.6	96.3

Time = 60 min , Consistency = 10%, pH >10 , T = 70 °C

Bleaching Sequence

The experimental conditions of sequences DEPD and DEDP selected to bleach APA pulp to viscose grade end products were fixed as shown in Tables 5 and 6, according to literature data and our own experience. According to Abrantes et al. (2007), although hydrogen peroxide is a successful bleaching agent, its effectiveness is limited by a poor selectivity, which is reflected by a severe viscosity loss. It is generally admitted that the radicals generated during the peroxide decomposition are responsible for this cellulose degradation. A possible alternative to minimize this problem would be the use of magnesium sulfate in the peroxide stage, because this salt is reported to be extremely efficient at reducing the rate of peroxide decomposition, and thus it could prevent the radical degradation reactions of carbohydrates (Lapierre et al. 2003). The bleaching results for each studied sequence are summarized in Table 7. Bleached pulp presented different characteristics according to the bleached stage used. The yield, α-cellulose, and brightness of pulp during the DEDP bleaching sequence and the COD of the liquid effluent were higher than those of pulp subjected to the DEPD bleaching sequence. The bleached pulp was without lignin, indicating that all the lignin present in unbleached pulp was removed using DEDP or DEPD bleaching sequences, and the cellulose pulp was more easily bleached, achieving a white colour corresponding to a high brightness.

The difference between the two sequences was 0.8% in terms of pulp yield, showing an advantage for the DEDP sequence, which reached a value of 93.6%. The losses in weight during the process of bleaching were the result of delignification, the hydrolysis, and the solubilisation of pentose and low-weight cellulose molecular (Dapia et al. 2003). The significant quantity of degraded and solubilised polysaccharides was estimated by the COD of the liquid effluents of extraction, which was of 53 and 58 g kg^{-1} dry fibres for DEPD and DEDP bleaching sequences, respectively. A brightness of 83.2% ISO and higher is to be regarded as a good value, considering the simplicity of the bleaching process employed and the use of an ECF bleaching sequence. Pulp subjected to the DEDP bleaching sequence showed a 11.6% higher ISO brightness than the pulp subjected to the DEPD bleaching sequence. These results are in agreement with the finding of French researchers (Lachenal et al. 2005a). They reported that use of peroxide in the end of the bleaching sequence results in better brightness. Peroxide is one of the best candidates for degrading quinines, which are mainly responsible for yellowing of the pulp (Kumar et al. 2007). Use of ClO_2 actually leads to slow and incomplete destruction

of quinonic chromophores and also the creation of new quinine groups (Lachenal et al. 2005b). Therefore, the use of ClO_2 at the end of the bleaching sequence is not the best choice in terms of brightness development. The viscosity of the pulp after bleaching sequence was remarkably decreased. Pulp after DEPD bleaching had higher viscosity (14.6 cp) than that of DEDP (13.2 cp). This could be due to the presence of pentosans in the pulp, after the alkali extraction stage, which protected the cellulose from degradation by the OOH free radical present during peroxide delignification of third stage. Pentosans compete with the cellulose for these radicals and thus avoid undue loss of molecular weight of the cellulose (Zou et al. 2002).

An essential requirement for textile fibers is that the pulp source should contain a high α-cellulose fraction (Mark 1941). This is necessary to obtain the desired physical properties, such as strength and extensibility. The two bleached pulps derived from the DEPD and DEDP sequences showed the highest proportion of the α-cellulose content, indicating that the average cellulose chain length (polymerization degree) was increased. The α-cellulose content in case of the DEDP sequence was better as compared to the DEPD sequence. The α-cellulose content was 96.8% and 95.1% in the DEDP and DEPD sequences, respectively. The high α-cellulose content is attributable to high cellulose yield and possibility the preservation of a high amount of high molecular weight.

Table 5. Conditions of Bleaching and the Amount of the Chemicals for the DEPD Sequence

Stages	D	E	P	D
Consistency of the pulp (%)	10	10	10	10
Temperature (°C)	70	60	80	70
Time (min)	180	80	120	60
Concentration of ClO_2 (%)	1.5	-	-	1
Concentration of NaOH (%)	-	10	-	-
Concentration of H_2O_2 (%)	-	-	3	-
pH	4	12	11	10
At the H_2O_2 stage, concentration of NaOH (%)	-	-	2	-
$MgSO_4$ (%)	-	-	0.05	-
Na_2SiO_2 (%)	-	-	1.5	-

Table 6. Conditions of Bleaching and the Amount of the Chemicals for the DEDP sequence

Stages	D	E	D	P
Consistency of the pulp (%)	10	10	10	10
Temperature (°C)	70	60	70	80
Time (min)	180	80	60	90
Consistency of ClO_2 (%)	1.5	-	1	-
Consistency of NaOH (%)	-	10	-	-
Consistency of H_2O_2 (%)	-	-	-	0.8
pH	4	12	10	11
At the stage H_2O_2, consistency of NaOH (%)	-	-	-	0.8
$MgSO_4$ (%)	-	-	-	0.5
Na_2SiO_2 (%)	-	-	-	2.5

Table 7. Physicochemical Parameters Bleaching Kraft Pulp from Two Distinct Sequences of Bleaching

Bleached Parameters	Bleaching sequences	
	DEPD	DEDP
Yield (%)	92.8	93.6
α-cellulose (%)	95.1	96.8
Brightness (%)	83.2	94.8
Lignin (%)	-	-
Viscosity (cp)	14.6	13.2
COD g/kg dried pulp.	53	58

CONCLUSIONS

Based up on these results it is concluded that the high hemicelluloses (22.15%) and extractives (6.59 %) contents in the original alfa affected the pulping and bleaching processes. However, kraft pulping of acid pre-treated alfa gave an α-cellulose rich pulp (76.8 %), although the pulp yield was low (36.7 %). These results show that kraft and ECF delignification of acid pre-treated alfa is an attractive approach for production high purity cellulose pulp. The results obtained in this study demonstrate that alfa presents technological characteristics suitable for production of bleached kraft pulp, making this species an excellent raw material source for dissolving pulp.

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