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Short Communication

TCF bleaching of soda-anthraquinone and diethanolamine pulp from oil palm empty fruit bunches

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ABSTRACT

The AOpAZRP bleaching sequence (A is an acid treatment, Op an oxygen and peroxide stage, Z an ozone stage, R a reductive treatment and P a peroxide stage) have been applied to oil palm empty fruit bunches (EFB) soda-anthraquinone and diethanolamine pulp. On similar Kappa numbers for the two types of pulp (14.2 and 17.3), paper from unbleached soda-anthraquinone pulp exhibited increased tensile index (25.8 Nm/g), stretch (2.35%), burst index (1.69 kN/g), tear index (0.50 mN m^2/g) and brightness (60.6%) relative to paper for unbleached diethanolamine pulp; but the latter type of pulp exhibited higher viscosity (659 mL/g) than the former. Upon bleaching with the AOpAZRP sequence, diethanolamine pulp exhibited higher viscosity (783 mL/g), and the properties of the paper sheets were close to or even better to those from soda-anthraquinone pulp, namely: 22.2 *vs* 20.4 Nm/g tensile index, 1.30 *vs* 1.42 kN/g burst index, 0.71 *vs* 0.70 mN m^2/g tear index and 71.3% *vs* 77.5% brightness. Therefore, the properties of paper from diethanolamine pulp evolved more favourably during bleaching than did those of paper from soda-anthraquinone pulp.

1. Introduction

Paper consumption has grown substantially over the past few decades; thus, the figure for 2005, world consumption of paper was 352 millions ton, a 31.8% higher than that for 1990 (Annual FAO, 2005). Consumption of pulping raw materials has also grown in parallel. Paper continues to be obtained largely (90–92%) from hardwood or softwood and, to a much smaller extent, from non-wood raw materials such as agricultural and agrifood residues (e.g., oil palm empty fruit bunches) or annual and non-annual plants providing large amounts of biomass (e.g., kenaf, sorghum). Wood pulp production increased by about 4% over the period 1999–2003; by contrast, non-wood pulp production rose by 10% in response to the need for alternative raw materials, a need which has arisen from the growing concern with environmental (e.g., deforestation) and economic problems (some countries lack wood but abound with non-wood resources) (Alaejos et al., 2004).

One specially attractive non-wood pulping material is provided by oil palm empty fruit bunches (EFB), which constitutes an effective source of lignocellulosic fibre as confirmed by various researchers. Thus Ibrahim (2002), compared the composition of kraft, kraft-anthraquinone, soda and soda-anthraquinone pulp from EFB and found the soda variant to exhibit the best properties. The soda process has also been used to obtain chemical and semi-chemical pulp from EFB (Law and Jiang, 2001; Wan Rosli et al., 2004; Roliadi and Pasaribu, 2004). EFB have also been used in organosolv (Aziz et al., 2002; Quader and Lonnberg, 2005; Rodríguez et al., 2008) and mechanical pulping processes (Daud et al., 2005; Ghazali et al., 2006).

Only three references to the bleaching of EFB pulp appear to exist, however. In them, kraft and soda pulp from EFB was bleached with totally chlorine free (TCF) sequences. In one (Tanaka et al., 2004), the pulp was subjected to an OZP (Oxygen-Ozone-Hydrogen Peroxide) sequence with a sulphuric acid treatment inserted between the O and Z steps. In other (Leh et al., 2005), soda, soda-anthraquinone, kraft and kraft-anthraquinone pulp from EFB was subjected to an OZP sequence in order to assess the effect of the bleaching treatment on viscosity and kappa number; soda-anthraquinone and kraft-anthraquinone pulp exhibited 80% brightness and while retaining a viscosity above 15 cp. And the last one (Leh et al., 2008) optimizes delignification with oxygen in TCF pulp production.

In this work, were examined and compared changes in the properties of soda-anthraquinone and diethanolamine pulp from EFB (yield, kappa number, beating grade and viscosity) and of paper sheets made from them (tensile index, stretch, burst index, tear index and brightness) after each step of an AOpAZRP bleaching sequence (A is a acid treatment, Op an oxygen and hydrogen peroxide stage, Z an ozone stage, R a reductive treatment and P an hydrogen peroxide stage).

The soda-anthraquinone pulping process was chosen on the grounds of its usually providing quality pulp (Law and Jiang, 2001; Ibrahim, 2002), using no sulphur which avoids the release of pollutants and causing bad odours and requiring only modest

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amounts of raw material to be profitable which is compatible with the low non-wood production of some regions in the world.

Organosolv pulping processes, which use no sulphur-containing reagent either, have only recently been implemented on the pilot plant or industrial scale (López et al., 2006; Rodríguez and Jiménez, in press), largely in response to the need to respond to the new economic and, especially, environmental challenges. Their greatest shortcoming is that they usually require high pressures, and hence special equipment, which raises operational costs. This makes the use of solvents with a high boiling point (e.g., diethanolamine) a potentially interesting alternative, because of installation is less expensive when operating to smaller pressures (Rodríguez et al., 2008; Rodríguez and Jiménez, in press).

On the other hand, the restrictive legislation of the developed countries with respect to the use of chlorine composed in the bleaching of pulps, by means ECF process (elemental chlorine free), it is leading to the scientific community to the use of TCF bleaching process (totally chlorine free). For that reason, in the last years, are studying and applying TCF bleaching sequences to pulps of different raw material, wood and non-wood: *Eucalyptus globulus* (Roncero et al., 2005; Freire et al., 2006; Shatalov and Pereira, 2008a), flax (Sigoillot et al., 2005), *Arundo donax* L. (Abrantes et al., 2007; Shatalov and Pereira, 2007, 2008b), *Asclepios syriaca* (Spiridon, 2007) and wheat straw (Hedjazi et al., 2008).

2. Experimental

2.1. Raw material

There are three major species of oil palm, namely: *Elaeis guineensis*, *E. oleifera* and *E. odera*. We used *E. guineensis*, which is known as African palm because it originated in West Africa, where it has been used to obtain oil for more than five thousand years (particularly in Western Guinea). After Columbus' travels, African palm was introduced in American, from which it reached the Asian continent (Sumatra and Malaysia) in *ca.* 1900. Malaysia is currently the greatest world producer of palm oil, with 51% of the world output; therefore, palm oil constitutes a great asset for this country. Cultivation of the plant is currently expanding in Western Africa (Nigeria, Guinea, Ghana), Latin America (Ecuador, Colombia, Honduras) and Asia (Thailand) (Rodríguez et al., 2008).

Palm plants give their first fruits 4–5 years after planting; production peaks after 20–30 years and then declines to eventually unprofitable levels particularly as result of the remaining fruits being too high to collect. Palm bunches weigh 15–25 kg and contains 1000–4000 egg-shaped fruits 3–5 cm long each. Each hectare of oil palm produces an average of 10 ton of fruits per year from which an amount of *ca.* 3000 kg of oil is obtained. The process leaves substantial amounts of empty fruit bunches (EFB) (Rodríguez et al., 2008).

2.2. Analysis of the raw material

The EFB were characterized as follows: holocellulose by the Wise et al. method (1946); and α-cellulose, lignin, ash and ethanol-benzene extractable according to T-203 os-61, T-222, T-211 and T-204 (TAPPI Standards, 2007), respectively.

Oil palm empty fruit bunches contain 67.0% holocellulose, 47.9% α-cellulose, 24.5% lignin, 4% hot water solubles, 40.2% soda solubles (1%), 1.8% alcohol-benzene extractable and 3.2% ash.

2.3. Pulping and pulp characterization

Pulp was obtained by using a 15 L batch cylindrical reactor that was heated by means of electrical wires and linked through a rotary axle to ensure proper agitation to a control unit including a motor actuating the reactor and the required instruments for measurement and control of the pressure and temperature.

Table 1
Operating conditions used to obtain EFB pulp for subsequent A_1OpA_2ZRP bleaching sequence

Pulp	Temperature (°C)	Time (min)	Chemical concentration (%)	Liquid/solid ratio
Soda-anthraquinone	170	60	15% soda 0.5% anthraquinone	4
Diethanolamine	180	150	80%	6

Table 2
Operating conditions used to bleach EFB pulp with an A_1OpA_2ZRP sequence

Variables	Stages of sequence AOpAZRP					
	A	Op	A	Z	R	P
Consistency (%)	1.5	10	7	40	10	10
Temperature (°C)	25	100	25	25	25	85
Time (min)	30	60	30	6	60	150
Oxalic acid (%)	4		4			
Oxygen pressure (kg/cm^2)		6				
$MgSO_4$ (%)		0.5				0.2
H_2O_2 (%)		2				2
NaOH (%)		1.8				1.8
DTPA (%)		0.1				0.5
Oxygen flow (L/h)				180		
Ozone (g/L)				35		
$NaBH_4$ (%)					2	
Na_2CO_3 (%)					1	

The raw material was cooked (with soda-anthraquinone or diethanolamine) in the reactor. Next, the cooked material was fiberized in a wet disintegrator at 1200 rpm for 30 min and the screenings were separated by sieving through a screen of 0.16 mm mesh size. The pulp obtained was beated in a Sprout–Bauer refiner.

The conditions used in the soda-anthraquinone and diethanolamine processes Table 1, were chosen in such a way as to provide similar kappa numbers for both types of pulp.

The viscosity, kappa number and beating grade (Shopper–Riegler index) of the pulp were determined according to T-254, T-236 cm-85 and T-248 (TAPPI Standards, 2007), respectively. Pulp yield was determined by weighing, after removing the uncooked material.

2.4. Bleaching

The two types of EFB pulp were bleached with an AOpAZRP sequence (Serrano, 2008). The operating conditions used to implement this bleaching sequence are summarized in Table 2.

2.5. Paper sheets formation and characterization

Paper sheets were prepared with an ENJO-F-39.71 sheet machine according to the UNE-57-042 standard.

The tensile index, stretch, burst index, tear index and brightness of paper sheets were determined according to T-494 om 96, T-494, T-403 om-97, T-414 om 98 and T-452 (TAPPI Standards, 2007), respectively.

3. Results and discussion

Table 3 shows the experimental values of yield, kappa number, beating grade and viscosity for bleached soda-anthraquinone pulp and diethanolamine pulp, and the tensile index, stretch, burst index, tear index and brightness of paper sheets obtained from them.