RELATION BETWEEN WOOD DENSITY AND PAPER PROPERTIES OF SOME HARDWOOD SPECIES

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INTRODUCTION

Bleached *Eucalyptus globulus* kraft pulp has the most used hardwood species to produce paper to printing and writing papers due to its singular characteristics. The performance of this specie is mainly due to the morphological characteristics of the pulp fibers, in particular its high Runkel ratio and the relatively low pulp fibers width. In addition to these characteristics, the low fiber length leads to a very high number of fibers per gram, which confers to the papers a good formation (Paavilainen, 2000). At the same time the paper exhibits good strength properties, even though at the expense of a relatively high-energy consumption in beating (Santos et al., 2006).

Acacia melanoxylon R. Br., usually named Blackwood, grows spontaneously in Portugal. This species is well adapted to the Portuguese soil and climate and can grow in pure or mixed stands with other species namely *Pinus pinaster* Aiton. In comparison with eucalypt acacia has good potential. These fibers lead to papers with good relationship between light scattering and tensile strength, at low refining energy consumption (Santos *et al*., 2006). On the other hand, at a given drainage resistance (30 ºSR), the papers produced with acacia (*A. dealbata* and *A. melanoxylon*) present higher apparent densities than eucalypt (Santos *et al*., 2006) because their pulp fibres have lower coarseness and higher flexibility and collapsibility, which can be a disadvantage in terms of paper stiffness.

The relationships between paper properties and raw material properties, namely wood chip density, have been studied by several authors (Paavilainen 1989; Paavilainen, 2000; Downes *et al*., 2003; Kibblewhite *et al*., 2003; Santos *et al*., 2008). In addition, it is a very well documented fact that there is quite a high variability of the fibers morphology within trees, between trees within a stand, and between trees from different stands (Downes *et al*., 2003; Evans *et al*., 1999), as a consequence of genetic variability, edapho-climatic conditions and cambium age.

In this work we study the relation between the wood density of too hardwood species and the behaviour in kraft cooking and papermaking. We analyzed three *Eucalyptus globulus* wood chip samples with basic densities of 0.467, 0.537 and 0.600 g/cm^3 and three *Acacia melanoxylon* wood chip samples, with basic densities of 0.449, 0.505 and 0.616 g/cm^3.

MATERIAL AND METHODS

The wood chip samples were previously screened in order to remove the over-thickness chips (>8 mm) and the fines. The chip basic density was determined according to the TAPPI 258 om-94 standard procedure. The wood chips were submitted to a conventional kraft cooking process under the following reaction conditions: effective alkali charge - variable; sulfidity index - 30%; liquor/wood ratio - 4/1; time to temperature - 90 min; time at temperature (160 ºC) - variable. Experiments were carried out with 1000 g o.d. of wood in a forced circulation digester. The cooked chips were disintegrated, washed, and screened on a L&W screen with 0.3 mm slot width. The accepted material was collected on a 200-mesh screen. The screened and total yields were gravimetrically determined. Kappa number and pulp viscosity were evaluated. The unbleached kraft pulps were submitted to a bleaching $D_0E_1D_1E_2D_2$ sequence, using a kappa factor of 0.2 in the D_0 stage and the same charges and reaction conditions in the remaining stages. The morphological properties of pulp fibers were determined automatically by image analysis of a diluted suspension (20 mg/L) in a flow chamber in Morfi®. The pulps were beaten in a PFI mill at 500 revolutions under a refining intensity of 1.7 N/mm.

Paper handsheets were prepared according to the Scan standard and tested regarding structural, mechanical and optical properties.

RESULTS AND DISCUSSIONS

Table 1 shows the cooking conditions and results for both hardwood species studied and for the different wood density samples. In general, the samples with higher wood densities require milder cooking conditions and the process exhibit higher pulp yields.

***Table 1**. Cooking conditions and results*

	E. globulus			***A melanoxylon***		
	Wood Chip basic density (g/cm^3)					
	0.467 (LDE)	0.537 (MDE)	0.600 (HDE)	0.449 (LDA)	0.505 (MDA)	0.616 (HDA)
Effective alkali charge (%, as NaOH)	18.7	18.7	17.9	19.6	21.3	20.4
Time at temperature (160ºC) (min)	60	58	45	80	80	80
Pulp yield (%, on wood)	49.0	52.4	58.7	53.6	49.0	57.7
Rejects (%, on wood)	0.2	3.0	0.9	1.6	1.7	1.6
Kappa number	15.3	16.2	14.0	15.7	15.8	13.2
Viscosity, cm^3.g^{-1} UP	942	1053	1274	769	1020	795
Viscosity, cm^3.g^{-1} BP	855	982	945	656	876	782

UP – unbleached pulps. BP- bleached pulps

These results are consistent with higher cellulose content of the wood sample with higher density.

For both species, the wood chips with the lowest density produce pulp with the lowest pulp viscosity before and after bleaching.

The pulp fibres obtained from the wood with the highest basic density have highest coarseness, highest width and highest length (length-weighted).That relation is more clearly for the Acacia species. These results are enhanced by the higher pulp yield of these wood samples.

The pulps produced from the wood chips with the lower basic density (for both species) exhibit values markedly higher of paper density than the pulps produced from wood samples with higher wood density. These results are a consequence of the different morphological characteristics of the pulp fibres (Table 2). This is certainly explained by higher ability of these fibres for collapsing in the paper structure and developing inter-fibre bonding. On the other hand, for all wood density levels the *A. melanoxylon* wood presented always higher paper density than *E. globulus*, which is consistent with the lower coarseness of these pulp fibres.

***Table 2**. Handsheets paper properties*

		E. globulus			***A melanoxylon***		
		LDE	**MDE**	**HDE**	**LDA**	**MDA**	**HDA**
Density (g/cm^3)	D	0.750	0.665	0.513	0.78	0.72	0.65
Tensile index (Nm/g)	T	67.7	54.0	43.7	73	60	54
Schopper Riegler degree	SR	26.5	21	21.25	28	23	26
Tear index (mNm^2/g)	TE	6.7	6.6	4.7	7.4	5.8	4.9
Dry zero-span tensile strength (Nm/g)	ZSD	187	193	194	200	202	189
Wet zero-span tensile strength (Nm/g)	ZSW	152	168	170	181	176	157
Light scattering coefficient (m^2/kg)	LS	40.1	37.0	37.1	40.3	39.7	39.6
Brightness (ºISO)	B	87.2	88.1	89.0	81.8	79.2	80.6
Fibre width (µm)	W	23.5	23.6	24.2	17.9	18.5	18.0
Length weighted in length (mm)	L	0.720	0.813	0.858	0.772	0.837	0.847
Coarseness (mg/m)	C	0.057	0.062	0.069	0.048	0.054	0.052

Regarding mechanical properties (Table 2), for both species the pulps produced with lower density wood exhibits the higher tensile index and tear index. In addition, these results are consistent with those observed for the paper density. In fact, papers with higher density have strong structures and consequently higher resistances.

The light scattering ability decreases with increasing paper density and the coarseness, as a consequence of the higher inter-fibre contact and the lower specific surface area of the fibres with high coarseness.

Principal components analysis define three factors to explained all variables (that explained 92% of the total variance) but we don’t represent the 3rd factor because it only explain the variation of wet and dry zero-span tensile strength. In Fig. 1 each point represents the mean of a given property, for the ten pulps. The first component explains 56.1% and the second explains 20.6% of total variation.

Factor 1, which defines the first component of paper properties, includes a series of properties, which are significantly correlated amongst themselves: paper density, Shopper degree, tensile index, tear index and light scattering coefficient. The wood density, coarseness, pulp yield, viscosity and brightness are also strongly correlated with the previous group but in inverse order. In fact, all the first variables showed a strong correlation with the paper density that is strongly correlated with wood density. Similar results were observed by Santos *et al.* (2005) for other wood samples of acacia and eucalypts.

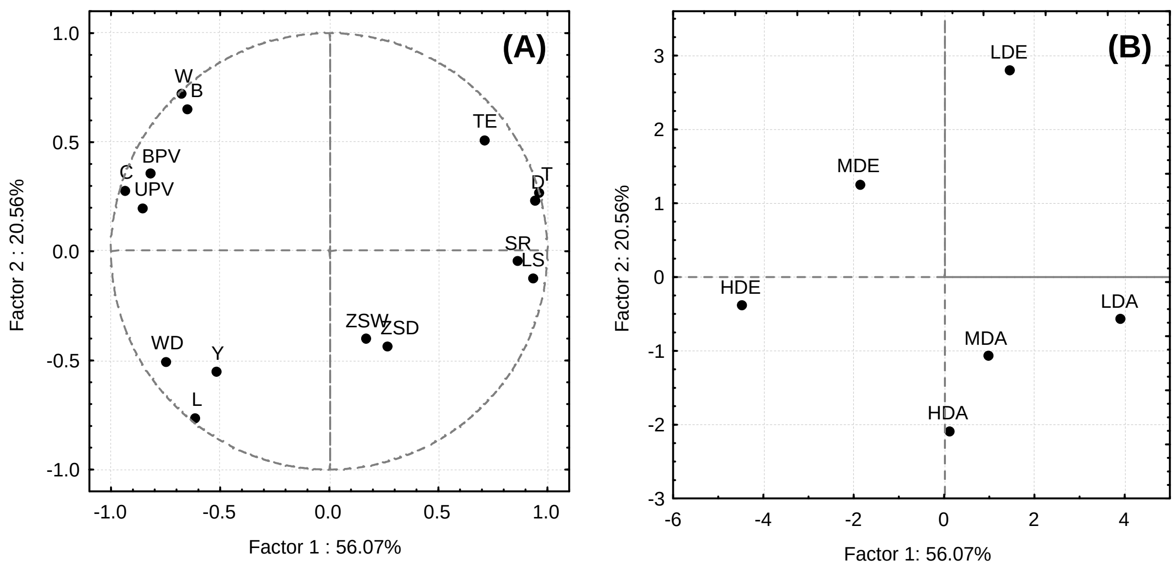

***Figure 1**. Results from Principal components analysis: (A) Relative distribution of paper characteristics according to the factors; (B) Projection diagram of the cases on the factor plane.*

Factor 2 explained the correlation between width and length of fibres with pulp Yield and Brightness. In fact pulp Yield and Brightness are well correlated for the variables studied in too factors.

We also projected the cases onto the same system of vectors. Figure 1 (B) shows how the values of different wood chips density and species are correlated. Cleary we can see the difference beaten paper and wood characteristics off the *A. melanoxylon* and *E. globulus* properties.

CONCLUSIONS

The experimental results show a great difference in the too hardwood species studied. The wood chip samples studied with different basic densities exhibit different behaviours in the kraft cooking process, in particular in pulp yield, which may be an effect to the wood chemical composition.

The wood basic density has an important impact on the apparent paper density. In turn, this structural property in conjugation with the fibre characteristics has a significative influence on the mechanical and optical properties of the papers.

There is a group of paper characteristics which depend strongly of the paper density that was negative correlations with the wood density.

The wood samples, for two species, with very high wood density provide coarse fibres that produce bulky paper structures.

Paper produced from Eucalyptus fibre has different properties from that produced from Acacia fibre.

BIBLIOGRAPHY

Downes, G., Evans, R., Wimmer, R., et al., Appita J. 56(3): 221(2003).

Evans, R., Kibblewhite, R.P. and Lausberg, M., Appita J. 52(2): 132(1999).

Kibblewhite. R.P.. Evans. R. and Riddell. M.J.C., Proc.57th Appita Ann. Gen. Conf.. Melbourne. p. 99(2003).

Paavilainen, L., Paperi Puu 82(3): 156(2000).

Paavilainen. L., Paperi ja Puu – Paper and Timber. 71 (4): 356 (1989).

Santos A, Simões R. and Anjos O., XV International Papermaking Conference, Efficiency of papermaking and paper converting processes, in Cd Room. Wroclaw, Poland, 28-30 September. (2005).

Santos A., Amaral, M.E., Anjos O., Simões R., 2008. TAPPI Journal (Accepted).

Santos, A., Anjos, O. and Simões, R., Appita J. 59(1): 58(2006).