THE POTENTIAL OF *CUPRESSUS ARIZONICA* AND *CUPRESSUS SEMPERVIRENS* FOR PULP PRODUCTION

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ABSTRACT

In this paper we report new data about two wood species that could play a role in the Portuguese forest as raw material for the paper industry: *Cupressus arizonica* and *Cupressus sempervirens*. Results on the behaviour of wood samples taken from 16 year-old trees, (two per species and at two height levels), have shown lower kraft pulp yields than reference pine softwoods, as a consequence of a higher lignin content. The pulps from *C. sempervirens* present values of fibre length and coarseness slightly lower than the Nordic *Pinus sylvestris*, but properties of pulp fibres from *C. arizonica* are significantly lower.

Keywords: Kraft cooking, *Cupressus arizonica*, *Cupressus sempervirens*, fibre length, coarseness.

INTRODUCTION

Eucalyptus globulus and *Pinus pinaster* are the most important species for the Portuguese pulp and paper industry. The bleached fibres produced from *Eucalyptus globulus* by the kraft process have excellent properties for writing and printing paper. The unbleached pine kraft pulp is used to produce kraftliner, sack paper and as market pulp. Softwood bleached pulp is not produced in Portugal, even if feasible (1,2). However, the morphological properties of the fibres are significantly different from the Nordic softwood pulps (1,3), which have excellent properties as reinforcement fibres in the writing and printing paper. In fact, the relatively high coarseness, and, consequently, the low wet fibre flexibility and collapsibility have been considered a disadvantage of *Pinus pinaster* pulps as reinforcement fibres. In order to evaluate the paper making potential of other softwoods with potential to be grown in Portugal, a research program was recently started. The focus will be put on species of the genus *Cupressus*. In this paper results will be presented for *Cupressus arizonica* and *Cupressus sempervirens,* concerning the behaviour of different wood samples in the kraft cooking process and the morphological properties of the corresponding pulps, using *Pinus pinaster* from Portugal and *Pinus sylvestris* from Finland as references.

MATERIAL AND METHODS

To evaluate the potential of the *Cupressus arizonica* and *Cupressus sempervirens* two trees from each species were harvested and wood chips were produced from two height levels in the tree (at the base and at 2m height). Representative wood chips from *Pinus pinaster* grown in Portugal and from *Pinus sylvestris* grown in Finland were used as references. The different wood samples, after screening, were submitted to the kraft cooking process under the following reaction conditions: active alkali charge = 25 % (as NaOH); sulfidity index = 30 %; liquor/wood ratio = 5:1; time to $T_{máx}$ (170 °C) = = 90 min; time at $T_{máx}$ = 150 min. At minimum 4 cooks per sample were carried out with 25 g o.d. of wood in a thermostatic oil bath. The cooked material was screened and washed. The pulp yield and the rejects, the kappa number and the pulp viscosity were determined according to standard methods. Residual alkali was determined in the black liquor by acid titration until pH 10.5, after appropriate dilution and $BaCl_2$ addition, in order to determine the corresponding effective alkali consumption. The morphological properties of pulp fibres were determined in Morfi®. The experimental data were analysed by variance analysis and Sheffé test using commercial software statistics® and statgraphics®.

In the study of Variance Components Analysis, each factor after the first is nested in the one above. The goal of such an analysis is usually to estimate the amount of variability contributed by each of the factors, called the variance components.

The model used for variance analysis (with fixed effects) is provided in Tab. 1.

Tab. 1. *Variance analysis of the different parameters, for two species (S), two trees (T) per species and two levels (L) per tree.*

Source	D.f.	Expected values of the average squares
Species (S)	(s−1)	$\sigma^2 + r.t.l.\sigma_S$
Tree (T)	(t−1)	$\sigma^2 + r.s.l.\sigma_T$
Level (L)	(l−1)	$\sigma^2 + r.s.t.\sigma_L$
S × T	(s−1)(t−1)	$\sigma^2 + r.l.\sigma_{ST}$
S × L	(s−1)(l−1)	$\sigma^2 + r.t.\sigma_{SL}$
T × L	(t−1)(l−1)	$\sigma^2 + r.s.\sigma_{TL}$
S × T × L	(s−1)(t−1)(l−1)	$\sigma^2 + r.\sigma_{STL}$
Residual	(s−1)(t−1)(l−1)r	σ^2

RESULTS AND DISCUSSION

Wood density

The wood density for the 16 year-old trees of the two *Cupressus* species (two trees per species and two levels per tree) and for the two reference woods can be observed in Tab. 2. the high variability between trees within the same species and between species is evident, as expected. In fact, although all the trees were taken from the same stand, their growing rates (radial and axial) are also very different, as can be seen in Tab. 3.

Tab. 2. *Wood basic density (L1: base level; L2: 2 m from the base).*

		Basic density	
		Tree 1	Tree 2
C. sempervirens	L1	0.476	0.451
	L2	0.472	0.433
C. arizonica	L1	0.429	0.432
	L2	0.432	0.429
Pinus Sylvestris		0.465	
Pinus pinaster		0.423	

Tab. 3. *Tree characteristics.*

	DBH, cm		Height, m	
	Tree 1	Tree 2	Tree 1	Tree 2
C. sempervirens	13.5	9.0	7.8	6.0
C. arizonica	19.0	17.0	7.9	7.9
P. pinaster	11.0	–	8.0	–

As reported by Zobel (4) and Kibblewhite (5), growth rates affect the wood and pulp and paper properties. As regards the effect of height level in the tree, in general, the wood density decreases for higher levels, as also reported by others (6,7).

Pulping

The results for kraft cooks are presented in Figures 1–5, for *Cupressus* and for the reference wood samples. It is evident that the *Cupressus* wood samples tested in this study exhibit lower pulp and total yields than the *Pinus* species, cooked under the same conditions. Apparently, these results represent a clear drawback, but the young age of the tested trees must be considered and definitive conclusions should not be drawn. In fact, it is very well documented that pulp yield increases with cambium age. Another result is the low yield of the Portuguese *Pinus pinaster*, when compared with the *Pinus sylvestris* grown in Nordic Countries.

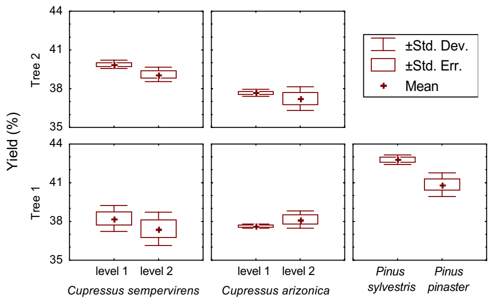

Fig. 1. Pulp Yield for *Cupressus sempervirens, Cupressus arizonica, Pinus sylvestris* and *Pinus pinaster.*

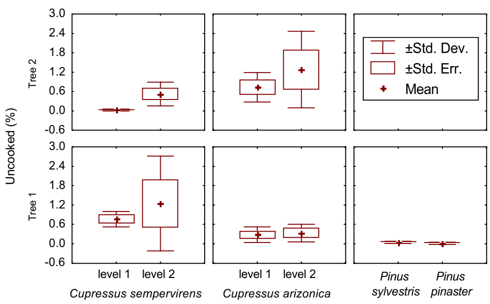

Fig. 2. Uncooked for *Cupressus sempervirens, Cupressus arizonica, Pinus sylvestris* and *Pinus pinaster.*

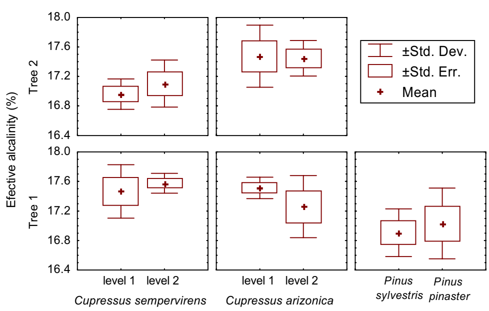

Fig. 3. Efective alkali consumption (as NaOH) for *Cupressus sempervirens, Cupressus arizonica, Pinus sylvestris* and *Pinus pinaster.*

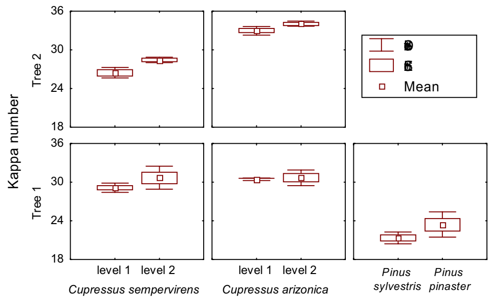

Fig. 4. Kappa number of pulps from *Cupressus sempervirens, Cupressus arizonica, Pinus sylvestris* and *Pinus pinaster.*

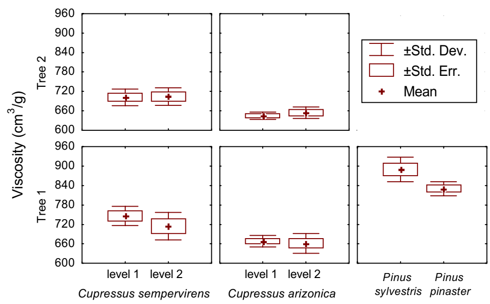

Fig. 5. Pulp viscosity for *Cupressus_sempervirens, Cupressus arizonica, Pinus sylvestris* and *Pinus pinaster.*

The lower yields of *Cupressus* agree with the slightly higher alkali consumption. For the *C. sempervirens*, the level of the wood in the tree also lowers the yield and the delignification extent, and increases the alkali consumption. For *C. arizonica* the effect is less obvious. The chemical composition, namely lignin and extractive content, and neutral sugar composition of the samples are under investigation. Preliminary results revealed that lignin content of *Cupressus* is, in general, close to 3 points higher than of *Pinus*. And some differences were also detected between trees and between levels in the trees (8).

Moreover, the pulps produced from the samples of *Pinus* show a lower kappa number (residual lignin content) than those of *Cupressus* for the same cooking conditions, respectively 20 and about 30. *C. sempervirens* delignifies a little better than *C. arizonica*. Component variance analysis shows (Tab. 4) that species is responsible for 38.4 % of the observed variance but the majority of the variance is attributed to the interaction between species and tree (49.7 %) (Fig. 4).

Another important parameter is pulp viscosity. The results for *Pinus* and *Cupressus* are very different. The *Cupressus* species present low pulp viscosity, which can be partially attributed to wood age, according to previously published results (9).

In Figures 6 and 7, Kappa number is plotted against cooking yield and pulp viscosity against Kappa number. It is evident that *P. sylvestris* shows the best performance while *C. arizonica* the worst.

Fibre properties

The data for fibre width, length, coarseness and curl are reported in Tab. 6. The differences between species are quite important. For the two *Cupressus* species, the variation of fibre length and coarseness (two parameters that significantly influence structural and mechanical properties of the paper) can reach 30 and 80 %, respectively.

Tab. 4. *Component variance analysis for the cooking parameters for the Cupressus wood samples (n.s.: not significant; *: significant ($P < 0.05$); **: very significant ($P < 0.01$);***: highly significant ($P < 0.001$)).*

		Variance (%)				
Source	D.f.	Alkali Consumption	Kappa number	Viscosity	Pulp Yield	Uncooked
Species (S)	1	2.7 (**)	38.4 (***)	63.8 (***)	19.0 (**)	0.0 (n.s.)
Tree (T)	1	8.5 (*)	0.0 (N-S.)	7.0 (*)	6.6 (*)	0.0 (n.s.)
Level (L)	1	0.0 (***)	4.8 (***)	0.0 (n.s.)	3.1 (n.s.)	8.8 (n.s.)
S × T	1	36.5 (n.s.)	49.7 (***)	0.0 (n.s.)	43.8 (***)	42.4 (n.s.)
S × L	1	3.5 (**)	1.3 (n.s.)	0.0 (n.s.)	4.0 (N.S.)	0.0 (**)
T × L	1	0.0 (***)	0.0 (n.s.)	2.4 (n.s.)	0.0 (N.S.)	0.0 (n.s.)
S × T × L	1	0.0 (***)	0.0 (n.s.)	0.0 (n.s.)	0.0 (N.S.)	0.0 (n.s.)
Residual	24	48.8	5.8	26.8	23.5	48.8

Tab. 5. *Results of the Scheffé test at 98 % confidence for alkali consumption, kappa number, pulp yield and uncooked material.*

		Alkali Consumption	Kappa number	Viscosity	Pulp Yield	Uncooked
Cupressus	tree 1	×	×	×	××	×
sempervirens	tree 2	×	×	××	××	×
Cuprassus	tree 1	×	×	×	×	×××
arizonica	tree 2	×	×	×	×	××
Pinus sylvestris		×	×	×	×	××
Pinus pinaster		×	×	×	×	×

Tab. 5 summarise the results obtained by the Scheffé test at 98% confidence for the cooking results. The position of x represents the relative position of the samples with the higher values on the right. For pulp viscosity, *Pinus sylvestris* and *Pinus pinaster* belong to the same groupbut they produce pulps with statistically different Kappa numbers.

According to the present data, *Cupressus* species produce fibres that, in general, are shorter than *Pinus*. However, considering the age effect on the fibre length, it is expected that in older *C. sempervirens* trees the fibre length will be higher

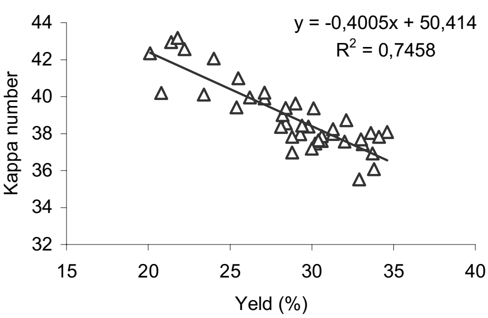

Fig. 6. *Kappa number vs pulp yield.*

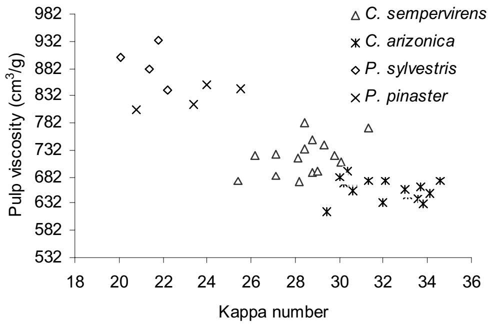

Fig. 7. *Pulp viscosity vs kappa number.*

Tab. 6. *Biometric characteristics of the fibres.*

		Fibre width (μm)		Length weighted in length (mm)		Coarseness (mg/m)		Curl (%)	
		Tree 1	Tree 2	Tree 1	Tree 2	Tree 1	Tree 2	Tree 1	Tree 2
C. sempervirens	L1	29.4	30.3	1.40	1.43	0.205	0.179	7.7	7.0
	L2	30.7	30.1	1.49	1.46	0.214	0.177	8.0	7.8
C. arizonica	L1	25.2	23.4	1.22	1.13	0.145	0.117	8.4	8.5
	L2	24.2	23.6	1.16	1.16	0.136	0.127	9.4	9.9
Pinus sylvestris		34.4		1.83		0.261		7.6	
Pinus pinaster		34.9		1.80		0.343		7.5	

and acceptable for most paper uses. Regarding coarseness, *C. sempervirens* presents values lower than Pinus *sylvestris* and *Pinus pinaster*. Similar results were reported by Somerville (10). However, if the age differences are considered, *Cupressus sempervirens* can compare well with the Nordic pulp, which is a reference reinforcement pulp in the market. The papermaking potential of representative pulps will be evaluated in future work.

CONCLUSIONS

The pulping potential of wood samples from 16 year-old trees of *Cupressus sempervirens* and *Cupressus arizonica* was investigated, using commercial wood chips of *Pinus pinaster* and *Pinus sylvestris* as reference. The results showed that the *Cupressus* samples had lower yield and higher residual lignin content than the *Pinus* samples but older trees could eventually overcome this disadvantage. Regarding morphological properties of the pulps, *Cupressus* samples exhibit lower fibre length, lower coarseness and higher number of fibres per gram, compared with *Pinus*.

REFERENCES

1. Santos, I., Gaiolas, C., Curto, J., Silvy, J., Santos Silva, M., Simões, R. M. S., “Estudo comparativo do potencial papeleiro das pastas kraft de Pinus pinaster e de Pinus sylvestris”, in Proc. 16° Encontro Nacional da TECNICELPA, Covilhã, 29–31 Outubro, 1998, p. 101–112.
2. Baptista, C., Duarte, A.P., Simões, R., Chirat, C., Brochier, B., “Branqueamento ECF e ECF light de pasta kraft de Pinus pinater: ensaios piloto, Pasta e Papel (2003, accepted),
3. Amaral, M. E., Gomes, P., Simões, R. M. S., “Characterisation of pulp fibres produced from different pinewood”, em Proc. Cost Action E10– Wood Properties for industrial use, Dipoli, Espoo, Finland, 18–22 June, 2000, p. 299–306.
4. Zobel, B. J., Buijtenen, J. P. V., “Wood Variation its Causes and Control”, Springer Series in Wood Science, Springer-Verlag, Berlin Heidelberg (1989).
5. Kibblewhite, R. P., “Designer fibres for improved papers through exploiting genetic varia-

tion in wood microstructure", Appita J. Vol. 52 (6): 429–435 (1999).
6. Hatton, J. V., "Pulping and papermaking properties of managed second-growth softwoods". Tappi J., Vol. 80 (1): 178–184 (1997).
7. Zobel, B. J., Sprague, J. R., "Juvenile Wood in Forest Trees". Springer Series in Wood Science, Springer-Verlag Berlin, Heidelberg (1998).
8. Esteves, S., "Caracterização química de madeiras de Cupressus sempervirens, Cupressus lusitanica e Cupressus arizonica", Lic. thesis, Instituto Politècnico de Castelo Branco, Castelo Branco, Portugal. (2003)
9. Gómez, E., "Caracterização da madeira de Pinus pinaster e da respectiva pasta, obtida a partir de diferentes anéis de crescimento", Lic. thesis, Universidade da Beira Interior, Covilhã, Portugal (1998)
10. Somerville, A., "Growth and utilisation of young Cupressus macrocarpa", New Zealand, J. Forestry Sci. 23(2): 163–78. (1993)