VARIABILITY IN THE CHEMICAL COMPOSITION OF PLANTATION EUCALYPTS (*EUCALYPTUS GLOBULUS* LABILL.)

Helena Pereira

Forest Department and Forest Research Center, School of Agronomy
Technical University of Lisbon
1399 Lisboa Codex, Portugal

(Received December 1986)

ABSTRACT

The chemical composition was determined for plantation-grown *Eucalyptus globulus* Labill., at time of harvest for pulpwood, with age 11–14 years, in four different locations and for the biomass components bolewood, bolebark, tops, and branches.

Chemical composition showed variation between trees and between geographical location, and variability was significantly larger for cellulose content. Average wood composition was: ash 0.4%, total extractives 4.9%, insoluble lignin 19.5%, soluble lignin 3.6%, cellulose 54.0%, pentosans 18.9% (% of o.d. weight). Wood carbohydrate composition was determined for one site; glucose with 49.4% and xylose with 19.1% are the main monosaccharides. Within the tree, biomass components also showed different chemical compositions, especially in ash, extractives, and cellulose contents and in 1% NaOH solubility.

Keywords: *Eucalyptus globulus* Labill., chemical composition, variability, site, biomass components.

INTRODUCTION

Utilization of plantation-grown eucalypt wood for the pulp industry has developed in the recent past in several countries and will likely increase in the future. Blue gum, *Eucalyptus globulus* Labill., is a fast-growing eucalypt being grown intensively in plantations for pulpwood production.

Eucalyptus globulus combines fast growth in temperate climates and a large concentration of above-ground biomass in the bolewood with favorable wood characteristics, including high cellulose content and pulp yield (Dillner et al. 1970; Pereira and Sardinha 1984a, b). Bleached kraft and sulphite eucalypt pulps have good mechanical and optical properties and are well prized in the international pulp market.

Development of such fast-grown plantations has been associated with tree selection and improvement programs that rely on genetic variability and heritability of some tree characteristics, such as growth, wood density, or pulping aptitude (Hillis 1972; Zobel and Talbert 1984; Matheson et al. 1986).

Few studies have been made on the variation of the chemical composition of eucalypt wood, although it is recognized that there is a clear variation in the chemical composition between species, between trees of one species, and within trees (Bland 1985). Environmental conditions and tree age have also been reported as affecting the chemical composition and pulping of eucalypts (Turner et al.

[1] This research was supported by the Portuguese National Institute for Scientific Research (INIC) through funding of research program no. 8 of the Forest Research Center. Some of the results have been presented as a poster at the 18th IUFRO World Congress, Ljubljana, Yugoslavia, 7–13 September 1986.

TABLE 1. *Characterization of the four* Eucalyptus globulus *plantation sites.*

Site characterization	Site 1	Site 2	Site 3	Site 4
	Águeda	Niza	Odemira	Cadaval
Designation, county	40°31′N	39°30′N	37°36′N	39°15′N
Site coordinates	08°19′W	07°46′W	08°25′W	09°01′W
Altitude, m	500–550	300	300	150
Climatic conditions				
Air temperature, °C	13.0	15.6	15.6	15.2
Rainfall, mm	1,273.0	710.7	858.3	882.9
Potential evapotranspiration, mm	792.0	1,019.0	1,019.0	824.0
Air relative humidity (9 a.m.), %	71	74	74	80
Sunshine, %	56	60	60	55

1983). Effects of length of rotation, site, and clones in chemical composition have also been reported in other fast-grown plantation hardwoods, e.g., in *Populus* hybrids (Blankenhorn et al. 1985a, b).

Variability of tree growth and of some wood properties has been shown in *Eucalyptus globulus,* including differences in chemical composition and especially in cellulose content (Dillner et al. 1970; Pereira and Sardinha 1984b). Together with growth and wood density, cellulose content of wood has been suggested as a tree selection parameter for *Eucalyptus globulus,* since it correlates with pulp yield and its increase will not be detrimental to pulp properties (Dillner et al. 1970). Topwood presents an average chemical composition most similar to the merchantable bolewood and may be considered from the chemical point of view as a possible lignocellulosic source for pulping (Pereira and Sardinha 1984b).

This paper reports on the chemical composition of plantation-grown *Eucalyptus globulus* trees for different locations in Portugal. The results presented were obtained within an on-going interdisciplinary research program on the *Eucalyptus globulus* ecosystem.

MATERIAL AND METHODS

The chemical analysis was performed in trees harvested at the end of their rotation from commercial pulpwood plantations of *Eucalyptus globulus* Labill. in four different locations in Portugal. Site localization and climatic conditions are presented in Table 1 and plantation characterization is shown in Table 2.

For each location, ten trees were selected: two plots, each with 100 trees were chosen and used to characterize the stand (Table 2), and from each plot, five trees were randomly selected. They were harvested, measured, and sampled by Coucelo (1980) and Carvalho (1984). The following biomass components were separated and analyzed: merchantable bolewood, bolebark, tops (nonmerchantable bole with

TABLE 2. *Characterization of the four* Eucalyptus globulus *stands (Carvalho 1984).*

Characteristic	Site 1	Site 2	Site 3	Site 4
Rotation	1st	1st	1st	2nd
Tree age, years	12	14	11	13
Density, no stems/ha	981	1,077	605	1,973
Mean dbh, cm	15.7 (±0.8)	16.2 (±0.7)	20.1 (±1.6)	12.6 (±0.7)
Mean height, m	17.7 (±1.9)	21.9 (±1.7)	16.9 (±2.2)	19.0 (±1.9)

TABLE 3. *Chemical composition of biomass components of* Eucalyptus globulus *in Site 1.*

Fraction % o.d. wood	Bolewood	Bolebark	Topwood	Branches <1 cm
Ash	0.38 (±0.05)	2.11 (±0.52)	0.76 (±0.19)	1.53 (±0.38)
Extractives, total	2.9 (±0.6)	6.3 (±1.1)	2.8 (±0.3)	16.7 (±1.1)
Benz.-eth. extr.	1.7 (±0.2)	2.5 (±0.6)	1.4 (±0.1)	8.6 (±1.7)
Ethanol extr.	0.3 (±0.1)	0.8 (±0.4)	0.5 (±0.1)	1.4 (±0.2)
Water extr.	0.9 (±0.5)	3.2 (±1.0)	0.9 (±0.2)	6.7 (±1.7)
Insoluble lignin	20.2 (±0.6)	18.3 (±0.8)	21.4 (±0.6)	21.8 (±1.8)
Soluble lignin	2.0 (±0.4)	1.9 (±0.3)	3.4 (±0.4)	n.d.
Cellulose	53.7 (±1.4)	51.5 (±1.4)	52.3 (±0.9)	41.2 (±1.6)
Pentosans	17.3 (±1.3)	14.6 (±0.5)	17.8 (±1.0)	17.8 (±1.0)
Water solubility	2.1 (±0.4)	6.0 (±1.1)	2.7 (±0.3)	10.8 (±2.7)
1% NaOH solubility	12.9 (±0.6)	24.6 (±2.7)	16.7 (±0.9)	32.1 (±1.6)

a diameter o.b. under 6 cm) and branches (including wood and bark). For Site 4, branches were further separated into three fractions by diameter: under 1 cm, 1–3 cm, above 3 cm.

Chemical analysis of these biomass components was made individually per tree and used a weighted sample made up of material from all heights or parts of each component according to their relative mass in the tree. In Site 4, where the plantation was on a second rotation, in three cases two stems were kept after each stump sprouting. These stems were harvested, sampled, and analyzed separately.

Determination of ash, extractives, lignin, pentosan, hot water extractives, and 1% NaOH followed Tappi standard methods. Total extractives were calculated from the results of successive extractions with benzene-ethanol, ethanol, and water. Cellulose was determined as a crude cellulose by treatment of extractive-free woodmeal with nitric acid-acetic acid (Pereira and Sardinha 1984b): 1 g extractive-free woodmeal was treated with 25 ml of a solution of nitric acid and acetic acid (90 ml HNO_3 and 732 ml CH_3COOH made up to 1 liter with water); the residue was filtered, washed with warm water and ethanol. Carbohydrate composition was determined after total hydrolysis by gas chromatography of the corresponding alditol acetates.

Results presented for each plantation are the average of tree individual values and include calculation of 5% exclusion confidence limits.

TABLE 4. *Chemical composition of biomass components of* Eucalyptus globulus *in Site 2.*

Fraction % o.d. wood	Bolewood	Bolebark	Topwood	Branches <1 cm
Ash	0.35 (±0.12)	2.01 (±0.67)	0.76 (±0.09)	2.34 (±0.20)
Extractives, total	8.0 (±2.6)	7.9 (±0.8)	3.5 (±0.4)	14.5 (±1.2)
Benz.-eth. extr.	1.8 (±0.3)	2.9 (±0.5)	1.4 (±0.2)	7.8 (±0.8)
Ethanol extr.	0.3 (±0.1)	0.6 (±0.1)	0.2 (±0.1)	1.0 (±0.3)
Water extr.	5.9 (±2.7)	4.5 (±0.5)	1.9 (±0.3)	5.6 (±0.6)
Insoluble lignin	19.3 (±0.7)	16.7 (±1.4)	20.4 (±0.8)	21.1 (±1.2)
Soluble lignin	3.0 (±0.3)	1.9 (±0.2)	4.0 (±0.2)	1.9 (±0.5)
Cellulose	50.1 (±1.8)	43.2 (±9.0)	49.5 (±1.0)	37.9 (±0.9)
Pentosans	20.5 (±0.9)	19.6 (±0.7)	21.7 (±2.0)	17.8 (±1.2)
Water solubility	8.5 (±2.1)	7.9 (±0.6)	2.6 (±0.6)	12.3 (±1.1)
1% NaOH solubility	22.5 (±3.9)	30.6 (±6.7)	17.8 (±0.9)	36.4 (±1.7)

TABLE 5. *Chemical composition of biomass components of* Eucalyptus globulus *in Site 3.*

Fraction % o.d. wood	Bolewood	Bolebark	Topwood	Branches <1 cm
Ash	0.49 (±0.06)	1.61 (±0.39)	1.06 (±0.16)	2.73 (±0.35)
Extractives, total	2.9 (±0.7)	6.4 (±1.1)	4.3 (±0.7)	15.2 (±1.6)
Benz.-eth. extr.	1.2 (±0.3)	1.8 (±0.2)	1.6 (±0.5)	6.9 (±0.7)
Ethanol extr.	0.2 (±0.1)	0.5 (±0.1)	0.6 (±0.2)	0.9 (±0.3)
Water extr.	1.5 (±0.4)	4.1 (±0.9)	2.1 (±0.4)	7.4 (±1.1)
Insoluble lignin	19.3 (±0.8)	18.3 (±1.1)	19.2 (±1.1)	19.7 (±0.8)
Cellulose	54.0 (±1.2)	54.9 (±1.5)	47.6 (±1.1)	39.6 (±1.0)
Pentosans	20.2 (±1.4)	19.6 (±1.1)	19.0 (±3.1)	20.2 (±1.2)
Water solubility	2.9 (±0.9)	7.0 (±1.2)	4.1 (±1.0)	11.6 (±1.7)
1% NaOH solubility	13.7 *	20.4 (±2.0)	17.6 (±0.6)	31.6 (±2.7)

* Average of five samples.

RESULTS AND DISCUSSION

Results refer to plantation *Eucalytpus globulus* in four different locations in Portugal, which are representative of different climatic situations in the country. The localization of site and climatic conditions are set out in Table 1 and the stand characterization is presented in Table 2. Trees harvested from Sites 1, 2, and 3 corresponded to a first rotation and from Site 4 to a second rotation. Results for a first rotation of *Eucalyptus globulus* in Site 4, with identical sampling and analysis, have already been reported (Pereira and Sardinha 1984b).

Chemical composition

The chemical composition of the biomass components bolewood, bolebark, topwood, and branches is presented in Tables 3–6 for each plantation site, as the average result from the ten tree individual values with the corresponding confidence limits at 95% probability level.

The average chemical composition of *Eucalyptus globulus* obtained for the four stands confirms this species to have a high cellulose content wood. The large number of trees sampled allows better knowledge of the chemical composition of this species at harvest time for pulpwood and in general confirms previous results obtained in our laboratory (Pereira and Sardinha 1984b).

The summative chemical analysis of *Eucalyptus globulus* wood as an average regardless of geographical variation is as follows (in % of o.d. wood): ash 0.4%,

TABLE 6. *Chemical composition of biomass components of* Eucalyptus globulus *in Site 4.*

Fraction % o.d. wood	Bolewood	Bolebark	Topwood	Branches <1 cm
Ash	0.49 (±0.04)	3.53 (±0.64)	0.60 (±0.08)	3.52 (±0.36)
Extractives, total	5.6 (±0.3)	8.5 (±1.2)	3.9 (±0.9)	15.0 (±2.2)
Benz.-eth. extr.	1.3 (±0.2)	2.9 (±0.3)	1.6 (±0.2)	5.1 (±1.2)
Ethanol extr.	0.4 (±0.1)	0.5 (±0.1)	0.4 (±0.1)	2.0 (±0.7)
Water extr.	3.8 (±0.7)	5.1 (±0.8)	1.9 (±0.9)	7.9 (±1.4)
Insoluble lignin	19.2 (±1.0)	21.1 (±1.0)	19.2 (±0.7)	20.9 (±1.1)
Soluble lignin	5.7 (±0.3)	n.d.	3.6 (±0.5)	4.1 (±0.5)
Cellulose	58.2 (±1.1)	46.7 (±1.5)	50.7 (±1.5)	37.9 (±1.4)
Pentosans	17.4 (±0.5)	18.1 (±0.7)	21.1 (±1.3)	17.3 (±1.2)
Hot water solubility	2.7 (±0.5)	7.2 (±1.1)	2.8 (±0.7)	12.6 (±1.6)
1% NaOH solubility	12.5 (±0.6)	25.0 (±1.0)	16.7 (±1.0)	32.4 (±2.3)

TABLE 7. *Carbohydrate composition of* Eucalyptus globolus *wood from Site 2.*

Monosaccharide	% o.d. wood
Arabinose	0.8
Xylose	19.1
Mannose	2.0
Galactose	1.9
Glucose	49.4

total extractives 4.9%, insoluble lignin 19.5%, soluble lignin 3.6%, cellulose 54.0%, pentosans 18.9%. The carbohydrate composition of eucalypt wood was studied for Site 2 and the results are presented in Table 7: glucose amounts to 49.4% and xylose to 19.1% of the wood. A comparison with the average cellulose content for this site (50.1%) allows some critical assessment on the determination method for cellulose used in this study, which may give results in excess of the real cellulose content of wood. The method used for the determination of cellulose content, which relies on delignification and hemicellulose hydrolysis by nitric acid in acetic acid, as a modified Kürschner and Hoffer method, should only be used as an approximative cellulose determination, as it is the case for most direct methods. The crude cellulose prepared by this method showed the following average composition: residual lignin 0.5%, xylose 5.0%, mannose 1.9%, and glucose 92.0% (% of o.d. crude cellulose). An approximate 7% of noncellulosic material in this cellulose preparate may thus be estimated.

This procedure for cellulose determination has, however, the advantage of rapidity and simplicity, and may be preferred over determination of holocellulose and α-cellulose when repetitive analysis for comparison purposes is used.

Determinations of the cellulose content of *E. globulus,* calculated from the wood carbohydrate composition, have been previously reported as 47.5% for a sample of 260 trees selected from different regions in Portugal, with a variation ranging from 36% to 58% (Dillner et al. 1970). Further average chemical data for these trees were: extractives 6.6%, total lignin 24.6%, glucuronoxylanacetate 18.0%, and other hemicelluloses 3.3%.

Total extractives in wood increase sharply with tree age, mostly as a result of the presence of more water-soluble material, for which phenolics will account for a large part (Fig. 1). This means that in plantation-grown *Eucalyptus globulus* wood, a tree age of 12–14 years may be considered as the threshold for an increased build-up and accumulation of extractive material, which is known to be present in high amounts in mature eucalypts. It should be remarked that content of extractives in topwood, corresponding to the tree's younger material, remains low even when wood extractives increased in the merchantable bole.

The fact that extractives will have a detrimental influence on pulping, affecting yield, consumption of chemicals, and black liquor processing should be accounted for when harvesting eucalypts for pulpwood.

Tops are similar in chemical composition to merchantable bolewood but with a somewhat lower cellulose content. This is in accordance with previous reports on the decrease of cellulose content along the bole (Pereira and Sardinha 1984b).

In bark, ash content is higher. It also contains more extractives, including higher benzene-ethanol and water extractives. No very clearly defined differences could

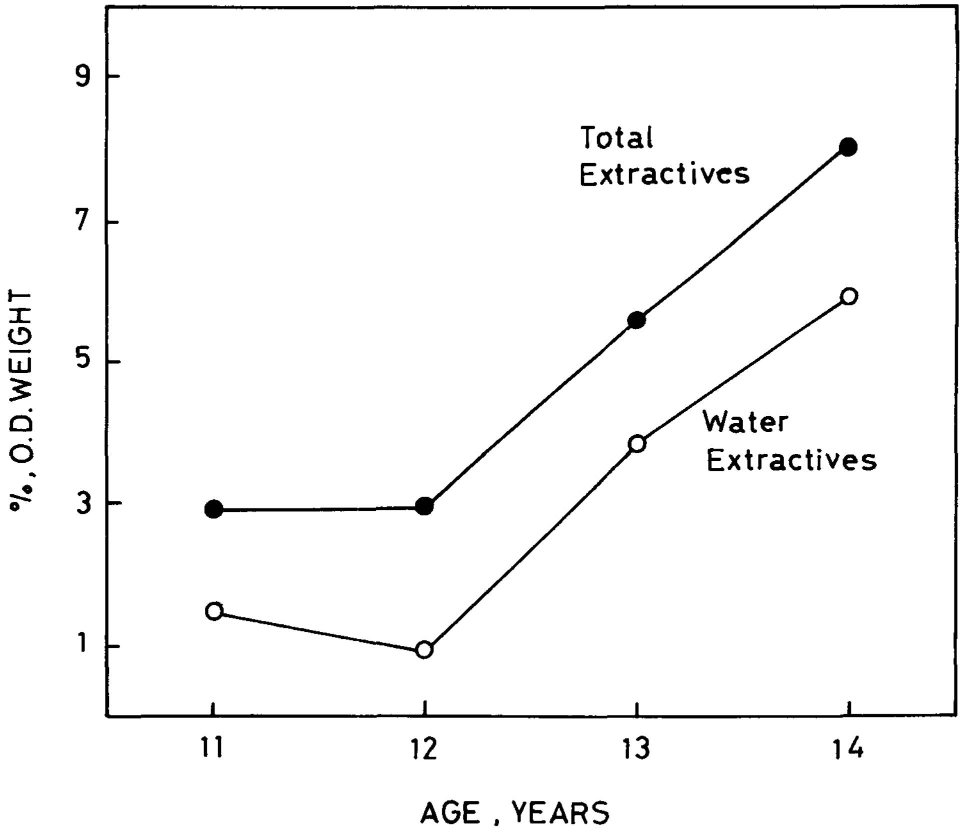

FIG. 1. Total extractives and water extractives of *Eucalyptus globulus* wood in relation to tree age.

be found in the composition of cell-wall regarding its main components, but in most cases cellulose content of bark is lower than in wood. However, variability between individual trees could be large, as in Site 2, where bark cellulose content varied from a lowest value of 30.6% to a highest value of 53.7%.

TABLE 8. *Chemical composition of branches of different diameter classes, in Site 4.*

Fraction % o.d. wood	Branches		
	<1 cm	1–3 cm	>3 cm*
Ash	3.52 (±0.36)	1.77 (±0.41)	1.47
Extractives, total	15.0 (±2.2)	6.9 (±1.1)	3.2
Benz.-eth. extr.	5.1 (±1.2)	2.9 (±1.0)	2.1
Ethanol extr.	2.0 (±0.7)	1.1 (±0.5)	0.5
Water extr.	7.9 (±1.4)	2.8 (±0.7)	0.5
Insoluble lignin	20.9 (±1.1)	20.9 (±0.9)	22.6
Soluble lignin	4.1 (±1.4)	4.9 (±2.3)	5.4
Cellulose	37.9 (±1.2)	44.2 (±1.4)	47.4
Pentosans	17.3 (±1.6)	19.3 (±1.1)	22.5
Hot water solubility	12.6 (±2.3)	6.1 (±1.1)	3.5
1% NaOH solubility	32.4 (±0.5)	19.8 (±0.6)	15.5

* Only two trees had branches >3 cm.

TABLE 9. *Analysis of variance for the chemical composition of* Eucalyptus globulus *wood.*

Chemical component	Source of variation	df	SS	MS	F
Lignin (Klason)	Among sites	3	5.32	1.77	1.39 n.s.
	Within sites	36	46.12	1.28	
Cellulose	Among sites	3	310.03	103.34	25.09**
	Within sites	36	148.26	4.12	
Pentosan	Among sites	3	91.10	30.37	12.76**
	Within sites	36	85.70	2.38	
Extractives	Among sites	3	181.39	60.46	13.84**
	Within sites	36	157.37	4.37	
Ash	Among sites	3	0.158	0.053	5.15**
	Within sites	36	0.370	0.010	

n.s. = Not significant; * = significant at 5% level; ** = significant at 1% level.

Solubility in 1% NaOH is much larger for bark, pointing out to differences in macromolecular structure and chemistry of cell-wall components. This is also the case for branches, which make up the biomass component with higher solubility in 1% NaOH. Further, branches can be characterized by a high amount of extractible material, largely outweighing the amount in any of the other biomass components, and by a significantly lower cellulose content. In case of an enhanced tree utilization, branches will constitute the biomass component of lowest pulping quality.

A more detailed analysis of branch material was made for Site 4, where two other classes were analyzed in addition to small-diameter material: branches with diameters between 1 and 3 cm and above 3 cm. The results, presented on Table 8, show that similarity to wood chemical composition improves with increase in diameter. Ash, extractives, and solubility in 1% NaOH decrease and cellulose content increases for thicker branches.

Variability of wood chemical composition

The chemical composition of *Eucalyptus globulus* wood showed that there is a variability between trees in the same site and between geographically different sites. Variability in chemical composition was larger in relation to cellulose and pentosan contents than in lignin content: for instance, tree cellulose contents of individual trees varied from a lowest value of 46.6% to a highest value of 60.7%. Significant differences between locations were also found, and the average wood cellulose content was highest in Site 4 (58.2%) and lowest in Site 2 (50.1%).

The analysis of variance for the different chemical components of *Eucalyptus globulus* wood is shown in Table 9. It can be seen that the wood chemical composition is significantly different between sites at the 1% level for cellulose, pentosan, extractives, and ash; differences in lignin content were not significant. In bark, the variability between trees in the same site was larger, and the analysis of variance showed that the differences between sites were not significant for cellulose and extractive content, significant at the 5% level for lignin and pentosan, and at the 1% level only for ash. On the other side, in tops, differences among sites were significant at the 1% level for all components except for ash and extractives, which were significant at the 5% level.

It is not possible, however, to find the probable origins for this variability

TABLE 10. *Comparison of wood chemical composition of stems sprouted from the same stump in a 12-year-old second rotation of* Eucalyptus globulus. *Site 4.*

Fraction % o.d. wood	Stump 20		Stump 32		Stump 35	
	A	B	A	B	A	B
Ash	0.46	0.50	0.56	0.49	0.63	0.41
Extractives, total	4.5	5.2	7.0	5.2	4.8	6.0
Benz.-eth. extr.	1.4	1.8	1.3	1.2	1.4	1.3
Ethanol extr.	0.6	0.4	0.2	0.4	0.3	0.2
Water extr.	2.5	3.0	5.4	3.5	3.1	4.6
Insoluble lignin	18.6	19.4	19.1	20.6	16.3	16.5
Soluble lignin	6.8	6.3	5.5	6.0	5.4	5.5
Cellulose	58.5	58.5	57.3	57.7	61.3	60.0
Pentosans	17.7	17.3	16.9	17.6	17.3	17.4
Water solubility	2.1	2.6	3.2	2.1	1.4	2.1
1% NaOH solubility	10.5	11.6	13.6	12.8	11.7	12.4
Dry biomass, kg	41.7	39.4	92.2	19.2	54.5	56.0

verified for the chemical composition between the different geographical locations. In fact, seed provenance for the plantations was neither controlled nor recorded. It is therefore to be expected that genotypic variation and environmental influence may jointly be contributing to the differences of chemical composition, and this sampling design could not allow further explanations on variability.

Stems sprouting from the same stump in coppices in the second rotation (in Site 4), and which are therefore of the same genetic origin, have the same chemical composition, even if they have very different growth and biomass production (Table 10).

In the case of plantation-grown *Eucalyptus globulus* for utilization as pulpwood, high cellulose content will be favorable for higher pulp yield production. The large variation found in cellulose content in the wood of *Eucalyptus globulus* allows the conclusion that it may serve as a selection parameter to be included in genetic improvement programs together with growth and other parameters (e.g., wood density). This has already been suggested, and the large between-tree variation of cellulose content has also been reported previously for *Eucalyptus globulus* (Dillner et al. 1970).

CONCLUSIONS

The analysis of plantation-grown *Eucalyptus globulus* trees at the time of harvest for pulpwood, of age 11–14 years, showed that this is a species with high cellulose and relatively low lignin contents.

There was a variability of chemical composition between trees and between the four different geographical locations. This variability was significantly larger for cellulose content.

Wood extractives increased with age, and for the cases studied, an age of 12 years was the limit for a low wood extractive content.

Tops in *Eucalyptus globulus* have a chemical composition similar to bolewood, and bark has more extractives and a higher ash content. Branches—especially small-diameter branches—comprise biomass material with a very high content of extractives and low cellulose.

ACKNOWLEDGMENTS

We thank Amélia Nobre and Glória Maia for the chemical analysis, Alfeu Santos for sample preparation and Clara Araujo for her help in the statistical analysis. Biomass samples were made available by Fernando Coucelo and Pedro O. Carvalho, who harvested the trees within the sampling design for another project on biomass production and nutrient cycling under the direction of Raul Sardinha, Forest Research Center, Lisbon, Portugal.

REFERENCES

BLAND, D. E. 1985. The composition and analysis of eucalypt woods. Appita 38(4):291–294.

BLANKENHORN, P. R., T. W. BOWERSOX, K. M. KUKLEWSKI, AND G. L. STIMLEY. 1985a. Comparison of selected fuel and chemical content values for seven *Populus* hybrid clones. Wood Fiber Sci. 17(2):148–158.

———, ———, ———, AND ———. 1985b. Effects of rotation, site and clone on the chemical composition of *Populus* hybrids. Wood Fiber Sci. 17(3):351–360.

CARVALHO, P. C. O. 1984. Biomassa e características físicas em *Eucalyptus globulus* Labill. Contribuição para o seu estudo. Relatório de estágio. Instituto Superior de Agronomia. Lisboa.

COUCELO, F. C. 1980. Dois estudos biométricos para o eucaliptal na estação ecológica AMxSM. Relatório de estágio. Instituto Superior de Agronomia. Lisboa.

DILLNER, B., A. LJUNGER, O. A. HERUD, AND E. THUNE-LARSEN. 1970. The breeding of *Eucalyptus globulus* on the basis of wood density, chemical composition and growth rate. Symposium on the production and industrial utilization of Eucalyptus. 29.6–3.7.1970, Lisbon, Portugal.

HILLIS, W. E. 1972. Properties of eucalypt woods of importance to the pulp and paper industry. Appita 26(2):113–122.

MATHESON, A. C., C. H. TURNER, AND G. H. DEAN. 1986. Genetic variation in the pulp qualities of *Eucalyptus obliqua* l'Herit. Appita 39(3):205–212.

PEREIRA, H., AND R. SARDINHA. 1984a. Utilization of *Eucalyptus globulus* Lab. for energy and fiber. Biomass production and nutrient removal assessment. Pages 119–126 *in* H. Egneus and A. Ellegard, eds. Bioenergy 84. Vol. II. Biomass Resources, Elsevier Applied Sci. Publ., London.

———, AND ———. 1984b. Chemical composition of *Eucalyptus globulus* Lab. Appita 37(8):661–664.

TURNER, C. H., V. BALODIS, AND G. H. DEAN. 1983. Variability in pulping quality of *E. globulus* from Tasmanian provenances. Appita 36(5):371–376.

ZOBEL, B. J., AND J. TALBERT. 1984. Applied forest tree improvement. Wiley and Sons, New York.