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WOOD AND BARK FIBER CHARACTERISTICS OF *Acacia melanoxylon* AND COMPARISON TO *Eucalyptus globules*

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ABSTRACT: Wood and bark fibers of *Acacia melanoxylon* were characterized and compared to *Eucalyptus globulus* which is a major quality source of pulp fibers. In 20 trees from four sites, fiber length and wall thickness were measured at 5, 35 and 65% of total tree height and at 10, 30, 50, 70 and 90% of the distance from pith. Maceration were prepared in a 1:1 glacial acetic acid:hydrogen peroxide solution. Wood and bark fiber length varied between 0.90 - 0.96 mm and 1.33 - 1.59 mm respectively. The cell wall thickness varied between 3.45 - 3.89 µm in wood and 5.01 - 5.40 µm in bark. Wood and bark fiber length decreased from the bottom to the top of the tree and cell wall thickness had no specific pattern for axial variation. Fiber length and wall thickness increased from the pith to the bark, but the wall thickness increased slightly with some fluctuations. In *Acacia melanoxylon* significant site differences were found in relation to bark fiber length and to wood wall thickness. The fibers of *Acacia melanoxylon* were similar to those of *Eucalyptus globulus* but the wood fibers were thinner and the bark fibers thicker. The radial variation was similar in both species. In wood of *Eucalyptus globulus,* fiber wall thickness increases from the base to the middle of tree height and decreases to the top; in the bark decreases from the base to the top. In *Eucalyptus globulus* fibers bark are higher in the top.

Key words: Xylem, phloem, cell biometry, acacia, eucalypts.

COMPARAÇÃO DAS CARACTERÍSTICAS DAS FIBRAS DA MADEIRA E DA CASCA DA *Acacia melanoxylon* COM AS DO *Eucalyptus globulus*

RESUMO: *Caracterizaram-se as fibras da madeira e casca da Acacia melanoxylon e compararam-se com as do Eucalyptus globulus, principal espécie usada em Portugal para celulose. Abateram-se vinte árvores da Acacia melanoxylon em quatro locais. Determinou-se o comprimento e a espessura de parede das fibras em elementos dissociados com o soluto de Franklin. A variação radial foi estudada a 10, 30, 50, 70 e 90% do comprimento do raio e a variação axial a 5, 35 e 65% da altura da árvore. Na Acacia melanoxylon, o comprimento das fibras da madeira e casca oscilou entre 0,90 – 0,96 mm e 1,33 – 1,59 mm respectivamente e a espessura da parede variou entre 3,45 – 3,89 µm na madeira e 5,01 – 5,40 µm na casca. O comprimento das fibras diminuiu da base para o topo da árvore. O comprimento e a espessura de parede aumentaram radialmente, embora a espessura com algumas flutuações. Axialmente a espessura da parede não mostrou um padrão específico de variação. Na Acacia melanoxylon o comprimento das fibras da casca e a espessura da parede das fibras da madeira apresentaram diferenças significativas entre locais. As fibras são semelhantes às do Eucalyptus globulus, embora mais finas na madeira e mais espessas na casca. O padrão de variação radial é semelhante nas duas espécies. No Eucalyptus globulus, a espessura da parede das fibras da madeira aumenta até meio da altura da árvore e depois diminui para o topo; na casca diminui da base para o topo. No Eucalyptus globulus as fibras da casca são maiores no topo.*

Palavras-chave: Xilema, floema, biometria celular, acácia, eucalipto.

1 INTRODUCTION

Acacia melanoxylon R. Br. and *Eucalyptus globulus* L. are tree species native to Australia that occur naturally across a wide range of forest ecosystems. They were introduced in Portugal as ornamentals in the late XIXth century and their expansion occurred through national forestation programs.

In Europe, *Acacia melanoxylon* is considered as invasive, characterized by vigorous tree or root sprouts and with seed germination stimulated by fire. *Eucalyptus globulus*, as most eucalypt species, also releases the seed and is capable of vegetative regeneration after fire. In Portugal, *Acacia melanoxylon* is found associated with pines along the Atlantic Coast and in pure or mixed stands with other hardwoods and pines in the inner part of the country, especially in fire risk areas.

Acacia species were primarily cultivated for bark, which was used in the tanning industry (ILVESSALO-PFAFFLI, 1995) but they are important for several

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purposes including building and furniture, fuelwood, perfume, traditional medicine, pulp and paper and in general have a good biomass potential (HARRIS, 2004). They are used also for wood-based composite and panel products (PEDIEU et al., 2009). The wood of *Acacia melanoxylon* is highly regarded in its natural region as a quality timber for carpentry and cabinet making (JENNINGS et al., 2003) and with potential to develop into a quality leader of short-fiber pulp (GIL et al., 1999).

Very little has been published on the wood and bark anatomy of *Acacia melanoxylon* and on its variability (GHOUSE; IQBAL, 1977; IQBAL; GHOUSE, 1983; QUINTANAR ISAIAS et al., 2005; SAHRI et al., 1993). In this context, the biometric characteristics of fibers are especially important given their relevance to properties and end-uses.

The aim of the this study is to characterize the wood and bark structure of *Acacia melanoxylon* in relation to fiber biometry (length and wall thickness) and their variation within and between trees growing in different site conditions in Portugal, in a context of raw-material quality evaluation for pulping. Therefore the results are compared with the fiber characteristics of *Eucalyptus globulus*, which is a major source for production of quality short fiber pulp.

2 MATERIAL AND METHODS

The study was made on 20 trees (five trees in each site), with a 40 cm DBH class sampled in four stands located in northern and central Portugal: Caminha, Ponte de Lima, Ovar, Viseu. The location and characterization of the sites are summarised in Table 1.

The trees were bucked and stem discs with 5 cm thickness were taken at different height levels. The axial variation of fiber length and cell wall thickness was studied in stem discs taken at 5%, 35% and 65% of total tree height, both in wood and bark. The radial variation of wood fiber length and cell wall thickness in each height level was measured in five radial positions at 10, 30, 50, 70 and 90% of the distance from pith.

Fiber length and cell wall thickness were measured in bark and wood samples macerated in a 1:1 glacial acetic acid:hydrogen peroxide solution. Two slides and 20 fibers per slide were measured for each sampling point. Preliminary testing showed that with this sampling intensity the error was below 5% for a 95% confidence level. The fibers were measured with a Leitz ASM 68K semi-automatic image analyser.

Mean values were calculated for each height level as the arithmetic mean of all the measured radial positions. Mean values for the tree were calculated as the arithmetic mean of the three height levels studied in each tree.

Statistical analysis was made using the Sigma Stat Scientific Statistical software SigmaStat from Jandel Corporation. Analysis of variance (ANOVA) was applied to compare if the differences between wood and bark fiber length and wall thickness from different sites are statistically significant different at a 0.05 confidence level (QUILHÓ et al., 2000).

3 RESULTS AND DISCUSSION

Figure 1 shows the general aspect of the dissociated wood fibers of *Acacia melanoxylon* (Figure 1a and 1b) and of *Eucalyptus globulus* (Figure 1c). The wood fibers in these two species are fusiform with apical extensions at both ends. In some of the trees the wood fibers were bifurcated at one end (Figure 1b).

Bark fibers of *Acacia melanoxylon* are similar to bark fibers of *Eucalyptus globulus* as shown in Figure 2a and 2b respectively. They are fusiform with apical extensions at both ends. Bifurcated fibers at one end can also be found in *Acacia melanoxylon*.

Table 1 – Location and characterization of sampling sites.

Tabela 1 *– Localização e caracterização dos locais de amostragem.*

Site	Caminha	Ponte de Lima	Ovar	Viseu
Latitude	41º 53’N	41º 43’N	40º 57’N	40º 41’N
Longitude	8º 50’W	8º 50’ W	8º 38’ W	7º 55’ W
Altitude (m)	8	154	7	548
Rainfall (mm/year)	1304	1720	1152	1229
Mean temperature (ºC)	14.3	14.0	13.9	13.0
Soil origin	Sand	Granite	Sand	Granite

(a) (b) (c)

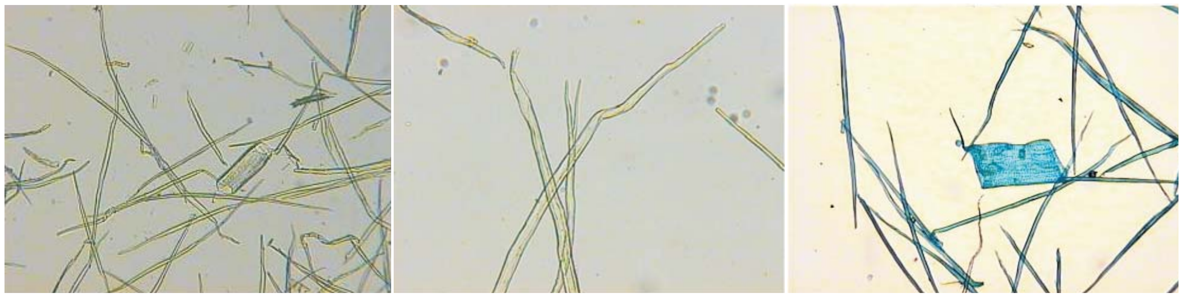

Figure 1 – Dissociated wood samples: (a) *Acacia melanoxylon*: libriform fibers and one vessel element; (b) *Acacia melanoxylon*: libriform fibers with one bifurcated fiber at one end and (c) *Eucalyptus globulus*: libriform fibers and one vessel element.

Figura 1 *– Elementos dissociados da madeira: (a)Acacia melanoxylon: fibras liberiformes e um elemento de vaso;(b) Acacia melanoxylon: fibras liberiformes, sendo uma bifurcada numa extremidade e (c) Eucalyptus globulus: fibras liberiformes e um elemento de vaso.*

(a) (b)

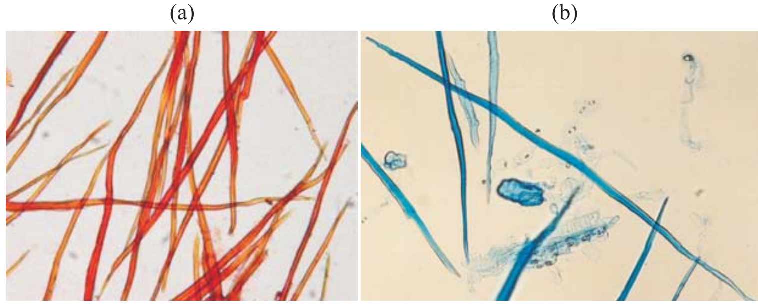

Figure 2 – Dissociated bark samples: libriform fibers; (a) *Acacia melanoxylon* and (b) *Eucalyptus globulus*.

Figura 2 – *Elementos dissociados da casca: fibras liberiformes; (a) Acacia melanoxylon e (b) Eucalyptus globulus.*

The fibers of *Acacia melanoxylon* and *Eucalyptus globulus* are morphologically identical in bark and wood, but longer in the bark of both species.

3.1 Fiber length

The fiber length of *Acacia melanoxylon* wood and bark ranged between 0.90-0.96 mm and 1.33-1.59 mm, respectively (Table 2).

Table 2 – Wood and bark fiber length (mm) for *Acacia melanoxylon* in four sites. Mean and standard deviation of five trees per site.

Tabela 2 *– Comprimento das fibras da madeira e da casca (mm) da Acacia melanoxylon nos quatro locais. Média e desvio padrão de 5 árvores por local.*

	Caminha	Ponte de Lima	Ovar	Viseu
Wood	0.90 ± 0.02	0.94 ± 0.02	0.96 ± 0.06	0.96 ± 0.04
Bark	1.33 ± 0.04	1.42 ± 0.11	1.59 ± 0.12	1.35 ± 0.05

The results are close to those described for other *Acacia* species, namely *Acacia mangium*: mean value of 1.08 mm with a range of 0.96 mm to 1.20 mm (LIM; GAN, 2000; LOGAN; BALODIS, 1982), 0.80 mm to 1.3 mm (WU; WANG, 1988) and 0.9 mm to 1.3 mm (RICHTER; DALLWITZ, 2000). Kim et al. (2008) in six natural hybrid clones of *Acacia mangium* and *Acacia auriculiformes* observed values from 0.86 mm to 0.93 mm.

The mean wood fiber length of *Acacia melanoxylon* obtained in this study is similar to values reported for *Eucalyptus globulus* of 1.0 mm (CARVALHO, 1962), 0.87 mm to 1.04 mm (JORGE et al., 2000), 0.923 mm (ONA et al., 2001), 0.941 mm to 1.192 mm (IGARTÚA et al., 2002) and 0.888 mm to 0.958 mm (MIRANDA; PEREIRA, 2002).

The average bark fiber length determined in *Acacia melanoxylon* fits into the range of 0.833 -1.100 mm reported for this species by Ghouse and Iqbal (1977) and also into other *Acacia* species (QUINTANAR ISAIS et al*.,* 2005), i.e. *Acacia bilimekii* (1.016 -1.201 mm) or *Acacia cochliacantha* (1.281-1.352 mm), and a little higher than those reported by Iqbal and Ghouse (1983) for *Acacia nilotica var. teli*a (0.986 – 1.188 mm).

The average bark fiber length in *Acacia melanoxylon* is similar to the values determined in *Eucalyptus globulus* bark of 1.28 mm (QUILHÓ, 1998) and of 1.02 mm and 1.04 mm (JORGE et al., 2000).

In *Acacia melanoxylon,* fiber length was in average 35% higher in bark than in wood. The same was also reported in *Acacia cochliacantha (*>30% higher) by Quintanar Isaias et al. (2005) and in various genus and species i.e. in *Eucalyptus* (20% higher) by Hillis (1972) and Jorge et al. (2000). However in *Acacia nilotica* Iqbal and Ghouse (1983) observed similar wood and bark fiber length.

The wood fiber length of *Acacia melanoxylon* was similar in the four sites and no statistical significant differences were found between sites. For bark fiber length, significant site differences (P <0.005) were found between Ovar and the other three sites. For *Eucalyptus globulus,* Jorge et al. (2000) and Quilhó et al. (2000) reported that wood and bark fiber length was affected by site, while Jorge (1994) and Onofre (1999) found no statistical significant differences between sites in relation to wood fiber length.

3.1.1 Radial variation of wood fiber length

Figure 3 shows the radial variation of wood fiber length in *Acacia melanoxylon* with increasing distance from the pith. Fiber length increased from an average 0.75 mm near the pith, to 0.98 mm at mid position and to 1.06 mm at the periphery (90% of the distance from pith). Average fiber length increased more rapidly between pith and middle positions than between mid and periphery positions (by 0.23 mm and 0.08 mm respectively). At the periphery, fiber length was longer than 1.00 mm in all sites. Radial variation of fiber length showed the minimal mean value near the pith in Caminha (0.69 mm), while the maximal mean value (1.09 mm) was found near the bark in Viseu (Figure 3).

Fiber dimensions increased in general from pith to bark. Sahri et al. (1993), in 4- and 8–year-old trees of *Acacia mangium* registered the same trend of radial variation as well as Honjo et al. (2005) for ages of 2 to 14 years where the fiber length varied between 0.9 mm and 1.3 mm near the bark and between 0.4 mm and 0.6 mm near the pith. The same pattern of fiber length variation

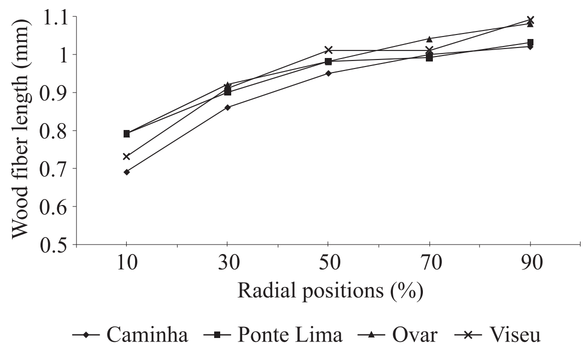

Figure 3 – Radial variation of fiber length of *Acacia melanoxylon* in four sites.

Figura 3 *– Variação radial do comprimento das fibras da Acacia melanoxylon nos quatro locais.*

was reported for *Acacia bilimeki* (1.032 mm to 1.077 mm) and it was different in *Acacia cochiacantha* with 0.780 mm near the pith and 0.727 mm close to the bark (QUINTANAR ISAIAS et al., 2005).

Eucalyptus globulus shows the same radial pattern of variation of wood fiber length with an increase from pith to bark: from 0.59 mm to 1.254 mm (TOMAZELLO FILHO, 1987), 0.69 mm to 1.18 mm (JORGE, 1994), 0.74 mm to 1.09 mm (ONOFRE, 1999), 0.63 mm to 1.03 mm (TAVARES et al., 2004). Igartúa et al. (2002) reported fibers longer than 1 mm in radial positions greater than 50%.

3.1.2 Axial variation of wood and bark fiber length

Figures 4 and 5 show the axial variation of wood and bark fiber length in *Acacia melanoxylon,* respectively.

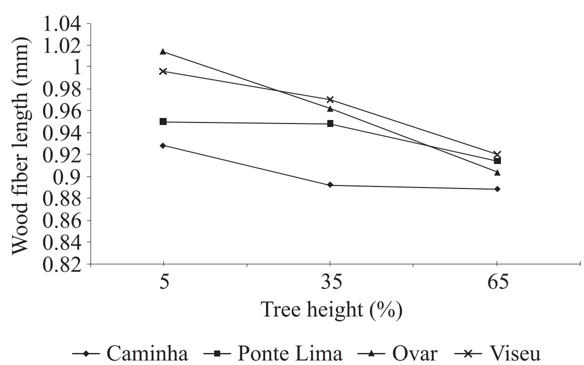

Figure 4 – Axial variation of wood fiber length of *Acacia melanoxylon* in four sites.

Figura 4 *– Variação axial do comprimento das fibras da madeira da Acacia melanoxylon nos quatro locais.*

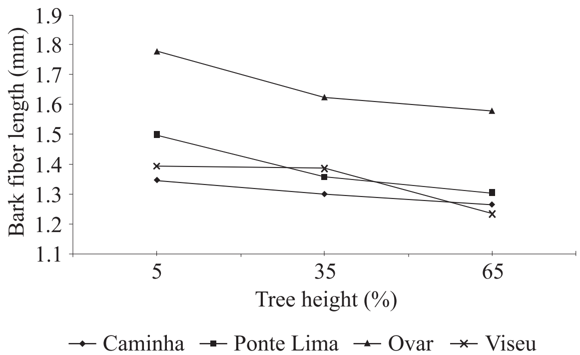

Figure 5 – Axial variation of bark fiber length of *Acacia melanoxylon* in four sites.

Figura 5 *–Variação axial do comprimento das fibras da casca da Acacia melanoxylon nos quatro locais.*

The axial variation of fiber length in wood was characterised by a slight decrease towards the top of the tree (Figure 4), from an average of 0.97 mm and 0.94 mm to 0.91 mm at 5%, 35% and 65% of total tree height respectively. The maximal mean value was determined at 5% of total tree height in Ovar (1.01 mm) and the minimum occurred in Caminha (0.89 mm) at 65% height level.

Very little has been published on axial variation patterns of fiber length in *Acacia melanoxylon*. Sahri et al. (1993) found the same axial variation in *Acacia mangium* with a fiber length decrease with height (1.026 mm to 0.849 mm). *Eucalyptus globulus* shows the same axial variation of wood fiber length.

The axial variation of bark fiber length observed in *Acacia melanoxylon* was characterised by a decrease towards the top of the tree (Figure 5) from an average of 1.51 mm and 1.42 mm to 1.34 mm at 5%, 35% and 65% of total tree height respectively. The maximal mean value was determined at 5% of total tree height level in Ovar (1.78 mm) and the minimum in Viseu (1.26 mm) at 65% height level. This is a pattern also described by Iqbal and Ghouse (1983) for *Acacia nilotica* with a variation of 1.12 mm in the base, 1.16 mm in the middle and 0.986 mm in the top of the tree.

The axial variation of *Acacia melanoxylon* wood and bark fibers showed a similar pattern, suggesting a similar cell differentiation mechanism in phloem and xylem. In *Eucalyptus globulus,* on the contrary, an inverse trend of fiber length variation was reported for wood and bark, with longer phloem fibers occurring at the top of the stem (JORGE et al., 2000; QUILHÓ et al., 2000).

3.2 Fiber wall thickness

Fiber wall thickness for wood and bark varied between 3.45-3.89 µm and 5.01-5.40 µm, respectively (Table 3). For wood wall thickness, there was a significant site differences (P <0.05) between Ovar and Viseu.

Table 3 – Wood and bark fiber wall thickness (µm) for *Acacia melanoxylon* in four sites. Mean and standard deviation of five trees per site.

Tabela 3 *– Espessura da parede das fibras da madeira e casca (µm) da Acacia melanoxylon nos quatro locais. Média e desvio padrão das cinco árvores por local.*

Site	Caminha	Ponte de Lima	Ovar	Viseu
Wood	3.77±0.20	3.63±0.22	3.45±0.30	3.89±0.17
Bark	5.01±0.25	5.12±0.14	5.40±0.11	5.36±0.40

The fiber wall thickness of *Acacia melanoxylon* wood is larger than the results obtained for *Eucalyptus globulus:* between 1.8 to 2.3 µm (JORGE, 1994), 1.79 µm to 3.06 µm (MOURA, 1999), 3.52 µm and 3.27 µm (ONOFRE, 1999).

For *Acacia mangium*, Sahri et al. (1993) in wood referred that fiber wall is relatively thin and varies little in thickness (3.1 - 3.5 µm and 4.1 - 4.5 µm for 4- and 8-year-old trees respectively), and Richter and Dallwitz (2000) reported very thin to medium wall thickness. The average bark fiber wall thickness fits into the values reported for *Acacia bilimekii* (6 µm) or *Acacia cochliacantha* (5 µm) (QUINTANAR ISAIAS et al., 2005).

In *Acacia melanoxylon* bark, the fibers had thinner walls than in the bark of *Eucalyptus globulus* where fiber wall thickness varied between 5-6 µm (QUILHÓ, 1998) and 6-7 µm (QUILHÓ et al., 2000).

3.2.1 Radial variation of wood fiber wall thickness

In average, fiber wall thickness in *Acacia melanoxylon* increased from pith to bark, with some fluctuations (Figure 6), from an average 3.55 µm near the pith, to 3.74 µm at the middle position and to 3.80 µm at the periphery (90% of the distance from pith). The minimal mean value was near the pith in Ovar (3.32 µm), and the maximum (3.94 µm) in Viseu. Average fiber wall thickness increased more rapidly between pith and middle positions than between middle and periphery positions (0.19 µm and 0.06 µm respectively).

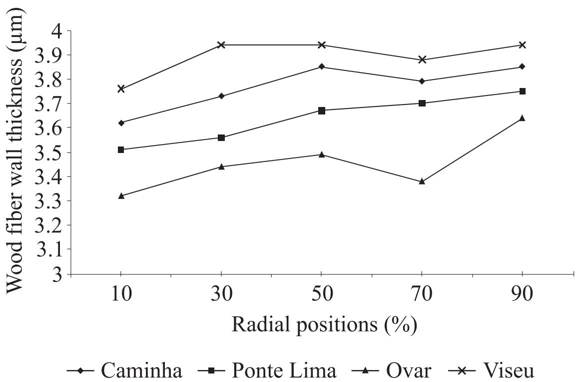

Figure 6 – Radial variation of wood fiber wall thickness of *Acacia melanoxylon* in four sites.

Figura 6 *– Variação radial da espessura de parede das fibras da madeira da Acacia melanoxylon nos quatro locais.*

Sahri et al. (1993) in 4 and 8–year-old samples of *Acacia mangium* observed that the fiber wall is relatively thin and varies little in thickness, between 3.1 µm and 3.5 µm for 4-year old trees and 4.1 µm to 4.5 µm for 8 year old trees and Salang e Fujii (2000) reported a slight increase from the pith to the sapwood. Quintanar Isaias et al. (2005) reported in *Acacia bilimekii* the value of 5 µm in the centre and in the periphery and in *Acacia cochliacantha* an increase from 5 to 7 µm from pith to bark.

For *Eucalyptus globulus,* Jorge (1994) registered also slight increases in wall thickness from pith to bark from 1.8 µm to 2.5 µm and Onofre (1999) found no radial pattern of wood wall thickness.

3.2.2 Axial variation of wood and bark fiber wall thickness

Figures 7 and 8 show the axial variation of wood and bark fiber wall thickness of *Acacia melanoxylon* in four sites, respectively.

In wood fiber wall thickness had no specific pattern for axial variation (Figure 7). Fiber wall thickness was higher in Viseu and Caminha than in Ponte de Lima and Ovar.

The maximal mean value of fiber cell wall was determined at 5% of total tree height level in Viseu (3.97 µm) and the minimum in Ovar (3.44 µm) at the same height level.

For *Eucalyptus globulus*, the fiber wall thickness increases from the base to 55 % tree height and decreases to the top from 1.97 µm, to 2.1 µm and 2.07 µm, respectively (JORGE, 1994).

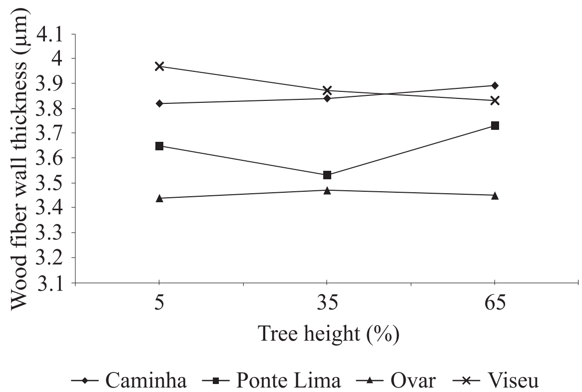

Figure 7 – Axial variation of wood fiber wall thickness of *Acacia melanoxylon* in four sites.

Figura 7 *– Variação axial da espessura de parede das fibras da madeira da Acacia melanoxylon nos quatro locais.*

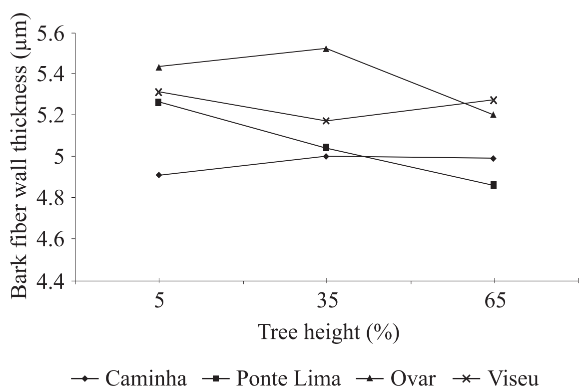

Figure 8 – Axial variation of bark fiber wall thickness of *Acacia melanoxylon* in four sites.

Figura 8 *– Variação axial da espessura de parede das fibras da casca da Acacia melanoxylon nos quatro locais.*

In bark, fiber wall thickness had also no specific pattern for axial variation at 5%, 35% and 65% of total tree height (Figure 8). Bark fiber wall thickness values were lower in Caminha (Figure 8) and the maximal mean value of fiber cell wall was determined at 35% of total tree height in Ovar (5.52 µm) and the minimum in Ponte de Lima (3.44 µm) at 65% height level.

For *Eucalyptus globulus*, the fiber wall thickness decreases from the base to the top with 7.3 µm, 6.4 µm, 6.1 µm, 5.5 µm, 5.4 µm at 5%, 15%, 35%, 55% and 75% of tree height (QUILHÓ et al., 2000).

4 CONCLUSIONS

In the wood of *Acacia melanoxylon*, fiber length and wall thickness increased radially from pith to bark. Axially the wood fiber length decreased from bottom to the top of the tree and wall thickness had no specific variation pattern.

In the bark of *Acacia melanoxylon*, fiber length decreased from bottom to the top of the tree and bark wall thickness had no specific variation pattern.

Significant site differences were found only in relation to wood fiber cell wall thickness and bark fiber length.

Fibers of *Acacia melanoxylon* were similar to those of *Eucalyptus globulus* in relation to length in wood and bark but wood fibers were thinner and bark fibers thicker.

5 ACKNOWLEDGMENTS

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