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A CARACTERIZAÇÃO E A VARIAÇÃO EM SECÇÃO TRANVERSAL DA ANATOMIA DA MADEIRA *ACACIA MELANOXYLON*

CHARACTERIZATION AND WITHIN-TREE VARIATION OF WOOD ANATOMY OF *ACACIA MELANOXYLON*

LA CARACTERIZACIÓN E LA VARIACIÓN EN SECCIÓN TRANSVERSAL DE LA ANATOMÍA DE LA MADERA *ACACIA MELANOXYLON*

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RESUMO

Introdução: A madeira de *A. melanoxylon* tem uma grande aplicação comercial devido às suas características anatómicas e propriedades mecânicas. No entanto, estudos sobre a caracterização anatómica desta espécie cultivada em Portugal são escassos.

Objetivos: Descrever as características anatómicas e sua variação em secção transversal da madeira de *A. melanoxylon* a crescer em Portugal.

Métodos: Foram analisadas 20 árvores em seção transversal para as seguintes posições radiais da árvore: 10%; 50%; 90% e cinco níveis de altura: junto à base; 15%; 35%; 65%; 80%. Para estas amostras foram determinados os valores médios referentes ao diâmetro transversal da fibra (mm), espessura da parede da fibra (μm), índice Runkle; índice de flexibilidade, número de vasos (número de vasos/mm^2), porosidade (%) e a largura do vaso (μm).

Resultados: As fibras de madeira de início de estação têm espessura de parede mais baixa e maior diâmetro do lúmen do que as fibras de madeira de lenho de fim de estação. Os índices de qualidade de pasta confirmam a qualidade da madeira de *A. melanoxylon* na produção de papel. A madeira de *A. melanoxylon* tem porosidade inferior perto da medula como resultado de um ligeiro aumento do número de vasos com tamanho inferior.

Conclusões: A madeira de Acácia demostrou que apresenta características anatómicas com potencial para ser uma espécie alternativa para a indústria.

Palavras-chave: *Acacia melanoxylon*, morfologia da madeira, fibras, vasos, índices de qualidade da pasta.

ABSTRACT

Introduction: *A. melanoxylon* wood has a large commercial application given its anatomical characteristics and mechanical properties. However studies on the anatomical characterisation of this species grown in Portugal are scarce.

Objectives: To describe the transverse anatomical characteristics and their within-tree variation of *A. melanoxylon* trees growing in Portugal.

Methods: 20 trees were analysed in transverse section for tree radial position (10%; 50%; 90%) and five height levels (base, 15%; 35%; 65%; 80%) in north and south directions. Measurements included: fibre diameter (μm), fibre wall thickness (μm), Runkle index; Flexibility index, vessel number (vessel number /mm^2), porosity (%) and vessel width (μm).

Results: Earlywood fibres have lower wall thickness and higher lumen diameter than latewood fibres. Runkle and flexibility indexes confirm its potential for pulp and paper production. Porosity was lower near the pith as a result of a slight increase of vessel number with smaller size.

Conclusions: Blackwood showed potential as an alternative species to supply the industry.

Keywords: *Acacia melanoxylon*, wood morphology, fibres, vessel, pulp quality indexes

RESUMEN

Introducción: Debido a las características anatómicas y a las características mecánicas, la madera de *A. melanoxylon* tiene una grande aplicación comercial. Sin embargo, los estudios relacionados con la caracterización anatómica de esta especie en asentamientos portugueses son escasos.

Objetivos: Describir las características anatómicas y su variación en la sección transversal de la madera de *A. melanoxylon* a crecer en Portugal.

Métodos: 20 árboles fueron analizados en la sección transversal para las siguientes posiciones radiales del árbol: el 10%; 50%; 90% y cinco niveles de altura: al lado de la base; 15%; 35%; 65%; 80%. Para las muestras mencionadas se analizaron el diámetro transversal de la fibra (mm), espesor de pared de la fibra (μm), índice del Runkle; índice de la flexibilidad, número de vasos (número de vasos/mm^2), porosidad (%) y el ancho del vaso (μm) se midieron en las mencionadas muestras de madera.

Resultados: Las fibras del inicio de estación tienen un grueso más bajo de la pared y de un mayor diámetro del lumen que las fibras del fin de estación. El índice de calidad de celulosa *A. melanoxylon* confirma la aptitud de la pulpa para la producción de papel. La madera de *A. melanoxylon* tiene la porosidad más baja cerca de la médula como resultado de un ligero aumento del número de del vasos con tamaño inferior.

Conclusiones: Acacia ha demostrado potencial para ser una especie alternativa para la industria.

Palavras-clave: *Acacia melanoxylon,* morfología de la madera, fibras, vasos, índices de calidad de la pulpa.

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INTRODUCTION

Acacia melanoxylon R. Br. (commercial name blackwood) grows in eastern Australia (from north Queensland to Southern Tasmania and westwards into South Australia). It was introduced into Europe as an ornamental and is now established as a forest plantation species.

Portuguese legislation (Decreto Lei nº 565/99, 21 December, ratified in 2000) lists several exotic plant species as introduced to Portugal, and some of them are invasive species like *Acacia* spp.. This means that it is forbidden to planting any of the invasive species listed in the legislation. The legislative process is still being implemented.

A. melanoxylon wood has a large commercial value given its anatomical and mechanical properties (Machado et al., 2014). The wood can be used for solid wood products (Griffin et al., 2011) in building and carpentry (Jablonski et al., 2010), panel products, pulp and paper (Santos el al., 2006, 2012; Anjos et al., 2011; Pereira et al., 2016) and food, fodder, poles and domestic fuelwood (Griffin et al., 2011).

The anatomic characteristics are important for all applications, but there are not many reports on the wood anatomy of *A. melanoxylon* and on its variability (Iqbal, 1983; Sahri et al., 1993; Wilkins and Papassotiriou et al., 1989; Rodrigues et al., 2007; Tavares et al., 2011).

The *A. melanoxylon* wood shows distinct growth rings with dense latewood bands, solitary or radial grouped vessels, vessel diameter between 100-300 μm, low percentage of paratracheal parenchyma, homogeneous 1-3-seriate rays up to 40 cells high (Dadswell & Eckersley 1935; Wilkins and Papassotiriou et al., 1989). Fibre length ranges between 0.90-0.96 mm (Tavares et al. 2011).

The aim of this study is to strengthen the knowledge on *A. melanoxylon* wood anatomy by characterizing the transverse anatomical features and their within-tree variation in radial and axial directions in trees existing in Portugal.

1. MATERIAL and METHODS

1.1. Samples

The samples used for the anatomical characterization were from 35 to 49 year old *Acacia melanoxylon* R. Br. trees from four stands in the north of Portugal that were well characterized by Machado et al. (2014). From each stand 5 trees were used and in each tree discs at different height levels (base, 15%, 35%, 65% and 80% of total tree height) were taken. The anatomical characteristics were measured at three radial positions (at 10%, 50% and 90% from the pith) in the two North and South opposing radii in 60 vessels or fibres.

1.2. Procedures

The wood samples were cut with 1x1cm in cross section and 2 cm in length. The samples were immersion in boiling water and glycerin (4:1) during approximately 2 hours and softened in a 1:10 solution of glycerin and water for several days. After that, the samples were cut in thin slices with 16 mm of thickness with a microtome (Leica SM 2400, Germany) equipped with a steel blade type C. The samples were suspended with sodium hypochlorite solution, washed with water and colored.

The wood anatomical characteristics were determined by image analysis on histological cuts using a reflective microscope (Leica, DMLL, Germany) at a magnification of 100 X and analysed with a Qwin 500 image analysis software (Leica, England).

The following characteristics were measured: fibre transversal diameter (μm), fibre wall thickness (μm), Runkle index (RK), Flexibility index (FI), vessel number (vessel number/mm^2), porosity (%) measured as vessels percentage (area %; percentage of pores area in transversal section of wood), vessel width (μm) and vessel area (mm^2).

The Runkle index (that measures fibre quality for pulp and paper, Runkle, 1952) was calculated according to:

$$RK=\frac{2 \text{ x wall thickness}}{\text{Lumen width}}$$

The flexibility index is related to the fibre tensile and bursting strength with higher values meaning higher tensile strength that correspond to higher bursting strength. The flexibility index was calculated according to:

$$FI=\frac{\text{Lumen diameter x 100}}{\text{Fibre diameter}}$$

2. RESULTS AND DISCUSSION

The transverse section of *A. melanoxylon* wood (Figure 1) shows distinct growth rings (Figure 1A) resulting from the spring and autumn radial growth. The vessels are isolate and distributed in a diffuse porosity (Figure 1B) or sometimes grouped (two vessels) in the radial direction (Figure 1C). A low percentage of paratracheal parenchyma was observed; the rays were mainly

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monoseriate, but 2-seriate rays were also found with a low percentage. These results are in agreement with those reported in the literature (Dadswell and Eckersley 1935; Wilkins and Papassotiriou et al., 1989).

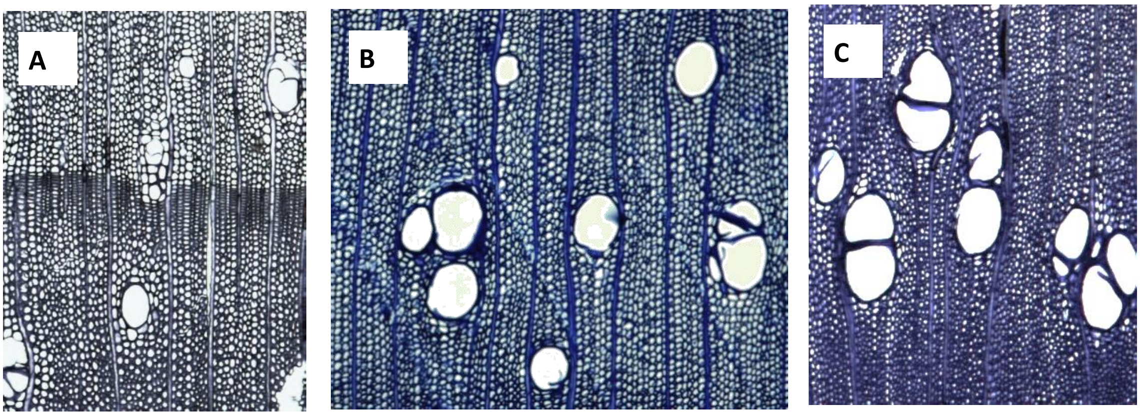

Figure 1 – Transverse section of a wood sample of *A. melanoxylon*.

The fibre diameter of *A. melanoxylon* wood ranged between 0.363 and 0.912 mm (Figure 2). These results are in agreement with those of Tavares et al. (2011) and similar also to the values found for *Eucalyptus globulus* (Gominho et al., 2014; Miranda and Pereira, 2002). Fibre diameters were higher in the earlywood than in latewood in both north and south positions. No trends of fibre diameter variation with the radial position were observed (Figure 2).

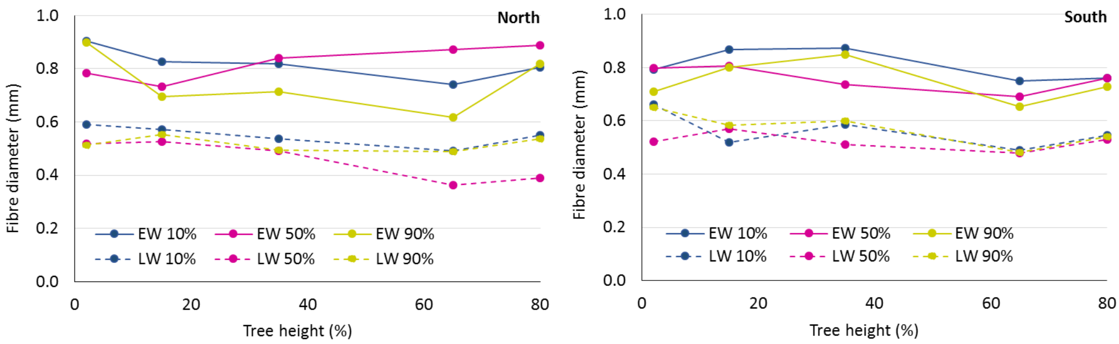

Figure 2 - Radial variation of transverse fibre diameter of *A. melanoxylon* wood.

Regarding fibre wall thickness, the variation from pith to bark and in north and south directions was very small (Figure 3). Average values between 2.00 and 2.40 µm were found respectively for earlywood and latewood for the north direction and between 2.01 and 2.38 µm respectively for earlywood and latewood for the south direction. The latewood fibre wall thickness was always higher than that observed for earlywood. These values are lower than those observed by Tavares et al. (2011) who measured the fibre wall thickness using dissociated samples.

It is well known that fibre characteristics such as lumen width and wall thickness are important parameters for the wood raw-material in the pulp and paper industry. Fibre lumen is important in the pulp beating process e.g. a larger fibre lumen improves the beating and the penetration of liquid to the empty spaces of the fibre wall (Young, 1981).The Runkle index is related with the suitability of a fibrous material for pulp and paper production: high Runkle index fibres produce bulkier paper because the fibres will be stiffer and less flexible and will have poor bonding ability (Kiaei et al. 2014).

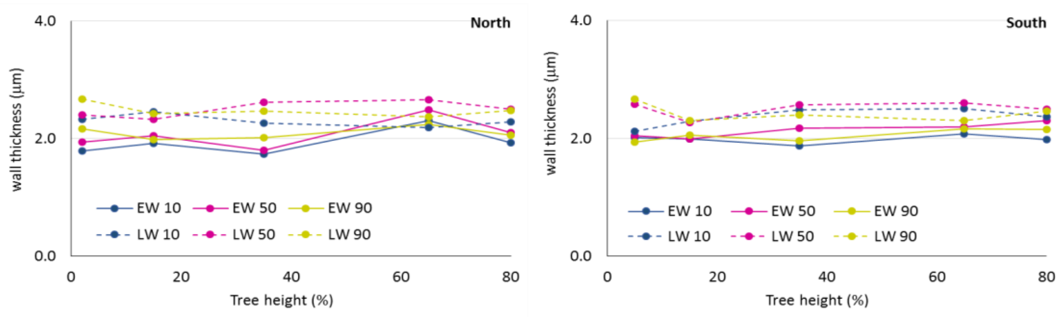

Figure 3 - Radial variation of transverse fibre wall thickness of *A. melanoxylon* wood.

Runkle index (RK) values were lower in earlywood than in the latewood and showed no variation along the stem in the different height positions. If RK is ≤ 1, the fibre is good for pulp and paper production, if RK < 1, the fibre is highly appropriate for pulp and paper production, from 1 to 2 is regular, and above 2 it may not be used for paper.

Almost all RK values of earlywood that corresponds to the highest proportion of acacia wood, (Rucha et al., 2011) were lower than 1 (Figure 4) suggesting a good potential for pulp and paper. This was shown in previously work of this research group (Santos el al., 2006, 2012; Anjos et al., 2011).The latewood presented higher RK values, but almost all were lower than 2 (regular use for pulp and paper).

The potential of *E. globulus* wood for pulp and paper is well known. For *E. globulus wood,* Patt et al. (2006) found RK values of 0.56 and Gominho et al. (2014) RK values ranging between 1.0 and 1.9. The RK values found for *A. melanoxylon* are close to the values reported for E. *globulus* wood, thus supporting its potential for pulp and paper.

The tensile and bursting strength depend mainly on the fibre bonding in the paper sheet which is largely related to the flexibility and compressibility of the individual fibres (Alao, 2009). Values of flexibility index ranging between 50 and 75 (Figure 4) mean that the fibres will produce good paper with high strength properties (Brindha et al., 2012).

According to Bektas et al., (1999) the flexibility index (FI) can be separated in four classes: high elastic fibres with FI over 75; elastic fibres with FI between 50 and 75; rigid fibres with FI between 30 and 50; highly rigid fibres with FI less than 30.

The *A. melanoxylon* fibres are included in the elastic fibres group. The FI values in latewood were lower than in earlywood for both north and south directions. In fact the earlywood fibres with lower wall thickness and higher lumen diameter are more flexible than the latewood fibres.

The porosity measured as vessel percentage (area %) was lower near the tree pith (Figure 5) but the vessel number was higher which suggests that the lower porosity observed near the pith is a result of slight increase vessel number with a lower size. These results are in agreement with those observed in other species (Sharma, 2005; Silva 1987).

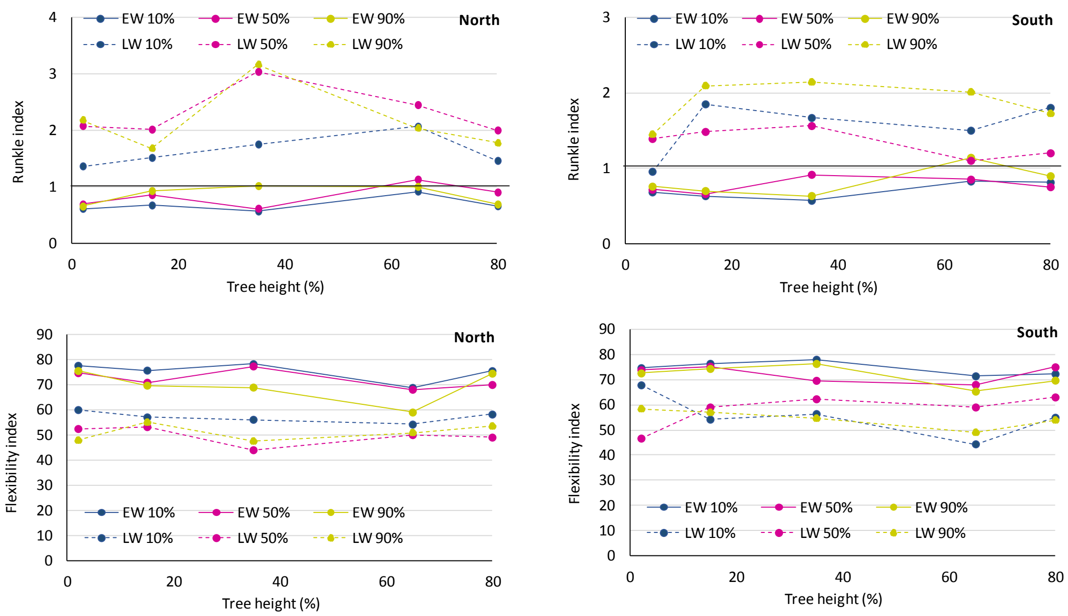

Figure 4 - Height and radial variation of Runkle and flexibility indexes of *A. melanoxylon* wood.

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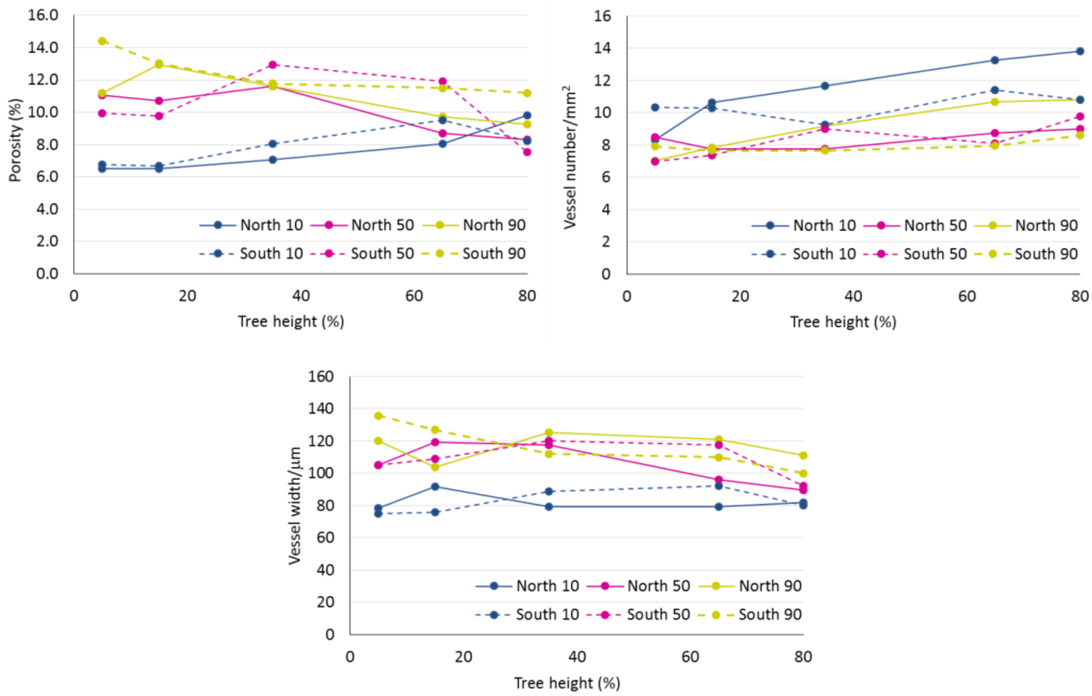

Figure 5 - Height and radial variation of porosity, vessel number and vessel width of *A. melanoxylon* wood.
The variation between North and South positions was not significant ($p<0.05$) for porosity, vessel number and vessel width. These results are in accordance to those reported by Rodrigues et al. (2007).

CONCLUSIONS

For *A. melanoxylon* trees growing in the north of Portugal the wood fibre diameter and wall thickness showed no specific within-tree variation pattern in axial and radial directions. The earlywood fibres were thinner and had higher lumen diameter than the latewood fibres.
A. melanoxylon wood was quite similar to *E. globulus* wood in relation to pulp quality indexes thus confirming its quality for pulp and paper production.
A. melanoxylon wood showed lower porosity near the pith corresponding to a slight increase of vessel number but with lower size.
For all the parameters measured in this study, the variation between north and south directions was not significant.

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REFERENCES

Alao, O. (2009). Fibre morphology and its extent in pulp and paper making. Unpublished Student's Industrial Work Experience Scheme (SIWES) notebook FRIN, Ibadan, Nigeria.

Anjos, O., Santos, A., & Simões, R. (2011). Effect of *Acacia melanoxylon* fibre morphology on papermaking potential. Appita Journal, 64(2), 185-191.

Bektas, I., Tutus, A. & Eroglu, H. (1999). A study of the suitability of Calabrian pine (*Pinus brutia* Ten) for pulp and paper manufacture. Turkish Journal of Agriculture, 23, 589-599.

Brindha, D., Vinodhini, S., & Alarmelumangai K. (2012). Fiber dimension and chemical contents of fiber from *Passiflora foetida* L. and their suitability in paper production. Science Research Reporter, 2(3), 210-219. ISSN: 2249-7846

Dadswell, H.E., & Eckersley, A.M. (1935). The identification of the principal commercial Australian timbers other than eucalypts. CSIR (Aust.) Bull. N^{o}. 90.

Gominho, J., Lopes, C., Lourenço, A., Simões, R., & Pereira, H. (2014). *Eucalyptus globulus* stumpwood as a raw Material for pulping. Bioresources, 9(3), 4038-4049.

Griffin, A.R., Midgley, S.J., Bush, D., Cunningham, P.J., & Rinaudo, A.T. (2011). Global uses of Australian acacias – recent trends and future prospects. Diversity and distribution. 17, 837–847. DOI: 10.1111/j.1472-4642.2011.00814.x

Iqbal, M., & Ghouse, A.K.M. (1983). An analytical study on cell size variation in some arid zone trees of India: *Acacia nilotica* and *Prosopis spicigera*. IAWA Bulletin, 4(1), 46-52. DOI: 10.1163/22941932-90000775

Jablonski, M., Sedliacik, J., & Ružinská, E. (2010). Less popular application of trees and bushes growing in Poland and Slovakia. Annals of Warsaw University of Life Sciences – SGGW, Forestry and Wood Technology, 71, 240-244

Kiaei, M., Tajik, M., & Vaysi, R. (2014). Chemical and biometrical properties of plum wood and its application in pulp and paper production. Maderas. Ciencia y tecnología 16(3), 313-322, DOI:10.4067/S0718-221X2014005000024

Machado, J., Louzada, J., Santos, A., Nunes, L., Anjos, O., Rodrigues, J., Simões, R., & Pereira, H. (2014). Variation of wood density and mechanical properties of blackwood (*Acacia melanoxylon* R. Br.). Material and Design, 56, 975–980. DOI: 10.1016/j.matdes.2013.12.016

Miranda, I., & Pereira, H. (2002). Variation pulpwood quality with provenances and site in *Eucalyptus globulus*. Annals of Forest Science, 59(3): 283-291. https://doi.org/10.1051/forest:2002024

Patt, R., Kordsachia, O., & Fehr, J. (2006). European hardwoods versus *Eucalyptus globulus* as a raw material for pulping. Wood Science and Technology, 40, 39-48. DOI: 10.1007/s00226-005-0042-9

Pereira, H., Santos, A.J.A., & Anjos, O. (2016). Fibre morphological characteristics of Kraft pulps of *Acacia melanoxylon* estimated by NIR-PLS-R models. Materials, 9, 8;. DOI:10.3390/ma9010008

Rodrigues, C., Santos, A., Tavares, M., & Anjos, O. (2007). Vessel morphological evaluation of *Acacia melanoxylon* wood. Proceedings of Wood Science and Engineering in the Third Millennium" - ICWSE 2007. Brasov - June 20 – 22. Romenia, p: 92-99.

Rucha, A., Santos, A., Campos, J., Anjos, O., & Tavares, M. (2011). Two methods for tree volume estimation of *Acacia melanoxylon* in Portugal. Revista Floresta. 41(1), 169-178.

Runkle, R.O.H. (1952). Pulp from Tropical Woods. Bundesanstalt fur Forst und Holzwirtschaft, ReinbekBez. Hamburg, pp 20-25.

Sahri, M. H., Ibrahim, F. H., & Shukor, N.A. (1993). Anatomy of *Acacia mangium* grown in Malaysia. IAWA Journal, 4(3), 245-251. DOI: 10.1163/22941932-90001326; ISSN

Santos, A., Amaral, M.E., Gil, N., Anjos, O., Rodrigues, J., Pereira, H. & Simões R. (2012). Influence on pulping yield and pulp properties of wood density of *Acacia melanoxylon*. Journal of Wood Science, 58(6), 479-486. DOI 10.1007/s10086-012-1286-2

Santos, A., Anjos, O., & Simões, R. (2006). Paper making potencial of Acacia. APPITA journal, 59 (1), 58-64.

Silva, A.C. (1987). Introdução á anatomia da madeira. Manaus: Instituto de Tecnologia da Amazónia.

Sharma, S.K., Rao, R.V., Shukla, S.R., Kuma, P., Sudheendra, R., Sujatha, M., Dubey, Y.M. (2005). Wood quality of coppiced *Eucalyptus tereticornis* for value addition. IAWA Journal 26 (1), 137-147. DOI: 10.1163/22941932-90001608

Tavares, F, Quilhó, T, & Pereira, H. (2011). Wood and bark fiber characteristics of *Acacia melanoxylon* and comparison to *Eucalyptus globules*, Cerne, Lavras, 17(1), 61-68.

Wilkins A. P., & Papassotiriou, S. (1989). Wood anatomical variation of *Acacia melanoxylon* in relation to latitude. IAWA Bulletin, 10 (2), 201-207. DOI: 10.1163/22941932-90000490

Young, J.H. (1981). Fiber preparation and approach flow in pulp and paper. In: Casey JP (eds). Chemistry and chemical technology, Interscience Publishers, New York.