



Bosque

ISSN: 0304-8799

revistabosque@uach.cl

Universidad Austral de Chile

Chile

Ismael Afonso, Cláudio Manuel; Alves Pereira Gonçalves, Thaís; Bolzon de Muñiz, Graciela Inés;
Monteiro de Matos, Jorge Luis; Nisgoski, Silvana
Mozambique's charcoals: anatomy of nine native species
Bosque, vol. 36, núm. 1, 2015, pp. 105-112
Universidad Austral de Chile
Valdivia, Chile

Available in: <http://www.redalyc.org/articulo.oa?id=173136974011>

- How to cite
- Complete issue
- More information about this article
- Journal's homepage in redalyc.org

redalyc.org

Scientific Information System
Network of Scientific Journals from Latin America, the Caribbean, Spain and Portugal
Non-profit academic project, developed under the open access initiative

Mozambique's charcoals: anatomy of nine native species

Carbones de Mozambique: anatomía de nueve especies nativas

Cláudio Manuel Ismael Afonso ^a, Thaís Alves Pereira Gonçalves ^b, Graciela Inés Bolzon de Muñiz ^c,
Jorge Luis Monteiro de Matos ^c, Silvana Nisgoski ^{c*}

^a Ministry of Agriculture, National Directorate of Land and Forestry, Av. Josina Machel, 537, Maputo, Mozambique, Africa.

^b Federal University of Parana, Doctoral Student of Forest Engineering. Av. Pref. Lothário Meissner, 632, Jardim Botânico, 80.210-170, Curitiba, PR, Brazil.

*Corresponding author: ^c Federal University of Parana, Department of Forest Engineering and Technology, Av. Pref. Lothário Meissner, 632, Jardim Botânico, 80.210-170, phone: (55) 41 – 3360-4275, Curitiba, PR, Brazil, silvana.ufpr@gmail.com

SUMMARY

Most of the charcoal commercially produced in Mozambique is from natural forests, including high value species. This production often negatively affects the environment and one of the main reasons is the lack of sustainable forest management techniques. To facilitate forest control, we characterize the anatomy properties of charcoal made from *Azelia quanzensis*, *Amblygonocarpus andongensis*, *Combretum imberbe*, *Dalbergia melanoxylon*, *Guibourtia conjugata*, *Khaya nyasica*, *Millettia stuhlmannii*, *Pterocarpus angolensis* and *Swartzia madagascariensis*. All these species possess high commercial value. The samples were carbonized at 450 °C for 1 h. Some shrinkage-related ruptures were present in charcoals, but the structure kept good definition of the cells features and did not influence the distinction of the species. The propagation of this knowledge would relieve pressure on valuable species and may also help with control of the charcoal supply chain.

Key words: carbonization, anatomical characteristics, commercial wood, wood anatomy.

RESUMEN

La mayor parte del carbón producido en el comercio en Mozambique es de bosques naturales, incluyendo las especies de alto valor comercial. Esta producción afecta negativamente el medio ambiente y una de las principales razones es la falta de técnicas de manejo forestal sostenible. Para facilitar el control del uso de los bosques, se caracterizan las propiedades de anatomía de carbón vegetal a base de *Azelia quanzensis*, *Amblygonocarpus andongensis*, *Combretum imberbe*, *Dalbergia melanoxylon*, *Guibourtia conjugata*, *Khaya nyasica*, *Millettia stuhlmannii*, *Pterocarpus angolensis* y *Swartzia madagascariensis*. Todas estas especies tienen un alto valor comercial. Las muestras fueron carbonizadas a 450 °C durante 1 h. Algunas rupturas relacionadas con las pérdidas estuvieron presentes en los carbones, pero la estructura mantuvo buena definición de las características anatómicas de las células y no influyeron en la distinción de las especies. La difusión de este conocimiento podría aliviar la presión sobre las especies valiosas y también puede ayudar con el control de la cadena de suministro de carbón.

Palabras clave: carbonización, características anatómicas, maderas comerciales, anatomía de la madera.

INTRODUCTION

Mozambique has a great diversity of natural forests, and forestry biomass has an important role due to its environmental, social and economic dimensions (Vasco and Costa 2009). Biomass energy in the form of charcoal or firewood is used by over 85 % of urban households in Mozambique. Charcoal commerce covers an extensive value chain, from those at the production sites to those transporting and retailing it in the cities. Despite the dimension of this sector, it is a largely informal activity with limited recorded information (Vasco and Costa 2009, Cuvilas *et al.* 2010). Practically all the charcoal comes from natural

forests. The production is characterized by a lack of sustainable forest management techniques; thus threatening natural resources (Bila 2005).

The estimated allowable cutting of trees in Mozambique is about two million cubic meters per year (Marzoli 2007). Regarding its commercial and scientific value, rarity, utility, resistance and quality, species which produce wood are classified into precious, first class, second class, third class and fourth class (Ministério da Agricultura). Some authors commented by Ali *et al.* (2008) explain that there are 118 wood species listed in the National Forestry Rules Guidelines classified in accordance with their value and some, classified as precious and first class, such

as *Berchemia zeyheri* (Sond.) Grubov (pau-rosa), *Spirostachys africana* Sond. (sandaló), *Swartzia madagascariensis* Desv. (pau-ferro), *Afzelia quanzensis* Welw. (chanfuta), *Millettia stuhlmannii* Taub. (jambirre), *Pterocarpus angolensis* DC. (umbila), *Androstachys johnsonii* Prain. (mercusse) and *Combretum imberbe* Wawra (monzo) are in declining availability in the Mozambican forests.

For energy purposes it is not allowed the use of wood from precious, first, second and third class, as well as those species that are scarce, protected or with historic and cultural value (Ministério da Agricultura 2002). Nevertheless, in Mozambique this is widely disobeyed by charcoal producers, because the choice of species for production depends on its availability and local culture (Bila 2005). In 2010 the use of firewood to produce charcoal was more than eleven million cubic meters (Steierer 2011). In African countries, the use of firewood and charcoal has been increasing as a consequence of urbanization and economic growth. This situation concerns environmentalists and those responsible for the management of forestry resources (Girard 2002, Clancy 2008).

Several studies have demonstrated that the anatomical structure of wood is maintained after carbonization (Kim and Hanna 2006, Gonçalves *et al.* 2012, Muñiz *et al.* 2013, Nisgoski *et al.* 2014). These authors have shown it is possible to identify species by examining charcoal samples. There are no scientific papers focusing on the features of charcoal made from species native to Mozambique. Along with this, literature on the anatomical features of arboreal species is not widely known in Mozambique, which contributes to the weak forestry control.

The present study characterizes the charcoal anatomy of nine species from Mozambique. All the species are prohibited for energetic purposes. We aim at contributing to the knowledge of these species and at helping to improve the forestry control.

METHODS

The samples were obtained from trees without a defined age growing in natural forests in Cabo Delgado (E39°17'01.70'' S12°09'17.82) and Sofala (E34°50'34.79'', S17°30'21.19''), provinces of Mozambique with annual average precipitation varying from 800 to 1,200 mm and predominant tropical and humid climate (INDE 2009). All the species chosen are native and possess high commercial value (table 1). For each species, three trees were randomly chosen for felling. The samples were taken as discs at breast height. The thickness of the discs was 5 cm with diameter of 18-35 cm outside the bark. All samples were free from defects. For the analyses, the samples were cut into blocks measuring 2.5 x 2.5 x 5 cm.

The samples were wrapped in aluminum foil and carbonized in an electric muffle furnace at 450 °C for 1 hour, with a heating rate of 7.5 °C per minute. After carbonization, the samples were cooled and weighed.

For anatomical analyses, the charcoal was broken by hand following the three structural planes of the wood and analyzed under a Zeiss Discovery v12 stereo microscope. The anatomical description was done based on the procedures of the Iawa Committee (1989). The images of charcoal were obtained by scanning electron microscopy with a tabletop microscope (Hitachi TM-1000). No metallic-sputter-coating was needed. The determination of qualitative anatomical features was based on 25 measurements of tangential vessel diameter (µm), vessel frequency (vessels mm⁻²), ray frequency (rays mm⁻¹), ray width (µm) and ray height (µm).

RESULTS

The anatomical characteristics of the charcoal samples are summarized in quantitative (table 2) and qualitative (table 3) features, and illustrated in figures 1 - 3.

Table 1. List of species studied.

Lista de las especies estudiadas.

Scientific name	Commercial name	Family	Commercial class
<i>Afzelia quanzensis</i> Welw.	Chanfuta	Caesalpiniaceae	First
<i>Combretum imberbe</i> Wawra	Mondzo	Combretaceae	First
<i>Khaya nyasica</i> Stapf ex Baker F.	Umbaua	Meliaceae	First
<i>Millettia stuhlmannii</i> Taub.	Jambire	Fabaceae	First
<i>Pterocarpus angolensis</i> DC.	Umbila	Fabaceae	First
<i>Swartzia madagascariensis</i> Desv.	Pau-ferro	Caesalpiniaceae	First
<i>Dalbergia melanoxylon</i> Guill. et Perr.	Pau-preto	Fabaceae	Precious
<i>Guibourtia conjugata</i> (Bolle) J. Léonard	Chacate-preto	Caesalpiniaceae	Precious
<i>Amblygonocarpus andongensis</i> (Welw. Ex Oliv.) Exell et Torre	Mutiria	Mimosaceae	Second

Source: Ministério da Agricultura (2002).

Table 2. Mean values and standard deviations of quantitative anatomical features of charcoal from nine Mozambique species.

Valores medios y error estándar de las características anatómicas cuantitativas del carbón de nueve Mozambique especies.

Species	Vessel mm ⁻²	Vessel diameter (μm)	Ray mm ⁻¹	Ray width (μm)	Ray height (μm)
<i>Afzelia quanzensis</i>	6 (1.8)	166 (25)	6 (1.7)	48 (8)	223 (39)
<i>Amblygonocarpus andongensis</i>	23 (3.4)	116 (32)	6 (1.1)	39 (5)	221 (45)
<i>Combretum imberbe</i>	5 (1.4)	142 (31)	9 (2.2)	30 (5)	161 (38)
<i>Dalbergia melanoxylon</i>	11 (1.9)	114 (33)	9 (1.8)	29 (8)	156 (47)
<i>Guibourtia conjugata</i>	30 (4.8)	80 (18)	7 (1.5)	38 (7)	303 (76)
<i>Khaya nyasica</i>	20 (3.0)	127 (40)	4 (2.4)	83 (21)	426 (106)
<i>Millettia stuhlmannii</i>	11 (1.7)	202 (72)	6 (2.4)	42 (10)	199 (25)
<i>Pterocarpus angolensis</i>	9 (1.1)	182 (39)	10 (3.2)	38 (7)	106 (16)
<i>Swartzia madagascariensis</i>	20 (3.9)	70 (20)	9 (2.0)	28 (5)	124 (15)

Table 3. Summary of qualitative anatomical features of charcoal from nine species.

Resumen de las características anatómicas cualitativas del carbón de nueve especies.

Species	GR	OD	PP	IP	Axial parenchyma	RW	RCC	SS	MI
<i>Afzelia quanzensis</i>	✓	✓	Simple	Alternate	Lozenge-aliform, confluent, and marginal	2-3	A	Absent	✓
<i>Amblygonocarpus andongensis</i>	✓	✓	Simple	Alternate	Aliform, confluent and marginal	1-2	A	Absent	✓
<i>Combretum imberbe</i>	✓	✓	Simple	Alternate	Vasicentric, aliform, confluent and in bands	1-2	D	Absent	✓
<i>Dalbergia melanoxylon</i>	✓	✓	Simple	Alternate	Vasicentric and diffuse-in-aggregates, aliform, confluent, marginal	1-2	A	Rays, axial parenchyma, vessels	✓
<i>Guibourtia conjugata</i>	✓	✓	Simple	Alternate	Vasicentric, aliform, confluent, marginal	3	A	Absent	✓
<i>Khaya nyasica</i>	✓	✓	Simple	Alternate	Vasicentric and scanty	2-5	C	Absent	✓
<i>Millettia stuhlmannii</i>	–	✓	Simple	Alternate	Confluent and bands	1-3	A	Rays, axial parenchyma, vessels	✓
<i>Pterocarpus angolensis</i>	✓	✓	Simple	Alternate	Aliform, confluent and bands	1-2	A	Rays, axial parenchyma, vessels	✓
<i>Swartzia madagascariensis</i>	✓	✓	Simple	Alternate	Aliform, confluent and bands	1-2	A	Rays, axial parenchyma, vessels	✓

Legend: GR – growth ring; OD – other deposits; PP – perforation plates; IP – intervessel pits; RW – ray width; RCC – rays: cellular composition; Rays: cellular composition: A – all ray cells procumbent; B – body ray cells procumbent with one row of upright and/or square marginal cells; C – body ray cells procumbent with mostly 2 to 4 rows of upright and/or square marginal cells; D – rays with procumbent, square and upright cells mixed throughout the ray; SS – storied structure; MI – mineral inclusions.

Shrinkage-related ruptures (figure 4) were observed in samples of *Afzelia quanzensis*, *Amblygonocarpus andongensis*, *Dalbergia melanoxylon*, *Guibourtia conjugata*, *Khaya nyasica*, *Pterocarpus angolensis* and *Swartzia madagascariensis*. *Dalbergia melanoxylon* presented ruptures in a parallel direction and perpendicular to the rays and *P. angolensis* only ruptures perpendicular to the rays. The other species only presented ruptures oriented in the direction of the rays.

DISCUSSION

The qualitative anatomical structures of charcoal are the same as those observed in the description of the wood from these species analyzed in other studies. The database of Inside Wood (2012) contains the anatomical description of the hardwood species *Afzelia quanzensis*, *Amblygonocarpus andongensis*, *Combretum imberbe*, *Dalbergia me-*

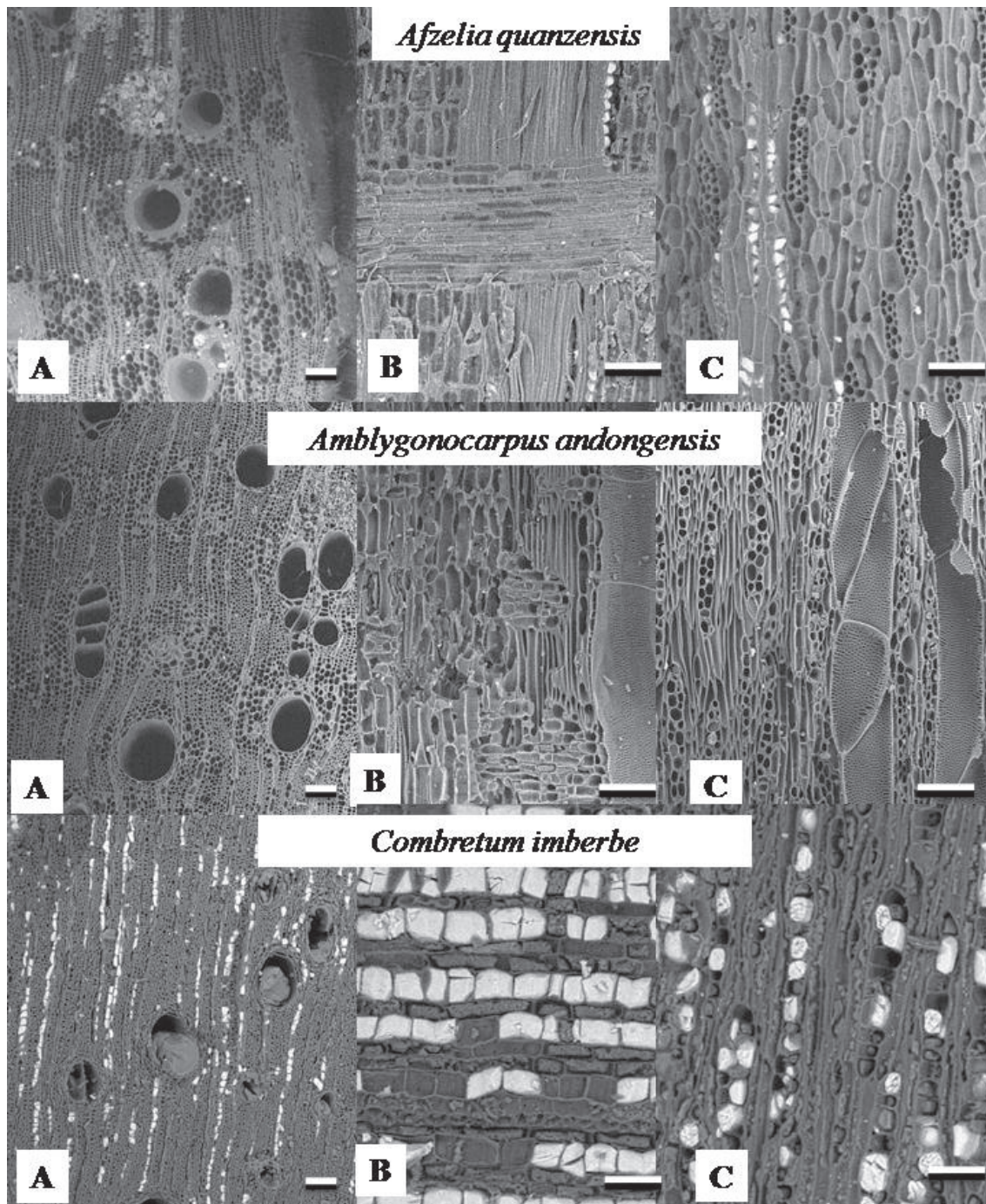


Figure 1. Scanning electron microscopy: images of transversal (A), radial (B) and tangential (C) section of charcoal. Scale bar = 100 μm.
Microscopía electrónica de barrido: imágenes de la sección transversal (A), radial (B) y tangencial (C) del carbón. Escala = 100 μm.

lanoxylon, *Millettia stuhlmannii*, *Pterocarpus angolensis*, *Swartzia madagascariensis*; Richter and Dallwitz (2000) described the hardwood of *A. quanzensis*, *D. melanoxylon*, *Guibourtia conjugata*, *Khaya nyasica*, *M. stuhlmannii*, *P. angolensis*, *S. madagascariensis*; and Ali *et al.* (2008) reviewed the anatomical characteristics of the hardwood of *A. quanzensis*, *K. nyasica*, *P. angolensis*, *M. stuhlmannii*.

The carbonization at 450 °C and 7.5 °C per minute of heating rate preserved well the structure of charcoal with good definitions of the cells features. Other works reported similar behaviors at different temperatures and/or heating rate, *e.g.*: (i) *Dichrostachys cinerea* (L.) Wight *et Arn.* (Leguminosae) and *Salix subserrata* Willd. (Salicaceae) carbonized at 400 °C and 6.67 °C per minute (Prior and

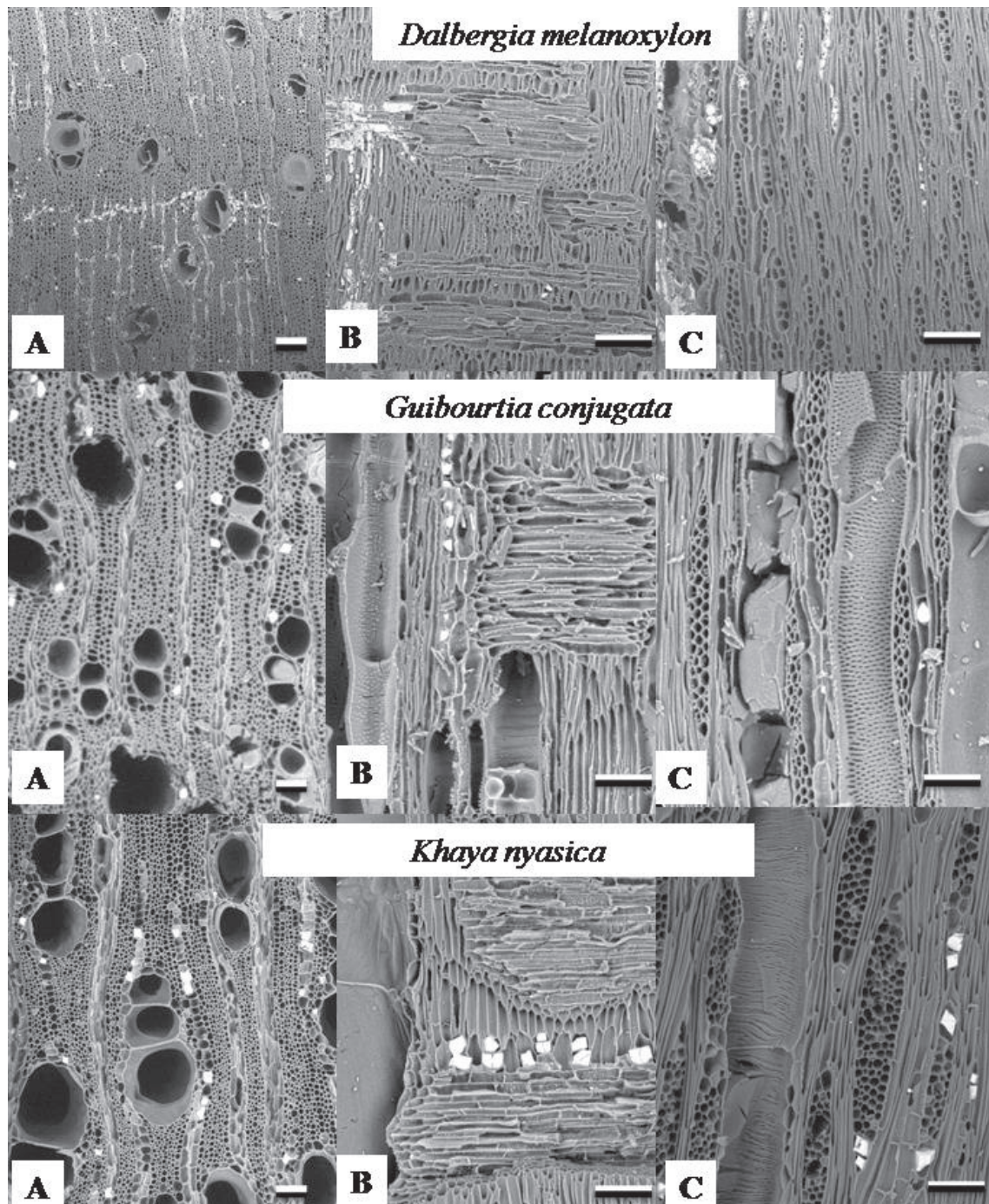


Figure 2. Scanning electron microscopy: images of transversal (A), radial (B) and tangential (C) section of charcoal. Scale bar = 100 μm.

Microscopía electrónica de barrido: imágenes de la sección transversal (A), radial (B) y tangencial (C) del carbón. Escala = 100 μm.

Alvin 1983); (ii) *Quercus variabilis* Bl. at 450 °C and 5 °C per minute (Kwon *et al.* (2009) (iii) *Corymbia* spp. and *Eucalyptus* spp. carbonized at 450 °C and 1.66 °C per minute (Gonçalves *et al.* 2014), (iv) *Ocotea porosa* (Ness *et Mart.*) Barroso carbonized at temperatures varying from 350-650 °C and heating rate from 1.04-1.24 °C per minute (Nisgoski *et al.* 2014). Kim and Hanna (2006), studying

Quercus variabilis BL. observed destroyed fiber walls, explaining that this effect is due to the tensions created by the effect of temperatures over 400 °C. Prior and Alvin (1983) evaluated the anatomical changes as being due to the increase of temperature in the woods of *Dichrostachys cinerea* and *Salix subserata*. They found that over 300 °C, the cell walls began to acquire amorphous features in the

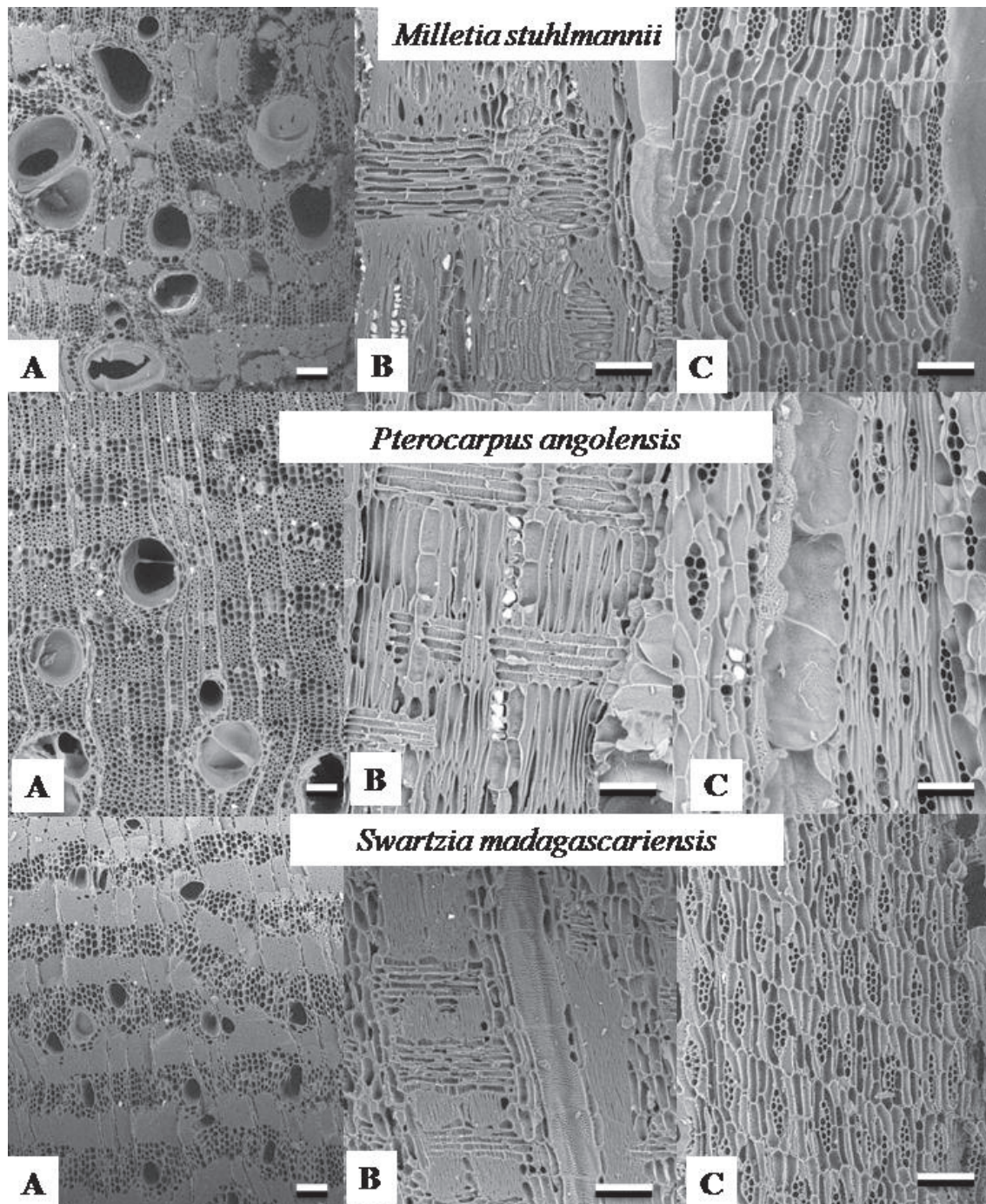


Figure 3. Scanning electron microscopy: images of transversal (A), radial (B) and tangential (C) section of charcoal. Scale bar = 100 μ m.
Microscopía electrónica de barrido: imágenes de la sección transversal (A), radial (B) y tangencial (C) del carbón. Escala = 100 μ m.

charcoal, although the medium line of the lamella and primary wall could still be distinguished. Kwon *et al.* (2009) studied *Q. variabilis* and found that over 350 °C it was impossible to observe the fiber walls.

Ruptures are also observed in other works in: (i) rays - *Corymbia citriodora* (Hook.) K.D.Hill *et al.* L.A.S. Johnson, *C. maculata* (Hook.) K.D.Hill *et al.* L.A.S. Johnson, *Eucalypt-*

tus dunnii Maiden, *E. tereticornis* Sm. and *E. viminalis* Labill. (Gonçalves *et al.* 2014), *Quercus variabilis*, *Q. robur* L. (Kim and Hanna 2006) and *Q. alba* L. (McGinnes *et al.* 1971); (ii) axial parenchyma cells - *E. dunnii* (Gonçalves *et al.* 2014); (iii) fibers - *Mimosa tenuiflora* (Willd.) Poiré and *M. ophthalmocentra* Martius (Dias Leme *et al.* 2010). As the causes of ruptures are not yet explained, our results

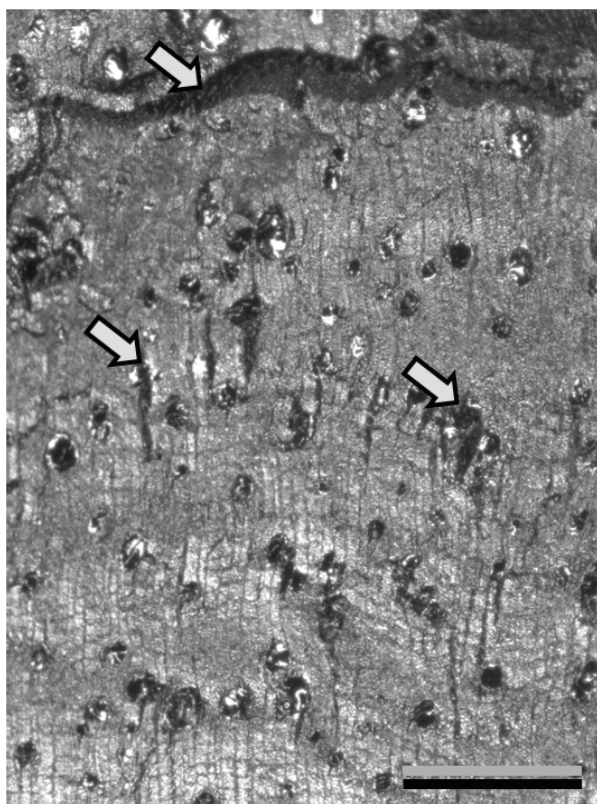


Figure 4. Ruptures in *Dalbergia melanoxylon* charcoal. Scale bar = 100 µm.

Rupturas en *Dalbergia melanoxylon* carbon. Escala = 100 µm.

were expected and did not compromise the identification of the anatomical features. Moreover, ruptures apparently did not influence charcoal quality.

The charcoal of species studied presented prismatic crystals in the cells of axial parenchyma of *Azelia quanzensis*, *Amblygonocarpus andongensis*, *Dalbergia melanoxylon*, *Guibourtia conjugata*, *Millettia stuhlmannii*, *Pterocarpus angolensis* and *Swartzia madagascariensis*. In the case of *Combretum imberbe* and *Khaya nyasica*, these were only observed in the ray cells.

CONCLUSIONS

Anatomical changes due to carbonization do not influence the distinction of species. The knowledge of charcoal anatomy can help in the control of the species in the charcoal supply chain. We hope this kind of study can be multiplied in order to contribute with nature conservancy in Mozambique.

ACKNOWLEDGEMENTS

We thank the Ford Foundation and Federal University of Paraná (UFPR), Brazil, for support and the opportunity provided to conduct this research.

REFERENCES

- Ali AC, E Uetimane Jr, IA Lhate, N Terziev. 2008. Anatomical characteristics, properties and use of traditionally used and lesser-known wood species from Mozambique: a literature review. *Wood Science and Technology* 42(6): 453-472. DOI:10.1007/s00226-008-0186-5
- Bila A. 2005. Estratégia para a fiscalização participativa de florestas e fauna bravia em Moçambique. TCP/MOZ/2904 (A) Support for the implementation of forest and wildlife legislation in Mozambique. Maputu, Mozambique. DNFFB/FAO. 42 p.
- Clancy JS. 2008. Urban ecological footprints in Africa. *African Journal of Ecology* 46(4): 463-470. DOI: 10.1111/j.1365-2028.2008.01041.x
- Cuvilas CA, R Jirjis, C Lucas. 2010. Energy situation in Mozambique: A review. *Renewable and Sustainable Energy Reviews* 14(7): 2139-2146. DOI:10.1016/j.rser.2010.02.002
- Dias Leme CL, C Cartwright, P Gasson. 2010. Anatomical changes to the wood of *Mimosa ophthalmocentra* and *Mimosa tenuiflora* when charred at different temperatures. *IAWA Journal* 31(3): 333-351. DOI: 10.1163/22941932-90000027
- Girard P. 2002. Charcoal production and use in Africa: what future? *Unasylva* 53(211): 30-35.
- Gonçalves TAP, CR Marcati, R Scheel-Ybert. 2012. The effect of carbonization on wood structure of *Dalbergia violaceae*, *Stryphnodendron polyphyllum*, *Tapirira guianensis*, *Vochysia tucanorum*, and *Pouteria torta* from the Brazilian cerrado. *IAWA Journal* 33(1): 73-90.
- Gonçalves TAP, AW Ballarin, S Nisgoski, GIB Muñiz. 2014. A contribution to the identification of charcoal origin in Brazil i: anatomical characterization of *Corymbia* and *Eucalyptus*. *Maderas Ciencia y Tecnologia* 16(3): 323-336. DOI:10.4067/S0718-221X2014005000025
- IAWA COMMITTEE. 1989. IAWA List of microscopic features for hardwood identification. *IAWA Bulletin* 10(3): 219-332.
- INDE (Instituto Nacional do Desenvolvimento da Educação, MZ). 2009. Atlas de Moçambique. Maputo-Moçambique.
- Inside Wood. 2012. Inside Wood - Search the Inside Wood Database. Accessed 10 october 2012. Disponible: <http://insidewood.lib.ncsu.edu/search.0.jsessionid=c83f708ab41790e999eda14d529d>.
- Kim NH, RB Hanna. 2006. Morphological characteristics of *Quercus variabilis* charcoal prepared at different temperatures. *Wood Science and Technology* 40(5): 392-401. DOI:10.1007/s00226-005-0062-5
- Kwon SM, N-H Kim, DS Cha. 2009. An investigation on the transition characteristics of the wood cell walls during carbonization. *Wood Science and Technology* 43(5-6): 487-498. DOI:10.1007/s00226-009-0245-6
- McGinnes Jr. EA, SA Kandeel, PS Szopa. 1971. Some structural changes observed in the transformation of wood into charcoal. *Wood and Fiber* 3(2): 77-83.
- Marzoli A. 2007. Inventário florestal nacional. Maputo, Moçambique. Direcção Nacional de Terras e Florestas, Ministério da Agricultura.
- Ministério da Agricultura. 2002. Regulamento da Lei de Florestas e Fauna Bravia. Decreto 12/2002. Maputo, Moçambique. p.1-45.
- Muñiz GIB, ME Carneiro, S Nisgoski, MGL Ramirez, WLE Magalhães. 2013. SEM and NIR characterization of four forest

- species charcoal. *Wood Science and Technology* 47(4): 815-823. DOI: 10.1007/s00226-013-0539-6.
- Nisgoski S, GIB Muniz, FRR Bati sta, RE Mölleken. 2014. Influence of carbonization temperature on the anatomical characteristics of *Ocotea porosa* (Nees *et* Mart. ex Nees) L. Barroso. *Wood Science and Technology* 48(2): 301-309. DOI: 10.1007/s00226-013-0602-3
- Prior J, KL Alvin. 1983. Structural changes on charring woods of *Dichrostachys* and *Salix* from Southern Africa. *IAWA Bulletin* 4(4): 197-206.
- Richter HG, MJ Dallwitz. 2000. Commercial timbers: Descriptions, illustrations, identification, and information retrieval. Delta. Accessed 3 Oct. 2012. Available in: Disponible: <http://delta-intkey.com>
- Steierer BF. 2011. Highlights on wood fuel: 2004-2009. FAOS-TAT-ForesSTAT. Rome, Italy. FAO. 4 p.
- Vasco H, M Costa. 2009. Quantification and use of forest biomass residues in Maputo province, Mozambique. *Biomass and Bioenergy* 33: 1221-1228. DOI:10.1016/j.biombioe.2009.05.008

Recibido: 11.06.14

Aceptado: 20.01.15