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WOOD SPECIES FOR THE BIEDERMEIER FURNITURE - A MICROSCOPIC CHARACTERISATION FOR SCIENTIFIC CONSERVATION

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Abstract

Wood species identification is an important, compulsory step in the scientific conservation of the historic furniture as a significant part of the cultural heritage. It is known that a visual examination of an investigated sample does not always bring enough information about the original species and that a microscopic approach is more reliable. Species identification can be performed if the microscopic images are interpreted for common, but also for specific features and characteristics, by means of identification keys and in comparison with reference images. This paper provides the microscopic characterization with identification keys for six hardwood species, some of the most common in Biedermeier furniture (elm - Ulmus glabra Huds., cherry - Prunus avium L., walnut - Juglans regia L., pear - Pyrus communis L., aspen - Populus tremula L., African mahogany - Khaya ivorensis A. Chev.). The characterization can be used for wood identification purposes by laboratories working in the field of cultural heritage wood conservation. This work is part of a recent research project that aims to develop and implement a scientific investigation for furniture conservation.

Keywords: *microscopy, wood identification, Biedermeier furniture, conservation*

Introduction

The history of furniture dates back to Antiquity and it evolved as an important part of human culture and civilization [1, 2]. The ingenuous structures, elegant shapes, skilfull decoration and diverse finishing techniques that employ natural materials are remarkable. Many historic furniture items are known as appreciated objects of art from both the aesthetical and the technical point of view. They continue to be a valuable source of information and inspiration. Moreover, any furniture object surviving through decades and centuries bears important historic information and brings us the charming flavor of the old times.

An example of such furniture is the Biedermeier furniture, which refers to a significant lifestyle and artistic development, best known in the fields of visual arts, furniture, architecture, music and literature, characteristic to the German and Austrian culture between 1815 and 1848. The name Biedermeier is an irony addressed to the *petit-bourjois* lifestyle and values which emerged in a period of peace after the Napoleonic wars [1].

The Biedermeier furniture design was influenced by the neoclassical furniture of the French Empire, but it certainly became less pompous. It got simplified and better adapted to

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more modern households, as the ones from Germany and Austria during the second, third and fourth decade of the 19th century.

Vienna was the city where some of the most interesting and attractive Biedermeier furniture objects were manufactured. That happened mainly due to the creative power of young designers, wishing to enter the league of imperial master cabinet-makers. Many of their masterpieces are exhibited in the *Hofmobiliendepot* Museum in Vienna.

Josef Dannhauser remains the best known Biedermeier furniture designer and manufacturer. He started by making Empire furniture for the Austrian imperial family and later adapted his designs for representatives of all social layers of Vienna.

Towards the end of the 19th century, due to an exhibition at the Vienna Applied Arts Museum, Biedermeier lifestyle and furniture became so successful that a revival era started in all corners of the Austrian-Hungarian Empire, which lasted until the third and fourth decade of the 20th century. Biedermeier furniture and interior decoration became popular in Britain and America after World War II [2]. However, in continental Europe its influence never really faded away (http://www.ritabucheit.com).

In Romania, due to the Austrian influence on urban Transylvanian interior and furniture design, Biedermeier became not only very popular, but a long lasting preference for most of the 19th century and the first four decades of the 20th century. Many furniture factories all over Romania, such as The Lengyel factory in Arad, manufactured Biedermeier furniture for almost a century. Its simplicity and clarity of structure made it very accessible for industrial purposes (http://cimec.wordpress.com/2009/02/11/arad-expozitia-lemnul/). Many original Biedermeier furniture pieces still exist in Romania in museum collections or in private property. They represent an important part of the cultural heritage, a part that is worth studying and conserving.

The style had a positive development and, due to its sobriety, simplicity and classical elegance, it became a source of inspiration for later styles and artistic trends, such as Secession, Jugendstil, Art Déco, Bauhaus and postmodernism. It is also an important influence of truly modern styles [1, 2].

In order to preserve such cultural heritage items, the conservation of historic furniture has become an elaborate process that currently involves a scientific interdisciplinary approach. In that regard, knowing the specific species characteristics of a certain historic style should be part of any scientific investigation that prior to the identification any style.

Therefore, it is known that in Biedermeier the cabinetmakers mostly used wood species which were available locally, such as oak, ash and cherry. Cherry and pearwood were processed to look like mahogany or ebony, which were only used for very expensive furniture. The furniture manufactured in Hungary was often made of ash, that in Transylvania of oak, cherry and walnut, that in North Germany of birch and elm. The style also became popular in Scandinavia and Russia, where birch and poplar were used [1, 2].

Given the variety of wood species that were used in the historic period of Biedermeier, any restoration intervention that involves wood completion or a replacement must be very well documented and must comply with characteristics of the original material. That involves, at first, a macroscopic analysis of the wood part, to identify its main features. Although sometimes a careful macroscopic examination of a clean transparently finished surface, or that of a freshly sanded surface should provide enough information, there are many cases when a microscopic investigation is needed and when reference microscopic samples are employed for comparison and identification. Wood species identification is based on the characteristic macroscopic and microscopic structural features that are included in an identification key.

This paper discusses such a microscopic characterization of six hardwood species, some of the most common in Biedermeier furniture (elm - *Ulmus glabra* Huds., cherry - *Prunus avium* L., walnut - *Juglans regia* L., pear - *Pyrus communis* L., aspen - *Populus tremula* L., African mahogany - *Khaya ivorensis* A. Chev.). It can be used for wood identification purposes by the laboratories working in the field of cultural heritage wood conservation. This study is part of a recent research project which aims to develop and implement a scientific investigation of furniture conservation (http://www.artimar.ro/ct/index.htm).

Materials and Methods

Reference microscopic samples were produced as aids for species identification during conservation processes of any Biedermeier furniture. The work principle consists in comparing the microscopy of wood samples from the historic artwork, with a complete set of reference images provided in this research together with the descriptions attached to those images and which are meant as guidance for features identification.

The selection of species was done according to the most commonly used wood in Biedermeier furniture: elm - *Ulmus glabra* Huds., cherry - *Prunus avium* L.,walnut - *Juglans regia* L., pear - *Pyrus communis* L., aspen - *Populus tremula* L. and African mahogany - *Khaya ivorensis* A. Chev. The choice of those materials also had the advantage of including a complete range of hardwoods useful for identification: a species with ring-porous arrangement (elm), one with semi ring porous display (cherry) and five species with diffuse porous arrangement, among which three local ones, (walnut, pear and aspen) and one exotic (African mahogany).

In order to produce the reference micro-slides, all the materials mentioned above were stored in a controlled environment (20°C and 65% relative air humidity). Then, two prisms of 30x10x10 mm were cut out of each type of material. They were then boiled in flasks with refluxing condenser until saturated (about 24 hours). The prisms were trimmed to expose the transverse, radial and tangential surfaces. Sections were cut from each surface with a sledge microtome to 25 micron thickness. Ethanol solution was used to prevent surface tension when attaching the sections to the knife. To enhance the contrast, the sections were colored with a safranine solution and then washed thoroughly in baths of ethanol solution, whose concentration was gradually increased up to 100%. After that, sections were permanently mounted on glass slides, one for each prism, by using a fixing solution with refractive index close to that of glass: dried Canada balsam dissolved in xylene [3]. By positioning the cover slip, the slides were gently pressed with a rubber tip to spread the glue uniformly and to remove air bubbles from inside. The glue was then allowed to dry by storing the slides for a few days in a warm environment at 60°C. Finally, the surplus of Canada balsam was removed with a razor blade and the slides were cleaned and polished with a cloth and a little xylene before labeling.

For each slide we took several images of each section at magnifications of 40x, 100x and 200x by means of an optical microscope (BIOSTAR OPTECH B5) fitted with an image capture system.

The relevant, also used as keys of identification for those species were:

- The presence of pores, which is the essential indicator of any hardwood species, as compared to softwoods where they are absent. The pores appear as holes of various sizes on the cross-sections and they have a specific distribution: larger in the early-wood areas and with abrupt transition to the late-wood in ring porous species (Fig.1); as a visible layer of pores marking the annual ring, with a gradual decrease towards the late-wood in semi-ring porous species (Fig.2) and rather uniformly spread in both growth areas if they are diffuse-porous (Fig.3).
- The pore size is also important in differentiating between species: some, with diameters less than 100 μm can be very small, visible only with a magnifying glass and easily distinguishable with the microscope. Those visible with the naked eye range from 101 to over 300 even 500 μm
- The pore arrangement and their proportion are another type of information which is relevant, as they can be solitarily bounded entirely by other cell types (Fig.2-A and

Fig.3-C); they may appear as a characteristic group of pores in the late-wood, which makes identification easy (ex. the wavy bands in elm, Fig.1-C) or they can be multiple pores when two or several features are disposed as radial arrangement (Fig.2-B and Fig.3-D).

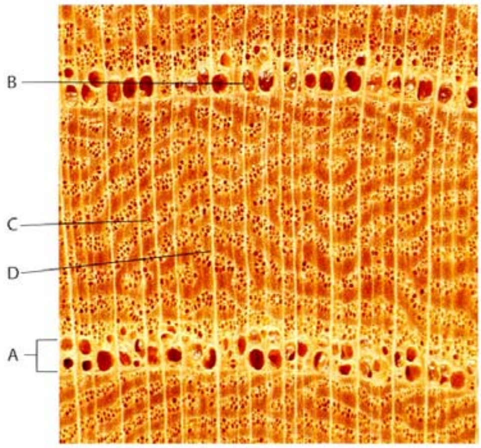


Fig. 1. An example of a ring-porous species - American elm (*Ulmus americana*), Hoadley, 2000 [4]:
A - earlywood large pores;
B - tyloses visible in the pores;
C - small and numerous latewood pores arranged in wavy bands;
D - rays not distinct to the naked eye, but visible as uniform narrow light lines with the microscope.

- The rays, appearing like stripes on the cross section are other indicators of a species according to their width and proportion (Fig.1-D; Fig.2-D and Fig.3-E); the apparent straightness of the rays versus a tendency to wave through the pores may be characteristic indicators (for instance, in poplar spp., Fig.9 a). On the tangential and radial surfaces, the height of rays can be measured as another element in species identification.
- The parenchyma cells, distinguished by a more porous appearance and different color (usually lighter) compared to the neighboring wood cells, can confirm by their presence and characteristic arrangement the affiliation to a certain species. When the parenchyma cells appear independent from vessels, they are called apotracheal, which can be diffuse (eg: in cherry, appears seldom), compact (eg: in walnut, Fig.3-F) or reticular (eg: in oak). When the parenchyma are associated with vessels they are called paratracheal, taking certain shapes around the pores. That helps the identification (for instance, in mahogany, the parechyma cells are vasicentric unilateral or discontinuous, Fig.10a,b)

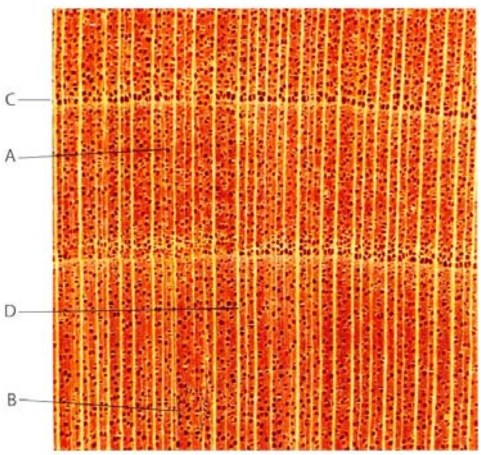


Fig. 2. An example of a semi ring-porous species, Black cherry (*Prunus serotina*), Hoadley, 2000 [4]:
A - solitary small pores uniformly distributed in the latewood;
B - pores in multiples and small clusters in the latewood;
C - row of pores in the early-wood that delineate the growth ring;
D - rays (distinct also with the naked eye) appearing as sharp light lines against the darker cell mass.

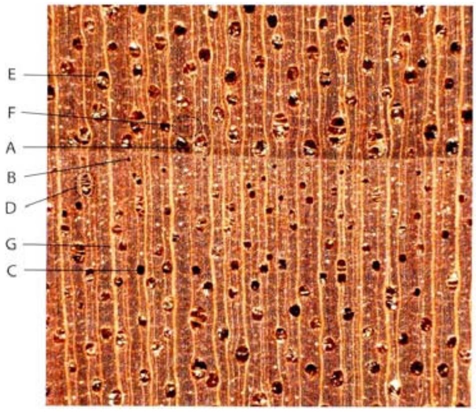


Fig. 3. An example of a diffuse porous species - Black walnut (*Juglans nigra*), Hoadley, 2000 [4]:
A - pores in the early-wood, that gradually are decreasing to the late-wood until they become small and indistinct with the naked eye (B);
B - small pores in the late-wood, visible only with the microscope;
C - solitary pores;
D -multiple pores grouped in radial rows;
E - pores contain tyloses visible as a white content;
F - fine irregular tangential lines of parenchyma barely visible with the magnifying glass, but visible with the microscope;
G - rays, visible as fine lines.

Together with the microscopic images for all 6 species, the macroscopic appearance on the radial section of the samples was included for a complete identification key.

Results and Discussions

From the images produced at various magnifications, the larger magnification 200x contains more detailed information, but the area included has less anatomical details, while the smaller magnification 40x gives more information about the pores distribution within and between annual rings, but some details, like parenchyma, are not really visible. Therefore 100x was chosen to be representative for the species as the best compromise, given the limits of an article. The reference images for identification purposes of the six species under investigation: elm - *Ulmus glabra* Huds., cherry - *Prunus avium* L.,walnut - *Juglans regia* L., pear - *Pyrus communis* L., aspen- *Populus tremula* L. and African mahogany - *Khaya ivorensis* A. Chev. are presented in Fig. 5, Fig. 6, Fig. 7, Fig. 8, Fig. 9 and Fig. 10 as transversal, tangential and radial sections.

The main microscopic characteristics of each species used for identification are centralized in Table 1.

The macroscopic views of the radial section for these species are contained in Fig. 4 and are used as references for the macroscopic characterization of the species analyzed in this study.

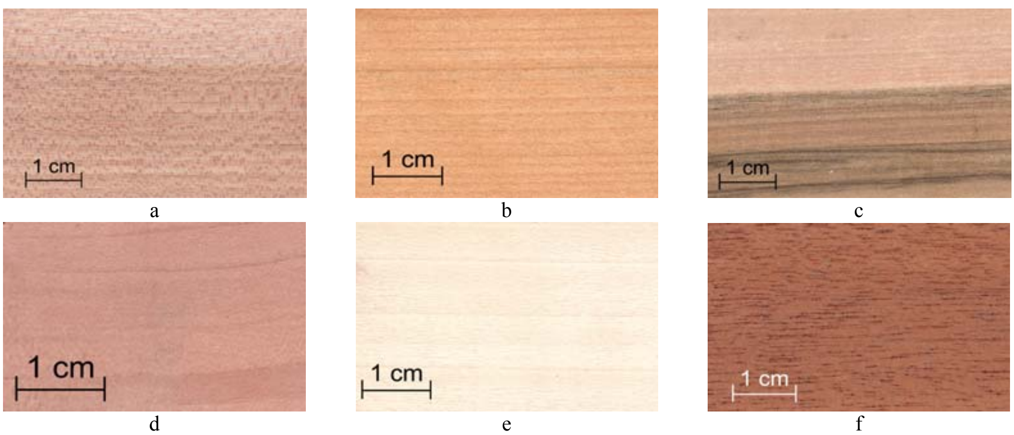


Fig. 4. Macroscopic views of the radial sections of: a - elm, *Ulmus glabra* Huds.; b - cherry, *Prunus avium* L.; c - walnut, *Juglans regia* L.; d - pear, *Pyrus communis* L.; e - aspen, *Populus tremula* L.; f - African mahogany, *Khaya ivorensis* A.

For all six species detailed identification keys were elaborated, based on the information gathered from the reference literature [5, 6], which are available as an electronic catalogue developed within the framework of this research project and guiding the user through sequential steps towards identification. Nevertheless, this paper only briefly presents the main characteristics in correlation with the microscopic images and the macroscopic views:

a. Elm (*Ulmus glabra* Huds)

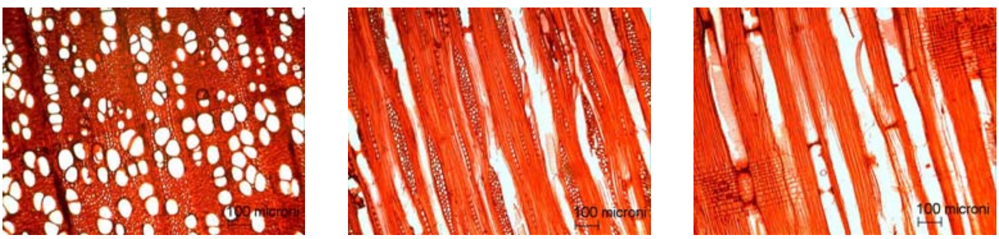
Is a ring porous hardwood, with wide white-yellowish-reddish sapwood (20 to 25 distinct annual rings) and light brown heartwood (Fig. 4a). The pores in the early-wood, solitary or in groups are on 1-3 tangential rows, with diameters ranging between 90-200-340 μm, partly filled with thyloses (Fig. 5a). The pores in the late-wood, 20-60 μm in diameter, are arranged in specific tangential wavy bands and have helical thickenings (Fig. 5a,c). The proportion of pores ranges between 15-35%. The rays are 1-7 seriated (frequently between 3-6) with heights of 200-700 μm: the uniseriated ones have 3-6 cells and those pluriseriated about 15-30 cells on the height. The species contains abundant paratracheal and apotracheal parenchyma with colored content (Fig. 5b).

a b C

Fig. 5. Micrographs of elm (*Ulmus glabra* Huds.) at 100X magnification. Type of section and visible characteristic features: a - transversal, ring-porous, pores in early-wood in 1-3 tangential rows; latewood pores arranged in specific tangential wavy bands, paratracheal vasicentric parenchyma; b - tangential, apotracheal and paratracheal parenchyma with coloured content; multi-seriated rays 15-30 height; c - radial, visible paratracheal and apotracheal parenchyma); vessels partially with tyloses

b. Cherry (*Prunus avium* L.)

As a semi-ring porous species, cherry has a narrow white-reddish sapwood and a pale brown-grey to reddish-brown heartwood (Fig. 4b). The pores in the early-wood are larger and gradually decrease in size towards the late-wood. They are solitary or in radial groups of 2-6 with diameters varying between 70-100 μm in the early-wood and about 30-77 μm in the late-wood with a general proportion of about 36% (Fig. 6a) and are partly filled with brown deposits. They communicate with other vessels through isolated simple pits and have helical thickenings (Fig. 6c). The rays, app. 17%, are 1-4 (frequently 2-3) seriated, have variable heights between 280-700 μm, meaning about 20-40 cells (Fig. 6b). The presence of diffuse parenchyma is seldom.

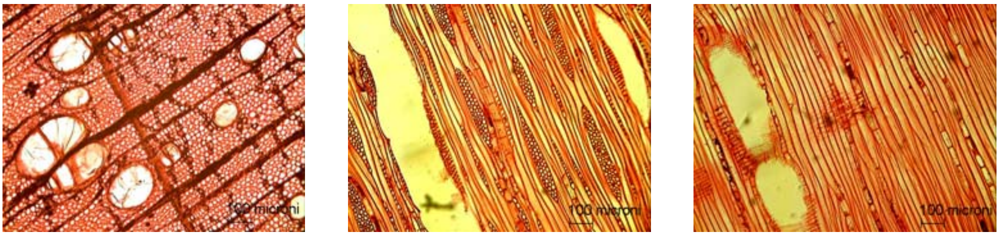


a b c

Fig. 6. Micrographs of cherry (*Prunus avium* L.) at 100X magnification. Type of section and visible characteristic features: a - transversal, semi-ring porous, with larger pores in the first part of the annual ring; they are solitary or in radial groups with brown deposits; b - tangential, rays of two types: uniseriated or multiseriated (2-4); vessels with thickenings; c - radial, vessels with brown deposits and spiral thickenings.

c. Walnut (*Juglans regia* L.)

Characterized as a diffuse porous species, walnut has a wide sapwood, white-grey or light-brown, while the heartwood is distinctive by its specific dark brown color with darker stripes (Fig. 4c). The pores, 9-12-14.2%, partly with brownish shiny thyloses, are solitary or radially grouped (2-4) with a tendency for a semi-ring arrangement (Fig. 7a). Their largest diameter is in the earlywood 160-240 μm, while that from the latewood ranges between 60-120 μm. The vessels communicate through round, oval, rarely polygonal, pits (Fig. 7c). Rays, in proportion of 15.3-16.2-16.9%, are 1 to 5 seriated (frequently 3-4) with heights below 600 μm, meaning 1-10 cells on the height for those uniseriated and 20 (rarely 40) for the multiseriated (Fig. 7b). Walnut contains frequent and clearly visible radial-metatracheal parenchyma with crystals (Fig. 7a,b,c).

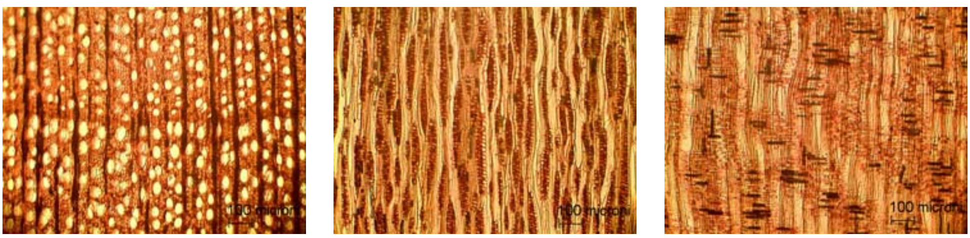


a b c

Fig. 7. Micrographs of walnut (*Juglans regia* L.) at 100X magnification. Type of section and visible characteristic features: a - transversal, diffuse oval porous, single or in radial groups of 2-5, partly with brownish shiny thyloses, diffuse parenchyma agglomerated as irregular tangential lines, frequently with crystals; b - tangential, rays 1 to 5 seriated (frequently 3-4), diffuse agglomerated parenchyma; c - radial, metatracheal parenchyma containing crystals; round inter-vascular pits.

d. Pear (*Pyrus communis* L.)

Pear tree is a diffuse porous species with no heartwood, light-yellow and red; with rare pith flecks (Fig. 4d). The pores, in percentage of about 27 %, smaller or at most equal to the rays width. They are solitary, rarely grouped, without thyloses and with diameters between 20-40-50 μm (rarely 80μm) as can be seen in Fig. 8a. Normally, helical thickenings are absent or very rare. The rays, 16-26 %, with a frequency of 14-16/mm are 1-3 (frequently 2) seriated up to 30 cells on the height (Fig. 8b). Pear wood has apotracheal parenchyma with brown deposits, which can also be found in vessels (Fig. 8b).

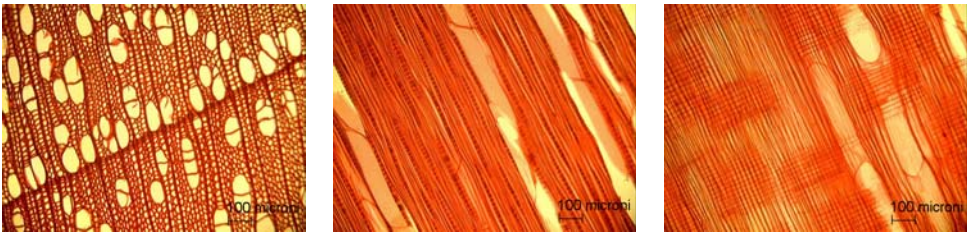


a b c

Fig. 8. Micrographs of pear (*Pyrus communis* L.) at 100X magnification. Type of section and visible characteristic features: a - transversal: diffuse porous, numerous, with diameters below 50 μm, smaller or at most equal to the rays width, without thyloses; b - tangential, 1 to 3 seriated rays; frequent apotracheal parenchyma; c – radial.

e. Aspen (*Populus tremula* L.)

As a species with diffuse porous arrangement, aspen does not contain heartwood and its color is shiny white-grey (Fig. 4e). The annual rings are clearly delimited by a darker band of fibers characteristic for this species (Fig. 9a). It contains specific white pith flecks. The pores, with a proportion of 24.3-26.4-27.5 %, are solitary or in radial rows of 2-7 (frequently 2-3), larger and more numerous (about 100/mm^2) in the early-wood with a diameters of over 100 µm, while in the late-wood the diameters is below 50 µm (Fig. 9a). The inter-vascular pits are numerous, round or poligonal as a honeycomb patern (visible only at higher magnification in radial section). The rays, 11.1-12.7-13.5 %, are very fine, uniseriated and frequent, over 10/mm, with a variable number of cells on the height, from 5-12 to 35 (Fig. 9b). A characteristic of this species is the fact that the rays are waved, following the contour of the pores (Fig. 9a). The parenchyma is apotracheal uniserial final.



a b c

Fig. 9. Micrographs of aspen (*Populus tremula* L.) at 100X magnification. Type of section and visible characteristic features: a - transversal, diffuse porous, solitary or in radial rows of 2-4, larger and more numerous in the earlywood; annual rings clearly delimited by a darker band; rays are waved following contour of the pores; b - tangential-uniseriated rays; c – radial.

f. African mahogany (*Khaya ivorensis* A. Chev.)

African mahogany is an exotic species, diffuse porous with pink-brow to dark-red heartwood and narrow pink-grey sapwood (Fig. 4f - note: only the heartwood is captured in this image). Pores in proportion of 10-17.7-29 %, are solitary or in pairs with brown deposits, small to medium sized with diameters between 35-145-230 µm (Fig. 10a). The rays, in proportion of 14.8-20.8-28.2 %, are 1-5 (rarely 7) seriated, with a frequency of 3-5-9/mm and about 9-19 (maximum 43) cells on the height (Fig. 10b). A characteristic is the fact that the rays are heterogeneous comprising horizontal as well as vertical cells (Fig. 10c). African mahogany contains concentric apotracheal parenchyma and unilateral or discontinuous vasicentric parenchyma (Fig a,b).

A b c

Fig. 10. Micrographs of African mahogany *(Khaya ivorensis* A. Chev.) at 100x magnification. Type of section and visible characteristic features: a - transversal, diffuse porous small to medium sized, solitary or in pairs with brown deposits; unilateral or discontinuous vasicentric parenchyma; b - tangential, uniseriated and multiseriated rays; apotracheal parenchyma; c - radial, heterogeneous rays made of horizontal as well as vertical cells, visible brown deposits in vessels.

The results presented above can be used as reference images for species identification, where guiding keys narrow the search from the most common characteristics (eg. the species is a hardwood), to more specific indicators (eg. distribution of pores can differentiate a ring-porous, from a semi-ring porous and diffuse-porous species) and finishing with detailed information that points exactly and beyond doubt to a certain species (eg; wavy bands of pores in the latewood of elm).

Table 1. Microscopic features important for the identification of the studied wood species according to the identification key

Wood species	Pores distribution	Vessels (pores) Diameter, μm		Rays		Parenchyma		Other features
		Early wood ew	Late wood lw	Uni-seriate	Multi-seriated	Apotracheal	Paratracheal	
				[cells on the height]				
Elm (*Ulmus glabra*-Huds)	Ring-porous	90-200 (340)	20-60	[3-6]	3-6 [15-30]	diffuse or metatracheal abundant	-	- in vessels (lw) helically thickenings -vessels (lw): 15 - 35%
European Cherry (*Prunus avium* L.)	Semi-ring porous	70-100	30-77	[20-40]	2-4 [20-40]	diffuse	agglomerated	- vessels: around 36% - in vessels ring-shaped thickenings - rays: around 17%
European Walnut (*Juglans regia* L.)	Dffuse -porous	160-240	60-120	[1-10]	3-5 [20 (40)]	metatracheal, metatracheal-diffuse	-	- vessels: 9 - 12 - 14.2% - rays: 15.3 - 16.2 - 16.9% - shiny tyloses
Pear Tree (*Pyrus communis* L.)	Diffuse-porous	25-40-50		[3-15-30]	1-2-3 [3-15-30]	diffuse or metatracheal-abundant	-	-with or without thickenings -vessels: around 27% -rays: 16 - 26%
Aspen (*Populus tremula* L.)	Diffuse-porous	35-50-70		[5 -12 (38)]	-	uniserial final	-	-between vessels numerous pits, round or polygonal-honeycomb -vessels: 24.3 - 26.4 - 27.5% -rays: 11.1 - 12.7 - 13.5%
African Mahogany (*Khaya ivorensis* A. Chev.)	Diffuse -porous	35-145-230		[9 -19]	5-7 [9 -19 (43)]	concentric interrupted	vassicentric, unilateral or interrupted	- vessels: 10 - 17.7 - 29 %. - heterogeneous rays - rays: 14.8 - 20.8 - 28.2%

The six species analyzed in this paper are among the 22 wood species important for historic furniture. They were studied as part of a research project ID_856: *Development and implementation of an advanced scientific research methodology for sustainable furniture restoration-conservation and eco-design*, for which a comprehensive collection of microscopic images at various magnifications, together with their identification keys were elaborated as an electronic catalogue.

Conclusions

As an important forerunner of the truly modern designs, the Biedermeier period left a consistent legacy in almost all countries in Europe. That motivated the need for conservation in the spirit of the original style.

The conservation of historic furniture has lately become more and more connected with a scientific interdisciplinary approach. In this regard, knowing the wood species characteristics of a certain historic style plays an important role in the identification of any style. Additionally, any restoration intervention that involves wood completion or a well justified replacement, must be very well documented and in compliance with the original material. Usually, a visual examination of an analyzed sample does not provide enough information about the original species, but this can definitely be solved by a microscopical investigation.

Species identification can be performed if the microscopic images are interpreted according to their common, but also to their specific features and characteristics, by means of identification keys and in comparison with reference images.

This paper analyzed six species commonly used in Biedermeier furniture, for which reference microscopic images were prepared, together with their identification keys: elm - *Ulmus glabra* Huds., cherry - *Prunus avium* L., walnut - *Juglans regia* L., pear - *Pyrus communis* L., aspen - *Populus tremula* L. and African mahogany - *Khaya ivorensis* A. Chev.

The results can be used in the process of species identification in laboratories working in the field of cultural heritage wood conservation and more information is provided in an electronic catalogue of 22 wood species important for historic furniture, to those interested in wood species identification.

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