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MICROSCOPIC IDENTIFICATION OF WOOD SPECIES AN IMPORTANT STEP IN FURNITURE CONSERVATION

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Abstract

Wooden religious artefacts such as iconostasis, polychromic wood statues and church furniture represent an important part of the cultural heritage, often needing careful conservation and restoration. Any restoration work of such an object that involves completion of missing elements or a replacement of severely damaged parts should be very well documented and in accordance with the original material. Identification of wood species becomes, therefore, a compulsory step prior to any intervention. A direct visual evaluation of species on an investigated object, based on the characteristic macroscopic features, is most often not possible or is not conclusive either because of the natural ageing of wood, possible biological degradation or due to an opaque finishing or painting. Therefore, a microscopic approach is more reliable.
This paper presents a case study of wood species identification for a bishop throne, dated 1838, from the Berislăvesti hermitage in Vâlcea County. For species identification, three small wooden samples, coded J1, J2, J3, were collected and prepared as slides for investigation by transmitted light microscopy. For objective measurements, a specialised image analysis software, offering a quantitative method to separate, measure and statistical data process for some anatomical features of interest, was employed. Two samples (J1, J3) were identified as walnut (*Juglans regia*) and one (J2) as lime (*Tilia cordata*).

Keywords: wood species identification, microscopy, imageJ analysis, furniture

1. Introduction

Since ancient times, wood has been widely used by mankind for different uses, so that almost any important step of the culture and civilisation evolution, as well as the spiritual values or the technical achievements have a wooden

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materialised proof as an artistic and/or functional object [1, 2]. Wooden objects represent, therefore, an important part of the cultural heritage. Artefacts such as iconostasis, polychromic wood statues and church furniture are representative elements for both religious art and wooden cultural heritage.

Old furniture items cumulate the flavour of old-times and patina with an important historical, aesthetical and technical value resulting from the ingenuity of structures, elegance of shapes, skilfulness of decoration and diversity of finishing techniques employing natural materials [3, 4]. A very special symbolistic value and particular structural characteristics related to a special functionality are often extra definitory elements for church furniture.

Due to the susceptibility of wood to degradation and deterioration caused by diverse biotic and non-biotic factors, it is often the case that these objects need careful conservation and restoration. Scientific investigation is well acknowledged as a component of conservation and in this respect the identification of wooden species is an important step in furniture/wooden objects conservation [5, 6], as any restoration intervention that involves wood completion or a replacement should be very well documented and in accordance with the original material.

Identification of wooden species is often a challenging task due to both the diversity of wooden species used throughout history and the ageing and degradation phenomena affecting the wooden material appearance and sometimes even its structural integrity. Only seldom, the identification of common wooden species can be made by a macroscopic investigation of the characteristic macroscopic anatomical features, on a cleaned not degraded area, but most often such an attempt is not conclusive. Consequently, relevant samples have to be extracted and adequately prepared for a microscopic investigation to observe the characteristic microscopic anatomical features. Microscopic identification keys and reference samples are then employed in order to conclude on the wood species involved [5, 6]. Moreover, microscopic measurements of different anatomical elements offer the possibility to compare these data with relevant literature information [7] for a more reliable identification. ImageJ [http://en.wikipedia.org/wiki/ImageJ] is a specialised software for microscopic data processing, successfully used for such purposes [8, 9].

It has to be mentioned that non-destructive advanced techniques, such as X-ray phase contrast micro-tomography [10] enable the 3D-analysis throughout the volume of the wood without physical sectioning. However, as this technique and other tomographic methods are not readily available, the most used remain the typical wood anatomy imaging techniques that include classical transmission light microscopy through thin microtome sections.

This paper presents a case study of microscopic species identification for three small samples extracted from a Bishop's throne, dated 1838, from the Berislăvesti hermitage in Vâlcea County.

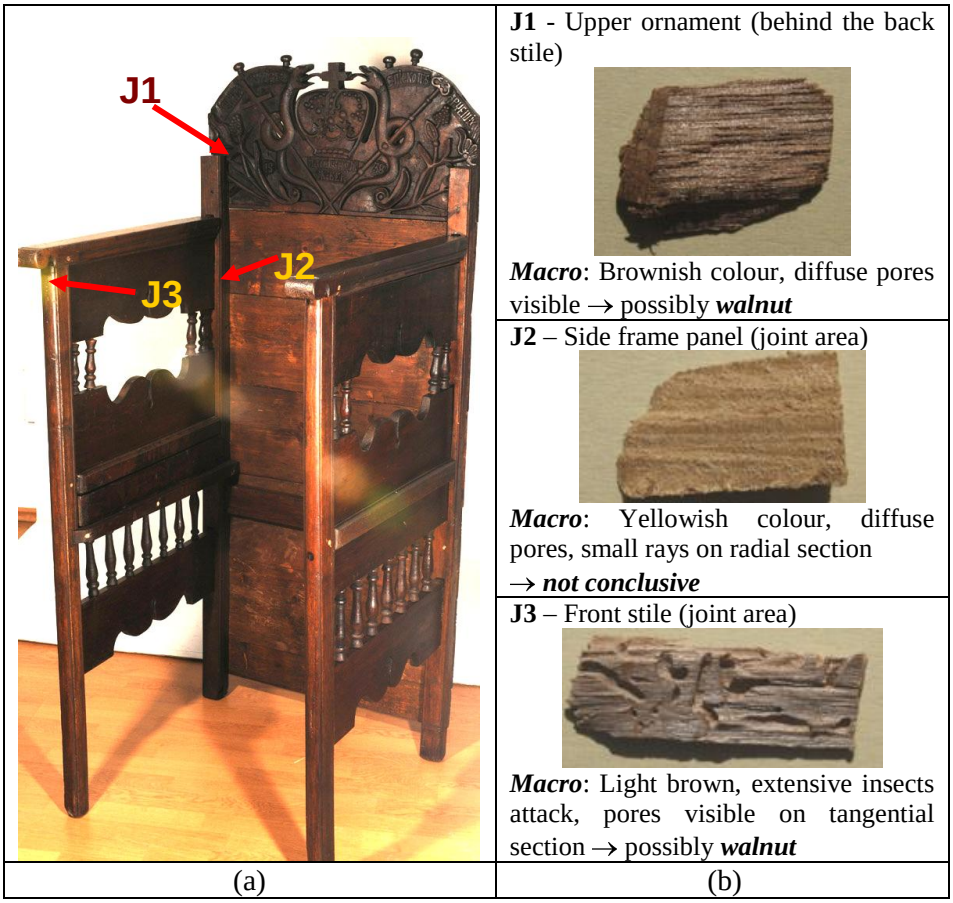

Figure 1. The object (a) and samples taken out for investigation (b): aspect, macroscopic features and presumptive identification; red arrows are pointing towards the elements and areas where from the samples J1, J2, J3 were taken out.

2. Experimental

2.1. The investigated object and extracted samples

The case study is referring to a bishop throne from the Berislăvesti hermitage in Vâlcea County, a beautiful example of art and craft of local communities at that period of time by shape, proportions, structure, decorative elements and especially the complex carved ornament of the backrest (Figure 1a). The object dating from 1838 was brought to our laboratory for investigation and conservation – restoration imposed by its initial poor conservation state. After surface cleaning, three small wooden samples, coded J1, J2, J3 (Figure 1b), were extracted from hidden areas of three different structural elements of the object for wood species identification. The macroscopic features observed on these samples under a magnifying glass (4x) and the resulting presumptions about the possible species are also included in Figure 1.

2.2. Samples preparation and investigation

The extracted samples were plasticised by boiling in distilled water approximately 8 hours, being further transferred into a mixture of glycerol/ethanol (1/4). The plasticised samples were then manually trimmed with a very sharp blade to expose the transversal, radial and tangential sections respectively. Thin, transparent microsections of about 30 μm were then cut with a microtome. They were stained with safranine, washed with water and then temporarily mounted in glycerol/water (1/1) for the microscopic investigation. The mounted samples were observed in transmitted light at different magnifications (40-200x) under an optical microscope BIOSTAR OPTECH B5 fitted with an image capture system.

The captured images were further processed with ImageJ, an image processing software for determining the edges of features that are envisaged (i.e. different types of cells), capable of returning a mask image where only the objects (areas) of interest are kept. This software also allows dimensional measurements of the selected anatomical features, calculation of their area, proportion and other useful determinations [http://en.wikipedia.org/wiki/ImageJ] This method was tested and found applicable on wood microslides, the sequence of operations for image processing being previously detailed by Gurau et al [9].

3. Results and Discussion

3.1. Sample J1 - Micrographs and interpretation

The micrographs resulting from the investigation of the sample J1 are presented in Figure 2 and Figure 3 and compared with the corresponding reference sample – walnut (*Juglans regia*) suggested by both the microscopic and macroscopic features.

As it can be easily observed from Figure 2a the species for identification is a hardwood with oval diffuse pores, unitary or grouped in pairs, with tylosses. Metatracheal parenchyma is present as fine tangential lines, very similar to the reference image from Figure 2b of walnut (*Juglans regia*). The image processing in Figure 2c allowed the automatic calculation of 13 pores/mm^2, which falls within the range of 6-14 pores/mm^2 reported by Wagenführ [7, p. 301] for walnut. The mean pores lumen diameter of 120.9 μm, calculated from the 'mask' image in Figure 2c, corresponds to the mean reported for walnut, 60-120(160)-240 μm. The maximum pores diameter, 148 μm, measured in Figure 2d indicates an area of latewood. The proportion of pores calculated with ImageJ of 10.7% is closer to the lower limit for walnut 9.1-12-14.2% [7, p. 303]. A number of 3 pluriseriated rays in Figure 2a corresponds to 6 rays/mm, which coincides to the lower range of walnut, 6-8 rays/mm [7, p. 303].

Figure 3a shows a tangential section through the investigated sample J1, where it can be noticed the presence of metatracheal parenchyma as in the reference image from Figure 3b (walnut). The ray lengths ranged between 202-

343 μm, values around the mean reported for walnut: 160-330-570 μm [7, p. 303].

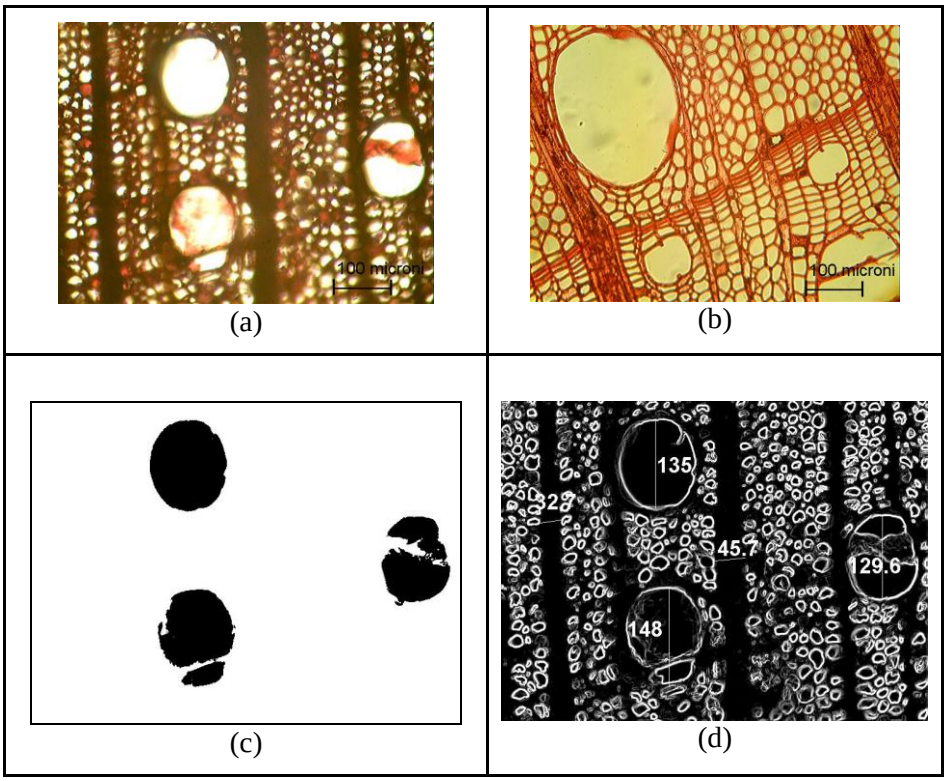

Figure 2. Cross sections, magnification 200x: (a) investigated sample J1, (b) reference sample (walnut - *Juglans regia*), (c) 'mask' image of the investigated sample J1, (d) investigated sample J1 with cell contour enhanced and measurements. Size of the investigated sample micrograph: 456.48x491.67 (μm).

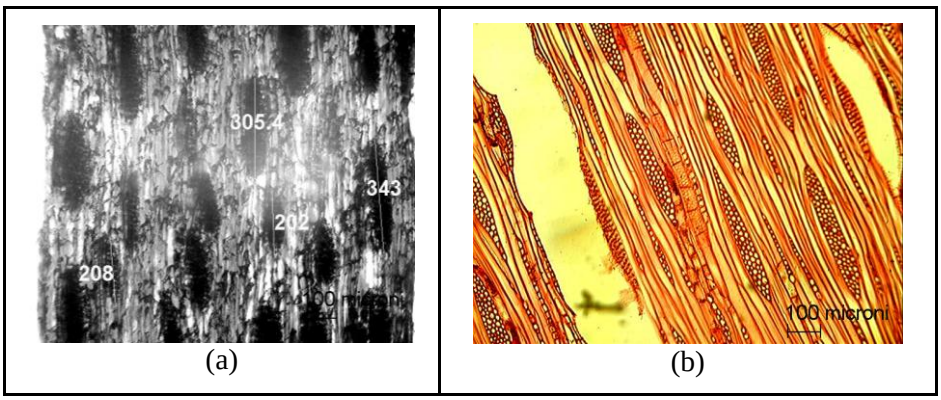

Figure 3. Tangential sections, magnification 100x: a- investigated sample J1; b- reference sample (walnut-*Juglans regia*)

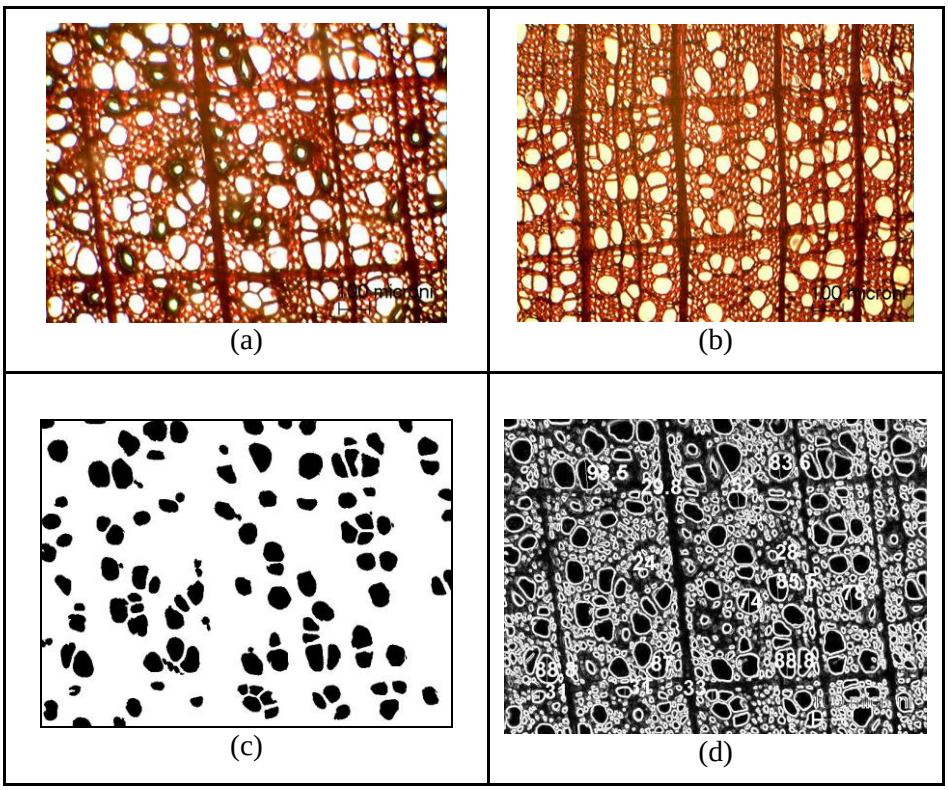

Figure 4. Cross sections: (a) investigated sample J2- magnif.100x, (b) reference sample (lime - *Tilia cordata*) - 100x, (c) 'mask' image of the investigated sample J2 - 100x (size 1312.96 x 983.33 µm), (d) investigated sample - cell contour enhanced and measurements - 100x.

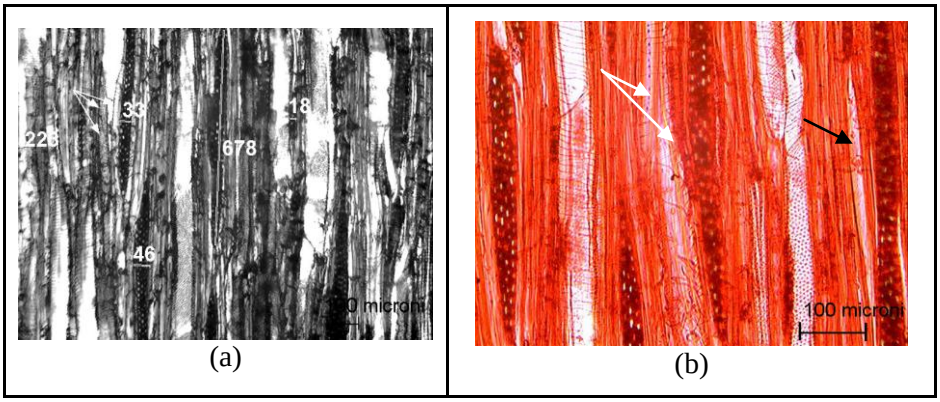

Figure 5. Tangential sections: (a) investigated sample J2, magnification 100x (white arrows - vasicentric tracheids - associated with vessels, have rounded ends and bordered pits); (b) reference sample (lime - *Tilia cordata*), white arrows - possible vasicentric tracheids, black arrow - possible a fibre-tracheid with bordered pits and pointed ends.

Based on the above observation and analysis, the investigated sample is most probably walnut – ***Juglans regia***. This result confirms the presumptions based on the macroscopic features.

3.2. Sample J2 - Micrographs and interpretation

The micrographs resulting from the investigation of the sample J2 are presented in Figures 4 and 5 and are compared with the corresponding reference sample – lime (*Tilia cordata*) suggested by the microscopic features.

The species for identification from Figure 4a is a hardwood, with diffuse pores dispersion with no pronounced difference between pores size from earlywood compared to latewood. Pores are numerous, have no tiles and appear unitary or grouped 2-3 in radial rows (Figure 4a). Similar pores distribution and size is visible in Figure 4b which describe the reference species, lime (*Tilia cordata*).

The crosssection in Figure 4a shows the presence of quite a large number of vessels with vasicentric tracheids, with a darker appearance. The vasicentric tracheids are visible also in Figure 5a of the investigated sample, as cells associated with vessels, having rounded ends, thin walls and bordered pits, but also in the reference sample in Figure 5d. However, the frequent occurrence of the vasicentric tracheids is more common for juvenile wood rather than mature wood of lime [11].

By processing with ImageJ the image of the investigated species from Figure 4a, a number of 83 pores/mm^2 were identified, which falls within the range of 70-130 pores/mm^2 reported by Wagenführ [7, p. 243] for lime. It has to be mentioned, that vessels with vasicentric tracheids were not identified, respectively counted by the program and if they were, the pores number would have increased to 100/mm^2. Also, it was difficult to distinguish the small pores from the fibro-tracheids, some of the latter being kept in the evaluation.

The mean pores lumen diameter of 55.2 μm, calculated from the 'mask' image in Figure 4c is close to the mean reported for lime, 20-60-90 μm. The maximum pores diameters 87-88.8-98.5 μm, measured in Figure 4d are close to the upper size limit reported for lime 90 μm [7, p. 243], while the smallest pores in Figure 4d, had values of 29.8-31-33 μm, towards the lower limit for lime, 20 μm. The vessels with vasicentric tracheids were smaller with measured diameters of 24-28 μm (Figure 4d). The proportion of pores calculated with ImageJ for the species for identification was 19.8%. For lime, Wagenführ [7, p. 243] appreciates pores proportion in the mature wood around 17%. The vessels contain distinct dense thickenings visible on tangential sections for both, the investigated species in Figure 5a and in lime, Figure 5b.

Apotracheal and metatracheal parenchyma are present as fine tangential lines in Figure 4a similar to the reference image from Figure 4b of lime (*Tilia cordata*).

The rays of the investigated species appear distanced with several pores diameters. From Figure 4a, a number of 4-5 rays/mm were calculated, which

falls in the frequency reported for lime, 2-3-9 rays/mm [7, p. 243]. Their widths and heights were measured in Figure 5a. For lime, ray heights vary in the range 180-240-1250 μm and their widths vary from 10 to 30 μm Wagenführ [7, p. 243]. In Figure 5a, one complete pluriseriate ray was measured, 678 μm, and one uniseriate, 228 μm, values which fall in the interval for lime. The rays widths, were of 18-33-46 μm, near the values for lime.

Based on the above observation and analysis, the investigated sample is most probably wood from lime – ***Tilia cordata***, perhaps cut from a region near the pith. For this sample the macroscopic examination was not conclusive, pointing only towards a hardwood diffuse porous species. This case is a proof for the utility of microscopic method of wood species identification based on identification keys, reference sample images and image data processing, as presented and used in this paper.

3.3. Sample J3 – Micrographs and interpretation

The micrographs resulting from the investigation of the sample J3 are presented in Figure 6 and Figure 7 and compared with the corresponding reference sample – walnut (*Juglans regia*) suggested by the microscopic features.

The species for identification from Figure 6a is a hardwood having diffuse pores dispersion. The pores appear oval in shape, unitary or in groups of 2-3, with tylosses in the latewood clearly visible in Figure 6a and Figure 7a. The pores distribution and size is comparable with images of walnut (*Juglans regia*) in Figure 6 b.

By processing with ImageJ the image of the investigated species from Figure 6a, a number of 13 pores/mm^2 were identified, which falls within the range of 8-20 pores/mm^2 reported by Wagenführ [7, p. 301] for walnut. The mean pores lumen diameter of 135.5 μm, calculated from the 'mask' image in Figure 6c is around the mean reported for walnut, 60-120(160)-240 μm. The maximum pores diameters in earlywood, 202.5-207.7 μm, measured in Figure 6d are close to the upper size limit of walnut earlywood pores, 160-240 μm. The pores from the latewood next to the annual ring limit had values of 67-72.4 μm (Figure 6d) close to the lower limit for walnut pore size range in the latewood, 60-120 μm. The proportion of pores calculated with ImageJ of 19% is higher than the upper value reported for walnut 9.1-12-14.2% [7, p. 303], but probably the sample comes from a young walnut tree or from a region closer to the pith.

Metatracheal parenchyma is present as fine tangential lines in Figure 6a and longitudinal lines in Figure 7a, very similar to the reference images from Figure 6b and Figure 7b of walnut (*Juglans regia*).

Based on the above observation and analysis, the investigated sample is most probably walnut – ***Juglans regia***. This confirms initial presumptions.

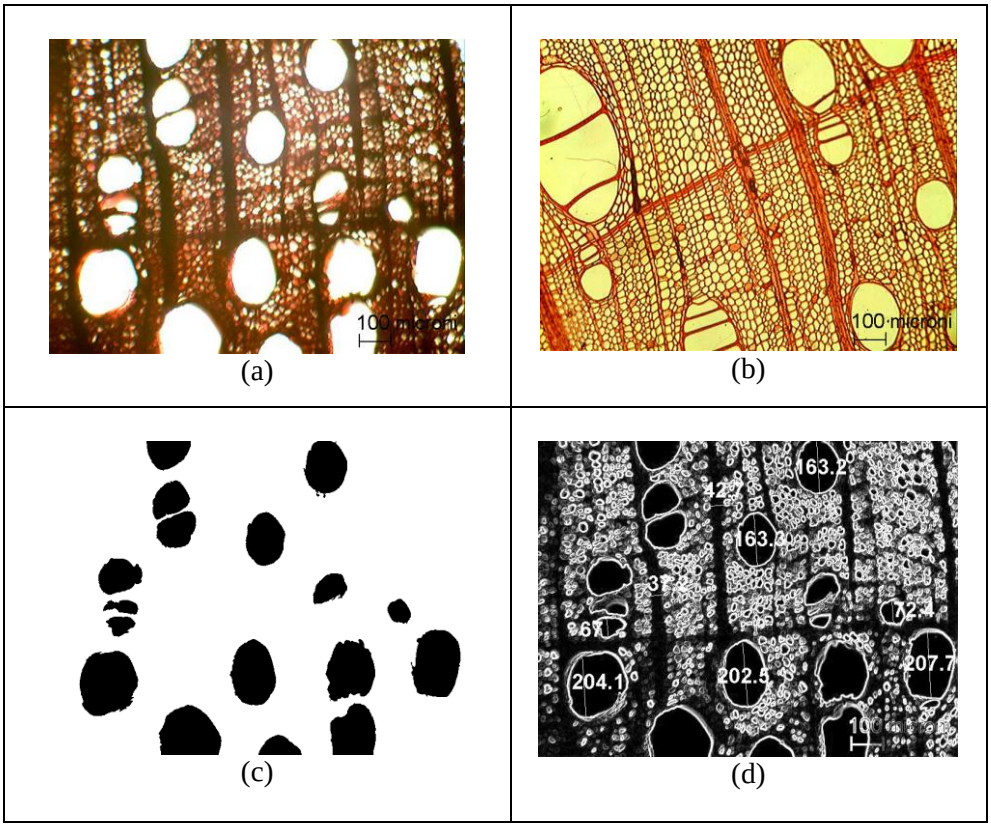

Figure 6. Cross sections: (a) investigated sample J3 - magnif.100x, (b) reference sample (walnut - *Juglans regia*) - 100x, (c) 'mask' image of the investigated sample J3 - 100x (size 1312.96x983.33 µm), (d) investigated sample - cell contour enhanced and measurements - 100x; e-investigated sample J3 – magnif. 200x (size 656.48x491.67 µm); f-reference sample (walnut- *Juglans regia*), 200x

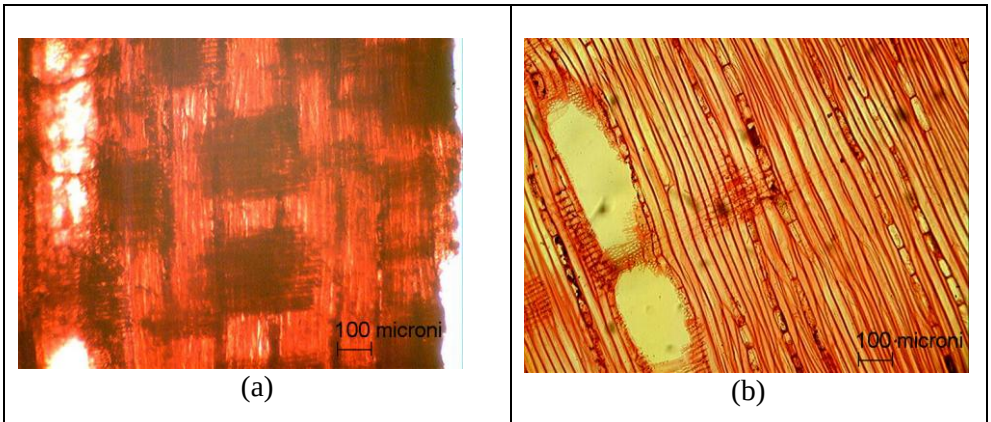

Figure 7. Radial sections, magnification 100x: (a) investigated sample J3, (b) reference sample (walnut - *Juglans regia*).

4. Conclusions

Restoration work on wooden religious objects, as components of the cultural heritage, requires that species of origin are identified and their degree of deterioration is analysed. A case study of a bishop throne from 1838 looked at the species identification of three furniture parts, whose visual evaluation was not conclusive. As this could be the case often occurring in practice, a microscopic approach was proposed and used in this paper. Examination and feature evaluation of microscopic microslides with ImageJ and comparison with reference data from literature has identified walnut and lime as species of origin for the furniture object under restoration.

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