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SCIENTIFIC INVESTIGATION OF THE WOODEN BOARD FROM THE 1802 BOOK OF PSALMS

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Abstract

This paper presents some investigations on the wooden board of the religious Book of Psalms, dated back to 1802, which was published at the typography of the Moldavian Metropolitan Church in Romania. The visual observation was performed to assess the conservation state and to choose the most appropriate diagnostic analyses to provide useful information for book restoration. Wood species and textile fibres has been characterised by optical microscopy; biological analysis was performed to identify fungi and bacteria, as well as insect species; superimposed materials, such as glue, were analysed by Fourier transform infrared spectroscopy. The analysis revealed the use of beech for the board, flax and cotton for the strips, original glue and a synthetic material, probably used in restoration works. Microbiological contamination was due to fungal attack ('Trichoderma viride, Aspergillus flavus'); the insect species was 'Anobium punctatum'. The critical observation of board made by the working group was an effective operation as it supplied useful information on original techniques of the book and allowed to choose the appropriate analyses with the aim of minimum intervention.

Keywords: optical, microscopy, FTIR, microbiological, identification

1. Introduction

The study of cultural heritage artefacts implies today the inclusion of scientific investigation as fundamental process for knowing the materials and the techniques. In the specific case of wooden artefacts with historical, artistic and religious significance the diagnosis is highly relevant because it provides useful information for restoration purposes, for gathering knowledge on ancient techniques and materials and for suggesting the most suitable conservation modalities [1-6].

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Starting from these general assessments, in the present paper the wooden board of the Book of Psalms was investigated in order to collect information about the original materials, the possible original structure and function, also to supply a valid aid to the restoration work. It must be underlined that the paper is an extension of the short contribution presented at ESRARC 2018 conference and published in the Proceedings Book [7].

The Book of Psalms is a religious book published in 1802 at the typography of the Moldavian Metropolitan Church in Romania. The book is printed in Romanian language with Cyrillic characters. It is based on hand-made paper from textile fibres and the text is written with black typographic ink. The board binding is made of wood and the cover is brown calf leather, decorated through cold pressing (Figure 1).

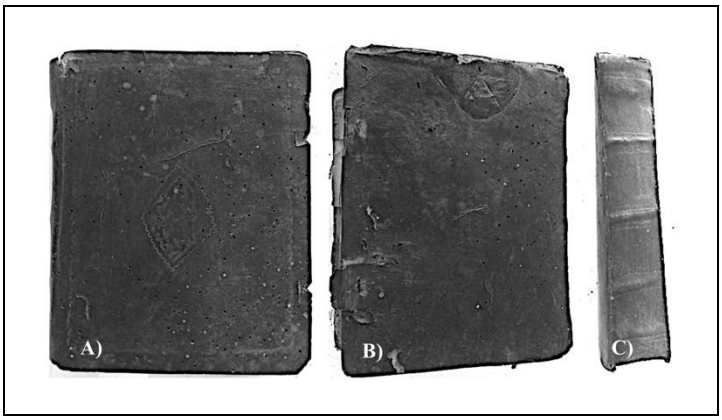

Figure 1. Images of the Book of Psalms, 1802: (A) front cover, (B) back cover, (C) spine.

The book and the wooden cover were interested by several degradation patterns such as:

- *physical-mechanical damages*: distortion of paper, ruptures, cracks, lack of material, functional patina;
- *physical-chemical damages*: natural aging (yellowing and fragility of paper), chromatic changes, increased acidity of the paper (pH 4.5-5.1); stains of different natures (oil, fat, wax), dirt and dust deposits, loss of support, degradation of adhesive used in bonding;
- *social damages*: empirical restorations, wax and dirt deposits, cracks, tears, bending, notes without documentary value (pencil and ink);
- *biological damages*: chromatic changes, pH value modification, fragility and staining of paper after microbiological attack, strong attack of xylophage insects.

So, it was decided to perform some investigations on the wooden board in order to obtain information on the original materials and above all on the degradation substances. In fact, the original wooden board was replaced, due to its damages, and so it was available for sampling and laboratory analysis.

2. Experimental

The first step of the analytical path was carried out at naked eyes and under a stereomicroscope in order to carefully examine the overall surface of the wooden board. An Olympus SZ stereomicroscope was used. It was equipped with fibre optics external light source and 10-63x magnification zooms.

A visual assessment was carefully carried out and samples were taken for laboratory analyses (Table 1, Figure 2). These were carried out through optical and polarizing microscopy and Fourier transform infrared spectroscopy (FTIR). Samples for biological attacks were taken.

Table 1. Description of the sampling points and of the performed analysis.

Sample	Description	Analysis
P1	Inner side, blue fibres	Polarising microscope
P2	Outer side, textile fibres	Polarising microscope
P3	Outer side, white powder	FTIR
P4	Outer side, white powder	FTIR
P5	Outer side, dark fibres	Polarising microscope
L1	Wood	Optical microscope
L2	Wood	Optical microscope
M1	Wood with biological attack	Culture medium (Sabaraud for Fungi, TSA for Bacteria)
M2	Wood with biological attack	Culture medium (Sabaraud for Fungi, TSA for Bacteria)

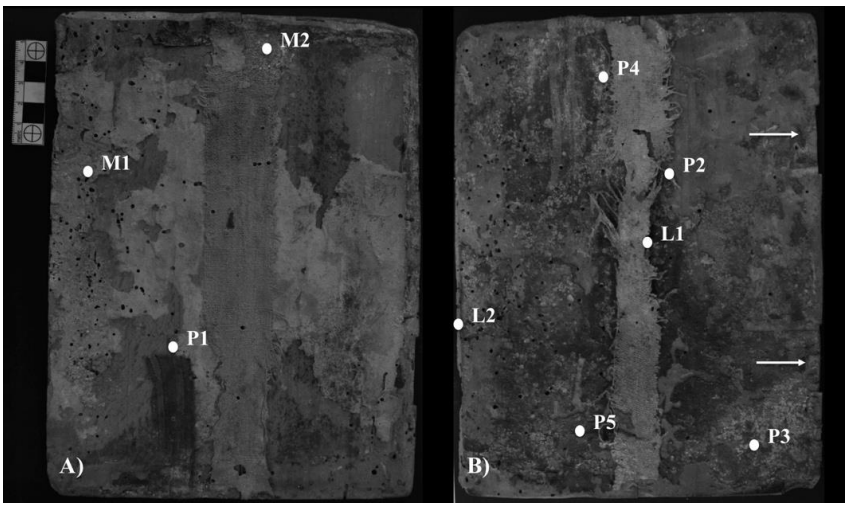

Figure 2. Photographs of the board with the sampling points. (A) inner side, (B) outer side. The two arrows indicate the traces of possible catch plates used for closing the volume. P, L and M indicate the sampling points described in Table 1.

Thin sections (15-20 mμ) of wood samples were examined by Polivar 100 light microscopy. The examined features were compared with the descriptions of Nardi Berti [8], Schweingruber [9] and with the data base Insidewood [http://insidewood.lib.ncsu.edu/search].

Microphotographs were captured through a Zeiss AxioCam digital camera directly connected to the microscope.

FTIR analysis was performed on sample powder, mixed with potassium bromide (KBr), by a Nicolet Avatar 360 infrared spectrophotometer in diffuse reflectance modality (DRIFT), operating in the 4000-400 cm^{-1} region with a resolution of 4 cm^{-1}. KBr was used also as background material.

The wood was infested by xylophage insects, and some dead insects were found. They were collected for identification [10]. In particular, biological analyses were made at the investigation laboratory of the National Museum of History, Bucharest, Romania to detect fungal and bacterial contamination.

The method used was the impression one, consisting in pressing sterile 1 cm^2 test specimens of filter paper (impregnated with sterile distilled water) onto the affected zones, so that the spores and mycelial fragments would adhere to the surface of the test specimens, which were subsequently transferred to culture media. For the examination and identification of bacteria, the incubation of the samples inoculated on the TSA medium at 37°C for 24 hours was followed by the examination of the growth of bacterial cultures on/around the test specimens. The bacterial examination of the smears was carried out using an Olympus optical microscope equipped with a 100x immersion objective [11]. The same technique was used for isolating the fungi from the examined paper supports. The culture medium was different (Sabouraud) and the incubation was carried out at 28°C for 7 days [12].

The fungal colonies, grown on the Sabouraud culture medium in the Petri dishes inoculated with the samples collected from the supports under investigation, were examined using a Nikon trinocular microscope equipped with a digital camera.

3. Results and discussion

3.1. Visual assessment

The critical observation of the object by the working group was an effective operation that supplied useful information on executive techniques of the book and allowed to choose the appropriate analyses with the aim of minimum intervention [2, 13, 14].

The wooden board (20.3x17.7 cm) (Figure 2) is made of a single piece divided into two parts by a fissure. The integrity of the board was probably re-established in the past by a flax fabric strip that held together the two parts and by blue-beige cotton strips to preserve other smaller cracks [7]. Along the main side of the board, in the outer surface, traces of possible catch plates (3.3 cm) are clearly visible (see arrows in Figure 2B). These plates served as attaching points

for the straps that fastened the tome [15]. The board thickness, measured by a calliper, varies from 5.01 mm (in correspondence of the board side with the traces of catch plates) and 4.01 mm (in the opposite side). The board corners appear rounded and moreover three sides, apart from that containing the traces of catch plates, appear thinned.

Observation of wood macroscopic characteristics shows a heteroxylous wood, i.e. wood from a broadleaf tree, with diffuse porosity and large rays. The board was cut in radial direction. The shrinking and swelling behaviour of the wood is a key factor in many uses. It is important to note that the radial cut makes the board less susceptible to deformations caused by the environmental thermo-hygrometric changes.

The careful examination allowed for highlighting that wood was infested by xylophage insects, deduced by the presence of exit holes and galleries appearing sometimes on the longitudinal surface. Some insects were found and they were collected for species identification.

3.2. Microscope analyses

3.2.1. Analysis of wood thin sections

The analysis of wood thin sections under optical microscope, allowed for revealing the anatomical characteristics typical of beech (*Fagus sylvatica* L.).

The identification features are indicated in Figure 3. Physical and mechanical properties of beech wood make it an appreciated species in Europe [16]. The identification of the botanical species provides relevant information on the technological characteristics of the wood and its natural durability [17] allowing a better approach to the conservation of the artefact [18].

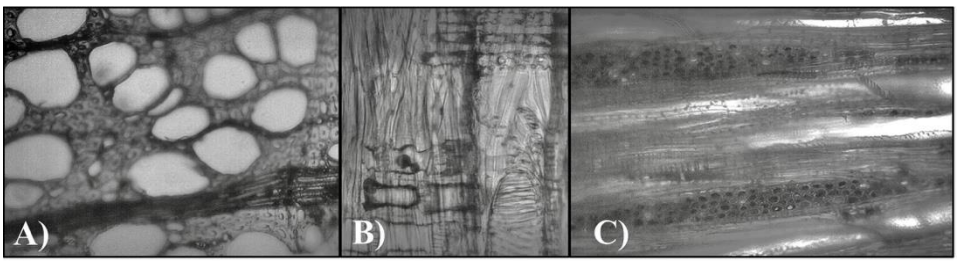

Figure 3. Microphotographs of wood thin sections showing the microscopic features of *Fagus sylvatica* L.: (A) cross section (10x magnification), diffuse porosity, rays of variable width, someone large, visible at naked eye, enlarged at the ring boundary; (B) radial section (25x), simple perforation plate, sometime scalariform in latewood; (C) tangential section (10x), uniseriate and multiseriate rays, easily detect due to the darker colour.

Beech in bindings was common in France, in Italy, in Germany and even in Island where this species was imported from Germany [19-21].

3.2.2. Insect identification

An insect, collected together with its dust of worm-eaten wood, is shown in Figure 4. The exit holes were circular, 2.5-3 mm in diameter, and larva galleries were packed with excrements. The observed adults belong to the species *Anobium punctatum* De Geer. This borer insect produces the greatest degradation during the larva stage, feeding of the wood, reaching the adult stage in about two years under favourable conditions. It attacks seasoned wood of conifers and broadleaves both in sapwood and heartwood and prefers relative humidity lower than 50% [11]. *Anobium punctatum* is able to dig through both the book block and the cover; that's why it causes perforations through the leather cover also, even if it is not attracted to it [22].

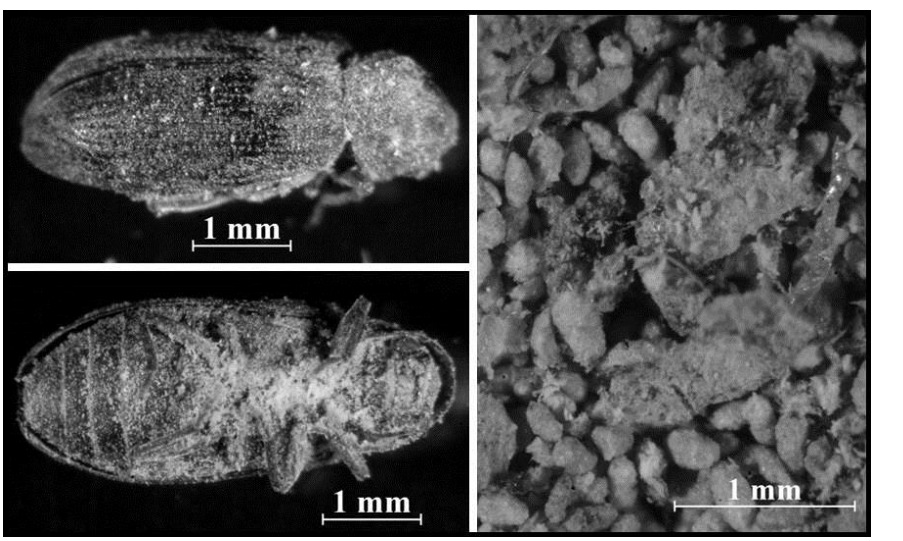

Figure 4. Images of the insect found in an exit hole and dust of worm-eaten wood, ellipsoid shaped.

3.3. Material identification by FTIR analysis

FTIR spectroscopy analysis was carried out in order to better characterize the white powder present on the wooden board and particularly in the samples P3 and P4 (Table 1).

The FT-IR analysis of the P3 sample (Table 2) shows the presence of the characteristic IR bands of proteinaceous materials (probably gelatine glue). This is the original glue used to guarantee the adhesion of the fabric or paper to the wooden frame [7; www.irug.org].

The white powder taken near the flax fibre in the middle of the board (P4) seems to be constituted by polyamide. The material clearly refers to residues of material used during a previous restoration [7; www.irug.org].

Table 2. Results of FTIR analysis in terms of wavenumbers detected in the experimental spectra.

Sample no.	Wavenumbers (cm^{-1})
P3	3402, 3079, 2934, 1643, 1547, 1453, 1314, 1238, 1153, 1075
P4	3405, 3306, 3066, 2954, 2926, 2873, 2852, 1759, 1670, 1638, 1548, 1455, 1379, 1242, 1166, 1074, 1047, 877

3.4. Microbiological survey

A fungal attack (*Trichoderma viride*, *Aspergillus flavus*) was identified on the board binding area. Macroscopic appearance of fungal colonies 7 days after inoculation on culture medium and of bacterial colonies after 24 hours from inoculation on culture medium are shown in Figure 5.

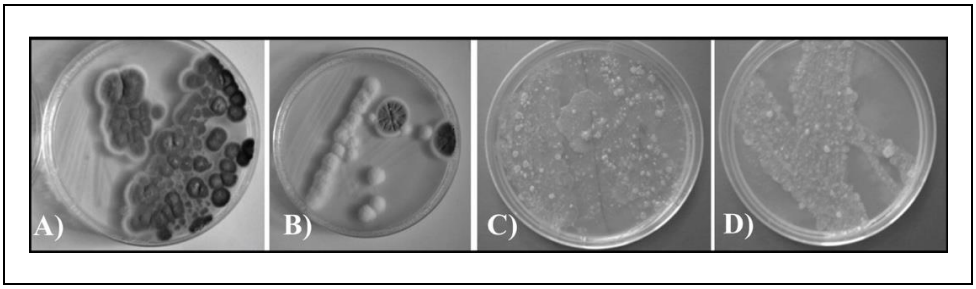

Figure 5. Microbiological contamination. Fungal contamination in: (A) the spine, (B) board wood. Bacterial contamination in: (C) the spine and (D) the board wood.

Between the biodegradation agents affecting the old wood, heterotrophic bacteria were found, which cause erosions and alterations of the physical-mechanical properties, and fungi (*Basidiomycetes*, *Ascomycetes*, *Deuteromycetes*) which produce rot, stains, pigments and changes of mechanical characteristics. Depending on the amount of water required for development, dry rot and wet rot can be identified. On old wood it was identified the following types of rot: brown rot, white rot and soft rot [23]. It is known that moisture contributes to the biological degradation of old wood, being necessary at all stages of microorganism development. The minimum wood humidity required for the development of the fungi varies between 16-24%, depending on the type of the species. The two *Deuteromycetes* species identified in this case study are *Aspergillus flavus* and *Trichoderma viride*. Optimum growth of *Aspergillus flavus* is obtained at 80-85% relative humidity and 25-42°C temperature. Light can have inhibitory influence on the growth of this kind of fungi. The optimum temperature for the growth of *Trichoderma viride* is between 20 and 28°C [Centre de Recherche sur la Conservation des Collections (CRCC), *Database Mycota. Fungal contaminants of cultural heritage*, http://mycota-crcc.mnhn.fr]. The effects of the biodegradation agents on the wooden board are: white rot, stains and alterations of the physical-mechanical and aesthetical properties.

The stability of the microclimate conditions is very important for preserving works of art made of hygroscopic materials. The environmental conditions, the exposure and storage modalities highly influence the preservation of wooden objects.

4. Conclusions

In the present paper the results of the analyses carried out on a wooden board belonging to the Book of Psalms have been reported and discussed. The careful visual observation of the board allowed for detecting several types of damages: physical-mechanical as fractures, physical-chemical such as colour changes, social damages as burning and unsuitable restorations, biological damages as insect galleries and stains caused by fungi.

The book suffered the natural ageing processes; however in addition the repeated manipulations, the inadequate conservative conditions, interventions with materials incompatible with the original, and the unsuitable microclimate of storage certainly caused further stresses and deterioration patterns.

The analyses on the wooden board gave interesting results: visual analysis allowed gathering information about the structure and state of preservation; laboratory analyses characterized the botanical species of wood as beech, the fabric fibres as flax, cotton and paper, the original gelatine glue and traces of a probable restoration material (polyamide). The data obtained by the microbiological survey were useful for supporting the intervention and also for properly preserving the book after the restoration work.

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