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THE INFLUENCE OF ARTIFICIAL AGEING ON SELECTED PROPERTIES OF WOOD SURFACES FINISHED WITH TRADITIONAL MATERIALS - AN ASSESSMENT FOR CONSERVATION PURPOSES

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Abstract: *Ageing is a complex, natural, irreversible process which occurs slowly in time and affects the material properties. Finished wood surfaces are affected by ageing and a deeper knowledge of the resulting effects is a key issue for authentic conservation of historic furniture. The research presented in this paper focused on the effects of four types of accelerated artificial ageing tests (for indoors conditions) on the colour, the resistance to selected cold liquids, and the adherence of three types of traditional finishing materials: beeswax, linseed oil, and shellac, applied on three different wood substrates: European walnut (Juglsns regia), European ash (Fraxinus excelsior), and Sycamore maple (Acer pseudoplatanus)*.

Key words: *ageing, traditional finishes, colour, adherence, resistance to cold liquids.*

1. Introduction

Worldwide, historic furniture represents an important and valuable part of cultural heritage which has to be authentically conserved and restored. Preserving the authenticity of historic furniture implies not only preserving the original wood material (solid wood, veneers) and the structural parts as much as possible, but also preserving the original finishing layer and patina. These are part of the beauty and distinctive charm of antique furniture, while also a precious element of history and authenticity [18], [23], 27]. Patina might be defined as a desirable change in

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appearance (colour, gloss) brought about by time and use, being in part a result of ageing.

Transparent finishes applied on wood surfaces enhance and highlight the natural beauty of wood, while also ensuring its insulation against humidity, a better behaviour of the wooden surfaces in contact with different liquids (e.g., water, alcohol and different coloured products), and a higher resistance to scratches and mechanical wear.

Traditional finishing materials for historic furniture belong to three major classes of natural products: waxes, drying oils, and natural resins, which differ in terms of chemical composition, solubility, mechanism of film formation, and properties of finished surfaces [1], [18, 19], [21], [23]. Beeswax, linseed oil, and shellac are the most important representatives of these classes for historic furniture in Europe [15, 16].

Ageing of materials has been defined as *a slow, gradual and irreversible alteration of the chemical or physical structure of a material with the passage of time, which usually has a detrimental effect on the material properties, leading to a gradual loss of the designed function and ultimate failure or unacceptable loss of efficiency* (adapted after David 2009). However, ageing may result in some cases in *formation of new substances and stabilisation*, which might be a desirable effect [20].

As natural ageing is a slow process, accelerated ageing tests under the action of the main ageing factors are often employed in research in this field [11].

Ageing is always related to chemical changes in the material composition and structure, which are actually reflected in changes of the physical and mechanical properties. The main ageing factors for wood and coating materials are: light /UV radiation, temperature and oxygen, causing specific chemical degradation processes which may be influenced by other environmental factors such as the relative atmospheric humidity. The actual ageing effects of these factors are different and depend on the type of material (wood, coating material) and the chemical particularities of each material (wood species, type/sort of coating material) [16].

Ageing and degradation of the traditional finishing materials, as well as wearing and deterioration during the use of furniture, followed quite often by periods of abandonment and storage in totally inappropriate conditions, most often cause serious degradation of the finishing layers [12, 18]. Different stains and various deposit of dirt can be usually solved by adequate cleaning methods. Structural changes in the chemistry of the coating films as a function of their chemical composition and of the wood substrate at the interface level may result in more serious damaging effects such as: formation of micro-fissures affecting transparency, decrease / loss of adherence, flaking, and ultimately exfoliation. In cases of adherence loss, the original finishing layer might not be fully restored, but just conserved or, in the worst case scenario, removed by gentle stripping, for the surface to be then refinished according to the original, in terms of materials and traditional technique [22, 23]. Unfortunately, there are many cases when old furniture is reconditioned, not restored, and new modern finishing materials are employed for reasons related to a better resistance of the finished surfaces to everyday use (cold liquids, temperature), simple application, costs, lack of knowledge of the coating materials, and poor practical skills [19], [21].

A deep knowledge of materials and understanding ageing phenomena are general key issues for the scientific conservation of cultural heritage [11]. Accordingly, ageing of wood species and traditional finishing materials, with relevance to cultural heritage conservation is an important and current research topic. However, wood ageing is better represented (67%) than ageing of traditional finishing materials (33%), and available data are difficult to compare or extend to wood finished surfaces due to a great variability in testing (tested materials, ageing factors, ageing procedures, investigated parameters). Most often, colour changes are employed as a very sensitive physical indicator of wood / polymers ageing [5, 6], [25], which can be correlated to the associated chemical changes, highlighted often by FTIR.

Ageing of natural finishing materials and especially wood finished surfaces for conservation purposes remains an open subject of investigation needing completion by dedicated approaches. Studies looking at the effects of ageing on the properties of the coating films, such as adherence to the substrate and resistance to cold liquids or gloss are very limited. Šimunková et al. (2018) compared a high-gloss polyurethane lacquer with traditional shellac varnish (applied on oak) and the effect of artificial UV ageing on some selected properties of the finished surfaces, including: resistance to cold liquids, adherence, hardness, and gloss. They concluded that UV ageing affected these properties differently, highlighting a marked decrease in the water resistance of shellac finish. Another study [13] on shellac and polyurethane finishes found these materials similarly effective in protecting gloss following UV exposure in an accelerated lab test.

Considering the importance of acknowledging the ageing induced changes on the quality of finished wood surfaces for the furniture conservation practice, the research presented in this paper aimed at bringing a necessary contribution. It focused on the effects of four types of accelerated artificial ageing tests (for indoors conditions) on the colour, the resistance to selected liquids, and the adherence of three types of traditional finishes applied on three different wood substrates.

The results presented in this paper are based on a complex PhD research project studying, at a complex level, ageing phenomena of wooden substrate and traditional materials for transparent finishes, in a comparative approach for Europe and China, and envisaging applicability in furniture conservation [16]. Only a few relevant data for the topic under discussion were extracted and processed adequately for this paper.

2. Materials and Methods

2.1. Wood Samples

Three wood species important for historic furniture were selected for the present study: European ash (*Fraxinus excelsior*), European walnut (*Juglans regia*), and Sycamore maple (*Acer pseudoplatanus*). Test samples with dimensions of 120 mm (length) by 80 mm (width) by 8 mm (thickness), with radial faces, were prepared by mechanical processing from sound, air dried wood material. Prior to the finishing process, the faces of all the prepared wooden samples were thoroughly sanded with 240 grit size sandpaper and conditioned at 20°C and 55% RH.

2.2. Traditional Finishing Materials

The selected traditional finishing materials were: Beeswax (BW), Linseed oil (LO), and Shellac (SL), as representative for three classes of natural products: waxes, oils, and resins. Data on the technical products employed, the solvents and preparation of finishes for application are included in Table 1.

Table 1

Finishing materials and auxiliary products for experimental research –type of products, suppliers and preparation for application

Finishing materials / auxiliary products	Code	Suppliers	Preparation for application
Beeswax	BW	Conrep SRL, Romania	Dissolution: 50 g BW / 250 ml WS
Boiled linseed oil	LO	Fabryo SRL Romania	Dilution (for the first 2 layers) LO:WS=2.5:1 (v:v)
Shellac flakes	SL	SC Vitalnet Med SRL, Romania	Dissolution: 10g SL + 1g Collophony / 100 ml EA
Ethyl alcohol (90%)	EA	Conrep SRL, Romania	-
White spirit	WS	Conrep SRL, Romania	-

2.3. Finishing of Wood Samples

Traditional finishing procedures and manual application techniques were employed in this research. Beeswax was applied using a soft pad covered with cotton, in five successive layers, each of about 25g/m^2, at 24 h intervals. After final drying, the finished wood samples were polished with a felt.

Linseed oil was applied by brush in five successive layers, each one of about 25g/m^2. Diluted linseed oil was employed for the first two layers, while for the last three layers undiluted linseed oil was applied. The drying interval between layers was 24 hours at normal temperature. An intermediary sanding step, with 360 grit size sandpaper, was included between layers three and four.

Shellac finish was applied first by brush in three successive layers of about 110g/m^2 at intervals of 2-4 hours (drying time at 20°C) without intermediary, as a base coat. The samples were then sanded with 360 grit size abrasive papers. Further finishing was achieved employing a polishing “rubber” made of cotton wool wrapped in a soft cotton textile; successive thin layers were continuously applied until the desired degree of pores filling and gloss was reached, according to the traditional French polishing technique [2], [21, 22, 23].

2.4. Ageing Procedures

Four accelerated artificial ageing tests (A1-A4) under the action of the main ageing factors, namely UV radiation, temperature and extreme variation of atmospheric humidity (RH) or temperature were carried out. These tests were designed based on previous research experience in this field [26] and literature data [3], [7, 8], [17], [24]. The four types of tests, coded as A1, A2, A3, A4 and their characteristic conditions are presented in Table 2.

All the artificial ageing tests (A1-A4) were carried out in an environmental climatic chamber FEUTRON FKS 400, endowed with a UV source of UVA Spot 400A type fitted with a H_2 filter glass which cuts off UV radiation below 295nm.

Table 2

Ageing procedures employed in the experiments

Code	**Ageing agent**	**Conditions**	**Time/cycle (step)**	**No. of cycle (step)**	**Total time**
A1	Temperature	100°C /RH 55%	72h	4	288h
A2	Cold check (variation of T)	Temperature: -50°C:1h -15 °C:1h -20 °C:1h RH 55%	3h	10	30h
A3	Relative humidity (variation of RH)	Temperature 20°C RH: 25% for24h 85% for24h	48h	5	240h
A4	Radiation UV	UVA –UVB T = 40 °C, RH 55%	4×6 h UV	3	72h (UV)

2.5. Investigation Methods and Equipment

The wood samples and finished surfaces were scanned using a HP LaserJet Pro CM1415 colour multifunction printer and the images were further processed to select areas of about 60×48 mm. These pictures were employed in the image cards illustrating aspect/colour changes of wood surfaces as a result of ageing.

Colour measurements were performed in the CIELab system, employing a spectrometer AvaSpec-USB2 equipped with an integrating AVA sphere having a diameter of 80 mm, interconnected by optical fibers and connected to a PC for data acquisition and processing. Colour measurements were performed for each test sample in 4 points (actually circular areas of about 8 mm diameter), and an average was calculated. Measurements were performed in exactly the same areas before and after ageing.

The measured coordinates were:

- L* - lightness, varying from 0 for black to 100 for white;
- a* - degree of red , respectively green, on a positive to negative scale of values;
- b* - degree of yellow, respectively blue, on a positive to negative scale of values.

2.6 Resistance of Finished Surfaces to Cold Liquids

The resistance of the finished surfaces to a selection of cold liquids relevant for furniture use and conservation was assessed according to the method described in EN 12720–2009 [4] (*Furniture. Assessment of surface resistance to cold liquids*). All the variants of finished wood surfaces (3 wood species × 3 types of finishing materials) investigated in this research were tested with respect to their resistance to cold liquids before and after accelerated ageing tests (A1-A4). All the samples were conditioned in the laboratory at about 20°C and a relative humidity 50% for 7 days, before assessing their resistance to the selected liquids presented in Table 3.

Discs of filter paper, immersed in the respective liquids, were placed on the surface and covered. At the end of the testing time, the surface was cleaned, conditioned and then the tested areas were carefully examined for any visible damage (marks, change in gloss and/or colour, blistering and other defects), being rated accordingly from 5 (maximum grade for no visible change) to 1 (minimum grade for strong mark / degradation) as presented in Table 4.

Table 3

Selected testing liquids and testing times

Testing liquids	**Tests duration**
Distilled water	1h, 6h and 24h
Ethyl alcohol (98%)	1h, 6h and 24h
Acetone (95%)	2 minutes

Table 4

Evaluation code for the resistance of finished surfaces to cold liquids
(according to EN 12720-2009)

Resistance grade (rate code)	**Description**
5	No visible changes (no damage).
4	Barely visible change as slight change in gloss and/or colour visible only when the light source is mirrored on the test surface or quite near the mark and is reflected towards the observer's eye, or a few isolated marks just visible.
3	Slight mark, visible from several viewing directions, for example almost complete disc or circle just visible.
2	Strong mark, the structure of the surface being, however, largely unchanged.
1	Strong mark, the structure of the surface being changed, or the surface material being totally or partially removed, or the filter paper adhering to the surface.

2.7. Adherence – Cross-Cut Test

Adherence of the finishing films to the substrate was assessed by a cross-cut test, according to the international standard ISO 2409:2007 [14]. This test was performed similarly for non-aged and aged finished samples to highlight the effect of ageing. It has to be stated that the loss of coating films adhesion to the wooden substrate is a practical problem in furniture conservation and that differences were noted among different types of finishing materials related to this property. The aspect of the resulting cut network and the percentage of exfoliated coating film areas are criteria for adherence appreciation on a scale from 0 (maximum) to 5 (minimum), according to the grading details in Table 5.

Table 5

Grading scale for adherence based on cross-cut test – from ISO 2409: 2007

Classification Adherence grade	Description
0	The edges of the cuts are completely smooth; none of the squares of the lattice is detached.
1	Detachment of small flakes of coating at the intersections of the cuts. A cross-cut area not significantly greater than 5% is affected.
2	The coating has flaked along the edges and/or at the intersections of the cuts. A cross-cut area significantly greater than 5 but not significantly greater than 15% is affected.
3	The coating has flaked along the edges of the cuts partly or wholly in large ribbons, and/or it has flaked partly or wholly on different parts of the squares. A cross-cut area significantly greater than 15% but not significantly greater than 35% is affected.
4	The coating has flaked along the edges of the cuts in large ribbons and/or some squares have detached partly or wholly. A cross-cut area significantly greater than 35%, but not significantly greater than 65% is affected.
5	Any degree of flaking that cannot even be classified by classification 4.

3. Results

3.1. Aspect and Colour Changes

Finishing of wood samples with the three types of traditional natural products (beeswax, linseed oil, and shellac) highlighted in a specific manner the structural features and beauty of all the three wood species employed, also influencing their natural colour. The colour of both unfinished and finished samples was further more or less modified as a result of the different ageing procedures. These aspects are illustrated in Figures 1-3 for the three European wood species: walnut, ash, and sycamore maple, respectively. The CIELab colour coordinates (L*, a*, b*), as average values and standard deviations were also included in these image cards to back up and complete the subjective visual assessment. Any further analysis of these colour changes is beyond the scope of this paper, which focuses mainly on the influence of ageing on the adherence and resistance of coating films to a selection of cold liquids. However, these colour changes are visible evidence of ageing and an indication that different processes should be involved in the four artificial experimental ageing procedures, as a function of the main ageing factor involved.

3.2. Adherence

Data on the adherence of the resulting coating films on the wood substrates and the influence of ageing are summarised in Table 6. The results show that all the finishing materials provided very good adherence of the films to the wooden substrates (grades 0 or 0-1). Ageing had only a slight effect on the adherence, depending on the wood species and the finishing material. It has to be noticed that these negative effects were registered especially for shellac. Adherence of shellac was mostly affected by UV radiation (tests A4), decreasing from 0 or 0-1 to 1-2 or 2.

Walnut (*Juglans regia*)	**A0**	**A1**	**A2**	**A3**	**A4**
Not finished	 L*= 56.75 ± 2.72 a*= 6.57 ± 0.66 b*= 13.03 ± 1.99	 L*= 50.43 ± 2.72 a*= 7.97 ± 0.64 b*= 15.76 ± 2.08	 L*= 57.66 ± 2.31 a*= 7.94 ± 0.67 b*= 12.37 ± 1.37	 L*= *58.08* ± 0.94 a*= *7.40* ± 2.11 b*= *12.64* ± 1.67	 L*= 59.32 ± 2.06 a*= 7.07± 0.68 b*= 15.48 ±1.10
Finished BW	 L*= 47.37 ± 2.94 a*= 9.20 ± 0.51 b*= 15.54 ± 2.12	 L*=46.37 ± 2.67 a*= 9.52 ± 1.07 b*=18.54 ± 2.25	 L*= 45.46 ± 4.62 a*= 10.64 ± 1.56 b*= 14.11 ± 3.88	 L*= 50.73 ± 3.83 a*= 10.61 ± 0.74 b*= 15.04 ± 1.83	 L*= 52.81 ± 3.89 a*= 12.02 ± 1.36 b*= 23.17 ± 3.01
Finished LO	 L*= 42.28 ±1.91 a*= 11.02 ±0.53 b*= 11.74 ±3.13	 L*= 32.41±1.69 a*= 9.22±2.28 b*= 9.25±2.36	 L*= 45.17 ± 2.60 a*= 11.73 ± 1.20 b*= 17.86 ± 1.41	 L*= 45.81 ± 3.20 a*= 9.90 ± 1.42 b*= 12.75 ± 2.81	 L*= 41.38± 1.83 a*= 12.57± 2.23 b*= 17.60± 2.75
Finished SL	 L*= 46.19 ± 2.08 a*= 10.18 ± 0.76 b*= 17.60 ± 1.93	 L*= 37.08 ± 1.42 a*= 10.21±1.29 b*= 14.81 ± 2.09	 L*= 46.12 ± 3.44 a*= 9.74 ± 1.30 b*= 14.37 ± 2.56	 L*= 29.63 ± 0.99 a*= 8.01 ± 2.07 b*= 2.72 ± 2.40	 L*= 47.03± 2.68 a*= 10.32± 0.93 b*= 21.52± 2.36

Fig. 1. *Illustration of the general aspect and colour of walnut (Juglans regia) samples before and after finishing with beeswax (BW), linseed oil (LO), and shellac (SL), and further colour changes brought about by artificial ageing (A1-A4) compared to the unaged controls (A0)*

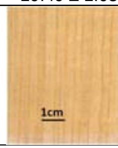
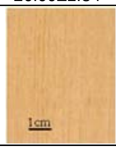
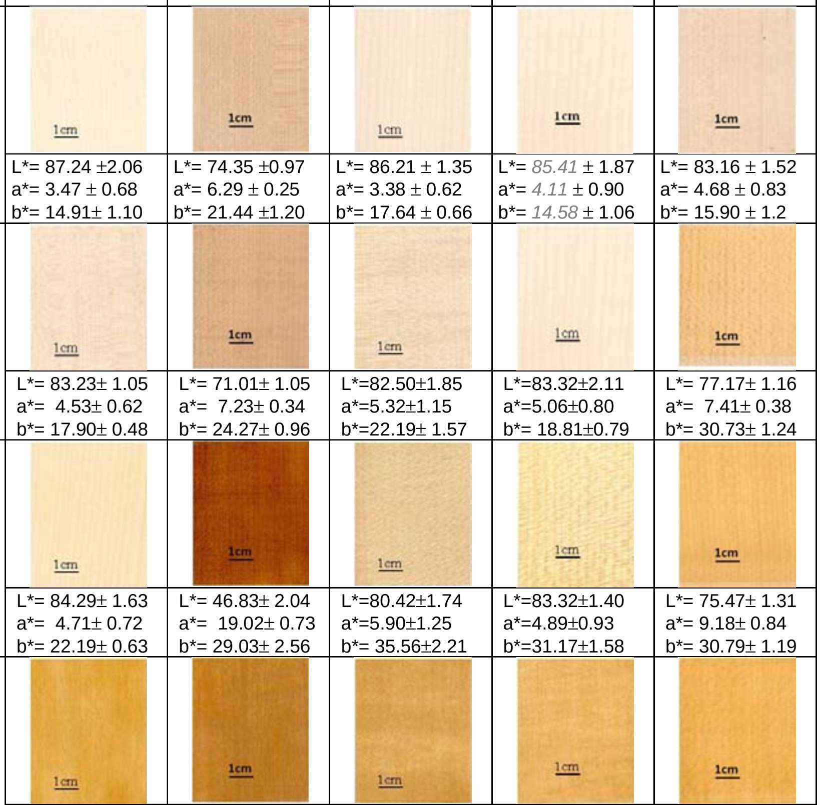
Ash *(Fraxinus excelsior)*	**A0**	**A1**	**A2**	**A3**	**A4**
Not finished	 L*= 78.66 ± 2.87 a*= 5.71 ± 0.74 b*= 20.58 ± 1.64	 L*= 63.91 ± 2.02 a*= 7.52 ± 0.77 b*= 22.63 ± 1.22	 L*= 78.25 ± 2.42 a*= 6.18 ± 0.88 b*=21.26 ± *2.85*	 L*= 78.07 ± 2.69 a*= 6.18 ± 0.94 b*= 17.77 ± 1.58	 L*= 77.84 ± 1.63 a*= 6.01± 0.53 b*= 19.49 ± 1.63
Finished BW	 L*= 76.42±1.57 a*= 6.47±1.25 b*= 21.76±1.14	 L*= 61.74±1.61 a*= 8.80±1.15 b*= 26.94±1.05	 L*=72.80±2.30 a*=8.62 ±1.35 b*=26.99±1.84	 L*=74.50±1.33 a*= 8.19±0.49 b*=21.46±2.04	 L*= 74.03± 2.00 a*= 7.36± 0.76 b*= 29.23± 0.85
Finished LO	 L*= 75.63±2.36 a*= 7.91±0.62 b*= 25.22±1.09	 L*= 43.22±1.65 a*= 17.15±0.95 b*= 23.60±1.10	 L*=69.32±2.58 a*=11.13±1.33 b*=33.59±1.03	 L*=74.03±3.19 a*=8.88±1.48 b*=29.97±1.85	 L*= 72.25± 2.21 a*= 8.24± 0.64 b*= 33.13± 1.70
Finished SL	 L*= 65.29±1.12 a*= 11.89±0.48 b*= 34.93±0.50	 L*= 50.38± 1.89 a*= 14.61± 0.43 b*= 30.14± 2.30	 L*=65.04±2.20 a*=12.66±0.77 b*=37.21±1.46	 L*=64.91±3.13 a*=12.84±1.17 b*=31.01±1.58	 L*= 66.75± 2.47 a*= 11.59± 1.31 b*= 36.11± 2.47

Fig. 2. *Illustration of the general aspect and colour of ash (Fraxinus excelsior) samples before and after finishing with beeswax (BW), linseed oil (LO), and shellac (SL), and further colour changes brought about by artificial ageing (A1-A4) compared to the unaged controls (A0)*

Table 6

Adherence of the finishing films to the wood substrate (three wood species) determined by the cross-cut test and influence of ageing

Wood species	Type of finish	A0	A1	A2	A3	A4
European ash (F)	BW	0	0	0	0	0
	LO	0	0-1	0	0	1
	SL	0-1	1	1	0-1	1-2
European walnut (N)	BW	0	0	0	0	0
	LO	0	0	0	0-1	1
	SL	0-1	0	1	0-1	2
Sycamore maple (P)	BW	0	0	0	0	0
	LO	0	0	0	0	1
	SL	0	0-1	0	0	1-2



Sycamore maple (*Acer pseudoplatanus)*	**A0**	**A1**	**A2**	**A3**	**A4**
Not finished	L*= 87.24 ±2.06 a*= 3.47 ± 0.68 b*= 14.91± 1.10	L*= 74.35 ±0.97 a*= 6.29 ± 0.25 b*= 21.44 ±1.20	L*= 86.21 ± 1.35 a*= 3.38 ± 0.62 b*= 17.64 ± 0.66	L*= *85.41* ± 1.87 a*= *4.11* ± 0.90 b*= *14.58* ± 1.06	L*= 83.16 ± 1.52 a*= 4.68 ± 0.83 b*= 15.90 ± 1.2
Finished BW	L*= 83.23± 1.05 a*= 4.53± 0.62 b*= 17.90± 0.48	L*= 71.01± 1.05 a*= 7.23± 0.34 b*= 24.27± 0.96	L*=82.50±1.85 a*=5.32±1.15 b*=22.19± 1.57	L*=83.32±2.11 a*=5.06±0.80 b*= 18.81±0.79	L*= 77.17± 1.16 a*= 7.41± 0.38 b*= 30.73± 1.24
Finished LO	L*= 84.29± 1.63 a*= 4.71± 0.72 b*= 22.19± 0.63	L*= 46.83± 2.04 a*= 19.02± 0.73 b*= 29.03± 2.56	L*=80.42±1.74 a*=5.90±1.25 b*= 35.56±2.21	L*=83.32±1.40 a*=4.89±0.93 b*=31.17±1.58	L*= 75.47± 1.31 a*= 9.18± 0.84 b*= 30.79± 1.19
Finished SL	L*= 73.52±1.68 a*= 9.30 ± 0.64 b*= 36.88± 0.95	L*= 57.60± 1.68 a*= 14.43± 0.84 b*= 39.76± 1.20	L*=72.00±1.49 a*=10.25±0.75 b*=40.20±1.51	L*=70.60±1.75 a*=11.15±0.98 b*=35.07±1.48	L*= 73.20± 1.32 a*= 10.52± 0.59 b*= 37.83± 1.55

Fig. 3. *Illustration of the general aspect and colour of sycamore maple () samples before and after finishing with beeswax (BW), linseed oil (LO), and shellac (SL), and further colour changes brought about by artificial ageing (A1-A4) compared to the unaged controls (A0)*

Table 7

Resistance of the finished surfaces to selected cold liquids (average data for all wooden substrates, only data for the longest testing time)

Type of finish	Testing liquid / time	A0	A1	A2	A3	A4
Beeswax (BW)	Water / 24h	1-2	3-4	1	2	2-3
	Ethyl alcohol / 24h	1	2	1	1	2
	Acetone / 2min	4-5	4-5	4	4-5	4-5
Linseed oil (LO)	Water / 24h	5	5	5	5	5
	Ethyl alcohol / 24h	3-4	3	3-4	3-4	4
	Acetone / 2min	3	4	2	2	4
Shellac (SL)	Water / 24h	3-4	4-5	4	3-4	4-5
	Ethyl alcohol / 24h	1	4-5	1	1	1
	Acetone / 2min	1-2	5	1-2	1	1-2

3.2. Resistance of Finishes to Cold Liquids

The resistance of the finished surfaces to the selected cold liquids and the influence of ageing result from the data centralized in Table 7, where average values are presented for the maximum testing time (24h for water and ethyl alcohol and 2 minutes for acetone).

3.2.1. Resistance to Water

The surfaces finished with beeswax presented the lowest water resistance (grade 1-2), both before and after the ageing tests (excepting test A1). Considering the hydrophobic character of waxes, these results are totally unexpected. However, the visible marks following testing should not be necessarily linked to the degradation of the film, but could be determined by the penetration of water through the film. Waxes are hydrophobic, but not impermeable to water.

The surfaces finished with oils were totally resistant to water (resistance 5) and this resistance was not affected by ageing.

The surfaces finished with shellac were graded 3-4 for their water residence before ageing. This resistance was slightly improved following ageing under the influence of higher temperature (A1) and UV radiation (A4). This result can be correlated with some chemical structural changes, including cross-linking by esterification and etherification during the ageing process [10, 23]. This result is in total contradiction with the findings of Šimunková et al. (2018) reporting a marked decrease of water resistance of oak surfaces finished with shellac, but the ageing conditions were totally different: 240 h UV exposure in cycles alternating UV radiation with water spray.

3.2.2. Resistance to Alcohol

Surfaces finished with beeswax were not resistant to alcohol (grade 1); this resistance seemed to be slightly increased following temperature (A1) and UV ageing (A4).

Surfaces finished with linseed oil showed a medium resistance to alcohol (grade 3-4), which was not negatively influenced by ageing, but contrarily UV ageing slightly increased this resistance, probably by promoting further cross-linking, possible due to the remained double carbon bonds.

Surfaces finished with shellac showed the lowest resistance to alcohol (grade 1), as perfectly expectable due to the solubility of shellac in alcohol. After temperature induced ageing (100°C), the surfaces finished with shellac became very resistant to alcohol (grade 4-5), due to the chemical changes in the film structure, especially cross-linking by esterification [16]. This is in good accordance with the literature [10], showing that this ageing mechanism is accelerated by heat, so that if heated above the melting point of 120-130°C, shellac becomes insoluble in alcohol in high proportion (75%) very quickly, while high air relative humidity also accelerates ageing. Moreover, photochemical ageing may affect the optical properties of the shellac films as their physical and chemical properties, including oxidation and cross-linking by esterification. It is also well known in the restoration practice that aged shellac films are more difficult strip off with alcohol, but do not become totally insoluble.

3.2.3. Resistance to Acetone

The surfaces finished with beeswax proved surprisingly good resistance to acetone (grade 4-5) and this was not affected by ageing. The surfaces finished with linseed oil showed initially (A0) a medium resistance to acetone (grade 3). This was influenced negatively by cold check (A2) and RH ageing (A3) and improved (grade 4) following temperature (A1) UV ageing (A4). These results might be explained by further cross-linking reactions, promoted by temperature or UV radiation, involving the remained C=C double bonds in the film structure. The acetone resistance of the surfaces finished with shellac was improved from 1-2 to 5 following temperature ageing (A1), due to cross-linking promoted by temperature.

4. Conclusions

An original approach to assess ageing of finished wood surfaces in direct relation with historic furniture conservation was developed and implemented.

Three types of traditional finishing materials: beeswax, linseed oil, and shellac, were applied employing traditional manual techniques on samples made of three wood species: European walnut (*Juglans regia*), European ash (*Fraxinus excelsior*), and sycamore maple (*Acer pseudoplatanus*).

Four accelerated ageing tests involving UV radiation, temperature and relative humidity in aerobic conditions, as ageing factors, were applied to simulate indoors natural ageing.

Effects of ageing were revealed not only by colour changes, which are actually part of aesthetical patina, but also by modifications of adherence and resistance of surfaces to selected cold liquids. These alterations depended on the type of finishing material and the ageing factor.

An interesting behaviour was revealed for shellac finishes: their adherence to the wood substrate slightly decreased by ageing, whilst their resistance to water and alcohol increased. These might be correlated to structural chemical changes (cross-linking) and are in good accordance with the conservation practice: aged shellac finished surfaces may present some loss of adherence but they are less soluble in alcohol. This reveals the fact that ageing might bring both positive and negative effects which should be carefully considered.

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