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EFFECT OF NATURAL AGEING IN INDOORS CONDITIONS ON THE COLOUR OF WOOD SURFACES FINISHED WITH NATURAL TRADITIONAL MATERIALS

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Abstract:
This research paper is related to conservation - restoration of decorated furniture objects with intarsia by highlighting the influence of aesthetic quality of these special surfaces. The effects of natural aging by indoor exposure are presented.

Different wood species as well as finishing materials was employed in order to show in time evolution of chromaticity changes of the unfinished and transparently finished wood surfaces.

The effect of in time colour modification, after, a total period of 18 month of natural aging exposure was studied. Three wood species were selected ash (Fraxinus excelsior), walnut (Juglans regia) and Sycamore maple (Acer pseudoplatanus) and three type of traditional finishing material (beeswax, linseed oil, shellac). This traditional finishing material was the most used material in furniture manufactured of old objects.

The experimental results show that a protective finishing material, resisted to light, has to be used for maintaining the esthetical value of intarsia design. Otherwise the contrast colour between wood species is lost in time and will become null. The data are also useful for current approaches of the intarsia technique to provide data for an adequate choice of finishing technology with traditional products, which will add value to the objects.

Key words: *wood aging; colour stability; colour contrast, intarsia.*

INTRODUCTION

Colour, along with texture is an aesthetic attributes and elements that differentiate the wood species. Natural aging of materials is a progressive process (natural or artificial) that changes the original colour with an old look (http://manual.museum.wa.gov.au/book). This colour changes usually appearing as a darkening effect with different shade. The colour modification is depending of the wood species, some are become more yellowness, other more red and they will be distinctive, compared to their original colour. The finishing material and environmental conditions are some important factors that influence the natural or artificial aging process (Timar et al. 2016, Liu et al. 2017, Reinprecht et al. 2017).

The natural colour of wood (veneer or timber), can give us information about wood species classification and can provide some esthetical effects by intarsia design (Cismaru and Cismaru 2007, Unger and Wang 2009, Unger 2010). This type of decorating technics, dated for thousands years ago, is based on the colour contrast between wood species. Intarsia is an ornamentation technique that associates different wood species of different colours to achieve a high artistic effect (Wbee 1899, Caprara 1978, Tormey and Tormey 1982).The situation is even more complex in the case of historic furniture that is enriched with intarsia design. In this type of wooden piece several species are used in a single symbol, simultaneously exposed to the same conditions of photodegradation. Wood aging is a very complex phenomenon due to a long and slow oxidation process, due to complex physical and chemical reactions and depends on the conditions in which the wood has been preserved, conditions that cannot be accurately known each time in the case of restoration (Unger and Unger 2010).

The different behaviour of the wood species needs to be very well known and understood. As a result of aging, the wood colour suffers changes over time. The same thing happens either outside or inside exposure. Although the inside exposure is not that aggressive, still sunlight (especially UV radiation) exposure through a window changes the wood colour.

Wood exposed under indoor conditions does not undergo colour changes due to UV radiation, because only a small part of it can penetrate the glass. In this case, the colour changes that occur are caused by visible light (400-700nm) that has enough energy to degrade the wood substances that give colour (http://www.fsec.ucf.edu/en/consumer/buildings/basics/windows/fading.htm, Liu 2017).

Visible light penetrates into the wood at 200μm deep, while UV radiation at 75μm, so light-induced modification is strictly a surface phenomenon. The rate of this colour change is usually dependent on: light intensity, wavelength, exposure time, wood species and environmental factors, of which humidity and temperature should be taken into account (Rowell 2015).

The present research is studying the colour modification and colour stability; of wood surface finished with traditional materials subjected to interior natural aging for a total period of 18 month. To this purpose, three wood species and three transparent finishing materials was taking in to account. The influence of this finishing materials is also a factor that contributing to the in time light resistance. Transparent finishing sometimes highlights the wood drawing and texture, as well as natural colour, following the decorative values of wood or veneers. Natural aging affects both the wood colour and the finishing film, so the initial colour contrasts changes over time.

OBJECTIVE

The main objective of the present research is the evaluation of chromaticity effects due to the indoor natural aging of wood unfinished and finished surface, based on the difference between wood colour and the concept of the comparative approach trough colour contrast.

MATERIAL, METHOD, EQUIPMENT

Wood material

Three wood species was selected (Fig. 1): ash –coded F (*Fraxinus excelsior*), walnut -coded N (*Juglans regia*) and Sycamore maple -coded P (*Acer pseudoplatanus*).

The wooden materials used in the present research have the dimension of 120mm (length) by 80mm (width) and 8mm (thickness), with radial faces. A number of 6 samples were selected, without any defects. All the selected test samples were conditioned at 20ºC temperature and 55% RH, in a climatic chamber, prior to finishing step.

Finishing material

As finishing materials was used beeswax (BW), linseed oil (LO) and shellac (SL) being the most used finishing material in furniture manufactured of old objects. All this products are natural, traditional finishing materials. The sample was coded after finishing as well. As example, for ash sample finished with beeswax the final cod was F-BW, finished with linseed oil was F-LO and for the ash samples finished with shellac the final code was F-SL.

In the same context the unfinished ash surface was coded F-M, the walnut unfinished sample was coded N-M and unfinished sycamore maple sample was coded P-M.

For the beeswax preparation before application an amount of 50g of grinded wax was putted into a vessel and was heated a 100ºC (on top of a water bath); 250ml white spirit was added progressively until complete dissolution. Linseed oil was diluted for finishing, a dilution of 2.5:1 (linseed oil: white spirit) was made for the first and second layers applied on wood, whilst the next three layers was applied non-diluted. For shellac preparation was used 100g shellac flakes and 10g colophony (powder) dissolved under stirring in 1000ml ethyl alcohol on water bath.

Finishing wood surfaces

For a better understanding of how the natural aging affect the wood colour the study was performed on finished surface and unfinished wood surface as well. After last sanded of wood with 240 grit size sandpaper and conditioned at the temperature of 20ºC and relative humidity of 55% the wood sample was manually finished.

The beeswax was applied with a soft pad covered with cotton in five layers, each of about 25g/m^2, applied by circular motions on the wood samples. The last step of finishing was the polishing of surface with a polishing machine equipped with a felt.

Linseed oil was applied with a brush in five layers, each one of about 125g/m^2. Between layers the finishing surfaces was sanding with 360 grit size sandpaper**.** For the first two layers a diluted linseed oil solution in white spirit (as it mentioned above) was used and for the last three layers undiluted linseed oil was applied.

Shellac finishing was made first by brush in three successive layers of about 110g/m^2 at intervals of 2-4 hours (drying time) without intermediary sanding. After the formation of base coat, the finished wood samples were sanded with 360 grit size sandpaper. In order to obtain a high gloss surface, it was considered necessary to filling the pore employing a polishing with cotton wool until a satisfactory degree of structure filling were obtained.

The drying interval between layers was 24 hours at environmental temperature.

Natural ageing test

The natural ageing test in indoors conditions at room temperature under the influence of natural light filtered by window glass was carried out in the L5 laboratory at the CDI Institute of Transilvania University of Brasov. Samples were exposed vertically to sunlight in a test rack located near the window, facing the South direction at a height of 650 to 1350mm from the ground level (Fig. 2). The testing period was about 18 months started at 1 May 2015 and ended at 1 November 2016. The wood samples exposed to natural ageing were covered with black cardboard on half of their surface; this aspect is visible in Fig. 2.

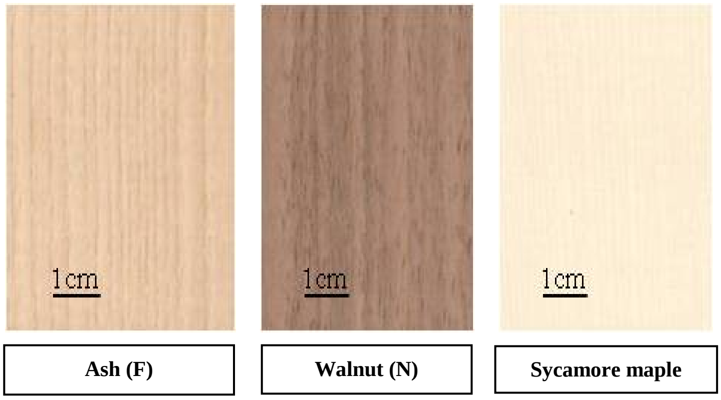


Fig. 1.
Wood sample used in present research (initial scanned images).

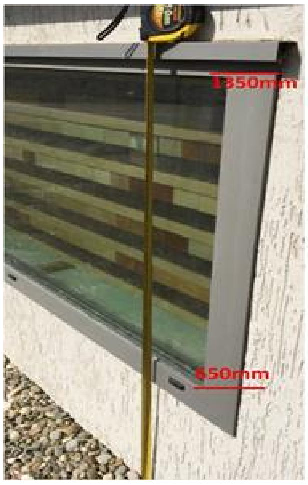


Fig. 2.
Wood sample exposed at CDI - Institute (exterior view).

Principle of method

The diagram presented in figure 3 shows a simulated in time colour changes and colour contrasts of natural ageing exposure, on two hypothetic type of sample with initial contrast white and grey.

In the top of the scheme is presented de initial state, according to the adjacent scale of colour. In this case, we have an initial contrast CI = 1.

In the first case, in time, the booth initial colour of sample suffering changes and the contrast value remaining the same C = 1. If we consider these contrasts in wood furniture intarsia design, we will have a similar contrast, so the colour changes will not being affect, the obvious colour effect remains.

In the case 2, the initial colours are changed different and the contrast is not the same we will have a value C = 2. In this case the contrast will increase. This can be a positive effect, but also a negative one because of the high difference between species, the esthetical value brought by the intarsia design will be lost.

In case 3, we will have also different colours changes. The value of contrast is in this case C= 0, so the desired colour effect will be null. The intarsia design, which is generated by the differences between colours, is not visible.

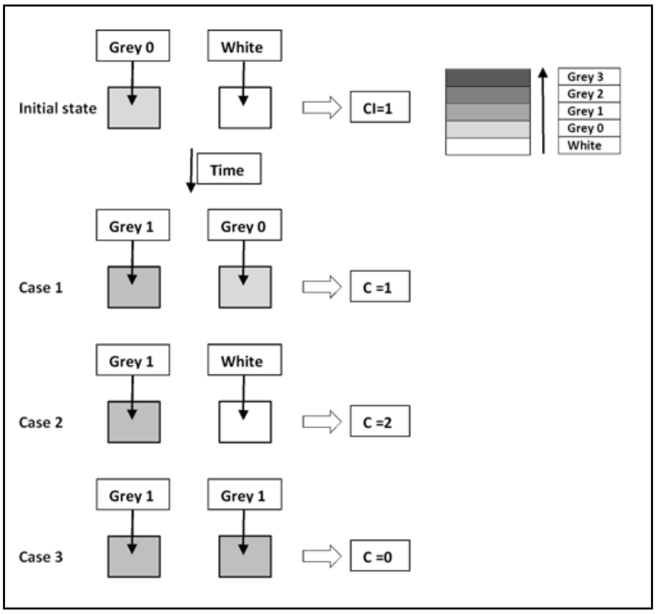


Fig. 3.
The scheme of simulated colours changes of two hypothetic type of sample.

Based on this principles in the present paper will be determined the effect of natural ageing on simulated intarsia using three studied wood species. In Fig. 4 is presented the scheme of this simulated intarsia.

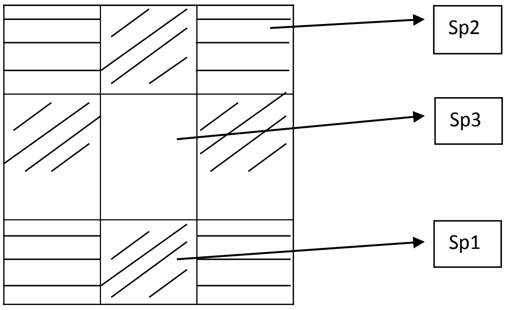


Fig. 4.
The scheme of simulated intarsia made of three wood species (Sp. 1, 2, 3).

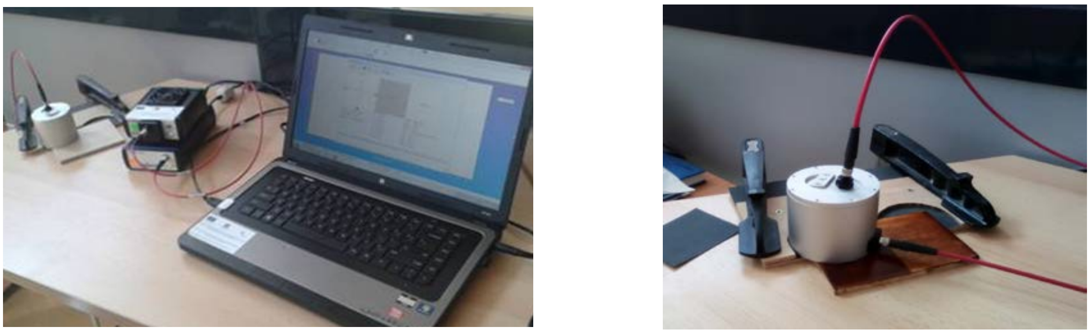
For this propose the wood samples and finished surfaces were scanned by a HP LaserJet Pro CM1415 colour multifunction printer.

Colour measurements

Colour measurements were performed in the CIE-Lab system (Fig. 5a) employing a spectrometer AvaSpec-USB2 equipped with an integrating AVA sphere having a diameter of 80mm, interconnected by optical fibbers, provided with dedicated software.

All colour measurements were performed for each test sample in 4 points, before testing – month 0 (L0) and at different interval of time (month 1, 2, 3, 4, 5, 6, 8, 10, 12, 18). The measurement was performed on finished surface and on unfinished one. For each type of sample it was calculated an average of 24 points.

In order to repeat the measurements in the same areas, a sample fixing plate (Fig. 5b) was designed and manufactured. This allows reproductive colour measurements in terms of investigating the same areas for unfinished and finished wooden samples, before and after ageing. Otherwise, the uniformity of wood colours and wood colours changes will have a higher dispersion of the experimental values.



a b

Fig. 5.
AvaSpec-USB2 spectrometer: a - General view on components; b - Integrated AVA sphere and the fixing plate for reproductive colour measurement.

The colour changes was calculated for each colour coordinate (*L*, a** and *b**) as related to its initial value on the same sample and in the same point. Finally, the total colour change (Δ*E**) was calculated in each point, according to equation (1):

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

where:
Δ*L** is the lightness change after aging compared with initial value:

$$\Delta L^* = L^*_{exposed} - L^*_{initial} \quad (2)$$

Δ*a** is the redness change after aging compared with initial value:

$$\Delta a^* = a^*_{exposed} - a^*_{initial} \quad (3)$$

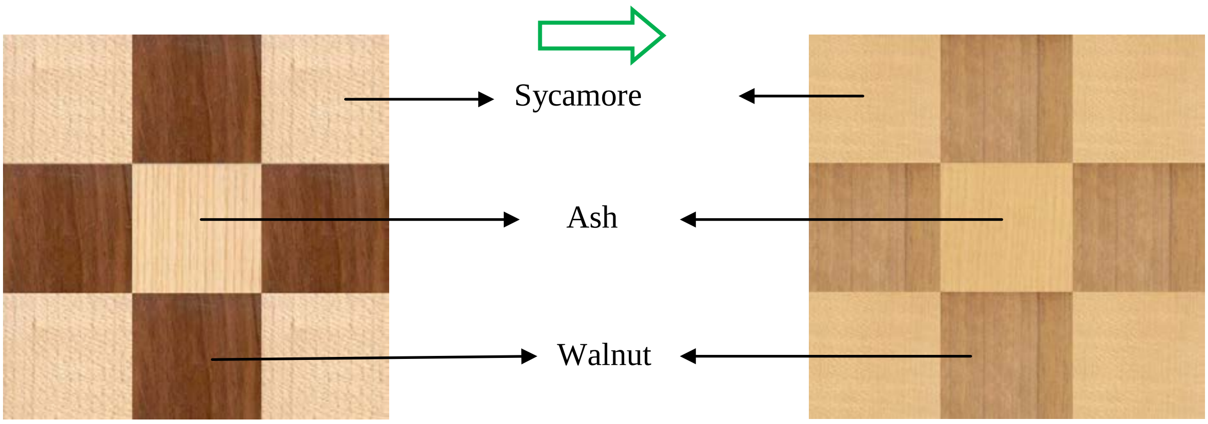
Δ*b** is the yellowness change after aging compared with initial value: :

$$\Delta b^* = b^*_{exposed} - b^*_{initial} \quad (4)$$

RESULTS AND DISCUSSION

Visual aspects

In Fig. 6 are presented the scanned images of simulated intarsia using the three wood species studied finished with beeswax, as example, recorded in initial state compared with the natural aged images scanned after 18 month exposure.



a B

Fig. 6.
Comparative view of the scanned images of simulated intarsia between initial state (a) and after 18 month of natural aging exposure for all three studied wood species.

It can be observed that the colour intensity is diminished and the contrast between species is almost lost. If we compare ash wood with sycamore maple it can be said that the colour contrast is lost. This behaviour is the same like case 3 of principle contrast changes, which is explained above when the value of contrast is considered null.

The wood surfaces underwent gradual colour changes; the contrast was changed in time. Referring to the natural ageing these slow changes is expected, in the first period of time (in the first six month) the colour changes is more rapid, but in time the effect of aging is slower. For a better view of the colour and contrast modification for all samples in Fig. 7 are presented the simulated intarsia images. These images include only first six month (1, 2, 3, 4, 5, 6) and the last month (18).

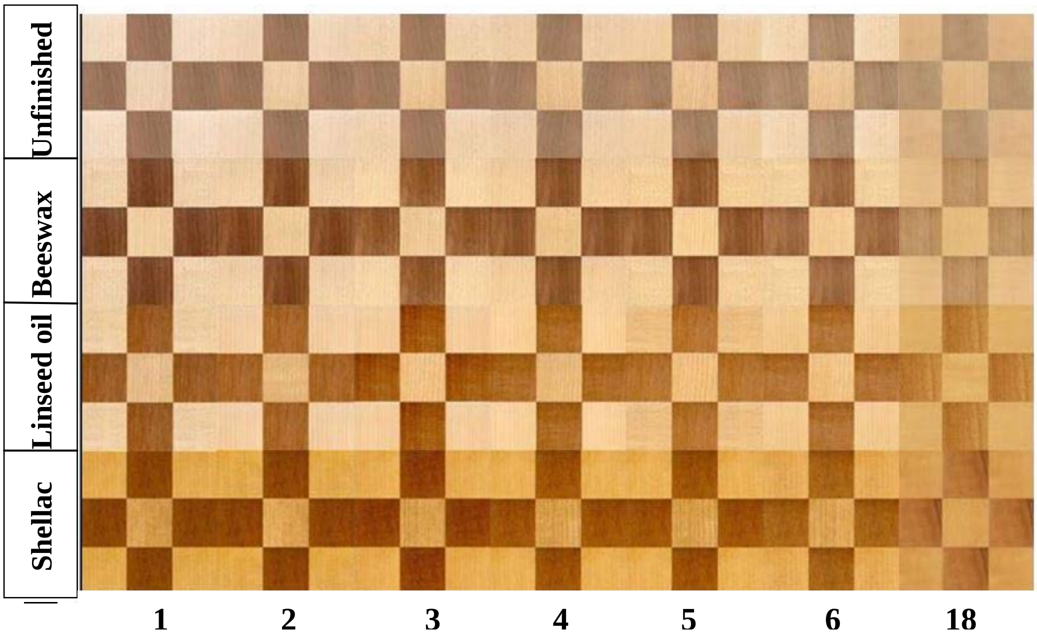


Fig. 7.
The simulated intarsia images for month 1, 2, 3, 4, 5, 6 and the last month 18.

Analysing the images shown in this figure (Fig. 7) it can be said that the colour differences between the studied wood species begin to fade, for all finished or unfinished surface, indifferent of the finishing material. However, the most affected wood surfaces are unfinished one, which leads to the idea that the finishing materials protect the surfaces.

Regarding to the finished surfaces only, the most durable finish material that preserve best the contrast was linseed oil.

Colour Changes

The visual aspects presented above can be analysed quantitatively by colour measurements in the CIE-Lab system. In the Fig. 8 are the graphical representations of in time evolution of colour coordinates (lightness, redness and yellowness) for all three woods samples unfinished (P-M, N-M and F-M) and finished with all finished material studied.

By analysing these images, presented in Fig. 8, it can be stated that all wood species suffered a progressive colour change, mostly in the first six month as was previously observed.

The lightness is decreased for sycamore maple and ash for unfinished and finished surface for all finishing material studied. Walnut registered an increase of lightness in all period of time exposure for all woods sample unfinished and finished.

In generally is observed an increase of redness. Regarding to yellowness it can be observed that at beginning an increase of yellowness was registered and after 12 month this trends stops and is almost linear or registered a decreasing trend.

Though, for all wood species the increasing or decreasing of colour coordinates was not linear and was different for studied wood species. The same behaviour was observed indifferent of the finishing material.

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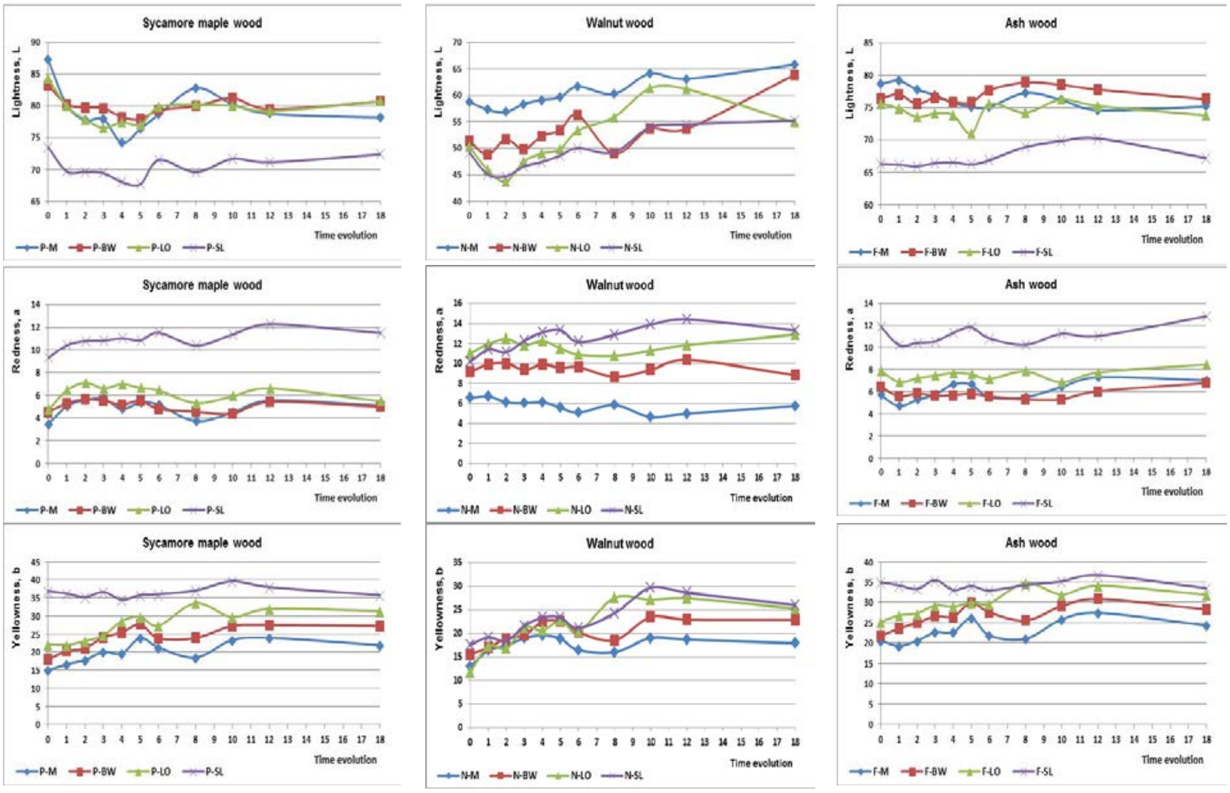

Fig. 8.
In time evolution of colours coordinates: lightness (L –top), redness (a–in the middle) and yellowness (b-bottom) for all wood species unfinished and finished.

Contrast Changes

As was stipulated before al visual colour changing can be analysed quantitatively by colour measurements.

In the same context, it can be calculated the contrast modification in time between species. The in time contrast modification is presented as calculated colour differences between wood species.

In table 1 are presented the data for contrast modification between ash and sycamore maple wood (ash-considered the darker species versus sycamore maple-considered the lighter species).

Table 1

Colour contrast (differences) between ash and sycamore maple wood

Time	Colour contrasts between Ash and Sycamore maple											
	M-unfinished			BW			LO			SL		
	ΔL	Δa	Δb	ΔL	Δa	Δb	ΔL	Δa	Δb	ΔL	Δa	Δb
0	**-8,58**	**2,24**	**5,67**	**-6,81**	**1,94**	**3,86**	**-8,65**	**3,19**	**3,03**	**-7,23**	**2,59**	**-1,95**
1	**-1,04**	**-0,31**	**2,61**	**-3,23**	**0,30**	**3,33**	**-5,13**	**0,47**	**4,81**	**-3,52**	**-0,15**	**-2,00**
2	**0,03**	**-0,32**	**2,78**	**-4,18**	**0,19**	**3,89**	**-4,28**	**0,11**	**4,26**	**-3,74**	**-0,35**	**-1,90**
3	**-0,95**	**0,05**	**2,60**	**-3,09**	**0,12**	**2,46**	**-2,44**	**0,85**	**4,63**	**-2,99**	**-0,25**	**-1,16**
4	**1,53**	**1,86**	**3,04**	**-2,32**	**0,50**	**1,07**	**-3,56**	**0,71**	**0,36**	**-1,47**	**0,32**	**-1,41**
5	**-2,26**	**1,27**	**2,23**	**-2,06**	**0,30**	**2,21**	**-5,05**	**0,95**	**0,14**	**-1,49**	**0,98**	**-1,76**
6	**-3,54**	**0,37**	**0,59**	**-1,61**	**0,79**	**3,68**	**-4,27**	**0,75**	**2,45**	**-4,62**	**-0,66**	**-3,07**
8	**-5,53**	**1,80**	**2,59**	**-1,06**	**0,77**	**1,63**	**-5,99**	**2,52**	**1,20**	**-0,70**	**-0,13**	**-2,80**
10	**-4,07**	**1,92**	**2,47**	**-2,69**	**0,95**	**1,85**	**-3,74**	**0,94**	**2,26**	**-1,86**	**-0,10**	**-4,45**
12	**-4,15**	**1,77**	**3,51**	**-1,68**	**0,62**	**3,39**	**-3,88**	**1,12**	**2,18**	**-0,86**	**-1,22**	**-1,28**
18	**-2,96**	**1,94**	**2,43**	**-4,36**	**1,78**	**1,09**	**-6,88**	**2,98**	**0,53**	**-4,17**	**1,33**	**-2,24**

Analysing the data presented in Table 1 it can be seeing that the contrast between wood species is decreasing and a possible esthetical effect is being faded. The lightness contrast is reduced more for unfinished sample, that for finishing one. The protection generated by the finishing material is visible here as well. The most affected contrast referring to lightness of finished sample was registered for beeswax (from -6.81 to -4.36) and shellac (from -7.23 to -4.17). The most resisted sample is the wood surface finished with linseed oil (from -8.65 to -6.88). In generally is observed a slightly modification of redness and the yellowness difference is decreasing.

As previous was showed that the increasing or decreasing of colour coordinates was not linear the effect is similar for the contrast difference between wood species. This behaviour is better observed in figure 9 in which is presented the global colour modification between ash and sycamore maple.

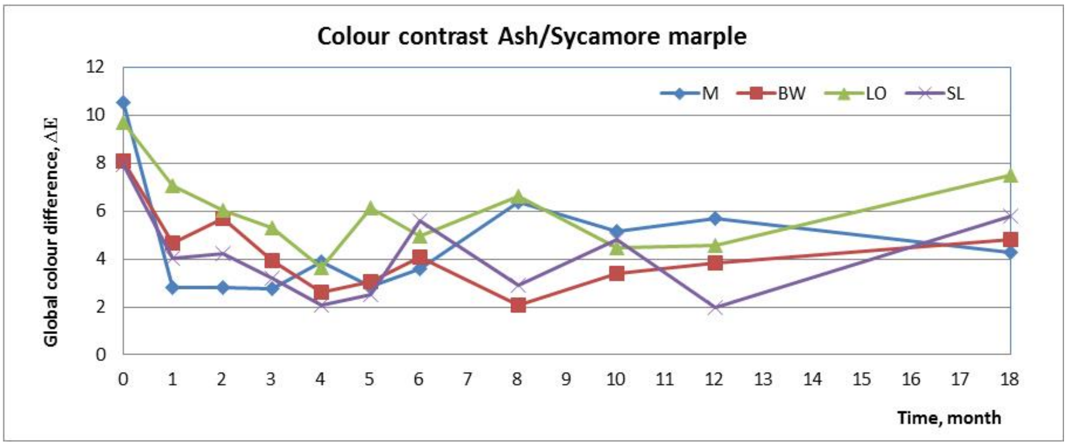

Fig. 9.
Global colour difference presented as colour contrast between Ash and Sycamore maple wood.

The graphical representation showed that for all unfinished and finished surfaces the contrast decreased with the exposure time. The recorded data show that there is a clear evolution of the species contrast between the first six months, after the wood species aged differently so we cannot say that there is a clear evolution. However, there is no longer the same contrast between species, since it is clear that wood species change their colour during aging, even for indoor exposed.

The in time evolution of contrast modification between walnut and sycamore maple wood (walnut-considered the darker species versus sycamore maple-considered the lighter species) is presented in Table 2.

Table 2

Colour contrast (differences) between walnut and sycamore maple wood

Time	Colour contrasts between Walnut and Sycamore maple											
	M-unfinished			BW			LO			SL		
	ΔL	Δa	Δb	ΔL	Δa	Δb	ΔL	Δa	Δb	ΔL	Δa	Δb
0	-28,49	3,10	-1,88	-31,86	4,67	-2,37	-34,01	6,31	-10,45	-24,33	0,88	-19,27
1	-22,91	1,70	-0,32	-31,49	4,61	-3,25	-34,04	5,54	-4,67	-24,61	1,01	-17,07
2	-20,92	0,54	-0,36	-28,08	4,36	-2,15	-34,12	5,36	-6,23	-24,98	0,37	-16,77
3	-19,55	0,35	-1,08	-29,76	3,85	-4,43	-29,02	5,21	-3,31	-22,88	1,50	-15,02
4	-15,09	1,33	-0,03	-25,91	4,71	-2,95	-28,37	5,30	-7,98	-20,62	2,09	-11,09
5	-16,79	0,20	-5,02	-24,53	4,03	-5,08	-27,23	4,86	-7,02	-19,11	2,49	-12,39
6	-17,01	-0,07	-4,81	-23,07	4,83	-3,63	-26,48	4,45	-6,92	-21,47	0,69	-14,87
8	-22,53	2,12	-2,46	-30,92	4,11	-5,33	-24,33	5,42	-5,98	-20,38	2,49	-12,76
10	-16,14	0,11	-4,33	-27,48	4,98	-3,72	-18,68	5,36	-2,55	-17,68	2,55	-9,90
12	-15,67	-0,59	-5,25	-25,83	4,92	-4,53	-17,97	5,23	-4,47	-16,64	2,17	-9,35
18	-12,37	0,64	-4,00	-16,84	3,85	-4,29	-25,84	7,40	-6,05	-17,12	1,83	-9,74

Analysing the data presented in Table 2 it can be seeing that the contrast is modified in this case to. The lightness contrast is more affected for unfinished sample, that for finishing one, as was in previous situation and is decreasing from -28.49 to -12.37. The protection generated by the finishing material is visible here as well. The most affected contrast referring to lightness of finished sample was registered for beeswax and linseed oil. The most resisted sample in this case is the wood surface finished with shellac, the lightness decrease from 24.33 to -17.12. The redness increase for unfinished surface and for wood surface finished with beeswax, and increase for linseed oil and shellac. The same behaviour is registered for yellowness.

In the Fig. 10 we can observe as graphical representation the evolution of the chromatic contrast between walnut considered the darker species and sycamore maple considered the lighter species.

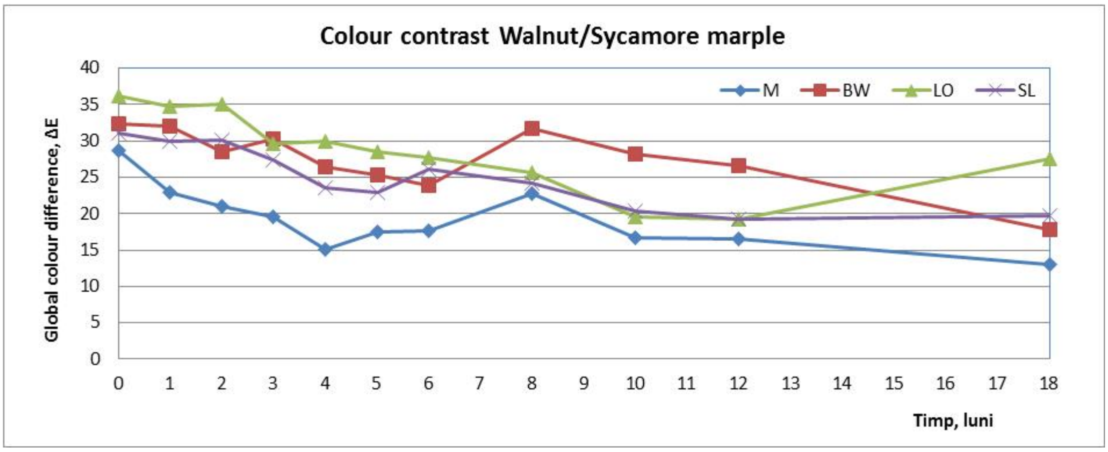

Fig. 10.
Global colour difference presented as colour contrast between Walnut and Sycamore maple wood.

By analysing the graphic representation it can be stated that in all cases the evolution of the chromatic contrast is the same. It decreases significantly in the first exposure period, and then varies, because of the wood surfaces resistance to light, having different properties.

In this case the data show that there is a clear evolution of the species contrast between the first six months as well, but after this period the evolution continues for wood unfinished sample and for finished one with beeswax and shellac.

CONCLUSIONS

Environmental factors, UV radiation from the natural light spectrum, cause aging of materials affecting both woods, finishing materials and finishing surfaces. The colour changes is the most visible and sensitive indicator of aging phenomena.

The aging of the finished surfaces is a cumulative result of wood substrate behaviour and of finishing films behaviour, the concrete effect being influenced both by the wood species and by the type of finishing material.

The results obtained within the present research demonstrated that ageing induced specific macroscopic aspect related most in colour changes. Natural light caused colours changes at a slower rate, depending of the wood species and on the finishing material.

All unfinished surface are more sensitive that finished one. The finishing materials generate a protect effect of wood surfaces against aging. The finishing material that is most resisted to natural ageing exposure is linseed oil, indifferent of the wood species.

As result, aging affects the aesthetics surfaces decorated by intarsia as a result of the modification of the original colour contrasts. This effect is the unmistakable patina of old wood objects, which generally have aesthetic value.

However, after a certain degree of aging, the colour suffers changes and it can be too pronounced, or can fade to a level that no longer highlights the decoration made by intarsia. In this case, we are talking about the aging patina that needs to be diminished by restoration action.

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