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# THE EFFECT OF ARTIFICIAL AGING ON THE COLOR PARAMETERS OF THE VARNISH USED IN THE CONSTRUCTION OF MUSICAL INSTRUMENTS

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***Abstract:***

*It is believed that old and used musical instruments have better accoustic than new fabricated ones. The nature of the type of varnish used on musical instruments it's a subject that has been debated for a long time. The main purpose of the paper is to analyze the effect of artificial aging on the color parameters of the varnish film used in violin varnishing. Thus, samples of resonance spruce wood from different classes of anatomical quality were studied, some covered with alcoholic varnish and others with oil-based varnish, in 5, 10, 15 layers. The color parameters were measured with a Konica Minolta colorimeter device, measurements being taken on the lacquered surface in 3 points, both before and during exposure to UV radiation for 1000 hours.*

*The results highlighted the fact that the lightness and the redness are the parameters most affected by the effect of photo-degradation. The anatomical structure of the spruce wood (class A and D) is another factor that influences the intensity of the color changes of the varnish film. The anatomical structure of the spruce wood (class A and D) is another factor that influences the intensity of the color changes of the varnish film. In general, all color parameters have lower values on class D spruce wood (with wide annual rings), compared to class A wood (with narrow annual rings) whose color parameters are up to 7 - 10% higher.*

***Key words:*** *maple wood, spruce wood, varnish, wood color, varnish.*

## INTRODUCTION

Wooden musical instruments are covered with layers of varnish, often made of different organic compounds, the most used varnishes for violins being spirit varnishes and oil-based varnishes. They protect musical instruments from variations in relative humidity (RH), from wear and tear, also contributing to the aesthetic appearance of the musical instrument. The nature of varnishes coating musical instruments has been a much-debated topic resulting in numerous hypotheses by instrument-makers, musicians and chemists without reaching a general understanding of the ancient varnishing techniques. A varnish is basically considered to be one of several layers of organic film-making substances. The organic compounds are natural products such as oils, tree resins and gums, insect resins, dyes, proteinaceous materials, either used alone or mixed together, pretreated or diluted in a volatile solvent (Echard & Bertrand 2010).

Oil-based wood finishes will usually give a piece of wood a slightly golden hue when applied either on unfinished wood or stained wood. So, it will change the color your finished piece slightly. In addition, oil-based finishes also "amber" over time, turning them an even deeper shade of gold. Easy to use, alcohol varnishes provide a unique finish to wood, they preserve the texture and authenticity of the wood grain. The studies carried out by Sedighi et al. 2016, Zeniya et al. 2019, Lämmlein et al. 2017, 2019, have shown that the varnish film influences the vibration and acoustic performance of the violin as a result of the differences

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in stiffness between the wood, the wood-varnish interface and the varnish film, the most influenced properties being the vibration capacity of the plates, the speed propagation and damping. Cai et al. (2020); Su et al. (2021), Odlyha, et al. (2022) highlighted the fact that the varnish of the old Cremona violins is partially responsible for the superior acoustic quality of the sound, having unique properties given both by the organic compounds but especially by the phenomena of oxidation and reticulation of the compounds due to aging. Lämmlein et al. (2017, 2019), showed that the influence of a coating system usually increases damping and radial stiffness and reduces longitudinal stiffness of wood strips. The physical and elastic properties of varnished wood are different from those of unvarnished wood, this is due both to the higher density of the varnish, lower propagation speeds and higher loss factors than in the case of unfinished spruce and maple wood.

## OBJECTIVE

The objective of the work is to analyze the color changes of the varnish films based on oil and alcoholic varnish, with different number of layers, after exposure to thermodegradation and artificial photodegradation, for 1000 hours.

## MATERIAL, METHOD, EQUIPMENT

### Materials

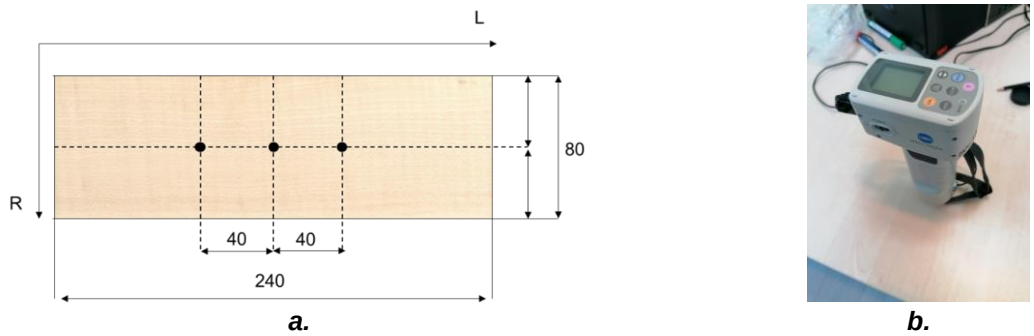
Samples of resonance wood from two species, used for the construction of musical instruments were analyzed. They were grouped into 2 classes of anatomical wood quality, some covered with alcoholic varnish and others with oil-based varnish, in 5, 10, 15 layers: class A characterized by a regular anatomical structure of annual rings in spruce wood and a wavy fiber structure in maple wood, respectively class D characterized by wider annual rings in spruce wood and straight fiber in maple wood.

The samples were coded according to the following principle: The first letter represents the species (M-spruce (Romanian langueage - *molid*) P-Maple (Romanian langueage - *Paltin*)), the next letter represents the quality class (A and D), the next group of letters represents the finish to which the samples were subjected (LU- oil based varnish, LS- alcoohol varnish) and the number represents how many layers of varnish were applied (Gall et al. 2022). This presentation will focus on 24 samples, selected from a big number of samples belonging to a long lasting research as seen in Fig. 1.

***Fig. 1.***
***Samples before varnish.***

### Determination of wood color

The color of the wood is affected by the physical characteristics and surface roughness. For color quantification, the CIELab chromatic space was chosen, described by the following coordinates: L* represents the brightness measured in percentage (%); a* represents the degree of red, if the indicated value is positive (+) or the degree of green, if the indicated value is negative (-); and b* represents the degree of yellowness if the indicated value is positive (+) or the degree of blueness if the indicated value is negative (-). The color was measured on each sample in 3 points (center, and symmetrical to the center at 40 mm) according to Fig. 2.a, with a Konica Minolta colorimeter device as seen in Fig. 2.b (Liu et al. 2017; Gurau et al. 2023).




*a.* *b.*

***Fig. 2.***
***The principle of measuring the color of wood on the studied samples.***

**Colour Change**

The color change after 1000 hours of UV exposure was calculated for each color coordinate (L*, a* and b*) in relation to its initial value on the same sample and at the same measurement points. The total colour change (Δ*E**) was calculated in each point, according to equation (1) (Stanciu et al. 2020):

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

where:
Δ*L** is the luminosity change in the respective point after open-air exposure compared to initial value:

$$\Delta L^* = L^*_{1000h\_UV} - L^*_{initial} \quad (2)$$

Δ*a** is the change of the red-green coordinate in the respective point after open-air exposure compared to initial value:

$$\Delta a^* = a^*_{1000h\_UV} - a^*_{initial} \quad (3)$$

Δ*b** is the change of the yellow-blue coordinate in the respective point after open-air exposure compared to initial value:

$$\Delta b^* = b^*_{1000h\_UV} - b^*_{initial} \quad (4)$$

The average of the three Δ*E** values obtained on the same sample was considered as total colour change of the respective specimen.

**Artificial aging of samples**

In the case of experimental tests, it is very important to keep the working conditions constant in order to be able to compare the obtained results. Thus, a photocatalytic reactor equipped with 3 tubes F 18W/T8 (Philips) placed circularly inside it was used for the static photodegradation processes of the samples. Each tube emits UV radiation with wavelengths between 340-400nm with λmax=365nm. For each of the three lamps there is a switch, and for the process of checking the samples a door can be observed in Fig. 3. The samples were successively exposed for 1000 hours in more stages, measuring after each stage the color of the wood, the propagation speeds and the mass.

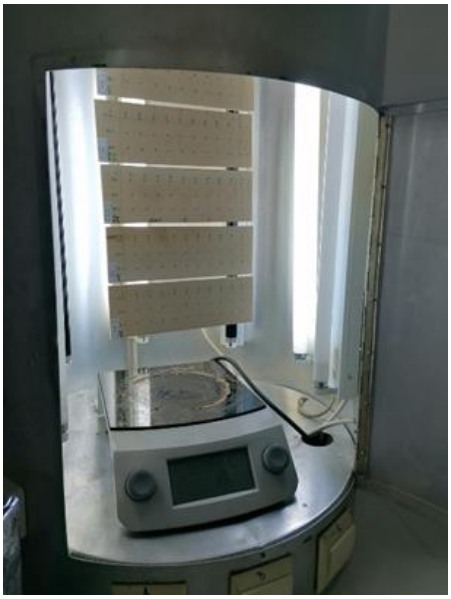


***Fig. 3.***
***Photocatalyctic reactor used for aging proccess.***

**RESULTS AND DISCUSSION**
**The influence of artificial aging on the color of wood**

As it was already mentioned above, varnishing of wood for musical instruments has a important effect on the color of the finished product, even more when it's applied by a specific number of layers as can be seen in Fig. 4.


***Fig. 4.***
***Difference between types of varnishes and layers applied on spruce wood.***

A comparasion was made between quality classes of the species with the same varnish applied to them and the next observations can be made: Color parameters of wood were measured before artificial aging with UV light, after 300 hours of photodegradation and again after 1000 hours of UV exposure. As it can be seen from the beginning there is a considerable difference between oil-based and alcohol varnish. As it can be seen in Figs. 5 – 7, the brightness mostly increase with the exeption of a few cases, an considerable increase can be observed in spruce wood varnished with 15 layers of alcohol finish.

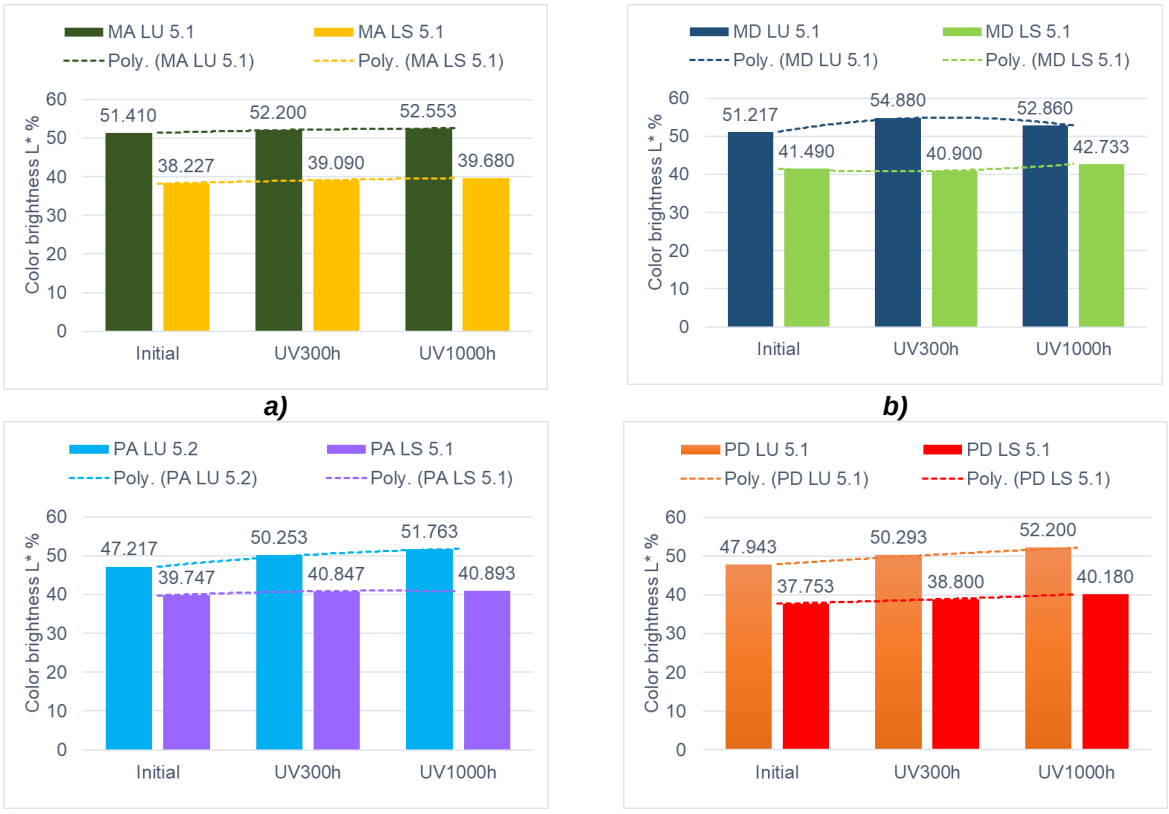



***Fig. 5.***
***Color brightness for 5 layers of varnish applied***

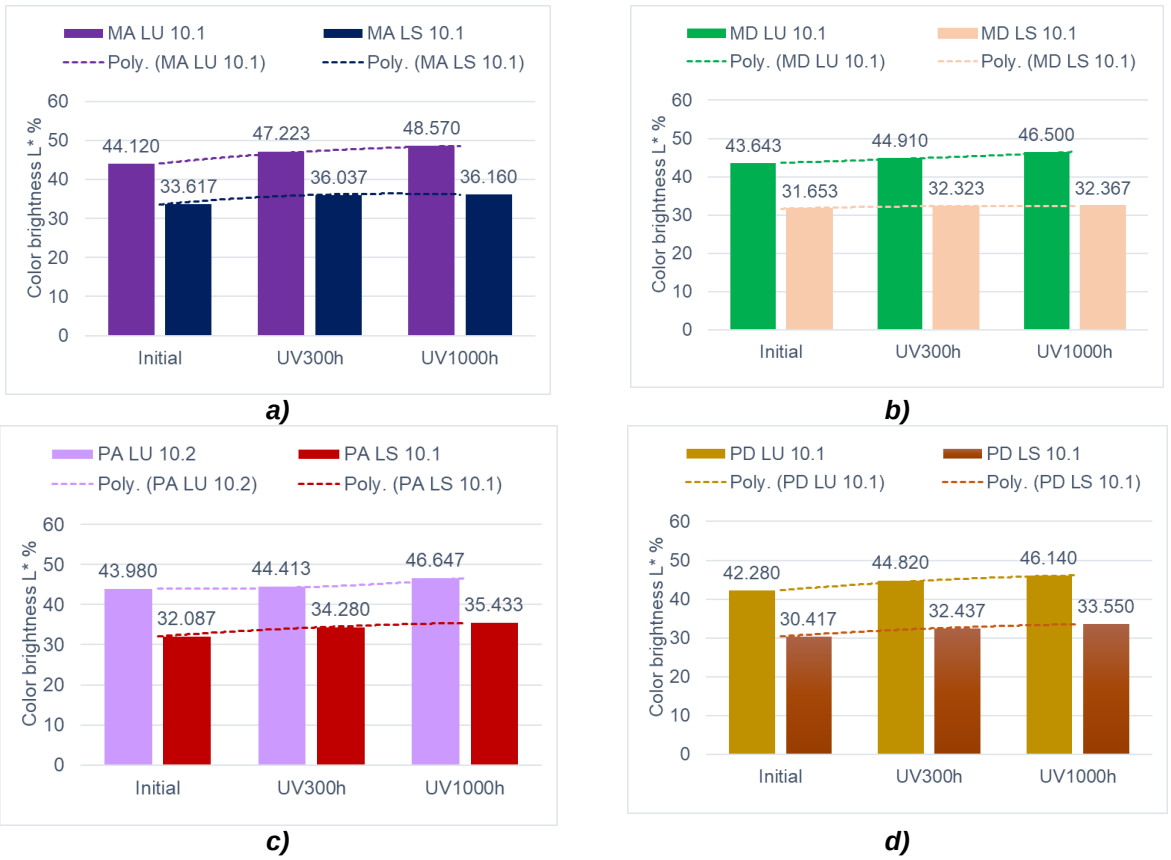



***Fig. 6.***
***Color brightness for 10 layers of varnish applied.***

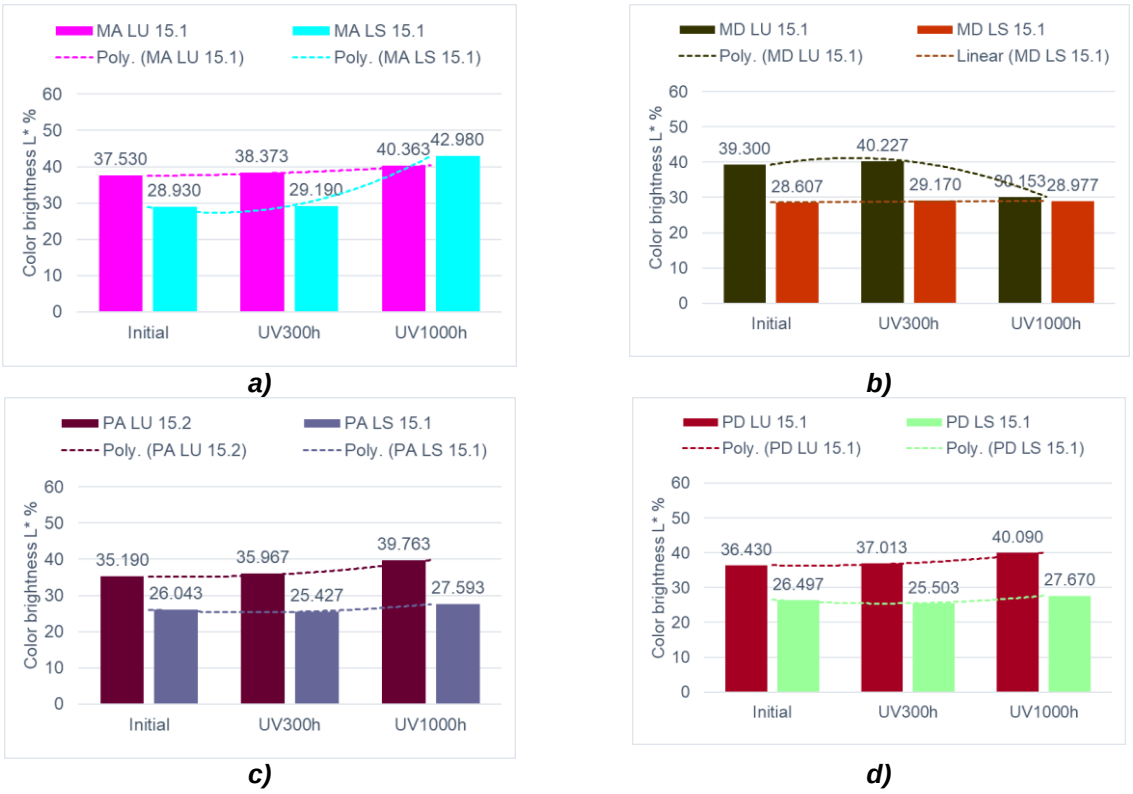



***Fig. 7.***
***Color brightness for 15 layers of varnish applied***

Considering there are a lot of charts as the ones presented above, for the next proprieties are presented only a few examples. As it can be seen in Fig 8 the degree of redness drecreses for both species and varnishes applied on them, this is mostly the case for the other samples where more layers were applied.

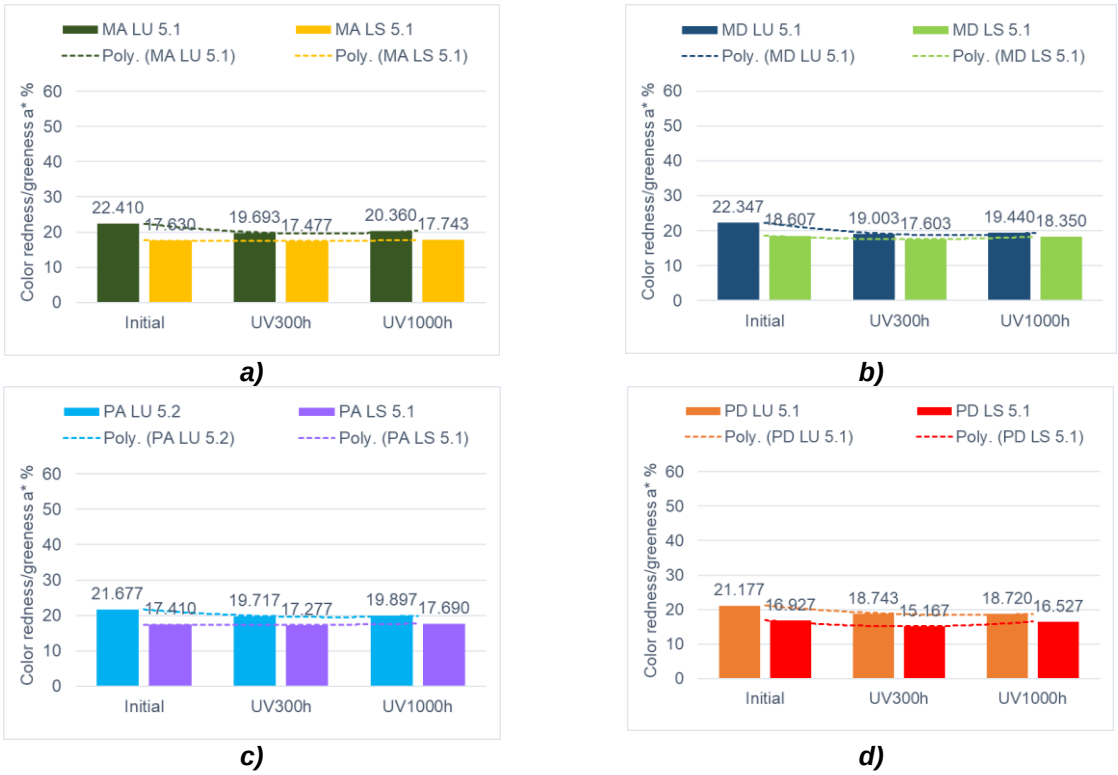



***Fig. 8.***
***Color redness/greenness for 5 layers of varnish applied.***

In the case of color yellowness we have constant increase for all the samples but a greater increase can be observed for oil-based varnished samples as it can be seen in Fig. 9.

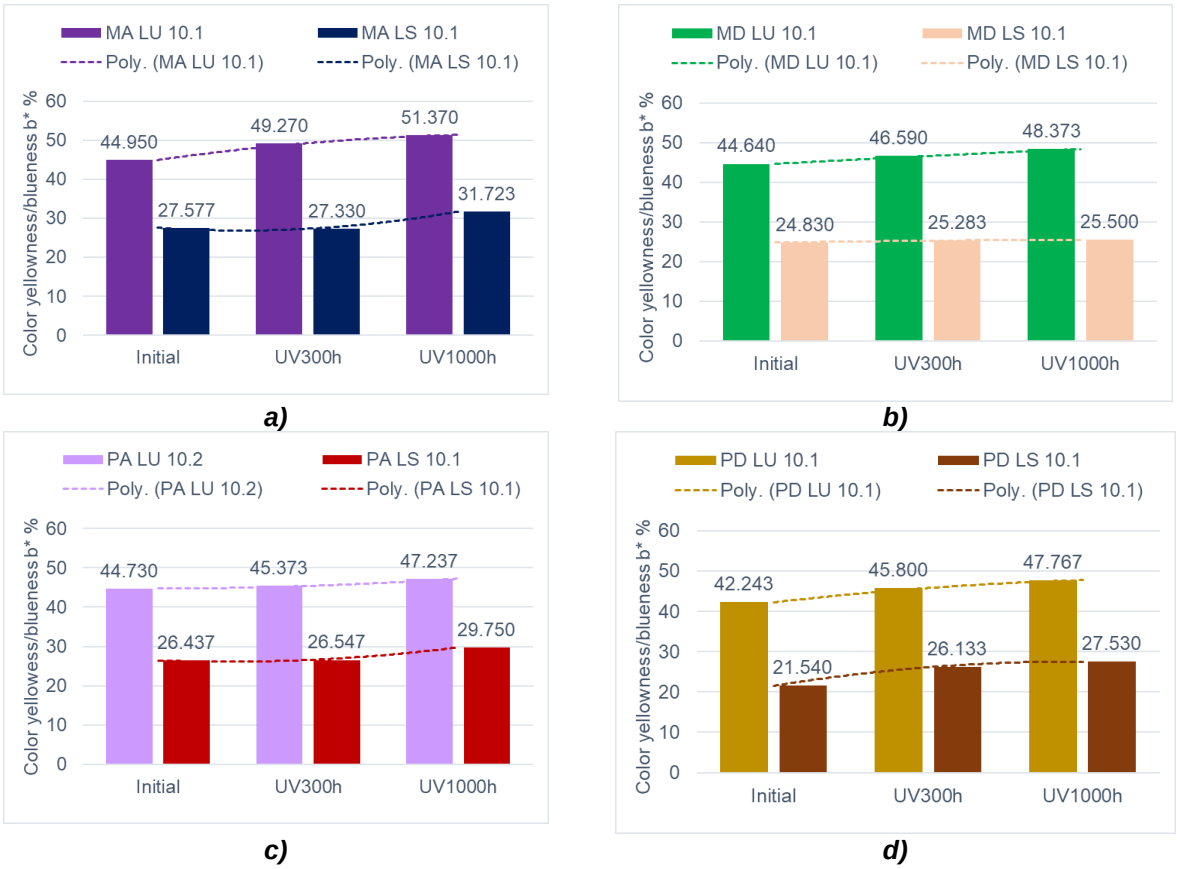
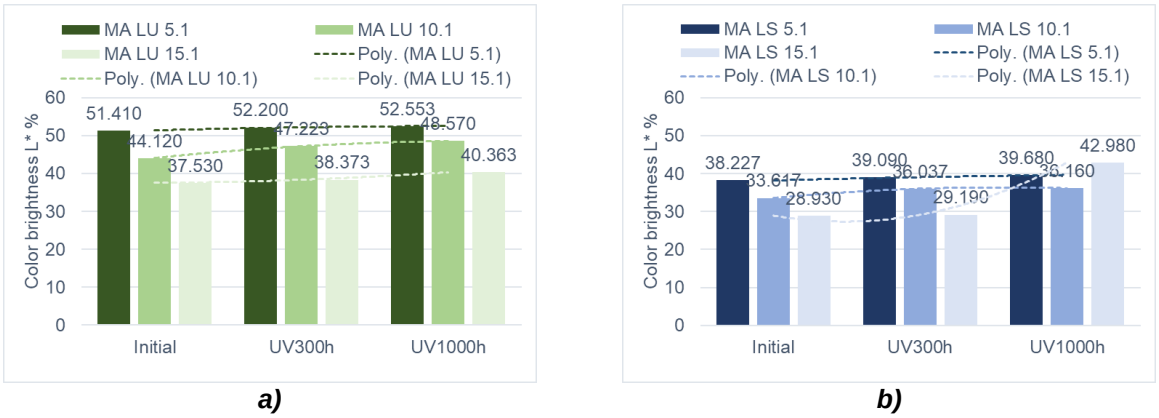
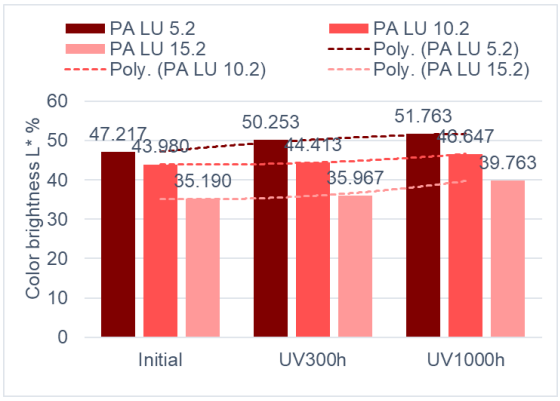


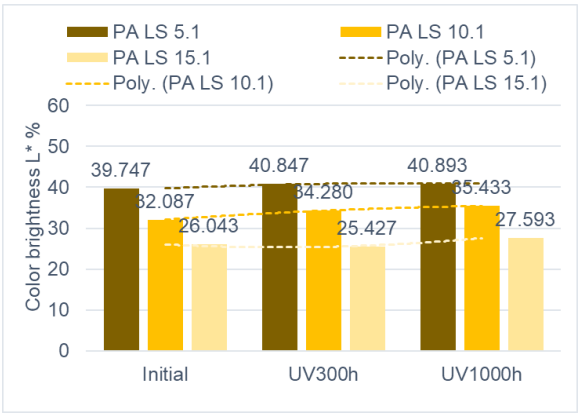

***Fig. 9.***
***Color yellowness/blueness for 10 layers of varnish applied.***

These results may not offer the best overview on the study so it is important to compare the samples with different layers between each other. Let's take the spruce and maple sample for quality class A varnished with oil and alcohol finish for example, the difference between layers 5,10 and 15 can easly be observed from the beginning. The samples with 5 layers have a slower and constant increase while the samples with 15 layers have an considerable increase in brightness (Fig. 10).





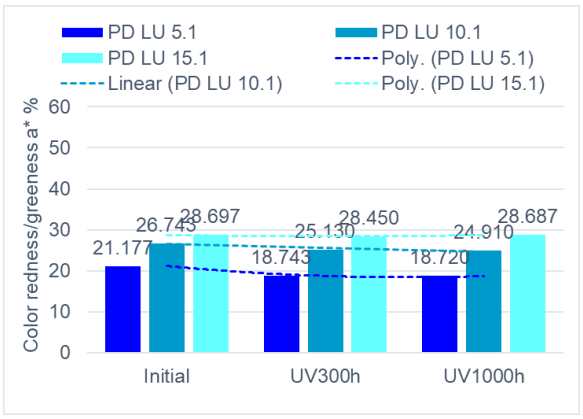

c)



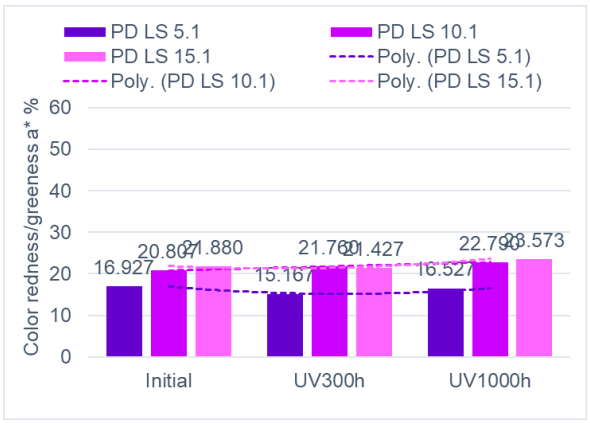

d)

***Fig. 10.***
***Color brightness for 5, 10 and 15 layers of varnish applied.***

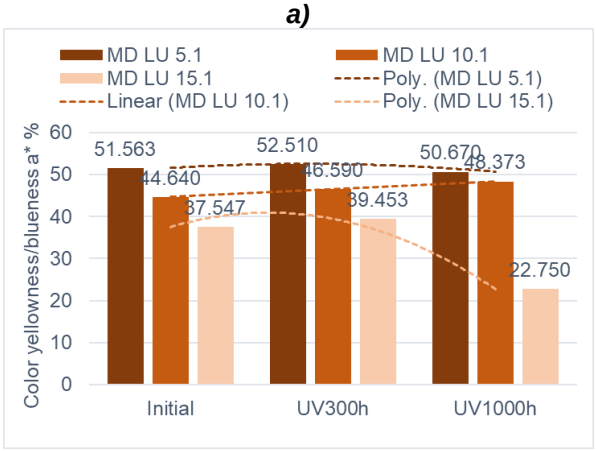
The observation above can be made for every chart of this type, even on color redness, the samplkes with 15 layers have a bigger value for 15 layers of varnish applied as seen in Fig. 11.



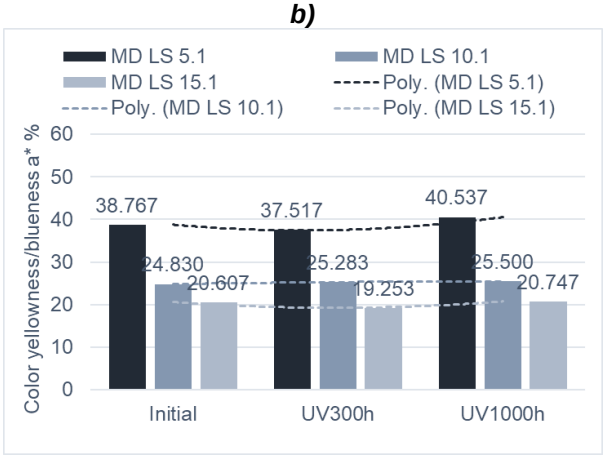

a)




b)




c)

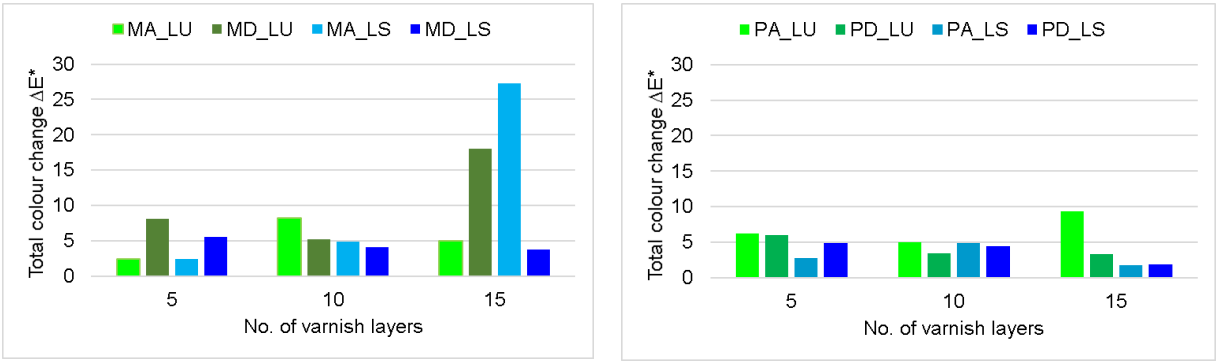



d)

***Fig. 11.***
***Color redness/greenness for 5, 10 and 15 layers of varnish applied.***

The change in color after 1000 hours of UV exposure highlighted that both the wooden support, the type of varnish and the thickness of the film play an important role in the color difference. In the spruce wood samples, the biggest color changes occur in the samples with 15 layers of varnish (Fig. 12, a). For maple wood, the color change is similar for 5 and 10 layers, regardless of the quality class and the type of varnish. The variations are more pronounced in samples with 15 layers (Fig. 12, b). The color of the aged wood samples became lighter over time: the total color change after 1000 hours of UV exposure ranged up to $\Delta E^*=8$ for 10 layers of oil-based varnish in the case of A quality spruce, $\Delta E^*=17$ for 15 layers of oil-based

varnish in the case of class D spruce, ΔE*=27 for 15 layers of spirit varnish in the case of class A spruce, ΔE*=5 for 5 layers of spirit varnish in the case of spruce class D. Also, in the case of maple wood, a lighter color trend was observed after photodegradation and thermal degradation. The most significant color change is recorded in the case of the 15-layer oil-based varnish in the case of A quality maple, ΔE*=9.




***a)*** ***b)***

***Fig. 12.***
***Total color change: a) spruce samples; b) maple samples.***

## CONCLUSIONS

The paper presents the results of the artificial aging on the color characteristics of two types of varnishing used on two specied of wood with two quality classes and the following can be said about the results:

- Varnishes have an important role in fabrication of musical instruments, offering aesthetic quailties and protection of wood to outside factors.
- Artificial aging has an effect on color of varnishing, changing the color parameters.
- Big differences can be observed between quality classes and species of wood.

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