INFLUENCE OF UV RADIATION ON COLOR STABILITY OF NATURAL AND THERMALLY TREATED MAPLE WOOD WITH SATURATED WATER STEAM

Ladislav Dzurenda, Michal Dudiak, Adrián Banski
Technical University in Zvolen, Slovakia
e-mail: dzurenda@tuzvo.sk

ABSTRACT

The aim of this paper is to present the results of color change on the surface of natural maple wood and thermally treated maple wood with saturated water steam after UV irradiation in Xenotest 450 – simulation of natural wood aging process. Thermally untreated maple wood is white to light white-gray-yellow in color with coordinates L* = 86.6 ± 2.5; a* = 5.3 ± 1.7; b* = 19.3 ± 2.3 in CIE L*a*b* color space. The thermally treated maple wood is brown-red in color with coordinates L* = 65.3 ± 1.4; a* = 10.8 ± 1.3; b* = 19.3 ± 1.3. The surface of samples maple wood with moisture content w = 12% was irradiated in Xenotest 450 with a xenon lamp with UV radiation of 340 nm. Irradiation of the wood surface took place in the exposure cycle A1 for 7 days. While the irradiated surface of the thermally untreated maple wood darkened and acquired a brownish-yellow hue, the brownish-red hue of the thermally treated maple wood turned paled slightly. The total color difference ΔE* caused by UV radiation of thermally untreated maple wood is ΔE* = 15.2 and thermally treated maple wood is ΔE* = 10.8. A comparison of the simulated aging of thermally treated and thermally untreated maple wood in Xenotest 450 suggests that the overall color change of thermally treated wood is 28.9 % less.

Key words: mountain maple, CIE L* a* b* color space, UV radiation, wood color aging simulation.

INTRODUCTION

The long-term exposure of wood to sunlight causes a change in color, known as natural aging. The solar radiation incident on the wood surface is partially absorbed and partly reflected from the surface. The human eye perceives the color of objects, including wood, as a reflection of the wavelength spectrum of sunlight. The absorbed spectrum of infrared red electromagnetic radiation turns into heat and the photon flux of ultraviolet and visible radiation of wavelengths λ = 200 – 400 nm is a source of initiation of photolytic and photooxidation reactions with lignin and polysaccharides *Hon (2001)*. In these reactions, the separation of macromolecules of lignin associated with the formation of phenolic hydroperoxides, free radicals, carbonyl and carboxyl groups as well as separation of polysaccharides to polysaccharides of lower degree of polymerisation associated with the carbonyl and carboxyl groups and gaseous products (CO, CO_2, H_2) are carried out. Photolytic degradation of wood components results in the change of colour of wood surface. In the process of natural ageing wood acquires a shade of yellow to brown color *Reinprecht (2008).*

The aim of the work is to present the effect of UV radiation on the wood surface in the exposure cycle A1 for 7 days in Xenotest 450 – simulating the natural wood aging process. The color stability of maple wood is evaluated by changing the color of the surface of natural and thermally treated maple wood.

MATERIALS AND METHODS

Wood *Acer pseudoplatanus* L. in the form of blanks with dimensions of 32 x 60 x 600 mm and moisture $W_p = 57.8 \pm 4.8\%$ was divided into 2 groups. The blanks of the first group were not thermally treated prior to drying. The blanks of the second group were thermally treated with saturated steam to modify the color of maple wood. Heat treatment of maple wood was carried out in a pressure autoclave APDZ 240 (Himmasch AD, Haskovo, Bulgaria) installed at Sundermann s.r.o. Banská Štiavnica (Slovakia). The steam-saturated mode of maple wood treatment is shown in Fig. 1. and the parameters of the heat treatment mode are shown in Table 1.

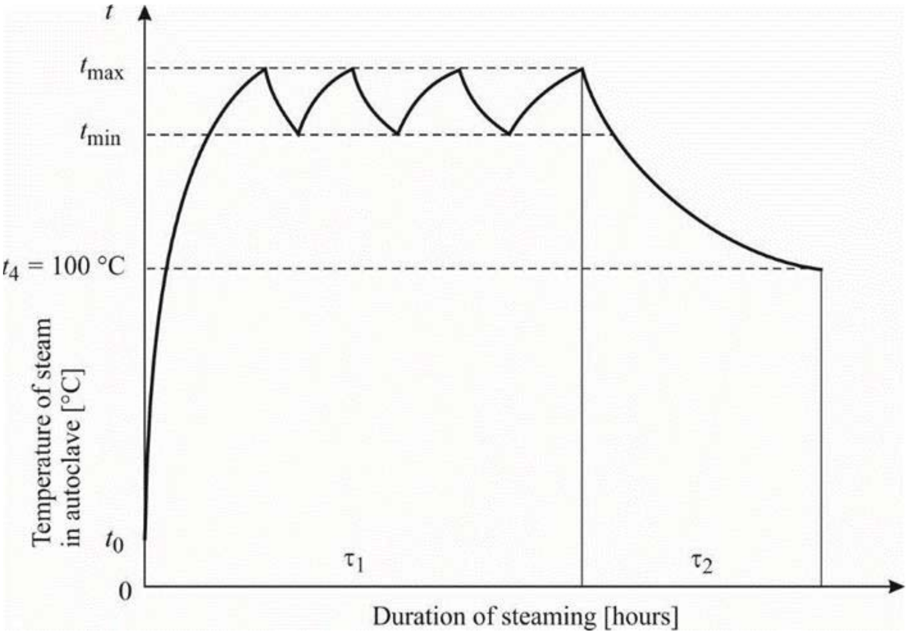

Figure 1: Mode of colour modification of maple wood with saturated water steam.

Table 1: Modes of colour modification of maple wood with saturated water steam.

Mode	Temperature of saturated water steam [°C]			Time of operation [h]		
	t_{min}	t_{max}	t_4	τ_1 -phase I	τ_2-phase II	Total time
Mode thermal treatment	132.5	137.5	100	6.0	1.0	7.0

The thermally treated and untreated maple blanks ware dried low-temperature mode, preserving the original color of the wood to a moisture content $W_p = 12 \pm 0.5$ % in hot air drying kiln: KC 1/50 (SUSAR s.r.o).

From blanks thermally treated and untreated maple wood were made with test samples dimensions: 5 x 40 x 220 mm. Subsequently, the surface of the samples in Xenotest 450 was irradiated with a xenon lamp with UV radiation at 340 nm. The simulation of accelerated standing was performed in the A1 exposure cycle for 7 days.

The surface color of both groups of maple wood samples in the CIE L* a* b* color space was evaluated using a color reader CR-10 (Konica Minolta, Japan) during Xenotest UV irradiation. A D65 light source was used and the diameter of the optical scanning aperture was 8 mm. Color coordinate values are given in the form of notation $x = \bar{x} \pm s_x$ i.e. average measured value and standard deviation.

The total color difference ΔE* of the color change of maple wood surface due to UV radiation during irradiation at time: 24, 48, 72, 96, 120, 144 and 168 hours was determined according to the following equation ISO 11 664-4:

$$\Delta E^* = \sqrt{\left(L_2^* - L_1^*\right)^2 + \left(a_2^* - a_1^*\right)^2 + \left(b_2^* - b_1^*\right)^2} \quad (1)$$

where: L^*_1, a^*_1, b^*_1 values of the CIE L* a* b* color space coordinates on the surface of dried and planed maple wood at the start of irradiation.

L^*_2, a^*_2, b^*_2 values of the CIE L* a* b* color space coordinates on the surface of dried and planed maple wood during irradiation.

RESULTS AND DISCUSSION

Wood *Acer pseudoplatanus* L., according to authors: *Perelygin (1965), Makoviny (2010), Klement – Réh – Detvaj (2010),* has white to light white-gray-yellow color. In the color space CIE L*a*b*, authors: *Babiak – Kubovský – Mamoňová (2004)*, the color of maple wood is described by the values of coordinates: L* = 80.99; a* = 5.20; b* = 16.36. In the work: „Wood color of central European wood species: CIELAB characterization and color intensification", authors: *Meints – Teischinger – Stingl – Hansmann (2017)* give the color of maple wood by the coordinates: L* = 87.9; a* = 5.3; b* = 22.3.

Maple wood in the steam-saturated thermal treatment process, as reported by *Trebula (1986), Dzurenda (2018), Dzurenda – Dudiak (2020)*, darkens depending on the steam temperature and the length of the thermal treatment and acquires various shades of brown-red color.

Table 2 shows the values of the coordinates in the CIEL*a*b* color space thermally treated and non-thermally treated maple wood after drying on the planed surface, measured by us.

The color of maple wood of both native and thermally treated before and after UV irradiation in Xenotest 450 is shown in Fig. 2.

Figure 2: View of maple wood: a) natural before and after UV irradiation, b) thermally treated before and after UV irradiation.

Coordinate values of the color space CIE L*a*b* thermally untreated maple wood and treated thermally maple wood before irradiation in the Xenotest 450 and after 168 hours irradiation are indicated in Table 2.

Table 2: CIE L*a*b* color space coordinate values of natural and thermally treated maple wood

Maple wood	Non-thermally treated wood			Thermally treated wood		
	CIE L*a*b* Color Space Coordinates					
	L*	a*	b*	L*	a*	b*
Before UV irradiation	86.6 ± 2.5	5.3 ± 1.7	19.3 ± 2.3	65.3 ± 1.4	10.8 ± 1.3	19.4 ± 1.3
After UV irradiation	77.1 ± 2.1	10.1 ± 1.4	30.1 ± 1.9	70.4 ± 1.3	10.3 ± 0.9	28.9 ± 1.1

The course of changes of values on the color coordinates L*, a*, b* in the CIE color space L*a*b* in the UV irradiation process of thermally untreated and treated maple wood is shown graphically in Figs. 3 and 4.

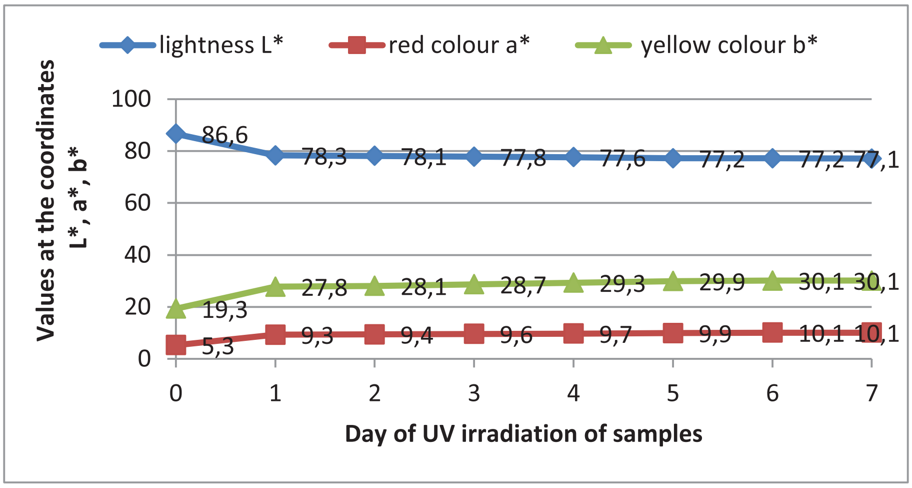

Figure 3: Change of values at the coordinates L*, a*, b* in the process of irradiation of natural maple wood by UV radiation.

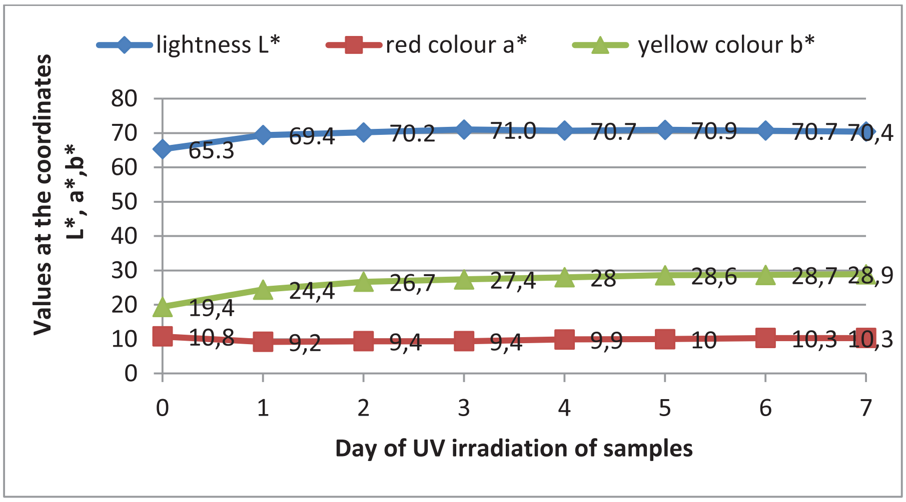

Figure 4: Change of values at the coordinates L *, a *, b * in the process of irradiation of thermally treated maple wood by UV radiation.

By comparing the wood colors in FIG. 2 and the measured data given in Table 2. it follows that while the surface of the untreated maple wood becomes dark, the surface of the heat treated wood fades.

The surface of the thermally untreated maple wood darkened under the influence of UV radiation and turned brown to a brown-yellow color shade, which is documented by shifts at individual coordinates. At the L* coordinate of the luminance due to UV radiation, the luminance value decreased from L_1* = 86.6 to L_2* = 77.1 i.e. o ΔL* = – 9.5 and the values at chromatic coordinates increased by Δa * = +4.8 and yellow by Δb* = + 10.8.

The fading of the surface of the thermally treated maple wood under UV radiation documents an increase in the luminance value from L_1* = 65.3 to L_2* = 70.7, i.e. o ΔL * = + 5.4 and increase in yellow color value by Δb* = + 9.3. The course of changes in the red color coordinate a* indicates slight and ambiguous reactions of photolytic degradation of the wood components manifested by a slight decrease in the red color value in the a* coordinate. The resulting decrease in the red coordinate value Δa* = – 0.5 is less than the standard deviation s = 0.9.

The course of the color changes on the surface of both thermally untreated and treated maple wood during UV radiation, as shown in Figures 3 and 4, is not linear.

Significant reductions in natural maple wood brightness (darkening of the wood surface) and increases in the values of the yellow b * and red a * chromatic coordinates occurred within the first 24 hours.

After that time, the values on the L* and red a* coordinates do not change. The values on the yellow b* coordinate slightly increased.

From the course of color changes on the surface of thermally treated maple wood it follows that while the lightness in the first 24 hours increases (the brown-red color on the wood surface fades), so the values on the yellow b* coordinate increase with varying yellowness of the wood surface over 120 hours.

The unevenness of color changes on the surface of thermally treated and untreated maple wood during UV irradiation of wood samples in Xenoteste 450 is also confirmed by the simulated aging process in the form of total color changes ΔE* in Fig. 5.

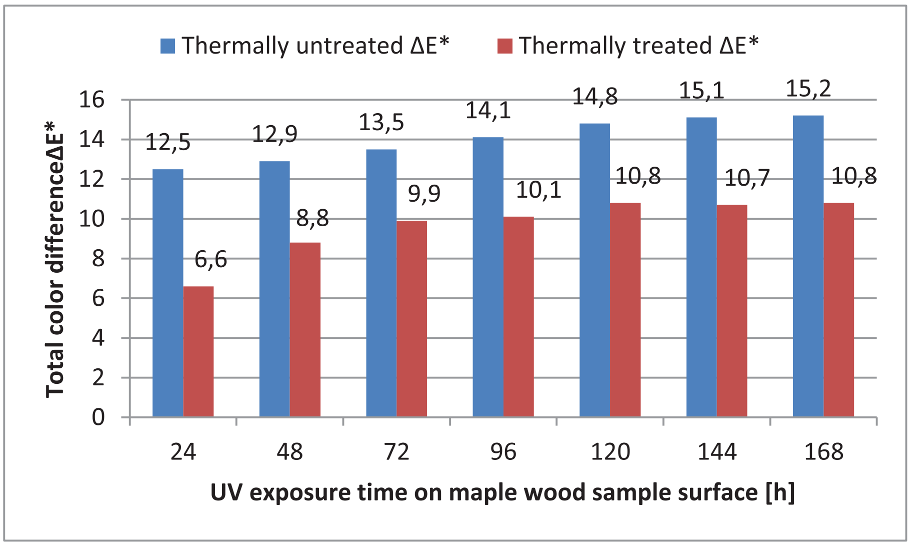

Figure 5: Changes in the total color difference ΔE* values in the process of irradiating the surface of thermally untreated and thermally treated maple wood by UV radiation.

The biggest changes in both cases are in the first 24 hours of UV radiation. The total color difference of the thermally treated maple wood after the first 24 hours is ΔE* = 61.1 % and for thermally untreated maple wood ΔE* = 82.2 % of the total color difference change.

The total color difference ΔE* of the surface treated with wood after 168 hours of exposure is approximately ΔE* = 28.9 % less than that of untreated maple wood.

According to the categorization of wood colour changes induced by wood thermal treatment processes in the form of total colour difference ΔE * presented at work *Cividini et al (2007)*, colour changes in thermally treated maple wood after UV irradiation with value ΔE* = 10.8 belong to a group of large colour changes (ΔE* = 6 – 12) and colours changes of untreated maple with ΔE* = 15.2 belonging to the group of other colours (ΔE*> 12).

CONCLUSION

The paper presents results of color change of thermally untreated and thermally treated maple wood in simulated precession of aging due to UV radiation in Xenoteste 450. Surface of samples of thermally untreated and thermally treated maple wood with moisture content w = 12% was irradiated by xenon lamp with UV radiation. with a wavelength of 340 nm. Accelerated standing was in exposure cycle A1 for 7 days. The simulated aging of natural and thermally treated maple wood showed:

- The surface of natural maple wood becomes dark and brown due to UV rays to a brownish-yellow hue. The brown-red surface of the thermally treated wood fades due to UV radiation.
- Due to UV radiation on the surface of natural – thermally untreated maple wood, the following changes occurred in the individual coordinates of the CIE L* a* b* color space: $\Delta L^* = -9.5$, $\Delta a^* = +4.8$, $\Delta b^* = +10.8$ and thermally treated maple wood changes: $\Delta L^* = +5.4$, $\Delta a^* = -0.5$ and $\Delta b^* = +9.3$.
- The course of color changes on the surface of both natural and thermally treated maple wood during irradiation is non-linear. Significant color changes occurred within the first 24 hours.
- The results of simulated aging of maple wood as a total color difference show that the total color difference of thematically treated maple wood is 28.9% less.

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