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The effect of UV radiation in Xenotest 450 on the colour of steamed beech wood during the process of simulated ageing

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Abstract: *The effect of UV radiation in Xenotest 450 on the colour of steamed beech wood during the process of simulated ageing* .The aim of the paper is to present the changes in colour of steamed beech wood in the pocess of simulated ageing in Xenotest 450. Red-brown colour of beech wood with the coordinates of L* = 62.6 ± 2.8; a* = 10.9 ± 2.3; b* = 17.1 ± 1.3 in the CIE L*a*b* colour space resulted from the mode of colour modification of wood with saturated vapour with the temperature of t = 120 ± 2 ^{o}C for τ = 6.5 hours. The surface of samples after drying to the moisture content of w = 12 % and planing was irradiated in Xenotest 450 with xenon gas-discharge tube by UV radiation with the wave length of 340 nm. Accelerated ageing experiment ran in exposure period A1 for seven days. Simulated ageing of thermally treated beech wood showed that due to UV radiation, the wood surface is turning pale and brown. The change in the lightness coordinate by the value of ΔL* = + 6.7 shows the rate of change in the surface lightness and the changes in the values of chromatic coordinates of red colour by the value of Δa* = - 0.1 and yellow colour by Δb* = + 12.3 shows the rate of getting brown. Therefore the hue angle increases from h^*_{ab} = 57.5 ° to $h°_{ab}$ = 69.8 °. The value of the total colour difference resulting from the process of ageing is ΔE^* = 14.5.

Key words: colour, CIE-L*a*b* colour space, beech wood, thermal treatment, simulated ageing.

INTRODUCTION

Wood colour is one of the most important macroscopic features differentiating the appearance of individual wood species. Wood colouring is caused, besides basic chemical components: cellulose, hemicelluloses, and lignin, by accessory substances such as dye, tanning agent, resins located in cell walls and lumens.

The range of the colour of commercially valuable tree species used as a structural material in joinery and furniture manufacturing is wide: from light white-grey-yellow hues of tree species like Norway spruce, white fir, small-leaved lime, European hornbeam and red-brown hues of heartwood of Scots pine to dark brown-grey hues of heartwood of English oak, European ash, English walnut Drápela et al. (1980), Klement et al. (2010), Makovíny (2010).

Using the technological processes like steaming, staining or surface treatment – irradiating, the wood colour or its hue can be purposefully modified. The change of light white-grey colour of beech wood with yellow tinge into red-brown hue in the process of atmospheric steaming with saturated humid air or in the process of pressure steaming with saturated vapour can be mentioned as an example, Molnar and Tolavj (2002), Dzurenda (2014). The change of light yellow-green-brown colour of heartwood of black locust wood into dark brown-grey hue during the process of steaming is another example Dzurenda (2018).

The colour change of the wood surface is caused also by the effect of long lasting solar radiation defined as natural ageing. Solar radiation falling on the wood surface is partly absorbed and partly reflected. Colour of objects including wood is perceived by a human eye as a perception of reflected wave spectra of solar radiation. Absorbed spectrum of infrared electromagnetic radiation is changed into heat and the photon flow of ultraviolet and visible radiation of wavelengths λ = 200 – 400 nm is a prerequisite to initiate 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 paper is to analyse the effect of UV radiation on the change in beech wood colour during simulated ageing in Xenotest 450.

MATERIALS AND METHODS

Beech wood in the form of wood turning blanks with the dimensions of 32 x 60 x 600 mm with the moisture content of W_p = 57.8 ± 4.8 % was thermally modified with saturated water vapour in the pressure autoclave: APDZ 240 in the company Sundermann s.r.o. Banská Štiavnica. Mode of colour modification of wood turning blanks of beech wood with saturated water vapour is shown in Fig. 1.

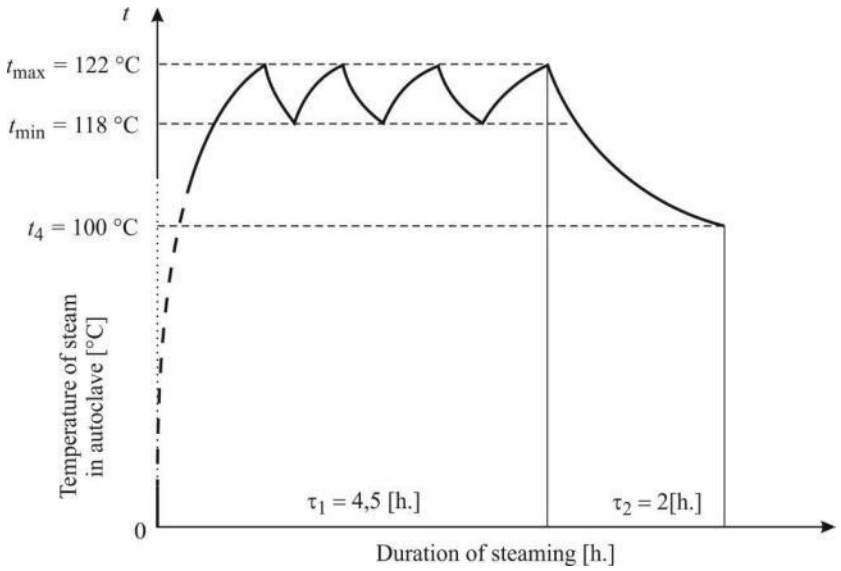

Figure 1. Mode of colour modification of beech wood with saturated water vapour.

Thermally treated wood turning blanks of beech wood were dried to the moisture content of W_p = 12 ± 0.5 % in conventional drying kiln KAD 1x6 (KATRES s.r.o). After drying and planing, the sample surface with the dimensions of 5 x 40 x 220 mm was irradiated in XENOTEST-e 450 with xenon gas-discharge tube by UV radiation with the wave length of 340 nm. Accelerated ageing experiment ran in exposure period A1 for seven days.

The colour of saturated beech wood surface as well as the irradiated surface in the CIE-L*a*b*colour space are evaluated using the calorimeter Color reader CR-10 (Konica Minolta, Japan). The light source D65 with lit area of 8mm was used.

The change in wood colour was evaluated, besides changes in chromatic coordinates, through the hue angle h°_{ab} and the position of the hue of the coordinate C* in chromatic plane.

Hue angle in the chromatic plane is described using the formula:

$$h^{\circ}_{ab} = arctan\left(\frac{b*}{a*}\right) \quad (1)$$

where: b* chromatic coordinate of yellow colour,
a* chromatic coordinate of red colour.

The position of the hue of the coordinate C* in the chromatic plane is described with the formula:

$$C^* = \sqrt[2]{a^{*2} + b^{*2}} \qquad (2)$$

where: b* chromatic coordinate of yellow colour,
a* chromatic coordinate of red colour.

Total colour difference ΔE^* of the colour change of the beech wood surface as a result of simulated UV radiation after the time of radiation after 24, 48, 72, 96, 120, 144 and 168 hours is determined according to the formula ISO 11 664-4:

$$\Delta E^* = \sqrt{\left(L_2^* - L_1^*\right)^2 + \left(a_2^* - a_1^*\right)^2 + \left(b_2^* - b_1^*\right)^2} \qquad (3)$$

where: L^*_1, a^*_1, b^*_1 are values of the coordinates in the colour space of the dried planed surface of thermally treated beech wood.
L^*_2, a^*_2, b^*_2 are values of the coordinates in the colour space of the dried planed surface of thermally treated and irradiated beech wood.

RESULTS AND DISCUSSION

The values of the coordinates in the CIE-$L^*a^*b^*$ colour space of red-brown colour of thermally treated wood of *Fagus sylvatica L*. with saturated water vapour after drying on the planed surface are L* = 62.6 ± 2.8; a* = 10.9 ± 2.3; b* = 17.1 ± 1.3.

Figure 2. View of the beech wood after heat treatment.

Measured values of coordinates in the CIE-$L^*a^*b^*$ colour space describing the wood colour before UV radiation in Xenotest 450, during 7 days of irradiating and values of hue angle h°_{ab} and total colour difference ΔE* determined subsequently are mentioned in Table 1.

Table 1. Measured values of the colour of steamed beech wood in the process of UV radiation.

Time of UV radiation (hours)	**L^***	**a^***	**b^***	**h°_{ab}**	**ΔE^***
0	62.6	10.9	17.1	57.5 °	- - - -
24	69.2	9.5	23.3	67.8 °	9.2
48	70.3	9.3	25.6	70.0 °	11.6
72	70.4	9.8	27.5	70.4 °	13.1
96	69.7	10.2	28.5	70,1 °	13.4
120	69.9	10.3	28.9	70.4 °	13.8
144	69.6	10.7	29.6	70.1 °	14.3
168	69.3	10.8	29.4	69.8 °	14.5

The changes in the values of colour coordinates L*, a*, b* in the CIE L*a*b* colour space during the process of UV radiation of thermally treated beech wood are shown graphically in Fig. 3 and the total colour difference ΔE^* is illustrated using the bar chart in Fig. 4.

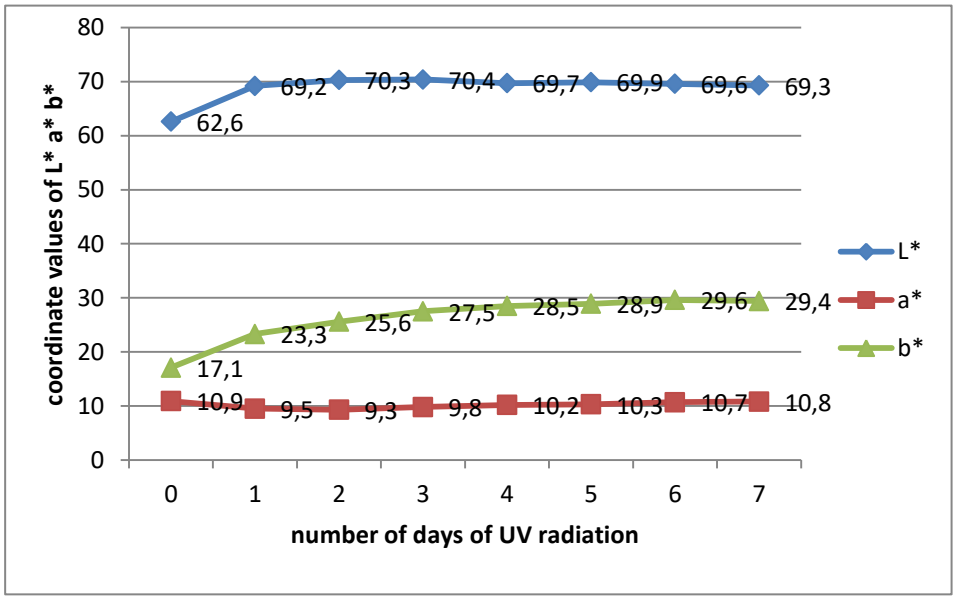

Figure 3. Changes in the values of coordinates L*, a*, b* during the process of UV radiation of steamed beech wood.

The surface of thermally treated beech wood due to UV radiation in Xenotest 450 turned pale what is presented by the change in the coordinate of lightness L* by the value of $\Delta L^* = + 6.7$. Significant increase in lightness happened during the first 24 hours. Similarly, the slight change in the chromatic coordinate of red colour $\Delta a^* = - 1.1$ was observed during the first hours of UV radiation. During further radiation it was eliminated and the value of the coordinate of red colour returned to the original value.

The most significant change in the colour of thermally treated beech wood was detected in the case of the coordinate of yellow colour b* by the value of $\Delta b^* = + 12.3$.

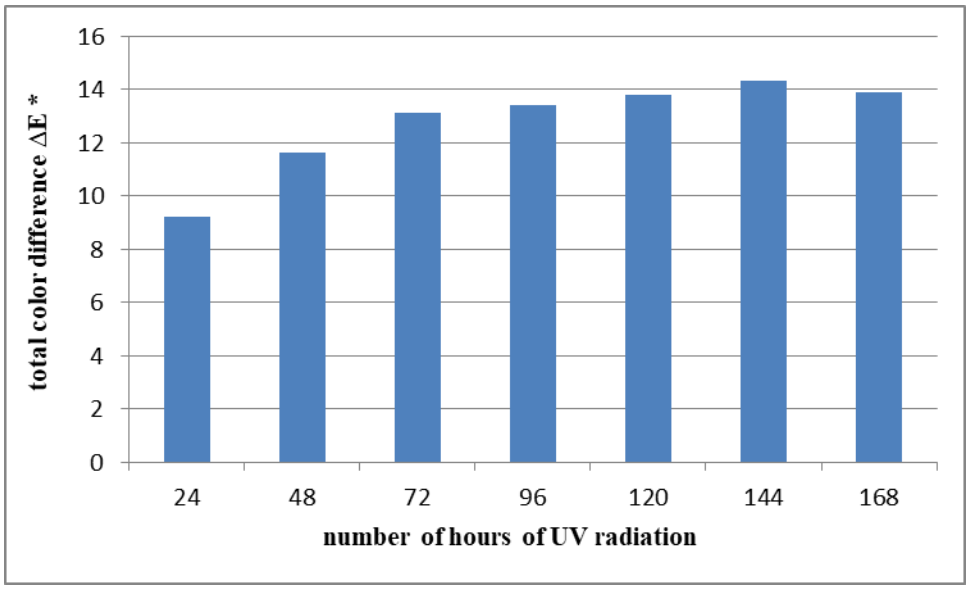

Figure 4. The change of the total colour difference ΔE* during the process of UV radiation of steamed beach wood.

The total colour difference of the colour of steamed beech wood caused by simulated ageing calculated using the formula (4) occurs during the first 24 hours of UV radiation when its value is $\Delta E^* = 9.2$. The colour change is caused by the wood turning pale due to a decrease in the coordinate of lightness by $\Delta L^* = +6.6$ and an increase in the value of the coordinate of yellow colour by $\Delta b^* = 6.2$. Studied change of colour of irradiated steamed beech wood is an example of the change visible to the naked eye Cividini et al. (2007). Further radiation of the surface of steamed beech wood with UV radiation in Xenotest 450 for 72 hours results in turning the wood surface brown with an increase in the value of the coordinate of yellow colour by $\Delta b^* = 5.2$.

The change in the C*coordinate in the chromatic plane as well as the change in the hue angle h°_{ab} are confirmed by the mentioned statements (Fig. 5).

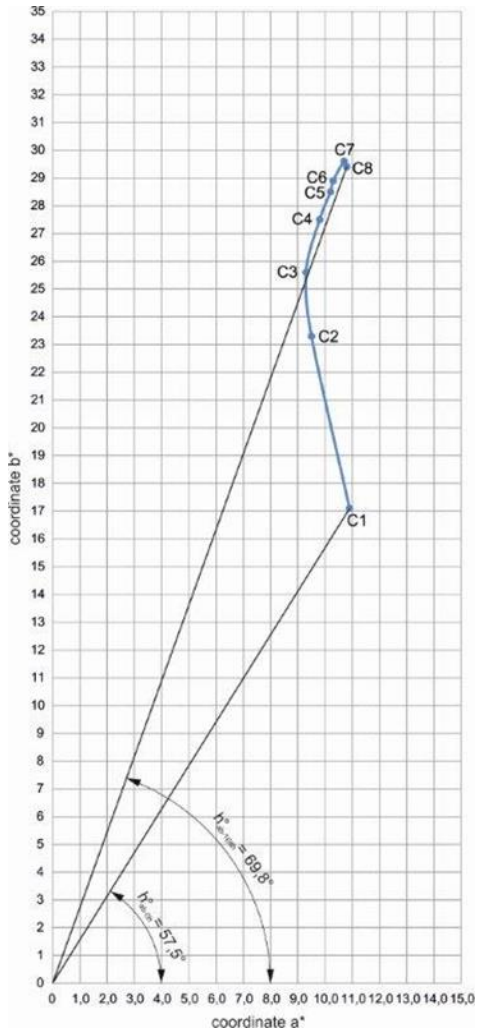

Figure 5. The change of the C* coordinate and the hue angle h°_{ab} in the chromatic plane during the UV radiation of steamed beech wood.

CONCLUSION

The changes of the colour of steamed beech wood during the process of simulated ageing due to UV radiation in Xenotest 450 are presented in the paper. The sample surface of thermally treated beech wood with the moisture content of w = 12 % was irradiated in Xenotest 450 with xenon gas-discharge tube by UV radiation with the wave length of 340 nm. Accelerated ageing experiment ran in exposure period A1 for seven days.

Simulated ageing of thermally modified beech wood showed that the wood surface is turning pale and brown. The degree of fading of the wood surface is declared by the shift to the co-ordinate of luminosity by the value $\Delta L^* = + 6.7$and the changes in the values of chromatic coordinates of red colour by the value of $\Delta a^* = - 0.1$ and yellow colour by $\Delta b^* = + 12.3$ shows the rate of getting brown resulting in an increase in hue angle from $h^*_{ab} = 57.5°$ to $h°_{ab} = 69.8°$.

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Streszczenie: *Wpływ promieniowania UV w urządzeniu Xenotest 450 na kolor parzonego drewna bukowego w procesie przyspieszonego starzenia*. Celem pracy było przedstawienie zmian barwy parzonego drewna bukowego w procesie przyspieszonego starzenia w urządzeniu Xenotest 450. Czerwono-brązowy kolor drewna bukowego o współrzędnych L* = 62,6 ± 2,8; a* = 10,9 ± 2,3; b* = 17,1 ± 1,3 w przestrzeni barw CIE L*a*b* jest efektem modyfikacji koloru drewna parą nasyconą o temperaturze t = 120 ± 2 ^{o}C w czasie τ = 6,5 h. Powierzchnię próbek po wysuszeniu do wilgotności w = 12% i przestruganiu naświetlono promieniowaniem UV o długości fali 340 nm w urzadzeniu Xenotest 450 z lampą ksenonową. Czas ekspozycji wynosił 7 dni. W efekcie procesu przyspieszonego starzenia z wykorzystaniem UV termicznie obrobionego drewna bukowego wykazano, że powierzchnia drewna stała się blada i brązowa. Zmiana współrzędnej jasności o wartość ΔL * = + 6.7 wskazuje na szybkość zmiany jasności powierzchni, zaś zmiany wartości współrzędnych chromatycznych koloru czerwonego o wartość Δa * = - 0,1 i koloru żółtego o wartość Δb * = + 12.3 wslkazują tempo brązowienia powierzchni. Kąt odcienia koloru wzrasta od h^*_{ab} = 57,5° do $h°_{ab}$ = 69,8°. Wartość całkowitej różnicy zmiany barw wynikającej z procesu przyspieszonego starzenia wynosi ΔE* = 14,5.

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