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# L* changes of black walnut (*Juglans nigra* L.) following exposure to $H_2O$, buffers and UV light irradiation

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**Abstract**: *L* changes of black walnut (Juglans nigra L.) following exposure to $H_2O$, buffers and UV light irradiation.* The paper presents changes in the parameter of lightness (ΔL*) in wood of eastern black walnut caused by the action of $H_2O$ and buffers with pH = 2 – 10 and irradiation with UV-A 340 and 351 lamps. Analyses concerning irradiation of samples were performed in an apparatus by Atlas, while changes in the lightness parameter were assessed using a Datacolour 600 device. A 100h irradiation of eastern black walnut wood surface caused a darkening of its surface. The range of recorded changes was dependent both on the type of used buffer solution and the type of the UV lamp used in the experiment. Greater changes were caused by wood irradiation with a UV-A 340 lamp emitting light found outdoors than in the case of a UV-A 351 lamp simulating light found indoors. The greatest darkening of sample surface was observed in wood samples following treatment with alkaline buffer with pH = 8. After exposure to irradiation with a UV-A 340 lamp the surface of tested wood darkened by 4.2 units, while under the UV-A 351 lamp it was by 2.8 units.

*Keywords:* lightness change (*ΔL**), black walnut , buffers, UV light

## INTRODUCTION

Colour of wood is its physical feature. Natural wood colour depends on the species and chemical composition, i.e. the presence of tannins and flavonoid pigments. Habitat conditions also have a considerable effect on wood colour.

Wood colour is of a significant practical importance. Defects in colour reduce its value. Changes in wood colour are caused by certain technological processes, applied in order to provide wood with specific properties, as well as degradation processes, occurring in wood as a natural material. Bleaching, impregnation or lacquering are processes causing wood discolouration (Deka and Petrič 2008). Moreover, wood containing phenolic compounds and particularly ellagitannin is stained to a dark color when it reacts with alkali (Sandoval-Torres et al. 2010). Wood colour may also change as a result of hydrothermal treatment, i.e. as a result of wood digestion (hot water treatment), its steaming or drying ( Mitsui and Tolvaj 2005, Sahin et al. 2011, Tolvaj et al. 2012, Wongprot et al. 2013). Wood is also discoloured under the influence of microorganisms (Pandey and Pitman 2003) . A significant effect causing discolouration of wood is also observed for light, both that found outdoors and indoors. Light can modify wood colour by affecting lignin molecules (Sandoval-Torres et al. 2010). Photochemical reactions are initiated by absorption of UV visible light, mainly by lignin. This leads to the formation of free radicals, which as a result of reactions with oxygen cause the formation of chromophoric carbonyl and carboxyl groups, which are responsible for colour changes (Pandey 2005).

The aim of this study was to determine stability of wood colour in eastern black walnut exposed to the action of water and buffers with varied pH ranging from 2 to 10 and irradiation with UV light in an apparatus by Atlas. The rate of wood surface discolouration was assessed based on the parameter of lightness (ΔL*).

MATERIALS AND METHODS

**Preparation of samples**

The investigated material was exotic wood of eastern black walnut (*Juglans nigra* L.). Samples of 60 x 30 x 4 mm (±1 mm) (long. x tang. x red.) were prepared from the same boards. After cutting they were polished with sandpaper (400 P) prior to analyses. Then, they were divided into eight groups. The first group was the control sample. The next groups were dipped in $H_2O$ and acid (pH = 2.0, 3.0, 4.0, 5.0), neutral (pH = 7.0) and alkaline (pH = 8.0, 9.0, 10.0) buffers, produced by Honeywell Burdick & Jackson. The tests were performed using three samples from each variant. Three circular measuring points were marked on each sample (diameter of 10 mm). The buffer treatment lasting for 1h and 24h was performed under laboratory conditions (23 °C, 45% RH). After dipping, the samples were dried at 40 °C for 24 h. The sample moisture content during the experiment was constant and amounted to 5.8%±0.1.

**Irradiation**

Light irradiation was carried out twice with an ATLAS apparatus. The first test was performed with the use of low-pressure UV radiators with maximum emission at 340 and the second one with 351 nm. The UV-A-340 lamp emitted UV resembling solar light found outdoors (with a wavelength range of 290 to 400 nm), while the UV-A-351 lamp emitted daylight that penetrates window panes and is found indoors (with a wavelength range of 300 to 400 nm) (EN-ISO 4892-3/2006). The distance between the UVA light sources and sample surface was set to about 4.0 cm. the intensity of light projected onto the tested surfaces was 0.5 W/m$^2$, and the black panel temperature (BPT) equaled 38 °C. The irradiation under an air atmosphere. The colour coordinates of tested samples was recorded after 1, 5, 10, 25, 50 and 100 h in all cases.

**Colour measurements**

All the colour measurements were taken from the surface of the samples before and after treatment in $H_20$ and buffers. The colour coordinates in the CIE $L^*a^*b^*$ system were recorded with a Datacolour 600 dual-beam d/8° spectrophotometer, using the $D_{65}$ standard illuminant. The wavelength range of the spectrophotometer ranged from 360 nm to 700 nm, reporting at 10 nm intervals. Reflectance of the instrument was 0.15 (max), 0.008 (avg.).The sensor head diameter was 10 nm. Colour coordinate $L^*$ was measured on three samples per each variant. Calibration of the instrument was performed before testing using the white tile, green tile and black trap standards provided with the spectrophotometer. Three points of fixed locations were measured on each sample.

Data listed in this paper are averages of nine replicated measurements. The colour sphere is described as a tridimensional system of colour coordinates (axes $L^*$, $a^*$ and $b^*$). Axis $a^*$ depicts the share of green or red colour within the analysed colour; hues of green take on negative values and hues of red, positive values. Axis $b^*$ depicts the share of blue or yellow colour within the analysed colour; hues of blue take on negative values and hues of yellow, positive values. Axis $L^*$ describes colour brightness within the value range from 0 to 100. $L^*$ = 100 means that a given colour is close to white, and $L^*$ = 0 that a colour is close to black.

## RESULTS

Results of analyses of the effect of UV light on wood surface discolouration of tested black walnut are presented in Tables 1 – 2.

Table 1. Changes in coordinates (Δ*L**) of eastern black walnut wood after treatment with $H_2O$ and buffers caused by UVA irradiation with light of wavelengths 290 - 400 nm (emitted by the UV-A 340 lamp)

| **Solution** | **Irradiation time** | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **5** | **10** | **25** | **50** | **100** |
| $H_20$ | 0.1 | -0.9 | -1.2 | -1.4 | -1.6 | -1.7 |
| B-2 | -0.8 | -1.4 | -1.6 | -1.9 | -2.6 | -2.9 |
| B-3 | 0.7 | 0.1 | -0.8 | -1.1 | -1.4 | -1.5 |
| B-4 | 0.4 | 0.1 | 0.3 | 0 | -0.5 | -1.5 |
| B-5 | 0 | -0.3 | -0.2 | -0.8 | -1.3 | -1.7 |
| B-7 | -0.1 | -0.1 | -1.4 | -1.5 | -1.6 | -1.7 |
| B-8 | 0.4 | 0 | -0.3 | -1.1 | -3.1 | -4.2 |
| B-9 | -0.1 | -0.2 | -0.3 | -0.4 | -0.6 | -0.8 |
| B-10 | -0.2 | -0.3 | -0.4 | -0.5 | -0.6 | -0.7 |

Table 2. Changes in coordinates (Δ*L**) of eastern black walnut wood after treatment with $H_2O$ and buffers caused by UVA irradiation with light of wavelengths 300 - 400 nm (emitted by the UV-A 351 lamp)

| **Solution** | **Irradiation time** | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **5** | **10** | **25** | **50** | **100** |
| $H_20$ | -0.6 | -0.5 | -0.7 | -1.3 | -1.5 | -1.4 |
| B-2 | 0.6 | 0.5 | 0.3 | 0.1 | -0.3 | -0.7 |
| B-3 | 0.3 | -0.2 | -0.4 | -0.6 | -0.8 | -1.0 |
| B-4 | 0.6 | 0.5 | -0.1 | -0.5 | -0.7 | -0.8 |
| B-5 | 0.6 | 0.5 | 1.5 | 1 | -0.2 | -0.7 |
| B-7 | 0.5 | 0.3 | 0 | -0.2 | -0.2 | -0.4 |
| B-8 | -0.7 | -1.0 | -1.1 | -1.5 | -2.6 | -2.8 |
| B-9 | -0.3 | -0.5 | -0.7 | -0.6 | -0.7 | -1.0 |
| B-10 | 0.5 | 0.4 | 0.2 | -0.2 | -0.4 | -0.6 |

When analysing the effect of UV light emitted by UV-A 340 and UV-A 351 lamps on lightness of wood surface in eastern black walnut, it may be stated that the type of light emitted by a UV-A 340 nm lamp, simulating solar radiation outdoors, had a greater effect than light emitted by a UV-A 351 lamp, i.e. simulating light penetrating through a window pane and found indoors. Under the influence of 1h sample irradiation with light at wavelengths of 290 – 400 nm and 300 – 400 nm the surface of some of them grew darker, while that of others turned lighter. In some cases a slight lightening of samples was observed for as long as 25 h after irradiation with these lamps. After 1h irradiation changes in the parameter of lightness (ΔL*) ranged from 0.3 to 0.7 units in the case of irradiation with light at wavelengths of 300 – 400 nm and from 0 to 0.8 units in the case of irradiation with light at wavelengths of 290 – 400 nm. A gradual increase in values of parameter (ΔL*), indicating a gradual darkening of wood surface, was recorded with an extension of irradiation time from 1 to 100 h. After 100h irradiation surface of all samples grew darker, while the range of these changes varied greatly and it was dependent on the type of used light and the type of solution, in which wood had been soaked for 24 h. After 100h irradiation under a UV-A 340 lamp the colour of eastern black walnut wood darkened by 0.6 up to 4.2 units, while after irradiation with a UV-A 351 lamp it was by 0.3 to 2.8 units. After 100h irradiation the greatest changes in the degree of wood darkening were found for wood pre-treated with alkaline buffer at pH =

8. In the case of wood following treatment with alkaline buffers a certain trend was observed for the degree of wood darkening to decrease with an increase in solution alkalinity. The smallest changes in the lightness parameter were recorded for samples treated with buffer at pH = 10, i.e. with the highest alkalinity among the tested variants. These changes after 100h irradiation amounted to 0.6 and 0.7 units depending on the type of the used lamp. Changes in lightness amounting to 1.5 – 2.9 and 0.7 – 1.0 units were found following 100h irradiation of eastern black walnut wood pre-treated with acid buffers. However, these changes did not show a marked trend. In the case of samples irradiated with a UV-A 340 lamp the greatest darkening of samples was recorded for samples pre-treated with acid buffer at pH = 2 (2.9 units), while in the case of irradiation with a UV-A 351 lamp it was in samples pre-treated with buffer at pH = 3 (1.0 unit).

Lightness of samples exposed to the action of water varied within a similar range of values. Irradiation using a UV-A 340 lamp for 100 h caused changes amounting to 1.7 units, while following the use of a UV-A 351 lamp it was by 1.4 units. Markedly greater differences were found for wood pre-treated with neutral buffers at pH = 7. The effect of the lamp emitting outdoor-like light was markedly greater. Under its influence the sample darkened by 1.7 units, whereas when irradiated with the lamp emitting light found indoors it changed by as little as 0.4 units.

## CONCLUDING REMARKS

- It was found that the surface of eastern black walnut wood as a result of 100h irradiation with UV light grew darker.
- Tested eastern black walnut wood exhibited varied sensitivity to the effect of UV light. Changes in parameter ($\Delta L^*$) were dependent both on the type of wood pre-treatment (i.e. solution pH) and the type of lamp used in irradiation.
- When comparing the effect of UV lamps used in the experiments it may be stated that the UV-A 340 lamp, emitting light found indoors, caused greater changes in lightness of sample surface than the UV-A 351 lamp, emitting light found indoors.
- Extending irradiation time of samples from 1 to 100 h caused a gradual increase in values of parameter ($\Delta L^*$), indicating a gradual darkening of wood surface.
- The greatest darkening under the influence of UV light was observed for surfaces of irradiated eastern black walnut samples pre-treated with alkaline buffer at pH = 8.

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**Streszczenie:** *Zmiany L* orzecha czarnego (Juglans nigra L.) po działaniu $H_2O$, buforami i naświetlaniu światłem UV.* W pracy przedstawiono zmiany parametru jasności ($\Delta L^*$) drewna orzecha amerykańskiego spowodowane działaniem $H_2O$ i buforami o pH = 2 – 10 oraz naświetlaniu lampami UV-A 340 i 351. Badania w zakresie naświetlania próbek wykonano w aparacie firmy Atlas, a zmiany parametru jasności oceniano przy użyciu aparatu Datacolour 600. 100h naświetlanie powierzchni drewna orzecha amerykańskiego spowodowało ściemnienie jego powierzchni. Zakres zarejestrowanych zmian uzależniony był zarówno od rodzaju użytego roztworu buforowego jak i od rodzaju zastosowanej w badaniach lampy UV. Większe zmiany spowodowało naświetlanie drewna lampą UV-A 340 emitującą światło występujące w warunkach zewnętrznych niż lampą UV-A 351 symulująca światło występujące wewnątrz pomieszczeń. Największe ściemnienie powierzchni próbek stwierdzono w przypadku próbki drewna po obróbce buforem zasadowym o pH = 8. Pod wpływem lampy UV-A 340 powierzchnia badanego drewna ściemniała o 4.2 jednostki a pod wpływem lampy UV-A 351 o 2.8 jednostek.

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