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L* changes of black walnut (*Juglans nigra* L.) exposed to H_2O, buffers and xenon irradiation

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Abstract: *L* changes of black walnut (Juglans nigra L.) exposed to H_2O, buffers and xenon irradiation.* The paper presents values of changes in the parameter of lightness (ΔL*) for eastern black walnut wood exposed to H_2O and buffers at pH = 2 – 10, caused by the action of UV-VIS light with wavelengths of 290-800 nm and 320-800 nm emitted by a xenon lamp. Changes in parameter (ΔL*) were measured after 1, 5, 10, 25, 50 and 100h irradiation. A greater effect on changes in the parameter of lightness (ΔL*) was found for UV-VIS radiation at wavelengths of 290-800 nm than 320-800 nm. Under the influence of 100h sample irradiation with wavelengths of 290-800 nm the surface of all tested samples grew darker by 0.4 up to 2.3 units. UV-VIS light at wavelengths of 320-800 nm caused changes ranging from 0.1 to 1.7 units. Under its influence the surface of certain samples darkened, while that of other samples grew lighter. This pertains to samples pre-treated with buffers at pH = 5 and pH = 7.

Keywords: eastern black walnut (*Juglans nigra* L.), lightness (ΔL*), buffer treatment, irradiation, xenon lamp

INTRODUCTION

Sunlight is a factor responsible for wood photodegradation processes. Under its influence wood changes colour. The rate of discolouration is usually related to the intensity of light and its wavelengths (Oltean et al. 2008, Kataoka et al. 2007, Pandey 2005). These parameters are variable. They change not only depending on the season of the year, but also within a given day. The spectrum of nearly all solar electromagnetic radiation striking the Earth's atmosphere spans a range of 100 nm to about 1 mm (1,000,000 nm). This band can be divided into five regions: ultraviolet C (100 – 280 nm), ultraviolet B (280-315 nm), ultraviolet A (315 – 400 nm), visible (380 – 780 nm) and infrared (700 nm – 1 mm) (https://en.wikipedia.org/wiki/Sunlight). As it results from literature data, the most significant damage in polymer materials is caused by UV radiation, although it represents only 4.6% the entire spectrum of solar radiation. The most aggressive part is UV-B (Teacă et al. 2013).
Frequently, due to the required rapid evaluation of materials, acceleration of their ageing process and full control over this process, material resistance to the effect of light is tested in artificial weathering chambers. Such chambers are equipped with artificial light sources, e.g. xenon, carbon and mercury fluorescent lamps. Some of them may imitate almost the entire spectrum of solar radiation, while other emit only its section. Very good simulation of sunlight is provided by xenon lamps. They emit radiation in the range of both UV light, as well as visible and infrared light. In the case of many materials, exposure to the action of the complete spectrum of solar radiation is necessary and it facilitates adequate simulation of changes in their colour.

This paper presents the effect of a xenon lamp exposure on wood of black walnut, following a 24h pre-treatement with water and buffers at pH = 2 - 10. Eastern black walnut is an exotic species with a characteristic colour and grain, hard, durable, elastic, which may be bent after hydrothermal treatment**.** It is used in multifaceted applications, e.g. to produce furniture, floors, stairs or doors. Changes related with discolouration of eastern black walnut wood surface were assessed based on changes in values of the lightness parameter (ΔL*). Changes in this parameter indicate whether wood surface under the influence of irradiation became darker or lighter and to determine the scope of these changes.

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 with a SUNSET CPS apparatus equipped with xenon lamps emitting light encompassing the radiation range of UV-VIS at 290 - 800 nm (resembling solar light found outdoors) and 320 - 800 nm (resembling solar light found indoors). The intensity of xenon lamps was 550 W/m^2. The temperature of Black Panel (BPT) in both cases was 38°C. Irradiation was carried out under air atmosphere. The total irradiation time was 100h. L* changes of tested samples was recorded after 1, 5, 10, 25, 50 and 100h.

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 concerning changes in the parameter of lightness (ΔL*) caused by irradiation of eastern black walnut wood using a xenon lamp emitting light at wavelengths of 290-800 and 320-800 nm are given in Tables 1 and 2.

Table 1. Brightness changes (ΔL*) in eastern black walnut wood to simulate outdoor sunlight exposure for 100 hours

Solution	Irradiation time					
	1	**5**	**10**	**25**	**50**	**100**
H_20	0,1	-0.3	-0.5	-0.7	-0.9	-1.3
B-2	1.3	0	-0.4	-0.6	-0.9	-2.3
B-3	0.6	-0.7	-1.1	-1.3	-1.8	-2.3
B-4	2.1	0.4	-0.1	-0.6	-1.0	-1.3
B-5	1.0	0.5	-0.2	-0.3	-0.5	-1.0
B-7	1.3	0.9	0.7	-0.1	-0.4	-0.5
B-8	0.1	-0.2	-0.5	-0.6	-0.8	-1.0
B-9	0.2	0	-0.1	-0.2	-0.5	-0.6
B-10	1.1	0.6	0.5	0.2	-0.1	-0.4

Table 2. Brightness changes (ΔL*) in eastern black walnut wood to simulate indoor sunlight exposure for 100 hours

Solution	Irradiation time					
	1	**5**	**10**	**25**	**50**	**100**
H_20	0.4	0.3	-0.4	-0.5	-0.7	-0.9
B-2	1.3	1.2	1.2	0.1	0	-0.1
B-3	0.9	0.8	0.8	0.5	-0.5	-0.8
B-4	1.8	0.9	0.6	0.6	0.2	-0.2
B-5	1.7	2.0	1.8	1.8	1.7	1.0
B-7	1.5	1.3	1.1	0.9	0.7	0.6
B-8	0.4	0.2	0.3	0.2	0	-0.1
B-9	0.2	0	-0.5	-0.6	-1.6	-1.7
B-10	0.5	0.2	-0.2	-0.3	-0.4	-0.5

It results from the presented data that the effect of UV-VIS light with a wavelength of 290-800 nm was greater than that of UV-VIS light with a wavelength of 320-800 nm. The range of light found indoors is smaller than that of light found outdoors. Outdoor light covers partly the range of UV-B radiation, which as it is shown in literature sources to the greatest extent contributes to degradation of polymer materials and discolouration of their surface. 100h irradiation of black walnut wood with light at a wavelength of 290-800 nm caused darkening of its surface in all tested cases. The range of these changes varied, ranging from 0.4 to 2.3 units. The greatest changes were observed in the case of wood pre-treated with alkaline buffer at pH = 9, while they were smallest following treatment with acid buffer at pH = 2. The effect of UV-VIS light at wavelengths of 320-800 nm in most cases also caused darkening of wood surface, although it was at a smaller range of values, from 0.1 to 1.7 units. Only in the case of wood pre-treated with buffers at pH = 5 and pH = 7 a lightening effect was observed on wood surface. The range of these changes was from 0.6 to 1.0 units. After 1h irradiation of samples using UV-VIS light emitted by a xenon lamp in all cases the surface of tested samples became lighter within the range of 0.1 – 2.1 units at irradiation with light simulating the type of outdoor light and 0.2 – 1.8 units at irradiation with light simulating the type of indoor light. With an increase in irradiation time from 1 to 100h the surface of eastern black walnut wood was becoming black. After 10h irradiation with light at wavelengths of 290-800 nm the surface of only two samples, pre-treated with buffers at pH = 7 and pH = 10 was lighter than that of the control samples, although it was darker than after 1h irradiation. After 50 h the Surface of all tested samples became darker than that of the control samples. In the case of irradiation with light within a smaller radiation range, i.e. 320-800 nm, changes in ΔL* were smaller. After 10h the surface of most samples was lighter than that of the control samples, not exposed to irradiation. An exception is this respect was found for samples treated with water and buffers at pH = 9 and pH = 10, in the case of which already after 10h irradiation darkening of sample surface was observed in relation to that of the control samples. the number of samples, which surface was darker in comparison to the control, non-irradiated samples, increased with the extension of irradiation time.

CONCLUDING REMARKS

1. Under the influence of 100h irradiation with UV-VIS light at wavelengths of 290-800 nm, emitted by a xenon lamp, the surface of eastern black walnut samples became darker in all tested cases.
2. Sensitivity of eastern black walnut wood to the action of UV-VIS light at wavelengths of 320-800 nm was more varied. After 100h irradiation the surface of some samples became darker, while it became lighter in other cases.
3. After 1h the surface of all samples under the influence of UV-VIS light became lighter. With an increase in irradiation time wood was becoming increasingly darker.
4. The range of recorded changes was also influenced by the wavelength of UV-VIS light applied during irradiation as well as the type of samples subjected to irradiation (the type of used buffer).
5. Greater changes were caused by UV-VIS light at wavelengths of 290-800 nm, simulating outdoor light than UV-VIS light simulating light found indoors.

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https://en.wikipedia.org/wiki/Sunlight

Streszczenie: *Zmiany L* orzecha czarnego* (*Juglans nigra* L.) pod wpływem *H_2O, buforów i naświetlania lampą ksenonową.* W pracy przedstawiono wartości zmian parametru jasności (ΔL*) drewna orzecha amerykańskiego po obróbce H_2O i buforami o pH = 2 – 10, spowodowane działaniem światła UV-VIS o długości fali 290-800 nm i 320-800 nm emitowanego przez lampę ksenonową. Zmiany parametru (ΔL*) mierzono po 1, 5, 10, 25, 50 i 100h naświetlania. Stwierdzono, że większy wpływ na zmianę parametru jasności (ΔL*) miał szerszy zakresie promieniowania UV-VIS 290-800 nm niż 320-800 nm. Pod wpływem 100h naświetlania prób światłem o długości fali 290-800 nm powierzchnia wszystkich badanych prób ściemniała w zakresie od 0.4 do 2.3 jednostki. Światło UV-VIS o długości fali 320-800 nm spowodowało zmiany w granicach od 0.1 do 1.7 jednostek. Pod jego wpływem powierzchnia niektórych prób ściemniała, innych uległa rozjaśnieniu. Dotyczy to próbek potraktowanych wcześniej buforami o pH = 5 i pH = 7.

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