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Colour changes in pine wood subjected to ageing tests in an UV chamber

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Abstract: *Colour changes in pine wood subjected to ageing tests in an UV chamber.* The paper presents results concerning colour changes in pine wood subjected to 24-hour cold water extraction and 100-hour UV irradiation. Two types of lamps were used in the tests, i.e. a UVA-340 lamp with a wavelength of 290 - 400 nm, emitting light resembling natural light, an a UVA-351 lamp with a wavelength of 300 – 400 nm, imitating light found indoors penetrating through window panes. Colour of samples was measured using a Datacolour 600 spectrophotometer prior to their soaking in water, after soaking and successively after 1, 5, 10, 25, 50 and 100-hour irradiation. Discolouration of wood surface (ΔE) was mainly related with changes in the chromatic coordinate (Δb*) and the lightness coordinate (ΔL*). After 100-hour irradiation pine wood was characterized by a similar degree of colour change, irrespective of the type of used UV radiator.

Keywords: Colour change, wood, CIE Lab, artificial light exposure

INTRODUCTION

In the course of time wood products change in colour under the influence of sunlight. This is caused by absorption of electromagnetic radiation waves, followed by chemical changes (Ayadi et al. 2003, Hayoz et al. 2003). Almost all wood components are sensitive to UV radiation. Lignin found in wood absorbs UV radiation to a markedly greater extent (80 - 95%) than carbohydrate components (5 - 20%). Colour change in wood is related not only with the principal components, but also extraction components, which absorb approx. 2% radiation (Deka and Petrič 2008).

Literature sources contain an extensive body of information on the effect of sunlight and artificial light sources on wood (Xiaoqing and Haiqing 2008).

It was shown that the effect of UV light in combination with other factors, e.g. heat treatment (Mitsui et al. 2001, Mitsui 2004, Mitsui and Tolvaj 2005, Bekhta and Niemz 2003, Chen et al. 2012) intensifies wood discolouration.

The aim of this study was to determine colour change in Scots pine wood subjected to 24-h cold water extraction followed by accelerated ageing tests consisting in irradiation of sample surface with two types of UV lamps, which maximum emissions were 340 and 351 nm, respectively.

MATERIAL AND METHODS

Experimental material comprised solid wood samples of Scots pine (*Pinus sylvestris* L.). Wood surface was ground using abrasive papers with a 180 and 220 grit. In order to determine the effect of water on colour changes in wood, the prepared pine wood samples prior to their irradiation were immersed in room temperature water for 24 h. Next samples were dried in a laboratory drier at 40°C for 24 h.

Irradiation

Samples after 24-hour water treatment were exposed to light. Irradiation was performed in an apparatus by ATLAS, equipped with two types of low pressure UV radiators with maximum emission at 340 and 351 nm. The UVA-340 lamp emitted ultraviolet light

resembling solar light found outdoors (with a wavelength range of 290 - 400 nm), while the UVA-351 lamp emitted daylight penetrating window panes and found indoors (with a wavelength range of 300 - 400 nm). The intensity of light projected onto the tested surfaces was 0.5 W/m^2 and the temperature Black Panel (BPT) equaled 38°C. Samples were irradiated for 100 h. Exposures were interrupted after 1, 5, 10, 25, 50 and 100 hours.

Colour change assessment

The colour of light irradiated surfaces of the test samples was measured with a Datacolour 600 ^{TM} Spectrophotometer (by Datacolour Int.). The colour coefficients were measured before and after water treatment and after exposure to light.

The three colour coordinates, L*, a* and b* of the CIE Lab system, were recorded after each irradiation and these parameters were used to calculate the total colour change (Δ E).

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

where:

ΔE – colour difference,

L* – achromatic coordinate of colour (brightness). The values of the brightness coordinate L* may range from 0 (black) to 100 (white).

a*, b* – chromatic coordinates of colour. The axis a* corresponds with green (–a) and red (+a), while the axis b* with blue (-b) and yellow (+b).

Colour coordinates were measured before and after irradiation of samples in identical sites. Colourimetric coordinates of tested samples were referred to the white standard of L = 96.29, a = -0.34 and b = 1.25.

RESULTS AND DISCUSSION

Table 1 presents colour of pine wood samples before and after water treatment. Pine wood prepared for testing (the control) had colour (ΔE*) of 25.10 units. Samples were subjected to 24-h cold water extraction, which caused a slight colour change, by over 1 unit (from 25.10 to 26.48). The change in the lightness parameter (ΔL*) indicates that water treatment caused darkening of samples, while the change in the chromatic coordinates (Δa* and Δb*) resulted in their colour change towards red and yellow. These changes were slight, with the value of the lightness coordinate increasing by 1.14, the parameters (a*) by 0.58 and (b*) by 0.83 units.

Tab. 1 The change of colour and colour coordinates in pine samples before and after water treatment.

Sample	ΔL*	Δa*	Δb*	ΔE*
Pine/control	-12.97	4.25	21.05	25.10
Pine/water	-14.11	4.83	21.88	26.48

Definitely greater changes in colour parameters (ΔL*, Δa*, Δb*) were caused by the action of light. Changes in these parameters caused by 100-h irradiation with UV lamps are presented in Fig. 1.

Depending on irradiation conditions, colour change (ΔE*) of pine wood samples subjected to 24-h water extraction and 100-h exposure to UV light, amounted to 16.43 (UVA-351 lamp) and 15.65 units (UVA-340 lamp). Slightly greater colour changes, by approx. 0.8

units, were caused by light with a wavelength of 300 - 400 nm (lamp 351 type), i.e. resembling that found indoors.

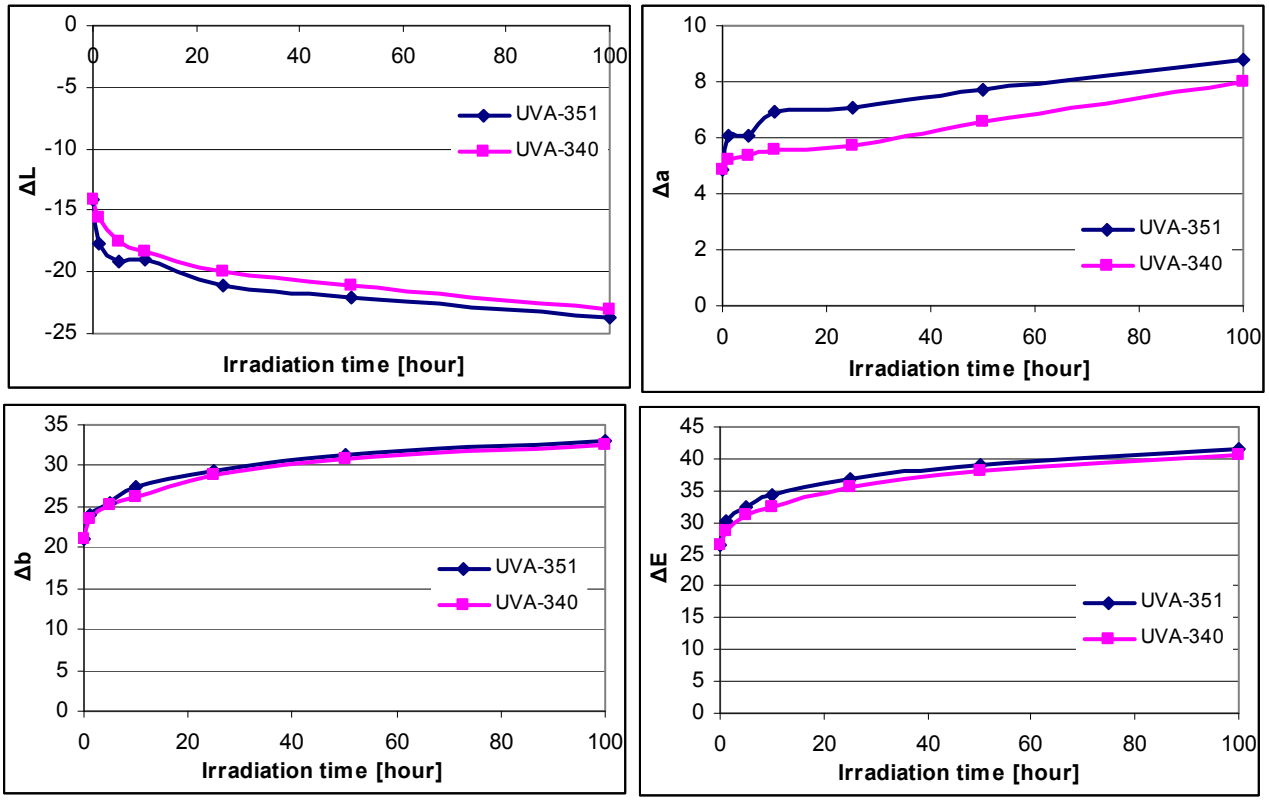

Fig. 1 Change of colour (ΔE*) and colour parameters (ΔL*, Δa*, Δb*) in pine wood samples caused by UV light irradiation

Change of colour (ΔE) in pine wood caused by the analyzed types of UV light resulted mainly from changes in chromatic coordinate "b" and lightness coordinate "L".

Irradiation of sample surface using a UVA-351 lamp caused changes in both parameters amounting to Δb = 11.04 units (from 21.88 to 32.92) and ΔL = 9.6 units (from -14.11 to -23.71). In turn, the effect of the UVA-340 lamp was slightly smaller. The value of coordinate Δb increased by 10.79 units (from 21.88 to 32.67), while lightness parameter ΔL by 8.9 units (from -14.11 to -23.01).

The change in parameter (Δb) indicates that colour of analyzed samples changed towards yellow. In turn, changes in the values of coordinate (ΔL) show that the samples darkened.

As it results from the progression curve the change in the second chromatic coordinate (Δa) was much smaller and depending on irradiation conditions it amounts to 3.93 and 3.17 units. The value of parameter (a*) in the case of the control sample was 4.25. After 24-hour soaking of samples it changed to 4.83, while as a result of 100-hour irradiation it increased, depending on irradiation condition, to 8.00 (UVA-340 lamp) and 8.76 units (UVA-351 lamp). The increase in the value of parameter "a" indicates a transition of colour samples towards of more red.

When analyzing differences in colour and parameters describing colour recorded after 1, 5, 10, 25, 50 and 100-hour irradiation using UVA-340 and UVA-351 lamps it may be stated that the trends were similar. The most intensive changes were found during the first 10 hours of sample irradiation, while the smallest were recorded in the last stage of the analyses, i.e. in the period between 50 and 100 hours of irradiation.

CONCLUSIONS

Discolouration of pine wood sample surface occurred as a result of both water treatment and UV light. Changes of colour (ΔE) resulting from photochemical reactions were caused by the range of ultraviolet light with use of both type of lamps. It was found that slightly greater changes occurred under the influence of a UV-351 lamp emitting the type of light resembling that found indoors. The change in colour (ΔE) for pine wood surface was mainly caused by changes in the chromatic coordinate (b*) and the lightness coordinate (L*). These trends were observed in the case of irradiation with the use of both the UVA-340 and UVA-351 lamps. With the passage of irradiation time sample lightness decreased and sample colour changed towards red and yellow.

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Streszczenie: *Zmiana barwy drewna sosny poddanej testom starzeniowym w komorze UV.* W pracy przedstawiono wyniki obrazujące zmiany barwy drewna sosny poddanego 24 godzinnej ekstrakcji zimną wodą i 100-godzinnemu naświetlaniu światłem UV. W badaniach zastosowano dwa rodzaje lamp, lampę UVA-340 o zakresie długości fal 290 - 400 nm, imitującą światło podobne do światła zewnętrznego i lampę UVA-351 o długości fali 300 - 400 nm, imitującej światło występujące wewnątrz pomieszczeń, przechodzące przez szybę okienną. Barwę próbek mierzono przed namoczeniem ich w wodzie, po namoczeniu oraz kolejno po 1, 5, 10, 25, 50 i 100-godzinach naświetlania za pomocą spektrofotometru Datacolour 600. Za przebarwienie powierzchni drewna (ΔE) odpowiedzialne były głównie zmiany współrzędnej chromatycznej (Δb^*) oraz współrzędnej jasności (ΔL^*). Po 100-godzinach naświetlania drewno sosny charakteryzowało się podobnym stopniem zmiany barwy, niezależnie od rodzaju użytego promiennika UV.

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