Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 86, 2014:210-214
(Ann. WULS - SGGW, For. and Wood Technol. 86, 2014)

Color changes of pine wood under the influence of xenon light irradiation after treatment with acid and alkaline buffers

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Abstrakt: : *The paper presents results of studies reporting color changes in pine wood treated with acid and alkaline buffers and after 100h irradiation with a xenon lamp with two wavelength ranges of 290 - 400 nm and 320 - 400 nm. Color changes were analyzed based on the CIE L*a*b* mathematical color-opponent space model. It was found that significant color changes were caused by alkaline buffer treatment and xenon lamp irradiation. Color changes caused by acid buffer were below the value of 1, i.e. imperceptible to the observer. Irradiation of samples with light at a wavelength of 290 - 400 nm, simulating solar radiation found outdoors, caused greater changes in wood color and values of coordinates describing color than light with a wavelength of 320 - 400 nm, resembling that found indoors. It was stated that pine wood surface both under the influence of buffers and xenon lamp irradiation became darker and changed color considerably towards the red color and changed slightly towards the yellow color.*

Keywords: color change, pine wood, buffer treatment , xenon lamp irradiation

INTRODUCTION

Photodegradation of wood caused by sunlight is a complex process. Photolytic, photo-oxidative and thermo-oxidative reactions occurring in wood under the influence of light cause its degradation (Rabek 1995, Scott 1990). The degree of these changes depends on light intensity, wavelength and on wood species (Teacă et al. 2013). These changes range from discoloration of wood surface to deterioration of its mechanical properties (Andrady et al. 1998). On exposure to light, some woods become bleached or grey, others turn yellow, red-orange, or brown in color, depending on the influence of their extractive compounds (Deka and Petrič 2008). Color changes in wood reflect changes taking place in the chemical structure of wood (Teacă et al. 2013). Chemical analyses showed that deterioration in color is first of all connected with lignin degradation (George et al. 2005, Müller et al. 2003 Pandey 2005, Pandey and Vourinen 2008 a,b).

This paper presents results of studies on color changes in pine wood caused by treatment with acid and alkaline buffers and irradiation with light emitted by a xenon lamp. The effect of two light ranges, i.e. 290 - 400 nm and 320 - 400 nm, was compared. Light with a wavelength of 290 - 400 nm simulates the effect of solar radiation found outdoors, while that of 320 - 400 nm imitates light found indoors (i.e. penetrating indoors through window panes).

MATERIALS AND METHODS

The experimental material comprised wood of Scots pine (*Pinus sylvestris* L.). Analyses were conducted on samples of 40 x 15 x 5 mm (±1mm) (long. x tang. x red.). Sample surface was polished with abrasive paper (400 P).

After color measurements were collected from the control, pine wood samples were soaked for 24 h in an acid buffer (pH = 4) and an alkaline buffer (pH = 10). Next they were dried at s temperature of 40°C for 24 h. After drying they were irradiated for 100 h under a xenon lamp in a SUNTEST CPS apparatus by Heraeus. Analyses were performed for two wavelength ranges of 290 - 400 nm and 320 - 400 nm. The lamp spectrum was adjusted by the application of optic filters. The intensity of light projected onto the tested surfaces was 550 W/m^2, and the Black Panel temperature (BPT) was 38°C.

Color of examined samples was measured before and after soaking in selected solutions and after 100-h irradiation using a Datacolor 600 spectrophotometer. Color changes were analyzed based on the mathematical CIE Lab color space model developed by the International Commission on Illumination according to the following formula:

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

where: ΔE – color difference,

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

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

Analyses were conducted on three samples, on each of which three measurement points of 10 mm in diameter were marked.

Colorimetric coordinates of tested samples were referred to the standard of whiteness (L = 96.29, a = -0.34, b = 1.25).

RESULTS

Table 1 presents values of color (ΔE*) and parameters describing color (ΔL*, Δa*, Δb*) of pine wood before treatment with acid and alkaline buffers.

Table 1. The color and color coordinates of pine wood before treatment with acid and alkaline buffers

Sample	**ΔL***	**Δa***	**Δb***	**ΔE***
Pine	-12,97	4,25	21,05	25,10

Figure 1 presents color changes of pine wood after 24-h treatment with acid and alkaline buffers. Analyses of recorded results showed that markedly greater color changes (ΔE*) were caused by alkaline buffer treatment of pine wood buffer than in the case of acid buffer. Pine wood color after soaking in alkaline buffer changed by 2.83 units, while after acid buffer treatment it was by as little as 0.52 units. Similar trends were recorded in the case of changes in color coordinates (ΔL*, Δa*, Δb*). Lightness of wood samples after treatment became darker. Alkaline buffer caused changes in the lightness parameter by 2.03 units, while in the case of acid buffer it was by 0.45 units. Pine wood after treatment both with acid and alkaline buffers became redder and yellower. Changes caused by alkaline buffer amounted to 0.18 and 0.31 units, while those caused by alkaline buffer were greater, i.e. 1.25 and 1.82 units.

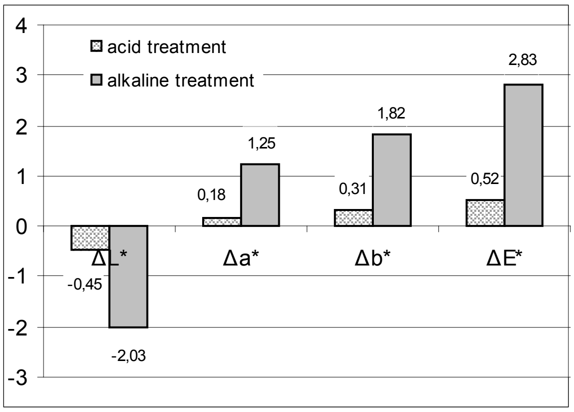

Fig. 1. The comparison of the color parameters of pine wood by treatment with acid and alkaline buffer

Figure 2 presents changes in wood color and parameters describing color, caused by 100h irradiation with light emitted onto sample surface by a xenon lamp with different ranges of electromagnetic wavelengths. Irradiation of pine wood samples with a xenon lamp emitting light imitating solar radiation found outdoors (with a wavelength of 290 - 400 nm) caused greater changes in color and color parameters than that of light found indoors (with a wavelength of 320 - 400 nm). Color of pine wood (ΔE*) before and after buffer treatment after 100h irradiation changed by 9.54 up to 14.12 units. The greatest changes in parameter (ΔE*) were recorded for the control (from 12.27 to 1.12 units), while the changes were smallest for samples soaked in the alkaline environment (9.54 to 9.85 units). All types of tested samples under the influence of xenon lamp light became darker. The lightness parameter (ΔL*) of these samples changed by 8.09 up to 11.61 units. The greatest changes in coordinate (ΔL*) were recorded for samples treated with acid buffer. Changes recorded in the control and after alkaline buffer treatment were similar. A comparison of changes recorded for chromatic coordinates Δa* and Δb* showed that the value of parameter Δb* changed within a markedly bigger range. Changes in values of parameter Δa* caused by light with a wavelength of 320 - 400 nm ranged from 0.53 to 1.77 units, while in the case of light with a wavelength of 290 - 400 nm it was from 0.72 to 1.87 units. Changes in coordinate Δb* recorded after sample irradiation with light of 320 - 400 nm wavelengths amounted to 5.85 up to 9.11 units, while for light with a wavelength of 290 - 400 nm it was from 7.07 to 10.42 units. The greatest changes in values of chromatic coordinates Δa* and Δb* after 100h irradiation were recorded for the control, while they were smallest for samples treated with alkaline buffer.

Irrespective of the type of applied light, recorded changes in parameter Δa* indicate that tested samples as a result of irradiation became redder, while parameters Δb* became yellower.

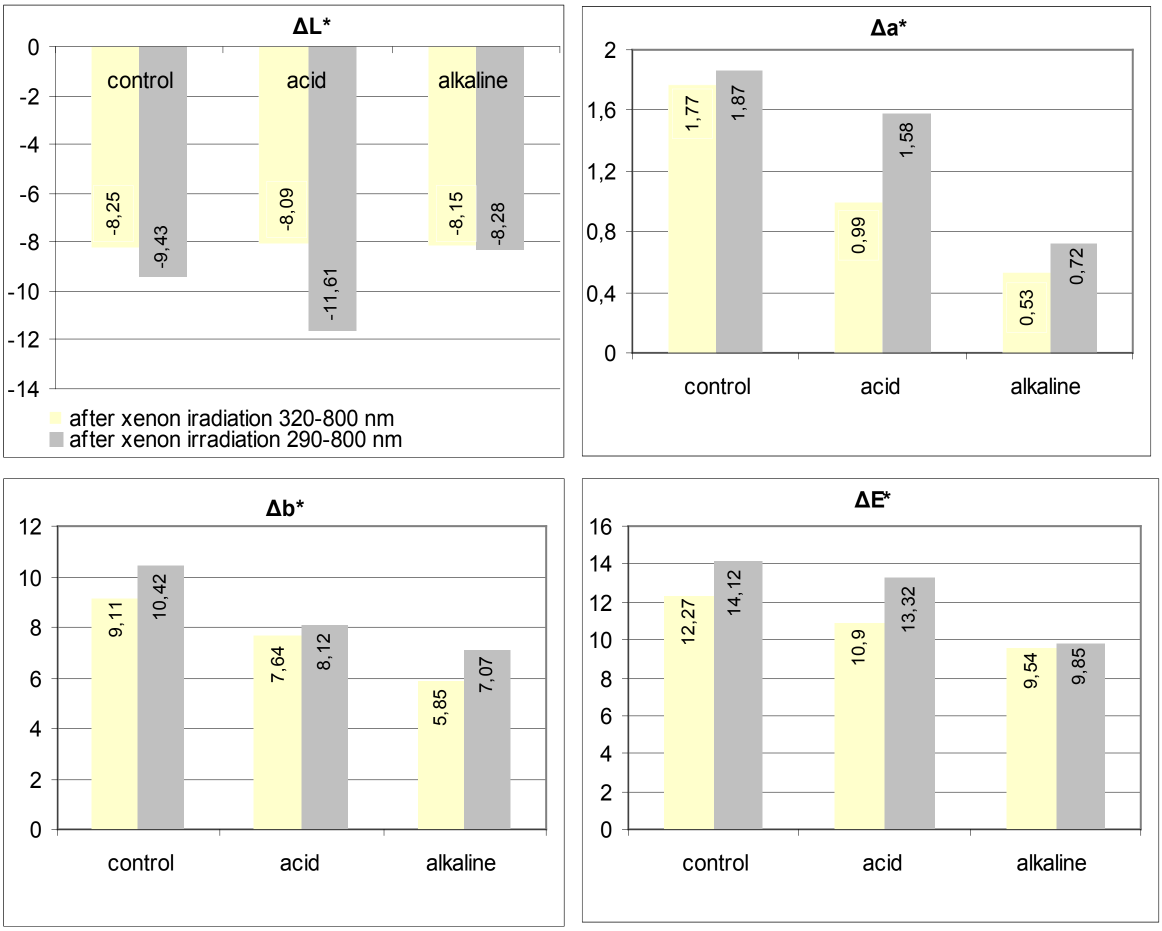

Fig. 2. Color changes of pine wood (ΔE*) and parameters characterizing color (ΔL*, Δa*, Δb*) after 100h irradiation with a xenon lamp with wavelengths of 290 - 400 nm and 320 - 400 nm

CONCLUDING REMARKS

1. Both soaking of pine wood samples in acid and alkaline buffers as well as their 100h irradiation with a xenon lamp caused their discoloration. However, markedly greater color changes were caused by their irradiation.
2. After 100h irradiation the greatest variation in color (ΔE*) was found for untreated pine wood (the control).
3. The light spectrum of 290 - 400 nm, simulating solar radiation found outdoors, caused greater changes in color and in parameters describing color than the light of 320 - 400 nm wavelength simulating conditions found indoors.
4. Recorded changes in values of chromatic coordinates (ΔL*, Δa*, Δb*) show that both buffer treatment of pine wood and its xenon lamp irradiation caused darkening of its surface, as well as considerable color changes towards red and slight changes towards the yellow color.

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Streszczenie: *Zmiany barwy drewna sosny pod wpływem naświetlania lampą ksenonową po obróbce buforem kwaśnym i zasadowym.* W pracy przedstawiono wyniki badań obrazujące zmianę barwy drewna sosny spowodowaną obróbką buforem kwaśnym i zasadowym oraz 100h naświetlaniem lampą ksenonową o dwóch zakresach fal 290-400 nm i 320-400 nm. Analizę zmiany barwy wykonano na podstawie matematycznego modelu przestrzeni barw CIE L*a*b*. Stwierdzono, że istotne zmiany barwy drewna sosny spowodowała obróbka buforem alkalicznym oraz naświetlanie lampą ksenonową. Zmiany barwy wywołane buforem kwaśnym były mniejsze od wartości 1, czyli niezauważalne dla obserwatora. Naświetlanie próbek światłem o długości 290-400 nm, symulującym promieniowanie słoneczne występujące w warunkach zewnętrznych spowodowało większe zmiany barwy drewna i wartości współrzędnych opisujących barwę niż światło o długości 320-400 nm, zbliżone do występującego w pomieszczeniach. Stwierdzono, że powierzchnia próbek drewna sosny zarówno pod wpływem buforów jak i naświetlania lampą ksenonową ściemniała, uległa znaczącemu przebarwieniu w kierunku czerwonym i niewielkiemu w kierunku żółtym.