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The influence of artificial weathering on changes in color of selected coniferous wood species

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Abstract: *The influence of artificial weathering on changes in color of selected coniferous wood species* The work deals with the change in color of two coniferous wood species during artificial weathering: Scots pine (*Pinus sylvestris* L.) and Siberian larch (*Larix dahurica* D. Dur.). The artificial weathering method consisting of alternating soaking wood in water, drying at a temperature of 70 °C and UV radiation exposure was used to determine the influence of weathering on color stability of wood surface. The result of wood discoloration was evaluated using CIE LCh measurement color system. Changes of particular color parameters (lightness, chroma, hue) were observed during exposure. Total color changes were also determinated. The results showed that tested species of wood change their color similarly under the influence of the artificial weathering.

Keywords: artificial weathering, Scots pine, Siberian larch, color stability.

INTRODUCTION

During outside exposition wood surfaces is subjected to changes in texture and color. Factors responsible for these changes are alternating actions of humidity and temperature, photo-chemical and biological processes as well as mechanical erosion caused by wind and rainfall [Roux et al. 1988]. Variability of weather conditions and prolonged exposure to them cause the process called wood weathering also referred to as an ageing. Wood weathering is a process of irreversible changes in the appearance and properties of a material caused by long-term impact of the weather: solar radiation, content of oxygen in air, changes in temperature and humidity, assuming no direct influence of biotic factors [Holz 1981; Matejak 1983, Feist 1990; Colom et al. 2003, Williams 1999, 2005].

During exposure in natural environment, initially smooth wood surface becomes rough as wood fibers rise. This is accompanied by a color change, wherein the certain species of wood exhibit a color change within a few minutes of exposure in outside [Williams 1999, Jankowska 2013]. The color of wood mainly depends on chemical components interacting with light such as extractives. Some species of wood (especially in heartwood) are saturated with dye-based substance which can be extracted from wood with water. The extraction (leaching from subsurface layers of wood) occurs during the action of water, for example during precipitation. During drying, these substances accumulate on the surface of wood, resulting in a color change [Donegan et al. 1999, Williams 1999]. All of these changes occur mainly in surface layer of wood. Research of chemical changes in wood represents explanation of degradation of the outer layers taking place in wood during exposure to natural conditions Feist [1990]. According to researchers, in addition to water extraction in the subsurface layers of wood, ultraviolet light has an important influence on changes in chemical structure. Lignin constitutes 20-30 % of wood tissue and due to phenolic nature lignin absorbs most of the UV radiation, which consequently causes its degradation. Lignin deprived of cellulose chain adhesives and coatings is also degraded as a result of other weathering factors (variable ambient conditions).

Describing the appearance of wood using physical values gives some difficulties because wood surface is never expressed with a simple color. Solution to these problems is

colorimetry giving objective information on wood color and has been widely used for a long time [Tolvaj and Mitsui 2005, Filson et al. 2009, Jankowska 2013].

Because of the color of wood and changes in wood color during exploitation are important factors in determining its use, a database with appropriate color information would be useful, especially in case of “new” on market wood species such as Siberian larch and others.

Objective of this study was determination and comparison the influence of artificial weathering (assuming the absence of biotic interactions) on color change of two wood genuses. The research includes coniferous wood: Scots pine (*Pinus sylvetris* L.) and Sibirian larch (*Larix dahurica* D. Dur.) - wood species often used for products dedicated to outside usage (garden furniture, fences, elevation, tarraces).

MATERIAL AND METHODS

Wood species selected for the research are coniferous wood: Scots pine (*Pinus sylvestris* L.) and Siberian larch (*Larix dahurica* D. Dur.) (names according to PN-EN 13556:2005). Samples of each wood genus were taken from one board to obtain "identical sample". That method let to keep wood structure so the appearing changes in the artificial weathering process were the main factor for the examined properties. 3 groups of 12 samples were taken from each species of wood. Tangential and radial wood surface was tested separately. Only longitudinal sections were tested because of the fact that in final product these sections dominate. Dimensions of samples were 100x100x15 mm. Each group was intended for the research of different stages of weathering. Surfaces of wood had been sanded before the experiment began. Prior to the determination of color parameters, each group was conditioned in air at a temperature close to 20 °C and relative humidity 65 ±5 %.

Change in appearance of wood is based on sensory observation. The analysis of wood color changes were made with use of a mathematical model of the CIE L^*C^*h drawn up by The International Commission of Illumination, based on the recommendations of ISO 7724-3:2003. The spherical SP60 Spectrophotometer was used in this research. To determine differences in color three parameters L^*, C^*, h (L^* - coordinate of brightness/lightness, C^* - chroma coordinate, h - hue coordinate) were used. The total color difference ΔE between the two colors was calculated using the following equation:

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta C^*)^2 + (\Delta h)^2]^{1/2},$$

where ΔL^*, ΔC^*, Δh represent the differences values between the original and the final coordinates, before and after artificial weathering. A low value of ΔE^* means a low change in color. To keep the natural color, wood samples had been isolated from direct sunlight until the first test was obtained. The surface color of samples was measured before the start of artificial weathering, and then during and after artificial ageing. Measurements were carried out on longitudinal sections (six measurements on each sample). The results obtained were averaged for each variant (artificial weathering step).

In this research, the artificial weathering method described by Matejak, Popowska and Szejka [1983] was used. This method was supplemented with UV rays irradiation - after every four replicates of soaking in water and drying at temperature of 70 °C (UV-irradiated wood for 24 hours). 40 cycles of artificial weathering have been conducted. Four fluorescent lamps 100R's Lightech of 100 W each, and the spectrum 300 - 400 nm (90 % of the radiation spectrum is a wavelength of 340 - 360 nm) were used for irradiation.

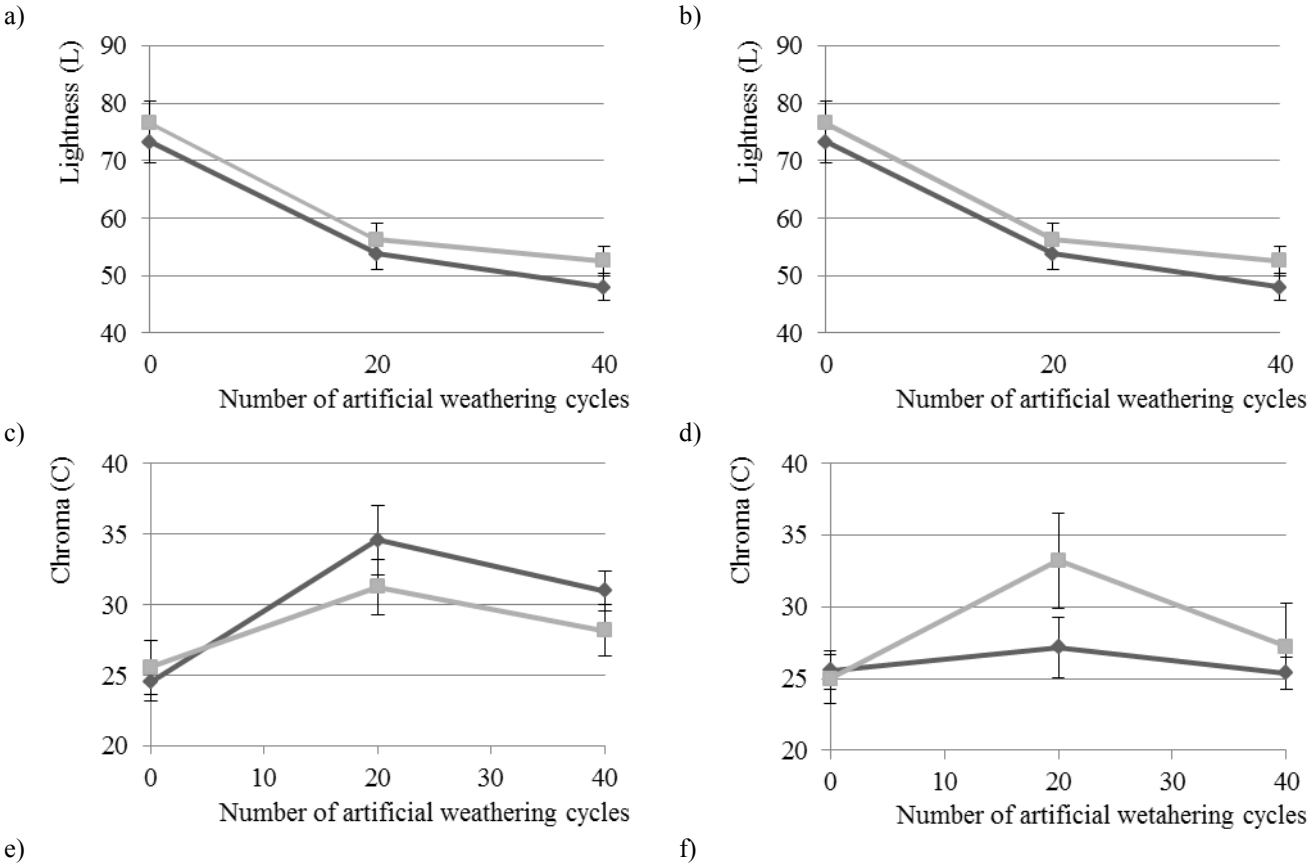
RESULTS

Carrying out 40 cycles of the process of artificial weathering resulted in changes of the appearance of wood samples. After the first cycles, wood samples surface became rough and

cracks occurred. Soaking wood in water resulted in raising wood fibers during drying and partial chipping of material (gentle rubbing the surfaces with a finger resulted in chipping of wood substance showing degradation of ligno-cellulosic backbone of cell walls). The artificial weathering process caused the cracking of the wood samples. Dealing with the issue of weathering, among others Matejak, Popowska and Rabiej [1983], Feist [1990], Williams [1999], the main reason that causes wood damage is sorption stress which occurs during rapid wetting and fast drying (running at high frequency of changes in humidity cause wood cracking).

Artificial weathering process caused a color changes. Initially, the surface of test wood samples became darker. The first cycles of ageing caused no obvious change in color, but after each stage of the process of artificial ageing differences were observed - samples became darker, which was probably the result of dissolved dye substances in deeper layers, and then depositing them on the surface of wood during drying. This phenomenon was confirmed by Donegan et al. [1999], Williams [1999] and Jankowska [2013].

Irradiation with ultraviolet light also had an impact on changing the color of weathered wood. According to the literature [Feist 1990, Williams 1999], UV radiation causes decomposition of lignin especially in the surface layer, what causes the yellowing or browning of wood. During weathering, discoloration of tested wood in direction of dark yellow to red hue was observed.



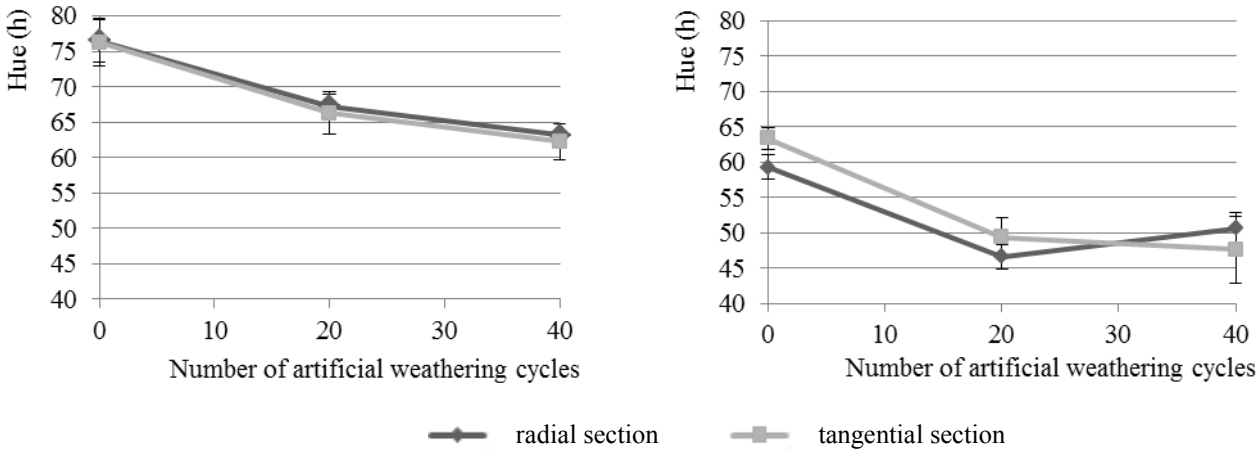


Figure 1. Summary of results testing changes of color parameters: a – lightness of Siberian larch, b – lightness of Scots pine, c – chroma of Siberian larch, d – chroma of Scots pine, e – hue of Siberian larch, f – hue of Scots pine

Macroscopic observations are confirmed by measurements of color with SP60 spectrophotometer. In analyzed cases wood was darkening. The scope of changes was similar in case of both tested wood species.

The tested wood genus showed a change of color chroma (saturation). Initially the color of wood became intense. With the increasing number of weathering cycles, contained in wood samples dyes washed out increasingly and finally top layers of wood in the amount of dye has become very limited, which resulted in wood became a little paler (decrease parameter *C*). The results showed no significant differences in tangential and radial wood surface (fig. 1).

Table 1. The statement of results designation of total color changes (ΔE) of tested wood species

Wood species	Total color change (ΔE)	
	after 20 cycles of artificial weathering	after 40 cycles of artificial weathering
Siberian larch	22,9	26,8
Scots pine	21,2	22,5

Resultant of change in lightness, chroma and color hue is total color change (*ΔE*). During artificial weathering increase in the parameter *ΔE* was observed. The initial increase was dynamic. Along with progressive aging process, the total difference between the color of weathered wood and untreated wood artificial weathering was changing slowly. This character of changes wood color during weathering process was confirmed in literature. The highest intensity of the color changes during the progressive weathering of the initial phases shows research of Tolvaj and Mitsui [2005] and Filson et al [2009].

The results showed that the greatest scope of total color change (*ΔE*) was in case of Siberian larch (tab. 1).

CONCLUSIONS

The artificial weathering method consisting of alternating soaking wood in water, drying at a temperature of 70 °C and UV radiation exposure was used to determine the influence of weathering on color stability of Scots pine (*Pinus sylvestris* L.) and Siberian larch (*Larix dahurica* D. Dur.). The result of wood discoloration was evaluated using CIE LCh measurement color system. The results of artificial weathering are changes in the parameters

describing the color of wood: lightness, color saturation and hue. With the progressive artificial weathering color of wood changed gradually. Tested wood species initially became darker and then lighter.

The scope of changes color hue occurred was similar in case of both tested wood species, but Siberian larch occurred greater range of the total color change than Scots pine wood.

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Streszczenie: *Wpływ przyspieszonego starzenia na zmianę barwy drewna iglastego wybranych gatunków* Praca dotyczy zmiany barwy dwóch gatunków drewna iglastego: sosny zwyczajnej (*Pinus sylvestris* L.) i modrzewia dahurskiego (*Larix dahurica* D. Dur.), spowodowanej działaniem sztucznego starzenia. Mająca symulować działanie naturalnych czynników atmosferycznych, zastosowana metoda starzeniowa polegała na przemiennym moczeniu drewna w wodzie, suszeniu w temperaturze 70 °C i naświetlaniu promieniami ultrafioletowymi. Do oceny zmian wykorzystano matematyczny model przestrzeni barw *LCh*. Stwierdzono, że charakter zmian barwy badanego drewna jest podobny, zmienny jest jedynie zakres zmian. Największa intensywność zmian barwy nastąpiła w początkowych etapach procesu sztucznego starzenia. Większą stabilność barwy wykazało drewno sosny zwyczajnej.

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