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The study of influence artificial weathering on color changes of selected wood species from Africa

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Abstract: *The study of influence artificial weathering on color changes of selected wood species from Africa* The work deals with the change in color selected tropical wood species from Africa during artificial weathering: doussie (*Afzelia* sp.), iroko (*Milicia excelsa* (Welw.) C.C. Berg.) and opepe (*Nauclea diderrichii* (De Wild. & Th.Dur.) Merr.). The accelerated weathering method was used to determine the influence of ageing on color stability of wood. This methods consisted of alternating: soaking wood in water, drying at a temperature of 70 °C and UV radiation exposure The result of wood discoloration was evaluated using CIE Lch system to the value of the total color change ΔE. Changes of particular color parameters (lightness, chroma, hue) were also observed during exposure. The results showed that tested species of wood change their color similarly under the influence of the artificial weathering and the changes in the tested wood appearance occur in different scope. *Afzelia* sp. showed the greatest range of the total color change. The largest changes in intensity of the color of wood took place at the beginning of artificial weathering process.

Keywords: artificial aging, tropical wood, color stability, afzelia, iroko, opepe.

INTRODUCTION

Because of the special aesthetical and durability properties, many products designated for outdoor use are made of exotics, such as garden furniture, fences, flooring, facades, terraces, etc. Such products, when used outdoors, are exposed to usual conditions like sunlight, snow, rain, alternating extensive actions of humidity and temperature, photo-chemical and biological processes as well as mechanical erosion caused by wind and rainfall [Roux et al. 1988]. These factors cause irreversible changes in wood structure, its texture and color. Variability of weather conditions and prolonged exposure to them cause the process called wood weathering also referred as wood ageing. The term “wood weathering” has been defined in literature many times. Many researchers describe the natural weathering (ageing) of wood as 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, Matejak et al., Feist 1990; Colom et al. 2003, Williams 1999, 2005].

The weathering of wood in natural outdoor conditions involves mainly degradation of material surface layers. This go with color change and the certain species of wood revealed a color changes within a few minutes of exposure of the first outer [Williams 1999]. 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 wood surface, resulting in a surface color change [Donegan et al. 1999, Williams 1999]. Analysis of chemical changes in wood gave explanation of degradation of the outer layers taking place in the wood during exposure to natural conditions Feist [1990].

The wood behaviour during ageing has been described in detail in literature [Holz 1981; Matejak 1983, Matejak et al., Feist 1990; Colom et al. 2003, Williams 1999, 2005]. However, the knowledge in this area is still incomplete due to a number new wood species on European market. Due to differences in the wood structure and chemical composition [Jankowska et al. 2012], it seems to be clear that the differences would be.

In this study, determination the influence of artificial weathering (assuming the absence of biotic interactions) on color change of selected tropical wood species from Africa during artificial weathering: doussie (*Afzelia* sp.), iroko (*Milicia excelsa* (Welw.) C.C.Berg.) and opepe (*Nauclea diderrichii* (De Wild. & Th.Dur.) Merr.). Wood species selected for the research are materials used for the production of elements used in external conditions (terrace boards, garden furniture, etc.).

MATERIAL AND METHODS

Wood species used in this study are summarized in table 1.

Table 1. The material tested

Trade name according to PN-EN 13356:2005	Latin name	Plant family	Origin	Special features
Afzelia	*Afzelia* sp.	Fabaceae	West Central Africa	irregular fibres arrangement, paratracheal axial parenchyma aliform to confluent
Iroko	*Milicia excelsa* (Welw.) C.C.Berg	*Moraceae*		irregular fibres arrangement, axial parenchyma in bands
Opepe	*Nauclea diderrichii* (De Wild. & Th.Dur.) Merr.	*Rubiaceae*		irregular fibres arrangement

Samples of each wood species were taken from one board to obtain "identical sample". The aim was to kept the wood structure so the appearing changes in the artificial weathering process were the main factor for the examined properties. 34 groups of 6 samples were taken from each species of wood. Dimensions of samples were 30x20x20 mm (L x T x R). Each group was intended for the research of different stages of weathering. Before the experiment began wood surfaces had been sanded. 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 %.

The examination of color wood changes was 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 PN-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 ageing. A low value of ΔE^* means a low scope of color changes. 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 aging, 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 design of the artificial weathering cycle was based on literature [Matejak et al. 1983, Follrich 2011]. One artificial weathering cycle took 30 hours and was separated into three steps. The first step was soaking speciemens in water at 20 °C (16 hours). The conditions of second step (8 hours) were 70 °C and 5-10 % rH and the third step was performed at 30 °C and 20-25 rH (6 hours) with irradiation with UV rays. Four fluorescent lamps100R'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 irradiating.

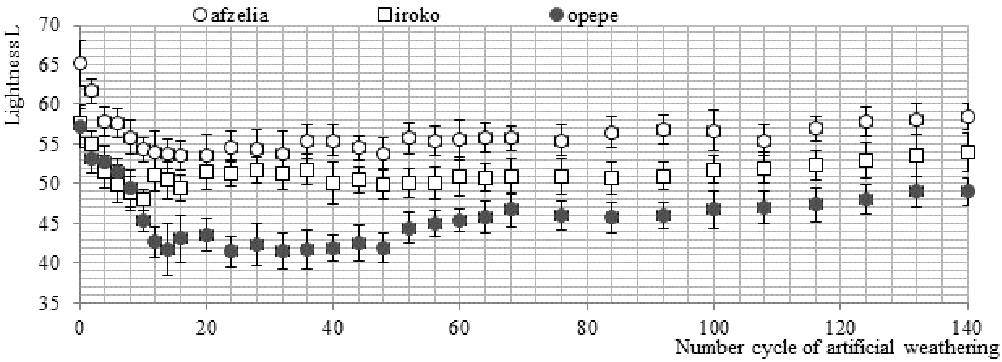
RESULTS

The artificial weathering process caused the cracking of the wood samples. The researchers dealing with the wood weathering, among others Matejak et al. [1983], Feist [1990], Williams [1999], Jankowska [2013, 2014] the main reason that causes wood damages is sorption stress which occurs during rapid wetting and fast drying.

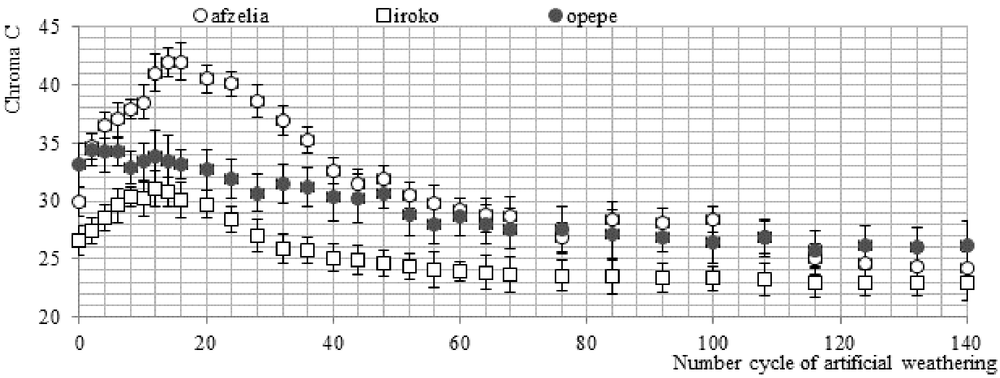
As expected, the alternating soaking, drying and UV irradiation resulted in a change of wood color. Initially, the surface of test samples of wood became darker (fig. 1a). The first cycles of ageing caused no obvious change in color, but after each stage of the process of artificial ageing differences 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] and Williams [1999]. Next cycles of artificial weathering caused a gradual leaching of dye substances, causing brightening the color of wood – value of lightness parameter (*L*) was higher.

a

b



c



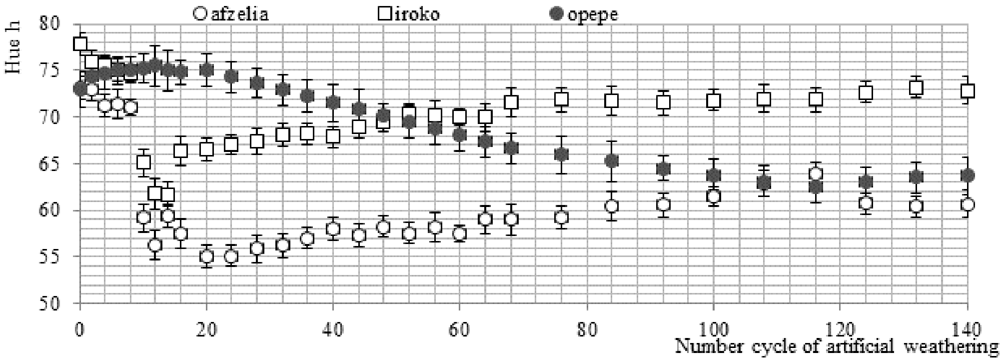


Figure 1. Summary of results testing changes of color parameters: a – lightness, b – chroma, c – hue

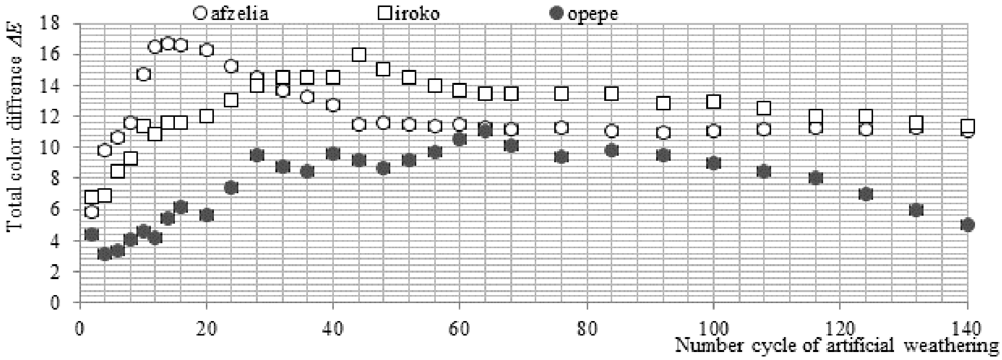


Figure 2. Summary of results testing of total color change

Probably, irradiation with ultraviolet light also had an impact on changing the color of weathered wood. According to the literature [Hon and Feist 1986, Feist 1990, Williams 1999], ultraviolet radiation causes decomposition of lignin especially in the surface layer, what causes the yellowing or browning of wood. Probably, washing out the degraded lignin from wood surface layers also contributed to brightening samples. Irrespective of the tested wood species, the direction of change changed from 30 to 50 cycle of artificial aging - wood color became lighter (brightening followed until the end of the process of artificial aging). Merely the scope of changes was different. Similar results were obtained in earlier tests [Jankowska 2013] during weathering two species from South America – piquia and angelim pedra.

The tested wood species showed a change of color chroma (saturation). Initially the color of wood became more intense. With the increasing number of artificial weathering cycles, contained in the wood dyes washed out to an increasing extent and finally top layers of wood in the amount of dye has become very limited and wood became a little paler (decrease parameter *C*) - fig. 1b. During weathering, yellowing of tested wood was observed - the surface color hue of tested samples of wood was more yellow. The increase in the value of a parameter *h* to values describing the color tones of yellow (90°). The biggest scope of changes color hue occurred in case of afzelia wood (fig. 1c).

Resultant of changes of particular color parameters is total color change (ΔE). The results are given on fig. 2. In the first fifty cycles of artificial aging increase in the parameter ΔE was observed. After an initial increase in the parameter describing total color change (to 30-40 ageing cycles) decrease in ΔE was detected. This means that the initially color of wood at different stages of artificial aging differed more and more. Along with progressive aging process, the total difference between the color of weathered wood and untreated wood artificial weathering was getting smaller.

The results revealed the greatest scope of changes at the beginning of artificial ageing. The highest intensity of the color changes during the progressive weathering process of the initial phases shows also research of Tolvaj and Mitsui [2005], Filson et al. [2009], Jankowska et al. [2013, 2014].

The greatest scope of total total color change (ΔE) was found in case of afzelia wood (the maximum value of ΔE was 16,7). In case of iroko the maximum value of ΔE was 14,5. The smallest scope of color changes was found in case of opepe wood (the maximum value of ΔE was 11,0).

CONCLUSIONS

The result of artificial weathering consisted of wood wetting, drying and UV irradiation are changes in the parameters describing the color of wood surfaces: lightness, saturation and hue. With the progressive artificial weathering process color of wood changed gradually. Tested wood species initially became darker and then lighter. These processes were depended on wood species and took place with variable intensity. *Afzelia* sp. (afzelia) showed the greatest range of the total color change. The largest changes in intensity of the color of wood took place at the beginning of artificial weathering process.

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Streszczenie:
Wpływ sztucznego starzenia na zmiany barwy drewna wybranych gatunków z Afryki Praca dotyczy zmiany barwy trzech rodzajów drewna tropikalnego: zakrwin (*Afzelia* sp.), iroko (*Milicia excelsa* (Welw.) C.C. Berg.) oraz badi (*Nauclea diderrichii* (De Wild. & Th.Dur.) Merr.). Stabilność barwy drewna była badana z wykorzystaniem 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 następowała w początkowych etapach procesu sztucznego starzenia. Największą stabilność barwy wykazało drewno badi. Największy zakres zmian w trakcie prowadzenia procesu starzenia zaobserwowano w przypadku drewna zakrwinu.

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