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Influence of ultraviolet radiation on colour of European ash sapwood and heartwood (*Fraxinus excelsior* L.)

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Abstract: Influence of ultraviolet radiation on colour of European ash sapwood and heartwood (*Fraxinus excelsior* L.). This paper examines the influence of ultraviolet radiation on the colour of ash wood, used principally as flooring material or in veneer and furniture manufacturing. The colour parameters were determined using the CIE L*a*b* and CIE L*C*h colour space model. The research results show a small decrease in wood lightness, by 7% in sapwood, and by 5% in heartwood, after 300 h exposure to radiation. Material change towards yellow was, however, observed in the colour of in both sapwood and heartwood. After 300 h exposure, the b* parameter increased 2 and 1.5 times for ash sapwood and heartwood, respectively. The highest total colour difference in ash sapwood and heartwood was observed after 20 h exposure. The total colour difference as a result of ultraviolet radiation was nearly twice as high in sapwood as it was in heartwood.

Keywords: ultraviolet radiation, colour, lightness, sapwood, heartwood, ash wood

INTRODUCTION

Colour is an important characteristic which affects the aesthetic value of wood as well as its usability. Wood colour depends on many factors, among other from its species, moisture content, type of protective coating applied, as well as the conditions and period of use. When the impact of biotic factors and direct influence of atmospheric conditions are reduced, the colour of wood is principally affected by the time of its exposure to ultraviolet radiation (Sharratt et al. 2009, Huang et al. 2012).

European ash (*Fraxinus excelsior* L.) is a rapid-growing tree. This widely occurring plant is one of the most important tree species in Europe (Gill et al. 2010), and its wood had (Galewski and Korzeniowski 1958) and still has major economic significance (EN 13566:2003, Kozakiewicz et al. 2012). The wood texture is made of distinctly outlined annual rings highlighted by rings of large vessels. The ash appears to have aggregate sapwood because of a wide layer of uncoloured heartwood situated between its narrow creamy white sapwood and coloured light brown heartwood (Wagenführ 2007, Kozakiewicz et al. 2012). Because of its excellent elastic properties and distinctive texture, ash wood is frequently used for flooring material and furniture fronts, where its colour stability is an issue of material importance (Kozakiewicz et al. 2012).

Changes in wood colour were the subject of many research papers. The issues addressed were the influence of atmospheric conditions (Jankowska et al. 2011), the impact of the drying process (Straze et al. 2003), thermal modification (Bekhta et al. 2014), or surface finishing methods (Kozakiewicz et al. 2012). These papers, however, lacked quantitative information on the influence of ultraviolet radiation on the intensity of colour change in natural ash wood.

The aim of this research was to determine the influence of artificial ultraviolet radiation (the crucial component of artificial lighting) on the colour of sapwood and heartwood of the European ash (*Fraxinus excelsior* L.).

MATERIALS AND METHODS

Ash (*Fraxinus excelsior* L.) sapwood and heartwood were used for the tests. The broad surfaces of the samples were characterised by tangential - radial section. Sample surfaces were finished by planing. The samples having been brought to air drying condition, wood moisture content was determined in accordance with ISO 13061-1:2014. Wood density was determined by using the stereometric method according to ISO 13061-2:2014. The ash wood moisture amounted to 8.34% (± 0.62%). Ash sapwood density was 611 kg/m^3 (± 8 kg/m^3), whereas ash heartwood density was 659 kg/m^3 (± 12 kg/m^3). The wood samples were exposed to ultraviolet radiation. Four fluorescent lamps of 100 W each were used for the purpose; their spectrum range was 300 to 400 nm where 90% of the radiation had the spectrum of wavelength 340 to 360 nm. Ultraviolet radiation causes the greatest changes in the appearance and structure of organic materials.

The wood samples were exposed to radiation for 300 hours, and the colour parameters were determined after every 20 hours of exposure. The colour parameters were stated by using mathematical colour space model CIE L*a*b* and CIE L*C*h. The following parameters were measured: lightness (L*), chromatic coordinate on the red - green axis (a*), chromatic coordinate on the yellow - blue axis (b*), chroma (C*), and hue angle (h) before and after the exposure, as well as the colour difference ΔE according to ISO 7724-3:2003. Trend lines were drawn, parameters of curve equation (y) were given, as well as determination coefficients r^2, for the wood colour values. The colour parameters were measured by using an NH300 colorimeter manufactured by 3nh company.

RESULTS AND DISCUSSION

The results of the research are presented in figures 1 and 2. Organoleptic observation revealed noticeable colour changes on the surface of the ash wood exposed to UV radiation.

a). L* b). a* c). b* d). ΔE

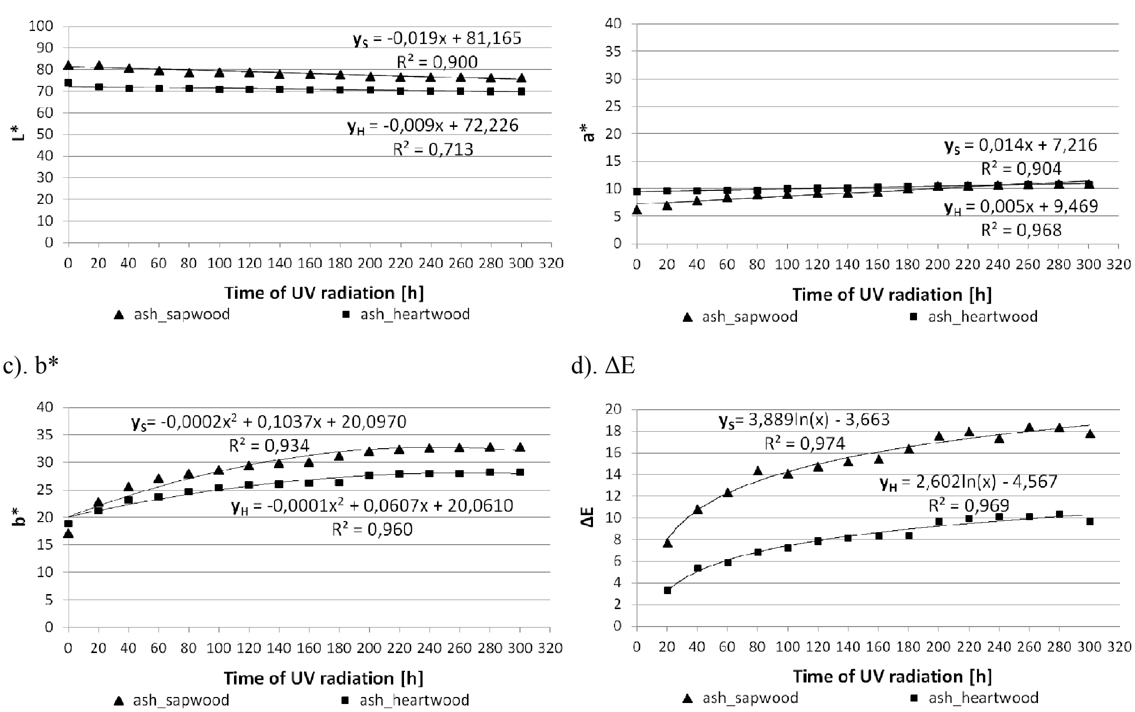

Figure 1. Colour parameters and total colour difference (ΔE) of European ash wood (curve equation y_S for sapwood, y_H for heartwood)

The test results showed that the course of changes in ash wood lightness under the influence of ultraviolet radiation was linear (Fig. 1a). After 300 h exposure the sapwood lightness decreased from 82.14 to 76.20 (drop by 7%) whereas the heartwood lightness decreased from 74.06 to 70.15 (drop by 5%). Changes in other colour components were likewise observed. Analysis of changes in the chromatic coordinate on the red - green axis (a*) revealed that the sapwood changed its colour towards red (change in a* parameter from 6.18 to 10.77). In the case of heartwood no significant change in a* parameter was observed (increase from 9.46 to 10.60) (Fig. 1b). However, material changes were found in the values of the chromatic coordinate on the yellow - blue axis (b*). Under the influence of ultraviolet radiation the ash sapwood and heartwood showed changes towards the yellow colour. After 300 h exposure, the b* parameter increased 2 and 1.5 times for sapwood and heartwood, respectively (Fig. 1c). The reasons for the colour change to yellow ought to be sought in the photochemistry of the wood structural components. The yellowing of wood is brought about chiefly by the lignin and its derivatives, i.e. quinones and stilbenes (Bekhta et al. 2014). The presence of starch in sapwood, but not in heartwood, and generally higher content of various non - structural components may also have contributed to the intensity of colour change (Bamford and Van Rest 1930).

The progress of total colour difference (ΔE) in sapwood and heartwood was logarithmic. The largest total colour difference, both in sapwood and heartwood, was observed after 20 h of exposure (sapwood ΔE 7.67, heartwood 3.31). After 300 h exposure the sapwood ΔE rose to 17.81 and the heartwood ΔE rose to 9.68 (Fig. 1d). Consequently, the total colour change caused by ultraviolet radiation in sapwood exceeded nearly twice the total colour change in heartwood. This resulted most probably from different chemical structures of sapwood and heartwood. In accordance with the five - degree colour durability scale proposed by Mielicki (1997), ash sapwood belongs to class 1 and heartwood to class 1 - 2 (wood of very low and low colour stability with regard to UV radiation).

a). C* b). h

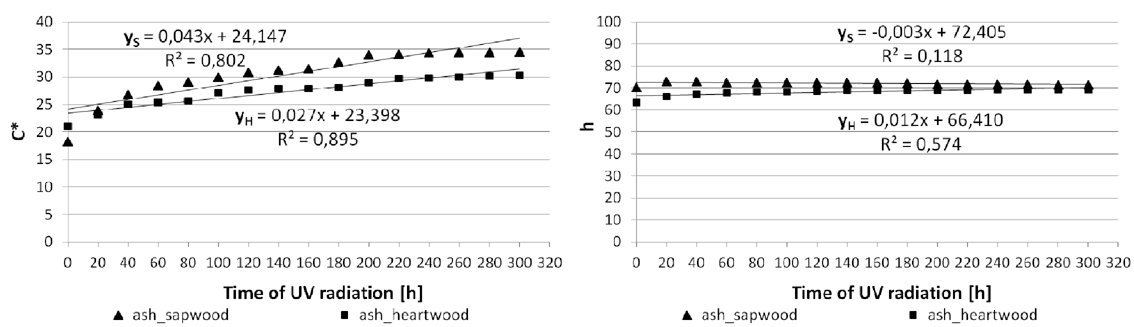

Figure 2. Chroma (C*) and hue angle (h) of European ash wood

The chroma of sapwood showed higher dynamics of change under the influence of ultraviolet radiation than the chroma of heartwood. After 300 h exposure the C* parameter was observed to have increased nearly 2 and 1.5 times for sapwood and heartwood, respectively (Fig. 2a). No material dependence was observed between the period of wood exposure and the change in hue angle. The h parameter changed from 70.22 to 71.43 for sapwood, and from 63.38 to 68.96 for heartwood after 300 h exposure (Fig. 2b).

CONCLUSIONS

1. Ultraviolet radiation makes ash wood darken. The research results show a small decrease in wood lightness, by 7% in sapwood, and by 5% in heartwood, after 300 h exposure to radiation.
2. Under the influence of ultraviolet radiation ash wood turns perceptibly yellow. After 300 h exposure, the b* parameter (a shift towards the yellow colour) increased 2 and 1.5 times for ash sapwood and heartwood, respectively.
3. The highest total colour difference in ash sapwood and heartwood was observed after 20 h exposure. The total colour change caused by ultraviolet radiation in sapwood exceeded nearly twice the total colour change in heartwood.
4. Ash wood (especially sapwood) is characterised by low colour stability to ultraviolet radiation.

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Streszczenie: *Wpływ promieniowania ultrafioletowego na barwę drewna bielu i twardzieli jesionu wyniosłego* (*Fraxinus excelsior* L.). W pracy zbadano wpływ promieniowania ultrafioletowego na barwę drewna jesionu stosowanego głównie jako materiał podłogowy oraz do produkcji oklein i mebli. Parametry barwy zostały określone przy użyciu modeli CIE L*a*b* i CIE L*C*h. Z przeprowadzonych badań wynika, że promieniowanie ultrafioletowe w istotny sposób wpływa na zmianę barwy drewna bielu i twardzieli jesionu. Po 300 h naświetlania całkowita zmiana barwy drewna bielu była niemal 2 - krotnie większa od całkowitej zmiany barwy drewna twardzieli. Analogiczne zależności odnotowano w przypadku zmiany nasycenia barwy drewna. Pod wpływem promieniowania ultrafioletowego drewno bielu i twardzieli wykazało zmianę w kierunku barwy żółtej. Ponadto, drewno bielu wykazało nieznaczną zmianę barwy w kierunku barwy czerwonej. Drewno jesionu (szczególnie bielu) wykazuje wysoką wrażliwość na oddziaływanie promieniowania ultrafioletowego, co stanowi jego wadę przy zastosowaniach na materiały podłogowe oraz fronty meblowe.

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