Colour Change of some Wood Species During Artificial Xenon Radiation

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***Abstract**: The different wood species have different color attributes. As a natural material, wood is also subject to degradation. In indoor environment between eventual humidity and abrasion the third most frequent factor of stress is the natural sun radiation. Due to the natural sun radiation the color of the wood changes which affects both the products of the furniture and the parquet industry. Instead the natural sun radiation which varies during the day and also with the seasons, an artificial Xenon lamp radiation was undertaken in order to get a systematic approach and comparable results. Wood has an inhomogeneous, anisotropic structure, and there are relevant differences in microstructure, color and appearance between the tangential and radial sections of the different wood species. Changes in color due to artificial Xenon radiation were measured in 1-, 3-, 5-, 8-, 10-, 15-, 20-, 30-, 40-, 60-, 80-, 90-, 100-, 120-, 140-, 160-, 180- and 200 hour cycles systematic till color permanency both on radial and tangential cut surfaces to investigate their time dependent behavior. The character of color development was investigated on Beech (Fagus Sylvatica L.), Oak (Quercus petraea) and Birch (Betula pendula) samples, the most common Hungarian wood species of the parquet and furniture industry, as function of (a*, b*, L*) parameters of the CIELAB system. After 200 hours Xenon radiation there were differences between the color of tangential and radial sections of the three investigated species which can be detected also by unaided eye.*

***Keywords:** color, pattern, harmony*

1 Introduction

As a natural material, wood is also subject to degradation. In indoor environment between eventual humidity and abrasion the third most frequent factor of stress is the natural sun radiation. Due to the natural sun radiation the color of the wood changes which affects both the products of furniture and the parquet industry. The color of wood is one of the most important attributes of indoor quality besides machining quality. Color of wooden products is often the only parameter of choice [1].The different wood species have different color attributes, further the variations in total extractive and phenolic content have different effects on the color parameters (L*, a*, b*) [2]. The light irradiation degrades the chromophor groups being originally in the wood. The degradation of lignin and the extractives fallowed by oxidation processes creates new chromophor chemical groups as well. The intensity of the two processes depends on the wood species [3]. Wood has an inhomogeneous, anisotropic structure, and there are relevant differences in microstructure, color and appearance between the tangential and radial cut surfaces of the different wood species.

The microscopic cellular structure of wood, including annual rings and rays, produces the characteristic grain pattern of different wood species. The grain pattern of a wood sample differs also in function of the plane in which the logs are cut at the saw mill: cross section, tangential section and radial section. In transverse or cross section, the annual rings appear like concentric bands. Tangential sections are made perpendicular to the rays and tangential to the annual rings and face of the log. This plane is also called slab-cut or plane-sawed lumber. The annual rings on tangential cut appear as flame-like wavy patterns. Radial sections are made along the rays or radius of the log, at right angles to the annual rings. This plane is also called quarter-sawed lumber because the logs are actually cut into quarters. The rings appear like closely-spaced, parallel bands (Fig.1). For the species investigated, growth occurs in a discrete annual pattern, called growth rings. In case of diffuse-porous wood species like Birch (*Betula pendula*) and Beech (*Fagus Sylvatica L.*) the demarcation between rings is not always so clear and in some cases is almost (if not entirely) invisible to the unaided eye. In case of ring-porous wood species like Oak (*Quercus petraea*) each season's growth is always well defined, because the large pores formed early in the season abut on the denser tissue of the year before. The flame-like pattern of the tangential and the parallel bands of the radial section are attributed to the earlywood and latewood of the annual rings.

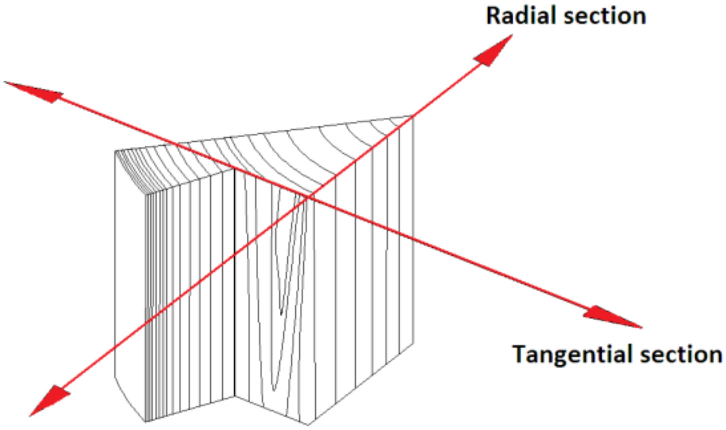


Fig. 1. The tangential and radial sections of a sample after cutting the log into quarters

The color of earlywood and latewood and their contrast differs upon wood species. On purely tangential section the rate of the earlywood is higher than on the purely radial section resulting a difference in color also [4]. For furniture and parquet production during side-grain and butt jointing the radial and tangential sections are arranged side by side for several times. Investigations were conducted in order to describe the time dependent behavior of purely tangential and purely radial sections due to sun radiation for a better understanding of the differences or similarities of their color ageing process.

Instead the natural sun radiation which varies with the seasons and also during the day, an artificial Xenon lamp radiation was undertaken in order to get a systematic approach and comparable results. Between the potential artificial radiation types (mercury lamp, Xenon lamp) the Xenon light is able to simulate the sunlight more properly than mercury lamps light [5].

Investigations were made in order to define the character of color development during 200 hours artificial Xenon radiation on Beech (*Fagus Sylvatica L.*), Oak (*Quercus petraea*) and Birch (*Betula pendula*) samples, the most common Hungarian wood species of the parquet and furniture industry.

2 Material and Method

1) Sample preparation: 2 samples of 55 mm x 95 mm x 25 mm with tangential section and 1 sample of 55 mm x 95 mm x 25 mm with radial section were prepared. 20 measurements were performed on tangential sections and 10 measurements on radial sections after each cycle. The higher number of measurements attributed to the tangential sections was justified by the fact that the earlywood and latewood waves are wider than the bands of the radial section and even wider than the area measured by the measuring instrument. A low number of measurements on tangential section could imply a false color interpretation. The samples were planed and cut to size by circular saw, and were conditioned 7 days at 20 $_{o}$C and 65% relative temperature prior to starting Xenon radiation.

2) The apparatus of artificial radiation and the curing procedure: Radiation curing was performed using an artificial Xenon radiation apparatus Original Hanau Suntest. The apparatus is equipped with Xenon bulb having a sunlight spectra filter. Changes in color due to artificial xenon radiation were measured in 1-, 3-, 5-, 8-, 10-, 15-, 20-, 30-, 40-, 60-, 80-, 90-, 100-, 120-, 140-, 160-, 180- and 200 hour cycles systematic till color permanency, meaning that for the last two measuring cycles the difference between (a*, b*, L*) parameters was found to be less than 3%.

3) Measurement of color: For to perform and evaluate the measurements a computer aided Minolta color measuring instrument was used, with a measuring diameter of 10 mm, the observer set on 10 degree, working upon the principles of the CIELAB system. Due to [6] the considerable amount of color changes of Lawson’s cypress, Norway Spruce, Black Locust and Beech were concentrated to the first 30 hours of treatment.

3 Results and Discussion

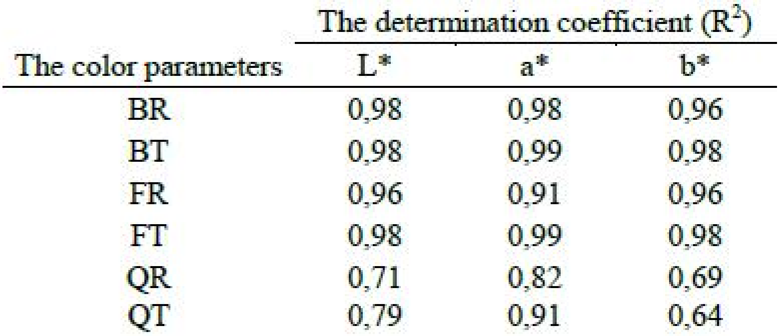
In case of all investigated wood species the graphs of L*, a* and b*show a relevant change of the color parameters during the first 30 hours.

The development of the lightness parameter L* and the development of the redness parameter a* was described as exponential function of time as in (1) for all three wood species on both tangential and radial sections. The development of L* on both radial and tangential sections was similar for all three wood species (Fig.2).

$$y = b2 * \left(e^{-\left(\frac{x}{b1}\right)^{b3}} - 1\right) + b0 \qquad (1),$$

where: $b_2 = 1$; $b_1 = 0{,}1$; $b_3 = 0{,}01$; b_0 = value of 0 hour irradiation

The determination coefficient as measure of fit tightness of the upper equations is represented in table nr. 1, Birch radial section (BR), Birch tangential section (BT), Beech radial section (FR), Beech tangential section (FT), Oak radial section (QR), Oak tangential section (QT).



	The determination coefficient (R^2)		
The color parameters	L*	a*	b*
BR	0,98	0,98	0,96
BT	0,98	0,99	0,98
FR	0,96	0,91	0,96
FT	0,98	0,99	0,98
QR	0,71	0,82	0,69
QT	0,79	0,91	0,64

Tab. 1. Determination coefficient (R2) indicating the tightness of fit.

For Beech and Birch the tightness was found rather similar, near a low value of spread; for Oak the tightness was lower near a wider spread of the color data.

The L* lightness of Oak samples after 200 hours Xenon radiation was targeting different values on tangential and radial sections, 54 and 58 accordingly. This 4 unit difference is equal with the difference between the L* of earlywood and latewood, measured on 0 hour irradiated tangential section of Oak samples, so as can be easily detected by unaided eye. The highest color difference between the earlywood and latewood at the beginning among the three wood species was detected on the Oak samples.

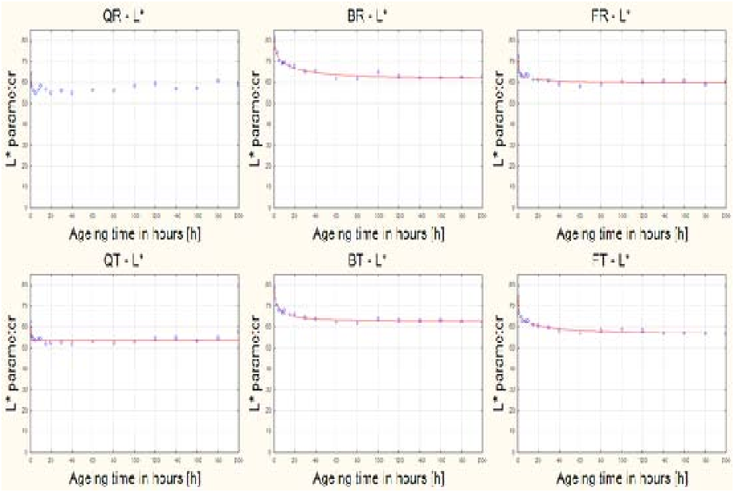


Fig. 2. The lightness (L*) parameters of Oak, Birch and Beech on both tangential and radial sections.

L* on Birch was targeting rather equal value, 62/63, both on radial and tangential sections. L* on Beech was targeting 60 units lightness after 200 hours Xenon radiation on radial and 58 units on tangential sections. The 2 unit difference corresponds to the difference between the L* of earlywood and latewood, measured on 0 hour irradiated tangential section of Beech samples, so as can be easily detected by unaided eye.

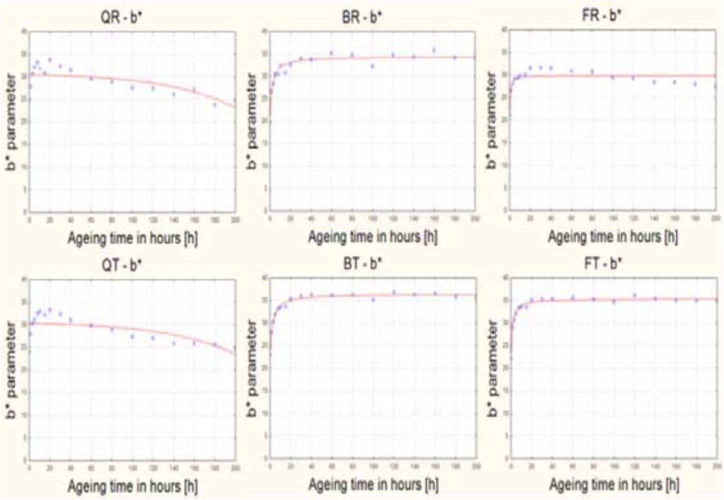


Fig. 3. The yellowness (b*) parameters of Oak, Birch and Beech on both tangential and radial sections

The b* yellowness parameter (Fig. 3) could be described with two different equations for the Oak and Beech/Birch samples. The feature of development of b* for Beech and Birch can be described as logarithm natural function of time as in (2).

$y = \frac{b2}{x - b1} + b0$ (2), where: b2 = 0,1; b1 = 0,1; b0 = 0,1

The feature of development of b* for Oak can be described as exponential function of time as in (3).

$y = b2 * (e^{-b1*x} - e^{-b0*x}) + b3$ (3), where: $b_2 = 1$; $b_1 = 0,1$; b_0 = value of 0 hour irradiation; $b_3 = 0,01$

The feature of development of b* on Oak samples on tangential and radial sections was found rather similar, but differed from the one of Beech and Birch samples. On Oak after an initial increase of the yellow and red content near a decrease of the lightness in the first 30 hours the yellow turned against blue, near a stabilized red and an also stabilized lightness. After the first 30 hours, b* still changes on Oak. On Beech and Birch samples the feature of development of b* was rather similar, showing an increase of the yellow content in the first 30 hours, near an increase of the redness parameter and a stabilized lightness. On Beech samples on tangential section based upon the actual data could be stated that the redness showed a slight increase even after 200 hours Xenon radiation.
The b* yellowness parameter of Oak was targeting 24 units, rather the same value on radial and tangential sections as well after 200 hours of Xenon radiation. On Birch b* was targeting 33 on radial and 36 units on tangential sections, corresponding to the difference between the b* of earlywood and latewood (18,02-21,72), measured on 0 hour irradiated tangential section of Birch samples, so as can be easily detected by unaided eye. The b* of Beech samples was targeting 29 on radial and respectively 35 units on tangential sections, this 5-6 unit difference being even higher than the difference between the b* of early wood and latewood, measured on 0 hour irradiated tangential section of Beech samples, so as can be easily detected by unaided eye.

The development of a*redness was also similar on both tangential and radial sections for all three wood species (Fig. 4) and can be described by the equation (1). On Oak samples the a* parameter of redness was targeting 10 units after 200 hours of Xenon radiation, rather the same value on radial and tangential sections as well. On Birch samples the a* parameter of redness was targeting 13 units after 200 hours of Xenon radiation, rather the same value on radial and tangential sections as well. On Beech samples the a* parameter was targeting 12 on radial and 14 units on tangential sections, the 2 unit difference is higher than the difference between the a* of earlywood and latewood, measured on 0 hour irradiated tangential section of Beech samples, so as can be easily detected by unaided eye. As compared to unprotected surfaces, using surface protective agents the color of wood can be kept natural [7].

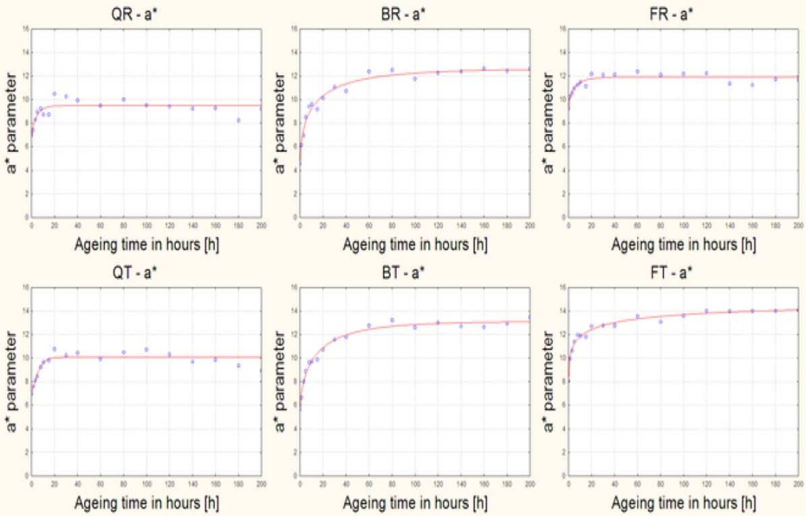


Fig. 4. The redness (a*) parameters of Oak, Birch and Beech on both tangential and radial sections

Conclusions

When ageing Oak samples by Xenon radiation there was no difference in b* and a* parameters of tangential and respectively radial sections after 200 hours, but there was a difference between the L* parameter. The 4 unit difference in lightness was interpreted as causing a visible color difference between the tangential and radial sections. Birch samples supposed to Xenon radiation manifested no difference between tangential and radial sections in L* lightness and a* redness, but there was a difference in the yellowness, these 3 units were interpreted as causing a visible color difference between the tangential and radial sections. On Oak samples there was difference between radial and tangential sections with regard to all three color parameters: L*, b*, a*. Whilst the overall difference in color between the radial and tangential sections of Oak samples is due to difference in lightness, the overall difference in color between the radial and tangential sections of Birch samples is due to difference in yellowness, the color difference between the radial and tangential sections after 200 hours Xenon radiation on Beech samples is due to the differences between lightness, yellowness and redness as well. After 200 hours Xenon radiation there are differences between the color of tangential and radial sections of the three investigated species which can be detected also by unaided eye.

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