

## Colourfulness of European beech wood with a round false heartwood in the color space CIE L\*a\*b\*

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**Abstract:** The paper analyzes the color of dry wood of false heartwood in the color space CIE L\*a\*b\*. The color of dry European beech wood with false heartwood perceived by the human eye is in a wide range of shades from light to brown-yellow to red-brown. The color of the wood of the false heartwood in the color space CIE L\*a\*b\* was measured with a Color reader CR-10 colorimeter (Konica Minolta, Japan). A D65 light source was used and the diameter of the optical sensing aperture was 8 mm. The results of the statistical processing of the measured values of the color of dry beech wood, false heartwood on the planed surface is identified through the values on the lightness coordinate  $L^* = 65.9 \pm 4.8$  and on the chromatic coordinates: red color  $a^* = 12.7 \pm 2.1$  and yellow  $b^* = 20.3 \pm 1.9$ . The colourfulness of the darkness and yellow-brown-red shades of wood of the false heartwood is numerically quantified by the total color difference  $\Delta E_{sx}^* = 5.5$ . The presented values of the color of false heartwood beech wood and the definition of color boundaries in the color space CIE L\*a\*b\* create space for designers to model the color variety of compositions and construction and joinery products made of beech wood.

*Key words:* European beech wood, false heartwood, wood color, wood colourfulness, color space CIE L\*a\*b\*.

### INTRODUCTION

The color of wood is one of the basic macroscopic features that distinguish the appearance of wood from individual trees. The color of the wood is formed by chromophores, i. functional groups of the type:  $>C=O$ ,  $-CH=CH-CH=CH-$ ,  $-CH=CH$ , aromatic nuclei found in the chemical constituents of wood (lignin and extractive substances such as dyes, tannins, resins and others), which they absorb some components of the electromagnetic radiation of daylight and thus create the color of the wood surface perceived by human vision *Hon – Minemura (2001), Gandelová et al. (2009), Geffert et al. (2017)*.

The perception of color by human vision is a psychophysiological sensation caused by the entry of reflected rays of electromagnetic radiation with wavelengths in the range from 380 to 780 nm from the surface of the object, into the human visual center. Its character depends on the wavelength. Light with shorter wavelengths of 380-450 nm evokes a sensation of blue and violet, light of medium wavelengths evokes a sensation of green, yellow and orange, and longwave light with wavelengths of 630-750 nm produces a sensation of red and wavelengths of 750-780 nm with a sensation of dark red *Wilson – Keil (1999), Kubovský – Urgela (2004)*.

The wood of the forest beech belongs to the scattered-porous, coreless woods with the possibility of forming a false heartwood. In some older trees, there is red-brown wood in the middle of the trunk, the so-called false heartwood. A false heartwood is a growth defect that arises in the zone of mature wood by reactions of atmospheric oxygen with wood *Bauch – Koch (2001), Račko – Čunderlík (2006)*. The primary cause of a false heartwood is the penetration of air into the tree trunk through wounded areas of the trunk or branches of the tree and the subsequent oxidation of soluble carbohydrates (= saccharides = glycosides = sugars) and starch contained in living or partially dead parenchymal cells in mature wood. In extreme frosts lasting several consecutive days with

temperatures below  $-30\text{ }^{\circ}\text{C}$ , the parenchyma begins to die in a growing tree and conditions are created for the emergence of the so-called frost false heartwood *Gorczyński, (1951)*. Polyphenolic compounds are formed by the oxidation of soluble carbohydrates and starch, which penetrate into the neighboring tissues and color them red-brown *Bauch – Koch (2001), Račko – Čunderlík (2010)*.

According to the appearance of the false heartwood in the tree trunk and its shape on the cross-section of the trunk, the false heartwood is divided into types: round, star mosaic, flame (eccentric, centric) *Mahler – Höwecke (1991)*.

The color of the wood of the false heartwood according to works: *Gorczyński, (1951), Nečasný (1959), Makovíny (2010), Dzurenda – Dudiak (2022)* is from brown-yellow to red-brown. The mentioned color shades of wood with false heartwood are significantly different from the light white-gray color of sapwood or light ocher white or pale pink color of mature beech wood *Dzurenda (2023)*. The color difference of the wood of the false heartwood from the sapwood and mature wood is the reason for the removal of sawmill assortments from the production of bent furniture, sports tools and some construction and carpentry products.

The aim of the work is to determine the coordinates in the color space CIE  $L^*a^*b^*$  of the wood color of the round false heartwood of *Fagus sylvatica* L. The presented data expand knowledge about the color of European beech wood and supplement the missing data in the professional literature.

## MATERIALS AND METHODS

The measurement of the color of the wood of the false heartwood (Fig. 1) was performed on beech wood from Štiavnické vrchy (South-western Carpathians, Slovakia). 30 sections with a healthy round false heartwood were selected from each location. 5 pieces of blanks with dimensions of  $24 \times 38 \times 800\text{ mm}$  were randomly selected from the central lumber of each cutout.



*Fig. 1 View of the frontal cut of a beech wood with a false heartwood.*

In order to preserve the original color of the wood, the blanks were dried in an air-conditioned room at a temperature of  $t = 20\text{ }^{\circ}\text{C}$  and a relative humidity of  $\varphi = 60\%$  to a moisture content of  $w = 10 \pm 0.5\%$ . The bearing surfaces of dry blanks and false heartwood were machined on a horizontal plane milling machine FS 200.

The color of the wood of the beech blanks in the color space CIE  $L^*a^*b^*$  was measured with a Color reader CR-10 colorimeter (Konica Minolta, Japan). A D65 light source was used and the diameter of the optical sensing aperture was 8 mm. On the planed surface of the bed surface of each blank, the color was measured by random selection in five places (light, medium-dark and dark-colored wood).

The results of measurements of lightness values  $L^*$ , values on the basic chromatic coordinates of red color  $a^*$ , yellow color  $b^*$  of the color space CIE  $L^*a^*b^*$  are presented in the form of notation of the average value  $\bar{x}$  and standard deviation  $s_x$ .

$$x = \bar{x} \pm s_x [-] \quad (1)$$

The degree of dispersion of the measured values is assessed (evaluated) through the coefficient of variation:

$$v_x = \frac{s_x}{\bar{x}} \cdot 100 [\%] \quad (2)$$

The variety of colors of the wood of the false heartwood of beech wood is evaluated by means of a modified mathematical equation of the total color difference  $\Delta E_{sx}^*$  (ISO 7724-4):

$$\Delta E^* = \sqrt{(s_L)^2 + (s_a)^2 + (s_b)^2} \quad (3)$$

Where:  $s_L$ ,  $s_a$ ,  $s_b$ , standard deviations of statistically processed measured values on the coordinate of lightness  $L^*$ , red color  $a^*$  and yellow color of the wood  $b^*$  of the false heartwood.

## RESULTS AND DISCUSSION

The color and color shades of samples of dry beech wood with false heartwood type: round haertwood are shown in Fig. 2. The results of statistical processing of the measured color values of beech wood samples on the individual coordinates of the color space CIE  $L^*a^*b^*$  are shown in Table 1.

Table 1. Coordinate values of the color space CIE  $L^*a^*b^*$  describing the white color of dry beech wood.

| Beech wood, false heartwood        | Color coordinates |                |                |
|------------------------------------|-------------------|----------------|----------------|
|                                    | $L^*$             | $a^*$          | $b^*$          |
| Number of measurements [-]         | 150               | 150            | 150            |
| Measured value                     | $65.9 \pm 4.8$    | $12.7 \pm 2.1$ | $20.3 \pm 1.9$ |
| Standard deviation $s_x$ [-]       | 4.8               | 2.1            | 1.9            |
| Coefficient of variation $v_x$ [%] | 7.3               | 16.2           | 9.3            |



Fig. 2 The color of the false heartwood European beech

The dispersion of colors of the wood of the round false heartwood is from light brown-yellow to red-brown. The light brown-yellow color is identified in the color space CIE  $L^*a^*b^*$  by the value on the lightness coordinate  $L^* = 70.7$  and the values on the chromatic coordinates: red color  $a^* = 15.0$ , yellow color  $b^* = 22.2$ . The red-brown color of the wood of the false heartwood is described (indicated) by the values on the coordinates: lightness  $L^* = 61.1$ , red color  $a^* = 10.4$  and yellow color  $b^* = 18.4$ . Author *Dzurenda (2023)* also state similar values of the color of the false heartwood in his work.

The comparison of the limit values of the colors of false heartwood on the coordinates of the color space CIE  $L^*a^*b^*$  is in the form of a bar diagram shown in Fig. 3.

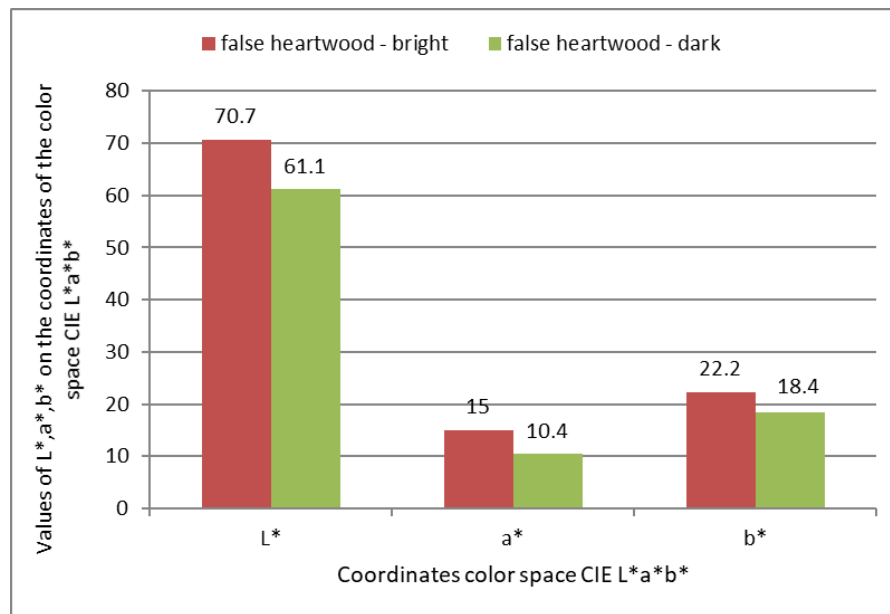


Fig. 3 Limit values of the colors of beech wood of false heartwood on the coordinates of the color space CIE  $L^*a^*b^*$ .

Dispersion of the wood color of the false heartwood, manifested by the variety of darkness and yellow-brown-red color shades of the wood, numerically characterizes the dispersion of the measured data expressed by standard deviations: lightness  $s_x = 4.8$ , red color  $s_x = 2.1$  and yellow color  $s_x = 1.7$ . Red color has the greatest influence on the color dispersion of false heartwood, whose value of variation coefficient  $v_x = 16.2\%$  is 2.2 times greater than the value of variation coefficient of lightness  $L^*$  and 1.7 times greater than the value of variation coefficient of yellow color  $a^*$ . The dispersion of the color of the wood of the false heartwood in the color space CIE  $L^*a^*b^*$  expressed in the form of the total color difference  $\Delta E^* = 5.5$ . Within the categorization of color difference, the stated value of the total color difference ranks the variance of the color of the false core wood in the category of visible color changes.

The colorful variety of the false nucleus is caused by the increased number of chromophores in polyphenolic compounds created by the oxidation processes of soluble carbohydrates and starch contained in the lumens of parenchymal cells. The length of time for the formation of the false heartwood also affects the color variety to a significant extent. Changes in the chromophoric system of the wood of the false heartwood compared to the chromophoric system of the mature wood are

manifested by a decrease in the absorption of electromagnetic radiation of wavelengths from 570 to 750 nm of red, orange and yellow colors, which, after being reflected from the surface of the wood, create a variety of shades of the color of the wood of the false core perceived by the human eye.

## CONCLUSION

The color of healthy European beech wood with false heartwood is identified in the color space CIE L\*a\*b\* by the value on the lightness coordinate  $L^* = 65.9 \pm 4.8$  and the values on the chromatic coordinates: red color  $a^* = 12.7 \pm 2.1$  a yellow  $b^* = 20.3 \pm 1.9$ .

The dispersion of the color of the wood of the false heartwood in the color space CIE L\*a\*b\* expressed in the form of the total color difference  $\Delta E^* = 5.5$ . Within the categorization of color difference, the indicated value of the total color, the difference between brown-yellow and red-brown color belongs to the category of visible color changes.

Red color has the greatest influence on the color dispersion of false core wood, whose value of variation coefficient  $v_x = 16.2\%$  is 2.2 times greater than the value of variation coefficient of lightness  $L^*$  and 1.7 times greater than the value of variation coefficient of yellow color  $a^*$ .

By delineating the color boundaries of the round false heartwood beech wood in the color space CIE L\*a\*b\*, it enables the identification of false heartwood by color and creates space for designers to model color compositions of sapwood and false heartwood beech wood depending on the color darkness, color and color shades Šustek (2022).

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**Streszczenie:** W pracy dokonano analizy barwy suchego drewna fałszywej twardzieli w przestrzeni barw CIE L\*a\*b\*. Barwa suchego drewna buka zwyczajnego z fałszywą twardzią odbierana przez ludzkie oko jest w szerokiej gamie odcieni od jasnej przez brązowo-żółtą do czerwono-brązowej. Kolor drewna fałszywej twardzieli w przestrzeni kolorów CIE L\*a\*b\* mierzono za pomocą kolorymetru Color reader CR-10 (Konica Minolta, Japonia). Zastosowano źródło światła D65, a średnica optycznej szczeliny detekcyjnej wynosiła 8 mm. Wyniki obróbki statystycznej zmierzonych wartości barwy suchego drewna bukowego, fałszywej twardzieli na struganej powierzchni identyfikuje się poprzez wartości na współrzędnej jasności  $L^* = 65,9 \pm 4,8$  oraz na współrzędnych chromatycznych: barwa czerwona  $a^* = 12,7 \pm 2,1$  i żółta  $b^* = 20,3 \pm 1,9$ . Kolorystykę szarości i żółto-brązowo-czerwonych odcieni drewna fałszywej twardzieli określa się liczbowo całkowitą różnicą barwy  $\Delta E_{sk}^* = 5,5$ . Przedstawione wartości barwy drewna bukowego fałszywej twardzieli oraz zdefiniowanie granic barwnych w przestrzeni barw CIE L\*a\*b\* stwarzają projektantom przestrzeń do modelowania różnorodności kolorystycznej kompozycji i wyrobów budowlanych oraz stolarskich wykonanych z drewna bukowego.

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