WOOD RESEARCH
53 (1): 2008
119-124

SHORT NOTICE

IDENTIFICATION OF DISCOLORATION OF BEECH WOOD IN CIELAB SPACE

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ABSTRACT

Beech wood is processed also in special area of wood industry where accentuate is on color. It is expected the color has a standard value without defects. Precise and fast determination of beech color can be useful for sorting of e.g. floorings. In the article we describe the method of recognition of such color.

KEY WORDS: beech wood, color, CIELAB space, method, defect.

INTRODUCTION

Beech *(Fagus sylvatica L.)*, in consequence of its properties, is processed in many branches of wood industry. Beech wood utilization can be found in the production of consumption articles, sporting requisits, furniture, and other high value products. In these areas emphasis is put on beech color as a surface property which value is standard without unusual coloration.

The aim of the work is to introduce the method of identification of beech wood unusual coloration.

Beech wood color was studied in several works. Katuščák and Kučera (2000) investigated color of 25 temperate wood species and beech wood was among them. They published results in CIELAB space. The results of similar work are presented by Babiak et al. (2002) for 18 species and Babiak et al. (2004) for 19 species with beech among them. The color homogenization of different wood species including beech was the aim of Tolvaj et al. (2002) and Molnár and Tolvaj (2004). Babiak et al. (2004) described the color change of beech wood during microwave drying. Fast grading of surfaces that utilized statistics of color coordinates for various materials, among which wood belongs, in CIELAB space is described by López et al. Beech parquets grading was also subject of interest of Vienonen, Asikainen and Eronen (2002). These authors graded beech parquets according the reflection in visible range.

MATERIAL AND METHODS

Color space CIELAB is defined by three coordinates L*, a*, b*. Lightness L* is directly proportional to luminance (Habel et al. 1995) and characterizes on the assumption of zero values of next two coordinates the gray colors. If the value of lightness is zero then the color is black. The maximum value of lightness is 100 for white color. Coordinate a* characterizes hues between red (positive values of a*) and green (negative values of a*). Coordinate b* describes hues between yellow (positive values of b*) and blue (negative values of b*). The plane a*b* in polar coordinates is defined by hue h_{ab} (the angle with positive axis a*) and by saturation C^*_{ab} (distance from coordinate L*).

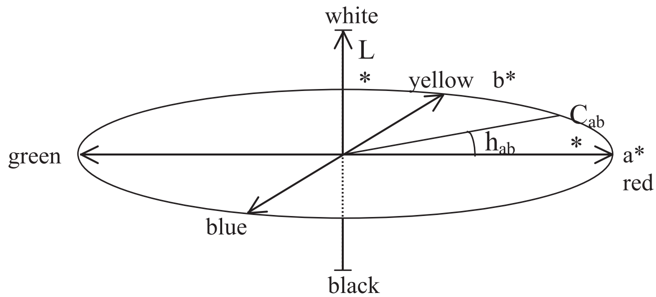

Fig. 1: CIELAB color space (constant saturation).

The next equation defines the change of color in CIELAB space:

$$E_{ab} = \sqrt{(L*_1 - L*_2)^2 + (a*_1 - a*_2)^2 + (b*_1 - b*_2)^2} \qquad (1)$$

It is possible to use this equation for the modeling of wood color space. The wood color is a heterogeneous quantity and in CIELAB space it represents a cluster of data. We interpret relationship (1) as surface of sphere with center in color 1 and radius E_{ab} (Hrčka a Babiak 2004). Let's put the center of sphere to mean of beech wood color coordinates $[\bar{L}*, \bar{a}*, \bar{b}*]$.

We determine the radius as:

$$E_{ab}^2 = \frac{(L* - \bar{L}*)^2 \sigma_{L*}^2}{\sigma_{L*}^2} + \frac{(a* - \bar{a}*)^2 \sigma_{a*}^2}{\sigma_{a*}^2} + \frac{(b* - \bar{b}*)^2 \sigma_{b*}^2}{\sigma_{b*}^2} \qquad (2)$$

where $\sigma_{L*}^2, \sigma_{a*}^2, \sigma_{b*}^2$ are coordinates' variances.

Let's suppose normal distribution of beech wood color coordinates, then:

$$E_{ab}^2 = u^2 \left(\sigma_{L*}^2 + \sigma_{a*}^2 + \sigma_{b*}^2\right) \qquad (3)$$

u is critical value of uniform normal distribution

This consideration is broadened by consideration with ellipsoid with the center in the mean of color coordinates. Its axis are identical with directions of eigenvectors of data co-variation matrix:

$$1 = \frac{(q* - \overline{q}*)^2}{3u^2 \mathring{u}^2_{q*}} + \frac{(r* - \overline{r}*)^2}{3u^2 \mathring{u}^2_{r*}} + \frac{(s* - \overline{s}*)^2}{3u^2 \mathring{u}^2_{s*}} \quad (4)$$

where $(q*, r*, s*)^T = V^{-1}(a*, b*, L*)^T$ (5)

V^{-1} is matrix of eigenvectors of co-variation matrix, $\overline{q}*, \overline{r}*, \overline{s}*$ are average values of transformed coordinates, $\sigma^2_{q*}, \sigma^2_{r*}, \sigma^2_{s*}$ are coordinates' variances.

The material used was beech radial board of dimensions of 25x250x1000 mm^3 (TxRxL) with unusual color with shape as longitudinal narrow streak. The board was dried by microwave drying. Daily during 10 days we took sample 25x250x100 mm^3 , at which we measured color by digital camera KODAK 256 Zoom under illumination D65 – Atlas TLL 1200 using the method described by Babiak et al. (2002). One observation represented area of 4,5x4,5 cm^2. Samples with unusual coloration were distinctly dark brown easy to distinguish from slightly red beech wood.

RESULTS AND DISCUSSION

Tab. 1 contains statistical data color coordinates of beech wood in CIELAB space.

Tab. 1: Color coordinates of beech wood in CIELAB space

	a*	b*	L*	$C*_{ab}$	h_{ab}
mean	3,85	9,36	90,33	10,16	67,47^o
var. coefficient/ [%]	23,22	13,33	1,30	11,58	8,33

Fig. 2 contains histogram of distance E_{ab} from average values of beech wood coordinates without unusual coloration.

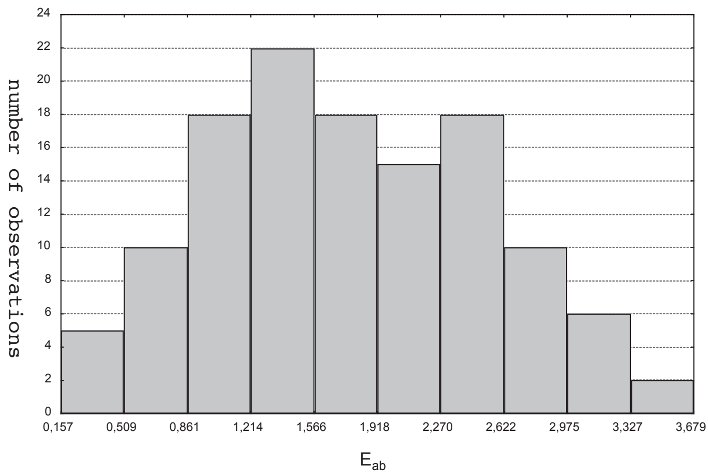

Fig. 2: Histogram E_{ab} for beech wood

Let critical value of the color coordinates be 1,7. Then radius of the sphere is equal to 3.29. Fig. 3 contains histogram with unusual beech wood coloration.

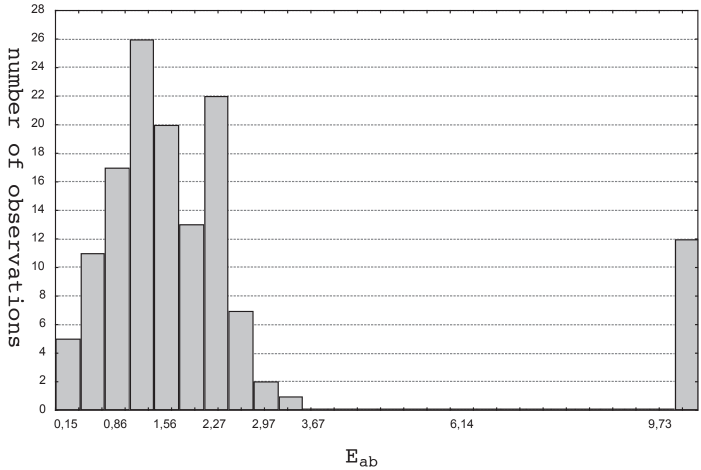

Fig. 3: Histogram E_{ab} for beech wood with unusual color

The color coordinates distance of unusual coloration exceeded value of sphere radius, what is documented in histogram in Fig. 4.

The ellipsoid appends consideration with sphere. The transformation matrix V^{-1} is:

$$V^{-1} = \begin{pmatrix} -0,297358 & 0,670042 & 0,680163 \\ -0,638859 & -0,669044 & 0,379788 \\ 0,709533 & -0,321595 & 0,627008 \end{pmatrix} \tag{6}$$

The change of the coordinate system is due to its turning around the origin and the directions of new coordinates are the directions of the eigenvectors of the co-variation matrix. Then ellipsoid is (with the same critical value as sphere) is:

$$1 = \frac{(q^* - 56,97)^2}{4,60} + \frac{(r^* + 32,73)^2}{3,24} + \frac{(s^* - 62,81)^2}{0,82} \tag{7}$$

Fig. 4 enables us to distinguish if color data are inside of ellipsoid.

Usual colored samples fall to ellipsoid area. Unusual colored samples are outside of ellipsoid. Usual colored samples uniformly edge the ellipsoid. Unusual colored samples directs from part of ellipsoid and we can conclude, that on appropriate alpha level don't fall into the ellipsoid.

The data of lightness in this work are the highest from those in literature review. Vice versa coordinates a* and b* are the smallest. These facts can be explained by mixing of striking and return light, which together fall into sensor.

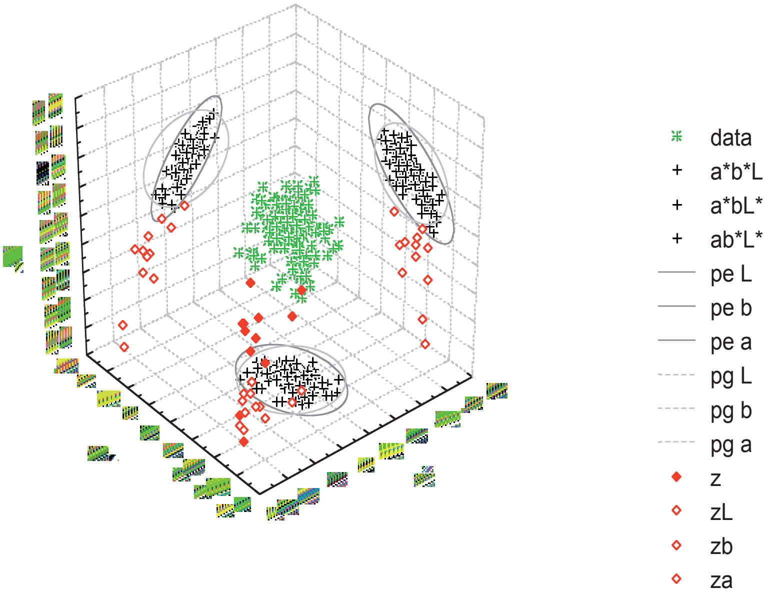

Fig. 4: Beech wood color (also with unusual color) in CIELAB space, pe– surface of the ellipsoid; pg – surface of the sphere; L, a, b – constants; z - coloration

CONCLUSION

In the article we showed a possibility of identification of unusual beech wood coloring with elliptical model of beech wood color in CIELAB space. Distribution of color data around of ellipsoid is equal for usual beech wood coloration. Unusual coloration is as one side buckling from ellipsoid. And this is the evidence for convenience of elliptical model for identification of unusual beech wood coloration. The results can be used for pass/fail decisions during sorting and grading of beech wood.

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