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SHORT NOTE

CORRELATION BETWEEN HUE ANGLE AND LIGHTNESS OF WOOD SPECIES GROWN IN HUNGARY

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ABSTRACT

The warmth and beauty of wood are mainly defined by its colour. This individual attribute of wood species, among others, provides emotive comfort for humans since ancient times. During this research, the colour data of 17 wood species growing in Hungary were analysed. The specific goal of the work presented here was to investigate the correlation between colour lightness and hue. Results revealed good linear correlation between lightness (L*) and hue angle (h*) for most of the species involved in the examination. Only black locust and oak samples (having high extractive content) demonstrated lack of correlation between the above mentioned parameters.

KEYWORDS: Wood, colour, lightness, hue angle.

INTRODUCTION

Colour is a very complex phenomenon. It can be described in general terms like red, green black or white. However, for more precise identification, their hue, saturation or chroma and lightness/brightness are used. In 1976 the Commission Internationale de l'Eclarige (C.I.E) proposed a specific scale for proper classification of colours, and since then it is used for scientific and industrial purposes. The CIE L*;a*;b* defines a colour space by two perpendicular axis (a* and b*) that are orthogonal to the vertical axis of lightness (L*). In the polar form of this colour space the hue is measured by angles (h*) and the chroma or saturation (C*) is given along the radius of the colour circle. Fig. 1 shows the schematic representation of these measurements.

The hue angle for most of the natural woods in the CIE L*;h*;C* colour sphere is between 45° and 90° which is perceived by human eyes somewhere between yellow and brown. There are only a few extremely dark species with hue angle below 45°. This warm image comforts the observer and the little colour deviation between earlywood and latewood does not cause too much stimuli and fatigue. Furthermore, woody cells contain lots of micro mirrors aligned parallel to the grain. Gloss from these micro mirrors gives us more elegant, soft and natural texture than plastics and metal (Masuda 2001).

The colour of wood is mainly influenced by the extractive contents of the species. Additionally, as Rinnhofer et al. (2003) reported, the visual colour of wood depends on the incidence angle of illumination as well. The colour of wood is sensitive to heat and light radiation (Tolvaj et al. 2010, Dianišková et al. 2008, Kubovský and Babiak 2009, Kačík and Kubovský 2011).

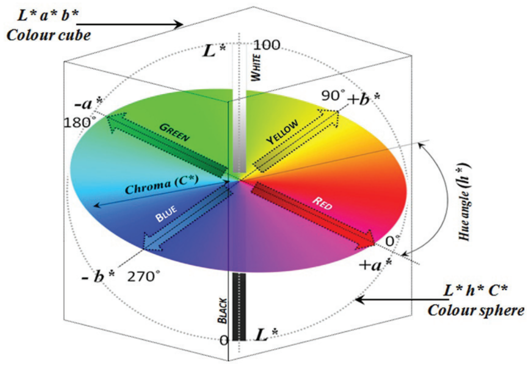

*Fig. 1: Schematic representation of the CIE L*a*b* and L*h*C* colour measurements.*

In both the Cartesian (L*;a*;b*) and polar (L*;h*;C*) systems, three coordinates identify a particular colour. Although these measures for each system are theoretically independent, for certain cases they might be correlated according to the literature. Tolvaj and Németh (2008) reported linear correlation between the lightness (L*) and hue angle (h*= arc tan b*/a*) of black locust having modified colour by steaming. Light-irradiated wood samples were analysed by Tolvaj and Mitsui (2010). Their results indicated significant linear correlation between lightness (L*) and hue angle (h*).

The objective of this work was to investigate a range of wood species in concern of correlation between their hue and lightness.

MATERIAL AND METHODS

The study included the evaluation of natural colours for 17 wood species grown in Hungary. Tab. 1 lists the analysed samples along with the average measured and computed colour coordinates. Appraisal happened on prepared radial surfaces (i.e., LR plane). Additionally, for five species, sapwood and heartwood specimens were examined as well. The populations, including sap- and heartwoods for certain genera, were represented by 20 samples. Measurements of 10 points for each sample were performed. This resulted 200 data points by species. Tab. 1 lists the averages of these parameters. Statistical process included linear regression and R^2 analyses with normality and equal variance tests at 95 % confidence level (α = 0.05). The colour measurements were carried out with a colorimeter (Konica-Minolta 2600d). The L* (lightness), a* (redness), b* (yellowness), h* (hue angle) colour coordinates were measured and calculated based on the D_{65}

illuminant and 10° standard observer with a test-window diameter of 8 mm.

Tab. 1: Average experimentally measured and computed colour parameters of selected species.

SPECIES		L*		a*		b*	
		AVE	ST.DEV.	AVE.	ST.DEV.	AVE.	ST.DEV.
1	Alder (*Alnus glutinosa* L.)	79.29	1.26	8.32	0.72	22.09	1.02
2	Ash (*Fraxinus excelsior* L.)	82.65	1.30	4.44	0.45	19.43	1.26
3	Beech (*Fagus silvatica*)	81.55	0.60	5.26	0.19	17.15	0.32
4	Beech red heart	69.91	3.45	9.63	2.87	20.19	0.86
5	Birch (*Betula pendula* Roth)	75.51	2.14	6.53	0.76	17.33	0.67
6	Black locust (*Robinia pseudoacacia* L.)	70.14	1.80	4.18	0.66	26.60	2.43
7	Cherry (*Prunus avium* Ehrh.)	73.69	1.93	10.45	0.63	22.72	1.26
8	Cherry (*Prunus serotina* Ehrh.)	70.15	1.52	10.63	1.48	20.92	1.11
9	Douglas fir (*Pseudotsuga menzesii*) sapwood	76.59	1.42	8.14	0.65	24.99	0.96
10	Douglas fir (*Pseudotsuga menzesii*) heartwood	73.62	1.58	11.72	0.49	27.58	0.81
11	Hornbeam (*Carpinus betulus* L.)	82.20	0.72	3.99	0.13	18.20	0.42
12	Larch (*Larix decidua* L.)	75.82	1.24	11.25	0.75	26.07	0.71
13	Lime (*Tilia cordata* Mill.)	84.02	0.71	3.79	0.29	19.28	0.56
14	Maple (*Acer pseudoplatanus* L.)	84.02	0.91	3.93	0.28	15.27	0.64
15	Oak (*Quercus petraea*) szapwood	81.83	1.12	3.81	0.34	22.12	0.45
16	Oak (*Quercus petraea*) heartwood	70.62	1.33	7.15	0.22	19.78	0.38
17	Poplar (*P. x euramericana Pannonia*)	83.40	2.82	4.05	0.89	17.34	0.66
18	Scots pine (*Pinus sylvestris* L.) sapwood	82.10	1.72	5.68	0.84	22.54	1.10
19	Scots pine (*Pinus sylvestris* L.) heartwood	77.43	1.15	9.95	0.87	26.46	0.95
20	Spruce (*Picea abies* Mill.)	86.08	0.69	3.03	0.21	17.39	0.50
21	Turkey oak (*Quercus cerris* L.) sapwood	80.97	1.12	4.24	0.32	18.18	0.51
22	Turkey oak (*Quercus cerris* L.) heartwood	68.14	2.36	4.91	0.84	16.12	0.72

RESULTS AND DISCUSSION

Fig. 2 demonstrates the changes of hue angles (h*) as a function of lightness (L*). After elimination of outliers (empty symbols on Fig. 2), regression analysis revealed strong correlation between L* and h* values. The regression equation turned out to be: $h^* = -10.57 + 1.05\ (L^*)$ with the coefficient of determination $R^2 = 0.90$. This confirmed that most of the wood species grown in Hungary have significant association between their lightness and hue.

The eliminated outliers included: Black locust (*Robinia pseudoacacia*), Oak (*Quercus petraea*) sap- and heartwood, Turkey oak (*Quercus cerris*) heartwood. The high extractive content of these species certainly justify their removal from the analysis. For instance, black locust has the highest extractive content among the trees grown in Europe. The yellowish colour of this hardwood is due to its high robinetin content.

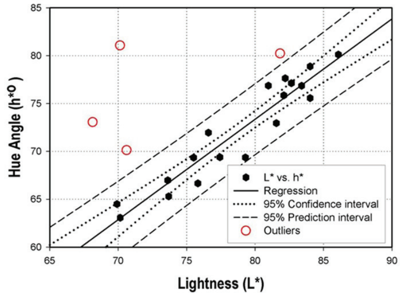

Fig. 2: Regression analysis of the colorimetric data pairs, R^2=0.90.

Furthermore, all of the eliminated outliers were ring-porous angiosperms where the large vertically cut vessels may have influenced the lightness under incident illumination.

It does appear that except for a few species, the lightness of wood is a good predictor of its hue. The developed prediction equation numerically supports the general observations that light wooden colours are more yellowish and dark species are rather brownish. Our finding gives the possibility to monitor the colour alteration effects of a process, measuring only the lightness. One possible process can be the thermal treatment of wood as it has already introduced in a previous paper (Tolvaj and Németh 2008) in case of steaming. The next process could be the thermowood production.

Lightness measurement is a more simple process than the complex colour assessment. The lightness is determined only by the "Y" CIE tristimulus value therefore it is enough to measure the Y value using the proper colour filter.

CONCLUSIONS

Results revealed good linear correlation between lightness (L*) and hue angle (h*) for most of the species involved in the examination. The regression equation turned out to be: h* = -10.57 + 1.05 (L*) with the coefficient of determination R^2 = 0.90. Only black locust and oak samples (having high extractive content) demonstrated lack of correlation with the above mentioned parameters.

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