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MEASURING AND ANALYSIS COLOUR OF BIRCH WOOD IN DIGITAL PICTURE

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Abstract:
The aim of the research was to verify a new method of measuring the colour of wood. The method was designed to automate wood colour measurement. In the experiments birch wood was used, which was heat treated with saturated water steam. Nikon D3200 camera was used in conjunction with the MATLAB program to implement the method. The assessments were conducted in the colour space of CIE *L* a* b**. The measured values confirmed the decrease in lightness from natural to thermally modified wood. The trends of the colour values *a** and *b** were the same as those reported by the authors who conducted experiments with birch wood. Differences were found in the magnitude of the measured chromatic component *a** values. It will be necessary to verify the above facts and determine the reasons for these differences by measuring the colour of other wood species.

Key words: *birch wood, heat treatment, CIE L* a* b*, wood colour, photography*

INTRODUCTION

Wood is an important natural renewable material [24], and the possibilities for its use are tremendous. Wood is an omnipresent material. It is as important a building material for the interior as it is for the exterior. Wood is used in the furniture industry, and it is an important industrial raw material in the paper industry as well as the power industry [19]. The possibilities of its use are constantly expanding on the basis of its examination by modern techniques [20]. It is a natural product, which is why its basic properties vary. They are influenced by tree species, locality of origin (altitude, soil type, lighting conditions), age of a tree etc. Colour is one of the properties taken into account when considering the choice of wood [2, 15, 17, 22]. The colour belongs to the macroscopic features of the woody species and thus determines the appearance of tree species [1, 6]. It significantly influences the appearance of wood and is one of the decisive starting points of wood type recognition. The colour of the wood is determined by the chemical composition of the wood, in particular by organic substances: cellulose, hemicellulose and lignin [2]. Extractive substances have a significant influence on the colour of wood, even though their proportion in the composition does not exceed 10% [7]. Colour is important when perceiving and evaluating wood by information technologies. If colour of wood in processing has to be analysed using information technologies and digital image processing methods, it is advisable to automate the wood colour identification.

In practice, manufacturers often encounter requirements to change or modify the original wood colour. There can be various such requirements, such as increasing the colour homogeneity, removing colour spots, highlight the colour shade or imitating others wood, e.g. exotic wood [23]. The change of the colour of wood or editing of colour can be achieved by thermal modification of the wood [25]. Thermal wood modification also affects the chemical composition of wood. This makes the wood less susceptible to insect and antifungal. Therefore, it is not necessary to apply insecticidal and antifungal preparations to the resulting wood product, which has a favourable economic impact on woodworking.

Currently, it is possible to use several types of heat treatment. Different methodologies of thermal modification have been patented in several countries in Europe and in Canada. Some examples include ThermoWood in Finland – which uses air, PlatoWood in Germany, which uses oil, and Rectification in France, which uses inert gases [26]. In our experiment used wood samples were steamed with saturated water steam.

The technological process of thermal modification of wood in saturated water steam consists of several phases. It is advisable to flush the machine with steam before the wood is treated to remove air from the working chamber. Then the wood is placed in a space filled with saturated water steam. Subsequently, the temperature starts increasing. It is advisable that the wood is heated to the required temperature in the shortest possible time [8]. Once the desired temperature is reached, the wood is exposed to water steam. Various visualization methods can be used to gain an overview of the temperature distribution in wood samples [5]. The temperature and water steam exposure time depend on the requirements for the properties of the treated wood. After the required time has elapsed, the process of simultaneous drying and cooling of the wood takes place. This process usually ends when the wood reaches a temperature of 20°C [21]. Due to the effect of water steam, the properties of wood as well as its chemical composition change. This process also results in change of colour of wood [23].

There is a requirement for accurate colour measurement when working with wood. Based on the gradual development and validation of the methodologies used in 1976, the International Commission on Lighting – CIE (Commision Internationale de l'Éclairage) proposed to use colour spaces CIE *L* a* b** and CIE *L*u*v**. The colour space CIE *L* a* b** is most often used to determine the colour of wood in research as well as in technical practice because it is close to human perception of colour [3]. The colour space CIE *L* a* b** is characterized by three parameters: *L**, *a**, and *b**. The vertical axis L* represents the lightness (100 = white, 0 = black). The chromatic axes are represented by the *a** and *b** components. The *a** axis represents the shift from green (-) to red colour (+), and the b* axis represents the shift from blue (-) to yellow (+) [1, 9, 13]. Apparatuses that are commonly used to measure colour are called spectrophotometers or colorimeters [1]. In addition, it is also possible to encounter colour measurement using optical colour sensors that have a multipurpose use. In order to be able to control the results from commercially available apparatuses and to automate the wood colour evaluation process, a new method of colour measurement has been proposed based on the processing of photography of wood species using programme MATLAB. If the results will be analogous to conventional colour measurement procedures, then this method can be used to create a multi-purpose wood surface treatment workplace. Rapid and accurate transformation of measured values into information technology, shortening of evaluation time and automation of activities (labour saving) will also bring economic savings.

METHODOLOGY OF RESEARCH

Birch wood (Betula Pendula) was selected for verification of the functioning of the proposed colour measurement methodology. Birch belongs to a group of pale wood species [7]. Boards with a thickness $h \leq 40$ mm were cut from wood [10]. The prepared lumber was divided into four groups. The first group remained natural and the other three were heat treated with saturated water steam based on different working modes. The heat treatment was carried out in the pressure autoclave: APDZ 240 (Himmasch AD, Haskovo, Bulgaria) in the company Sundermann Ltd. Banská Štiavnica, Slovakia. The operating modes of the heat treatment of birch timber with saturated water steam are shown in Figure 1.

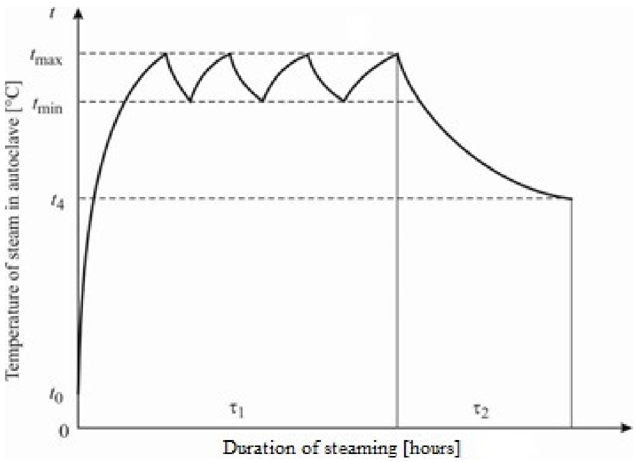

Fig. 1 Mode of colour modification of birch wood with saturated water steam

The technical parameters of each mode are given in Table 1 [10].

Table 1
Technical parameters

Modes	Temperature of the saturated water steam [°C]			Duration technological process of thermal treatment of wood τ [hours]		
	t_{min}	t_{max}	t_4	$τ_1$ – stage I	$τ_2$ – stage II	Total $τ_1+τ_2$
Mode I (M1)	102.5	107.5	100			
Mode II (M2)	122.5	127.5	100	6.0	1.5	7.5
Mode III (M3)	132.5	137.5	100			

The change in colour can be seen in the Figure 2.

Fig. 2 Colour of birch wood: a, natural; b, Mode I; c, Mode II; d, Mode III

The camera Nikon D3200 (Nikon, Tokyo, Japan) (Figure 3a) is a single-lens reflex that is equipped with a 4.2 mega pixel sensor complementary metal-oxide-semiconductor (CMOS) and an effective image processor EXPEED 3. The images were captured in full high definition quality; the overall number of pixels was 24.7 million. The reference standard with the precise colour value of the sample in CIE XYZ (Y = 83.7) was aligned with the assessed sample to eliminate the mistakes caused by the change in colour conditions during the capturing of the images.

Subsequently, the colour coordinates of all points in the marked area were processed andexpressed in the colour model of RGB. These values can then be recalculated into the colour space of CIE *L* a* b** and CIE XYZ. The calculated values were exported into an MS Excel program (Microsoft, Redmond, WA, USA) [11].

Fig. 3 a) camera Nikon 3200, b) application to calculate colour components

The colour determination process itself consists of several steps. The first step was to select a photo of the wood to be evaluated using the Open Picture button (Figure 3b). Then it was calibrated based on the sample already prepared in the program, which may be white or black. This eliminated the influence of different light conditions. Calibration was performed based on the white colour with the White colour calibration button. The differences found in white colour were used to determine the coefficients. These coefficients adjusted the colour of all pixels in the picture. Then the area for which the colour would be evaluated were determined in the picture. This selection is made via the Colours button. The results calculated bythe program are listed in three different ways: colour model RGB, components of colour space CIE *L* a* b** and components of colour space CIE *XYZ* [16].

RESULTS OF RESEARCH

The measurement was performed at the temperature of 23°C. Twenty-five places were selected to determine the colour of the natural sample as well as the samples treated in each mode (Table 2).

The main criterion for their selection was the homogeneity of the colour of the sample. Measurements were not made in places where there were defects of wood species that had already occurred during its growth or during its preparation.

The measurements and calculations were executed according to ISO 11664-2 (2007) [12], ISO 11664-4 (2008) [13] and ISO 11664-6 (2014) [14] standards. The end results were the values of the individual components of the CIE *L* a* b** colour space (Fig. 4, 5, 6). Values measured at different locations across multiple samples were averaged and then evaluated by the program MS Excel a Statistica 12 (Statsoft, Tulsa, OK, USA).

Table 2
Measured values

NIKON D3200												
	Natural			**Mode I**			**Mode II**			**Mode III**		
No.	*L**	*a**	*b**	*L**	*a**	*b**	*L**	*a**	*b**	*L**	*a**	*b**
1	89.4	1.8	15.9	79.6	4.0	19.7	67.8	8.9	23.0	63.5	10.7	21.7
2	89.9	2.5	16.1	79.7	1.5	24.8	67.2	10.9	24.1	60.9	10.9	22.1
3	92.9	1.7	20.4	82.0	3.6	16.9	66.1	5.8	21.1	62.7	9.1	22.6
4	83.0	1.2	21.8	76.2	4.6	21.3	69.3	8.0	23.7	62.5	11.1	24.3
5	86.1	0.4	18.7	79.8	5.6	16.7	64.2	8.3	23.2	63.8	8.7	21.9
6	88.7	0.8	21.5	77.5	2.3	19.6	73.2	8.3	23.0	65.0	11.0	22.8
7	85.9	0.9	15.0	83.0	5.1	16.8	69.9	9.1	22.8	56.6	11.6	21.9
8	91.9	1.6	19.3	77.8	2.3	19.5	71.6	7.8	22.5	63.6	9.5	22.3
9	92.5	1.5	19.5	76.7	4.4	21.0	69.7	6.6	22.1	64.2	9.3	24.4
10	86.3	2.0	16.2	80.2	3.4	14.1	73.1	7.7	23.5	62.2	11.8	23.9
11	81.0	0.9	13.0	81.6	5.0	15.6	75.6	7.3	22.3	62.2	11.1	24.3
12	92.1	1.0	21.3	79.0	3.1	22.1	70.5	4.8	19.3	63.2	8.2	24.2
13	92.1	1.2	21.2	81.1	4.4	20.9	73.2	8.2	23.1	64.0	10.3	24.7
14	86.2	1.7	21.0	79.0	3.4	17.7	63.1	7.8	20.6	61.7	9.3	23.6
15	83.6	1.2	18.4	82.5	3.4	21.9	75.1	6.5	21.5	61.3	10.6	22.3
16	78.1	1.5	20.4	81.9	5.0	22.1	73.8	9.0	22.8	56.3	10.9	21.5
17	88.7	1.8	20.5	79.7	4.3	22.6	68.9	6.9	21.1	56.6	10.3	22.3
18	88.6	1.7	19.3	78.4	3.0	20.3	72.3	5.3	21.0	64.0	7.8	22.1
19	84.3	1.6	20.9	79.8	2.8	23.5	74.6	8.0	22.5	58.8	7.6	20.7
20	85.0	1.5	20.2	82.4	5.3	22.2	71.3	7.4	23.7	59.9	10.3	21.5
21	87.4	1.6	22.5	79.7	5.4	20.9	72.4	8.0	23.7	60.3	11.0	21.3
22	86.9	1.5	22.4	78.7	4.2	22.6	70.5	8.7	24.3	56.7	7.9	18.7
23	85.4	1.6	22.6	78.5	5.8	20.0	68.2	8.9	24.1	62.8	10.0	21.3
24	80.9	0.9	21.4	79.6	4.0	19.7	72.0	9.5	24.9	65.1	10.4	22.0
25	88.1	1.3	22.3	74.4	4.5	21.1	66.8	9.3	24.7	54.5	10.4	20.0

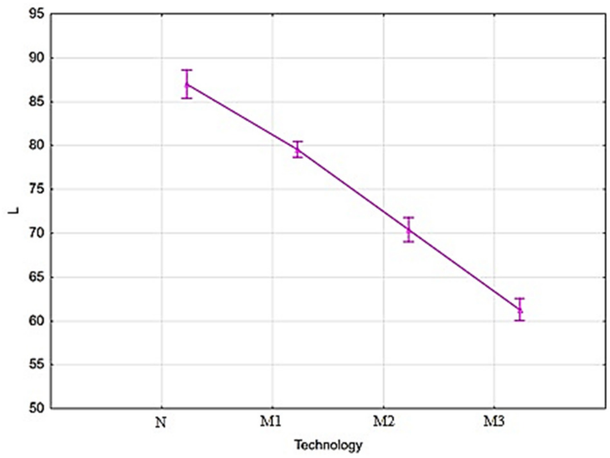

Fig. 4 Lightness L*

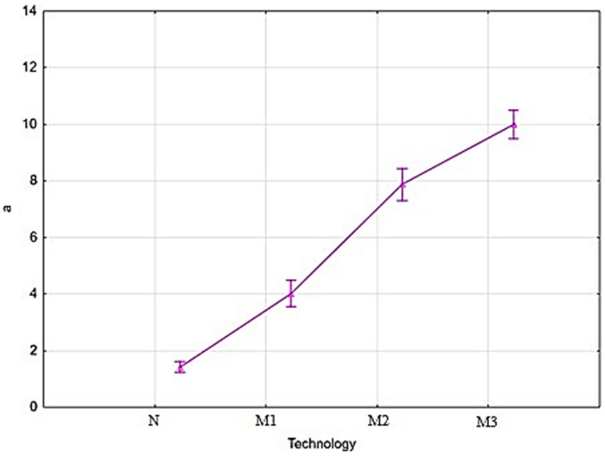

Fig. 5 Colour coordinates a*

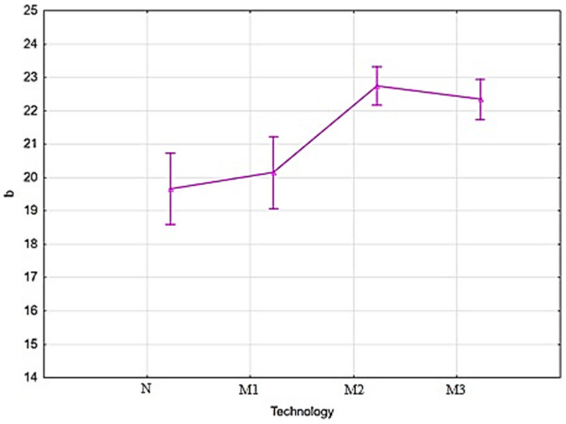

Fig. 6 Colour coordinates b*

When evaluating the amount of colour change of individual samples, colour space CIE L^* a^* b^* was used. The Euclidean distance ΔE, which expresses the total colour change [18], was used to compare the individual colour shades. The value for Δ*E* was calculated according to Eq. 1:

$$\Delta E = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \quad (1)$$

The classification of the overall colour change was carried out based on assessment guidelines by Cividini et al. [4] (Table 3, 4, 5).

Table 3

The Criteria to Assess the Colour Change

ΔE < 0.2	Invisible changes
0.2 < ΔE < 2	Small changes
2 < ΔE < 3	Colour changes visible by high quality filter
3 < ΔE < 6	Colour changes visible by medium quality filter
6 < ΔE < 12	Distinct colour changes
ΔE > 12	A different colour

Table 4

Assessment of Colour Change

	Mode	Colour change ΔE	Assessment
Birch	I	9.08	Distinct colour changes
	II	18.60	A different colour
	III	27.52	A different colour

Table 5

Data evaluation in program the Statistica 12

	MODE	N	M1	M2	M3
*L**	average	87.00	79.55	70.42	61.29
	standard deviation	3.87	2.08	3.32	3.06
	standard error	0.77	0,42	0.66	0.61
	confidence interval -95%	85.40	78.69	69.05	60.03
	confidence interval +95%	88.60	80.41	71.79	62.55
*a**	average	1.42	4.01	7.88	9.99
	standard deviation	0.44	1.13	1.38	1.21
	standard error	0.09	0.23	0.28	0.24
	confidence interval -95%	1.24	3.55	7.31	9.49
	confidence interval +95%	1.60	4.48	8.45	10.49
*b**	average	19.67	20.15	22.75	22.34
	standard deviation	2.59	2.60	1.40	1.47
	standard error	0.52	0.52	0.28	0.29
	confidence interval -95%	18.60	19.07	22.17	21.73
	confidence interval +95%	20.73	21.22	23.33	22.95

DISCUSSION

The measurement results confirmed that the original pale colour of birch wood darkened. The lightness L^* of wood species decreased considerably due to thermal treatment. The average value of the natural sample that was not heat treated was $L^* = 87$. The lightness L^* values gradually decreased for other mode: Mode I. – 79.5, Mode II. – 70.4, Mode III. – 61.3. When comparing the above data with the results reported by Dzurenda [10], who used the Color Reader CR-10 (Konica Minolta, Japan) for colour measurement, it can be seen that the L^* decrease is identical. The difference is that the values in each mode are shifted by an average of 5 units. Compared to the experiment made with birch wood, which was thermally treated with ThermoWood technology [2], a decrease in lightness L^* can be seen. In this case, specific numerical values cannot be compared because Barcik at al. [2] did heat treatment with significantly higher temperatures. The colour component a^* increased depending on the temperature in each treatment mode. The increase between natural timber and timber processed in Mode I averaged $\Delta a^* = 2.6$ and between Mode II and III $\Delta a^* = 2.1$. The highest increase was between the samples treated with Mode I and II, namely 3.9. This difference can also be seen in Figure 5. Compared to the results of other authors, the chromatic value a^* is lower in our measurements. Because of this, it will be necessary to carry out colour measurements of our samples with other procedures, possibly with commercial apparatuses and to find out what caused the deviation. The increase values in chromatic component a^* is also confirmed in experiments conducted by Dzurenda [21] and Barcík [2]. The change in chromatic component b^* is not significant. The increase in chromatic component b^* between natural wood and others modes ranges from

1% to 2%. Between Mode II and Mode III there is a slight decrease in chromatic component *b** values. These small changes, as well as the alternation of the rise and fall of the chromatic component *b**, are also confirmed by measurements of Dzurenda [10] and Barcík [2].

The total colour change ΔE* was evaluated for all thermally modified samples of birch relative to the untreated birch samples. At the beginning of the calculation, values of lightness and individual chromatic components are measured. The colour change between natural birch wood and birch wood treated at Mode I is visible and according to the assessment by [4] big colour change can be observed. In the other two modes, the colour change is already very significant and it can be stated that it is a different colour. It can be assumed that at higher temperatures the colour change would be even more significant.

Such a colour change depending on the technology of thermally modified wood can be used in the furniture industry. If customer requires certain wood colours, the wood can be thermally modified according to the given technology with the result of wood darkening. In this way, the resulting product does not need to be additionally coated for the desired shade, which reduces the economic cost of treating wood with colored glazes.

CONCLUSION

Based on the experiment carried out with a new method of measuring wood colour on birch wood samples with a thickness *h* < = 40 mm, which have been heat treated with water steam, it can be concluded that the colour of the birch wood darkened. The level of dark colour depends on the water steam temperature and the duration of exposure of the birch sample to the water steam. The values measured by our method are comparable with the results of other authors. The measured values of the chromatic component *a** by our method are different with respect to the measurements of other authors. Although the overall course of chromatic component *a** is analogous to the results of other authors, the measurements will be repeated on samples of other wood species to determine the cause of the deviation.

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