Correlation Between Hue-angle and Colour Lightness of Steamed Black Locust Wood

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Abstract – Black locust (*Robinia pseudoacacia L.*) wood was steamed at wide range of temperature (75-130°C) applying long (22 days) steaming time. The colour change was monitored by CIE L*a*b* and L*h*c* colour co-ordinate systems. A wide range of colours from greenish yellow up to chocolate brown were created by steaming in function of the steaming time and temperature. In spite of this wide colour range a good linear correlation was found between the lightness and the colour hue. This linearity had little distortion only above 100°C at a long steaming time. Accordingly, this linear correlation gives the possibility to follow the colour change during steaming by measuring only the lightness.

black locust / steaming / lightness / colour hue

Kivonat – A színezeti szög és a világosság kapcsolata gőzölt akác faanyag esetében. Akác (*Robinia pseudoacacia L.*) faanyagot gőzöltünk széles hőmérséklet tartományban (75-130°C), és hosszú ideig (22 nap). A színváltozást CIE L*a*b* és L*h*c* színkoordináta rendszerekkel határoztuk meg. A gőzölési időtől és hőmérséklettől függően a sárgászöldtől a csokoládé barnáig a színek széles skáláját állítottuk elő. A színek széles skálája ellenére jó lineáris korrelációt találtunk a világosság és a színezeti szög között. Ez a linearitás csupán 100°C fölött, hosszú gőzölési időknél nem teljesült. Ez a lineáris kapcsolat lehetőséget ad a gőzölés során bekövetkező színváltozás követésére csupán a világosság mérésével.

akác / gőzölés / világosság / színezeti szög

1 INTRODUCTION

The texture of wood is one of the most marvellous natural colour harmonies (Kucera and Katuscak 1992). Ranging between yellow and red the colour of wood creates the feeling of warm (Masuda 2001), that is why wood is often used as decorative material in our milieu. The reproduction of colour in wood industry is more and more important. Nowadays the colour determination and selection occur visually in industry, but in research and hopefully in industry the future is the objective colour measurement. Many articles have been published using objective colour measurement technique in last years (Németh – Faix 1988, Bekhta –

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Niemz 2003, Hapla – Militz 2004, Mitsui et al 2001, 2004, Mitsui 2004). Mostly the CIE L*a*b* colour co-ordinate system is applied based on D65 light source. The colour co-ordinates are calculated from the reflexion data of the surface. This calculation is a complicated mathematical process (Németh 1984), but for computer supported colorimeters this is more simple. Correlation could be established between the co-ordinates which simplify the industrial colour measurement. It would not be necessary to calculate all tree co-ordinatees. Németh (1982) found that light wooden colour is always accompanied with close to yellow hue and dark colour usually has reddish hue.

In this study the correlation between colour hue and lightness was examined during steaming of black locust. A special attention was paid to determine the influence of temperature and steaming time because of the high temperature sensitivity of the colour change of black locust (Tolvaj et al 2004). On the basis of the results an easy method is proposed to monitor the colour change caused by steaming.

2 MATERIAL AND METHODS

For laboratory steaming black locust (*Robinia pseudoacacia L.*) wood specimens were investigated. Specimens were prepared with the size of 200x60x20 (mm) and only those without any wood defects were used for the tests. The treatment was carried out in a steam chest at 100% relative humidity with temperature values of 75-130°C. Wood specimens were placed in a large pot with distilled water for conditioning the air to maintain maximum relative humidity between 75-100 °C. The pot was heated in a drying chamber to the indicated temperatures. The steaming process started with a six hours heating. The temperature was regulated automatically around the set values with a tolerance of ± 0.5°C. Specimens were removed after 1; 2; 4; 6; 9; 12; 15; 18 and 22 days. The temperatures above 100°C were generated in an autoclave because of the high pressure. Specimens were removed from here after 0.5; 1; 2; 3; 4; 5 and 6 days of steaming between 105-115°C and after 0.25; 0.5; 1; 2; 3; and 6 days of steaming at 120°C and at 130°C.

Before colour measurements, the steamed wood specimens were conditioned for one month at room temperature. The specimens were then cut with a sharp circular saw through the centre parallel to the longer side and the newly prepared surfaces were used for colour measurements. For the colour measurements a MINOLTA 2002 colorimeter was used. The reflection spectrum was measured in the 400-700 nm regions. From these data, the L*, h*, c* colour co-ordinates were calculated based on the D65 light source. On each specimen, colour measurements were taken at 10 randomly chosen spots and the results were used for further analyses.

3 RESULTS AND DISCUSSION

The colour hue of wood is between 0° and 90°, where 0° represents the red colour and 90° represents the yellow colour. The full intensity range of lightness is 0-100 units, where 0 represents the total dark followed by grey up to bright white (100 units). Németh (1982) found linear relationship between lightness and colour hue examining the colour co-ordinates of different wood species. Tolvaj (1994) demonstrated the same relation within one sample if the colour change was created by steaming at 90°C in case of black locust, poplar, spruce, Scots pine and larch, the only difference among the species consist of the slope of the line.

Based on these results the temperature and steaming time dependence of the above mentioned linear relationship was investigated in the case of black locust. A wide range of colours from greenish yellow up to chocolate brown were created by steaming varying the steaming time and temperature (Tolvaj et al 2004). The correlation between lightness and colour hue the results are presented in Fig. 1 and 2. Where the linearity is well demonstrated. The linear regression equations and the coefficients of determination are listed in Table 1. (The curved end parts in Fig. 2 were ignored.) The coefficients of determination shows high correlation between the hue and the lightness in all cases. The dots representing the nonsteamed samples are located in the top-right corner followed by the colour dots of the steamed samples towards left with growing steaming time listed in “Materials and methods”. In Fig. 1 the colour parameters are presented for specimens with steaming temperatures below 100°C. The initial colour of black locust is one of the most yellow wooden colour, represented here by the 1.4 - 1.5 units of hue. With increasing temperatures the change towards red (decreasing hue values) is greater. At 75°C the decrease stops at 1.2 units, but at 95°C it goes down to 1 unit for the longest treatment time. In Fig. 2 the colour parameters are presented for specimens with steaming temperatures above 100°C. The linearity between lightness and colour hue is accentuated at short steaming times. Only exceptions are the end parts of the lines. The curves have minimum values close to 0.96 of hue independently of the steaming temperature, but they are obtained at different time values. With rising temperature this time values are decreasing rapidly, for example at 100°C this time value is 18 days but at 130°C this drops to 1 day. The chemical background of this phenomenon needs further investigations.

Table 1. The linear regression equations and the coefficients of determination (R2)

Temperature (°C)	Fitted linear function	R^2
75	y = 0.0143x + 0.4818	0.983
80	y = 0,014x + 0.47	0.997
85	y = 0,0161x + 0,319	0.9954
90	y = 0,0154x + 0,3726	0.9853
95	y = 0,0146x + 0,400	0.9968
100	y = 0.0153x + 0.3708	0.9915
105	y = 0.0144x + 0.3889	0.9986
110	y = 0.013x + 0.4607	0.9938
115	y = 0.0148x + 0.3999	0.9955
120	y = 0.0158x + 0.3321	0.9998
130	y = 0.0165x + 0.2856	0.998

The above discussed linear correlation gives the possibility to follow the colour change during steaming by measuring only the lightness. This result represents the main impact of this study. Because the lightness depends only on the Y colour component it can be measured by a proper colour filter too, avoiding the use of an expensive colorimeter. This possibility permits a fast and easy colour monitoring at steaming. But a special attention has to be paid for high steaming temperatures and long treatment times where the linearity is distorted.

4 CONCLUSIONS

A wide range of colours for black locust wood, from greenish yellow up to chocolate brown can be created by steaming using different steaming time and temperature. In spite of this wide colour range a linear correlation was found between the lightness and the colour hue. This linearity had little distortion only above 100°C and just in the case of long steaming time. The linear correlation makes possible to control the colour change during steaming by measuring only the lightness, which does not need expensive colorimeter, only using a colour filter and a detector are sufficient.

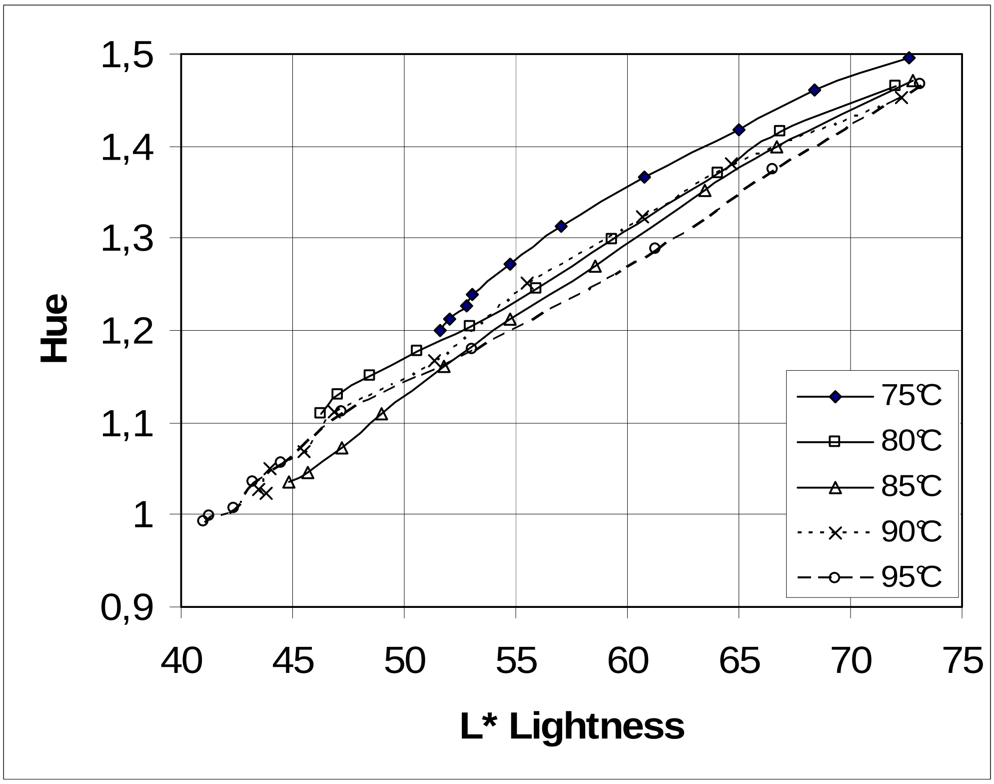

Figure 1. Correlation between lightness and hue of steamed black locust (temp. below 100°C). Colour dots of nonsteamed wood are in the right corner followed by the dots of steamed wood with increasing time

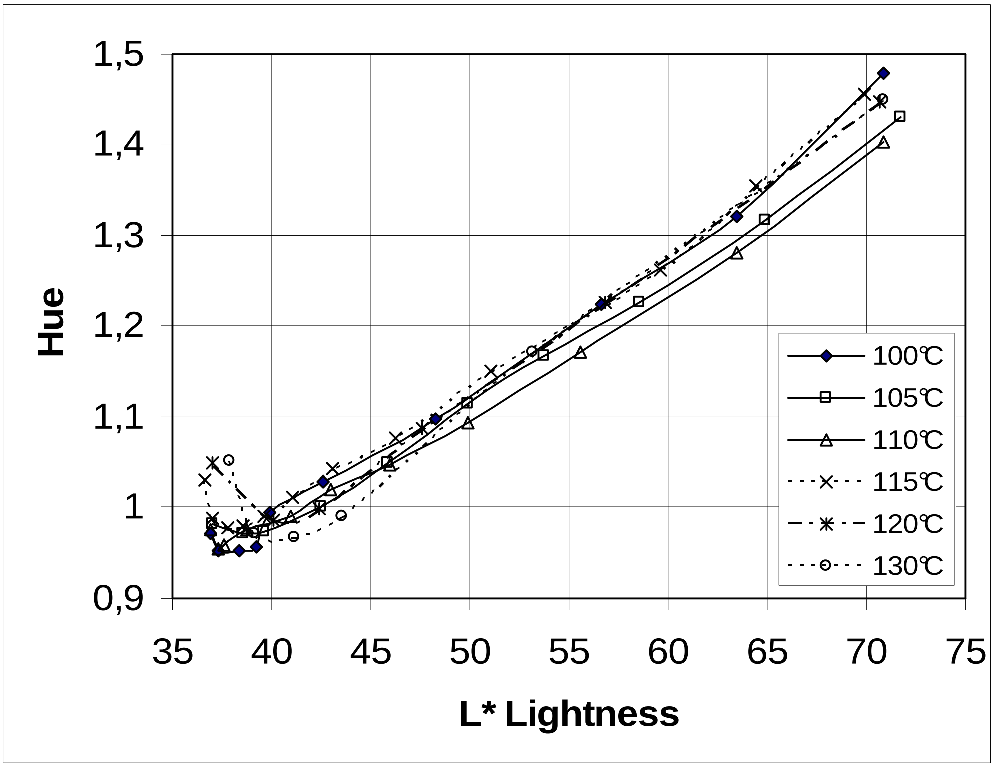

Figure 2. Correlation between lightness and hue of steamed black locust (temp. above 100°C). Colour dots of nonsteamed wood are in the right corner followed by the dots of steamed wood with increasing time

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