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COLOUR MODIFICATION AND HOMOGENISATION OF LARCH WOOD BY STEAMING

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ABSTRACT

Larch (*Larix decidua* L.) wood samples were steamed applying broad range of steaming time (0-20 days) at 90°C and 110°C steaming temperatures. The colour change was monitored by objective colour measurement using the CIE Lab colour system. The initial colour of earlywood and latewood within sapwood and heartwood has highly different values for larch wood. Wide range of colours was created by steaming between the initial colour and brown colour depending on the steaming time and temperature. The steaming produced excellent colour homogenisation and resulted in an increase of saturation. The redness showed the greatest homogenisation effect. The redness value difference among the tissues was seven times smaller after 9 days of steaming at 110°C than the initial redness difference. The yellowness values increased and moved toward each other during steaming. The results showed that the best visualisation effect of homogenisation can be presented on the a^*-b^* plane. The colour saturation of the examined tissues increased considerably and showed homogenisation effect as well. Because of the colour homogenization, it was difficult to differentiate sapwood and heartwood at the end of the steaming process at 110°C. The effective steaming time for colour homogenisation was 5 and 2 days at 90°C and 110°C, respectively.

KEYWORDS: Steaming, colour modification, larch wood, colour homogenisation, colour saturation.

INTRODUCTION

The colour hue of wood between red and yellow gives us the feeling of warmness. That is why humans prefer wooden furniture and claddings. But not all of the wood species have attractive colour. There are some species having white-greyish colour without visible texture. Some other species have disturbingly inhomogeneous colour. Both disadvantages can be modified by steaming.

In industrial practice, steam treatment of wood for a natural, environment-friendly yet efficient and permanent way of colour alteration was started in the second half of the last century. Although, in theory any wood species could be subjected to hydrothermal treatment, mostly beech and Black locust timbers were steamed. The systematic research to discover specific effects of steaming parameters for individual wood species has been carried out only for 30 years. Steaming of Black locust has the most detailed literature, well establishing this specific field of researches dealing with hydrothermal treatment. The unattractive and highly inhomogeneous greenish yellow colour of black locust can be modified up to chocolate brown applying different steaming parameters (Tolvaj and Faix 1996, Molnar 1998, Horvath 2000, Horvath and Varga 2000, Tolvaj et al. 2010, Dzurenda 2018a). Investigation of the steam treatment of beech has also been in the focus for about twenty years, but it is less published compared to black locust (Milic et al. 2015, Geffert et al. 2017). Beech is usually steamed to turn its white-grey initial colour into more attractive reddish. The great colour difference between white and red heartwood of beech can also be minimalised by steaming (Tolvaj et al. 2009).

There are only a few publications regarding the steaming properties of other species than beech and black locust. Varga and van der Zee (2008) investigated some of the altering mechanical and physical properties of two European and two tropical hardwood species caused by different steam treatments. Colour variations of steamed cherry wood were discussed by Straze and Gorisek (2008) and by Dianiskova et al. (2008). The steaming properties of Turkey oak were published by Tolvaj and Molnar (2006), by Todaro et al. (2012 a, b) and by Csanady et al. (2015). The colour change possibilities of poplar (*Populus* x *euramericana cv. pannonia*) by steaming were investigated to obtain an attractive brown wood colour suitable for various indoor applications (Banadics and Tolvaj 2019). Steaming was found to be a proper technique to turn the naturally unattractive colour of poplar wood to a pleasant brown colour. The colour of steamed poplar samples was homogeneous throughout the whole cross section proving that the hydrothermal process affected not only the surface of wood. It is an important result for wood industry that the colour saturation can be doubled by steaming. The applied treatment increased both redness and yellowness values and reduced the lightness. Dzurenda (2017, 2018b) investigated the steaming behaviour of oak and maple wood for getting attractive brown colour shades.

Scots pine and spruce samples were steamed applying wide range of steaming time (0-22 days) and temperature (70-100°C) (Tolvaj et al. 2012). A variety of colours was created between the initial colour and light brown colour. These new colours were similar to the colours of aged indoor wooden constructions and furniture. Surface quality and hardness of eastern red cedar as function of steaming time and temperature were studied by Kaygin et al. (2014).

The colour of solid wood is sensitive to light and heat. The indoor wooden applications change their colour during decades, getting more brown and darker. The maintenance and replacement of damaged parts of old wooden constructions is difficult because of the unique aged colour. The proper coloration of the surface is usually produced using chemicals. This method, however, only changes the colour of the surface. If the surface is damaged, the thin coloured layer disappears. Steaming can be the proper solution creating the colour matching between the old and the new wooden parts. The colour of steamed wood is homogeneous in the whole cross section. There is no risk of damage or secondary processing. Although many of our indoor wooden applications are made of softwoods and they tend to get damaged easier compared to hardwoods, colour modification of softwoods by steaming is rarely discussed in the scientific literature.

The colour of larch timber is highly inhomogeneous. The heartwood is much darker and redder than the sapwood. The aim of this study was to use steaming for colour homogenisation and to monitor in an objective way all the possible colours created by steaming for larch samples.

The created figures could be useful to find out the proper steaming parameters if desired colours are needed.

MATERIALS AND METHODS

Larch (*Larix decidua* L.) samples were used for the steaming tests. All steaming temperatures and steaming times were represented by a series of 10 samples and 10 randomly chosen points were used for colour measurement on each sample. The sample size was 120 x 20 x 10 mm. The largest surface contained only earlywood or latewood (tangential surface). Half part of each sample was sapwood while the other half part was heartwood. The average moisture content of the samples was 8.5% before the steaming process. The hydrothermal treatment was carried out in a steam chest at 100% relative moisture content at 90°C and 110°C. Wood specimens were placed in a large pot with distilled water at the bottom for conditioning the air to maintain maximum relative humidity. At 110°C the pot was able to keep the pressure. The pot was heated in a drying chamber up to the indicated temperatures. The steaming process started with a 4-hour heating period. The temperature was regulated automatically around the set values with a tolerance of 0.5°C. Specimens were removed after 2; 5; 9; 14 and 20 days of steaming. Wood specimens were conditioned before steaming and after steaming for one month at room temperature (normal laboratory condition) before the colour measurements.

The colour of the wood specimens was measured before and after steaming with a colorimeter (Konica-Minolta 2600d) on the tangential surface. Colour data of earlywood and latewood were determined separately. The L*, a*, b* colour co-ordinates were calculated based on the D_{65}illuminant and 10° standard observer with a test-window diameter of 3 mm.

RESULTS AND DISCUSSION

Based on the objective colour measurements, the investigated four types of larch tissues have highly different colour hue and lightness. The initial average colour data of the investigated samples are presented in Tab. 1. The heartwood proved to be much darker than the sapwood. Especially, the earlywood in sapwood was much lighter than all other tissues. The latewood in sapwood had almost the same lightness as earlywood in heartwood. The darkest tissue was the latewood in heartwood. The border between the dark and light portions was sharp.

The redness of larch wood showed the greatest diversity among the tissues. The latewood in sapwood and the earlywood in heartwood were more than two times redder (a* value), the latewood in heartwood almost four times redder than the earlywood in sapwood. There were moderate differences among the tissues in the yellow hue colour coordinate. These great colour differences can be diminished by steaming. The standard deviation (SD) values were small representing the relatively high colour homogeneity of earlywood and latewood separately. The latewood in heartwood had the highest SD values. This tissue has the greatest extractive content determining the colour of the tissue. The individual samples might contain extractives in different quantity establishing the colour in homogeneity of the latewood in heartwood.

Tab. 1: Initial colour data of different larch wood tissues (average and standard deviation SD). S=sapwood, H= heartwood, E= earlywood, L= latewood.

	L*	SD	a*	SD	b*	SD
SE	79.29	1.25	4.80	0.54	23.37	1.17
SL	70.53	1.59	11.20	0.81	30.77	1.77
HE	71.92	2.80	13.08	1.94	29.65	1.79
HL	61.40	3.40	18.39	2.07	34.12	2.26

Fig. 1 represents the redness change generated by steaming at 90°C. The colour dots of all tissues moved toward each other with elapsed steaming time representing the colour homogenisation. The colour homogenisation continued during the first 9 days of steaming. During this steaming period the initial redness value difference among the tissues (13.6 units) was reduced to 4.3 units. The redness of the two earlywood types was almost equal after 20 days of steaming and the same happened for the two latewood parts as well. However the end values were different for earlywood and latewood.

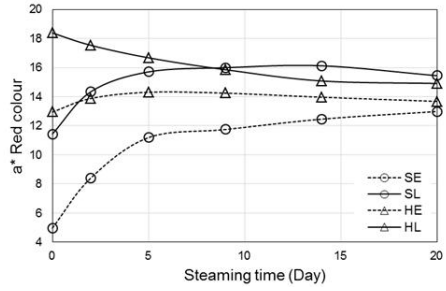

Fig. 1: The redness change of different tissues during steaming at 90°C. (S=sapwood, H=heartwood, E=earlywood, L=latewood).

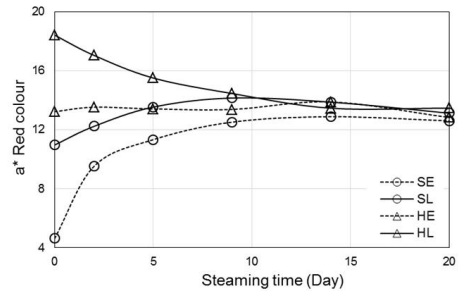

Fig. 2: The redness change of different tissues during steaming at 110°C. (S=sapwood, H=heartwood, E=earlywood, L=latewood).

The steaming at 110°C produced similar redness change as the treatment at 90°C, but this alteration was more intensive during the first five days of steaming (Fig. 2). Applying this higher temperature the homogenisation was completed during the first 9 days of steaming meaning that the maximum of effective steaming time is 9 days if the aim is to homogenize the colour of larch. For industrial practice, however, the proper steaming time is less than 9 days since it is better not to do complete colour homogenisation. The unique colour harmony of the wood texture is generated by the moderate colour difference between earlywood and latewood. The redness difference can be altered between 14 and 2 units by choosing the proper steaming time (indicated by Fig. 2) for getting the desired colour harmony.

The redness values were almost constant in the second part of the applied steaming period (between 9 and 20 days). It means that the chromophore chemical groups generating the redness are stabile to the thermal treatment at 110°C. The colour of steamed larch wood is even more stable at ambient temperatures during the everyday usage. The colour change of wood is related to the alteration of conjugated double bound chemical systems. These bounds can be found in the lignin and in the extractives. Thus, the colour changes in the examined temperature range originated mostly from the alteration of the extractives. Previous research showed that flavonoids play a significant role in the discoloration of wood (Németh 1997. Csonka-Rákosa 2005).

The steaming results of other wood species than larch (black locust, beech, Turkey oak, Scots pine, spruce) indicated that the red colour created by steaming was not stabile above 100°C (Tolvaj et al. 2009, 2010, 2018, Tolvaj and Molnar 2006). The high temperature degraded the newly generated chromophore molecules and the steam leached out partly these coloured chemical compounds from the samples resulting in the decrease of a*values. In contrast, current experiments showed that the chromophore groups of larch were stable during the 20-day steaming at 110°C. The colour stability of larch wood is an important advantage of steaming.

Fig. 3 represents the yellowness change caused by steaming at 90°C. The colour dots of all tissues moved toward each other during the first 9 days of steaming representing the colour homogenisation. During this steaming period, the initial yellowness value difference (10.8 units) was reduced up to 1.8 units. Yellow hue values decreased continuously after the second day of steaming. The only exception was the earlywood in sapwood. Its yellowness has not changed after the fifth day of steaming. The yellowness values of the two types of tissue (earlywood and latewood) of sapwood samples were almost equal after 20 days of steaming, and the same happened for the heartwood as well. However, the end values were different for sapwood and heartwood.

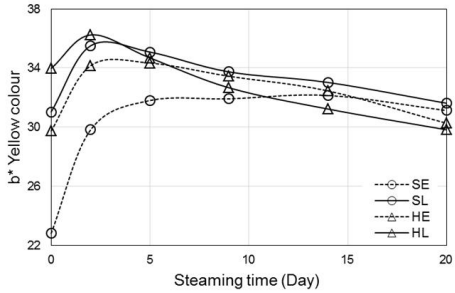

Fig. 3: The yellowness change of different tissues during steaming at 90°C. (S=sapwood, H=heartwood, E=earlywood, L=latewood).

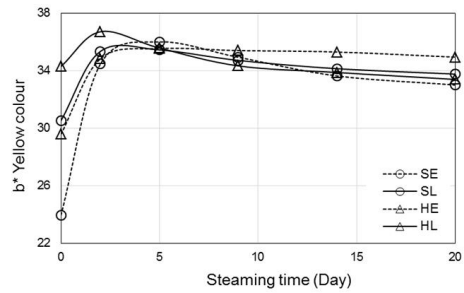

Fig. 4: The yellowness change of different tissues during steaming at 110°C. (S=sapwood, H=heartwood, E=earlywood, L=latewood).

The yellowness change at 110°C (Fig. 4) was slightly different to the change at 90°C. Determinative part of the yellowness change occurred during the first two days of steaming. The yellowness of earlywood in heartwood hardy changed after this period. But the yellowness value all other tissues slightly decreased during the further steaming process. The average value of yellowness after 20 days of steaming at 110°C (33.7 units) was higher than at 90°C (30.7 units). It shows that increasing temperature creates higher yellowness values.

The lightness difference among the tissues was 17.9 units at the beginning of steaming (Fig. 5). The lightness values decreased continuously with elapsed steaming time at both temperatures (only the data of steaming at 110°C are presented here). The difference between the effects of two temperatures was negligible during the whole treatment process.

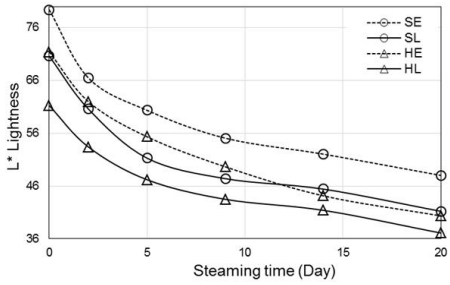

Fig. 5: The lightness change of different tissues during steaming at 110°C. (S=sapwood, H=heartwood, E=earlywood, L=latewood).

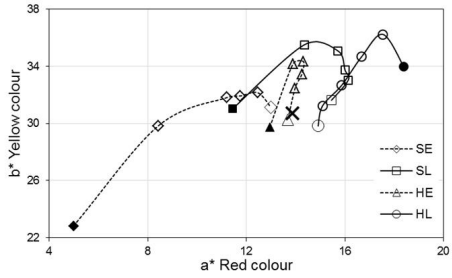

Fig. 6: The colour dots locations on the b-a* plane during steaming at 90°C. (Filled marks represent untreated samples).*

The homogenisation effect of steaming can be visualised if the colour dots are presented on the a*-b* plane as shown in Fig. 6 and 7 for 90°C and 110°C steaming, respectively. It is well visible that the initial colour dots (filled marks) representing untreated samples are fare from each other. The colour dots move toward each other, towards a centre dot (X). The coordinates of this centre dot were a*=12.1 and b*=27.4 units. The distances among the proper dots decreased representing the homogenisation.

In case of steaming at 110°C (Fig. 7), the changes were large during the first 2 days of steaming. The directions of changes differed comparing to the effect of steaming at 90°C. The colour dots moved towards a point, but this point was not in central position. This happened because the yellowness values increased considerably lifting up the colour dots during the steaming. The middle point (X) of the final colour dots is located on the top of the figure with coordinates a*=12.8 and b*= 33.5 units. The colour dots were close to each other after the fifth day of steaming, representing the colour homogenisation.

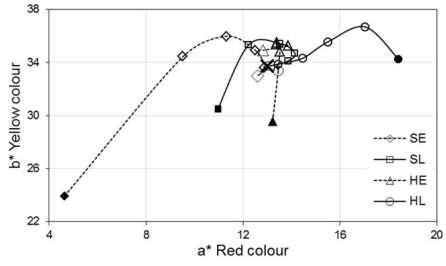

Fig. 7: The colour dots locations on the b-a* plane during steaming at 110°C. (Filled marks mean unsteamed).*

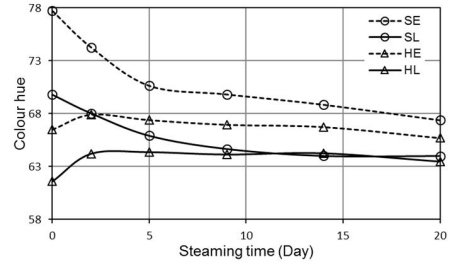

Fig. 8: The change of colour hue for different tissues during steaming at 90°C. (S=sapwood, H=heartwood, E=earlywood, L=latewood).

The colour hue represents the integrated value of both redness (a*) and yellowness (b*) coordinates. The values of colour hue are presented in Fig. 8 for the steaming at 90°C. It shows that the homogenisation stopped for earlywood at the fifth day of steaming, and an almost constant distance remained between the hue values of the two types of earlywood. However, the hue values of the two types of latewood remained equal after the 9th day of steaming. The steaming at 110°C generated similar hue change than the steaming at 90°C. The only difference

was that the hue values of the two types of earlywood tissues were almost the same after 9 days of steaming.

The chroma is also an important parameter because it represents the saturation of the given colour. High saturation means that the colour is vivid while low saturation represents greyish colour. The values of chroma increased rapidly during the first two days of steaming at 110°C (Fig. 9). After this period, the chroma values remained constant or slightly decreased. Steaming at 90°C caused similar changes, only the end values were slightly lower than at 110°C. In viewpoint of saturation, the optimum steaming time was 2 days at both temperatures. This result is important for the wood industry because colours that are more saturated are more acceptable for humans than the greyish colour.

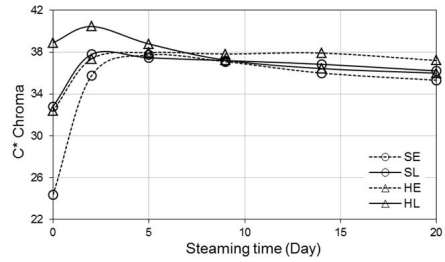

Fig. 9: The change of colour saturation for different tissues during steaming at 110°C. (S=sapwood, H=heartwood, E=earlywood, L=latewood).

CONCLUSIONS

The colour of larch wood is highly inhomogeneous. It has light earlywood in sapwood. The colour of latewood in sapwood has similar colour as the earlywood in heartwood. This colour is darker and much redder than the colour of earlywood in sapwood. The latewood in heartwood has the darkest and most reddish colour. Steaming can reduce these large colour differences. Wide range of colours was created by steaming between the initial colour and brown colour depending on the steaming time and temperature. The colour homogenisation was so successful that it was difficult to differentiate sapwood and heartwood by naked eye at the end of the steaming process at 110°C. The effective steaming time for colour homogenisation was 5 and 2 days at 90°C and 110°C, respectively. The chroma of all tissues increased considerably due to the steaming at both applied temperatures, representing that this treatment could generate saturated colour. The created figures are useful to find out the proper steaming parameters if specific colours are needed.

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