

Colour Change of Scots Pine and Spruce Wood by Steaming for Renovation of Wooden Cultural Heritages

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Abstract – 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 replacing 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 for surface modification. This method 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. Scots pine and spruce samples were steamed applying wide range of steaming time (0-22 days) and temperature (70-100°C). Broad range of colours was created between the initial colour and light brown colour. These new colours are similar to the colours of aged indoor wooden constructions and furniture. This fact gives the possibility of replacing the damaged old wooden parts by properly steamed new ones. This method also allows us to produce old looking furniture and other indoor wooden applications.

Keywords: scots pine / spruce / discolouration / modification

1. INTRODUCTION AND OBJECTIVES

The natural colour of wood varies between light yellow and dark brown usually with certain colour inhomogeneity. The diversity is due to the different colours of the inside lumen surfaces, cell walls and earlywood/latewood regions in any anatomical planes of the machined surfaces. Wood has one of the most beautiful colour harmony created by the nature. However, not all of the wood species have attractive colour. There are a few species with white-greyish tint without any visible texture. Some of them may have disturbingly inhomogeneous colour. Both disadvantages can be modified by steam treatment.

Industrial scale steam treatment of wood to achieve colour changes was started as early as the second half of the last century. Mostly beech and black locust timbers were steamed. Beech (*Fagus*) is usually steamed to turn its white-grey initial colour into more attractive reddish. The sharp colour difference between white and red heartwood of beech can also be alleviated by steaming (TOLVAJ et al. 2009). The systematic research to explore the specific effects of steaming parameters for individual wood species has started about twenty years ago. Primarily the steaming behaviour and discolouration of black locust (*Robinia pseudoacacia* L.) were the targets of these investigations. Some relevant discussions were provided by TOLVAJ – FAIX (1996), MOLNAR (1998), HORVATH-SZOVATI (2000), HORVATH-SZOVATI – VARGA (2000) and TOLVAJ et al. (2010). During a research project HORVATH (2000) developed an exponential function that demonstrates the temperature and time dependency of lightness change for black locust exposed to steaming. On the other hand, there are only a few publications regarding the steaming properties of other species than

beech and black locust. VARGA – VAN DER ZEE (2008) investigated several mechanical property changes under different steam treatment conditions. Their research involved two European and two tropical hardwood species. Colour variations of steamed cherry (*Prunus*) wood were discussed by STRAZE – GORISEK (2008) and by DIANISKOVA et al. (2008). Recently, the steaming properties of Turkey oak (*Quercus cerris* L.) were presented by TOLVAJ – MOLNAR (2006) and by TODARO et al. (2010, 2011). Although a significant percentage of indoor wooden objects are made of softwoods, the time-temperature dependent discolouration of gymnosperms is a hardly researched area.

The primary goal of this study was to explore the practicality of steaming in colour modification of softwoods. It included the identification of optimal steaming parameters to achieve a particular colour hue by measuring standard CIE L*a*b* colour coordinates. Our intent was to develop graphical representations for the visualization of steaming time/temperature and colour parameter relations. Such diagrams may aid the selection of appropriate steaming parameters to bring about desired colour hues and darkness of softwoods.

2. MATERIALS AND METHODS

Two conifers, Scots pine (*Pinus sylvestris* L.) sapwood and spruce (*Picea abies* Mill.) were selected for analyses. These are the most frequently used softwood species in Hungary for furniture and indoor products manufacture. All species were represented by a series of 10 samples for each steaming temperatures, and 10 points were measured on each sample. The sample dimensions were 100x30x10 mm³. The radially cut in-plane (i.e. 100x30 mm) surfaces contained sapwood and heartwood regions as well. The treatment was carried out in a steaming vat in 100% relative humidity condition at pre-set temperatures of 70; 80; 90; 95 and 100°C. A heat sensor regulated the temperature automatically around the set values with a tolerance of 0.5°C. The schedule of treating time comprised of 1; 2; 4; 6; 9; 12; 15; 18 and 22 days of steaming. Specimens were removed right after the designated steaming time elapsed. Prior and after treatments, the specimens were kept in normal laboratory conditions (i.e. 65 % RH and T=21°C) that followed by initial and post treatment colour assessments. Measurements were carried out with a colorimeter (Konica-Minolta 2600d). The L*, a*, b* colour co-ordinates were calculated based on the D65 illuminant and 10° standard observer with a test-window diameter of 8 mm. The relatively large window was chosen to measure the average colour of earlywood and latewood regions combined.

3. RESULTS AND DISCUSSION

The specimens became visibly darker during steaming and the colour hue turned towards brown. These changes were sensitive to the steaming temperature and to the steaming time. The chemical background of colour change is the alteration of the conjugated double bond systems found mainly in extractives. Wood species having high extractive content (e.g. black locust) can undergo great colour changes by steaming. Conifers have moderate extractive content, but it is quantitatively enough for colour modification by steaming. As demonstrated on *Figures 1* and *Figure 2*, the lightness of spruce and Scots pine samples decreased in the whole time interval with the increase of treatment time. The increasing temperature resulted in rapid lightness decrease during the first 4 days of treatment for both species. However, at 70°C treatment temperature this trend could not be observed. Apparently, because 70°C is not high enough to initiate substantial chemical changes.

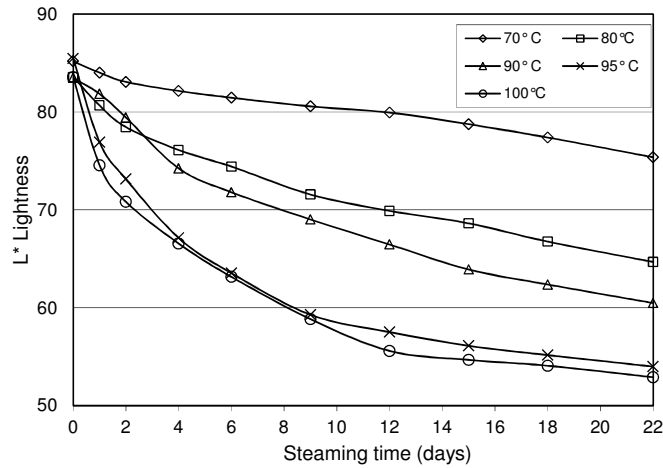


Figure 1. Lightness change of spruce treated with different steaming parameters

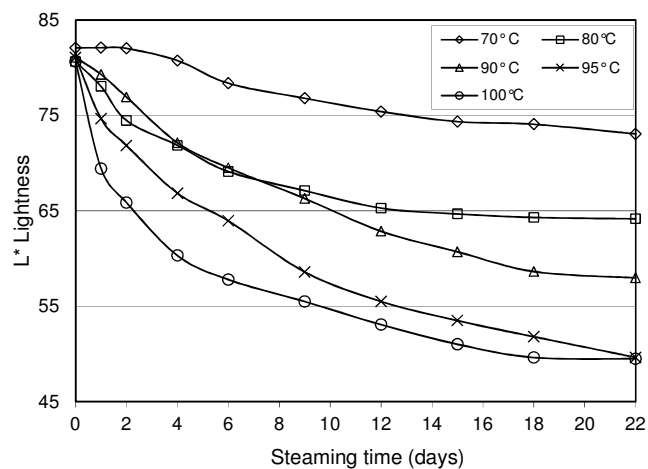


Figure 2. Lightness change of Scots pine treated with different steaming parameters

The lightness decrease of the examined two conifers was similar. The only difference was that the lightness of Scots pine samples hardly altered beyond the 18th days of steaming. In contrast, spruce samples had continuous lightness decrease during the 22 days of treatment.

The red colour co-ordinates showed more distinct deviations between the examined species (Figure 3 and Figure 4) than lightness did. The 70°C temperature produced slow but continuous redness increase.

Steaming at 80°C generated the same redness alteration for Scots pine as the 70°C treatment temperature did. However, spruce suffered much greater red colour change than that of Scots pine at 80°C. In fact, steaming at 80°C temperature ensured the highest a* value for spruce after 22 days of treatment. Up to 9 days of treatment, the higher temperatures caused higher increase in redness for both species. Except in case of 100°C treatment temperature, when the initial redness increase was slightly less intensive for spruce and considerably less for Scots pine compared to the a* values detected at 90°C treatments. The 100°C was the only temperature where redness decrease was observed after 12 days of treatment for spruce and after 6 days for Scots pine.

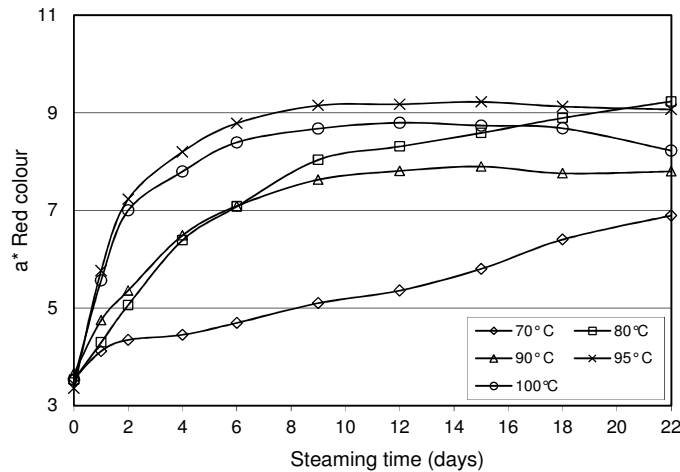


Figure 3. Red hue shift of spruce treated with different steaming parameters

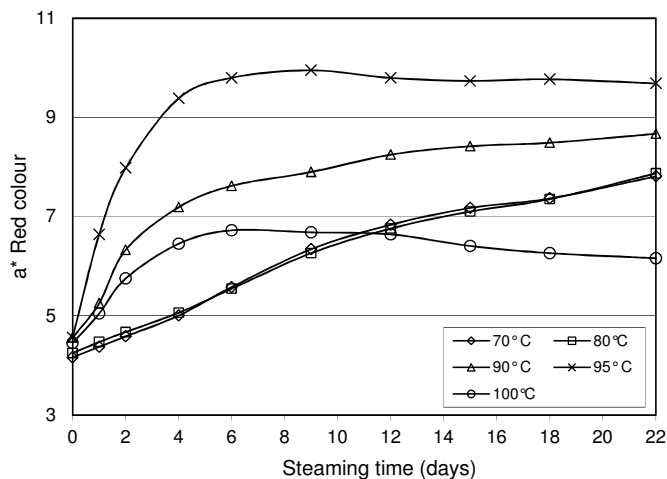


Figure 4. Red hue shift of Scots pine treated with different steaming parameters

During steaming, new chemical components are formulated that contain conjugated double band systems as a result of the extractives thermal degradation. In comparison, poplar (*Populus spp.*), which hardly have any extractives, changes its colour only by a limited value towards red by steaming (TOLVAJ – FAIX 1996). These newly created, coloured molecules are extractable and the hot steam leaches them out decreasing the values of the a^* co-ordinates. These leached components can be found in the condense water of the steaming. Similar results observations were found and reported by TOLVAJ et al. (2010) when they steamed black locust specimens.

The changes of yellow colour coordinate (b^*) demonstrate the leaching effect more clearly (Figure 5 and Figure 6). Only the 70°C treatment temperature resulted in continuous increase of yellowness for both species.

For Scots pine specimens the 80°C temperature created lower yellow colour increase than the 70°C treatment did. Most of the other trend lines for spruce have distinct maximum values that were observed after 15; 6; 4 and 2 days of treatments, for 80°C; 90°C; 95°C and 100°C temperature, respectively (Figure 5). The temperature has a shifting effect on the location of the maximum values of redness, i.e. higher temperature causes earlier decrease in b^* values. It does appear that the steam leaches out almost all of chromophoric groups which were created during steaming at 100°C.

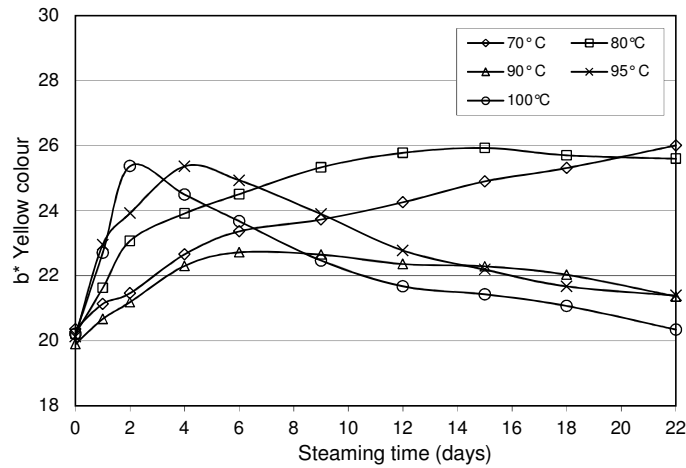


Figure 5. Yellow hue shift of spruce treated with different steaming parameters

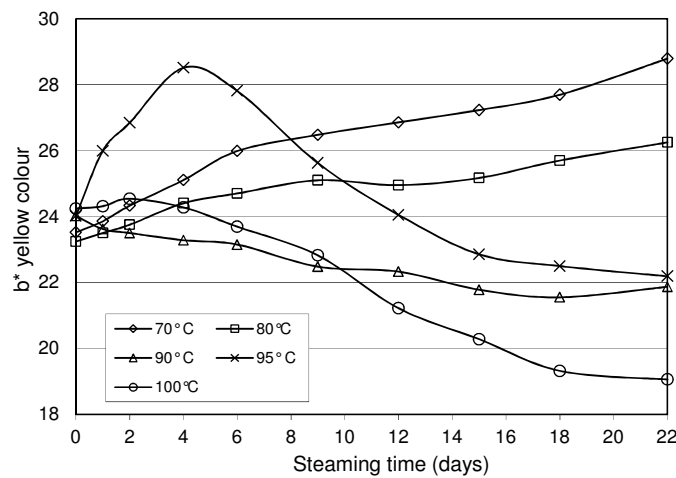


Figure 6. Yellow hue shift of Scots pine treated with different steaming parameters

The yellow hue shift of Scots pine exhibited somewhat different behaviour than spruce (Figure 6). The initial yellowness of Scots pine is definitely higher than the base b^* values of spruce. Similarly to that of spruce, the lower temperature treatments (70 and 80°C) steadily increase the value of b^* . However, no distinct peak values were identified, except under the 95°C treatment, after 4 days of exposure.

4. CONCLUSION

Methodology and results of the research devoted to explore the potential of steam treating were outlined. Spruce and Scots pine specimens were exposed to steam treatment of 70 to 100°C for a range of time period (0 to 22 days). The different exposures initiated a variety of colour changes of the examined softwoods, mostly similar to the colours of naturally aged indoor objects. The lightness of softwoods (L^*) decreases rapidly in the initial phase of exposures (first 2-5 days), except when exposed to low temperature steaming (70°C). Red hue (a^*) increases during the initial phases and after 10-15 days of treatments it tends to be stabilised. The changes of yellow coordinates (b^*) undoubtedly demonstrate the wash away effect of steam above 90°C treatment temperature. The developed data base and the graphical representations have practical values. These can be used to identify optimum steaming parameters. Once the desired colour coordinates are established, by selecting the appropriate

steaming parameters, the current expensive trial and error practices may be avoided or at least reduced. Furthermore, steam treated softwoods may be used to manufacture replicated historical furniture, joinery constructions and other artefacts.

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References

- DIANISKOVA, M. – BABIAK, M. – TOLVAJ, L. (2008): Colour homogenisation of cherrywood (*Cerasus avium* L.) and black locust (*Robinia pseudoacacia* L.) during steaming. *Wood Research* 53(4):45-5.
- HORVATH-SZOVATI, E. (2000): A gőzölt akác világosság-változásának hőmérséklet- és időfüggése. [Temperature and time dependence of lightness change of steamed black locust.] *SE Tudományos Közleményei* 46:179-189. (in Hungarian with English and German abstracts)
- HORVATH-SZOVATI, E. – VARGA, D. (2000): Az akác faanyag gőzölése során bekövetkező színváltozás vizsgálata. II. A 105, 110 és 115°C-on történő gőzölés eredményei, javaslat az ipari hasznosításra. [Colour change of black locust by steaming. II. Results of steaming at 105, 110 and 115°C, recommendation for industrial applications.]. *Faipar* 48(4):11-13. (in Hungarian with English abstract)
- MOLNAR, S. (1998): Die technischen Eigenschaften und hydrothermische Behandlung des Robinienholzes. [Technical properties and hydrothermal treatment of black locust.] In: Molnar S (ed.) *Die Robinie Rohstoff für die Zukunft*. Stiftung für die Holzwissenschaft, Budapest. 50-63. (in German)
- STRAZE, A. – GORISEK, Z. (2008): Research on colour variation of steamed Cherry wood (*Prunus avium* L.). *Wood Research* 52(2):77-90.
- TODARO, L. – ZUCCARO, L. – MARRA, M. – BASSO, B. – SCOPA, A. (2010): Steaming effects on selected wood properties of Turkey oak by spectral analysis. *Wood Sci Technol* 46(1-3): 89-100.
- TODARO, L. – ZANUTTINI, R. – SCOPA, A. – MORETTI, N. (2011): Influence of combined hydro-thermal treatments on selected properties of Turkey oak (*Quercus cerris* L.) wood. *Wood Sci Technol*. 46(1-3): 563-578
- TOLVAJ, L. – FAIX, O. (1996): Modification of wood colour by steaming. ICWSF '96 Conference. 10-12 April 1996. Sopron, Hungary. 10-19.
- TOLVAJ, L. – MOLNAR, S. (2006): Colour homogenisation of hardwood species by steaming. *Acta Silvatica et Lignaria Hungarica* 2:105-112. (<http://aslh.nyme.hu/>)
- TOLVAJ, L. – NEMETH, R. – VARGA, D. – MOLNAR, S. (2009): Colour homogenisation of beech wood by steam treatment. *Drewno-Wood* (Poznan, Poland) 52:5-17.
- TOLVAJ, L. – MOLNAR, S. – NEMETH, R. – VARGA, D. (2010): Color modification of black locust depending on the steaming parameters. *Wood Research* 55(2):81-88.
- VARGA, D. – VAN DER ZEE, M.E. (2008): Influence of steaming on selected wood properties of four hardwood species. *Holz Roh Werkstoff* 66(1):11-18.