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COLOUR MODIFICATION OF SCOTS PINE, LARCH AND SPRUCE WOOD BY STEAMING

Denes VARGA

Institute of Physics and Electrotechnics, University of West Hungary,
Bajcsy Zs. u. 4., Sopron, HUNGARY

Laszlo TOLVAJ

Institute of Physics and Electrotechnics, University of West Hungary,
Bajcsy Zs. u. 4., Sopron, HUNGARY

Andrea CSISZAR

Institute of Physics and Electrotechnics, University of West Hungary,
Bajcsy Zs. u. 4., Sopron, HUNGARY

Robert NEMETH

Institute of Wood Sciences, University of West Hungary,
Bajcsy Zs. u. 4., Sopron, HUNGARY

vargadenes@nyme.hu

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ABSTRACT

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 during 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. Larch samples were also steamed at 95°C to analyse the colour homogenisation effect of steaming. The most intensive homogenisation was found between earlywood and latewood of heartwood for larch.

1 INTRODUCTION

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 and Faix (1996), Molnar (1998), Horvath-Szovati (2000), Horvath-Szovati and 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 and 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 and Gorisek (2008) and by Dianiskova et al. (2008). Recently, the steaming properties of Turkey oak (*Quercus cerris* L.) were presented by Tolvaj and Molnar (2006) and by Todaro et al. (2011a, 2011b). 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

Three conifers, Scots pine (*Pinus sylvestris* L.) sapwood, larch (*Larix decidua* L.) and spruce (*Picea abies* Mill.) were selected for analyses. Scots pine and spruce were represented by a series of 10 samples while larch by 15 samples for each steaming temperatures. Colour of each samples were measured at 10 locations of their surface. Sample dimensions were 100x30x10 mm^3. The radially cut in-plane surfaces contained sapwood and heartwood regions as well except for larch where sapwood and heartwood was analysed separately on tangential sections. 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 in case of Scots pine and spruce, and at 95°C for larch. 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 except the larch where the samples were steamed for 1; 2; 4; 7; 11 and 16 days. 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. The test-window diameter was 8 mm except for larch where a 3 mm test-window was applied in order to separately measure earlywood and latewood colour.

3 RESULTS AND DISCUSSION

3.1 Colour change of Scots pine and spruce

The specimens became visibly darker during steaming and the colour hue turned towards brown. This change was sensitive to the steaming temperature and 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) may suffer substantial colour change during steaming. Conifers, however, 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. Higher steaming 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, 70°C is not high enough to initiate substantial chemical changes.

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.

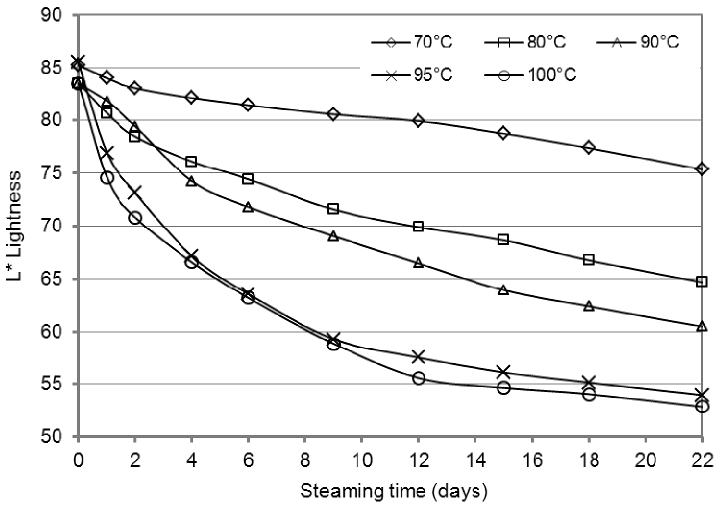

Figure 1. Lightness change of spruce caused by different steam treatments

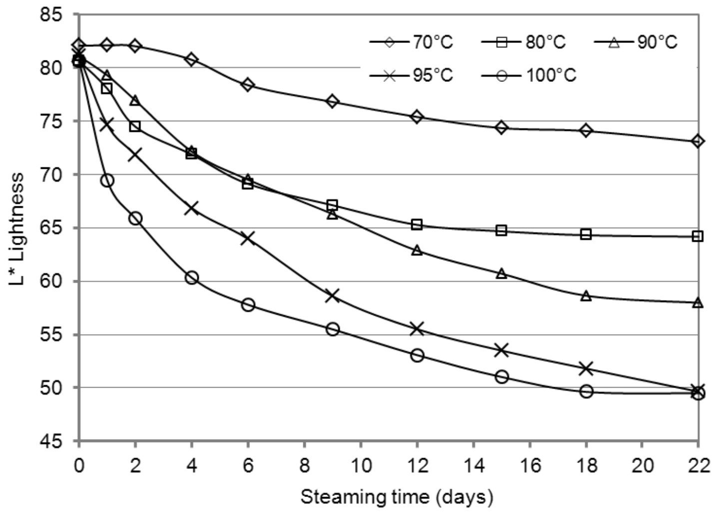

Figure 2. Lightness change of Scots pine caused by different steam treatments

The red colour co-ordinates showed more distinct deviations between the examined species (Figure 3 and Figure 4) than lightness did. The treatments at 70°C 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, elevated temperatures caused higher increase in redness for both species. Except in case of 100°C treatment temperature, where 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.

During steaming, new chemical components are formulated that contain conjugated double band systems as a result of the thermal degradation of extractives. In comparison, poplar (*Populus* spp.), which hardly have any extractives, changes its colour only by a limited value towards red by steaming (Tolvaj and Faix 1996). These newly created, coloured molecules are extractable thus 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 were found and reported by Tolvaj et al. (2010) when they steamed black locust specimens.

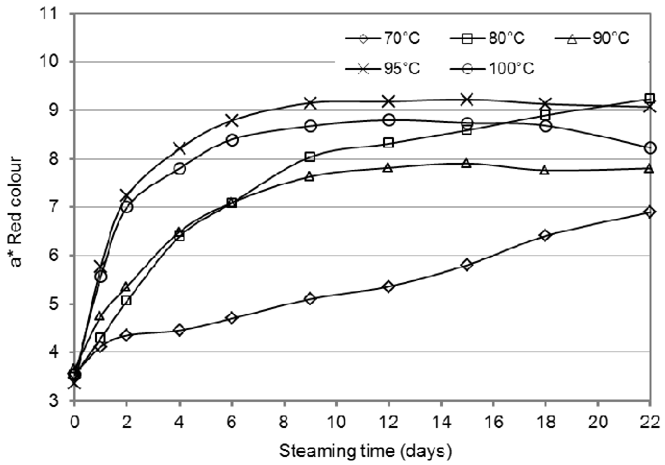

Figure 3. Red hue shift of spruce caused by different steam treatments

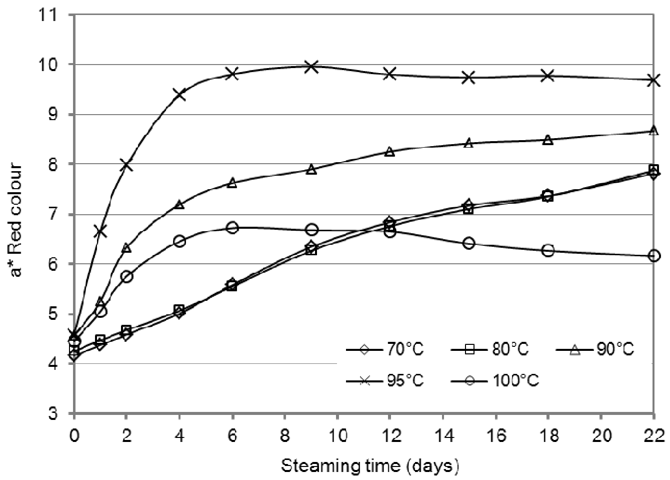

Figure 4. Red hue shift of Scots pine caused by different steam treatments

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.

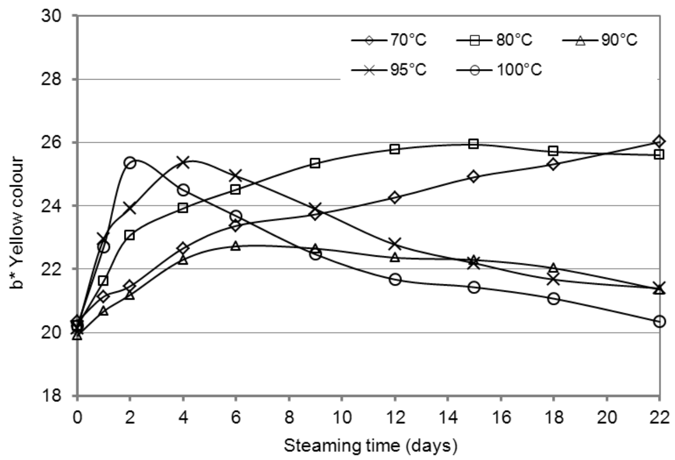

Figure 5. Yellow hue shift of spruce caused by different steam treatments

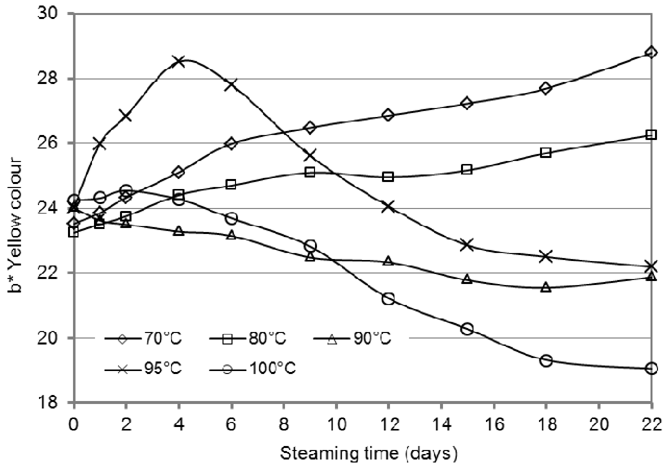

Figure 6. Yellow hue shift of Scots pine caused by different steam treatments

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.

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.

3.2 Colour change of larch sapwood and heartwood

In case of larch, the sapwood and heartwood were investigated separately in order to reveal the colour homogenization effect of steaming between the earlywood and latewood part.

Figure 7 shows the lightness change of larch caused by steaming at 95°C. For both the sapwood and the heartwood, the earlywood of the untreated samples was brighter than the latewood but the difference was greater in the heartwood part. It is clearly visible that each and every wood part constantly darkened during the whole process although this alteration slowed down after 8 days of treatment. It was found that due to the 16-day treatment the lightness difference between the earlywood and the latewood in the sapwood part increased by 50% while that in the heartwood part decreased by 34% resulting in a more homogenous colour.

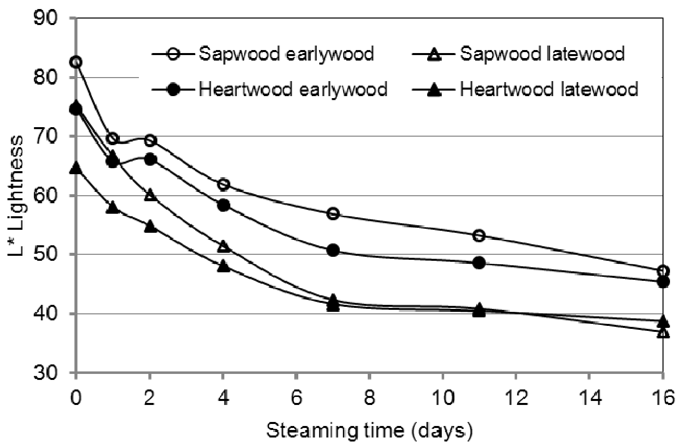

Figure 7. Lightness change of larch wood parts during a 16-day steam treatment at 95°C

Taking a closer look at the red hue (a*) of the different wood parts on the Figure 8, there were huge differences between them before the treatment. Due to the dynamic change of the red hue of the samples caused by the steam treatment, these differences disappeared after the first 12 days of the hydrothermal treatment ensuring a more homogeneous wood texture.

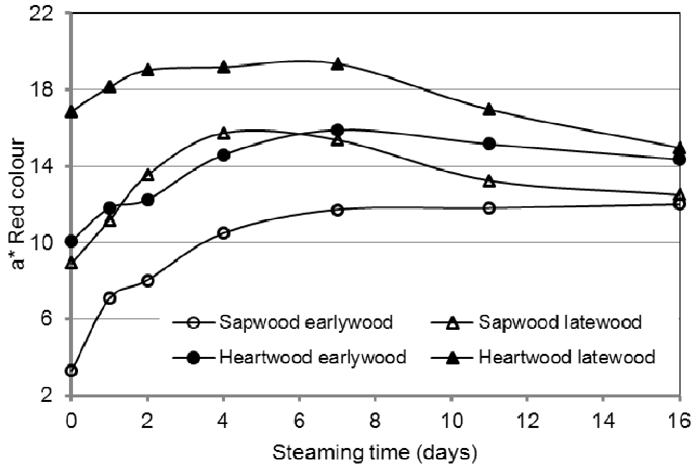

Figure 8. Red hue shift of larch wood parts during a 16-day steam treatment at 95°C

Interesting changes have been found concerning the alteration of the yellow hue (b*) as shown on the Figure 9. During the first 2-3 days of the treatment a dynamic increasing of the yellow colour has been detected. Initial yellow colour differences were equalized within this short time frame. The diversity in the chemical structure of each wood part is reflected by the change of their yellow colour but just in case of the red hue (see Figure 8), the diagrams referring to the earlywood and latewood act similarly in both the sapwood and heartwood. This allows us to conclude that those heat sensitive chemical structures, that define the wood colour, are similar in both the sapwood and the heartwood while we have to draw some distinction between the two wood parts (ie earlywood or latewood). Obviously, the chemical components resulting in a more yellowish colour of the latewood were leached out by the steam from the 2nd day of the treatment since the yellow colour decreased constantly afterwards.

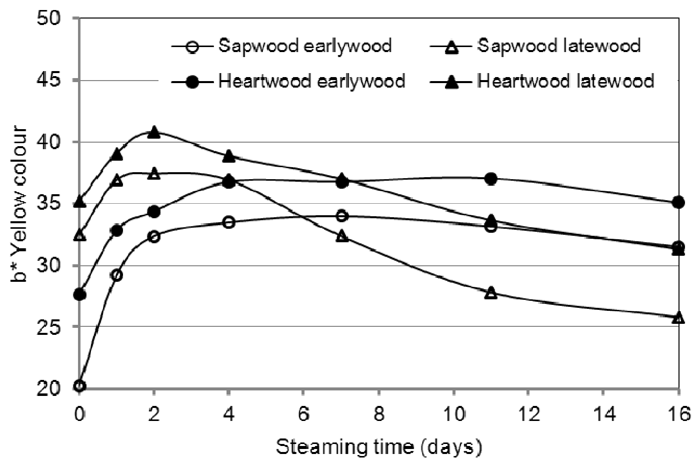

Figure 9. Yellow hue shift of larch wood parts during a 16-day steam treatment at 95°C

4 CONCLUSIONS

Methodology and results of the research devoted to explore the potential of hydrothermal treatment 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.

The applied 16-day hydrothermal treatment at 95°C resulted in a clearly visible colour homogenisation between earlywood and latewood in the heartwood part of larch. Colour differences decreased by 41% in the heartwood. According to the demonstrated red hue and yellow hue shift, the colour alteration of earlywood and latewood showed an interesting characteristic regardless of the wood part. Also, colour differences between heartwood and sapwood decreased considerably during the treatment. In terms of colour homogenisation of larch, the applied steam treatment proved to be effective in the heartwood part as well as between the sapwood and heartwood.

5 ACKNOWLEDGEMENT

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