Colour homogenisation of hardwood species by steaming

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Abstract – For colour homogenisation three hardwood species, black locust (*Robinia pseudoacacia* L.), beech (*Fagus silvatica* L.) and Turkey oak (*Quercus cerris* L.) were investigated. Steaming was applied to change the colour. Steaming parameters (steaming time and temperature) were varied to find the optimum of treatment. The results are given in the CIE L*, a*, b* colour co-ordinate system. Black locust wood was most sensitive to the steaming temperature. With rising temperature, the colour change was faster and less time was needed for homogenisation. The behaviour of the other two wood species was different from black locust but similar to each other. Below 95°C homogenisation was insensible to temperature and within one day the colour change stopped. Above 95°C the colour change was continuous but without further colour homogenisation. The optimum homogenisation time was found about 12 hours at 80-95°C temperature range and 6 hours at 110°C for Turkey oak, and 18 hours at any temperature for beech.

steaming / colour homogenisation / black locust / beech / Turkey oak

Kivonat – Lombos faanyagok színhomogenizálása gőzöléssel. Három fafaj, akác (*Robinia pseudoacacia* L.), bükk (*Fagus silvatica* L.) és csertölgy (*Quercus cerris* L.) színhomogenizálását vizsgáltuk. A színváltoztatáshoz gőzölést alkalmaztunk. Változtattuk a gőzölési paramétereket (gőzölési idő és hőmérséklet), hogy meghatározzuk az optimális értékeket. Az eredményeket a CIE L*, a*, b* színkoordináta rendszerben adtuk meg. Az akác faanyag nagyon érzékeny volt a gőzölési hőmérsékletre. Emelkedő hőmérséklettel a színváltozás felgyorsult, és egyre kevesebb időre volt szükség a színhomogenizáláshoz. A másik két faanyag gőzölési tulajdonságai eltértek az akácétól, de egymástól alig különböztek. A homogenizálás 95°C alatt független volt a hőmérséklettől, és egy nap után a színváltozás megállt. A 95°C fölötti hőmérsékleteken a színváltozás folyamatos volt egy nap után is, de további színhomogenizálás nem történt. Cser esetében az optimális homogenizálási idő 80 és 95°C között 12 órának, 110°C-nál pedig 6 órának, míg bükk esetében 18 órának adódott a hőmérséklettől függetlenül.

gőzölés / színhomogenizálás / akác / bükk / csertölgy

1 INTRODUCTION

Black locust heartwood has by nature a yellowish to greenish brown colour caused by a number of chemical substances such as robinetin deposited in cell lumina and cell walls. The less appealing and extremely inhomogeneous colour causes serious marketing problems of products made from black locust. In order to be competitive on the market, the colour

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appearance of black locust, particularly of products with large surfaces, such as flooring or furniture fronts, needs to be technically modified and homogenised before secondary processing (Molnar 1998, Tolvaj – Faix 1996, Tolvaj et al. 2000, Horváth 2000, Horváth – Varga 2000).

Beech wood often has red heartwood and Turkey oak has dark heartwood together with light sapwood. These great colour differences with definite irregular colour margins reduce the value of wood considerably.

These days, a new method of homogenising wood's colour is emerging. Mitsui and his co-workers discovered that UV treatment before steaming amplifies the darkening effect of steaming (Mitsui et al. 2001, Mitsui 2004, Mitsui et al. 2004)

The colour change is related to the change of the conjugated double bound chemical systems. These bounds can be found in lignin and in the extractives. Thus, the colour changes in the examined temperature range originate mostly from the alterations of the extractives. Flavonoids play a significant role in the discoloration of wood (Németh 1997). Melcerová et al. (1993) found that the tannins in black locust participate in the condensation reaction caused by hydrothermal treatment at 80 and 120°C.

This research was performed with the aim to change and homogenize the colour of wood by steaming. For observation of the colour change, the CIE L*a*b* colour co-ordinate system was used which is a useful routine for an objective determination of colour changes of wood (Tolvaj – Faix 1995, Mitsui et al. 2001).

2 MATERIAL AND METHODS

For laboratory steaming black locust (*Robinia pseudoacacia* L.), beech (*Fagus silvatica* L.) and Turkey oak (*Quercus cerris* 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. Dark and light heartwood surfaces were also prepared. The treatment was carried out in a steam chest at 100% relative humidity in the temperature range of 80-130^{o}C (black locust), 80-95^{o}C (beech) and 80-110°C (Turkey oak), respectively. Wood specimens were placed in a large desiccator with distilled water for conditioning the air to maintain maximum relative humidity. The desiccators were heated in a drying chamber to the indicated temperatures. The steaming process started with a six hours heating process. The temperature was regulated automatically around the set values with a tolerance of ± 0.5^{o}C. Specimens were removed after 1, 2, 3, 4, 5 and 6 days. The temperatures above 100°C were generated in an autoclave. Specimens were removed from here after 6, 12, 24 and 48 hours.

Before making colour measurements, the steamed wood specimens were subsequently 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*, a*, b* 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

Steaming of black locust

The effect of chemical changes induced by steaming can be observed with naked eye already after a few hours of treatment. The specimens become visibly darker and the colour changes from the unattractive greenish yellow to relatively more pleasant reddish hues. Besides the steaming parameters, colour change also depends on the original colour of the specimen. Rather large variation of natural colour of black locust heartwood is shown in *Figure 1*, where the location of numerous colour spots of randomly chosen untreated (non-steamed) specimens are plotted in the a* b* co-ordinate system. The measured colour spots are spread over a large area within the a* and b* colour co-ordinates. Considerable differences can be observed and measured not only between specimens but also within one specimen.

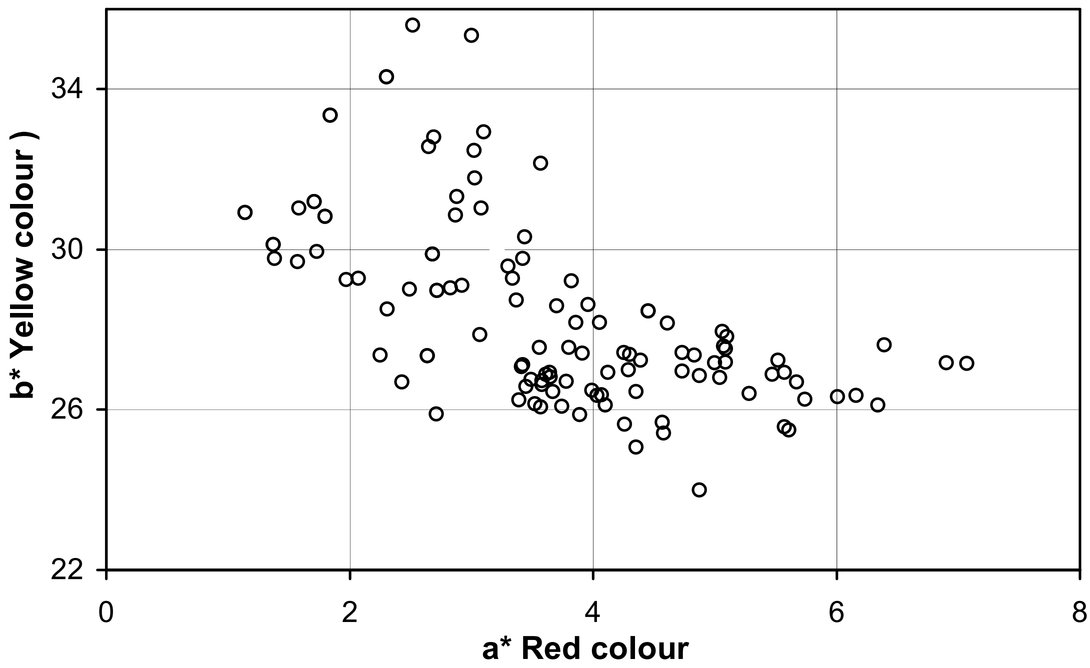

Figure 1. Natural variation of 110 randomly chosen black locust heartwood colour in the spectrum of a (red) and b* (yellow) colour co-ordinates.*

This very obvious inhomogeneity in colour can be reduced by steaming. The results are shown in *Figure 2* where corresponding colour measurements performed after steaming at 98°C temperature are plotted in the a* b* co-ordinate system as a function of steaming time. During the first day, the colour shifted towards red (increasing a* value). This change is followed by a rapid loss of yellow (decreasing b*). After four days, further colour changes become almost unnoticeable. Steaming considerably decreases the inhomogeneity of colour. The areas occupied by the colour spots are decreasing during steaming showing the colour homogenisation. Colour variation already decreases noticeably after a one-day steam treatment and continues until the fourth day. After the fourth day, this trend levels off, and at the same time, the colour change becomes very slow. At higher temperatures, the homogenisation effect was faster and the created dark surface became more and more uniform.

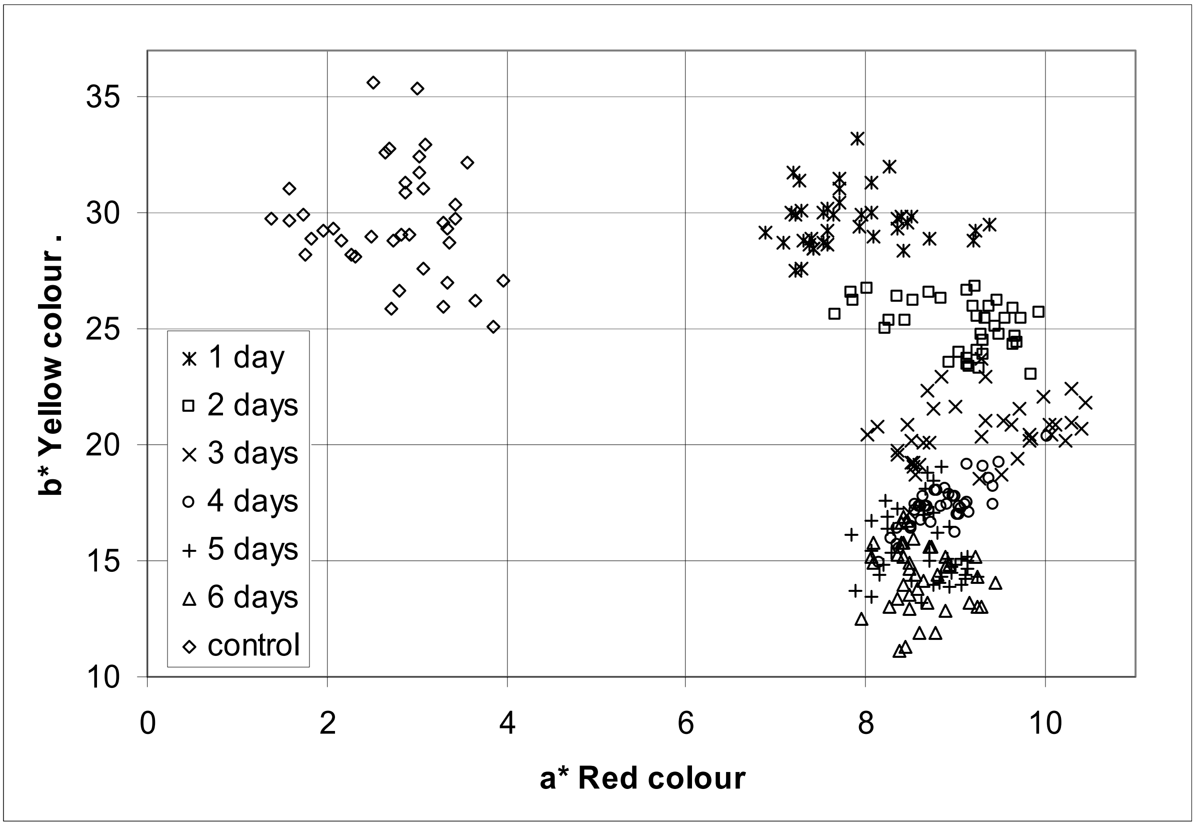

Figure 2. Colour change and homogenisation of black locust heartwood at steaming temperature of 98 ℃ as a function of time with respect to untreated controls (upper left)

Steaming of beech

The aim of the treatment was to reduce the colour difference between the two types of heartwood. Beech wood was steamed under atmospheric pressure. We realised that applying high pressure and high temperature the final colour was grey rather than red. So the applied temperatures were between 80-95°C. Red heartwood and white heartwood were treated parallel. *Figure 3* represents the change in lightness. It shows the great differences between red and white heartwood before steaming as well. This deviation was about 10 units in lightness. During the first 18 hours of steaming the lightness decreased rapidly. The white heartwood changed its lightness more rapidly than the red one. After this period, the lightness change was moderate or it remained constant. The 95°C treatment was an exception compared to the other temperatures. At this temperature, the decrease of the lightness was continuous in the whole examined interval. The trend lines were parallel after 18 hours of steaming (except at 95°C). It can be concluded, that the homogenisation effect has happened in the first 18 hours of steaming. This effect was not sensitive against the steaming temperature.

The yellow content of beech wood did not change considerably during steaming. In contrast, there was a marked difference in change of red content. The original colour difference in unsteamed state is well demonstrated in *Figure 4*. The red colour component of white heartwood changed a lot during the first 18 hours of steaming. After this period the change stopped. The steaming also increased the red colour of red heartwood during the first day of steaming. However, this change was moderate. After one day of steaming the red colour component of red heartwood decreased slightly. The trend lines of two types of heartwood moved towards each other. The yellow colour component of all types of examined beech wood remained intact during steaming. Comparing *Figure 3* and *Figure 4* one can conclude that the effective steaming time for homogenisation is 18 hours and is not depending on the steaming temperature. After this period the colour change is negligible. For saving energy, steaming at 80°C is recommended.

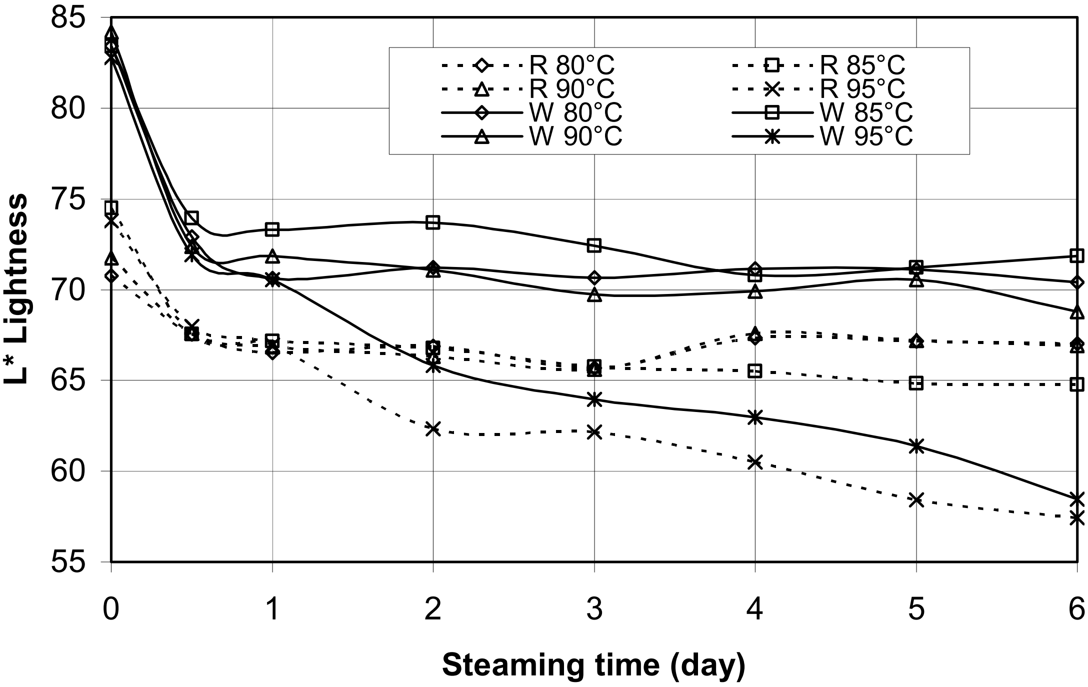

Figure 3 Lightness change of beech red heartwood (R) and white heartwood (W) during steaming

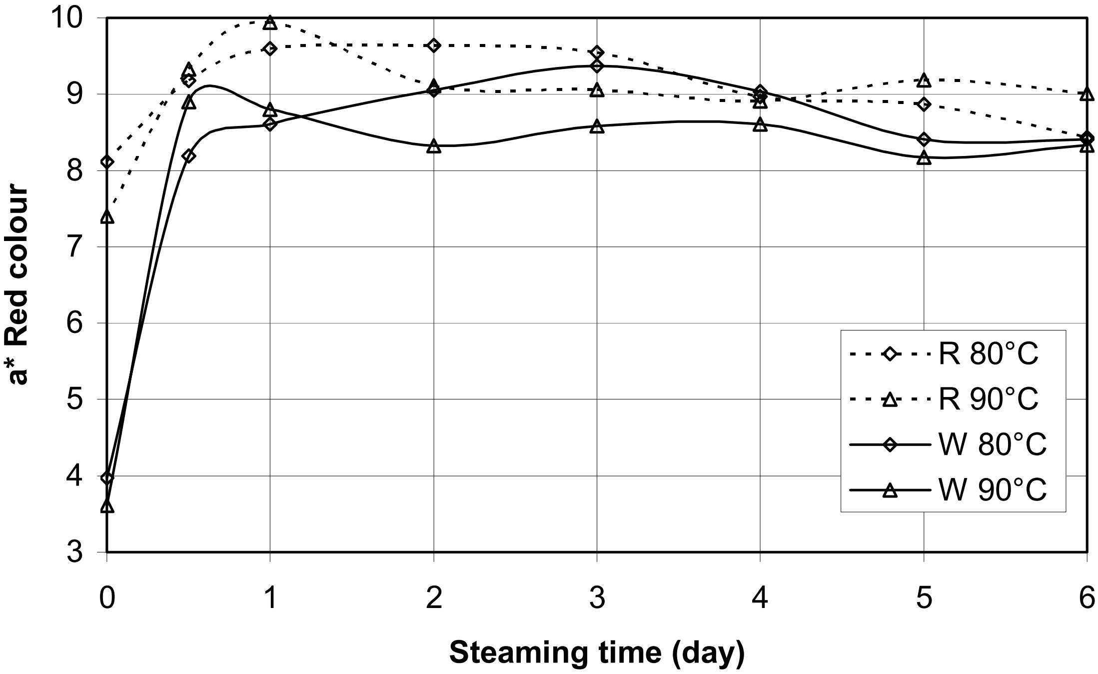

Figure 4. The change of red hue of beech red heartwood (R) and white heartwood (W) during steaming

Steaming of Turkey oak

Turkey oak has white sapwood but many trees have irregular dark grey heartwood that does not follow the year ring border. The border between the dark and white portion is usually extremely sharp. The big colour difference can be diminished by steaming. The lightness changes are plotted in *Figure 5*. Most of lightness change happened within the first 12 hours of steaming. There was a great difference above and below 100°C. At 80°C and at 95°C the decreases were similar up to 2 days. After this time the lightness change at 80°C stopped but at 95°C it decreased continuously. At 110°C the lightness change was rapid in the first 6 hours of steaming, and then the decrease became moderate. Lower temperatures (80-95°C) resulted moderate homogenisation during 2 days of steaming, but applying high temperature (110°C) the homogenisation was successful. The lightness difference was about 15 units before steaming and it decreased up to approximately 5 units during 12 hours of steaming. After this time limit the trend lines were parallel.

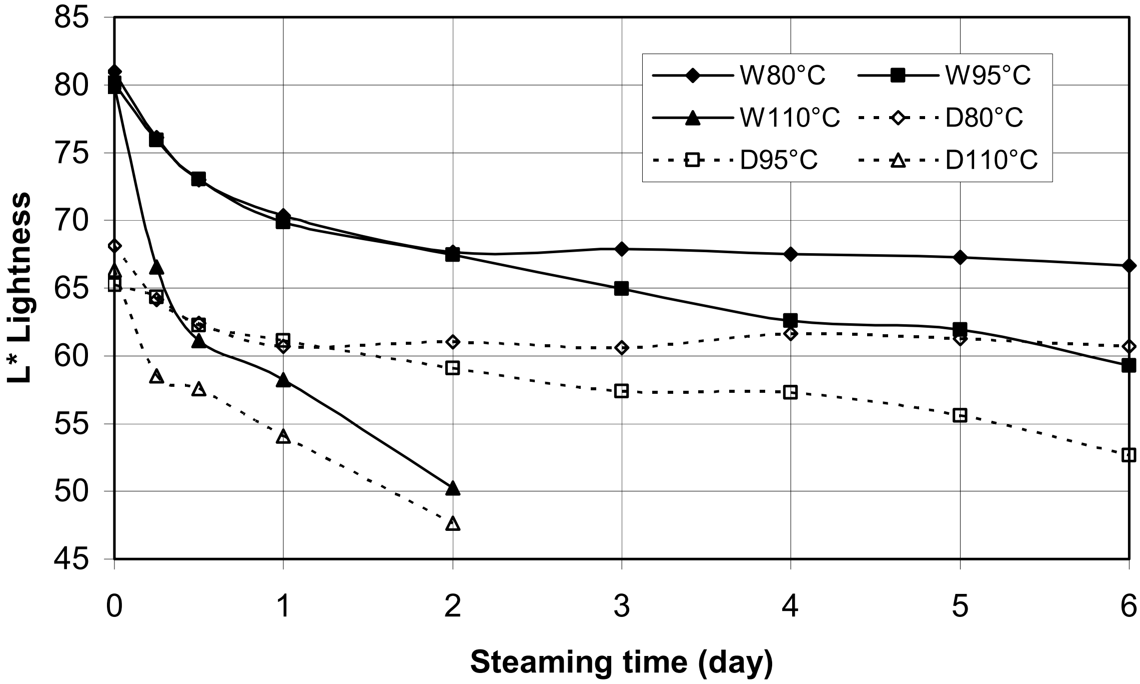

Figure 5. Lightness change of Turkey oak white sapwood (W) and dark heartwood (D) during steaming

The changes of red colour component are presented in *Figure 6*. Before steaming the dark heartwood was a little more red than the sapwood. During steaming the trend changed. The red colour component of white sapwood increased more rapidly than the same of heartwood. The trend lines crossed each other at 8 hours of steaming time (in case of 110°C treatment after 6 hours). After this time the colour inhomogeneity increased. Plotting the yellow colour components (*Figure 7*) of both type of Turkey oak samples the parallel changes were visible. These trends indicate that the steaming does not result in any homogenisation in case of yellow colour hue.

Comparing the lightness change and the change of the red colour component, the optimum steaming time at 80-95°C temperature range is about 12 hours and at 110°C 6 hours.

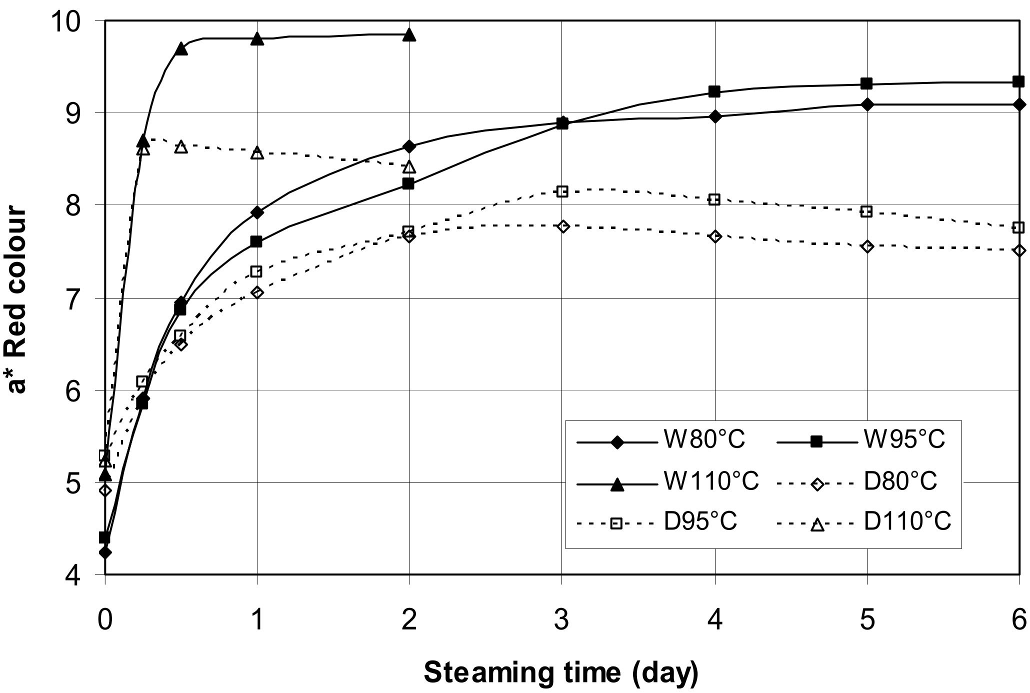

Figure 6 Change of red hue of Turkey oak white sapwood (W) and dark heartwood (D) during steaming

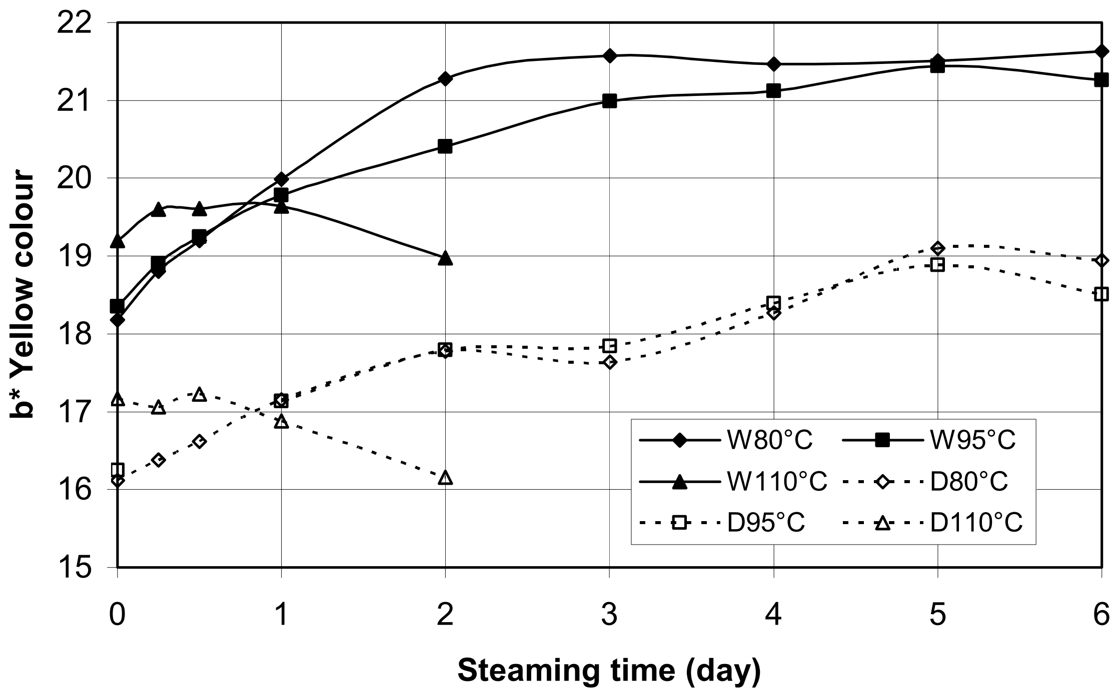

Figure 7. Change of yellow hue of Turkey oak white sapwood (W) and dark heartwood (D) during steaming

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