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PRACE NAUKOWE – RESEARCH PAPERS

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COLOUR HOMOGENISATION OF BEECH WOOD BY STEAM TREATMENT

In our study beech (Fagus silvatica L.) samples containing white and red heartwood were steamed to obtain colour homogenisation. Wide range of steaming temperatures (80–120°C) was applied for wet (47%), semi-wet (28%) and dry (8%) samples. All temperature values were effective in minimising the colour difference between white and red heartwood of beech. Below 100°C the colour change was similar irrespective of the temperature value. Determinative part of the colour change occurred during the first 12 hours of the process. It was found that the optimum homogenisation time is 0.5–2 days depending on the applied temperature value. The initial moisture content had no effect on the colour change if it was above the fibre saturation point. The colour shift was less intensive in the case of initially dry samples than in the case of wet samples. Colour homogenisation of beech wood by steaming below 100°C is not recommended if the timber is initially dry.

Keywords: beech, steaming, red heartwood, colour homogenisation, moisture content

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Introduction

In practice steam treatment of wood to obtain colour change was started as early as in the second half of the previous century. However, systematic research on discovering of specific effects of steaming parameters has been carried out for 10 years only. The most relevant publications concerning the steaming behaviour of black locust (*Robinia pseudoacacia*) are as follows: Molnár [1998]; Tolvaj and Faix [1996]; Tolvaj et al. [2000]; Horváth [2000]; Horváth and Varga [2000]. Horváth created an exponential function presenting the steaming temperature and time dependence of the lightness change of black locust [Horváth 2000]. Varga and van der Zee investigated some of the mechanical and physical properties of two European and two tropical hardwood species. The altering of these properties is caused by different steam treatments [Varga, van der Zee 2008]. Colour variations of steamed cherry wood are discussed in Straze and Gorisek [2008]. Black locust and beech timber are the wood species that are steamed mostly. It is usually thought that steaming of beech is uncomplicated, while steaming of black locust is difficult.

Beech is usually steamed to turn its white-grey initial colour into more attractive reddish. These days the increasing red heartwood portion of beech poses a great challenge to the timber industry. The identification of discoloration by colour measurement is described by Hrcka [2008]. The reason for red heart formation in logs is still only partly discovered. Recently published results [Hofmann et al. 2004, 2008; Albert et al. 2003] have revealed that the increase of pH value found at the border of red heartwood is indispensable for enzymatic processes to take place. At these increased pH values both enzymes (peroxidase and polyphenol-oxidase) responsible for oxidation of phenolic compounds are very active. The sharp decrease in concentration as well as change of the composition of phenolic compounds can be found at the red heartwood border. The chromophores of the red heartwood are formed in a narrow tissue range in front of the colour border by hydrolysis and oxidative polymerisation of beech polyphenols.

A new promising colour modification method, which is a combination of ultraviolet irradiation and thermal treatment, was also discovered. Mitsui and his co-workers found that UV treatment before steaming amplifies the darkening effect of steaming [Mitsui et al. 2001, 2004; Mitsui 2004].

The colour shift is related to alteration of conjugated double bound chemical systems. These bounds can be found in lignin and in the extractives. Thus colour changes in the tested temperature range originated mostly from alteration of the extractives. Sundqvist and Morén [2002] found that not only the extractives but also products of wood polymer degradation participate in formation of colour during hydrothermal treatment. Flavonoids play a significant role in discoloration of wood [Németh 1997; Csonka-Rákosa 2005]. 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.

The objective colour measurement helps the researchers to perform exact and detailed investigation in the field of colour modification of wood. This measurement method has been widely applied in wood research only recently [Bekhta, Niemz 2003; Hapla, Militz 2004; Mitsui et al. 2001, 2004; Mitsui 2004; Oltean et al. 2008; Tolvaj et al. 2000]. The objective colour coordinates allow description of behaviour of different wood species during steam treatment.

Materials and methods

The dimensions of beech (*Fagus silvatica L.*) specimens used in our laboratory experiments were 200 × 100 × 30 mm^3 (long. × tang. × rad.) and 200 × 100 × × 50 mm^3 (long. × tang. × rad.). Only samples without any wood defects were used for tests. Red and light heartwood surfaces were prepared as well. The treatment was carried out in a steam chest at 100% relative humidity in the temperature range of 80–120°C (98°C was applied instead of 100°C because it is the highest temperature which do not need a pressure chamber.) Wood specimens were placed in a large pot with distilled water for conditioning the air to maintain maximum relative humidity. The pots were heated in a drying chamber to the indicated temperatures. The steaming process started with a six-hour heating process. The temperature was regulated automatically around the set values with a tolerance of ± 0.5°C. Specimens were removed after 0.25, 0.5, 1, 2, 3, 4, 5, and 6 days. The temperatures between 110 and 120°C were generated in an autoclave. Samples of three different initial moisture content values (wet samples: EMC = 47%, semi-wet samples: EMC = 28% and dry samples: EMC = 8%) were investigated. No conditioning phase was applied at the end of the process. Samples were removed from the steaming chest right after the treatment finished and stored in laboratory conditions.

Before colour measurements treated wood specimens were conditioned for one month at a room temperature. Then the specimens were cut with a sharp circular saw along the centre line parallel to the longer side. Colour of the newly prepared planned surfaces was measured using a KONICA-MINOLTA 2600d colorimeter. The reflection spectrum was determined in the 400–700 nm region. L*, a*, b* colour coordinates were calculated in accordance with the CIELab system based on D65 light source automatically. On each specimen the measurements were conducted at 10 randomly chosen spots. Then the average value was calculated for further analyses.

Results and discussion

As described above samples of two different thicknesses (30 and 50 mm) were examined. It was found that there is no difference in steaming behaviour of these two types of samples.

The most intensive shift was experienced in the case of L* coordinate representing lightness. During the first 12 hours of steaming lightness decreased rapidly. After this period lightness change was moderate or it remained constant. The lightness of white heartwood decreased more rapidly than that of red heartwood (fig. 1). This phenomenon gives the possibility of colour homogenisation.

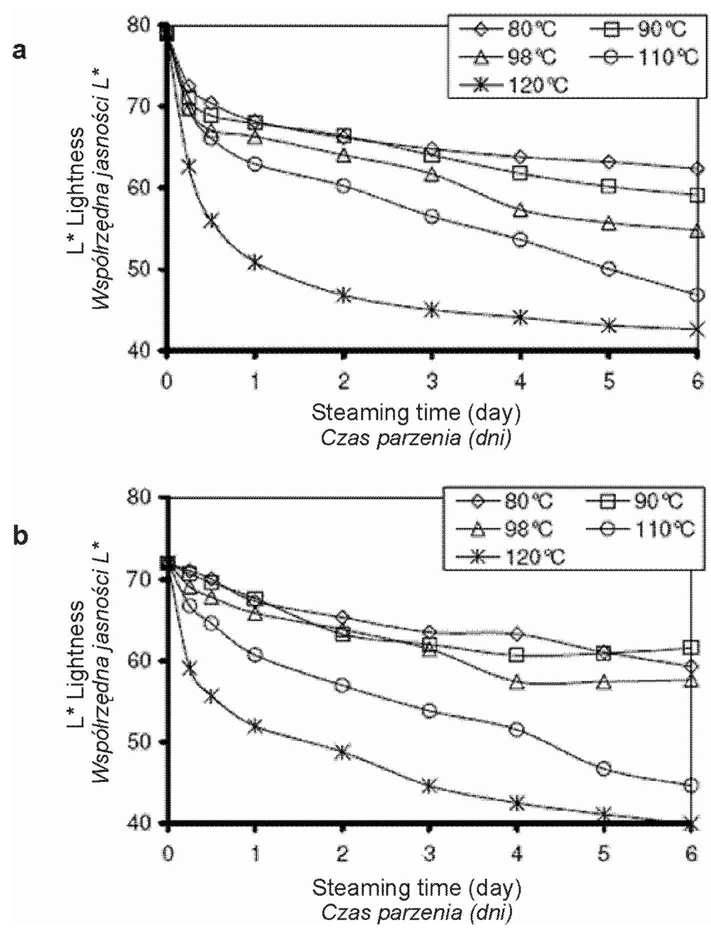

Fig. 1. Lightness change of white (a) and red (b) heartwood of beech (EMC = 47%)
Rys. 1. Zmiana współrzędnej jasności (L*) białej (a) i czerwonej (b) twardzieli drewna bukowego w procesie jego parzenia (EMC = 47%)

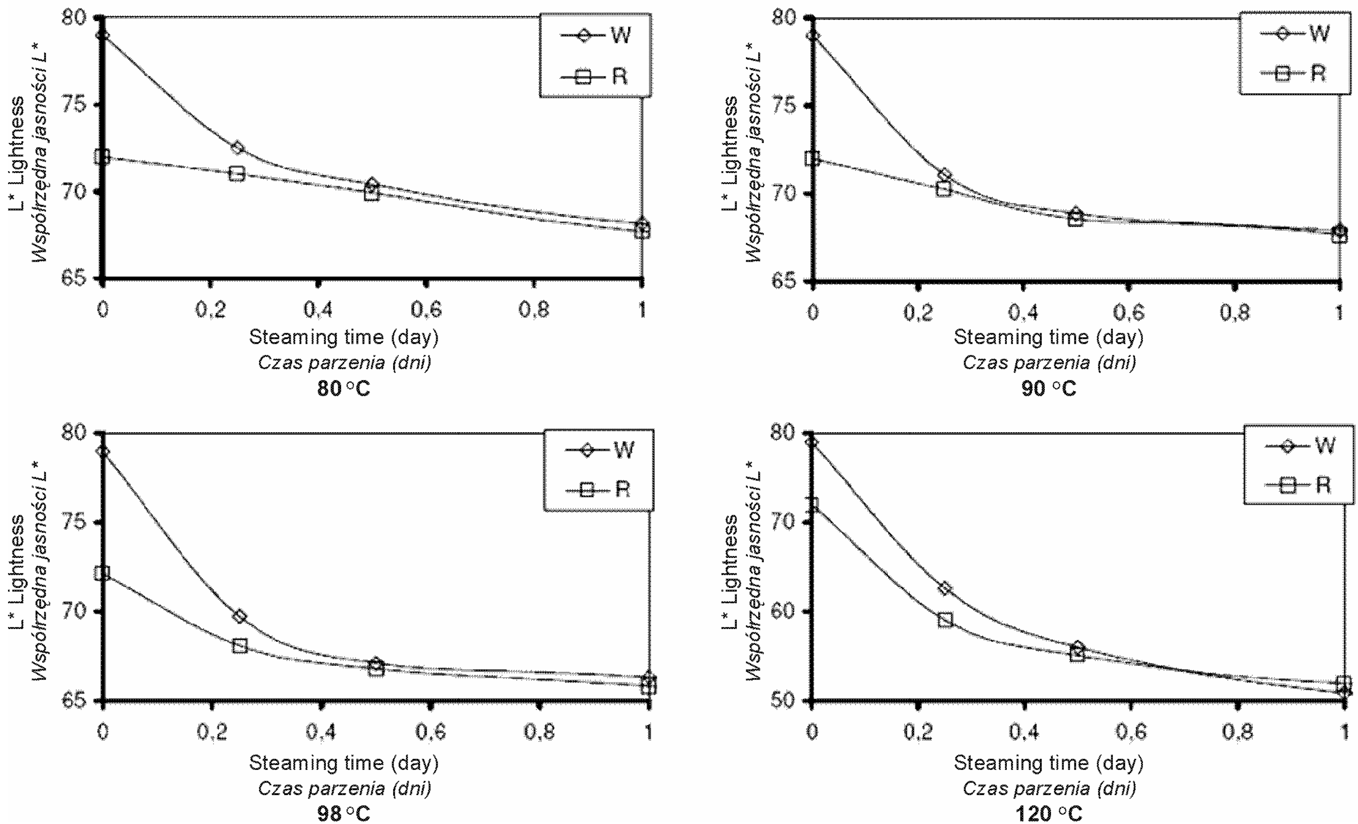

Fig. 2. Lightness change of white (W) and red (R) heartwood of beech at different temperatures (EMC = 47%)
Rys. 2. Zmiana współrzędnej jasności (L*) białej (W) i czerwonej (R) twardzieli drewna bukowego parowanego w różnych temperaturach (EMC = 47%)

It can be stated that below 100°C the effect of temperature on lightness is not significant. However lightness alteration above 100°C is more intensive. The difference between the lightness decrease of white and red heartwood was significant during the first 12 hours of steaming. After that time the trends proved to be the same. It means that colour homogenisation takes about 12 hours at any temperature. It is well visible in fig. 2 where the lightness changes of white and red heartwood are presented together at different temperatures. Differences are observed only in the trend of lightness decrease.

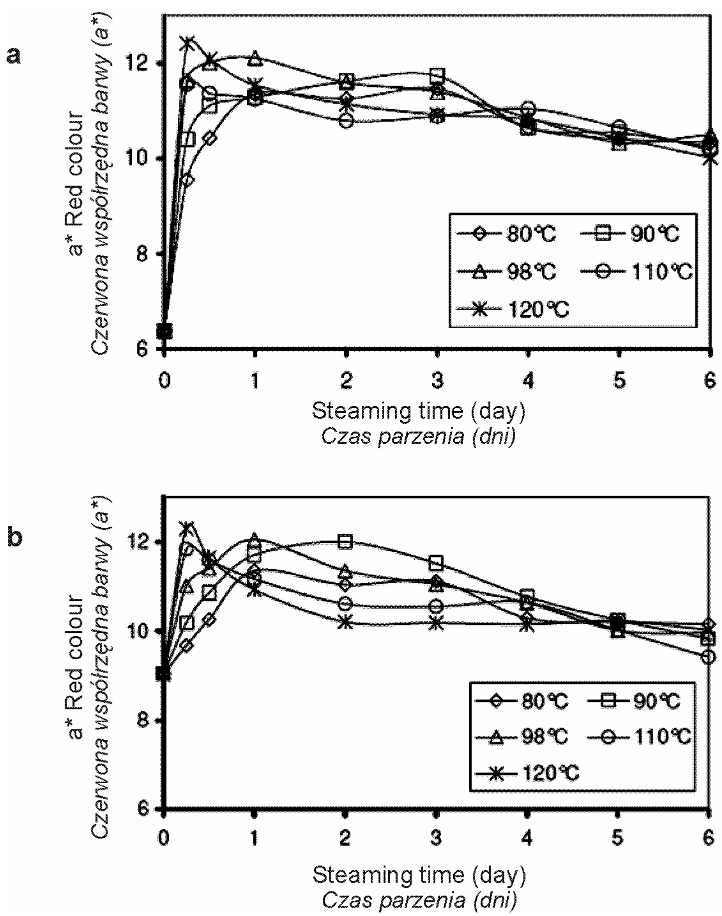

Fig. 3. Red colour change of white (a) and red (b) heartwood of beech (EMC = = 47%)

Rys. 3. Zmiana czerwonej współrzędnej barwy (a*) w procesie parowania białej (a) i czerwonej (b) twardzieli drewna bukowego (EMC = 47%)

The shift of red colour coordinate (a*) was opposite to that of lightness (fig. 3). The curves of red colour have a maximum. The increase before the peak was extremely intensive, while the decrease after that was moderate. With rising temperature the peak values shifted towards shorter steaming time values. The peak value was almost the same both in white and red heartwood. From the viewpoint of red colour the optimum steaming time belongs to the highest peak value. After that the steam partly leached out coloured chemical compounds

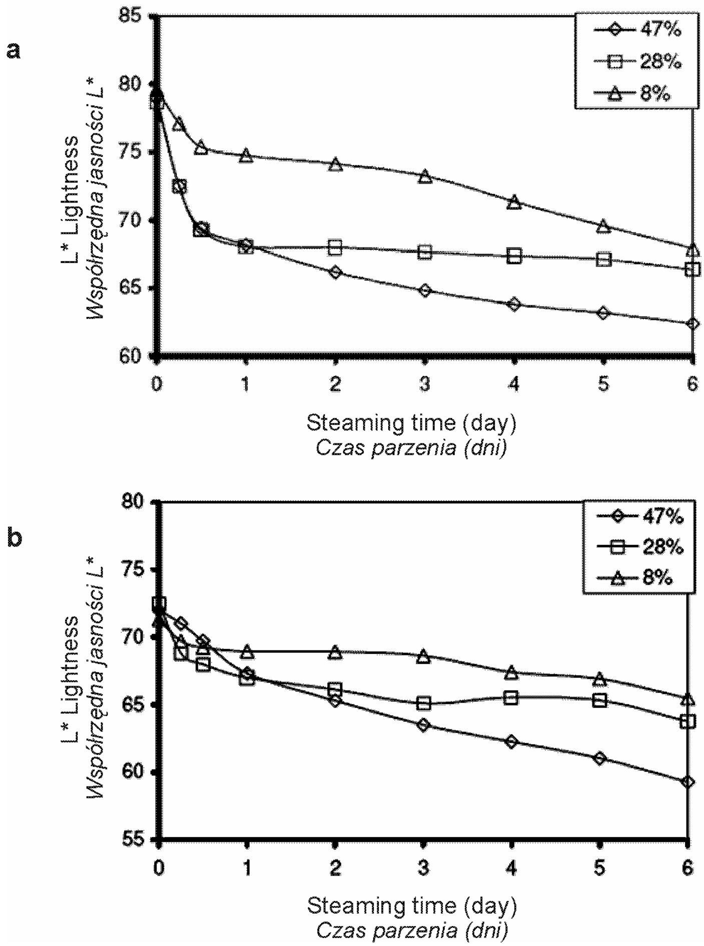

Fig. 4. Lightness change of white (a) and red (b) heartwood of beech at 80°C depending on the initial moisture content

Rys. 4. Zmiana współrzędnej jasności (L*) białej (a) i czerwonej (b) twardzieli drewna bukowego parowanych w temperaturze 80°C w zależności od początkowej wilgotności próbek

from the samples resulting in a decrease of a*. These times were longer below 100°C and shorter above 100°C than the times calculated according to lightnes change. To get the most attractive red colour the preferred steaming times are 2 days at 80–90°C, 1 day at 98°C, and 0.5 day at 110–120°C. Application of these treatment times also ensures colour homogenisation. To find out the effective steaming times under industrial conditions further semi-industrial investigations should be done.

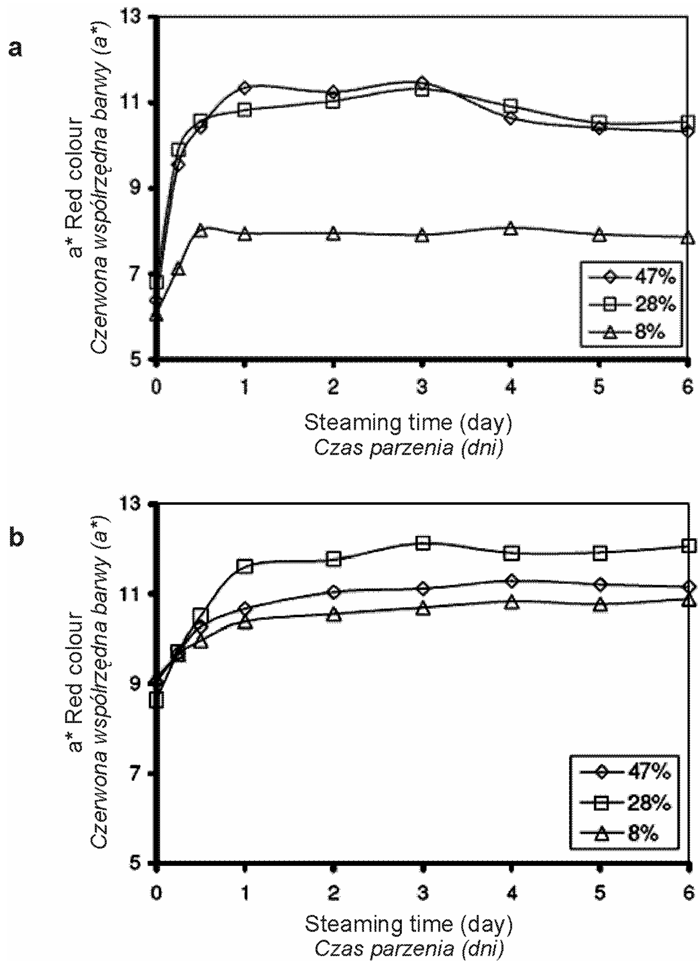

Fig. 5. Red colour change of white (a) and red (b) heartwood of beech at 80°C depending on the initial moisture content

Rys. 5. Zmiana czerwonej współrzędnej barwy (a*) białej (a) i czerwonej (b) twardzieli drewna bukowego parowanych w temperaturze 80°C w zależności od początkowej wilgotności próbek

The yellow colour hardly changed during the treatment process, only a slight decrease was observed on the first day. This decrease was similar for white and red heartwood. Therefore, it is assumed that the shift of yellow colour is not significant from the viewpoint of colour homogenisation.

The effect of the initial wood moisture content was also examined. The investigation of this parameter is important because there are many cases when relatively long time passes after falling until the actual steaming process is

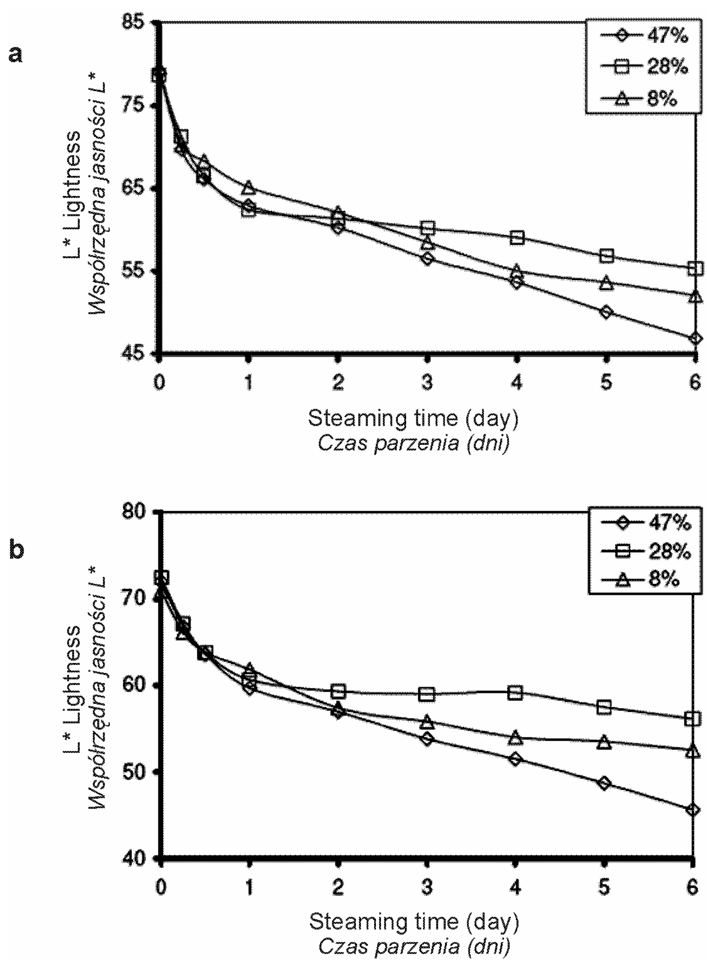

Fig. 6. Lightness change of white (a) and red (b) heartwood of beech at 110°C depending on the initial moisture content

Rys. 6. Zmiana współrzędnej jasności (L*) białej (a) i czerwonej (b) twardzieli drewna bukowego parowanych w temperaturze 110°C w zależności od początkowej wilgotności próbek

performed. In these particular cases the sawn timber tends to dry quickly depending on the wood species, thus semi-wet or even dry boards have to be hydrothermally treated. To imitate the situation semi-wet (EMC = 28%) and dry (EMC = 8%) samples were investigated as well. Results are shown in fig. 4–7 representing lightness and red colour change during steaming processes at 80 and 110°C. The figures confirm that colour changes of initially wet and semi-wet samples are similar. The only difference can be seen in fig. 7 where the red

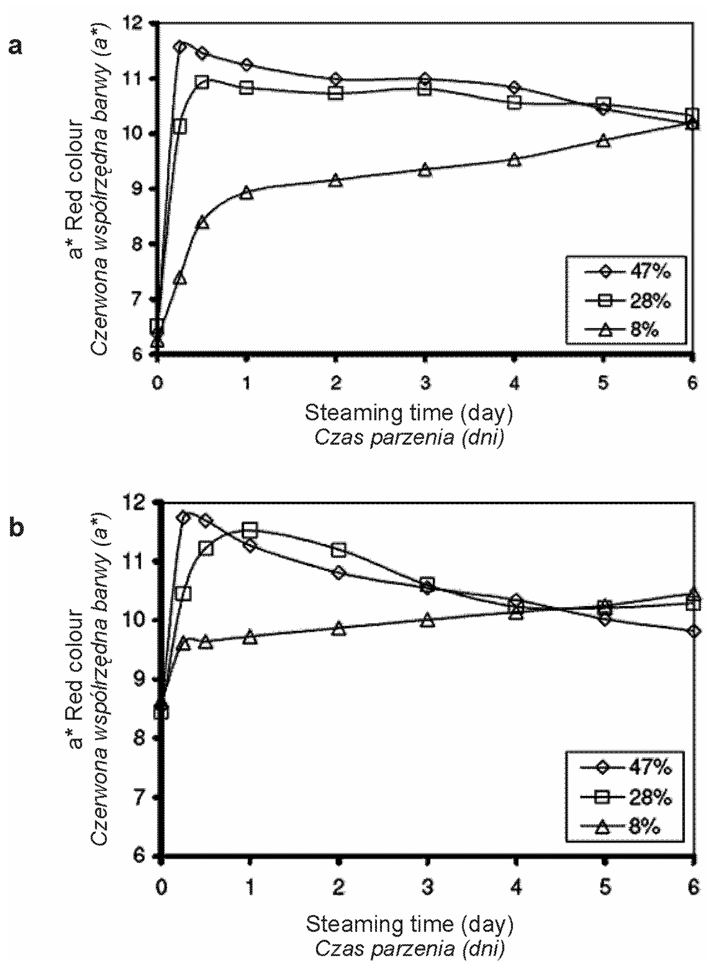

Fig. 7. Red colour change of white (a) and red (b) heartwood of beech at 110°C depending on the initial moisture content

Rys. 7. Zmiana czerwonej współrzędnej barwy (a*) białej (a) i czerwonej (b) twardzieli drewna bukowego parowanych w temperaturze 110°C w zależności od początkowej wilgotności próbek

colour increase was faster in the case of wet samples than in the case of semi-wet samples during the first 6 hours of treatment; however this difference seems to disappear after 2–4 days of steaming.

Below 100°C the lightness change of initially dry samples was slower than that of wet samples. It was found that white heartwood was more sensitive to the initial moisture content value than red heartwood as it is well presented in fig. 4–5. Above 100°C there was no significant difference among the examined series.

Based on fig. 5 and 7 it is clear that red colour is more sensitive to the initial moisture content. The increase of a* value was less intensive in the case of dry samples and below 100°C the difference was visible in the whole examined time interval. In timber industry beech samples are usually steamed below 100°C. Unfortunately, these temperatures are not suitable for colour homogenisation if the timber is initially dry. Above 100°C the increase of red colour of dry samples did not stopped after one day but continued in the whole examined time scale, so the a* coordinate was able to reach the red hue value of wet samples after 5 days of steaming.

Conclusions

All steam treatments in the examined temperature range (80–120°C) are suitable for homogenisation of the colour of white and red heartwood of beech assuming that the timber is in wet or at least semi-wet state. Below 100°C the temperature has no significant effect on the colour. Decisive part of the colour alteration occurred during the first 12 hours of treatment. Under laboratory conditions the optimum duration of the homogenisation process is 0.5–2 days depending on the applied temperature. Above fibre saturation point no relation was found between the initial moisture content and colour change. The colour shift was slower in initially dry samples than in wet samples. Colour homogenisation of beech wood by steaming below 100°C is not recommended if the timber is initially dry.

Acknowledgements

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UJEDNOLICENIE BARWY DREWNA BUKOWEGO POD WPŁYWEM PARY WODNEJ

Streszczenie

Badania, których celem była homogenizacja barwy drewna, obejmowały parzenie próbek drewna bukowego (*Fagus silvatica L.*) z białą i czerwoną twardzielą. Zastosowano szeroki zakres temperatur parzenia (80–120°C) dla próbek wilgotnych (47%), półsuchych (28%) i suchych (8%).

Wszystkie stosowane temperatury skutecznie zmniejszały różnice barwy pomiędzy białą i czerwoną twardzielą drewna bukowego. Po procesie parzenia w temperaturach poniżej 100°C zmiana barwy była na tym samym poziomie bez względu na zastosowaną temperaturę. Znaczące zmiany barwy wystąpiły podczas pierwszych 12 godzin procesu parzenia. Stwierdzono, że optymalnym czasem dla homogenizacji barwy jest okres od 0,5 do 2 dni w zależności od zastosowanej temperatury. Początkowa wilgotność drewna nie ma wpływu na zmiany barwy, jeśli jest ona powyżej punktu nasycenia włókien. W porównaniu z próbkami wilgotnymi, przesunięcie barwy w określonym kierunku było mniej intensywne. Jeśli drewno jest suche nie zaleca się homogenizacji barwy drewna bukowego poprzez parowanie poniżej 100°C.

Słowa kluczowe: drewno bukowe, parowanie/parzenie, czerwona twardziel, homogenizacja barwy, zawartość wilgoci