

COLOUR ALTERATION OF BEECH WOOD DURING AND AFTER DRYING

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Abstract

Undesirable colour alterations are not so rare during wood drying. Beech wood is a valuable wood species for furniture making but it is very prone to such discolourations. A darker area may appear in the interior of beech wood planks (known as “sandwich effect”) during kiln drying but the intensity of the phenomenon may be milder when planks are exposed to indirect light for some short period. In present paper these colour differences are discussed using colourimetric analysis, when planks appearing “sandwich effect” were exposed to indirect light for 12 months. Wood colour showed less differences month after month, compared to initial differences. Adding varnish just after surface planning contributed to higher visible differences.

Key words: Wood drying, discolouration, beech wood.

INTRODUCTION

Beech wood is one of the most important products of European forests. It is used mainly for indoor constructions, especially for furniture, as it performs excellent mechanical properties but it is not durable in external conditions. Beech wood is perishable in warm and humid conditions, permeable for preservation treatment, rather fast in drying but with a tendency to checks, warping and discolouration (Tsoumis, 1983). Discolourations that may be observed before and after drying, play a very important role on beech wood, as this is a very common wood species for furniture making. That's the main reason that steaming installations were used extensively for beech wood before drying, while it was totally wet, in order to give a darker but uniform reddish colour and a great experience has occurred in this field. Steamed beech wood obtains a more smooth and glossy surface and the intensity of how reddish it is depends on the time it is exposed to steams (Kakaras, 2009). On the contrary, air dried beech wood normally has a uniform pale colour, used to be called “white” among experts in Europe, but the specific method of drying lasts too much.

Last two decades there is a tendency in the market for light coloured wood species, so this fact restricted steaming as a common practice in sawmills, steaming installations are being abandoned and interest is focused on other techniques for controlling the wood colour. A lot of research is focused on the causes of discolouration (not only in beech but also in other species) in order to address measures for preventing it, especially during log storage and lumber kiln drying.

Discolourations during storage can be avoided, if the changes in temperature and moisture content that favour growth of microorganisms and the initiation of physiological and biochemical reactions are restricted. So, quick harvesting, transport and processing of logs is very important for the conservation of wood quality (Koch, 2008).

During lumber kiln drying intense conditions dominate inside kiln (raised temperatures, high relative humidity), that favour chemical reactions. The presence of oxygen also assists colour change. Hydrolysis of hemicelluloses may occur and is assumed one of the reasons that cause discolouration, as well as oxidation of the accessory compounds and cell wall components.



Fig.1. Darker inner part of a beech plank, known as “sandwich” effect, effect” combined with darker spots on all transverse section

As a result, many light-coloured species and especially beech, appear a darker inner part of the planks, known as “sandwich” effect (Allegretti et al. 2009) (Fig. 1).

It is suggested by many researchers that phenolic compounds are converted by oxidation and polymerisation into reddish, reddish-brown or dark compounds, that affect wood colour. It can be easily viewed that these colour altered compounds are mostly concentrated in wood rays and parenchyma cells (Fig. 2).

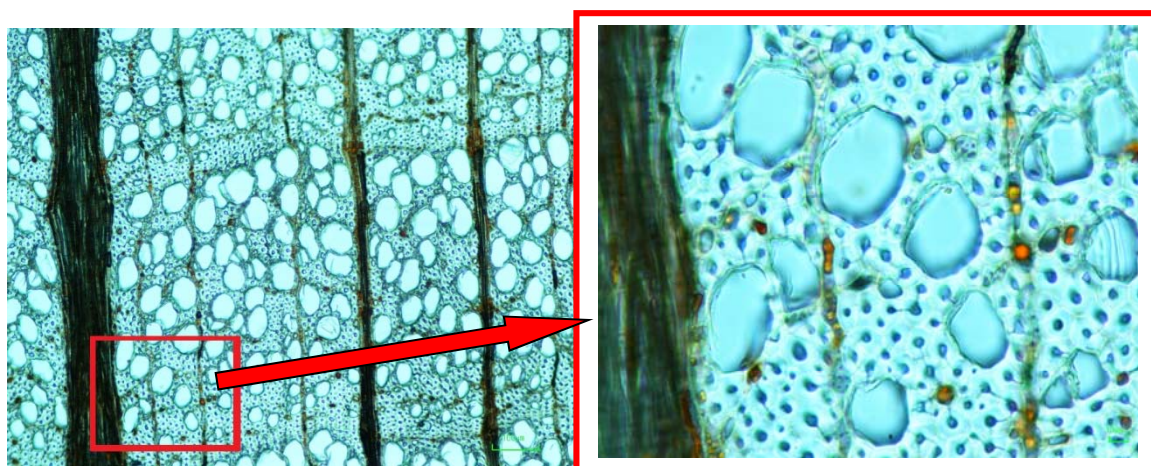


Fig. 2. Reddish accessory compounds inside parenchyma cells and in rays cause discolouration of beech wood.

In order to avoid oxidation there are techniques that proposed drying in nitrogen atmosphere (Wassipaul and Fellner, 1992), use of methanol and ethanol vapors (Pang, 2006) or vacuum drying to eliminate oxygen inside kiln (Cividini and Travan, 2003). They seem effective but difficult to find industrial application.

Concerning conventional drying, different drying schedules have been proposed, which may prolong drying procedure but keep colour more uniform and pale. As critical factor is drying temperature, it has been proposed that timber should be dried at a low temperature (Wengert 1990, Koch and Skarvelis, 2007). Temperatures below 40°C reduce discolouration and special drying schedules are proposed for this purpose (Allegretti et al., 2009).

There is a great degree of subjectivity, when someone tries to evaluate the degree of discolouration, so many researchers have used the colorimetric method to evaluate colour changes in different wood species during steaming or just after drying (e.g. Allegretti et al., 2009, Pervan et al. 2009, Ozciftci and Ozbay, 2010, R  ther and Jelle 2013).

Except the above, it is well known that wood colour changes also after drying, as it exposed to day light. Light influences lignin molecules and radicals react with oxygen and produce chromophoric carbonyl and carboxyl groups, which are responsible for colour changes. Photochemical reactions are initiated by the absorption of UV-visible light, which causes the formation of aromatic and other free radicals. These free radicals may then cause

degradation of lignin and photo-oxidation of cellulose and hemicelluloses (Pandey 2005a, Pandey 2005b, Sandoval – Torres et al. 2010). Besides the presence of light, oxygen (air circulation) also contributes to further colour changes. Exposure of sawn timber in the air causes changes in colour and contributes to the mitigation of chromatic contrasts of planed and unpainted wood, but not to the same extent observed with exposure to indirect lighting conditions (Skarvelis et al., 2012).

So, it is a challenge to examine if discolourations occurred during drying are affected - and how- after drying and a series of experiments carried out using beech wood. Beech wood specimens that had been previously kiln dried, were exposed to indirect natural light and measured.

Material and method

After finishing a drying run of beech sawn timber of greek origin (*Fagus sylvatica* L.), 3.5 m in length, 50 mm thick with different widths of planks, at a final moisture content 9%, 6 planks were selected from various rows of the wood stack and 6 specimens were taken from each plank. Inside end grain surfaces of all these specimens a darker area was appearing, that consists the so called “sandwich effect” (Mousilopoulos 2012).

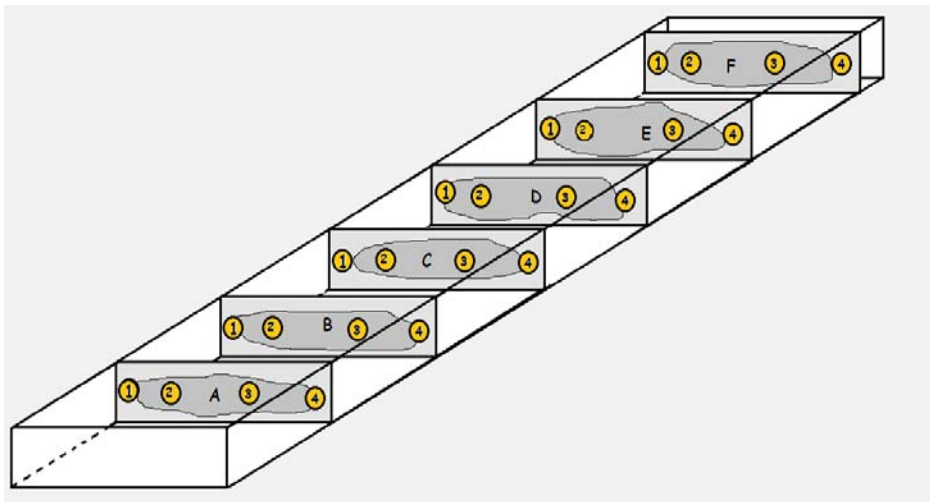


Fig. 3. In each plank 6 specimens were taken, in a distance of 50 cm from each other. In order to study the “sandwich effect” 2 pairs of colour measurements took place (1,2 left side - 3,4 right side).

On every specimen the same 4 colour measurements were taken (2 on the lighter – exterior side and 2 in the neighboring darker - interior area, Fig. 3). In order to avoid similarity due to neighboring, values in points “1” compared to values on points “3”, while values on points “4” compared to those on points “2”. Colour measurement was achieved using a portable Gardner 6805 BYK spectrophotometer. Measuring area window was 25 mm large, measuring in angles of 0° and 45°. The results were expressed in terms of colour coordinates L^* , a^* , b^* . In order to evaluate colour differences in different positions ΔE was estimated, where:

$$\Delta E = ((L_2 - L_1)^2 + (a_2 - a_1)^2 + (b_2 - b_1)^2)^{1/2}$$

Classification of measurements was done taking into account the magnitude of ΔE according to following plan (Allegretti et al., 2009):

ΔE value	Result
$\Delta E < 0,2$	Not visible difference
$0,2 < \Delta E < 2$	Small difference
$2 < \Delta E < 3$	Colour difference visible with high quality screen
$3 < \Delta E < 6$	Colour difference visible with medium quality screen
$6 < \Delta E < 12$	High colour difference
$12 < \Delta E$	Different colours

After that the sanded specimens were exposed to indirect daylight (behind a window) for 12 months (September '11 to September '12) and colour difference evaluations were repeated every month in the beginning and then after 4 months, in exactly the same positions.

RESULTS AND DISCUSSION

As it was expected, initial measurements showed that in every position there was a colour difference, compared to the adjacent position. These differences could be easily observed in every one of the 6 sections along the planks but they didn't occur in the same extend in all of them. Every different plank showed a heterogeneity through its length and such a heterogeneity of the material has been pointed out by other researchers, too (Allegretti et al., 2009).

ΔE values were always higher than 0,2 so differences were visible, but month after month these differences were alternating. The following diagrams show the averages of every months' measurements in each plank. Numbering of the planks (2.4, 4.4, 6.5, 8.4 etc.) represents the row of the stack and the order inside each row respectively, starting from top-left of the stack. So, planks were examined from allover wood stack size.

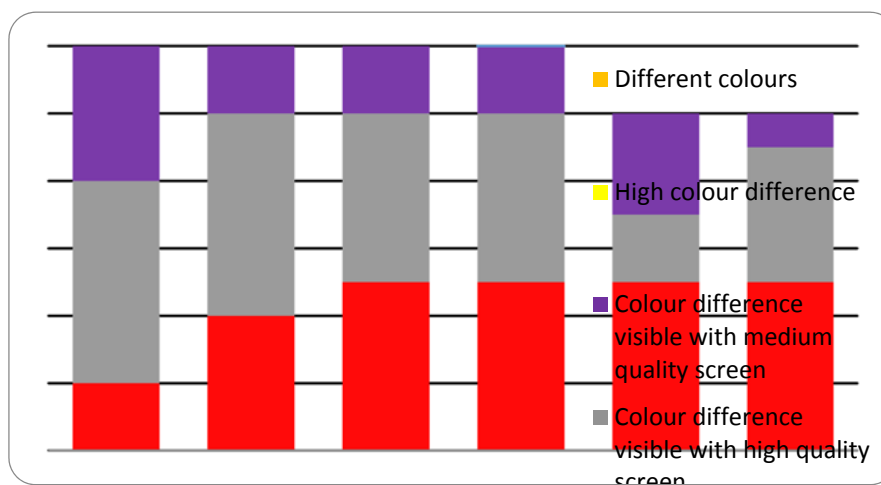


Fig.4. Colour differences along plank 2.4

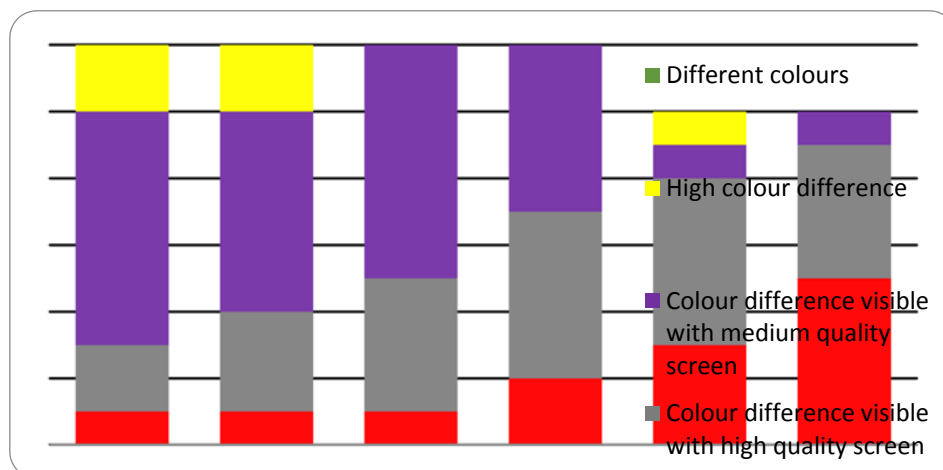


Fig.5. Colour differences along plank 4.4

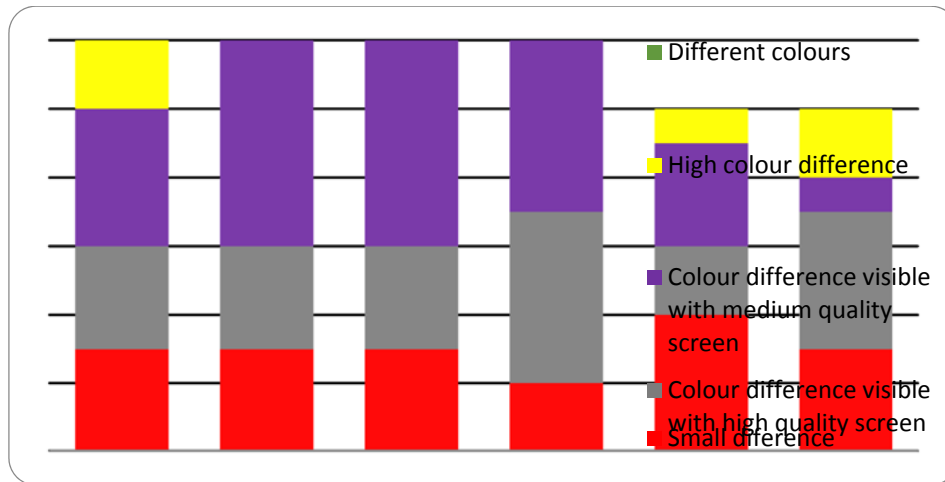


Fig.6. Colour differences along plank 6.5

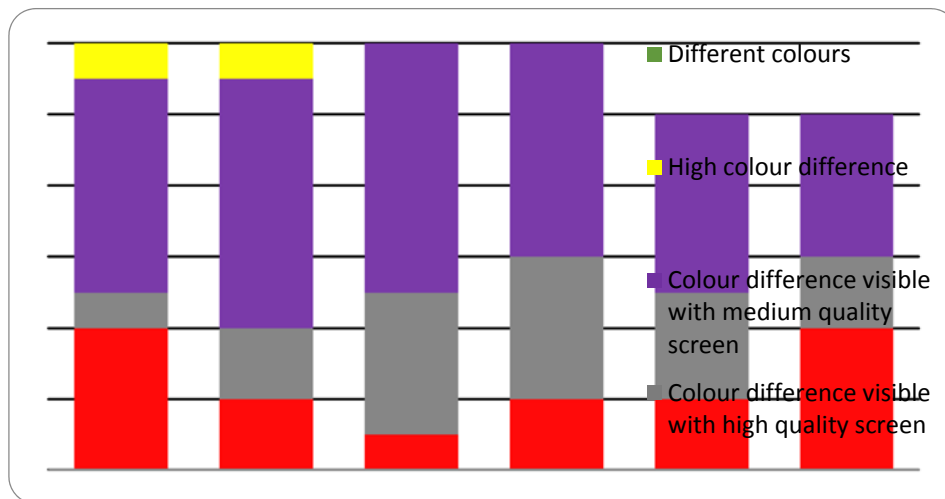


Fig.7. Colour differences along plank 8.4

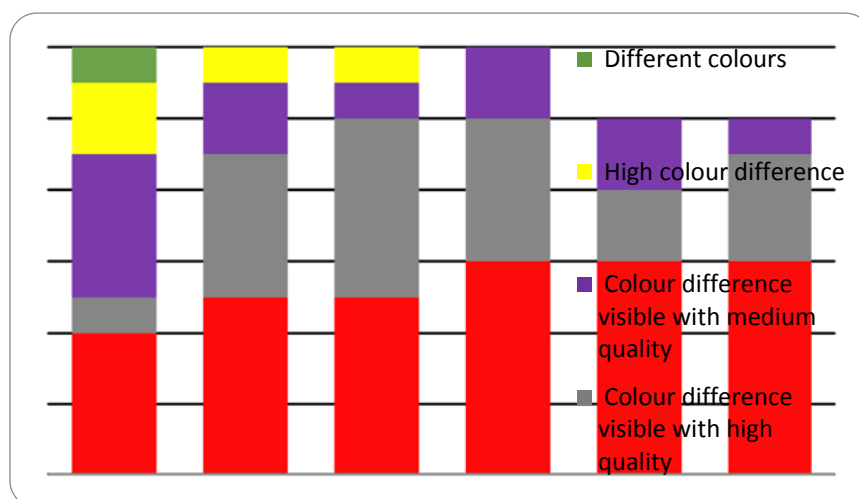


Fig.8. Colour differences along plank 10.2

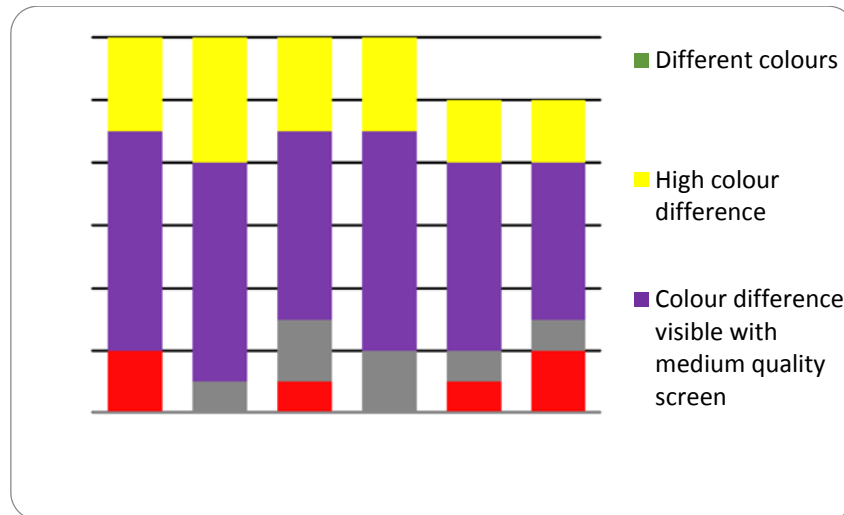


Fig.9. Colour differences along plank 12. 1

From the above diagrams it is shown that as time passes colour differences become smaller. This observation is not ideally repeated in all planks (i.e. planks 8.4 and 12.1 show different results in the beginning), but the trend throughout the whole period examined clearly shows that ΔE becomes continuously lower for each pair of measurements, especially for the first 4 months. All surfaces became darker compared to first exposure on indirect daylight (September 2011) but lighter in colour areas (on the exterior part of the specimens) had a higher degree of transformation. Observations belonging in “Small difference” class were increasing, corresponding to a decrease in observations of “Colour difference with medium quality screen” class. Only in one case the result “Different colour” was observed and this happened only for the first month. So, indirect light might be a remedy when colour differences occur.

A second series of observations took place, when 3 of the above used planks were varnished, using a water-soluble varnish. The difference compared to previous examples was that in this case all measurements were not taken on the cross section but on the face of the planks, which was always a tangential surface. Each point taken, was compared to all other neighboring points for a period of 20 months.

The results are shown in the following diagrams, where – for comparison – the results of the same unvarnished plank (as they were previously presented) are given in the right column. Time passed from each measurement to the next is very similar in both cases, although total time in varnished specimens is extended to 20 months.

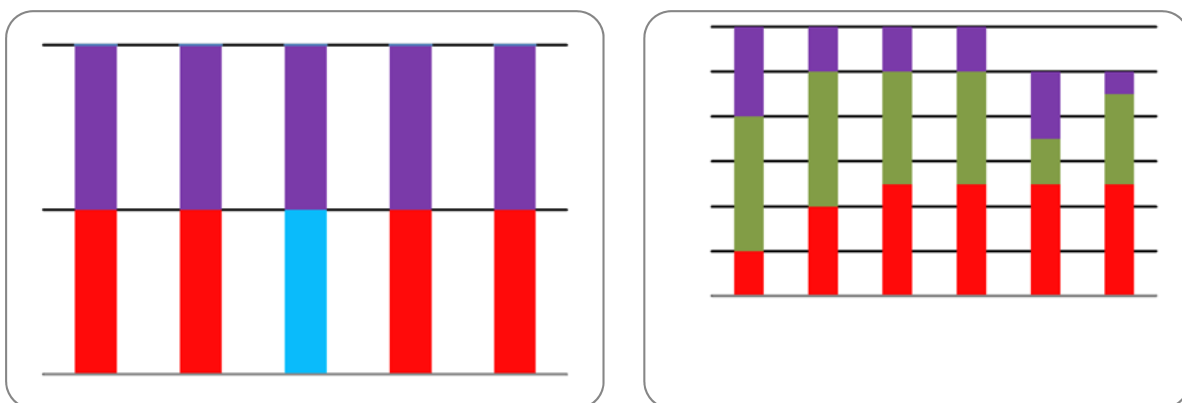


Fig. 10. Colour differences along varnished plank 2.4

Colour differences along plank 2.4

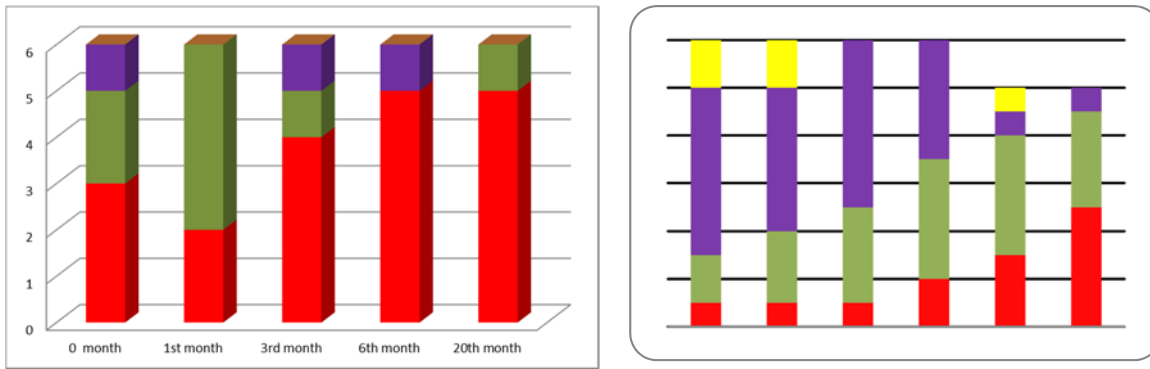


Fig. 11. Colour differences along varnished plank 4.4

Colour differences along plank 4.4

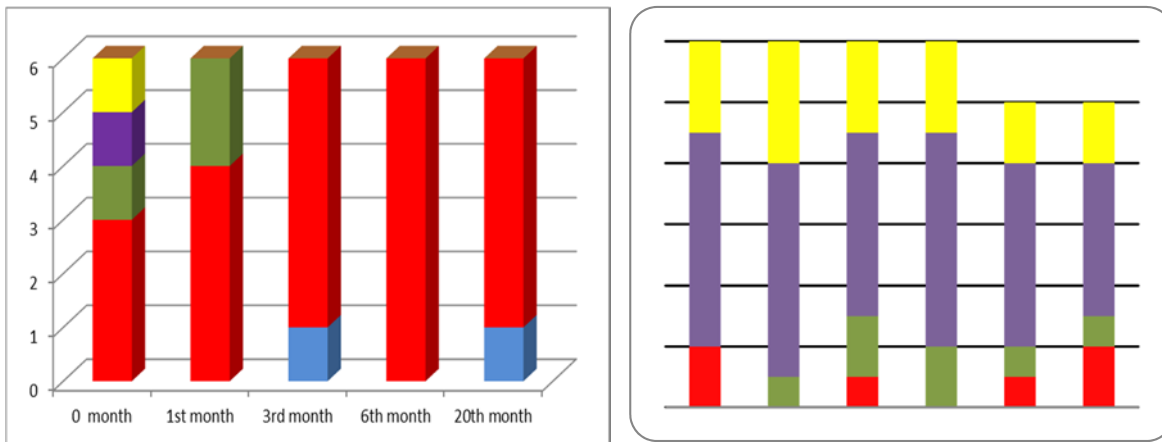


Fig. 12. Colour differences along varnished plank 12.1

Colour differences along plank 12.1

Legend		Different colours
		High colour difference
		Colour difference visible with medium quality screen
		Colour difference visible with high quality screen
		Small difference
		Not visible difference

From the above given comparison it is clearly shown that even with varnished specimens, colour differences become smaller in a more rapid way as time passes, although there is not a free oxygen exchange with the environment, compared to end grain unvarnished surfaces. Even in plank 12.1, where from the beginning colour changes didn't prove the same clear transfer from to more uniform colours, when it was varnished on tangential surfaces gave a significant uniformity in colour after 6 months. Of course colour changes are still going on but the general trend is that differences are minimized. Perhaps spectrophotometer is affected by varnish, its gloss and film thickness, but it has to be further examined. Varnished surfaces show also mitigation of colour changes even from the beginning and these mitigations become much lower at a period of 20 months, although the comparison is between unvarnished cross sections and varnished tangential surfaces.

CONCLUSIONS

Discolourations caused during drying are common in many wood species and for beech wood it is a common case. The existence of light and oxygen influences these discolourations as they become lower. Colour change is proportional to exposure time, at least for the first 12 months, according to our observations. Varnished surfaces show also mitigation of colour changes even from the beginning and these mitigations become much lower at a period of 20 months.

Colourimetric analysis that was proposed by other researchers was also applied in this work successfully. Our data showed that environmental conditions after drying continue to affect the colour of the timber, varnished or not.

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