SOME ASPECTS OF BEECH WOOD DISCOLOURATION DURING DRYING

Michalis SKARVELIS
TEI of Larissa, Department of Wood and Furniture Design and Technology,
V. Griva 11, 43100 KARDITSA GREECE
skarvelis@teilar.gr

Konstantinos MOUSILOPOULOS
TEI of Larissa, Department of Wood and Furniture Design and Technology,
V. Griva 11, 43100 KARDITSA GREECE
kmousilo@gmail.com

George NTALOS
TEI of Larissa, Department of Wood and Furniture Design and Technology,
V. Griva 11, 43100 KARDITSA GREECE
gntalos@teilar.gr

Abstract

Many factors influence the colour of beech wood and some of them are related to drying conditions. Air dried beech wood normally has a uniform pale colour (unless a red false heartwood occurs), used to be called "white" among experts in Europe. Concerning kiln dried beech wood the situation is not the same, as it varies too much from pale reddish to dark brown-red colour. Present paper adds some more information how to mitigate beech wood discolololourations after kiln drying, focusing mainly on experiences and observations made using different handling just after drying of Greek origin beech wood.

Key words: Wood drying, discolouration, beech wood.

Introduction

The importance of colour uniformity in wooden planks intended to be used in furniture has been reported by many researchers and timber traders. Discolourations in general and especially discolourations during drying phase of wood is a topic of big interest in recent years, as the demand for light coloured furniture has increased.

Concerning wood for furniture, beech (mainly *Fagus sylvatica L.*) is an important wood species for European market, as extended forest areas are covered by beech trees. The mechanical properties of beech wood are also very good and its ability to be easily bended has turned it into a very important species for home furnishing as well as a major substitute for other, more valuable, species (e.g. oak, walnut and some tropical woods). Air dried beech wood normally has a uniform pale colour, used to be called “white” among experts in Europe. On the other hand, beech wood is prone to differentiations of colour, not only among different trees but also in the same tree and even more in the same plank. These disparities appear as alternating dark - bright stripes, spots or dark- reddish false-heartwood.

It is this heterogeneity of colour that resulted in steaming of beech wood even before the stage of drying, to obtain a uniform reddish color. For years and years special steaming installations were used by sawmillers who converted beech logs into planks, great experience has occurred in this field and a lot of (scientific or not so much) papers have been written on this topic. It is believed that steamed beech wood gives more smooth and glossy surfaces, while mechanical properties of beech wood practically remain the same after steaming, although there is a slight decrease in impact (Tsoumis, 1983).

Nowadays, market data have changed: requirements for light coloured woods have restricted steaming as a common practice in sawmills, steaming installations are being abandoned and interest is focused on other techniques. The goal is to better understand the causes of discolouration (both in beech and in other species) and take preventive measures, especially during log storage and lumber kiln drying.

Just after felling trees and during storing logs, a lot of parenchyma cells are still alive and this leads to physiological reactions for several weeks after felling. Formation of tyloses and accessory compounds in living cells cause discolourations in beech wood (Bauch, 1984). Fungi infestation is another reason for discolouration and chemical treatments have been used to prevent log staining from fungi, but beech and also some other species did not respond (Cassens, 1991). 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).

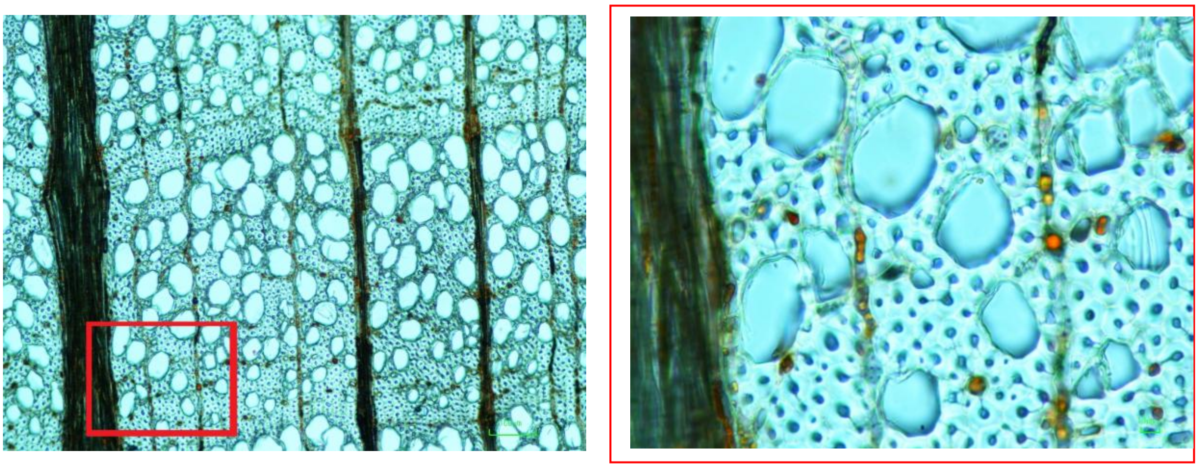


Fig. 1. Reddish accessory compounds inside parenchyma cells and in rays cause discolouration of beech wood.

During lumber kiln drying intense conditions dominate inside kiln (raised temperatures, high relative humidity), that favour chemical reactions of the accessory compounds and cell wall components.

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. Hydrolysis of hemicelluloses may also cause discolouration. The presence of oxygen assists colour change. As a result, many light-coloured species appear a darker inner part of the planks, known as “sandwich” effect (Fig.2).

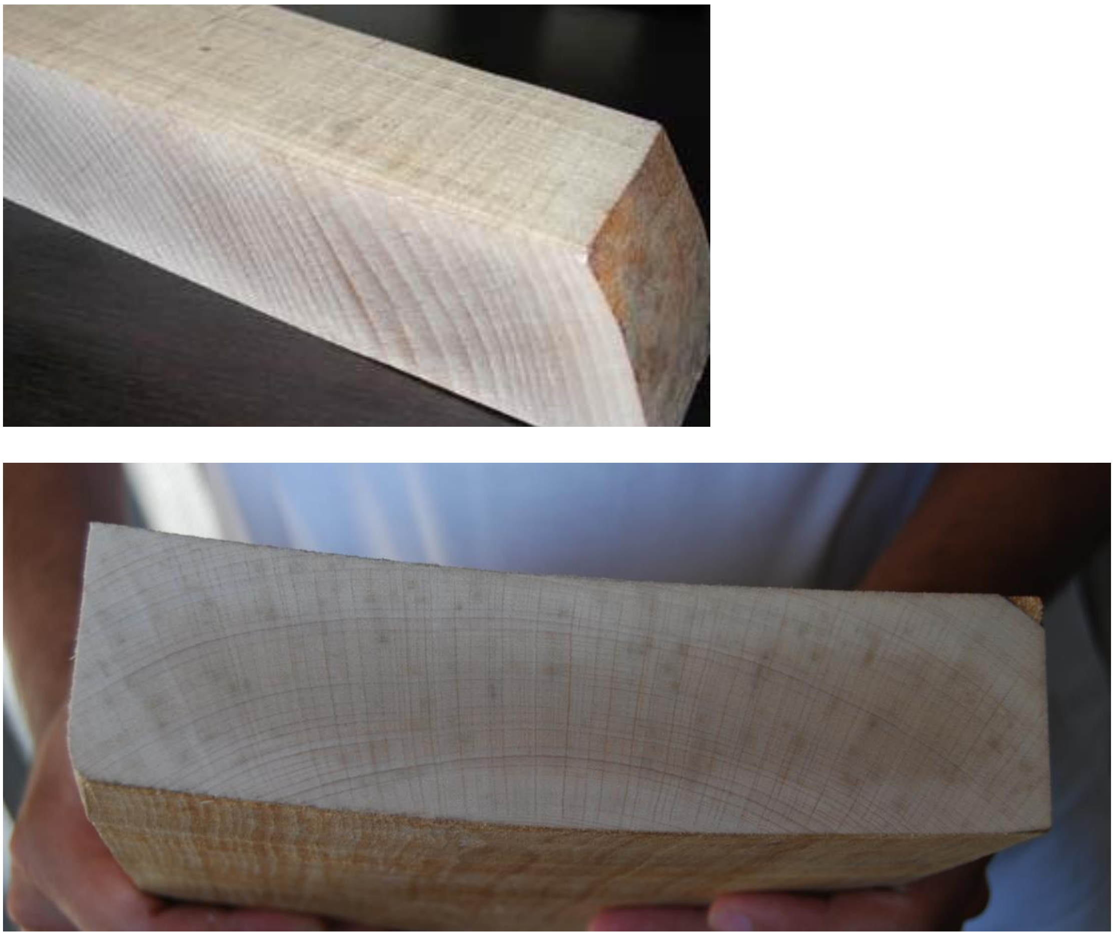


Fig.2. Darker inner part of a beech plank, known as “sandwich” effect (above). “Sandwich effect” combined to darker spots on all transverse section (below).

Some techniques that proposed drying in nitrogen atmosphere (Wassipaul and Fellner, 1992) or using methanol and ethanol vapors (Pang, 2006) didn’t find any industrial application yet. Vacuum drying seems that gives good results, due to eliminated quantities of oxygen in kiln’s atmosphere (Cividini and Travan, 2003).
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^oC reduce discolouration (Ananias et al., 2006) and special drying schedules

are proposed for this purpose (Allegretti et al., 2009). It is also proposed to keep temperatures below 30^{o}C until MC drops below 20% (Gard et al. 2010).

It is very difficult to evaluate with naked eye 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. Ho-yang Kang 2006, Allegretti et al., 2009, Pervan et al. 2009, Özcifci and Özbay, 2010,)

Another question also is: what happens just after drying? Does discolouration terminate after drying? 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, mainly by lignin, which leads to 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).

In order to examine the discolourations just after drying, during dried lumber storage and further conversion phases, a series of experiments carried out using beech wood, measuring specimens exposed to indirect natural light.

Methodology

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

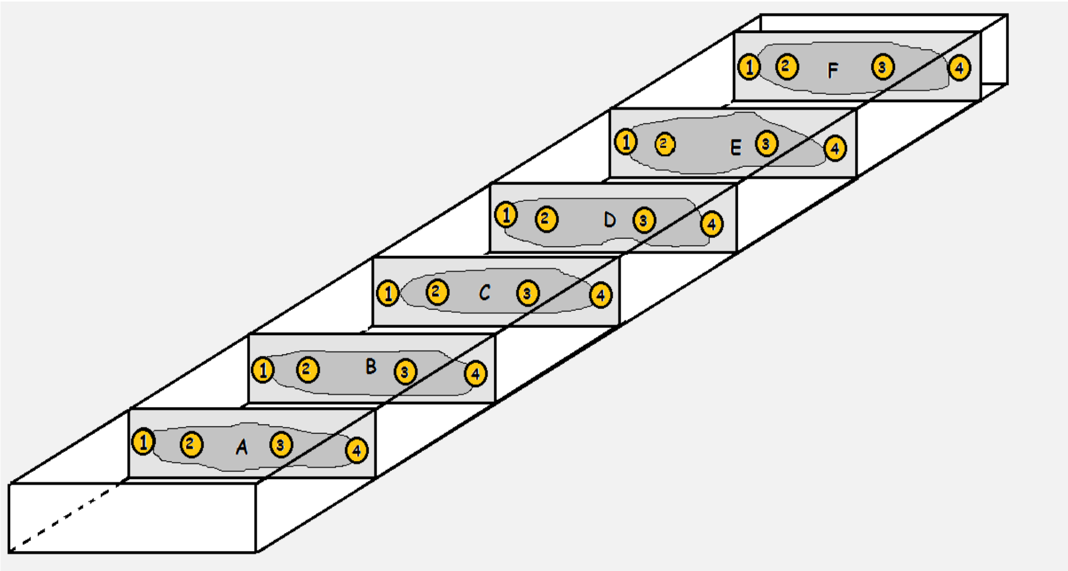


Fig. 3. In each plank 6 specimens were taken, in a distance of 50 cm from each other. In order to study the “sandwich effect” 2 pairs of colour measurements took place (1,2 left side - 3,4 right side).

On every specimen the same 2 pair of colour measurements were taken (2 on the lighter – exterior side and 2 in the neighboring darker - interior area). Values in points “1” compared to values on points “2”, while values on points “4” compared to those on points “3”. Colour measurement achieved using a portable “Gardner BYK“ spectrophotometer. Measuring area window was 25 mm large, measuring in angles of 0^o and 45^o. 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:

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

They were classified taking into account the magnitude of ΔE according to following plan (Allegretti et al., 2009):

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

After that the sanded specimens were exposed to indirect daylight for 4 months (September to December) and colour difference evaluations were repeated every month, in exactly the same positions.

Results and Discussion

Initial measurements showed that in every position there was a colour difference, compared to the adjacent position.

These differences were obvious in everyone of the 6 sections along the planks but not to the same extend. E.g. in plank 2.4 sections A,C and D look alike (only “Colour difference visible with high quality screen”, although not in the same degree), sections B and E look also alike (1 “Small difference” and 1“Colour difference visible with high quality screen”), while section F is different (1 “Colour difference visible with high quality screen” and 1 “Colour difference visible with medium quality screen”). So there is a variation in differences along the planks which was observed in all examined planks. The heterogeneity of the material has also been pointed out by other researchers (Allegretti et al., 2009)

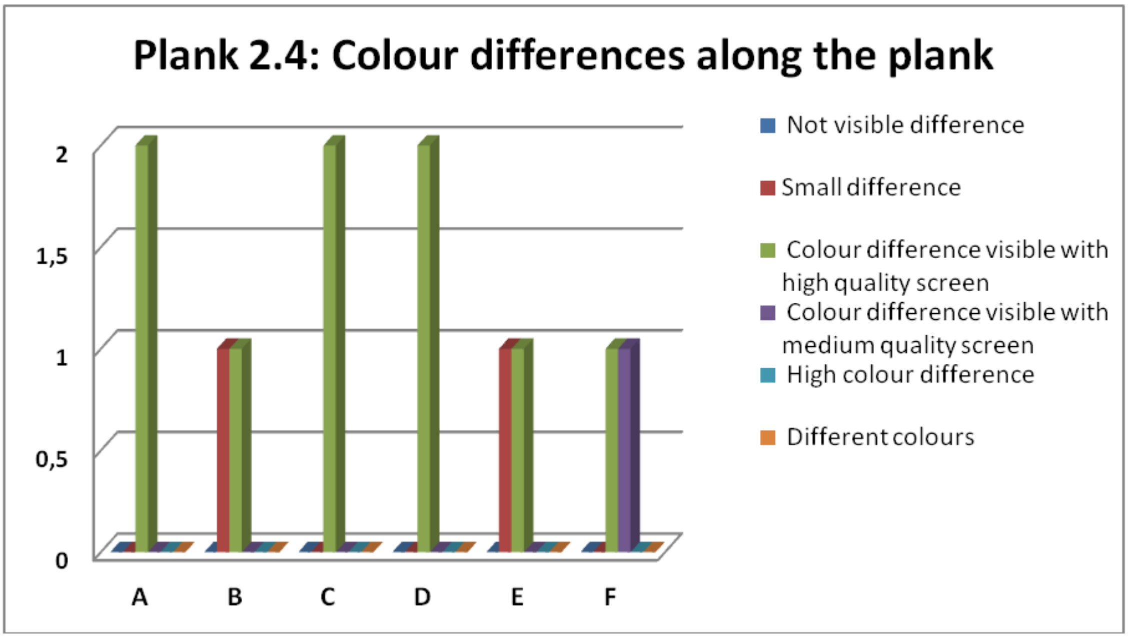
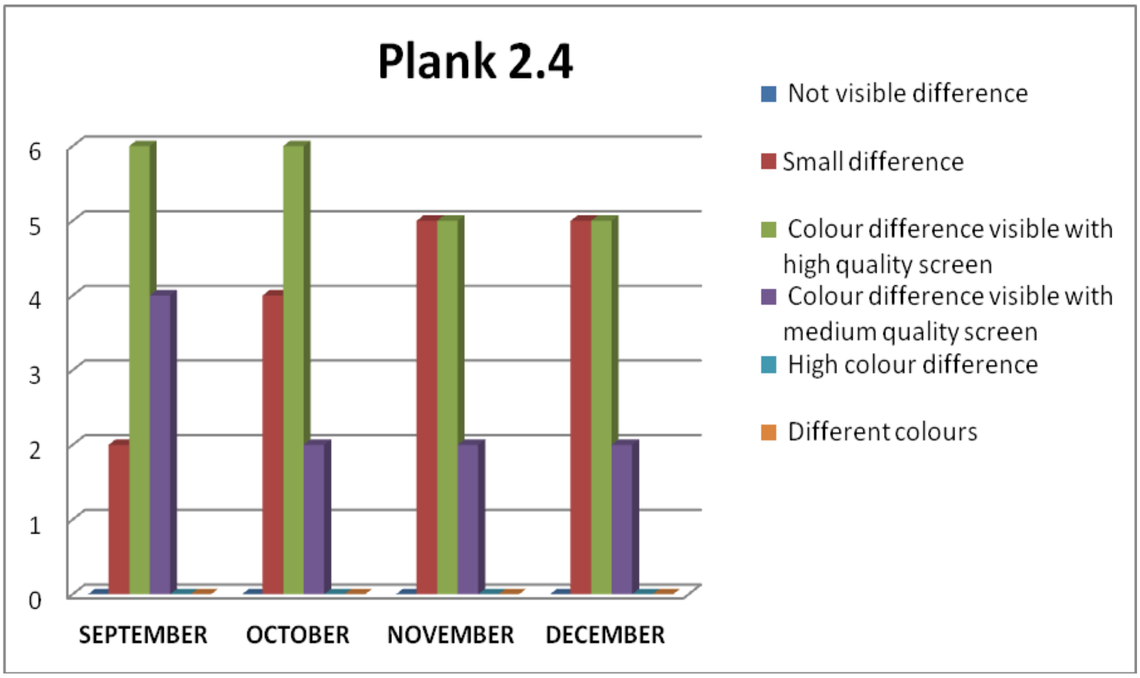
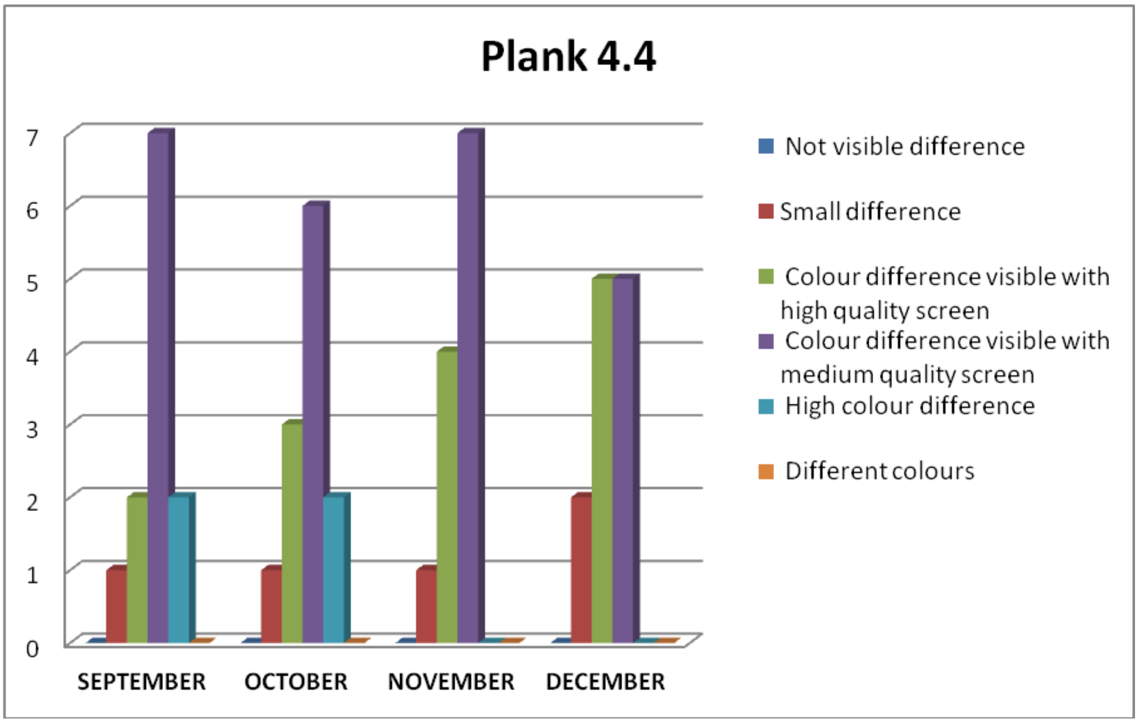
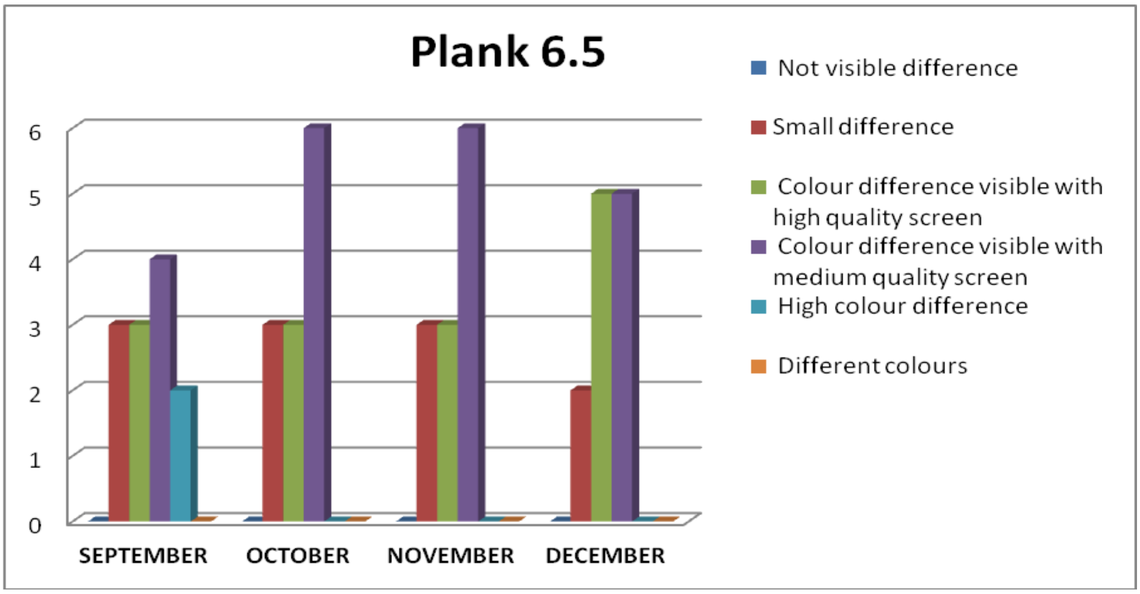


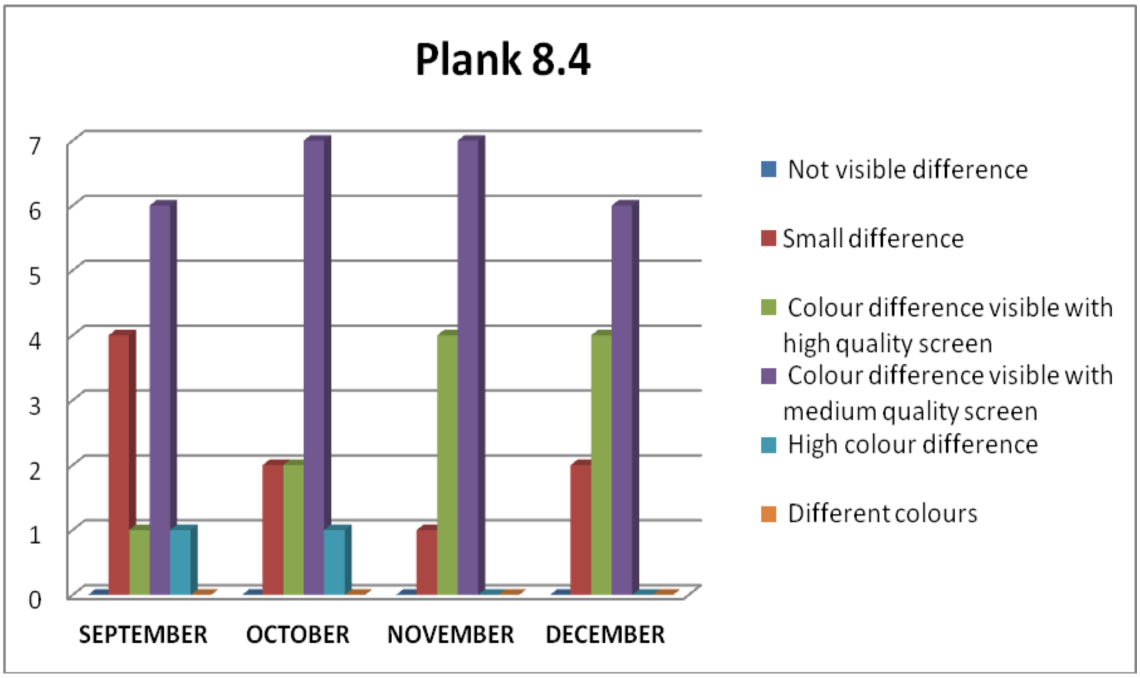
Fig. 4. Discolourations do not appear in the same extend along the planks.

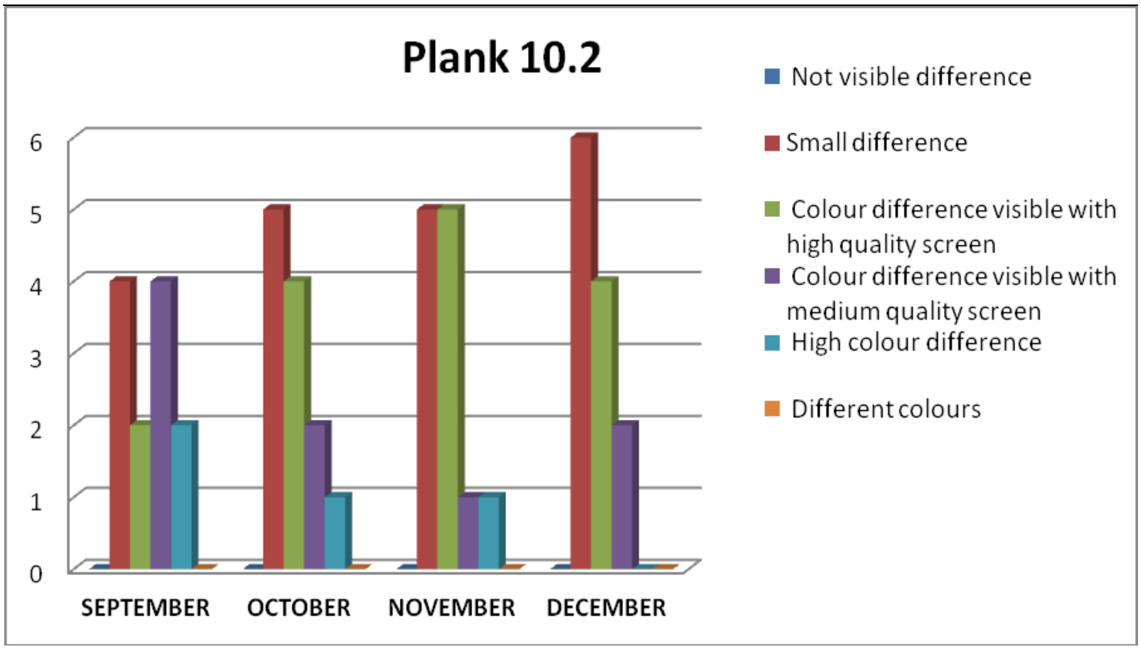
ΔE values were always higher than 0,2 so differences were visible, but month after month these differences were alternating. The following diagrams show the averages of every months' measurements in every plank.




Plank 4.4
7
6
5
4
3
2
1
0
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
Not visible difference
Small difference
Colour difference visible with high quality screen
Colour difference visible with medium quality screen
High colour difference
Different colours


Plank 6.5
6
5
4
3
2
1
0
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
Not visible difference
Small difference
Colour difference visible with high quality screen
Colour difference visible with medium quality screen
High colour difference
Different colours


Plank 8.4
7
6
5
4
3
2
1
0
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
Not visible difference
Small difference
Colour difference visible with high quality screen
Colour difference visible with medium quality screen
High colour difference
Different colours


Plank 10.2
6
5
4
3
2
1
0
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
Not visible difference
Small difference
Colour difference visible with high quality screen
Colour difference visible with medium quality screen
High colour difference
Different colours

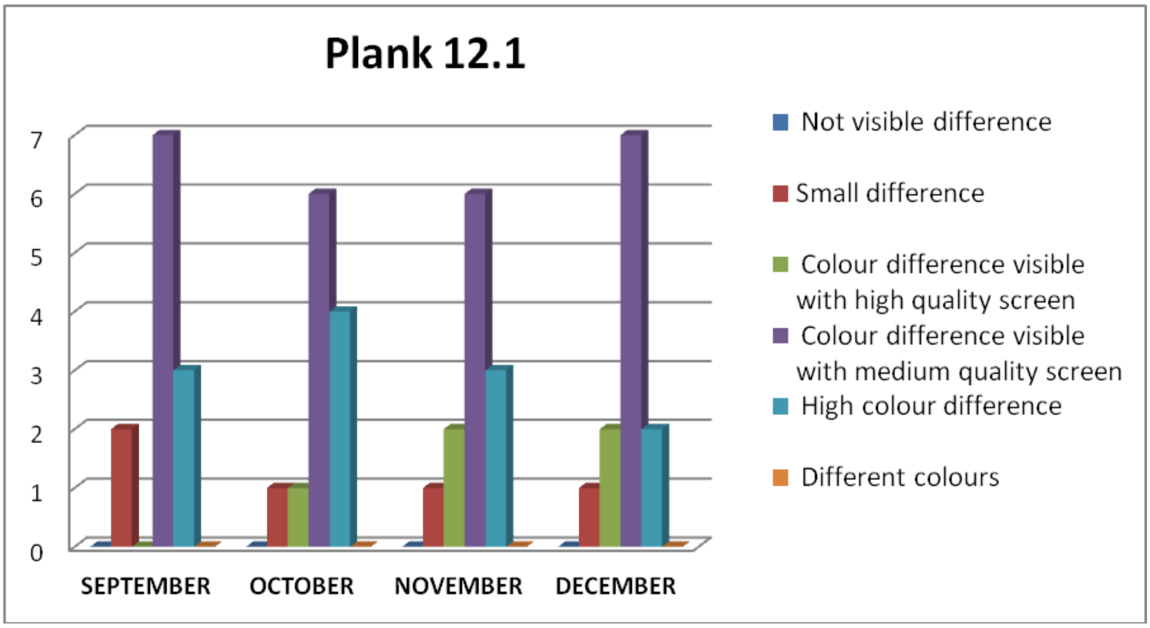


Fig. 5. Discolourations were becoming less intensive from month to month.

As it is shown in diagrams, from month to month there is a transfer from right to the left, in other words colour differences become lower as time passes. A slight difference was appeared in planks 8.4 and 12.1, where there was a transfer to the right in October and then behaved as all the other planks. As light influences wood colour it becomes darker, the values of L*, and b* were lowering while a* values were becoming higher. All surfaces were becoming darker compared to first exposure on daylight (September) but lighter in colour areas on the exterior part of the specimens had a higher degree of transformation. As a general result in most of the cases the value of ΔE was lowering as time passed.

As it was shown above, exposure to indirect daylight influenced wood colours, leading to milder differences.

A second series of measurements took place took place after January (4 months after the initial exposure of the sections to the indirect light), in order to examine if other factors affect colour, too. Specimens from the first section ("A") of each plank were measured on January, using the same procedure described previously, without caring if measured points belong to lighter or darker (from "sandwich effect" affected) areas. Then they were sanded in a depth of 2 mm and colours were measured again. Depth of 2 mm is assumed to be very sufficient to isolate the light-influenced surface, as light does not penetrate wood more than 0,200 μm (Feist and Hon, 1984). After that specimens were deposited in a dark room, were there was a slight air circulation, for 4 more months. Colour measurements on May showed that there were also colour changes, even in the absence of direct or indirect daylight.

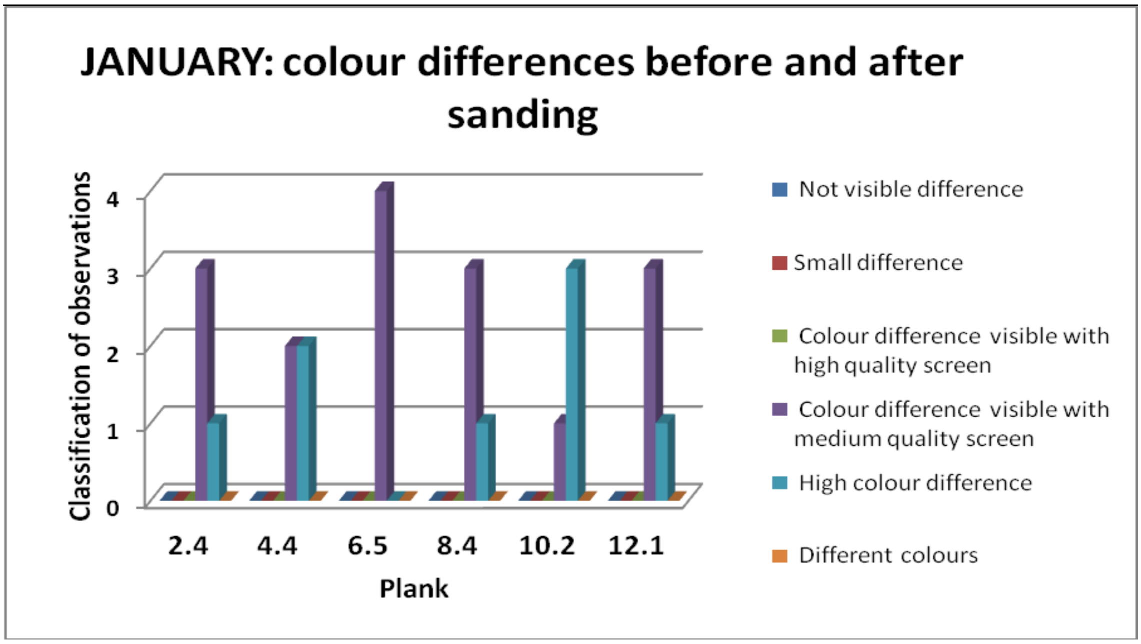


Fig. 6. Indirect daylight influenced colour causing “Colour difference visible with medium quality screen” and “High difference colour”.

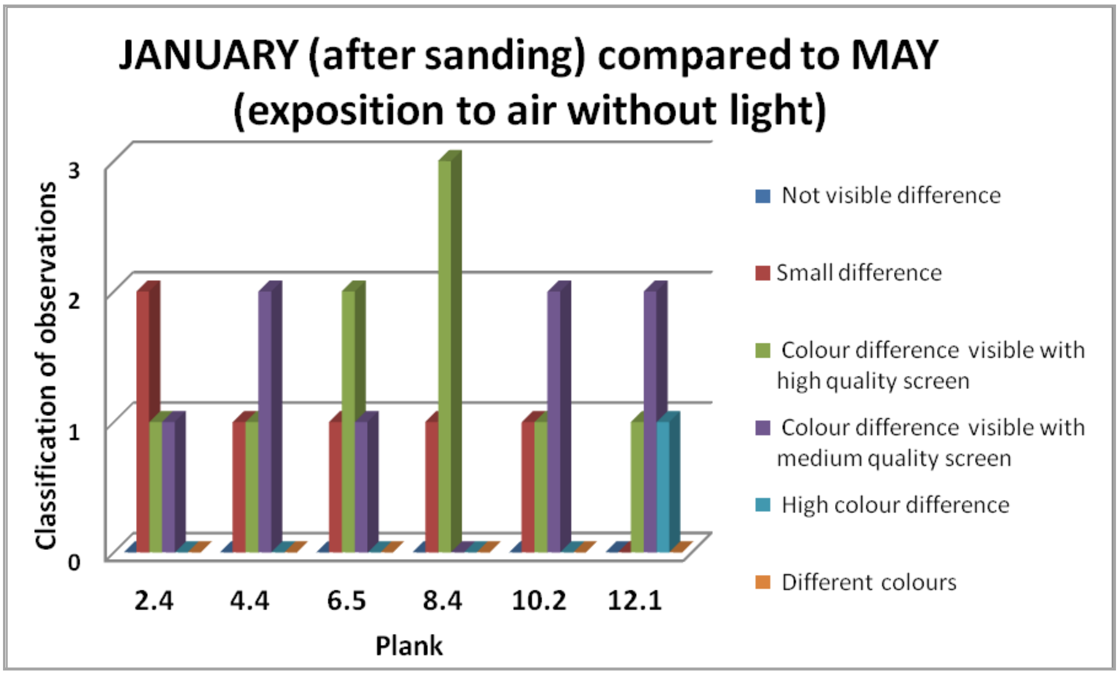


Fig. 7. Exposure in air and darkness caused discolourations, too.

As it is shown, sanding to a 2 mm depth is enough to reveal important colour differences. Depth of 2 mm seems to “protect” wood from colour alteration due to light or/either air (oxygen) influence. All colour differences belong now to class “Colour difference visible with medium quality screen” and “High colour difference”, in a ratio 2:1. On the other hand, there are also colour differences when specimens were exposed in air, in a dark environment. In all specimens appeared colour differences, although now these differences are classified in classes “Small difference”, “Colour difference visible with high quality screen”, “Colour difference visible with medium quality screen” and “High colour difference”, in a ratio 6:9:7:1 respectively. It is clear that in the complete absence of light the differences of colour are milder, but they can not be ignored. So it is concluded that discolourations in beech wood are still going on just after drying, when wood is exposed to indirect light and oxygen. It might be then a solution for furniture makers, once they recognize colour differences on their semi- finished products, to leave for some period these products exposed to indirect light (given that they are protected from moisture increase), in order to mild these differences. It is also effective to leave them in dark places (e.g. warehouses), given that there is a slight air circulation. It has as a result to obtain not so “white” beech wood but colour differences become now milder. Exposure in weathering after drying does not always causes colour alterations (Ho-yang Kong, 2006), but in beech wood it happened.

In all previous cases wood specimens were exposed to normal environment temperatures. In future studies it might be useful to examine the temperature influence on colour alterations, just after drying.

Conclusions

Discolourations during drying in beech wood are favoured mainly by temperature and oxygen presence and are also affected by the heterogeneity of the material itself.

Complexity of factors that have to be examined before, during and after drying makes the situation too complicated. Also sorting boards by colour is characterized by intense subjectivity as there aren’t any standards and it is difficult to determine the criteria by which the timber will be checked in order to classify the color differences. The colourimetric analysis that was proposed by other researchers and applied in this work successfully, helped in the classification of the boards and to understand the problems. Our data showed that environmental conditions after drying continue to affect the colour of the timber. If the existence of the phenomenon "sandwich" is present, exposure to indirect lighting of the semi- finished products helps to alleviate the problem and the colour uniformity of wood, although causing a total shift of the timber to darker colours. The colour change is proportional to exposure time, at least the first 4 months, according to our observations.

Besides the presence of light, oxygen (air circulation) also contribute 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. So slow conversion in (secondary) handling of sawn timber helps to mitigate the problem of discolourations.

Of course we need more data with larger numbers of specimens of different thicknesses, wood origins, different environmental conditions (air temperature, air circulation, presence of oxygen, etc.) in order to fully support statistically the above data, which then may be able to find an industrial application through in-line colourimetric observations.

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