Investigation on bleaching Beech wood using environment friendly agent

Csilla Csiha, Eva Annamaria Papp

Institute of Product Development and Manufacturing, Faculty of Wood Sciences, University of West Hungary, Hungary

Abstract: Bleaching of wood on industrial scale is mostly performed in order to eliminate defects or to satisfy sudden design demands of furniture design. Both practice and literary data are available on bleaching some wood species with H_2O_2, but no data was found on use of environment friendly agents. A first trial was made to experience the efficiency of bleaching wood with sodium percarbonate, a naturally degradable salt. The effect exerted by the agent was expressed by color evaluation. A first comparison was made between untreated and sodium percarbonate treated samples regarding their color difference. In order to adjudicate the long term performance of the bleached surface, in indoor environment, the samples were supposed to artificial Xenon radiation (Original Hanau Suntest). Results were also interpreted in mirror of earlier results obtained by using hydrogen peroxide. The physical influence of the sodium percarbonate treatment on the wood tissue was investigated by measuring the surface roughness prior and after treatment. For to perform and evaluate the measurements, a computer aided Minolta color measuring instrument was used, working upon the principles of the CIELab system. Changes in color due to artificial radiation were measured in 10 hour cycles systematic till color permanency was reached. We've found that sodium percarbonate may be suitable for bleaching beech wood. The behavior of samples under long term radiation exposure was similar to the one bleached with hydrogen - peroxide.

Keywords: bleaching wood, beech, environment friendly, sodium percarbonate, Xenon radiation

1 Introduction

Both oxidizing and reductive agents are used (Edwin & Carter 1983) for bleaching wood. In reactions caused by the treating agents the number of covalent bonds in cellulose, hemi cellulose and lignin is reduced. With the decreasing number of covalent bonds the color of the wood appears lighter. There are several bleaching agents, first of all hydrogen peroxide, but oxalic acid, sodium hypochlorite and sodium bisulfite are also suitable in some cases (Forest Products Laboratory 1967). As oxidizing agent mostly 30 – 35% hydrogen peroxide is used (Uysal & Atar 1999), being the most reactive agent for bleaching wood – during its decomposition huge quantities of reactive oxygen are released, being able to whiten wood. About 50% of the world's production of hydrogen peroxide in 1994 was used for pulp- and paper-bleaching (Hage - Lienke 2005). According to the EU hazard classification hydrogen peroxide is oxidative (O), corrosive (C) and harmful (Xn) but even so is seen as an environmentally benign alternative to chlorine-based bleaches. Further to hydrogen peroxide the sodium percarbonate which is an adduct of sodium carbonate and hydrogen peroxide is considered an environment friendly cleaning product, and is mostly used in a number of home and laundry cleaning products, as after dissolved in water, it yields a mixture of hydrogen peroxide (which eventually decomposes to water and oxygen) and sodium carbonate ("soda ash"). A trial was made with the sodium percarbonate in order to evaluate its suitability for bleaching wood and further to the stability of bleached surfaces against Xenon radiation was recorded.

In indoor environment between eventual humidity and abrasion the third most frequent factor of stress is the natural sun radiation. Due to the natural sun radiation the color of the wood changes which affects both the products of furniture and the parquet industry. The color of wood is one of the most important attributes of indoor quality besides machining quality. Color of wooden products is often the only parameter of choice (Csiha 2012).

Bleached wood surfaces are also subject to color changes due to sun radiation in indoor environment. Instead the natural sun radiation which varies with the seasons and also during the day, an artificial Xenon lamp radiation was undertaken in order to get a systematic approach and comparable results. Between the potential artificial radiation types (mercury lamp, Xenon lamp) the Xenon light is able to simulate the sunlight more properly than mercury lamps light (Tolvaj, 2005). The measure of color change and the feature of color development of SP treated samples during ageing is investigated in the present study.

2 Materials and methods

Sample preparation

Bleaching was performed on beech (*Fagus Sylvatica L.*) samples. In order to reduce to the minimum the standard deviation of the color difference of different boards, in the present study 1 board of 900x80x20 mm3 kiln dried, of selected furniture quality, with selected homogeneous, tangential cut was used. Prior to be cut to the testing size, the whole board was surface planed with a 3 knife planer, 6200 RPM, feeding speed of 9 m/min, depth of cut 2 mm, cutting tool diameter 60 mm with 5000 rot/min, sharpened with magnetic grinder. The average density of Beech samples was 748 kg/m3 (st dev. 1,4 kg/m3), after brought from the factory, all were conditioned at 20oC±2oC and 60±% relative humidity in laboratory, having in average 9,2 MC. The board was cut in 4 pieces by circular saw to size: 200x80x20 mm3, fitting the inside area of the Xenon radiation apparatus.

Bleaching

Bleaching was performed on: beech (*Fagus silvatica L.)* (Molnar, 2001) samples. The 4 samples were roller treated with the bleach, applied quantities according to Table 1.

The bleaching agent

1. 60% concentration sodium percarbonate ($2Na_2CO_3 \cdot 3H_2O_2$)
2. 20% concentration sodium hydroxide ($NaOH$)
3. oxalic acid ($H_2C_2O_4$) (waterfree)
4. 20% concentration acetic acid (CH_3COOH)

Steps of treatment

1st step: the bleach was applied by roller, av. 43,23 g/m^2 as roller coating procedure is most frequently used on industrial-scale or in serial production (Tab.1).
2nd step: after 5 minutes exposure time the surplus of bleach was eliminated from the surface
3rd step: Elimination of stains which occurred after bleaching by means of hot oxalic acid.
4th step: After 3 minutes curing time elimination of oxalic acid reminiscences.
5th step: Elimination of stains which occurred after bleaching by means of hot oxalic acid.
6th step: After 3 minutes curing time elimination of oxalic acid reminiscences.
7th step: elimination of the alkaline reminiscences by acetic acid (3 min.)

Table 1. The amount of applied sodium percarbonate

Beech samples				
	Untreated sample [g]	After treatment [g]	Mass difference [g]	Applied quantity [g/m²]
B10	99,835	100,1767	0,3417	47,445
B12	99,965	100,243	0,278	38,6121
B13	98,982	99,303	0,321	44,5833
B14	100,014	100,3185	0,3045	42,2917

It takes time the bleach to have its effect. The longer the time elapsed from applying the bleach the lighter the color of the surface becomes, till reaching a maximum. After 96 hours following the application of the bleach no more lightening of the surfaces could be measured (at the end of the lightening process for the last two measurements the difference was found less than 5% separately in case of each color parameter: L*, a*, b*). The samples were considered ready to start their ageing by Xenon radiation.

The apparatus of artificial radiation and the curing procedure

Instead the natural sun radiation which varies with the seasons and also during the day, artificial Xenon lamp radiation was used in order to get a systematic approach and comparable results. Between the potential artificial radiation types (mercury lamp, Xenon lamp) the Xenon light simulates the sunlight more properly than mercury lamps light (Tolvaj 2005).

Xenon curing started 96 hours after the bleach was applied, when no more lightening of the surfaces could be measured. Radiation curing - ageing of the bleached samples was performed using an artificial Xenon radiation apparatus Original Hanau Suntest. The apparatus is equipped with Xenon bulb having sunlight spectra, due to a “Daylight” filter of 0,51 W/m2 irradiation intensity with a UV peak at 340 nm. A cooling unit keeps the chamber temperature at 38°C.

Measurement of color

On each sample 10 color measurements were performed. The measuring points were recognized and a pattern was used to identify them during ageing. Changes in color due to artificial radiation were measured in 10 hour cycles systematic till color permanency, meaning that for the last two measurements the difference in data was found less than 5% separately for each color parameter: L*, a*, b*).

For to perform and evaluate the measurements a computer aided Minolta color measuring instrument was used, working upon the principles of the CIELab system, having a measuring diameter of 8 mm, the observer set on 10°. The following color parameters were measured: a* referred as red/green content, b* referred as yellow/blue content and L* referred as lightness. Results of color measurements were processed in Microsoft Excel and are presented in Table 2 and 3. Evaluation was performed upon the measured data and the time/color graphs. The significance was investigated using Student’s t test ($p<0,05$) when evaluating the changes in color.

Measurement of surface roughness

The traditional bleaching agent H_2O_2 was proved in an earlier study to roughen the wood tissue significantly, increase in R_z around 30% (Papp 2009). Both hydrogen peroxide and sodium percarbonate are dissolved in water. Surface roughness of untreated and sodium percarbonate treated samples was measured in order to get information on the roughening effect of the bleach.

After planning 10 roughness measurements were performed on all four samples, using a Mahr Perthen SP 3 instrument equipped with a stylus tip of 5 μm radius. The instrument calculates the roughness parameters automatically using a Gaussian filter. For the surface roughness characterization the R_z parameters were used. The stylus detected the surface geometry perpendicular to the grain, along a 17,5 mm long trace, consisting of 7 each 2,5 mm long consecutive sampling lengths. R_z parameters are calculated as mathematical mean of five consecutive l_e sampling lengths, not considering the first and the last l_e of the total measured length as shown on Figure 1. Since single extreme profile peaks usually only have a limited influence on the parts performance, R_z followed by R_a is the most suitable surface parameter for characterization of diffuse porous wood species with relative homogeneous structure (Gurau, 2005). More than one measurement on one sample is recommended (Magoss – Tatai 2011).

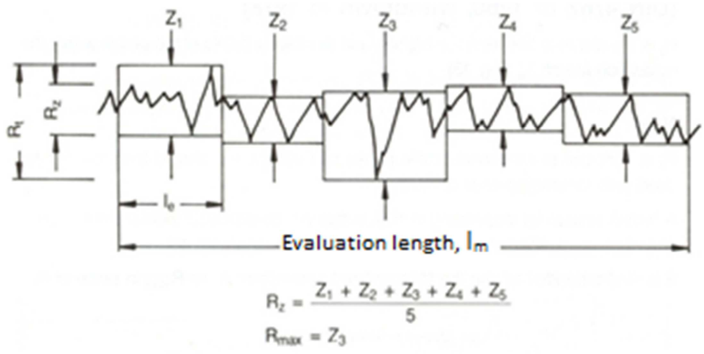

Figure 1. The calculation of the R_z parameter along the evaluation length (Csiha 2003)

R_z was found the most appropriate parameter to describe the status of the surface based on earlier studies (Csiha 2004).

3 Results and discussion

Color stability after the application of the bleach

There were no literary data available on the mechanism of bleaching with sodium percarbonate, thus the first question was whether it is effective or not for bleaching wood and in how much time a 60% concentration will manifest its effect. On the surface of the investigated beech samples the bleaching process came to its end in 96 hours after the application of the bleach: there was no more significant difference in the color parameters of two consecutive 24 hours measurements (p=0,05). The samples were considered bleached and ready to start the test serial of artificial Xenon radiation.

Figure 2. Beech samples: untreated (left) and sodium percarbonate treated (right)

Behaviour of environment friendly Beech samples during artificial Xenon radiation

Due to artificial Xenon radiation the bleached samples suffered a continuous color change manifested as darkening, - which reached a level of stability after 80 hours of continuous radiation. As previously agreed the level of color stability was attributed to the stage when the difference between two consecutive color data was less than 5% for all 3 color parameters (L*, a*, b*). During the first 10 hours of Xenon radiation there was a very intense and relevant color change registered.

Table 2. Average of color parameters of beech samples treated with eco-friendly bleach during artificial Xenon radiation

Artificial Xenon radiation [h]	L*	a*	b*
0	72,100	8,793	19,244
10	63,808	11,212	28,966
20	60,176	12,587	30,055
30	58,472	13,012	30,288
40	57,100	13,515	29,641
50	56,392	12,872	29,104
60	55,712	13,801	28,627
70	56,876	13,501	27,827
80	56,294	13,651	28,227

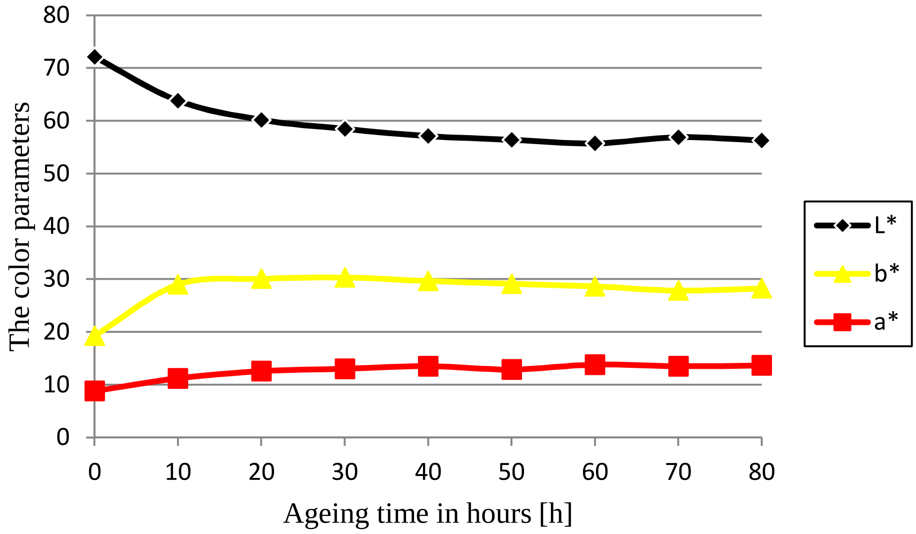

Figure 3. Average of color parameters of Beech samples treated with eco-friendly bleach during artificial Xenon radiation

Comparison of color development of Beech samples treated with hydrogen peroxide and sodium percarbonate

In an earlier study (Csiha 2012) was reported that beech samples treated with hydrogen peroxide suffered an intense color change during the first 10 hours of Xenon radiation. Due to artificial Xenon radiation the H_2O_2 bleached samples suffered a continuous color change manifested as darkening, - which reached a level of stability after 80 hours of continuous radiation which is in concordance with the color development of samples treated with sodium percarbonate. The two batches of beech samples used for H_2O_2 and SP were not of the same color, they especially differed in their red content and their lightness. For to compare the effect of the two different bleaches, the overall color change is considered: in case of samples treated with sodium percarbonate a* also referred as red/green content increased from 8,8 to 13,6 totaling 4,8 units, whilst in case of H_2O_2 a* increased from 5,95 to 11,84 totaling 5,9 units. The difference is significant. In case of samples treated with sodium percarbonate b* also referred as yellow/blue content increased from 19,2 to 28,2 totaling 9 units, whilst in case of H_2O_2 b* increased from 18,3 to 31,7 totaling 13,4 units. In case of samples treated with sodium percarbonate L* also referred as lightness decreased from 72,1 to 56,2 totaling 15,9 units, whilst in case of H_2O_2 L* decreased from 74,2 to 61,4 totaling 12,8 units.

Based upon the upper results the 30% concentrated H_2O_2 proved to be more efficient than the 60% sodium percarbonate as the L* lightness parameter showed a smaller change, indicating that the samples stay lighter, whilst the samples treated with SP went darker under Xenon radiation. The total changes in red/green and yellow/blue content were more accentuated in case of H_2O_2 treated samples but the overall character of color development under Xenon radiation was similar for both sample serials.

Table 3. Average of color parameters of beech samples treated with H_2O_2 bleach during artificial Xenon radiation

Ageing time [h]	L*	a*	b*
0	74,28	5,958	18,302
10	66,794	8,902	29,448
20	64,588	9,97	30,861
30	63,689	10,562	31,25
40	63,104	11,062	31,982
50	62,438	11,079	31,494
60	62,308	11,304	31,494
70	62,29	11,427	31,632
80	61,419	11,846	31,702

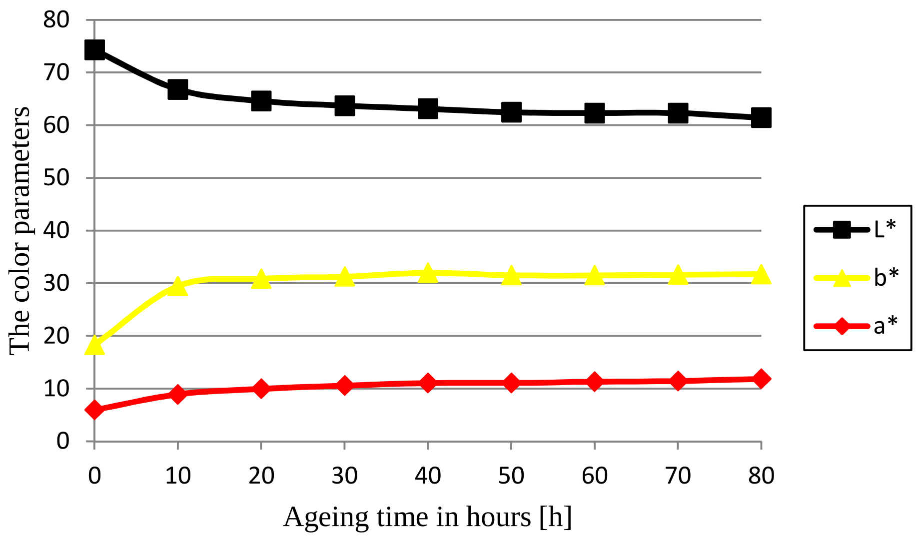

Figure 4. Average of color parameters of beech samples treated with H_2O_2 bleach during artificial Xenon radiation

Comparison of surface roughness of SP and H_2O_2 treated Beech samples

Both sodium percarbonate and hydrogene peroxide are diluted in water and thus may cause the swelling of wood fibers. During roughness measurements the R_z surface roughness parameter of untreated samples was recorded, being 53,93 μm. Surface roughness of SP treated samples indicated that the substance causes a kind of "smoothening" of the surface as the roughness decreased to 49,4 μm, whilst treatment with H_2O_2 resulted an extremely high roughening of the surfaces as R_z increased to 102,6 μm.

Table 4. Surface roughness results of beech samples treated with SP, H_2O_2 and untreated

Surface roughness (R_z) of beech samples		
Untreated samples [μm])	SP treated samples [μm])	H_2O_2 treated samples [μm])
56,46	46,45	100,32
57,68	48,43	102,76
54,5	47,49	99,87
58,9	70,89	103,77
51,61	52,34	104,71
45,50	55,31	99,10
47,44	56,50	109,30
46,52	53,39	105,61
69,44	57,70	102,91
51,27	50,56	98,10
average: 53,9	average: 49,4	average: 102,6

4 Conclusions

The sodium percarbonate proved to be suitable to lighten the wood surface of planed beech samples. In comparison with the widely used H_2O_2 the ageing process developed simultaneously, but there were differences in the total lightness change, the H_2O_2 treated samples stayed lighter. Further investigations are planned to check the adhesion capacity of SP treated samples.

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Corresponding author:
Cs. CSIHA
Institute of Product Design and Technology, University of West Hungary, *Bajcsy Zs. u. 4, HU-9400 Sopron, Hungary*
e-mail: cscsiha@fmk.nyme.hu