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Full Length Research Paper

Impacts of impregnation with boric acid and borax on the red colour tone of some hardwoods and varnishes

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This study was performed to determine the impacts of impregnation with boric acid and borax on the red colour tone of some hardwoods and varnishes. For this purpose, the test specimens prepared from Oriental beech (*Fagus orientalis* Lipsky) and European oak (*Quercus petraea* Liebl.) wood which met the requirements of ASTM D 358 are impregnated with boric acid and borax according to ASTM D 1413-99 by vacuum technique. After impregnation, surfaces were coated by cellulosic, synthetic, polyurethane, water-borne, acrylic and acid hardening varnishes in accordance with ASTM D 3023 standards. The red colour tone values were determined according to ASTM D 2244 standards after varnishing. Depending on wood material types, the red colour tone value was highest in Oriental beech, synthetic and borax, whereas it was lowest in European oak, water-borne and boric acid. According to wood material + impregnation material + varnish interaction, the red colour tone value was highest in Oriental beech + boric acid + synthetic varnish, whereas it was lowest in European oak + boric acid + polyurethane varnish. Consequently, impregnation of wood material with boron compounds show decreasing impact on the red colour tone. This impact might be taken into consideration in the applications where red color tone values of hardwood are important.

Key words: Red colour tone, boric acid, borax, impregnation, varnishes, hardwoods.

INTRODUCTION

Impregnation of wood materials with chemicals before usage seemed to be an obligation in many usage areas. Furniture made with unimpregnated wood materials and coated only with paint and varnish have surface protection only for two years (Evans et al., 1992).

Color distinction may occur because of bruises on living parts of the tree, the formation of dead knots, diseases, and so forth. In addition, the oxidation of some chemicals in wood, the formation of heartwood in older trees and metal contact with tannin wood is also known to cause changes in the natural color of wood (Shigo and Hillis, 1973). Furthermore, differences between the specific weights of the growing rings may also result in color distinction. By the chemical degradation of extractive materials and lignin in wood, yellow and brown colors occur which accelerates in open air conditions (Anderson et al., 1991). There is no change in living trees but when the tree is cut, the color of wood becomes dark or light. Surface process of wood avoids partly or completely this change or degradation and also makes the natural color and pattern of wood much more apparent and makes its living image longer (Cassens and Feist, 1999). Technical surface processes also increase esthetic and economic value of wood.

It is reported that the impregnation of some softwoods with Imersol-Aqua have increased the yellow color tone, and is highest in Scotch pine, synthetic varnish and medium-term dipping method, while it is lowest in Uludag fir, water-borne varnish and long-term dipping method. Yellow color tone was found 3% higher in pine than spruce and fir. It was measured in more than 42% of control samples in short-term, 46% of control samples in medium-term and 36% of control samples in long-term dipping method (Atar et al., 2007).

It was assessed that the impregnation of hardwoods

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Table 1. Technical specifications of varnishes.

Type of varnish	pH	Density ($g.cm^{-3}$)	Viscosity (snDINCup/4mm)	Amount applied ($g.m^{-2}$)	Nozzle gap (mm)	Air pressure
Polyurethane (filler)	5.94	0.98	18	125	1.8	2
Polyurethane (finishing)	4.01	0.99	18	125	1.8	2
Synthetic	-	0.94	18	100	-	-
Water-borne (primer)	9.17	1.014	18	100	1.3	1
Water-borne (filler)	9.30	1.015	18	67	1.3	1
Water-borne (finishing)	8.71	1.031	18	67	1.3	1
Cellulosic (filler)	2.9	0.955	20	125	1.8	3
Cellulosic (finishing)	3.4	0.99	20	125	1.8	3
Acrylic (filler)	4.3	0.95	18	125	1.8	2
Acrylic (finishing)	4.6	0.97	18	125	1.8	2
Acid hardening (finishing)	8.0	0.99	18	100	1.8	3

with Imersol-Aqua increased the red color tone with highest values in Oriental beech, synthetic varnish and medium-term dipping method (21.630) and the lowest in European oak, water-borne varnish and long-term dipping method (9.412). Red color tone was found 29% higher in beech than oak. It was measured in more than 11% of control samples in short-term, 7% of control samples in medium-term and 2% of control samples in long-term dipping (Yavuzcan et al., 2008). In another study, boron compounds (boric acid and borax) treatment caused a decrease of 8 - 12% in the red color tone of different wood types (Ors et al., 2005).

Scotch pine, Oriental beech and European oak wood are bleached with NaOH + H_2O, NaOH + Ca $(OH)_2$ + H_2O_2, hypochlorite and hydrochloric acid and varnished with synthetic and polyurethane varnishes. The red colour tone values of these wood samples were determined (Uysal et al., 1999).

The aim of this study was to determine the impact of impregnation with boron compounds on the red colour tone of Oriental beech, European oak and cellulosic, synthetic, polyurethane, water-borne, acrylic, acid hardening varnishes.

MATERIALS AND METHODS

Materials

Wood Material: The woods of Oriental beech (*Fagus orientalis* Lipsky) and European oak (*Quercus petraea* Liebl.) were chosen randomly from timber merchants of Ankara, Turkey. Special emphasis was given for the selection of the wood material. Accordingly, non-deficient, proper, knotless, normally grown (without zone line, without reaction wood and without decay, insect mushroom damages) wood materials were selected according to TS 2476 standard (TS 2476 1976).

Varnishes: Cellulosic (Cv), synthetic (Sn), polyurethane (Pu), water-borne (Wb), acrylic (Ac) and acid hardening (Ah) varnishes are supplied and used according to the producer's definition. Technical specifications of varnishes are given in Table 1.

Impregnation Material: Impregnation materials (Ba and Bx) were obtained from Etibank - Bandırma (Turkey) Borax and Acid Factory. Boric acid (H_3BO_3) contains 56.30% ½B_2O_3 43.7% H_2O with a molecular weight 61.84, density 1.4 $g.cm^{-3}$, melting point 171°C. Borax ($Na_2B_4O_7$ $5H_2O$) contains 21.28% Na_2O 47% B_2O_3, 30.9% H_2O with a molecular weight 291.3, density 1.8 $g.cm^{-3}$, melting point 741°C (Atar and Keskin, 2007).

Methods

Preparation of test specimens: The rough drafts for the preparation of test and control specimens were cut from the sapwood parts of massive woods with a dimension of 190 x 140 x 15 mm and conditioned at a temperature of 20±2°C and 65±3% relative humidity till they reach 12% humidity distribution according to ASTM D 358 (ASTM D 358 1983). The air-dry specimens with a dimension of 150x100x10 mm were cut from the drafts for impregnation and varnishing. The test specimens were impregnated with 3 layer brushing according to ASTM D 1413 (ASTM D 1413-76 1976).

Varnishing: Test specimens were varnished according to ASTM D 3023 (ASTM D 3023 1981). The surfaces of specimens were sanded with abrasive papers to remove the fiber swellings and dusts are leaned before varnishing. Varnishing was done under 20 ± 2°C temperature and 65 ± 3% humidity conditions.

Colour measurements: Measurement of colour tone value measurements were done according to ASTM D 2244-02 under 20 ± 2°C temperature and 50 ± 5% humidity conditions before and after the colour changes by a colour meter having calibration values a = 4.91, b = -3.45, c = 6.00 and H = 324.9 (ASTM D 2244-02 2003).

Statistical analysis: By using 2 different types of wood, 2 types of impregnation material, 6 types of varnish a total of 120 samples was prepared with 5 samples for each parameter (2 x 2 x 6 x 5). Multiple variance analysis (MANOVA) was used to determine the effects of impregnation with boron compounds on the red colour tone of woods and varnishes. Duncan test was used to determine the significant difference between the groups.

Table 2. Retention quantity of impregnation material (kg.m^{-3}).

Wood type	x	HG*
Oriental beech	30.87	A
European oak	2.329	C
Impregnation materials	**x**	**HG****
Boric acid	15.75	A
Borax	9.714	B

*LSD: 3.181, **LSD: 2.012.

Table 3. Duncan test results for retention quantity of impregnation materials (kg.m^{-3}).

Type of process	x	HG*
Oriental beech + Boric acid	40.99	A
Oriental beech + Borax	20.75	B
European oak + Boric acid	2.879	F
European oak + Borax	1.779	F

*LSD: 2.012.

Table 4. The red colour tone means values for wood types, varnish types and periods of impregnation

Types of wood*	Colour (red)[a]
Oriental beech (I)	16.96 A
European oak (II)	9.64 B
Impregnation materials**	**Colour (red)[a]**
Control (Co)	14.46 A
Boric acid (Ba)	12.05 C
Borax (Bx)	13.38 B
Varnishes***	**Colour (red)[a]**
Cellulosic (Cv)	12.31 C
Synthetic (Sn)	15.02 A
Polyurethane (Pu)	12.53 C
Water-borne (Wb)	10.97 D
Acrylic (Ac)	14.93 A
Acid hardener (Ah)	14.01 B

(a) Different letters in a column refers to significant differences among types of processes and materials at 0.05 confidence level (*LSD $_{0.5}$: 0.4356, **LSD$_{0.5}$: 0.5335, ***LSD$_{0.5}$: 0.7545).
I: Oriental beech, II: European oak, Ba: Boric acid, Bx: Borax, Cv: Cellulosic, Sn: synthetic, Pu: Polyurethane, Wb: water-borne, Ac: Acrylic, Ah: Acid hardener.

RESULTS

Retention quantity

Retention quantity of impregnation materials are given in Table 2. Retention quantity is found the highest in Oriental beech and boric acid and the lowest in European oak and borax. The retention amounts were different depending on wood material and impregnation material Table 3. Retention quantity of impregnation materials is the highest in Oriental beech + boric acid and the lowest in European oak + borax. Accordingly, wood material types are important for retention quantity.

Red colour change

The red colour tone mean values according to wood types, varnish types and methods of impregnation are given in Table 4. Depending on types of material, the red colour tone value was the highest in Oriental beech, borax and synthetic varnish, the lowest in oak, boric acid and water-borne varnish. Accordingly, the red colour tone value was different in wood material and varnishes. The impregnation materials decreased the red colour tone value in wood material and varnishes. The average red colour tone values according to wood material + impregnation material, impregnation material + varnish type, and wood material + varnish type are given in Table 5.

The red colour tone in wood type + impregnation material type combination was found highest in Oriental beech + boric acid and lowest in European oak + boric acid. For the combination of impregnation material + varnish type, red colour tone was highest in borax + synthetic varnish and lowest in boric acid + polyurethane varnish. Thus, boric acid and borax decreased red colour tone value and this impact was found different depending on varnishes. For wood material + varnish type interaction, it was highest in Oriental beech + synthetic varnish, and lowest in European oak + polyurethane and European oak + water-borne varnish.

Multiple variance analysis results for the impact of wood type, varnish type and impregnation material on the red colour tone are given in Table 6. The difference between the groups has been found important for the effect of variance sources on the red color tone (α: 0.05). Duncan Test results are given in Table 7 to indicate the importance of differences between the groups.

The red color tone value was highest in Oriental beech + synthetic varnish and lowest in European oak + water-borne varnish for varnished wood material without impregnation. For samples varnished after impregnation, it was highest in Oriental beech + boric acid + synthetic varnish and lowest in European oak + boric acid + polyurethane. The red color tone values according to wood material, impregnation material and varnish type are shown in Figure 1.

Conclusion

The retention value was highest in Oriental beech and

Table 5. The average red colour tone values according to the interactions of wood types, varnish and impregnation materials.

Types of material	Colour (red)[a]
Types of wood + Impregnation materials*	
I	16.82 AB
I + Ba	17.46 A
I + Bx	16.59 B
II	12.10 C
II + Ba	6.640 E
II + Bx	10.16 D
Impregnation materials + Types of varnishes**	
Cv	13.78 CDE
Ba + Cv	10.66 HI
Bx + Cv	12.49 EF
Sn	16.30 A
Ba + Sn	12.65 DEF
Bx + Sn	16.10 A
Pu	14.41BC
Ba + Pu	9.720 I
Bx + Pu	13.45 CDE
Wb	10.97 GHI
Ba + Wb	11.37 FGH
Bx + Wb	10.57 HI
Ac	15.65 AB
Ba + Ac	15.58 AB
Bx + Ac	13.58 CDE
Ah	15.66 AB
Ba + Ah	12.31 EFG
Bx + Ah	14.10 CD
Types of wood + Types of varnishes***	
I + Cv	15.585 D
I + Sn	19.983 A
I + Pu	16.693 C
I + Wb	13.414 E
I + Ac	17.959 B
I + Ah	18.107 B
II + Cv	9.037G H
II + Sn	10.059 G
II + Pu	8.366 H
II + Wb	8.528 H
II + Ac	11.919 F
II + Ah	

(a) Different letters in a column refers to significant differences among different interactions of types of wood, varnish and impregnation materials at 0.05 confidence level (*$LSD_{0.5}$: 0.7545, **$LSD_{0.5}$: 1.307, ***$LSD_{0.5}$:1.067).
I: Oriental beech, II: European oak, Ba: Boric acid, Bx: Borax, Cv: Cellulosic, Sn: Synthetic, Pu: Polyurethane, Wb: Water-borne, Ac: Acrylic, Ah: Acid hardening.

boric acid interactions, and lowest in oak and borax. The retention amounts of impregnation materials were different depending on wood material and impregnation material. Thus, flow ways of wood material might be effective for retention value and fluid type might be effecttive for impregnation material. The layer thickness of varnishes were 89 µm in cellulosic varnish, 95 µm in synthetic varnish, 98 µm in polyurethane varnish, 80 µm in water-borne varnish, 101 µm in acrylic varnish and 100 µm in acid hardening varnish.

The red color tone value was highest in beech (26.95) and lowest in oak (9.63). The red color tone in beech was 43% more than oak. This case might be due to physical characteristics of wood material. It should be taken into consideration for usage areas where the red color tone value is important. The red color tone value in impregnation process was highest in borax (13.37), and lowest in boric acid (12.05). In control sample, it was 17% higher than boric acid, and 8% higher than borax. Accordingly, impregnation materials showed decreasing impact on the red color tone. In a similar research, it was reported that boric acid and borax treatment caused a decrease of 8-12 % in the red color tone of different wood types (Ors et al., 2005).

The red color tone value in varnishing process was highest in synthetic varnish (15.02), and lowest in water-borne varnish (10.97). In samples varnished with synthetic varnish, it was higher than cellulosic varnish by 18%, polyurethane varnish by 17%, water-borne varnish by 27%, acrylic varnish by 1% and acid hardening varnish by 2%. This might be because of structural characteristics of varnishes. According to wood material + impregnation material interaction, the red color tone was highest in Oriental beech + boric acid (17.456), and lowest in European oak + boric acid (6.64). The impregnation materials have affected the red color tone value in boric acid by 4% positively, 45% negatively, in borax by 2% positively and 16% negatively for beech and oak, respectively.

According to impregnation material + varnish type interaction, the red color tone was highest in borax + synthetic varnish (16.1), and lowest in boric acid + polyurethane varnish (9.725). The red color tone value of unimpregnated varnished samples was higher than impregnated varnished samples. Accordingly, impregnation materials decreased the red color tone value. Thus, for boric acid, it decreased in cellulosic, synthetic, polyurethane, acrylic and acid hardening varnishes by 23%, 23%, 33%, 1% and 22%, respectively, and increased in water-borne varnish by 4%. For borax, it decreased in cellulosic, synthetic, polyurethane, water-borne, acrylic and acid hardening by 10%, 2%, 7%, 4%, 14%, and 10%, respectively. Impregnation process might affect the red color pigments negatively for varnishes except water-borne varnish in boric acid.

According to wood material + impregnation material + varnish interaction, the red color tone was highest in Oriental beech + boric acid + synthetic varnish (20.20), and lowest in Oriental beech + boric acid + polyurethane (3.06).

Table 6. Multiple variance analysis results for the impact of wood type varnish type and impregnation material on the red color tone.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Signature (P < 0.05)
Factor A	1	2410.988	2410.988	1099.6100	0.0000
Factor B	5	394.442	78.888	35.9797	0.0000
AB	5	125.347	25.069	11.4337	0.0000
Factor C	2	174.959	87.479	39.8978	0.0000
AC	2	295.945	147.972	67.4877	0.0000
BC	10	167.989	16.799	7.6617	0.0000
ABC	10	62.104	6.210	2.8325	0.0031
Error	144	315.732	2.193		
Total	179	3947.507			

Factor A = Wood materials (I: Oriental beech, II: European oak).
Factor B = Varnish type (Cv: Cellulosic, Sn: Synthetic, Pu: Polyurethane, Wb: Water-borne, Ac: Acrylic, Ah: Acid hardening).
Factor C = Impregnation materials (Ba: Boric acid, Bx: Borax).

Table 7. Duncan test results.

Process type	Color (red)[a]	Process type	Color (red)[a]	Process type	Color (red)[a]
I+Ba+Sn	20.20 A	I+Ba+Cv	15.96 HIJK	II+Ba+Ac	39.93 FT
I+Bx+Sn	19.94 AB	I+Bx+Cv	15.55 IJK	II+Bx+Ah	10.77 N
I+Sn	19.81 ABC	I+Cv	15.24 JK	II+Bx+Ac	10.16 NO
I+Ba+Ac	19.01 BCD	I+Ba+ Wb	15.02 K	II+Bx+Pu	9.746 NOP
I+Ah	18.76 CD	II+Ac	13.43 L	II+Bx+Cv	9.436 OP
I+Ba+Ah	18.19 DE	II+Sn	12.80 LM	II+ Wb	9.264 OP
I+Ac	17.88 DEF	I+ Wb	12.68 LM	II+Bx+ Wb	8.592 PQ
I+Bx+Ah	17.37 EFG	II+Ah	12.55 LM	II+Ba+Wb	7.728 Q
I+Bx+Pu	17.16 EFG	I+Bx+ Wb	12.55 LM	II+Ba+Ah	6.422 R
I+Bx+Ac	16.99 FGH	II+Cv	12.31 LM	II+Ba+Cv	5.366 RS
I+Pu	16.56 GHI	II+Pu	12.27 LM	II+Ba+Sn	5.118 S
I+Ba+Pu	16.36 GHIJ	II+Bx+Sn	12.26 LM	II+Ba+Pu	3.086 T

(a) Different letters in a column refers to significant differences among the different interactions of wood types, varnishes and impregnation materials at 0.05 confidence level ($LSD_{0.5}$: 1.06).
I: Oriental beech, II: European oak, Ba: Boric acid, Bx: Borax, Cv: Cellulosic, Sn: synthetic, Pu: Polyurethane, Wb: Water-borne, Ac: Acrylic, Ah: Acid hardening.

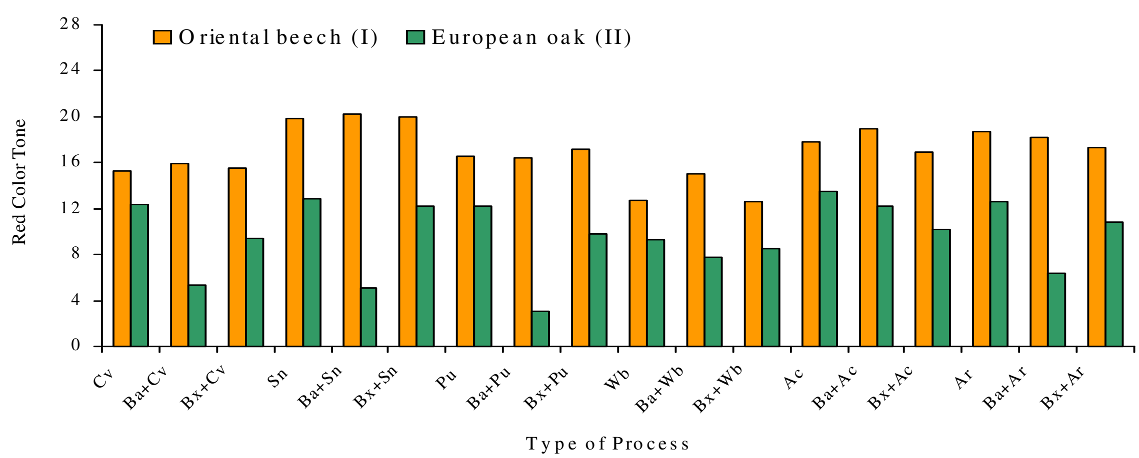

Figure 1. Change of the red color tone according to wood materials, impregnation materials and varnishes.

Accordingly, impregnation of wood material with boron compounds before varnishing is important for wood materials where the red color tone values are important.

REFERENCES

Evans PD, Michell AJ, Schmalzl K (1992). Studies of the degradation and protection of wood surfaces. Wood Sci. Technol. 26: 151-163.

Shigo AL, Hillis WE (1973). Heartwood, discolored wood and microorganism in living trees, Ann. Rev. Phytopathol. 11: 197-222.

Anderson EL, Pawlak Z, Owen NL (1991). Infrared studies of wood weathering. Appl. Spectroscopy, 45: 641-647.

Cassens DL, Feist WC (1999). Exterior wood in the south: selection, application and finishes. USDA For. Service, FPL-GTR, 69: 55-59.

Atar M, Keskin H (2007). Impacts of coating with various varnishes after impregnation with boron compounds on the combustion properties of Uludag fir. Journal of Applied Polymer Science (JAPS). 106(6): 4018-4023.

Atar M, Keskin H, Colakoglu MH (2007). Effects of impregnation with Imersol-aqua on yellow color tone of some softwoods and varnishes. J. Appl. Polymer Sci. 103(2): 1048-1054.

Yavuzcan HG, Atar M, Keskin H (2008). Impacts of impregnation with Imersol-aqua on red color tone of Oriental beech and European oak woods and varnishes. Forest Products Society 62st International Convention, St. Louis. Missouri. USA.

Ors Y, Atar M, Demirci Z (2005). Effects of impregnation with boron compounds on wood finishing and combustible properties. TUBITAK-The Scientific and Technological Research Council of Turkey. Project code: MISAG-237.

Uysal B, Sönmez A, Atar M, Özcifci A (1999). Ağaç malzemede renk açma işlemleri ve verniklerin renk değiştirci Etkileri. Türk-Tarım ve Ormancılık Dergisi. Tübitak. 23(4): 852-859.

TS 2476 (1976). Odunda fiziksel ve mekaniksel deneyler için numune alma metotları ve genel Özellikler. TSE. Ankara. Turkey.

ASTM D 358 (1983). Wood to be used as panels in weathering test of coating. ASTM Standards. USA.

ASTM D 1413-76 (1976). Standard test method of testing wood preservatives by laboratory soilblock cultures. ASTM Standards. USA.

ASTM D 3023 (1981). Practica for determination of resistance of factory applied coating on wood. ASTM Standards. USA.

ASTM D 2244-02 (2003). Standard practice for calculation of color tolerances and color differences from instrumentally measured color coordinates. American Society for Testing and Materials. ASTM Standards. USA.