Impacts of Impregnation with Timbercare Aqua on the Red and Yellow Color Tone of Some Woods and Varnishes

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ABSTRACT: This study has been performed for determining the effects of impregnation with Timbercare Aqua (Tc) on the red and yellow color tone of some woods and varnishes. For this purpose, the test samples prepared from Oriental beech, European oak, Scotch pine, Oriental spruce, and Uludag fir woods, which met the requirements of ASTM D 358, was impregnated with Tc according to ASTM D 1413 and producer's definition. After impregnation, wood surfaces have been coated by Sayerlack parquet varnish (Sp), Sayerlack interior varnish (Si), and Sayerlack exterior varnish (Se) varnishes in accordance with the ASTM D 3023 standards. According to ASTM D 2244, the red and yellow color tone of samples after varnishing process was determined. As a result, the value of red color tone was the highest in Oriental beech (15.21) and the lowest in Uludag fir (5.38). For the wood material, impregnation material, and varnish interaction, the red color tone value was the highest in Oriental beech + Tc + Sp (18.43) and the lowest in Uludag fir + Tc + Si (3.92). The value of the yellow color tone was the highest in pine (34.45) and the lowest in Oriental beech (26.50). For the wood material, impregnation material, and varnish interaction, the yellow color tone value was the highest in Oriental spruce + Tc + Sp (42.12) and the lowest in Oriental beech + Tc + Si (21.47). This effect may be due to the impacts of impregnation chemical on wood extractives and color pigments in varnish. Accordingly, it should be taken into care for applications where the red and yellow color tone value is important. © 2007 Wiley Periodicals, Inc. J Appl Polym Sci 106: 3952–3957, 2007

Key words: coatings; color measurement; compounding; density

INTRODUCTION

Impregnation of wood materials with chemical materials before usage is 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 2 years.[1]

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.[2] Furthermore, differences between the specific weights of the growing rings may also result in color distinction. In wood, by the chemical degradation of extractive materials and lignin in wood, yellow and brown colors occur that accelerates in open air conditions.[3] 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 partly or completely avoids this change or degradation and also makes the natural color and pattern of wood much more apparent and makes its living image longer.[4] Technical surface also processes increase in economic, esthetic, and economic value of wood.

It is reported that the impregnation of some softwoods with Imersol-Aqua increased the yellow color tone that measured the highest in Scotch pine, synthetic varnish and medium-term dipping method and the 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 more than control samples 42% in short-term, 46% in medium-term, and 36% in long-term dipping method.[5]

It was assessed that the impregnation of hardwoods with Imersol-Aqua increased the red color tone that found the highest in Oriental beech, synthetic varnish, and short-term dipping method and the lowest in European oak, water-borne varnish,

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and long-term dipping method. Red color tone was found 29% higher in beech than oak. It was measured more than control samples 11% in short-term, 7% in medium-term, and 2% in long-term dipping.[6] 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.[7]

The aim of this study was to determine the effects of impregnation with Timbercare Aqua (Tc) on the red and yellow color tone of beech, oak, pine, spruce, and fir woods and varnishes Sp, Si, and Se.

METHODS

Material

Wood materials

The woods of Oriental beech (*Fagus orientalis* Lipsky), European oak (*Quercus petraea* Liebl.), Scotch pine (*Pinus sylvestris* Lipsky), Oriental spruce (*Picea orientalis* Lipsky), and Uludag fir (*Abies Bornmülleriana* Mattf.) were randomly chosen from timber merchants of Ankara, Turkey. Special emphasis is given for the selection of the wood material. Accordingly, nondeficient, proper, knotless, normally grown (without zone line and without decay, insect mushroom damages) wood materials were selected according to TS 2470 standard.[8]

Varnishes

Sayerlack parquet varnish. Sayerlack parquet varnish (VS 5341) is a one-pack/two-pack clear nonyellowing waterborne self-priming topcoat for use on parquet flooring, an application that requires special characteristics of elasticity, abrasion resistance, ease of application by roller and brush, and ease of touching-up and maintenance. Addition of AH 1547 hardener improves chemical resistance, abrasion resistance, and final hardness. With these properties, VS 5341 is used for parquet floorings with heavy trafficlike offices, restaurants, shops, bars, etc., and of course in residential houses. It is semimat, having 30 gloss, and is ready to use for brush applications. For roller, it should be thinned 2–3% with drinking water. It can be easily applied to every layer at an amount of 80–100 g m^{-2} with brush or roller.[9]

Sayerlack exterior varnish. Sayerlack hydroplus (AZ 2330/86) is an elastic water-based exterior locality varnish with high corrosion resistance, which is used for the protection of all wood material types. It is easily applied without draining at vertical surfaces. It protects the wood material from sun light with its UV absorbers. For the wood material type, application with min 250–320 g/m^2 brush or pistol is suggested. After 2-h waiting without sanding, application for the other layer can be performed or with min 4 h waiting second layer can be applied after sanding. Thinning of varnish should be done only with drinkable water. Some technical properties of varnish are given as follows: solid material rate (%), 40 ± 1; density (kg/lt), 1.030 ± 0.03; viscosity (sn), 15 s ± 3 (20°); and application amount (g m^{-2}), 100–300.[9]

Sayerlack interior varnish. Sayerlack hydroplus water-based interior locality varnish (AU 465) is used for the preservation of all wood material types in interior locality. It is a nonflammable, gloss retention, nonyellowing film, short-drying time, solvent-emission abatement, odorless, fluent, completely soluble in water, and noncorrosive material with a density (kg/lt), 1.028 ± 0.02; viscosity (sn), 14 s ± 2 (20°). With appropriate brushing materials, max three layers with 80–140 g m^{-2} should be applied.[9]

Impregnation chemical

Tc is a water-based, nonflammable, odorless, fluent, and completely soluble in water, noncorrosive material with a pH value of 4 and a density of 1.02 g cm^{-3}. It is available as a ready-made solution. It contains 0.5% w/w tebuconazole, 0.5% w/w propiconazole, 1% w/w 3-iodo-2-propynyl-butyl carbonate, and 0.5% w/w cypermethrin. Before the application of Tc on the wood material, all kinds of drilling, cutting, turning, and milling operations should be completed and the relative humidity should be in equilibrium with the test environment. Tc should be applied by the brush, and 1 lt of impregnation material for 4–5 m^2 of wood. The impregnated wood should be left for drying for at least 24 h. The wood material can be painted, varnished, or glued after it is fully dried.[10]

Method

Determination of densities

The densities of wood materials, used for the preparation of test samples, were determined according to TS 2472.[11] For determining the air-dry density, the test samples with a dimension of 20 mm × 30 mm × 30 mm were kept under the conditions of (20 ± 2)°C and 65% ± 3% relative humidity until they reached to a stable weight. The weights were measured with an analytic scale of ±0.01 g sensitivity. Afterward, the dimensions were measured with a digital compass of ±0.01 mm. The air-dry densities (δ_{12}) of the samples were calculated by Formula 1;

$$\delta_{12} = \frac{W_{12}}{V_{12}}\ \mathrm{g\,cm^{-3}} \quad (1)$$

where W_{12} is the air-dry weight (g) and V_{12} is the volume (cm^3) at air-dry conditions.

The samples were kept at a temperature of (103 ± 2)°C in the drying oven until they reached to a stable weight for the assessment of oven-dry density. Afterward, oven-dried samples were cooled in the desicator containing P_2O_5 (phosphorus pent oxide). Then, they were weighted on a scale of ±0.01-g sensitivity, and their dimensions were measured with a compass of ±0.01-mm sensitivity. The volumes of the samples were determined by stereometric method, and the densities (δ_o) were calculated by Formula 2;

$$\delta_o = \frac{W_o}{V_o}\ \mathrm{g\,cm^{-3}} \quad (2)$$

where W_o is the oven-dry weight (g) and V_o is the oven-dry volume (cm^3) of the wood material.

Determination of humidity

The humidity of test samples before and after the impregnation process was determined according to TS 2471.[12] Thus, the samples with a dimension of 20 mm × 20 mm × 20 mm were weighed and then oven dried at (103 ± 2)°C till they reach to a constant weight. Then the samples were cooled in desicator containing P_2O_5 and weighed with an analytic scale of 0.01-g sensitivity. The humidity of the samples (h) was calculated by Formula 3;

$$h = \frac{W_r - W_o}{W_o} \times 100\,\mathrm{g\,g^{-1}} \quad (3)$$

where W_r is the initial weight of the samples (g) and W_o is the final dry weight (oven-dry) of the samples (g).

Preparation of test samples

The rough drafts for the preparation of test and control samples were cut from the sapwood parts of massive woods with a dimension of 190 mm × 140 mm × 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.[13] The air-dry samples with a dimension of 150 mm × 100 mm × 10 mm were cut from the drafts for impregnation and varnishing. The test samples were impregnated with three-layered brushing according to ASTM D 1413.[14]

Varnishing

Test samples were varnished according to ASTM D 3023.[15] The surfaces of samples were sanded with abrasive papers to remove the fiber swellings, and dusts were cleaned before varnishing. Varnishing was done under (20 ± 2)°C temperature and 65% ± 3% humidity conditions. Synthetic varnish was applied with a hard and strong brush.

Color measurements

Measurement of color tone value measurements were done according to ASTM D 2244-02[16] under (20 ± 2)°C temperature and (50 ± 5)% humidity conditions before and after the color changes by a color meter having calibration values $a = 4.91$, $b = -3.45$, $c = 6.00$, and $H = 324.9$.

Statistical analysis

In this study, by using five different types of wood, three types of varnished samples, three types impregnated and varnished samples, and a total of 135 samples (5 × 3 × 3 × 3) were prepared with three samples for each parameter. MANOVA (multiple variance analysis) was used to determine the impacts of impregnation with Tc on the red and yellow color tone of some woods and varnishes. Duncan's test was applied to determine the significant difference between the groups.

RESULTS AND DISCUSSION

Densities

Results of test for the air-dry and oven-dry densities of test samples impregnated with Tc and control samples unimpregnated were summarized by using descriptive statistics such as the maximum, minimum, mean, standard deviation, and variance. Descriptive statistical values of tested densities of test samples were given in Table I.

Air-dry and oven-dry densities of the test samples were increased when compared with the control samples. This case may be due to more absorption of impregnation chemical.

Red color change

The red color tone mean values according to wood types, varnish types, and methods of impregnation are given in Table II.

The red color tone was the highest in beech (15.21), the lowest in fir (5.38) according to wood material type. The red color tone in beech was higher than oak by 26%, pine by 49%, and fir by 65% and beech by 62%. This case may be due to the physical characteristics of wood material.

According to varnish type, the red color tone was the highest in Se (11.49) and the lowest in Si (6.10). It was higher in Se than Si by 47% and Sp by 37%.

According to the impregnation and varnish interaction, the red color tone value was the highest in Tc + Sp (11.48) and the lowest in Tc + Si (7.21). The

TABLE I
Air-Dry and Owen-Dry Densities of Wood Materials (gcm^{-3})

Density values	Statistics values	Oriental beech	European oak	Scotch pine	Oriental spruce	Uludag fir
Control (owen-dry)	*x*	0.657	0.652	0.537	0.405	0.380
	Min	0.605	0.596	0.512	0.388	0.349
	Max	0.679	0.572	0.572	0.435	0.406
	Sd	0.0196471	0.0206274	0.016681	0.0154602	0.0192202
	v	0.0003862	0.0002782	0.000278	0.0002390	0.0003694
Owen-dry density	*x*	0.658	0.655	0.543	0.408	0.382
	Min	0.638	0.606	0.524	0.393	0.352
	Max	0.685	0.698	0.566	0.425	0.426
	Sd	0.0136902	0.0266076	0.011758	0.0105399	0.0228182
	v	0.0001871	0.0007081	0.000138	0.0001112	0.0005206
Control (air dry)	*x*	0.679	0.672	0.577	0.420	0.401
	Min	0.655	0.655	0.555	0.401	0.385
	Max	0.705	0.699	0.592	0.441	0.412
	Sd	0.01678101	0.01382290	0.0121909	0.01435143	0.00922841
	v	0.00028202	0.00014860	0.0001486	0.00020596	0.00008546
Air-dry density	*x*	0.682	0.676	0.579	0.428	0.407
	Min	0.662	0.658	0.558	0.407	0.392
	Max	0.708	0.702	0.600	0.455	0.415
	Sd	0.01669811	0.01422672	0.0002416	0.01238621	0.00700391
	v	0.00027920	0.00020241	0.0002416	0.00012340	0.00004905

x, Mean; Min, Minimum; Max, Maximum; Sd, Standard deviation; *v*, Variance.

red color tone value of impregnated and varnished materials was high except Tc + Se. Thus, according to control specimen, the red color tone value was low in Tc + Se by 6%, in Tc + Si by 15%, and high in Tc + Sp by 36%. Accordingly, impregnation material showed increasing impact in Si and Sp, decreasing impact in Se.

MANOVA results for the impact of wood type, varnish type, and impregnation material on the red color tone are given in Table III.

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 IV to indicate the importance of differences between the groups.

For the wood material, impregnation material, and varnish interaction, the red color tone was the highest in beech + Tc + Sp (18.43), the lowest in fir + Tc + Si (3.92). The red color tone value was different according to wood material and varnish type. Indeed, for beech impregnation, material showed decreasing impact in Se by 5%, Si by 4%, and increasing impact in Sp by 18%, for oak showed decreasing impact in Se by 11%, in Si by 3% and increasing impact in Sp by 27%. For pine, impregnation material showed increasing impact in Se by 2%, in Si by 36%, in Sp by 68%, for spruce decreasing impact in Se by 13%, increasing impact in Si by 49%, in Sp by 99% and last for fir decreasing impact in Se by 10%, in Sp by 40% and increasing impact in Si by

TABLE II
The Red Color Tone Mean Values for Wood Types, Varnish Types, and Periods of Impregnation

Types of material	*x*	HG
Wood materials[a]		
Oriental beech (I)	15.21	A
European Oak (II)	11.01	B
Scotch pine (III)	7.82	C
Oriental spruce (IV)	5.81	D
Uludag Fir (V)	5.38	D
Varnishes[b]		
Se	11.49	A
Si	6.10	B
Sp	7.32	C
Impregnation methods[c]		
Tc + Se	10.77	B
Tc + Si	7.21	C
Tc + Sp	11.48	A

x, mean; HG, degrees of homogeny.
[a] LSD = 0.4683.
[b] LSD = 0.5130.
[c] LSD = 0.5130.

TABLE III
MANOVA 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	Probably % 5 (Sig)
Factor A	4	1210.814	302.704	605.3356	0.0000
Factor B	5	445.272	89.054	178.0877	0.0000
AB	20	227.579	11.379	22.7553	0.0000
Error	60	30.004	0.500		
Total	89	1913.669			

Factor A = Oriental beech, Oak, Scotch pine, Oriental spruce, Uludag fir.

Factor B = Se, Si, Sp, Timbercare Aqua + Se, Timbercare Aqua + Si, Timbercare Aqua + Sp.

TABLE IV
Duncan Test Results (Red Color Tone)

Material	x	HG[a]	Material	x	HG[a]
I + Tc + Sp	18.43	A	IV + Tc + Se	8.173	IJ
I + Sp	17.83	A	II + Si	7.713	JK
I + Se	15.14	B	IV + Tc + Sp	7.580	JK
II + Tc + Sp	14.88	B	V + Tc + Se	7.547	JK
I + Tc + Se	14.43	B	II + Tc + Si	7.470	JK
II + Se	13.23	C	V + Tc + Sp	6.587	KL
I + Si	12.97	CD	III + Tc + Si	6.147	L
I + Tc + Si	12.51	CDE	IV + Tc + Si	5.990	L
II + Tc + Se	11.86	DEF	III + Si	4.787	M
III + Tc + Se	11.52	EF	V + Sp	4.003	MN
III + Se	11.38	EF	V + Tc + Si	3.923	MN
II + Sp	10.90	FG	III + Sp	3.163	N
III + Tc + Sp	9.920	GH	IV + Si	3.077	NO
IV + Se	9.380	HI	V + Si	1.943	O
V + Se	8.320	IJ	IV + Sp	0.7033	P

[a] LSD: 1.147.

50%. The red color tone values according to wood material, impregnation material, and varnish type are shown in Figure 1.

Yellow color change

The yellow color tone mean values according to wood types, varnish types, and methods of impregnation are given in Table V.

The yellow color tone was the highest in pine (34.45), the lowest in beech (26.50) according to wood material type. The yellow color tone in pine was higher than beech by 23%, oak by 5%, spruce by 7%, and fir by 9%.

According to varnish type, the yellow color tone was the highest in Se (36.96), the lowest in Si (23.59). It was higher in Se than Si by 39% and Sp by 34%. This case might be due to the characteristics of varnishes. This case should be taken into care for applications where the yellow color tone value is important.

According to impregnation + varnish interaction, the yellow color tone value was the highest in Tc + Sp (38.70) and the lowest in Tc + Si (27.45). The yellow color tone value of impregnated and varnished materials was high except Tc + Se. Thus,

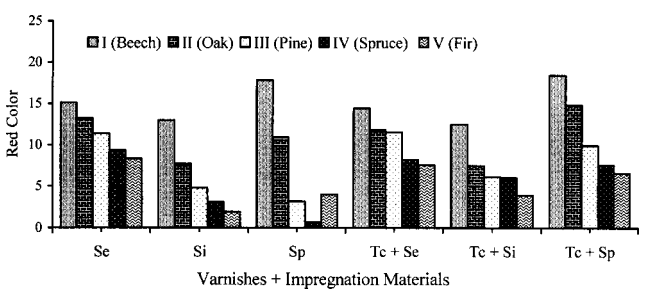

Figure 1 Change of the red color tone according to wood material, impregnation chemical and varnish.

TABLE V
The Yellow Color Tone Mean Values for Wood Types, Varnish Types, and Periods of Impregnation

Types of material	x	HG
Wood materials[a]		
Oriental beech (I)	26.50	D
European Oak (II)	32.75	B
Scotch pine (III)	34.45	A
Oriental spruce (IV)	32.01	BC
Uludag Fir (V)	31.46	C
Varnishes[b]		
Se	36.96	A
Si	23.59	C
Sp	25.49	B
Impregnation methods[c]		
Tc + Se	36.41	B
Tc + Si	27.45	C
Tc + Sp	38.71	A

[a] LSD = 0.7701.
[b] LSD = 1.8436.
[c] LSD = 1.8436.

according to the control specimen, the yellow color tone value was low in Tc + Se by 2% and high in Tc + Si by 14%, in Tc + Sp by 34%. Accordingly, impregnation material showed an increasing impact in Si and Sp and a decreasing impact in Se.

MANOVA results for the impact of wood type, varnish type, and impregnation material on the yellow color tone are given in Table VI.

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 VII to indicate the importance of differences between the groups.

For the wood material, impregnation material, and varnish interaction, the yellow color tone was the highest in spruce + Tc + Sp (42.14) and the lowest in beech + Tc + Si (21.47). The yellow color tone value was different according to wood material and varnish type. Indeed, for beech impregnation material showed decreasing impact in Se by 11% and

TABLE VI
MANOVA Results for the Impact of Wood Type, Varnish Type, and Impregnation Material on the Yellow Color Tone

Source	Degrees of freedom	Sum of squares	Mean square	F value	Probably % 5 (Sig)
Factor A	4	638.721	159.680	118.1356	0.0000
Factor B	5	3314.174	662.835	490.3826	0.0000
AB	20	575.393	28.770	21.2845	0.0000
Error	60	81.100	1.352		
Total	89	4609.388			

Factor A = Oriental beech, Oak, Scotch pine, Oriental spruce, Uludag fir.

Factor B = Se, Si, Sp, Timbercare Aqua + Se, Timbercare Aqua + Si, Timbercare Aqua + Sp.

TABLE VII
Duncan Test Results (Yellow Color Tone)

Material	x^a	HG	Material	x^a	HG
IV + Tc + Sp	42.14	A	III+Tc+Si	29.09	HIJ
III + Tc + Sp	41.80	A	II+Tc+Si	29.02	HIJ
III + Tc + Se	41.42	AB	IV+Tc+Si	28.95	HIJ
III + Se	40.79	ABC	III+Sp	27.93	IJK
V + Tc + Sp	40.19	ABCD	V+Tc+Si	27.69	JKL
IV + Se	39.60	BCDE	I+Tc+Se	27.27	JKLM
IV + Tc + Se	38.88	CDE	II+Si	26.34	KLMN
II + Tc + Sp	38.47	DEF	I+Sp	26.13	KLMN
V + Tc + Se	37.87	EFG	III+Si	25.68	LMN
V + Se	37.61	EFG	V+Sp	25.32	MN
II + Tc + Se	36.62	FG	IV+Si	24.36	NO
II + Se	36.10	G	I+Si	22.51	OP
I + Tc + Sp	30.94	H	I+Tc+Si	21.47	PQ
I + Se	30.70	H	V+Si	20.11	Q
II + Sp	29.95	HI	IV+Sp	18.11	R

[a] LSD = 1.886.

increasing impact in Si by 5% in Sp by 16%, for oak increasing impact in Se by 1%, Si by 9%, and Sp by 23%. For Scotch pine, impregnation material showed an increasing impact in Se by 2%, Si by 12%, and Sp by 23%, for spruce decreasing impact in Se by 2%, increasing impact in Si by 16%, in Sp by 47%, and last, for fir increasing impact in Se by 1%, Sp by 37%, and Si by 28%. The yellow color tone values according to wood material, impregnation material, and varnish type are shown in Figure 2.

The impacts of impregnation with Tc on the red and yellow color tone may be due to the effect of impregnation material characteristics (pH:4), which contains 0.5% w/w tebuconazole, 0.5% w/w propiconazole, 1% w/w 3-Iodo-2-propynyl-butyl carbonate, and 0.5% w/w cypermethrin on wood extractives, which include tannins, polyphenolics, and coloring matter. In a similar research, it was reported that Imersol Aqua treatment caused to an increase of the yellow color tone of some softwood types.[5]

CONCLUSIONS

The red color tone value was the highest in Oriental beech + Sp and the lowest in Uludag fir + Si varnish for varnished wood material without impregnation. For samples varnished after impregnation, red color tone value was the highest in Oriental beech + Tc + Sp and the lowest in Uludag fir + Tc + Si after impregnation with Tc.

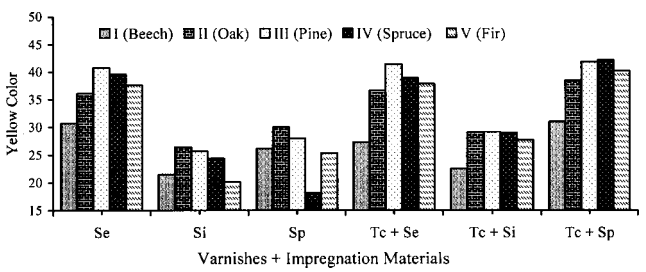

Figure 2 Change of the yellow color tone according to wood material, impregnation chemical and varnish.

The yellow color tone value was the highest in Scotch pine + Se and the lowest in Uludag fir + Si for varnished wood material without impregnation. This case may be due to physical characteristics of Scotch pine wood. Thus, the yellow color value is declared to be high in Scotch pine wood.[5] For samples varnished after impregnation, yellow tone value was the highest in Oriental spruce + Tc + Sp and the lowest in Oriental beech + Tc + Si after impregnation with Tc.

As a result, for samples tested, impacts of wood material type, impregnation material, and varnish type on the red and yellow color tone value were found significant alternately. This impact may be due to the effect impregnation chemical on wood extractives and color pigments in varnish. It should be taken into care for applications where the red and yellow color tone value is important.

References

1. Evans, P. D.; Michell, A. J.; Schmalzl, K. Wood Sci Technol 1992, 26, 151.
2. Shigo, A. L.; Hillis, W. E. Annu Rev Phytopathol 1973, 11, 197.
3. Anderson, E. L.; Pawlak, Z.; Owen, N. L. Appl Spectrosc 1991, 45, 641.
4. Cassens, D. L.; Feist, W. C. USDA Forest Service FPL-GTR 1999, 69, 55.
5. Atar, M.; Keskin, H.; Colakoglu, M. H. J Appl Polym Sci 2007, 103, 1048.
6. Keskin, H.; Atar, M. Mater Sci 2006, 2, 252.
7. Ors, Y.; Atar, M.; Demirci, Z. 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, Ankara, 2005.
8. TS 2470. Odunda Fiziksel ve Mekaniksel Deneyler için Numune Alma Metotları ve Genel Özellikler, Türk Standartları Enstitüsü, Ankara, Turkey, 1976.
9. Sanayi, H. E.; Ticaret, A. Ş. Sayerlack Technical Data Sheet, Kore Şehitleri Cad. 20/1 Zincirlikuyu, İstanbul, Turkey, 2007.
10. Hemel Hickson's Timber Impregnation Co. (GB) Ltd., Hickson Timber Treatments, Brochure of Timbercare Aqua, 2000; p 1.
11. TS 2472. Odunda Fiziksel ve Mekanik Deneyler için Hacim Yögunluk Dĕgerinin Tayini, Türk Standartları Enstitüsü, Ankara, Turkey, 1976.
12. TS 2471. Odunda Fiziksel ve Mekanik Deneyler için Rutubet Miktarı Tayini, Türk Standartları Enstitüsü, Ankara, Turkey, 1976.
13. ASTM D 358. Wood to be used as panels in weathering test of coating, Annual Book of ASTM Standards, 1983.
14. ASTM D 1413-76. Standard method of testing wood preservatives by laboratory soil blocks cultures, Annual Book of ASTM Standards 1976, 452.
15. ASTM D 3023. Practical for determination of resistance of factory applied coating on wood, product of stain and reagents, Annual Book of ASTM Standards. 1981.
16. ASTM D 2244-02. Standard practice for calculation of color tolerances and color differences from instrumentally measured color coordinates, Annual Book of ASTM Standards, 2003.