

Effects of water-soluble varnishes on red color tone in wood material colored with water-soluble wood stains

Ahmet Cihangir Yalınkılıç^{a,*}, Abdullah Sönmez^b

Abstract: In this study, changing effect of water-soluble varnishes on red color tone in different wood materials which were colored with water-soluble wood stains in brown tone has been researched. For this purpose, samples which were prepared from the Oriental beech (*Fagus orientalis* L.), Sessile oak (*Quercus petraea* L.) and Scots pine (*Pinus sylvestris* L.) woods in accordance with TS 53 and TS 2470, after being colored with aniline, ready-mix and chemical stains according to ASTM-E 1347-97, were coated with one-component and two-component waterborne varnishes according to ASTM-D 3023. Color changes were determined in accordance with ASTM 2244. According to research results, the highest color change in red color tone was obtained on oak wood colored with ready-mix stain and after coated with one-component waterborne varnishes; and the lowest change was obtained on Scots pine wood colored with chemical stain and after coated with two-component varnishes.

Keywords: Red color tone, Waterborne varnishes, Water-soluble stains, Wood material

Suda çözünen ağaç boyaları ile renklendirilen ağaç malzemede su bazlı verniklerin kırmızı renk tonuna etkisi

Özet: Bu çalışmada, suda çözünen ağaç boyaları ile kahverengi tonda renklendirilmiş farklı ağaç malzemelerde su bazlı verniklerin kırmızı renk tonunu değiştirici etkisi araştırılmıştır. Bu maksatla, Doğu kayını (*Fagus orientalis* L.), sapsız meşe (*Quercus petraea* L.) ve sarıçam (*Pinus sylvestris* L.) odunlarından TS 53 ve TS 2470 esaslarına uyularak hazırlanan örnekler, ASTM-E 1347-97'ye göre anilin, hazır karışım ve kimyasal boya ile renklendirildikten sonra ASTM-D 3023 esaslarına göre tek ve iki bileşenli su bazlı vernikler ile kaplanmıştır. Renk değişimleri ASTM 2244' e göre belirlenmiştir. Araştırma sonuçlarına göre, en fazla kırmızı renk tonu değişimi tek bileşenli vernik uygulanmış hazır karışım boyalı meşede, en az iki bileşenli vernik uygulanmış kimyasal boyalı sarıçamda elde edilmiştir.

Anahtar kelimeler: Kırmızı renk tonu, Su bazlı vernikler, Suda çözünen boyalar, Ağaç malzeme

1. Introduction

While choosing massive and veneer for furniture and decoration, the most important point to be considered is the color of wood as well as its structure. Because, color determines the beauty and aesthetic value of wood (Şanivar and Zorlu., 1999), and affects the appearance of wood just as much as form and size (Şanivar, 1997).

Different colors can be seen even in the same wood species (Şanivar and Zorlu, 1999). While producing furniture and decoration elements, a coloring treatment is needed in order to obtain colors that are different from the natural color of the wooden material with such thoughts as providing color harmony etc. by force of decoration practices (Sönmez, 2005).

Additionally, in case of demanding to keep natural structure of the wooden material, coloring can be performed with powder stains that solve in water as well as ready mix wood stains sold in the liquid state (Şanivar, 1997).

“Wood stains which are used on wood surfaces do not serve as protective layer, but create a change in color and

tone.” Objects that are made from wooden material and left natural or coated without varnishing have low resistance against external effects (Sönmez, 2005). Therefore, wood surfaces should be coated with protective layers (Sönmez, 1989).

Structural differences are seen due to differences in chemicals ingredients used in producing varnishes for wood surfaces (Sönmez, 1989). When varnishes in different forms are applied over different wood stains, they have a color changing effect on color and tone of colored wood surfaces. This causes results that are undesirable after application, and brings about various conflicts on furniture production (Çakıcıer, 1994).

This study was conducted to determine the changes, which are caused by waterborne varnish application to woods of alder, Scots pine (*Pinus sylvestris* L.), Oriental beech (*Fagus orientalis* L.) and sessile oak (*Quercus petraea* L.) that are colored in brown color tone with water-soluble wood stains, in red color tone of the sample color.

It was reported that varnish type was significant, and the wood species was insignificant in terms of the change,

✉ ^a Dumlupınar University, Simav Faculty of Technical Education, Department of Furniture and Decoration, Kütahya, Turkey

^b Gazi University Technology Faculty, Department of Wood Products Industry Engineering, Ankara, Turkey

@ * **Corresponding author** (İletişim yazarı): acihangir.yalinkilic@dpu.edu.tr

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which was caused by solvent-borne varnishes applied over the surfaces of wooden material, in the color of water-soluble wood stains (Çakıcıer, 1994).

Color changing effect of the UV rays on acacia, pear, chestnut, sessile oak and Taurus cedar which were processed with teak oil, liquid paraffin and antique varnish was examined. Following the research, it was stated that oil, wax and polish cannot protect the color of wooden materials that were subject to UV rays for 72 hours, and the lowest change in color was seen in liquid paraffin (Söğütü and Sönmez, 2006).

The effect of outdoor conditions on the color of wood was researched by applying cellulosic, synthetic, polyurethane and acid-catalyzed varnish on to the wood panels made from Scots pine, Oriental beech and chestnut. As a result, it was reported that polyurethane varnish and synthetic varnish caused an increase in red color tone (Sönmez, 1996).

Similar color parameters between sapwood and heartwood and causes of differences in color parameters were examined based upon CIE L*a*b* color parameters of Scots pine samples in the air-dried state which were collected from 5 geographic regions of Finland and Switzerland. Following of the research, it was reported that there were important differences between sapwood and heartwood color parameters, and these differences result from the geographic region and use of different woods which belong to the same species (Grekin, 2007).

Color change of Jatoba, Angelim vermelho, Garapeira and Marupa which are from Tropical hardwoods in artificial UV radiation (350 nm, UV-A) was examined with the CIE L*a*b* color measurement system. Following the research, it was stated that the highest loss in value with UV radiation in CIE L*a*b* parameters (ΔL , Δa and Δb) was observed in the characteristics of Marupa wood; Angelim vermelho wood was less affected (Pastore et al., 2004).

Calculability of color coordinates that belong to the color of rough timber in wood industry with CIE L*a*b* color measurement theory has been researched recently. Following of the research, it was reported that, to identify appearance characteristics of wood by means of color and sample features with CIE L*a*b* color measurement is appropriate for classifying; change in the color of wood and color variety can be determined with whitening, seasoning and ageing methods; it will be beneficial to compare wooden pieces that are used indoor and for furniture (Janin et al., 2001).

Color change of wood stains after accelerated wilting was analyzed with CIELAB color measurement system. For this purpose, Scots pine, beech and oak were used as wood materials; and Vandyke Brown stain, aniline, chemical and solvent-borne ready-mix stains were used as wood coloring. Brown color tone was applied as the sample color. Following the research, it was indicated that stain type and wood species were effective in wilting; and the highest wilting appeared in beech wood material that was colored with eco-color stain (Sönmez et al., 2003).

After different types of wood materials were colored with Vandyke Brown stain, aniline, chemical and ready mix stains, accelerated ageing treatment was applied for 72 hours that was prepared under xenon arc lamp; it was found that there was a considerable decrease in the red color tone (Delikan, 2001).

It was indicated that waterborne varnishes had color-changing effect, especially in tannin-rich trees (Budakçı, 2003).

Effects of bleaching treatments in the surfaces of impregnated and not impregnated wood materials on macroscopic change, color, brightness and strength of adhesion to surface were researched; and it was stated that bleaching solutions caused color changes in all impregnated and not impregnated samples; synthetic and waterborne varnishes showed more sensitivity (Atar, 1999).

After bleaching treatment with NaOH + H₂O₂ and NaSiO₃ + H₂O₂ in 25% concentration was applied to the experiment samples which were prepared from witch elm wood, effects of bleaching chemical substances on red color tone formation on the surfaces over which polyurethane and polyester varnish were applied were determined according to ASMT-D 2244 principles. Following the research, it was stated that the darkest red color tone was in the natural samples over which polyurethane varnish was applied; and the lightest red color tone was in the samples over which NaOH + H₂O₂ and polyester were applied (Özçifçi and Atar, 2002).

Color changing effect of one and two-component waterborne varnishes on Oriental beech (*Fagus orientalis* L.), Sessile oak (*Quercus petraea* L.) and Scots pine (*Pinus sylvestris* L.), which were colored in brown color tone with water-soluble aniline, ready-mix and chemical stains was researched. According to results of the research, it was indicated that the highest color change appeared in oak wood colored with ready-mix stain which were coated with one-component varnish; and the lowest color change was in beech wood colored with chemical stain which were coated with two-component varnish (Yalınkılıç, 2008).

2. Material and method

2.1. Wood material

Oriental beech (*Fagus orientalis* L.) and Sessile oak (*Quercus petraea* L.), which are from broad-leaved trees and commonly used in woodworking industry in Turkey, and Scots pine (*Pinus sylvestris* L.), which is from needle-leaved trees were used as experiment materials. Wood materials used in experiments were supplied from the market with the random method.

2.2. Coloring materials

Aniline, ready-mix and chemical stains were used in experiments. In order to obtain brown color, the aniline stains and tannin and potassium bicarbonate were procured in powder form, while ready-mix stain was procured in liquid form from market.

2.3. Coating materials

One-component (self crosslinked) waterborne varnish that was used in coating experiment samples was applied as silk matt and two-component waterborne varnish was applied as bright. Single-component varnish was procured from TRIMETAL's Turkey distributor Uzertaş Paint Industry Trade and Investment Inc. (İstanbul), while dual-

component varnish was procured from KIMETSAN Ltd. Şti. (Ankara).

2.4. Preparing experiment samples

Samples were prepared according to TS 53 (1981) and TS 2470 (1976) principles, by using sapwood parts and the parts of randomly-chosen first class material that are smooth fibrous, without knot or crack and have no color and density difference, and by using them in a way that the annual rings were upright.

After experiment, samples were cut to $110 \times 110 \times 12$ mm, and they were kept under the conditions of 20 ± 2 °C temperature and $50 \pm 5\%$ relative humidity until they reached constant weight TS 2471, (1976). Average moisture of 10 randomly-chosen samples was determined as $9 \pm 0.5\%$. After samples which were taken into their final sizes ($100 \times 100 \times 10$ mm) were sanded with No. 80 and No. 100 sandpapers following the first coarse and medium in grit, very fine was made with No. 120 sandpaper following the final sponging with water. Before coating treatments, sanded surfaces were cleaning out the dust. In the research, 180 experiment samples in total were prepared; 10 for each wood species, coating and varnish type and 10 for each color measurement treatment and sample ($3 \times 3 \times 2 \times 1 \times 10$).

Brown color tone was chosen for coloring experiment samples. Coloring was made according to ASTM-E 1347 – 97 (2005) principles. In parallel with it, while preparing coloring formulas, it was taken into consideration that the colors should be in the same tone in solved that was prepared with different stains. Example of brown color formula of aniline coating is shown in Table 1 (Sönmez, 2005).

Examples of brown color formula of water-soluble one and two-stage chemical staining are shown in Table 2 (Sönmez, 2005).

Walnut color stains which are sold as ready-mix was used in order to obtain brown color. It was applied to experiment samples as concentrated.

pH values of the stains used in experiments were measured via pH-meter, and were given in Table 3 (Yalınkılıç, 2008).

Varnishing samples were made in the form of industrial application according to ASTM D-3023 (1998) principles and proposals of producing companies. Varnishes were applied to experiment samples with a medium brush. The amount of varnish was determined by conforming to the proposals of producing companies about the number of layer that are required to be applied, and by scaling with analytical and 0.01 precision balance in a way that there are 120 grams (4.2329 ounce) per m^2 .

In accordance with the proposals of producing companies, one-component varnish was applied in three-coat without filler layer at 24 - hour intervals to the polished samples without sanding between the layers and they were kept drying for 3 weeks.

Two-component filler varnish, in accordance with the proposals of producing companies, was applied in two-coat at 1-hour intervals to the polished samples after resin (prime) was applied in one-coat so as to prevent varnish from being absorbed unnecessarily and to increase layer performance. Samples over which filler varnish was applied

were kept drying for 24 hours in a dust-free environment at room temperature in parallel with the ground plane. Dried samples were sanded with 220 and 320 water sandpaper equally, and varnish dusts were cleaned with a soft hair brush and vacuum method. Gloss varnish to which hardener was added was applied in two-coat to the surfaces of experiments samples and kept drying for 3 weeks under the conditions of 20 ± 2 °C temperature $50 \pm 5\%$ relative humidity.

2.5. Color measurement

Color measurements were performed with MINOLTA CR - 231 color measurement device according to principles stipulated in ASTM D 2244, (2007). Measurement principle of the device which can measure according to CIE $L^*a^*b^*$ color system is shown in Figure 1 (Özçifçi and Atar, 2002). Color change in the surface of wood material is determined with H° angle. Constriction of the angle shows approach to red color, and extension of it shows approach to yellow color.

CIELAB color intent was identified by International Commission on Illumination (Commission Internationale de l'Eclairage (CIE)) in 1976. In the system, color is represented as a spot in three dimensions (Çağlar and Yamanel, 2007). Differences in colors and their positions are determined according to L^* , a^* , b^* color coordinates. Here, L^* is located in the axis of black and white ($L^* = 0$ for black, $L^* = 100$ for white); a^* in the axis of red and green (positive value red, negative value green); and b^* in the axis of yellow and blue (positive value yellow, negative value blue) (Sögütü and Sönmez, 2006).

Table 1. Example of brown color formula of aniline stain

Wood Species	Color	Mix (5% Basic Melt)
Beech Oak Scots pine	Brown	Red 10 Part Yellow 20 Part Blue 10 Part Black 5 Part

Table 2. Examples of brown color formula of water-soluble one and two-stage chemical staining

Chemical Coloring	Wood species	Color	Stain Formula	Explanation
One-stage	Oak		3 - 5% Bichromate of Potassium solution	30 - 50 g Bichromate of potas is solved in 1 L hot water and applied to the surface as cold.
Two-stage	Scots pine Beech	Brown	5% Tannic acid 5% Bichromate of Potassium	50 g Tannic acid is solved in 1 L water. Then 50 g Bichromate of potas is solved in 1 L water and applied to the surface as cold.

Table 3. pH values of water-soluble stains

pH values of water-soluble stains		
Stains		pH-meter (25 °C)
Ready-mix	Walnut	7,8
Chemical	Bichromate of potassium	4,3
	Tannic acid	3,9
Aniline	Mix	8

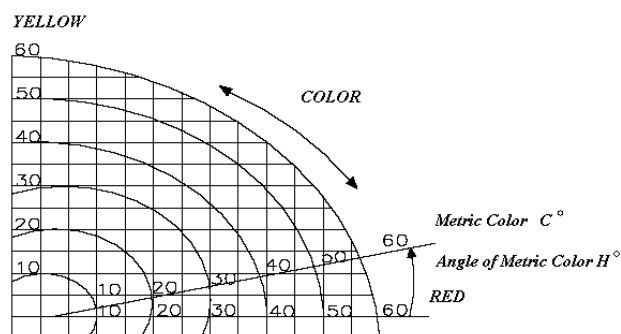


Figure 1. Color measurement principle

In order to determine the change in red color tone (a^*) of brown, variable quality Δa^* was calculated as ($\Delta a^* = \text{Post-vernishing } a^* - \text{Post-coloring } a^*$). That Δa^* is in low value means red color tone of the sample color did not change or changed little.

2.6. Statistical evaluation

Measurement differences were used as data in evaluating the results (post-vernishing – post-coloring). Multiple analysis of variance (MANOVA) was applied to the data in the MSTAT-C statistical evaluation program; when difference between groups is proven significant, difference between the average values was compared with the Duncan test. So, order by performance between the factors that were included in experiment was determined to be divided into homogeneity groups according to critical value of the least significant difference (LSD).

3. Results

Red color tone values, which were obtained with post-vernishing and post-coloring measurements, were used in order to determine the interaction of waterborne varnishes with water-soluble wood stains and on their differences were given in Table 4.

According to the table, red color values were found different in terms of wood species, varnish and coating type. Multi-factor analysis of variance was performed in order to determine the source of differences, and its results were shown in Table 5.

According to the results of the variance analysis; wood species, coating and varnish type and their mutual interactions were found statistically meaningful ($P \leq 0.05$). Comparison results of Duncan test which was made at the level of wood species, stain and varnish type were given in Table 6.

According to Table 6, the highest change in red color tone was found in beech at the level of wood species; in ready-mix stain at the level of stain type; in one-component varnish at the level of varnish type, the lowest change in red color tone was found in Scots pine, chemical stain and two-component varnish.

Comparison results of Duncan test, which was made at the level of interaction of wood species-stain type, wood species-varnish type, were given in Table 7.

According to Table 7, at the level of interaction between wood species and stain type, chemical stain made the lowest change in red color tone on beech wood with 2.094 value,

while ready-mix stain made the highest change with 12.72 value. While chemical stain made the lowest change in red color tone on oak wood with 2.750 value, ready-mix stain made the highest change with 13.53 value. While chemical stain made the lowest change in red color tone on Scots pine wood with 0.193 value, ready-mix stain made the highest change with 11.86 value. According to these results, the highest change in red color tone was obtained in oak which was colored with ready-mix stain; and the lowest change was obtained in Scots pine which was colored with chemical stain. Difference between the beech and oak which were colored with chemical stain was found statistically insignificant.

Two-component varnish, at the level of interaction of wood species-varnish type, made the lowest change in red color tone while one-component varnish made the highest change. According to these results, the highest change in red color tone was obtained in beech over which one-component varnish was applied; and the lowest change was obtained in beech over which two-component varnish was applied. Difference between oak and Scots pine over which one-component varnish was applied, and beech and oak over which two-component varnish was applied were found statistically insignificant.

Comparison results of Duncan test which was made at the level of interaction of stain-varnish type were given in Table 8.

According to Table 8, two-component varnish made the lowest change in red color tone on aniline stain with 3.924 value, one-component varnish made the highest change with 7.647 value. While two-component varnish made the lowest change in red color tone on ready-mix stain with value of 11.04, one-component varnish made the highest change with value of 14.37. While two-component varnish made the lowest change in red color tone on chemical stain with value of 1.337, one-component varnish made the highest change with value of 2.021. According to these results, the highest change in red color tone was obtained in one-component varnish which was applied over ready-mix stain; and the lowest change was obtained in two-component varnish which was applied over chemical stain.

Comparison results of Duncan test which was made at the level of interaction between wood species and stain and varnish type were given in Table 9.

According to Table 9, the highest change in red color tone was seen in oak over which one-component varnish and ready-mix stain were applied, the lowest change was obtained in Scots pine over which two-component varnish and chemical stain were applied.

Change in red color tone at the level of interaction of wood species and stain and varnish type is shown in Figure 2.

4. Discussions

Results below can be discussed according to the findings which were obtained in the research.

Waterborne varnishes caused an increase in red color tone of the sample color. In literature, it has been reported that varnishes having different structures had different effects on colors and tones of painted wood surfaces when applied to different wood stains (Çakıcıer, 1994).

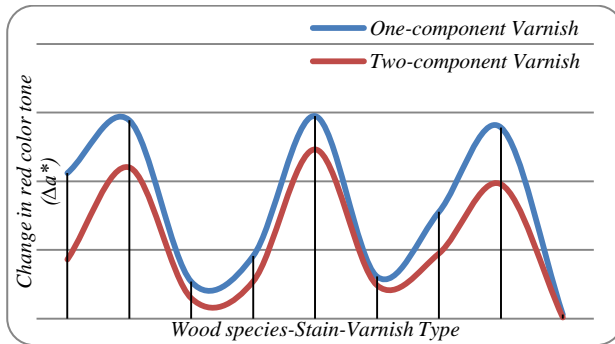


Figure 2. Change in red color tone at the level of interaction of wood species stain varnish type

It was determined that in comparison with one-component varnish, two-component varnish had a less color changing effect on three wood species and stain types.

It was determined that use of chemical stain had a less color changing effect on three wood species compared to other stain types. It can be said that this situation is caused from acidic characteristic of the chemical stain (Table 3). In literature, it has been stated that the most important metal salt used as final staining tool in chemical coloring is potassium bichromate, that the potassium bichromate obtained as a result of reaction of chrome metal, which is used in coloring, with acids gives different colors when reacting with chemicals used in first staining, and that the final staining materials obtained in this way give acid reaction (Sönmez, 2005).

Table 4. Average values on post-varnishing and post-coloring measurement of red color tone (a*) and their differences

Wood species	Varnish type	Coating type	Post-varnishing	Post-coloring	Difference
Beech	One-component	Aniline	15.23	4.63	10.6
		Ready-mix	23.44	9.00	14.14
		Chemical	13.50	10.81	2.69
	Two-component	Aniline	9.33	5.02	4.31
		Ready-mix	20.37	9.36	11.01
		Chemical	12.65	11.16	1.49
Oak	One-component	Aniline	10.17	5.61	4.56
		Ready-mix	24.45	9.71	14.74
		Chemical	13.77	10.71	3.06
	Two-component	Aniline	8.23	5.51	2.72
		Ready-mix	20.23	7.91	12.32
		Chemical	13.42	10.98	2.44
Scots pine	One-component	Aniline	14.23	6.46	7.77
		Ready-mix	28.24	14.32	13.92
		Chemical	11.72	11.42	0.3
	Two-component	Aniline	10.63	5.89	4.74
		Ready-mix	23.61	13.82	9.79
		Chemical	11.78	11.69	0.09

Table 5. Results of variance analysis on change in red color tone

Factor	Degrees of freedom	Total square	Square average	F value	P ≤ 0,05
Wood species (A)	2	52.983	26.491	15.9040	0.0000*
Coating type (B)	2	3726.033	1863.017	29.7259	0.0000*
Interaction (AB)	4	198.059	49.515	24.6305	0.0000*
Varnish type (C)	1	299.615	299.615	4.8379	0.0010*
Interaction (AC)	2	30.451	15.226	9.1407	0.0002*
Interaction (BC)	2	82.055	41.027	24.6305	0.0000*
Interaction (ABC)	4	32.234	8.059	4.8379	0.0010*
Error	162	269.845	1.666		
Total	179	4691.275			

*Difference is meaningful according to 0.05

Table 6. Comparison results of duncan test made at the level of wood species, stain and varnish type

Wood species					
Beech		Oak		Scots pine	
\bar{X}	HG	\bar{X}	HG	\bar{X}	HG
7.424	A*	6.641	B	6.103	C
Stain type					
Ready-mix		Aniline		Chemical	
\bar{X}	HG	\bar{X}	HG	\bar{X}	HG
12.70	A*	5.786	B	1.679	C
LSD : ± 0,4650					
Varnish type					
One-component			Two-component		
\bar{X}	HG	\bar{X}	HG	\bar{X}	HG
8.013	A*	5.433	B		
LSD : ± 0.3797					

\bar{X} : Arithmetic average HG: Homogeneity Group
*: The highest increase in red color tone

Table 7. Comparison results of duncan test made at the level of interaction of wood species-stain type, wood species-varnish type

Wood species	Stain type						Varnish type			
	Aniline		Ready-mix		Chemical		One-component		Two-component	
	\bar{X}	HG	\bar{X}	HG	\bar{X}	HG	\bar{X}	HG	\bar{X}	HG
Beech	7.456	D	12.72	B	2.094	G	9.246	A*	5.603	C
Oak	3.640	F	13.53	A*	2.750	G	7.460	B	5.821	C
Scots pine	6.260	E	11.86	C	0.193	H	7.333	B	4.874	D
LSD : ± 0.8054						LSD : ± 0.6576				

*: The highest increase in red color tone

Table 8. Comparison results of duncan test made at the level of interaction of stain-varnish type

Stain type	One-component Varnish		Two-component Varnish	
	\bar{X}	HG	\bar{X}	HG
Aniline	7.647	C	3.924	D
Ready-mix	14.37	A*	11.04	B
Chemical	2.021	E	1.337	F
LSD : ± 0.6576				

*: The highest increase in red color tone

Table 9. Comparison results of duncan test made at the level of interaction between wood species and stain and varnish type

Wood species	Stain type	One-component Varnish		Two-component Varnish	
		\bar{X}	HG	\bar{X}	HG
Beech	Aniline	10.60	CD	4.311	F
	Ready-mix	14.44	A	11.01	C
	Chemical	2.697	G	1.490	H
Oak	Aniline	4.566	F	2.714	G
	Ready-mix	14.75	A*	12.32	B
	Chemical	3.066	G	2.433	GH
Scots pine	Aniline	7.775	E	4.746	F
	Ready-mix	13.92	A	9.788	D
	Chemical	0.2990	I	0.08700	I**
LSD : ± 1.139					

*: The highest increase in red color tone **: The lowest increase in red color tone

It was found that in comparison with other stain + varnish interactions, chemical stain + two-component varnish had a less coloring effect on three wood species. It can be said that this situation might be caused from that chemical stain doesn't make homogenous coloring, which is one of top surface quality criteria, (Sönmez, 2005) and from the difference between the chemical stain and the chemicals used in production of dual-component varnish. In literature, it has been reported that structural differences occur due to the chemicals used in production of varnishes used in wood surfaces (Sönmez, 1989).

It was found that ready-mix stain increased change in red color tone maximally. It may be said that this stems from the fact that ready-mix stain was used as concentrated. It may be suggested that ready-mix stain be used mixing with water at a certain rate.

Minimum change exhibited by Scotch pine may be caused from that its color is lighter than the woods of beech and oak trees. In literature it has been reported that the red color is obtained in Scotch pine at minimum and beech tree at maximum in terms of tree species. This situation is in parallel with the literature (Pelit, 2007).

Conclusion

As a result, it may be suggested that in furniture and decoration practices where red color tone of brown which was chosen as sample is not required to be changed, wood

material of Scots pine which is coated with two-component varnish colored with chemical stain be used. In the case that in furniture and decoration field, beech and oak are used as wood material; aniline and ready-mix stains are used as coating type; and one-component varnish is used as varnish type, it is important to consider the difference which should occur in color tone in this regard.

Ability of waterborne varnishes and water-soluble wood stains to wet wood materials may be the research subject. Additionally, it may be suggested to work on color and brightness of different colors that are obtained mixing stains certain rates.

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