THE COLOR CHANGING EFFECT OF THE MOISTURE CONTENT OF WOOD MATERIALS ON WATER BORNE VARNISHES

Mehmet Budakçı,[a,]* Abdullah Sönmez, [b] and Hüseyin Pelit [c]

One-component semi-matte (A) and two-component shiny (B) water-borne varnishes were applied on the surface of the test panels made of Scots pine (*Pinus sylvestris* L.) and Eastern beech (*Fagus orientalis* Lipsky) with 8%, 10%, and 12% moisture content in this study. The changes in color caused by the type of wood and moisture content on the water borne varnish layers were then investigated. The change of color in the samples was determined based on the statements in ASTM D 2224. It was determined that variations in the type of wood and moisture content affected water borne varnishes adversely, and the most apparent color change was observed in the Scots pine samples with 12% moisture content when varnish type B was applied.

Keywords: Wood material; Moisture content; Water borne varnishes; Color change.

*Contact information: a: Department of Wood Works Industrial Engineering, Technology Faculty, Düzce University, Konuralp, 81620, Düzce, Turkey; b: Department of Furniture and Decoration, Technical Education Faculty, Gazi University, Teknikokullar, 06500, Ankara, Turkey; c: Department of Furniture and Interior Design, Fatsa Industrial Vocational High School, Fatsa, 52400, Ordu, Turkey; *Corresponding author: mehmetbudakci@duzce.edu.tr*

INTRODUCTION

Color is an important parameter in terms of the aesthetic and decorative value of wood material. The color of the wood material may vary not only in different species of trees from which the wood was attained, but also in different trees from the same species. Color differences may even be observed in wood specimens from various different locations of a single tree. The amount of coloring material localized at the cell membrane, as well as density, moisture content, texture, and similar factors may affect color differentiation (Sönmez 2005).

The water that might already be present in the wood body or that might enter the body at a later time plays a significant role in the success of finishing (varnish, coloring, dying) applied on wooden furniture and decorative elements (Wheeler 1983; De Meijer and Militz 2001; De Meijer 2002; Sönmez 2005; Sönmez *et al.* 2009; Sönmez *et al.* 2011). The moisture content of the wooden material, as well as its many other characteristics, is an important aspect that needs to be mastered by the people using wood as the raw material in order to prevent faulty applications. The varnish layer-surface binding of the wood surfaces with high moisture content may not be effectively established for small water molecules and may have an effect of reducing the adhesion of the large polymer molecules, as well as saturating the hydroxyl groups and preventing the establishment of a chemical bond between the varnish and the wood material (Sönmez and Budakçı 2004). It has been reported in the literature that cellulosic paints and varnishes deteriorate rapidly from water and moisture (Engler 1992; Özen and Sönmez 1990; Sönmez 1995; Sönmez 1998; Yolanda 1998; Sönmez and Kesik 1999; Sönmez and

Budakçı 2004; Flexner 2005; Budakçı *et al.* 2010). Polyester, polyurethane, and other varnishes with a reaction drying base are affected by water prior to and during application and by application upon wood materials with high moisture content, causing the formation of faulty layers (Sönmez and Budakçı 2004). It was reported that even though the varnish completes its reaction and hardens, since sufficient adhesion cannot be established between the layer and the surface, the varnish will strip from the surface in the form of films or layers if the moisture content of the wood on which polyester varnish is to be applied is greater than 12% (Sönmez 2005). Excess moisture in wood material causes problems such as reducing surface tension in water borne finishes, lowering viscosity, causing faulty layers, and increasing pigment wetting (Sönmez and Budakçı 2004).

Generally all water-borne finishes, whether crosslinking or not, have some characteristics in common; they contain less solvent than most other finishes, they are not a fire hazard, they are non-yellowing, they contain and clean up with water, and they are virtually colorless. But these finishes have drawbacks. They raise the grain of the wood; they are weather-sensitive during application; they have only moderate resistance to heat, solvent, acid, alkali, water, and water vapor resistance (about the same as nitrocellulose laquer); and they produce a bland, washed-out appearance on dark and dark-stained woods (Sönmez and Budakçı 2004; Flexner 2005). It has been reported in various studies that water-borne varnishes have a color changing effect on especially tanniferous trees (De Meijer and Militz 2001; Sönmez *et al.* 2004; Budakçı 2006; Pelit 2007).

In this respect, the aim of this study was to determine the color changes caused by different types of trees and moisture content affecting water-borne varnish layers. The data obtained in this study is thought to benefit both the producers and the consumers in the furniture and interior design sector to provide knowledge regarding the subject.

EXPERIMENTAL

Materials

Wood material

The test samples were prepared from Scots pine (*Pinus sylvestris* L.) and Eastern beech (*Fagus orientalis* Lipsky), which are widely used in the woodwork and furniture industries in Turkey. The samples were prepared from the sapwood of randomly selected 1st grade timbers; they were chosen to be regular-fiber, knotless, crack-free, exhibiting no variation in color or density, and having annual rings perpendicular to the surface, with regard to the principles in TS 2470 (1976).

The samples with a moisture content ensured by air-drying were cut into the dimension of 110 x 110 x 12 mm (width x length x thickness) as roughcast. Then, the samples were left in air-conditioning cabinets; at 20 ± 2 ºC temperature and 42 ± 5 % relative humidity for 8 % target moisture content, at 20 ± 2 ºC temperature and 53 ± 5 % relative humidity for 10 % target moisture content, and at 20 ± 2 ºC temperature and 65 ± 5 % relative humidity for 12 % target moisture content until their mass no longer varied (TS 2471 1976). The samples were then dimensioned to 100 x 100 x 10 mm (width x length x thickness) and sanded with 80-grit (on Norton scale) sandpaper and then with 100-grit sandpaper for varnishing. According to the experimental design, a total of 90 pieces (30 pieces control-unvarnished) were prepared by creating 5 samples in order to obtain data for each factor such as 2 wood type, 3 moisture content, and 2 varnish types.

Varnishes

The one-component semi-matte (A) and two-component gloss (B) water-borne wood varnishes that are listed by their research codes in Table 1 were used in the finishing of the test samples. Information regarding several technical properties of these varnishes is given in Table 2.

Table 1. Varnishes Used in the Experimental Runs

Type of Varnish	Company Code	Research Code	Polymer Family
One-component water borne (semi-matte)	Tri-metal	A	Acryl-urethane resins
Two-component water borne (glossy) (two-pack catalyzed)	AST D 17 Primer	B_1	Acrylic copolymer resin
	AST D 18 Filling	B_2	Acrylic copolymer resin
	AST D 45 Topcoat	B_3	Acrylic modified polyurethane resin
	AST D 45 Improver	B_4	Activator for B_3

Table 2. Characteristics of the Varnishes Used in the Study

Type of Varnish	pH	Density g/m^3	Application Viscosity (second /DIN Cup 4 mm/20 ºC)	Amount of Varnish Applied (g/m^2)	Solid Content (%)
A	8.8	1.03	18	70	33.60
B_1	9.2	1.15	18	100	14.20
B_2	8.2	1.25	18	67	40.80
B_3	8.6	1.25	18	67	35.20

The ASTM D 3023 principles and the suggestions by the production companies were followed in the application of the varnishes. The amount of varnish was determined on an analytical balance with ± 0.01 g sensitivity, and it was uniformly applied with a medium-hardness bristle brush.

Varnish A was applied in three consecutive coats with 24 hr intervals, without any sanding in between layer applications. During the application of varnish B, a single coat of B_1 was applied in order to prevent unnecessary absorption of the varnish and to increase the layer performance; two coats of B_2 were applied on top with 1 hr intervals in between. The samples were sanded using 180 sandpaper after 24 hours. Then B_4 mixed with B_3 was applied for three coats with 1 hr intervals, as indicated by the company's instructions.

Methods

Measurement of color

Samples that were thoroughly dried following varnish application were left in an acclimatization cabinet with a relative humidity of 50 ± 2 % at a temperature of 20 ± 2 ºC for 16 hours to be conditioned for the color measurement experiment, as stated in the ASTM D 3924 principles. A Minolta CR-231 Colorimeter (tristimulus colorimeter) was then used as stated in the ASTM D 2224 standard principles in order to determine the color changes occurring in the water-borne varnish layers caused by the differences in tree species and moisture content (Anonymous 2001). The cross section of the equipment, which measures colors according to the standard *CIEL*a*b** color scheme, is shown in Fig. 1.

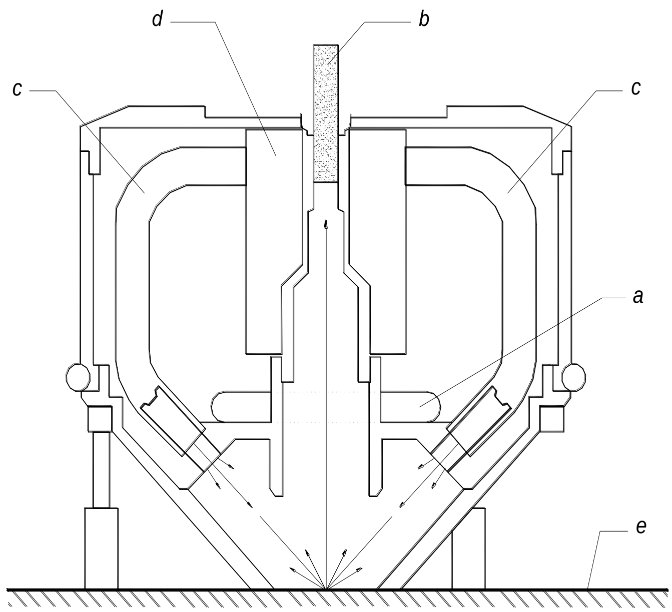

Fig. 1. Color measurement device (Anonymous 2001)

a: Xenon arc lamp, b: Fiber optic cable (for measurement), c: Fiber optic cable (for light conduction), d: Mixing chamber, e: Experiment sample

The differences in colors and their locations are determined according to the L^*, a^*, and b^* color coordinates in the *CIEL*a*b** color scheme. In this scheme, L^* (lightness) is located on the black-white axis ($L^* = 0$ for black, $L^* = 100$ for white), a^* on the red-green axis (positive values for red and negative values for green), and b^* for the yellow-blue axis (positive values for yellow and negative values for blue) (Oliver *et al*. 1992; McGuire 1992). The $CIEL^*a^*b^*$ color area is shown in Fig. 2.

The red coloration ($+a$) and the yellow coloration ($+b$) were independently investigated in order to determine which color tone was affected in each color during change and in addition, the total change in color (ΔE^*) was calculated using the following equation:

$$\Delta E^* = \sqrt{(\Delta L)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \qquad (1)$$

The low ΔE^* values obtained from the calculations would indicate very low or no change in color (Söğütlü and Sönmez 2006).

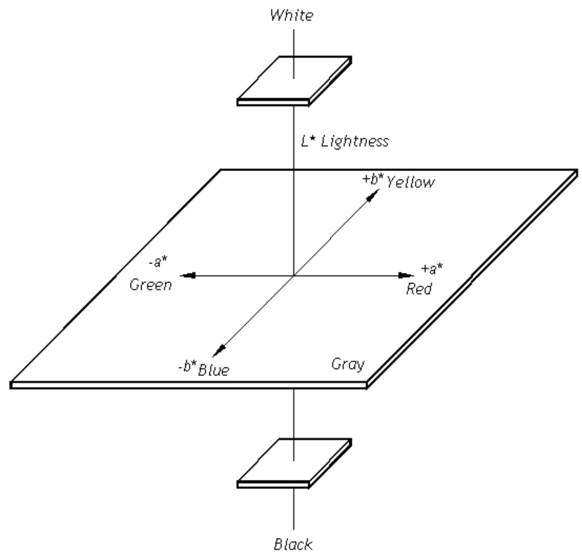

Fig. 2. *CIEL***a***b** color space (Anonymous 2001)

Statistical evaluation

A statistical software package called MSTATC was used in the statistical evaluation of the data. In the analysis, the values of factors were determined based on a multiple variance analysis. Factor effects were considered significant with $\alpha = 0.05$ error rate. According to variance analysis ''ANOVA'' results, Least Significant Difference (LSD) critical values were used, and causal factors were determined.

RESULTS AND DISCUSSION

Color Measurements

The type of the tree, the variation of the amount of the humidity, and the average value of the L^*, a^*, and b^* data obtained before and after varnishing are given in Table 3.

According to color measurement results, the red color value (+*a*), the yellow color value (+*b*), and the total change in the color (ΔE^*) were analyzed separately, and the factors affecting the color changes were determined in comparison to the control samples.

Value of the Color Red (+*a*)

The results of the multiple variance analysis on the variation of the color red in water borne varnish layers as a response to moisture content and differentiation in tree species are given in Table 4.

The change in red coloration was determined to be significant as a result of the analysis of variance in terms of the tree species, type of varnish, and the tree species-type of varnish levels, whereas it was insignificant in terms of other factors and interactions ($\alpha = 0.05$). Based on this information, the comparison results of the Duncan test that used the LSD critical value on the tree species and the type of varnish factor levels are provided in Table 5.

Table 3. *L*, a*, b** Measurement Values Before and After Varnishing

Wood Type	Moisture Content	Control (Unvarnished)			A Varnish			B Varnish		
		*L**	*a**	*b**	*L**	*a**	*b**	*L**	*a**	*b**
Scots Pine	8 %	72.52 (3.49)	8.10 (0.82)	26.46 (0.75)	64.53 (0.32)	10.77 (0.27)	26.36 (0.48)	62.32 (0.32)	11.77 (0.17)	29.95 (0.27)
	10 %	73.92 (3.51)	7.02 (0,61)	25.40 (0.74)	64.98 (0.81)	10.36 (0.19)	26.48 (0.37)	62.90 (1.74)	11.67 (0.66)	30.28 (0.39)
	12 %	74.37 (3.26)	7.52 (0.03)	26.37 (0.72)	62.07 (1.46)	11.20 (0.63)	26.55 (0.39)	61.96 (0.53)	12.16 (0.20)	30.11 (0.13)
Eastern Beech	8 %	66.91 (0.80)	10.51 (0.47)	19.18 (0.77)	62.21 (0.49)	11.22 (0.11)	23.10 (0.47)	62.83 (1.11)	11.15 (0.62)	23.12 (0.30)
	10 %	66.92 (0.74)	10.29 (0.59)	19.34 (0.84)	60.28 (0.59)	14.32 (0.38)	25.93 (0.59)	59.17 (0.96)	14.69 (0.63)	26.12 (0.69)
	12 %	67.10 (0.71)	10.39 (0.46)	19.73 (0.80)	60.26 (1.41)	11.57 (0.81)	23.45 (0.33)	61.40 (1.22)	11.60 (0.41)	23.25 (0.28)

Values in parenthesis are standard deviations

Table 4. Results of the Multiple Variance Analysis in Terms of Color Red

Factor	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Level of Significance (P<0.05)
Wood Type (A)	1	12.867	12.867	18.9292	0.0000*
Varnish Type (B)	2	86.271	43.135	63.4576	0.0000*
Interaction (AB)	2	26.110	13.055	19.2054	0.0000*
Moisture Content (C)	2	2.810	1.405	2.0669	NS
Interaction (AC)	2	1.831	0.915	1.3467	NS
Interaction (BC)	4	2.451	0.613	0.9015	NS
Interaction (ABC)	4	0.417	0.104	0.1535	NS
Error	72	48.942	0.680		
Total	89	181.689			

*: Significant at 95% confidence level NS: Not Significant

Table 5. Results of Singly Carried Out Comparisons for Each Wood Type and Varnish Type (Red Color Value)

Wood Type	$\bar{x}$	HG	LSD± 0.3454
Scots Pine	10.06	b	
Eastern Beech	11.75	a*	
Varnish Type	$\bar{x}$	HG	LSD± 0.4231
Control	8.97	c	
A Varnish	11.57	b	
B Varnish	12.17	a*	

*: The highest red color value $\bar{x}$: Average value HG: Homogeneous group

The highest red color was obtained for the Eastern beech at the tree species level. The natural color of the beech material was thought to be effective in this result. Although the natural color of beech material has been reported as reddish white in the literature, it was emphasized that following technical drying, the color changes to brick red (Örs and Keskin 2001).

The highest red color was obtained for type B varnish at the type of varnish level, and the lowest red color was observed for the control (unvarnished) samples, as indicated in Table 4. It was reported in the literature that bonds such as C=C, C=O, and C=H were established between the varnishes hardening as a result of the polymerization reactions and cellulose molecules ($C_6H_{10}O_5$) (Payne 1965; Jaic and Zivanovic 1997; Sönmez 2005; Budakçı and Sönmez 2010). The fact that varnish B also settled as a result of a reaction on the surface of the wood material would be thought to have contributed to this result. In addition, the higher pH of varnish B in comparison to varnish A (Table 2) would also be effective in terms of the increase in red color. Various studies reported that the changes in the acidity or the basicity of the application surface would adversely affect layer performance according to the acid-base theory (Corcoran 1972; Nelson 1995).

The pair-wise comparison results of the Duncan test that used the LSD critical value on the tree species-type of varnish interaction levels are provided in Table 6.

Table 6. Bilateral Comparison Results for Wood Type-Varnish Type Interaction (Red Color Value)

Varnish Type	Wood Type			
	Scots Pine		Eastern Beech	
	$\bar{x}$	HG	$\bar{x}$	HG
Control	7.54	e	10.40	d
A Varnish	10.78	c	12.37	a*
B Varnish	11.87	b	12.48	a*
LSD ± 0.5983				

*: The highest red color value $\bar{x}$: Average value HG: Homogeneous group

The pair-wise comparisons indicated that the highest red color was attained in varnish A and B applied to Eastern beech samples. The lowest red color was attained in Scots pine samples with no varnish applied on top. Application of water-borne varnish caused an increase in red color in both tree species. This condition might have resulted from the reddening due to the formation of chromophore groups in the Eastern beech and the high tendency of the resin within the Scots pine to redden as a result of varnish application. Previously conducted studies report that water borne varnishes has a color changing effect, especially on tanniferous tree species (De Meijer and Militz 2001; Sönmez *et al.* 2004; Budakçı 2006; Pelit 2007).

Value of the Color Yellow (+*b*)

The results of the multiple variance analysis on the variation of the color yellow in water borne varnish layers as a response to moisture content and differentiation in tree species are given in Table 7.

Table 7. Results of the Multiple Variance Analysis in Terms of Color Yellow

Factor	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Level of Significance (P<0.05)
Wood Type A)	1	703.921	703.921	2520.8619	0.0000*
Varnish Type (B)	2	229.101	114.550	410.2247	0.0000*
Interaction (AB)	2	65.326	32.663	116.9711	0.0000*
Moisture Content (C)	2	1.088	0.544	1.9479	NS
Interaction (AC)	2	0.463	0.231	0.8288	NS
Interaction (BC)	4	1.888	0.472	1.6904	NS
Interaction (ABC)	4	1.555	0.389	1.3921	NS
Error	72	20.105	0.279		
Total	89	1023.446			

*: Significant at 95% Confidence Level NS: Not Significant

The change in yellow coloration was determined to be significant as a result of the analysis of variance in terms of the tree species, type of varnish, and the tree species-type of varnish levels, whereas it was insignificant in terms of other factors and interactions (α = 0.05). Based on this information, the comparison results of the Duncan test that used the LSD critical value on the tree species and the type of varnish factor levels are provided in Table 8.

Table 8. Results of Singly Carried Out Comparisons for Each Wood Type and Varnish Type (Yellow Color Value)

Wood Type	$\bar{x}$	HG	
Scots Pine	27.55	a*	LSD± 0.2213
Eastern Beech	22.58	b	
Varnish Type	$\bar{x}$	HG	
Control	22.75	c	LSD± 0.4231
A Varnish	25.31	b	
B Varnish	27.14	a*	

*: The highest yellow color value $\bar{x}$: Average value HG: Homogeneous group

The highest yellow color was obtained for Scots pine at the tree species level. The natural yellowish color of the pine material was thought to contribute to this result. The highest yellow color was obtained for type B varnish at the type of varnish level, and the lowest yellow color was observed for the control (unvarnished) samples. These results, which were similar to the measurements obtained for the investigation of the red pigmentation, revealed the color changing effect of water borne varnishes that were applied on wood material once again.

The pair-wise comparison results of the Duncan test, based on the LSD critical value on the tree species-type of varnish interaction levels, are provided in Table 9.

Table 9. Bilateral Comparison Results for Wood Type-Varnish Type Interaction (Yellow Color Value)

Varnish Type	Wood Type			
	Scots Pine		Eastern Beech	
	$\bar{x}$	HG	$\bar{x}$	HG
Control	26.08	c	19.42	e
A Varnish	26.47	b	24.16	d
B Varnish	30.11	a*	24.17	d
LSD ± 0.5983				

*: The highest yellow color value $\bar{x}$: Average value HG: Homogeneous group

The pair-wise comparisons indicated that the highest yellow color was attained in varnish B applied to Scots pine samples, whereas the lowest yellow color was attained in Eastern beech samples with no varnish applied on top (control samples). The increase in yellow color was thought to stem from the fact that varnish B has a reaction-based drying finish and that the natural look of the Scots pine is yellowish; the overall outcome results form a chemical interaction between these two materials.

Total Change in Color (ΔE*)

The results of the multiple variance analysis on the variation of the total change in color in water-borne varnish layers as a response to moisture content and differentiation in tree species are given in Table 10.

Table 10. Results of the Multiple Variance Analysis in Terms of Total Change in Color

Factor	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Level of Significance (P<0.05)
Wood Type A)	1	345.600	345.600	59.2022	0.0000*
Varnish Type (B)	1	8.894	8.894	1.5235	NS
Interaction (AB)	1	40.049	40.049	6.8606	0.0118*
Moisture Content (C)	2	56.373	28.187	4.8284	0.0123*
Interaction (AC)	2	10.394	5.197	0.8902	NS
Interaction (BC)	2	5.939	2.970	0.5087	NS
Interaction (ABC)	2	3.350	1.675	0.2869	NS
Error	48	280.206	5.838		
Total	59	750.805			

*: Significant at 95% Confidence Level NS: Not Significant

The total change in color was determined to be significant as a result of the analysis of variance in terms of the tree species, type of varnish, and the tree species-type of varnish levels, whereas it was insignificant in terms of other factors and interactions ($\alpha = 0.05$). Based on this information, the comparison results of the Duncan test that used the LSD critical value on the tree species and the type of varnish factor levels are provided in Table 11.

Table 11. Results of Singly Carried Out Comparisons for Each Wood Type and Moisture Content (Total Color Change)

Wood Type	$\bar{x}$	HG	LSD± 1.248
Scots Pine	11.59	a*	
Eastern Beech	8.07	b	
Moisture Content (%)	$\bar{x}$	HG	LSD± 1.529
8	8.03	b	
10	9.27	ab	
12	10.40	a*	

*: The highest total color change value $\bar{x}$: Average value HG: Homogeneous group

The total change in color was higher for Eastern beech than for Scots pine at the tree species level, and it was the highest for wood samples with 12% moisture content and the lowest for the wood samples with 8% moisture content at the moisture content level. These results indicated that both the tree species and the moisture content had effects on the total change in color, and this change was directly proportional to the increase in moisture content. The excess moisture present in the wood body was reported to have adverse effects especially in water borne finishes (Sönmez and Budakçı 2004).

The pair-wise comparison results of the Duncan test that used the LSD critical value on the tree species-type of varnish interaction levels are provided in Table 12.

Table 12. Bilateral Comparison Results for Wood Type-Varnish Type Interaction (Total Color Change)

Varnish Type	**Wood Type**			
	Scots Pine		Eastern Beech	
	$\bar{x}$	HG	$\bar{x}$	HG
A Varnish	10.38	b	8.17	c
B Varnish	12.79	a*	7.97	c
LSD ± 1,765				

*: The highest total color change value $\bar{x}$: Average value HG: Homogeneous group

The pair-wise comparisons indicated that the highest total change in color was attained in varnish B applied to Scots pine samples, whereas the lowest total change in color was attained in Eastern beech samples with either varnish A or B applied on top. This situation was thought to stem from the chemical interaction of the resin within the Scots pine and the chemicals within the varnish causing a change in color, as well as the deeper penetration of varnish into Scots pine having a lower density than the Eastern beech, causing more change in color.

CONCLUSIONS

The results of the study indicated that the tree species, moisture content, and the type of varnish had significant effects on the color change values measured for different wood material surfaces, on which water borne varnish layers were applied. Also, the highest color change was attained for the Scots pine wood with 12% moisture content upon the application of varnish type B. Based on these results, it would be suggested to the producers and the consumers of the furniture and interior design sector to keep the moisture content of the used wood material within a constant range of 8% ± 0.5% in order to minimize the color changes that might take place as a result of the water borne varnish applications.

REFERENCES CITED

Anonymous (2001). "Minolta CR–231 Chroma meter", ver 3.0. (Tristimulus Colorimeter), Instruction Manual Composition," *Holz als Roh-und Werkstoff* 57, 45-50.

ASTM D 2224 (2003). "Standard practice for calculation or color tolerances and color differences from instrumentally measured color coordinates."

ASTM D 3023 (1998). ''Standard practice for determination of resistance of factory applied coatings on wood products of stain and reagents."

ASTM D 3924-80 (2005). "Standard specification for standard environment for conditioning and testing paint, varnish, lacquer, and related materials," American Society for Testing and Materials.

Budakçı, M. (2006). "The design and the production of a pneumatic adhesion tester," *Gazi University, Faculty of Technical Education Polytechnical Journal* 9(1), 53-58.

Budakçı, M., Korkut, D. S., and Esen, R. (2010). "The color changes on varnish layers after accelerated aging through the hot and cold-check test," *African Journal of Biotechnology* 9 (24), 3595-3602.

Budakçı, M., and Sönmez, A. (2010). "Determination of adhesion strength of various wood varnishes on different wooden material surfaces," *Gazi University, Journal of the Faculty of Engineering and Architecture* 25(1), 111-118.

Corcoran, E. M. (1972). "Adhesion, Chapter 5.3," *Painting Testing Manual*, ASTM Special Technical Publication, Philadelphia, PA., 314-332.

De Meijer, M. (2002). "Comparison between laboratory water permeability tests and wood moisture content of full-scale window frames," *Surface Coatings International Part B: Coatings Transactions* 85(2), 131-137.

De Meijer, M., and Militz, H. (2001). "Moisture transport in coated wood. Part 2: Influence of coating type, film thickness, wood species, temperature and moisture gradient on kinetics of sorption and dimensional change," *Holz als Roh-und Werkstoff* 58, 467-475.

Engler, N. (1992). *Finishing, Techniques for Better Wood Working*, Rodale Press, Pennsylvania.

Flexner, B. (2005). *Understanding Wood Finishing, How to Select and Apply the Right Finish*, The Reader's Digest Association, Inc., Pleasantville, New York, Montreal.

Jaic, M., and Zivanovic, R. (1997). "The influence of the ratio of the polyurethane coating components on the quality of finished wood surface," *Holz als Roh-und Werkstoff* 55, 319-322.

McGuire, R. G. (1992). "Reporting of objective color measurements," *HortScience* 27, 1254-1255.

Nelson, G. L. (1995), "Adhesion, Chapter 44," *Paint and Coating Testing Manual, ASTM* Special Technical Publication, Philadelphia, PA., 513-523.

Oliver, J. R., Blakeney, A. B., and Allen, H. M. (1992). "Measurement of flour color in color space parameters," *Cereal Chem*, 69, 546-551.
Örs, Y., and Keskin, H. (2001). "Information on wood materials," *Atlas Publishing,* Istanbul, 151-153.
Özen, R., and Sönmez, A. (1990). "Resistance of varnishes used in wood furniture surfaces against significant mechanical, physical and chemical effects," *TÜBİTAK Nature Magazine* 14(2), 226.
Payne, H. F. (1965). *Organic Coating Technology, Volume I*, Printed in New York U.S.A. Fourth Printing.
Pelit, H. (2007). "Effect of the moisture content of wood materials on the layer properties of water borne varnishes," Graduate Thesis, *Gazi University Institute of Natural Sciences,* Ankara.
Söğütlü, C., and Sönmez, A. (2006). "Color changing effect of UV rays on some local wood species treated with various shielding agents," *Gazi University Journal of the Faulty of Architecture and Engineering* Ankara 21(1), 151-159.
Sönmez, A. (1995). "Endurance of finishing layers on wood surfaces subject to outdoor effects," *Standards Magazine* 404, 57-60.
Sönmez, A. (1998). "Color changing effect of outdoor conditions on varnished surfaces," *Gazi University Journal of the Institute of Sciences,* 11(3)(493-505).
Sönmez, A., and Kesik, H. İ. (1999). "Accelerated aging experiments imposing the hot-cold effect on varnish layers," *Gazi University Polytechnic Journal* 2(4), 27-32.
Sönmez, A., Budakçı, M., and Yakın, M. (2004). "Effect of water borne varnish applications on wooden material on hardness, gloss and surface adhesion," *Gazi University, Faculty of Technical Education Polytechnical Journal* 7(3), 229-235.
Sönmez, A., and Budakçı, M. (2004). "Protective layers and paint/varnish systems, finishing on woodworking II," Gazi University, Technical Education Faculty, Ankara.
Sönmez, A. (2005). "Preparation and coloring, finishing on woodworking I," *Gazi University, Technical Education Faculty,* Ankara, 3-26.
Sönmez, A., Budakçı, M., and Bayram, M. (2009). "Effect of wood moisture content on adhesion of varnish coatings," *Scientific Research and Essay* 4(12), 1432-1437.
Sönmez, A., Budakçı, M., and Pelit, H. (2011). "The effect of the moisture content of wood on the layer performance of water borne varnishes," *BioResources* 6(3), 3166-3177.
TS 2470 (1976). "Wood - Sampling methods and general requirements for physical and mechanical tests," *Turkish Institute of Standards*, (in Turkish).
TS 2471 (1976). "Wood-determination of moisture content for physical and mechanical tests," *Turkish Institute of Standards*, (in Turkish).
Yolanda, L. T. (1998). "Evaluation of finishing properties and coating systems for gubas," *Forest Products Research and Development Institute (FPRDI) Journal,* 24(1), 33-41.
Wheeler, E. A. (1983). "Wood structure and properties," *Finishing Eastern Hardwoods,* Proceedings 7318, Carter, R. M. (ed.), Forest Products Res. Soc., Madison, 5-14.

Article submitted: March 17, 2012; Peer review completed: July 10, 2012; Revised version received: July 21, 2012; Accepted: September 18, 2012; Published: September 20, 2012.