Effects of Artificial Weathering on the Surface Properties of Ultraviolet Varnish Applied to Lemonwood (*Citrus limon* (L.) Burm.)

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Ultraviolet varnishes are widely used for production processes in the parquet industry. A large number of chemicals are used in this sector, and each one has different characteristics. In this study, the effects of accelerated aging of ultraviolet varnish (3 and 5 coats) when applied to lemonwood (*Citrus limon* (L.) Burm.) (grown in Mezitli, Mersin, Turkey) were investigated. The ultraviolet varnish coated samples were subjected to aging processes (144 h, 288 h, and 432 h) by using UV-A 340 nm lamps. Color (L^*, a^*, b^*, and ΔE^*) parameters, glossiness (perpendicular (⊥) and parallel (//) at 20°, 60°, and 85°), and surface adhesion strength *via* the pull-off method for ultraviolet varnish coated samples were quantified before and after weathering. According to the results, the varnish type, aging period, and interaction between all studied variables, *i.e.* L^*, a^*, b^* color parameters, glossiness (perpendicular (⊥) and parallel (//) at 20°, 60°, and 85°), and adhesion strength were found to alter the surface properties. As a result, the lemon tree can be used in the production of an ultraviolet parquet system.

Keywords: Lemonwood; Weathering aging; UV varnish; Color; Glossiness; Adhesion

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INTRODUCTION

Lemonwood trees (*Citrus limon* (L.) Burm.) are grown in Ceylon, where they are called East Indian satin, and in the Bahamas, Bermuda, and Jamaica, where they are called West Indian satin. The annual rings of this tree are evident, with a bright satin surface. There is no color difference between the earlywood and the latewood, and self-rays are very evident. This wood type is very hard, with a tight structure, and it is resistant to changing weather conditions. The wood releases a spicy odor that irritates the respiratory system. It is resistant to physical effects (Sanivar and Zorlu 1980). Lemonwood can be used as a raw material in forest products (such as the pulp and paper industry, *etc*.) (Tutus *et al.* 2018).

Lemonwood is fine-grained, compact, and easy to work with. In Mexico, it is carved into small spoons, toys, chessmen, and other articles (Morton 1987). Lemonwood has been used in the manufacturing of archery bows, tool handles, fishing rods, shuttles, turnery, picker sticks, and other textile manufacturing items. Machined surfaces have a smooth and silk-gloss appearance (Chudnoff 1979). It is nicely veined and when polished and varnished, the appearance gains vitality (Grieve 1984). The veneer of this wood is also sought for valuable furniture and decorations. It is used for the production of high-quality furniture, living room furniture, lathe, and inlaid works. It is also marketed under various names, such as silk tree, atlas tree, and satin (Sanivar and Zorlu 1980).

The goal of this study was to examine the response of lemonwood (*Citrus limon* (L.) (Burm.) (grown in Mezitli-Mersin, Turkey) to artificial weathering, after being coated with an ultraviolet (UV) cured varnish (3 and 5 coats). There was no literature that applied a UV cured varnish to this wood type; therefore, the aim of this study was to create a new application for lemonwood with a light-yellow surface.

EXPERIMENTAL

Wood Material

Lemonwood (*Citrus limon* (L.) Burm.) was obtained from a timber company located in Mezitli, Mersin, Turkey. Lemonwood samples with dimensions of 100 cm × 10 cm × 1.8 cm (longitudinal × tangential × radial) were prepared. Later, these samples were kept in a conditioned room (65% ± 3% relative humidity and 20 °C ± 2 °C) until a constant weight was achieved using the TS 2471 (1976) standard.

Application of UV varnish

In this study, laminated parquet flooring made from lemonwood (*Citrus limon* (L.) Burm.) was selected and cut to 100 cm x 10 cm x 1.7 cm dimensions by the KPS Company (Duzce City, Turkey). The production methods of the UV varnishes (3 and 5 coats) are shown in Table 1. The UV varnish was applied to the lemonwood according to industrial applications.

Table 1. UV Varnish Application Methods (3 and 5 Coats)

	Methodology Steps	
3 Coats	Sanding and calibrating machines (80 to 120 grit sizes)	3 coated UV varnish
	Clear UV curing hydro primer applied to 10 g/m^2 then dried (70 °C)	
	UV curtain coating high gloss applied 8 g/m^2	
	UV lamp drying (2 times) Total (177 mJ/cm^2)	
	Sanding and calibrating machines (280 to 320 grit sizes)	
	clear mat UV oil applied (8 g/m^2)	
	UV lamp drying (71 mJ/cm^2)	
	clear mat UV oil to be applied (8 g/m^2)	
	UV lamp drying Total (314 mJ/cm^2)	
5 Coats	Sanding and Calibrating Machines (80 to 120 grit sizes)	5 coated UV varnish
	Clear UV curing hydro primer applied to 10 g/m^2 then dried (70 °C)	
	*UV clear curing sealer applied to 20 g/m^2 then dried (70 °C)	
	UV clear curing sealer applied to 10 g/m^2 then dried (70 °C)	
	UV clear curing sealer applied to 10 g/m^2 then dried (170 °C)	
	Sanding and Calibrating Machines (280 to 320 grit sizes)	
	clear mat UV oil applied (8 g/m^2)	
	UV lamp drying (71 mJ/cm^2)	
	clear mat UV oil applied (8 g/m^2)	
	UV lamp drying Total (2 times) (314 mJ/cm^2)	

The clear UV curing hydro-primer (Kneho-Lacke GmbH, Horn-Bad Meinberg, Germany) (T8028-0000) contained polyurethane acrylate and unsaturated acrylate resins dispersed in water. The density at 20 °C, the solid content, the viscosity at 20 °C, the organic solvents, and the water properties of T8028-0000 were 1.07 g/cm³, 38.73 wt%, 20" to 30" / 6 mm, 0 wt%, and 61 wt%, respectively.

The medium viscosity UV curtain coating high gloss (Kneho-Lacke GmbH, Horn-Bad Meinberg, Germany) (T9120-0900N1) contained glycerol, propoxylated esters with acrylic acid (l-methyl-l,2-ethanediyl) bis[oxy(methyl-2,l-ethanediyl)]diacrylate, 2.2-bis(acryloyloxymethyl)butyl, acrylate, mequinol, 2,2'-oxydiethyl diacrylate, 4,4'-isopropylidenediphenol oligomeric reaction products with l-chloro-2,3-epoxypropane esters with acrylic acid, 1.3-Propanediol,2,2-bis (hydroxymethyl)-, reaction products with l-chloro-2,3-epoxypropane, reaction products with acrylic acid, alpha-oxophenylacetic acidmethylester, and ethylenglykoldiacrylat. The melting point, density at 20 °C, solid content, the viscosity at 20 °C, the organic solvents, and the water properties of T9120-0900N1 were less than 0 ºC, 1.10 g/cm³, 99.72 wt%, 15" to 20" / 6 mm, 0 wt%, and 0 wt%, respectively.

The contents of the UV oil clear mat for roller coating UV curing (Kneho-Lacke GmbH, Horn-Bad Meinberg, Germany) (T9115-0000) were dipropylenglykoldiacrylate, alpha-oxophenyloxophenylacetic acidmethylester, ethylphenyl (2,4,6-trimethylbenzoyl) phosphinat, 1,3-propanediol,2,2-bis (hydroxymethyl)-, reaction products with 1-chloro-2,3-epoxypropane, reaction products with acrylic acid, 4,4'-isopropylidenediphenol oligomeric reaction products with 1-chloro-2, 3-epoxypropane esters with acrylic acid, 2-propenoic acid, 2-hydroxyethyl ester, polymer with (chloromethyl) oxirane, 1,3-isobenzofurandione, 4,4'-(1-methylethylidene) bis[phenol]z-oxepanone glycerol, propoxylated, esters with acrylic acid, 2-propenoic acid, (l-methyl-l, 2-ethanediyl) bis[oxy(methyl-2,l-ethanediyl)l ester, reaction products with diethylamine, and (1-methyl-1,2-ethanediyl) bis[oxy(methyl-2,1-ethanediyl)] diacrylate. The melting point, the water solubility (g/L) at 20 °C, the density at 20 °C, the solid content, the viscosity at 20 °C, the organic solvents and the water properties of T9115-0000 were less than 0 ºC, partially soluble, 1.18 g/cm³, 95.67 wt%, 75 s 4 mm, 4 wt% and 0 wt%, respectively.

The contents of the *UV sealer clear S (Kneho-Lacke GmbH, Horn-Bad Meinberg, Germany) (T9110-0000H) were 4,4'-isopropylidenediphenol oligomeric reaction products with 1-chloro-2, 3-epoxypropane esters with acrylic acid, (1-methyl-1,2-ethanediyl) bis[oxy(methly-2,1-ethanediyl)] diacrylate; 2-propenoic acid(1-methyl-1,2-ethanediyl) bis[oxy(methly-2,1-ethanediyl)] ester, reaction products with diethylamine; 2,2-bis(acryloyloxmethyl)butyl acrylate, mequinol, 4-Hydroxybutlacrylat, neopentyglcol, propoxylated, esters with acrylic acid, 2,2'-(ethylenedioxy) diethyl diacrylate, and tetramethylene diacrylate.

Contents of the UV sealer clear S (Kneho-Lacke GmbH, Horn-Bad Meinberg, Germany) (T9110-0000) are (1-methyl-1,2-ethanediyl) bis[oxy(methly-2,1-ethanediyl)] diacrylate, 2-propenoic acid(1-methyl-1,2-ethanediyl) bis[oxy(methly-2,1-ethanediyl)] ester, reaction products with diethylamine;2,2-bis(acryloyloxmethyl) butyl acrylate, 4-hydroxybutlacrylat, 4,4'-(1-methylethylidene) bis-phenol polymer mit acrylat, biophenol A epoxy acrylat neopentyglcol, propoxylated, esters with acrylic acid, 2,2'-(ethylenedioxy)diethyl diacrylate; tetramethylene diacrylate.

Methods

Artificial weathering

The lemonwood samples coated with UV varnish (3 and 5 coats) were exposed in a QUV weathering tester (Q-Lab, Westlake, OH, US) (Fig. 1A), using ASTM G 154-06, (2006) with some modifications (0.67 light intensity, 18 min water spray, 2 h UV exposure and 50 °C ambient temperature) for either 144 h, 288 h, or 432 h.

Determination of light quality measuring instrument

A UV integrator (Kühnast, Brachttal, Germany) was used to measure the UV energy of different light sources according to DIN EN ISO/IEC 17025 (2016) (Fig. 1B) for UV varnishes with either 3 or 5 coats applied.

Determination of color measurement

The red/green color tone (a^*), the yellow/blue color tone (b^*), and lightness (L^*) of all coated specimens was determined using a X Rite Ci62 Series Portable (X-Rite, Grand Rapids, MI, USA) (Fig. 1C) (Wavelength resolution 10 nm, measurement geometry D/8^o) with a D65 standard illuminant according to ASTM standard D 2244-3 (2007). A CIELAB system, characterized by the three axis L^*, a^*, and b^* was used. A total of 480 measurements for color were made (UV varnish type 2 x aging 4 x color parameters 3 x N 20 = 480 measurement). The ΔL^*, Δa^*, Δb^* and total color difference (ΔE^*) were calculated using Eq. 1, 2, 3 and 4,

$$\Delta L^* = L^*_{\text{aged coated}} - L^*_{\text{unaged coated}} \quad (1)$$

$$\Delta b^* = b^*_{\text{aged coated}} - b^*_{\text{unaged coated}} \quad (2)$$

$$\Delta a^* = a^*_{\text{aged coated}} - a^*_{\text{unaged coated}} \quad (3)$$

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \quad (4)$$

where the L^* axis represents lightness, varying from 100 (white) to zero (black), a^* is the red (+) or green (–) tone; and b^* is the yellow (+) or blue (–) tone (Esteves *et al*. 2019).

Determination of glossiness measurement

Glossiness levels parallel (//) and perpendicular (⊥) to the grain at 20°, 60° and 85° angles in both aged and unaged coated samples (100 mm x 100 mm x 17 mm) were recorded with a glossmeter (Poly gloss GL0030 TQC BV, Neuss, Germany) (Fig. 1D) according to ISO 2813 (1994) standards. A total of 960 measurements for the glossiness were made (UV varnish type 2 x aging 4 x different angles 3 x fiber direction 2 x N 20 = 960 measurement).

Determination of surface adhesion strength

The surface adhesion strength of the aged and unaged samples (100 mm x 100 mm x 17 mm) coated with UV varnish (3 and 5 layers) were tested with a PosiTest AT-A (automatic) pull-off Adhesion Tester (Defelsko® crop., S/N AT11802, US) (Fig. 1E) according to ASTM standard D 4541 (1995). Dolly cylinders (Ø 20 mm) were attached to the aged and unaged coated samples surfaces at 20 °C (room temperature). All coated samples were glued using 404 Fast Plastic Steel glue (404 Kimya ve Sanayi Ticaret A.Ş., Cekmekoy/Istanbul, Turkey), which is composed of 2,4,6-tris (dimethylaminomethyl) phenol and fixed with tools. All test specimens were air-dried for 24 h, after which the glue residue was removed with a cutter. A total of 40 measurements were made for the adhesion strength tests (UV varnish type 2 x aging 4 x N 5 = 40 measurement). The adhesion X (MPa) was calculated using Eq. 5. (Gurleyen *et al.* 2019),

$$X = 4F / \pi . d^2 \quad (5)$$

where F is the rupture force (N) and d is the diameter of the experiment cylinder (mm).

Fig. 1. (A) QUV weathering tester, (B) UV integrator, (C) X Rite Ci62 Series Portable, (D) Novo-Gloss Trio gloss meter, (E) PosiTest AT-A (automatic) pull-off adhesion tester, (F) dolly, (G) cutting tool, and (H) test sample

Statistical analysis

In this study, the test samples were 5 pieces. Statistical analysis was performed for a total of 1480 measurements (glossiness 960 + color 480 + adhesion strength 40 = 1480). The minimum and maximum values, standard deviations, homogeneity groups, analysis of variance, and multiple comparisons were determined, with the data obtained before and after aging, for color, glossiness, and adhesion strength using the SPSS 17 program (Sun Microsystems, Inc., 4150 Network Circle, Santa Clara, CA, USA).

RESULTS AND DISCUSSION

The results of the UV integrator device were 177 mJ/cm^2 for filling of 3 coats of the UV system varnish and 71 mJ/cm^2 and 314 mJ/cm^2 were for the topcoats of 3 and 5 coats of UV system varnish application during UV system varnish applications (Table 1). The results of the variance analysis (Table 2) showed that the varnish type (A), aging period (B), and the interaction (AB) between these variables, were all significant in the change of the L^*, a^*, and b^* color parameters. This meant that there was a significant difference between the colors of the samples when 3 coats or 5 coats were applied. In terms of lightness, the difference between 3 coats and 5 coats for unaged wood was low, but a larger difference was observed in a^*, which was lower and b^* higher for the 5 coat wood samples (Table 3).

Table 2. Analysis of Variance Results

Test	Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F Number	Level of Sig.
Glossiness at ⊥ 20°	Varnish type (A)	0.116	1	0.116	109.442	0.000*
	B: Aging period (B)	3.868	3	1.289	1220.952	0.000*
	AB: Interaction (AB)	0.114	3	0.038	35.889	0.000*
	Error	0.161	152	0.001		
	Total	220.250	160			
Glossiness at ⊥ 60°	Varnish type (A)	1.620	1	1.620	68.968	0.000*
	B: Aging period (B)	33.587	3	11.196	476.614	0.000*
	AB: Interaction (AB)	7.172	3	2.391	101.776	0.000*
	Error	3.571	152	0.023		
	Total	6037.430	160			
Glossiness at ⊥ 85°	Varnish type (A)	2.162	1	2.162	214.252	0.000*
	B: Aging period (B)	2.484	3	0.828	82.053	0.000*
	AB: Interaction (AB)	8.503	3	2.834	280.855	0.000*
	Error	1.534	152	0.010		
	Total	1070.440	160			
Lightness (*L**)	Varnish type (A)	20.837	1	20.837	136.576	0.000*
	B: Aging period (B)	3830.657	3	1276.886	8369.382	0.000*
	AB: Interaction (AB)	222.616	3	74.205	486.381	0.000*
	Error	23.190	152	0.153		
	Total	882819.571	160			
Yellow color (*b**) tone	Varnish type (A)	116.417	1	116.417	302.545	0.000*
	B: Aging period (B)	4693.232	3	1564.411	4065.578	0.000*
	AB: Interaction (AB)	130.141	3	43.380	112.736	0.000*
	Error	58.489	152	0.385		
	Total	230888.658	160			
Glossiness at // 20°	Varnish type (A)	0.072	1	0.072	45.380	0.000*
	B: Aging period (B)	4.877	3	1.626	1021.028	0.000*
	AB: Interaction (AB)	0.297	3	0.099	62.129	0.000*
	Error	0.242	152	0.002		
	Total	232.540	160			
Glossiness at // 60°	Varnish type (A)	2.139	1	2.139	52.160	0.000*
	B: Aging period (B)	52.039	3	17.346	422.977	0.000*
	AB: Interaction (AB)	14.424	3	4.808	117.238	0.000*
	Error	6.234	152	0.041		
	Total	8241.570	160			
Glossiness at // 85°	Varnish type (A)	49.506	1	49.506	85.115	0.000*
	B: Aging period (B)	51.963	3	17.321	29.780	0.000*
	AB: Interaction (AB)	89.817	3	29.939	51.474	0.000*
	Error	88.409	152	0.582		
	Total	28390.900	160			
Red color (*a**) tone	Varnish type (A)	3.519	1	3.519	120.019	0.000*
	B: Aging period (B)	2740.771	3	913.590	31154.989	0.000*
	AB: Interaction (AB)	42.883	3	14.294	487.458	0.000*
	Error	4.457	152	0.029		
	Total	16980.224	160			
Adhesion (MPa)	Varnish type (A)	0.721	1	0.721	6.616	0.015*
	B: Aging period (B)	53.745	3	17.915	164.417	0.000*
	AB: Interaction (AB)	1.139	3	0.380	3.484	0.027*
	Error	3.487	32	0.109		
	Total	655.152	40			
* Significant according to α less than or equal to 0.05						

Table 3. Statistical Data for Color Parameters (*L**, *a**, and *b**)

Test	Varnish type	Aging period	N	Mean	*HG*	Standard Deviation	Minimum	Maximum
Lightness (*L**)	3 coats UV varnish system	Unaged	20	81.35	B	0.71	78.86	81.97
		144 h	20	71.61	D	0.30	70.91	71.99
		288 h	20	72.53	C	0.26	72.13	73.03
		432 h	20	72.38	C	0.20	72.00	72.67
	5 coats UV varnish system	Unaged	20	83.76	A*	0.30	83.06	84.17
		144 h	20	72.32	C	0.46	71.93	73.71
		288 h	20	69.59	E	0.31	69.31	70.58
		432 h	20	69.33	F**	0.33	68.82	69.86
Red color (*a**) tone	3 coats UV varnish system	Unaged	20	2.76	G	0.31	2.47	3.57
		144 h	20	11.26	E	0.18	11.09	11.61
		288 h	20	11.38	D	0.14	11.09	11.68
		432 h	20	11.67	C	0.09	11.48	11.84
	5 coats UV varnish system	Unaged	20	1.84	H**	0.10	1.67	2.02
		144 h	20	10.73	F	0.18	10.20	11.02
		288 h	20	12.78	B	0.06	12.55	12.83
		432 h	20	12.91	A*	0.18	12.61	13.16
Yellow color (*b**) tone	3 coats UV varnish system	Unaged	20	25.88	E**	1.47	24.28	29.59
		144 h	20	40.49	B	0.44	39.97	41.18
		288 h	20	40.55	B	0.32	39.92	40.86
		432 h	20	39.97	C	0.15	39.70	40.25
	5 coats UV varnish system	Unaged	20	30.52	D	0.69	29.13	32.01
		144 h	20	40.29	BC	0.25	39.70	40.75
		288 h	20	41.42	A	0.05	41.34	41.51
		432 h	20	41.48	A*	0.20	41.06	41.75

N: Measurements of number, * Highest value, ** Lowest value, *HG* Homogeneity Group

The aging period was also found to have significant effects. The major differences were found between the unaged and aged samples. However, there was a clear decrease in lightness with an increase in aging time. The lightness value for the unaged samples with 5 coats was 83.8, and with 144 h of aging, it changed to 72.3. But after 144 h the decrease with aging was smaller and reached a minimum value of 69.3 for 432 h of aging. There was an increase in *a** due to the increased redness of the surface and at the same time there was an increase in *b**, which corresponded to a more yellow surface (Table 3). Results also showed that the varnish type (n^{o} of coats) also interacted with the aging period. Lightness decreased more for the 5 coats system which seems to indicate that it gave less protection to the wood surface. This is likely because the 5 coated wood has 3 coats of sealer and 2 coats of oil while the 3 coated wood has 3 coats of oil.

The total colour difference and the differences in lightness, *a**, and *b** are presented in Table 4. The ΔL^*, Δa^*, and Δb^* state the differences previously discussed with a decrease in lightness and an increase in *a** and *b** with the aging.

Overall, the total colour difference (ΔE^*) of the samples with 5 coats was higher than the samples with 3 coats. With the aging period, the total color difference decreased for 3 coat wood samples and increased for 5 coat wood samples. This is probably due to the strong influence of lightness that has a significant decrease for 5 coated wood. In relation to the 5 coats UV system, good correlations can be obtained between ΔE^* and ΔL^* (R^2=0.9998), Δa^*(R^2=0.9994) and Δb (R^2=0.9989) since all the parameters increase with aging. This is not seen in the 3 coats.

Table 4. Total Colour Differences (Δ*L**, Δ*a**, Δ*b**, and Δ*E**)

Varnish type	Aging period	Δ*L**	Δ*a**	Δ*b**	Δ*E**
3 coat UV varnish system	144 h	-9.74	8.50	14.61	19.51
	288 h	-8.82	8.62	14.67	19.17
	432 h	-8.97	8.91	14.09	18.93
5 coat UV varnish system	144 h	-11.44	8.89	9.77	17.47
	288 h	-14.17	10.94	10.90	20.96
	432 h	-14.43	11.07	10.96	21.23

Table 5 presents the surface adhesion strength *via* the pull-off test. The differences between the 3 coat and 5 coat samples were not significant, as can be seen by the homogeneity groups that are the same for unaged samples. Overall, there seems to be a decrease in adhesion strength with an increase in aging period, although the adhesion strength for the samples aged for 432 h was higher than that of the samples aged for 288 h. The decrease in adhesion strength might be due to multiple factors like wood degradation, chemical degradation of the coating or migration of extractives to the wood surface affecting the bond line. Nevertheless in accordance to Clerc *et al.* (2017) adhesion strength loss with weathering is in most times due to the degradation of wood rather than chemical degradation of the adhesive. In this case for similar aging periods there is a higher decrease in adhesion strength for 5 coat UV system which might indicate that there is some degradation of the adhesive system. This would also explain the higher decrease observed in wood lightness for the 5 coat system (Table 3).

Table 5. Statistical Data for Surface Adhesion strength (MPa) Values

Varnish type	Aging period	N	Mean	Homogeneity Group	Standard Deviation	Minimum	Maximum
3 coat UV varnish system	Unaged	5	5.720	A	0.554	5.100	6.600
	144 hours	5	3.944	B	0.455	3.200	4.300
	288 hours	5	2.766	D	0.115	2.660	2.950
	432 hours	5	3.548	BC	0.170	3.380	3.770
5 coat UV varnish system	Unaged	5	5.840	A*	0.503	5.300	6.600
	144 hours	5	3.488	C	0.119	3.330	3.650
	288 hours	5	2.750	D**	0.194	2.500	2.950
	432 hours	5	2.826	D	0.106	2.670	2.940
N: Measurements of number, * Highest value							

In relation to glossiness values (perpendicular (⊥) and parallel (//) at 20°, 60° and 85°), the ANOVA results (Table 2) were similar to those found for color, with a significant difference between the varnish and aging period and an interaction between both variables.

In Table 6 it can be seen that glossiness, both parallel and perpendicular to the grain measured at 20º angle, decreases with aging as stated by Ayata *et al.* (2018). The measurements for the 60° angle showed a decrease in glossiness until 288 h of aging, with a small increase afterwards. The results for 85° were more erratic, although a general decreasing trend seemed to apply. This generally occurs since at an 85° angle, the glossiness is more affected by small differences in the surface roughness.

Table 6. Statistical Data for Glossiness Values

Test	Varnish type	Aging period	N	Mean	*HG*	Std. Deviation	Minimum	Maximum
Glossiness at ⊥ 20°	3 coat UV varnish system	Unaged	20	1.45	A*	0.07	1.30	1.50
		144 h	20	1.10	D	0.00	1.10	1.10
		288 h	20	1.10	D	0.00	1.10	1.10
		432 h	20	1.11	D	0.02	1.10	1.20
	5 coat UV varnish system	Unaged	20	1.41	B	0.02	1.40	1.50
		144 h	20	1.13	C	0.05	1.10	1.20
		288 h	20	1.00	E**	0.00	1.00	1.00
		432 h	20	1.01	E	0.02	1.00	1.10
Glossiness at ⊥ 60°	3 coat UV varnish system	Unaged	20	6.90	A*	0.22	6.40	7.10
		144 h	20	5.90	D	0.18	5.70	6.30
		288 h	20	5.94	D	0.08	5.80	6.10
		432 h	20	6.15	C	0.21	5.80	6.40
	5 coat UV varnish system	Unaged	20	6.81	A	0.11	6.60	7.00
		144 h	20	6.34	B	0.19	6.00	6.80
		288 h	20	5.29	F**	0.06	5.10	5.40
		432 h	20	5.64	E	0.07	5.50	5.70
Glossiness at ⊥ 85°	3 coat UV varnish system	Unaged	20	2.58	D	0.14	2.30	2.90
		144 h	20	2.54	D	0.14	2.40	2.80
		288 h	20	2.59	D	0.04	2.50	2.70
		432 h	20	3.04	A*	0.08	2.90	3.20
	5 coat UV varnish system	Unaged	20	2.68	C	0.15	2.40	2.90
		144 h	20	2.84	B	0.05	2.80	2.90
		288 h	20	2.13	E**	0.05	2.10	2.20
		432 h	20	2.17	E	0.08	2.00	2.30
Glossiness at // 20°	3 coat UV varnish system	Unaged	20	1.51	A*	0.06	1.40	1.70
		144 h	20	1.11	DE	0.03	1.10	1.20
		288 h	20	1.10	E	0.00	1.10	1.10
		432 h	20	1.13	D	0.05	1.10	1.20
	5 coat UV varnish system	Unaged	20	1.46	B	0.05	1.40	1.50
		144 h	20	1.21	C	0.04	1.10	1.30
		288 h	20	1.00	F**	0.00	1.00	1.00
		432 h	20	1.01	F	0.03	1.00	1.10
Glossiness at // 60°	3 coat UV varnish system	Unaged	20	8.07	A*	0.26	7.70	8.50
		144 h	20	6.97	D	0.23	6.60	7.40
		288 h	20	6.81	E	0.22	6.40	7.10
		432 h	20	7.20	C	0.24	6.80	7.70
	5 coat UV varnish system	Unaged	20	7.84	B	0.11	7.60	8.10
		144 h	20	7.72	B	0.26	7.10	8.20
		288 h	20	6.03	G**	0.06	6.00	6.20
		432 h	20	6.54	F	0.15	6.40	7.00
Glossiness at // 85°	3 coat UV varnish system	Unaged	20	12.01	F	1.03	9.90	13.50
		144 h	20	13.29	CD	1.08	12.10	14.90
		288 h	20	11.92	F**	0.63	11.00	13.10
		432 h	20	13.58	C	0.79	12.40	15.20
	5 coat UV varnish system	Unaged	20	15.30	A*	0.84	14.10	16.60
		144 h	20	14.45	B	0.15	14.20	14.70
		288 h	20	12.87	DE	0.80	11.90	13.90
		432 h	20	12.63	E	0.24	12.30	13.00

N: Measurements of number * Highest value, ** Lowest value, *HG*: Homogeneity Group

The higher number of coats decreased the glossiness at 20° and 60° angles but increased at 85° angles. It should be mentioned, however, that according to the glossiness of the samples, the correct angle to make the measurements should be 85°, since at 60° the quantity of gloss units is less than 10, as stated in ISO 2813 (1994). An increase in glossiness with the application of more coats could be due to the UV curtain coating (T9120-0900N1), which has a high level of gloss.

CONCLUSIONS

1. The varnish type, the aging period, and the interaction between these variables were found significant relative to the change in *L**, *a**, and *b** color parameters, glossiness (perpendicular (⊥) and parallel (//) at 20°, 60°, and 85°), and the adhesion test.
2. Lightness values decrease, whereas *a** and *b** values increase with aging, with the greatest differences seen between unaged and aged wood. For unaged wood, lightness values and *b** values increase and *a** values decrease with an increase in the number of coats.
3. Gloss at a 20° angle decreases with aging in both perpendicular and parallel directions. Glossiness at a 60° angle is similar to that at 20°, except for 432 h of aging. With the 85° angle there is general decrease, but with more erratic results, which is likely due to the differences in roughness of the surface.
4. Overall, there seems to be a decrease in adhesion strength with an increase in aging period; although the adhesion strength for the samples aged for 432 h was higher than that of the samples aged for 288 h.

ACKNOWLEDGMENTS

The author thanks the KPS factory in Duzce, Turkey for UV varnish applications.

REFERENCES CITED

ASTM D 2244-3. (2007). “Standard practice for calculation or color tolerances and color, differences from instrumentally measured color coordinates,” ASTM International, West Conshohocken, PA.

ASTM D 4541. (1995). “Standard test method for pull-off strength of coatings using portable adhesion testers,” ASTM International, West Conshohocken, PA.

ASTM G 154-06. (2006). “Standard practice for operating fluorescent light apparatus for UV exposure of nonmetallic materials,” ASTM International, West Conshohocken, PA.

Ayata, U., Sahin, S., Esteves, B., and Gurleyen, L. (2018). “Effect of thermal aging on colour and glossiness of UV system varnish-applied laminated parquet layers,” *BioResources* 13(1), 861-868. DOI: 10.15376/biores.13.1.861-868

Chudnoff, M. (1979). *Tropical Timbers of the World* (Report No. 1979) U. S. Department of Agriculture, Forest Products Laboratory, Madison, WI.

Clerc, G., Brülisauer, M., Affolter, S., Volkmer, T., Pichelin, F., and Niemz, P. (2017). "Characterization of the ageing process of one-component polyurethane moisture curing wood adhesive," *International Journal of Adhesion and Adhesives* 72, 130-138. DOI: 10.1016/j.ijadhadh.2016.09.008

DIN EN ISO/IEC 17025. (2016). "General requirements for the competence of testing and calibration laboratories," German Institute for Standardization, Berlin, Germany.

Esteves, B., Ayata, U., and Gurleyen, L. (2019). "Heat treatment effect on colour and glossiness of black locust, wild pear, *Tilia*, logwood and willow," *Drewno* 62(203), DOI: 10.12841/wood.1644-3985.267.10

Grieve, M. (1984). *A Modern Herbal*, Penguin, London, UK.

Gurleyen, L., Ayata, U., Esteves, B., Gurleyen, T., and Cakicier, N. (2019). "Effects of thermal modification of oak wood upon selected properties of coating systems," *BioResources* 14(1), 1838-1849. DOI: 10.15376/biores.14.1.1838-1849

ISO 2813. (1994). "Paints and varnishes - determination of specular gloss of non-metallic paint films at 20 degrees, 60 degrees and 85 degrees," International Organization for Standardization, Geneva, Switzerland.

Morton, J. F. (1987). "Lemon," in *Fruits of Warm Climates*, C. F. Dowling (ed.), J. F. Morton, Ann Arbor, MI, pp. 160-168.

Sanivar, N., and Zorlu, I. (1980). *Ağaçişleri Gereç Bilgisi Temel Ders Kitabı, Mesleki ve Teknik Eğitim Öğretim Kitapları* [*Woodworking Materials Knowledge Basic Textbook, Vocational and Technical Education Teaching Books*], Milli Eğitim Basımevi, İstanbul.

TS 2471. (1976). "Wood - determination of moisture content for physical and mechanical tests," Turkish Standards Institution, Ankara, Turkey.

Tutus, A., Cicekler, M., Bektas, I., Odabas Serin, Z., and Ozdemir, F. (2018). "Investigation of the chemical and morphological properties of lamas lemon tree wood growing in the Erdemli," in: International Erdemli Symposium, Erdemli, Mersin, Turkey, pp. 894-899.

Article submitted: June 17, 2019; Peer review completed: August 25, 2019; Revised version received and accepted: August 28, 2019; Published: September 3, 2019.
DOI: 10.15376/biores.14.4.8313-8323