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Research Article

THE EFFECTS OF WATER-BASED COLOR-PROTECTIVE BARRIERS ON NATURAL WOOD VENEER

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ABSTRACT

In this study, the effects of water-based color-protective barriers on the color change of wooden veneers of various tree species were investigated. Wooden veneers of castanea, eucalyptus, and scots pine species - which are widely used industrially - were selected for this purpose. The wood veneers were then divided into two groups and two separate top surface prescriptions were applied to each group. In the first group, only varnish was applied. On the second group, a water-based color-protecting barrier and varnish application was used, and a total of 6 variation test samples were prepared, with and without water color-protecting barriers applied to each tree type. Test samples were tested on both UVA and UVB lamps in the QUV aging device. It has been determined that water-based color-protective barriers do not show a significant color change in the applied parts, and that the veneer experiences discoloration in the areas not subjected to color-protective barriers. These results can be regarded as an industrially significant result, helping to overcome problems associated with the weathering of varnished surfaces.
Keywords: Water based colour barrier, wooden coating, QUV.

1. INTRODUCTION

Wood is a natural and renewable raw material that has been used in countless contexts by humans for centuries. Relevant literature puts the number of distinct wood products created to meet human needs at around ten thousand [1].

The application of surface treatment products and coatings can help protect, clean, and aesthetically enhance wooden furniture pieces in particular. However, the value and lifespan of wooden furniture can still be negatively impacted by numerous factors – such as the deformation of surface treatments and coating, or the discoloration of the wood itself by contact with harmful ultraviolet (UV) rays. It is well-known that every year considerable damage is done to outdoor wooden furniture and building materials by climatic factors like sunlight, moisture, and high temperatures. Cracking, fading, and hazing are the most common forms of outdoor damage to wood [2] and extensively studied in the literature.

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As an organic material, wood is liable to undergo changes in size, color and biological formation; characteristics generally seen as problematic for users [3]. Shifts in color occur particularly quickly for wood used in exterior settings. Çakıcıer [4] notes that wood extractives and lignin degradation are responsible for the yellow and brown hues commonly observed on weathered wood surfaces. Below are some examples of wood degradation as a result of external weather conditions (Figure 1).

(a) (b) (c)

Figure 1. (a) Examples of wood degradation [2].

Aside from in traditional buildings or furniture, wood is also commonly used on the likes of ships and yachts, where it may be negatively affected by direct contact with salt water, sunlight, rain, waves, and wind. As such, wood used in these kinds of environments must be naturally resistant to climatic factors or must be speciality materials with increased durability [5]. Similarly, the selection of surface treatment agents and coatings is particularly important where the durability of wood products is concerned.

Various surface degradations may occur on wood that is subjected to light, humidity, wind, and temperature common to salt-water settings. The weathering and degradation of wood, which usually begins with a change in its color, is said to have an effect on a number of other structural features. On a microscopic level, it has been observed that lignin degradation (caused by harmful UV rays) leads to the disruption of the middle lamella, cracks in the edged passages, and separations in the cell wall. As color is an aesthetic consideration for wood furniture, suffice it to say that the phenomenon of color changes in wood products is seen as a negative attribute [6].

In order to sustain the value and lifespan of wood materials used in exterior settings, it is necessary to develop tools to prevent lignin degradation and color changes; both conditions known to be affected by UV rays. In this regard, surface treatment agents and coatings for wood must primarily target and prevent lignin degradation.

Owing to the fact that the color of wood is an aesthetic matter and that it can be used to predict possible wood deformations, the quantifiability of color values and the ability to determine total color changes in wood are both vital. The CIELab color system is a conventional method for determine color values. It is a color system comprised of three coordinates L*, a*, and b* calculated using the tristimulus values X, Y, and Z. The "*" after each coordinate is used to differentiate the CIE formulas from previously developed color systems [7].

Figure 2 sho ws the values of L*, a* and b* and their points of measurement (in accordance with the CIELab system).

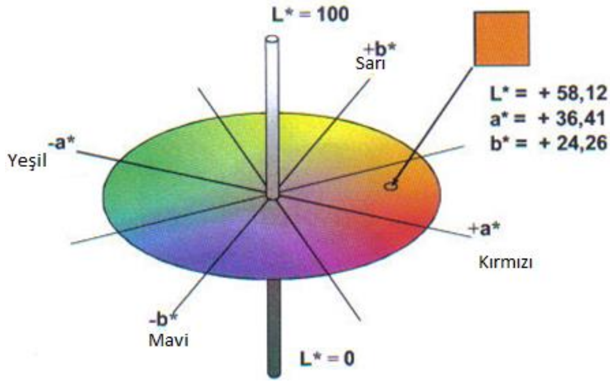

Figure 2. Determination of L *, a * and b * values according to CIELab color system [2].

In Figure 2, L* denotes the black-white axis (black is L*=0, white is L*=100), a* is the red-green axis (positive value is red, negative value is green), and b* is the yellow-blue axis (positive value is yellow, negative value is blue). The angle of L denotes the change of color in the wood; a tighter angle would mean the color has shifted towards red (a) while a wider angle would mean the color has shifted towards yellow (b).

Varnish (coating?) is used to give wood a layer of protection from external influences, and also for aesthetic reasons. It is a liquid agent comprised of soluble particles that create a transparent coating layer. Appropriate varnishes can vary depending on the conditions in which the wood is to be used and selecting the most suitable coating agent is of particular importance. The quality and durability of a given piece of wooden furniture is often dependent on the type of coating agent used [8].

Water-based coatings are generally colorless, odourless, and non-yellowing; they dry via chemical reaction, and do not change the color of the surface onto which it is applied. The chemical reaction through which it dries makes the hardened layer irreversible [9]. Water-based coating systems are some of the easiest to adjust and repair, both during application and afterwards. These coatings can be produced using many different resins, including (but not limited to) alkyd, polyester, acrylic and polyurethane. Glossy water-based varnishes do not contain coloring pigments, while matte varnishes contain matting agents. Designed for the polymerization of dispersion and emulsion, these coatings have become increasingly important in their industrial use [10].

Predictions and foresight into the climatic conditions that will be faced by surface-treated wood may help prevent or lessen the impact of weathering. To that end, it is possible to test the surface coating’s performance using various aging techniques.

Coated wood can be tested in specially prepared conditions to determine its performance under the influence of factors such as dampness, temperature, rain, and varying wavelenghts of sunlight. In the last century, natural test stations and specialised aging devices have been developed for use in laboratories [11]. Aging techniques can be grouped into three different classifications: natural outdoor aging tests, accelerated outdoor aging tests, and finally accelerated laboratory aging tests [4]. Once aged, coated wood surfaces can be tested for color changes, glossiness, coating thickness, adhesion, scratch-resistance and surface smoothness.

This study investigates the differences between two different water-based coating solutions by comparing how they affect discoloration on three different natural wood veneers on plywood;

chestnut (castanae), eucalyptus, and Scots pine. The first solution is a water-based varnish, while the second is a combination of water-based varnish and water-based color-protecting barrier. It is estimated that the combined varnish+barrier coating solution will positively affect the possible color changes on the wood.

2. MATERIALS AND METHOD

The three types of natural veneer used in this study (Castanea, Eucalyptus and Scots pine) were randomly selected from the market of tree-types suitable for exterior uses. Next, the veneers were pressed onto plywood (50*50cm) at an industrial facility that produces plywood. In preparation for their accelerated weathering, the pieces of plywood were cut into strips measuring 7,8*30,5 cm. Later, the surface coating agents were applied to the test and control samples. The procedure for applying the surface treatments is listed below.

Table 1. Classification and properties of applied surface treatments.

Sample type	Type of coating solution applied	Defining features	Solid additives (%)	Application method	Application layers
Test group	AQUACOOLFX1707Wood color-protecting barrier	Two component, water-based color-protective barrier with "New Generation Acrylic Resin" technology	25	"Conventional 1,8mm Spray gun"	2 layers
	AQUACOOLAG 4850 Parquet Varnish	Two component, water-based parquet varnish	31		2 layers
Control group	AQUACOOL AG 4850 Parquet Varnish	Two component, water-based parquet varnish	31	"Conventional 1,8mm Spray gun"	3 layers

In order for the dry film thickness in both groups to be similar, the ‘control group’ was coated in three layers of varnish, and the ‘test group’ in four. For each type of natural veneer, there was one ‘control’ and one ‘test’ sample, totaling six different panels. Each sample’s surface was divided in two, with a line drawn down the middle. For each sample, AQUACOOL AG 4850 Parquet Varnish was applied on one side, and AQUACOOL AG 4850 Parquet Varnish with AQUACOOL FX 1707 color-protective barrier) on the other side(Figure 3).

Figure 3. Test sample, color protective barrier and paint gun

One sample from each veneer type was subjected to accelerated aging for 144 hours with type-A UV lighting (labelled ‘kuva’ for the control group, and ‘duva’ for the test group). The other sample for each veneer was subjected to accelerated aging for the same amount of time under type-B UV lighting (labelled ‘kuvb’ for the control group, and ‘duvb’ for the test group). Table 2 shows the variations in veneer types and abbreviations used, while table 3 describes the three-step aging process.

Table 2. Veneer variations and abbreviation index

Variation abbreviations	Variation name
Eucalyptus kuva	Eucalyptus with varnish control sample – UVA aged
Eucalyptus duva	Eucalyptus with varnish and barrier test sample – UVA aged
Eucalyptus kuvb	Eucalyptus with varnish control sample – UVB aged
Eucalyptus duvb	Eucalyptus with varnish and barrier test sample – UVB aged
Castenae kuva	Castenae with varnish control sample – UVA aged
Castanea duva	Castenae with varnish and barrier test sample – UVA aged
Castenae kuvb	Castenae with varnish control sample – UVB aged
Castenae duvb	Castenae with varnish and barrier test sample – UVB aged
Scots pine kuva	Scots pine with varnish control sample – UVA aged
Scots pine duva	Scots pine with varnish and barrier test sample – UVA aged
Scots pine kuvb	Scots pine with varnish control sample – UVB aged
Scots pine duvb	Scots pine with varnish and barrier test sample – UVB aged

Table 3. Aging program cycle (repeated)

Cycle phase	Factor	Temper ature	Light intensity	Duration
1	UV	50°C	0.85 W/M2	8 hours
2	Spray			15 minutes
3	Condensation	40°C		3 hours 45 minutes
4	Final step - Go to step 1			

The color differences between the control and test groups were scrutinized. Each sample was analyzed using a Konica Minolta CD-600 brand spectrophotometer according to ISO 7724-2/1984 [12] standards. (ΔE^*) was calculated using the formula below, according to standard ISO 7724–3/1984 [13].

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

Index;

ΔE* : The total color difference apparent in the samples after heating
ΔL* : Black-white color change
Δa* : Red-green color change
Δb* : Yellow-blue color change

3. RESULTS AND DISCUSSION

Table 4 presents the results of the multiple variance analysis for the castanae, eucalyptus and Scots pine veneers aged for 144 hours in UVA/UVB lights after being coated with varnish, and with the varnish and protective barrier combination.

Table 4. Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	AL	872.243(a)	11	79.295	20.866	0.000	0.793
	Aa	601.779(b)	11	54.707	152.233	0.000	0.965
	Ab	4862.567(c)	11	442.052	365.500	0.000	0.985
	AE	4708.722(d)	11	428.066	361.496	0.000	0.985
Intercept	AL	1516.720	1	1516.720	399.119	0.000	0.869
	Aa	1047.370	1	1047.370	2914.514	0.000	0.980
	Ab	5169.242	1	5169.242	4274.062	0.000	0.986
	AE	5324.604	1	5324.604	4496.561	0.000	0.987
Variation	AL	694.877	9	77.209	20.317	0.000	0.753
	Aa	503.372	9	55.930	155.637	0.000	0.959
	Ab	4591.324	9	510.147	421.803	0.000	0.984
	AE	4455.548	9	495.061	418.073	0.000	0.984
Error	AL	228.010	60	3.800			
	Aa	21.562	60	.359			
	Ab	72.567	60	1.209			
	AE	71.049	60	1.184			
Total	AL	2616.973	72				
	Aa	1670.711	72				
	Ab	10104.375	72				
	AE	10104.375	72				
Corrected Total	AL	1100.253	71	a R Squared = 0.793 (Adjusted R Squared =0 .755)			
	Aa	623.341	71	b R Squared = 0.965 (Adjusted R Squared = 0.959)			
	Ab	4935.134	71	c R Squared = 0.985 (Adjusted R Squared = 0.983)			
	AE	4779.771	71	d R Squared = 0.985 (Adjusted R Squared = 0.982)			

According to table 3, the difference between the multiple color values for the veneers after 144 hours of aging under UVA and UVB lights was P≤0.95. To better understand these color differences, variations in wood type and its sub-variations were examined in an attempt to determine which color factor had the most effect on the total color differences (tables 4,5,6,7,8) Similarly, in order to determine similar groups among the tables the Duncan test was applied to averages, and the results displayed below.

Table 5 illustrates the results from the Duncan test, as well as the arithmetic averages (M) showing the specific color deviations.

Table 5. Results from the Duncan test, as well as the arithmetic averages (M) showing the specific color deviations

Wood type	N	M	HG	M	HG	M	HG	M	HG
Eucalyptus	24	2.37	B	-2.32	A	-11.20	B	11.21	A
Castanea	24	5.52	A	-3.93	B	-7.31	A	7.65	B
Scots pine	24	5.86	A	-5.18	C	-6.90	A	6.92	C

Table 6 illustrates that ΔE is greatest for eucalyptus and smallest for scot's pine. To see total color changes, Table 7 outlines the sub variations for each veneer-type, along with its Duncan test result.

Table 6. ΔE averages and Duncan test results for each veneer sub variation

Wood type and sub-variation	**N**	**ΔE**				
		A	**B**	**C**	**D**	**E**
Eucalyptus duvb	6	0.48				
Castenae duvb	6	0.72				
Eucalyptus duva	6	0.76				
Scots pine duvb	6	0.93				
Scots pine duva	6	1.48				
Castanea duva	6	1.87				
Scots pine kuva	6		12.16			
Scots pine kuvb	6		13.09	13.09		
Castenae kuva	6			13.52	13.52	
Castenae kuvb	6				14.50	
Eucalyptus kuva	6					21.71
Eucalyptus kuvb	6					21.90
Sig.		0.055	0.143	0.496	0.124	0.757

Table 7 shows the average changes in brightness (ΔL) for each veneer, as well as their Duncan test results.

Table 7. Brightness-related (ΔL) averages and Duncan test results

Wood type and sub-variation	N	ΔL					
		A	B	C	D	E	F
Eucalyptus duva	6	-0.77					
Eucalyptus duvb	6	-0.45					
Castanea duva	6	1.51	1.51				
Scots pine duvb	6		2.20				
Castenae duvb	6		3.48	3.48			
Scots pine duva	6		3.64	3.64			
Eucalyptus kuvb	6			5.02	5.02		
Eucalyptus kuva	6			5.72	5.72		
Castenae kuvb	6				6.99	6.99	
Scots pine kuvb	6					8.23	8.23
Scots pine kuva	6						9.38
Castenae kuva	6						10.11
Sig.		0.058	0.089	0.073	0.103	0.275	0.120

Table 8. Average changes in red-green coloring (Δa) and Duncan test results

Wood type and sub-variation	N	Δa								
		A	B	C	D	E	F	G	H	I
Scots pine kuva	6	-8.49								
Castenae kuva	6		-7.70							
Scots pine kuvb	6		-7.05							
Castenae kuvb	6			-5.76						
Eucalyptus kuva	6				-5.04					
Eucalyptus kuvb	6					-4.26				
Scots pine duva	6						-3.16			
Scots pine duvb	6							-2.01		
Castenae duvb	6							-1.37	-1.37	
Castanea duva	6								-0.90	
Eucalyptus duvb	6									-0.05
Eucalyptus duva	6									0.06
Sig.		1.000	0.063	1.000	1.000	1.000	1.000	0.067	0.184	0.726

Table 8. Average changes in yellow-blue coloring (Δa) and Duncan test results

Wood type and sub-variation	N	Δb						
		2	3	4	5	6	7	1
Eucalyptus kuvb	6	-21.90						
Eucalyptus kuva	6	-21.71						
Castenae kuvb	6		-14.50					
Castenae kuva	6		-13.52	-13.52				
Scots pine kuvb	6			-13.09	-13.09			
Scots pine kuva	6				-12.16			
Castanea duva	6					-1.87		
Scots pine duva	6					-1.48	-1.48	
Scots pine duvb	6					-0.85	-0.85	
Eucalyptus duva	6					-0.76	-0.76	
Eucalyptus duvb	6						-0.44	-0.44
Castenae duvb	6							0.67
Sig.		0.760	0.128	0.501	0.148	0.116	0.141	0.082

4. CONCLUSIONS

Both from the multiple variance analysis and from the Duncan test and averages, it can be observed that on all veneer types and under each UV type, the discoloration was less prominent on samples that had been coated with the color-protective barrier. A noticeable difference can be seen in the total discoloration of samples coated with only varnish, as opposed to varnish and protective barrier. Figure 4 presents the sampled panels before and after artificial weathering.

Figure 4. Eucalyptus, Castanae and Scots pine panels before and after weathering.

Modern technology has enabled the advent and frequent use of specialized varnishes which are resistant to UV rays. However, despite being successful in protecting themselves from UV rays, these varnishes are unable to protect the structural integrity of the wood onto which it is applied, resulting in discoloration.

As such, color-protective barriers – which have been demonstrated in this study to have significantly reduced discoloration on weathered wood – appear to be a new industrial option. This situation bears the utmost importance for relevant industries. For wooden furniture pieces where quality and aesthetics are prioritized, color-protective barriers appear to minimize the threat of discoloration. This development also has serious implications for the longevity of wooden furniture used in outdoor settings.

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