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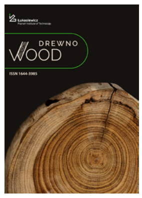

Comparison of Color Parameters in Layers of Yacht Varnish, Waxy Varnish, and Stone Varnish Applied to Various Wood Species

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In this study, solvent-based yacht varnish, stone varnish, and waxy varnish were applied in two coats using a brush, following industrial application standards, to the surfaces of the following tree species: black alder (Alnus glutinosa L. Gaertn.), curupay (Anadenanthera macrocarpa Benth.), iatandza (Albizia ferruginea), lemon (Citrus limon (L.) Burm.), loquat (Eriobotrya japonica L.), magnolia (Magnolia grandiflora L.), plane (Platanus orientalis L.), sucupira (Bowdichia nitida Benth.), and hornbeam (Carpinus betulus L.). Subsequently, the color parameters (b*, C*, L*, a*, ho, ΔE*, ΔH*, Δb*, ΔC*, Δa*, and ΔL*) of the varnish layers were compared with those of the untreated surfaces. The results of analysis of variance revealed significant differences in all color parameters. Decreases in L* values and increases in a* values were observed for all wood types when treated with three different varnishes. Additionally, in plane, black alder, and hornbeam wood, application of all varnishes resulted in increases in b* and C* values, with decreases in ho values. In sucupira wood, however, decreases were observed in b*, C*, and ho values with the application of all three varnishes. It was observed that a single type of varnish yielded different results on different wood types. This finding was attributed to the different types of resins present in the varnish types used in the study, which resulted in varying outcomes.

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Introduction

The long-term durability of furniture greatly depends on how its surfaces are treated. If left untreated or unsealed, surfaces deteriorate quickly in both appearance and functionality. Furniture is made from various types of wood, including veneer, solid wood, plywood, and chipboard. Solid wood and veneer, sourced from different tree species, possess distinct characteristics influenced by their resin and volatile oil content. It is essential to lower the natural moisture content of freshly cut wood to a maximum of 10–15% before applying finishes [Freitag and Stoye 2008].

Typically, varnishes are removed using a cotton swab soaked in organic solvents, which have both mechanical and chemical effects. Removing an old, oxidized varnish necessitates highly polar solvents, which may pose risks to the substrate: swelling and expanding paint layers can induce mechanical stress, potentially causing damage, while soluble components may be extracted from the paint layers [Stolow 1985].

The deterioration of wood caused by weather conditions is a complex process involving multiple factors. Reactions triggered or accelerated by light can lead to various changes, such as shifts in color, loss

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of glossiness, and alterations in surface texture. These transformations commonly occur following exposure to artificial UV rays or extended periods of sunlight [Teacă et al. 2013].

Finishes serve various purposes, including protection, enhancing appearance, cost-effectiveness, and maintaining cleanliness. In the manufacture of furniture and construction elements, finishing materials are classified as liquids, solids, and other types of coatings [Kurtoğlu 2000].

A quality varnish should be gentle and pliable, dry rapidly, and produce a glossy, lustrous film once set. It should resist shrinking or cracking post-drying and effectively adapt to the expansion and contraction of the underlying material, particularly wood, under varying temperatures. Typically applied with a brush, varnishes' application characteristics are heavily influenced by viscosity. High viscosity can impede application by causing brush resistance, whereas low viscosity may lead to dripping on vertical surfaces and excessively thin coating [Morgans 2000].

In the literature, it is observed that various types of varnishes are applied to different tree species. Examples include messassa wood for water-based and polyurethane varnishes [Bila et al. 2020], jebio for water-based marine varnish [Naide et al. 2022], ayous for polyherbal varnish [Bessike et al. 2022], black alder for UV varnish [Salca et al. 2016], beech and spruce for single-component polyurethane and colorless two-component polyurethane furniture varnish with an acrylic resin base with UV [Bomba et al. 2017], black locust for solvent-based yacht varnish [Ayata et al. 2024], Swedish pine for stone varnish, yacht varnish, and solvent-based wood varnish [Ayata and Bal 2024], maple wood for oil- and alcoholic-based varnishes [Gall et al. 2023], and European ash, European larch, white oak, maple, paulownia, and walnut for water-soluble varnish [Mitan et al. 2019].

Various surface tests are conducted on varnish layers, including adhesion resistance, thermal conductivity, yellowness index, blackness index, glossiness, color, Taber abrasion resistance, whiteness index, resistance to termites and fungi, natural or artificial aging, scratch resistance, pencil hardness, surface roughness, pendulum hardness, and others.

In the literature, it has been observed that yacht varnish, solvent-based stone varnish, and waxy varnish are not applied to plane, black alder, iatandza, lemon, curupay, magnolia, loquat, sucupira, and hornbeam wood. We shall briefly describe the areas of usage of these tree species.

Lemon wood is used in the production of toys, small spoons, archery bows, shuttles, chess pieces, fishing rods, turning work, tool handles, gathering sticks, and other textile manufacturing products [Chudnoff 1979; Morton 1987]. Black alder is used in the production of matchsticks and pencils, cigar and cigarette cases, packaging in the coating industry, and in construction lumber. It is also utilized in the American furniture industry for dining room, bedroom, and kitchen sets [Gürsu 1967; Eyüboğlu et al. 1983]. Black alder is commonly used in plywood manufacturing and accepts paint and polish well. In Europe and America, it is used extensively in solid furniture production [Dinçel et al. 1970]. Typically, it is sold in lumber form and can provide timber of standard dimensions suitable for hardwood applications [Şanıvar and Zorlu 1980]. Loquat wood is not commonly used in woodworking or carpentry [Orwa et al. 2009]. Plane is used in woodturning and furniture making. Hornbeam wood is used for joinery works, structural timber, dock piles and posts, bentwood furniture, fence and fence posts, tool handles, barrel staves, and basket making [Hammond et al. 1969]. Magnolia lumber is used primarily in the manufacture of boxes, blinds, doors, windows, plywood, furniture, and carpentry products [Anonymous 1955]. Sucupira wood is used in furniture making, woodturning, and boat building. It is very heavy for plywood production, but selected logs are used for inlay work in furniture, doors, and panels, and sliced for decorative veneers [Lincoln 1986]. Iatandza wood finds application in construction, cabinet making, glued laminated timber, intricate carvings, light and heavy flooring, joinery, furniture crafting, staircases, woodturning, and veneer production [Grubben 2008].

In this study, yacht varnish, solvent-based stone varnish, and waxy varnish were applied in two coats using a brush, following industrial application standards, to the surfaces of the following tree species: black alder, iatandza, lemon, plane, curupay, loquat, magnolia, sucupira, and hornbeam. Afterwards, the color parameters of the varnished surfaces were compared with those of the untreated surfaces. It is observed that the selected surface protective chemicals have not previously been applied to these wood species, according to the literature. These chemicals were chosen to determine the potential results if applied.

Materials and methods

In this study, the selected wood species included black alder (*Alnus glutinosa* L. Gaertn.), curupay (*Anadenanthera macrocarpa* Benth.), iatandza (*Albizia ferruginea*), lemon (*Citrus limon* (L.) Burm.), loquat (*Eriobotrya japonica* L.), magnolia (*Magnolia grandiflora* L.), plane (*Platanus orientalis* L.), sucupira (*Bowdichia nitida* Benth.), and hornbeam (*Carpinus* *betulus* L.). The test specimens were cut to dimensions of 100 mm x 100 mm x 20 mm. The wood used in the study was purchased in ready-made sizes specified by a special timber supplier. Following this, they were conditioned at a temperature of 20±2 °C and a relative humidity of 65%, in compliance with ISO 554 [1976]. This treatment was conducted in a computer-controlled environment.

In the study, three different types of varnish were used, acquired from a specialized company.

1. A solvent-based yacht varnish, known for its high hardness and excellent resistance to water (solid content 50%, containing alkyd resin at 60–70%, density 0.87–0.92 g/ml, applied in two coats, coverage: 14–16 m^2/lt).
2. A waxy varnish, formulated for interior and exterior wood coatings, consisting of a mixture of natural oils, waxes, and resins (transparent, density 0.87 g/cm^3, first coat drying time 6–8 h, full drying time 24–48 h, applied in two coats, coverage: 16–20 m^2/lt).
3. Stone varnish (applied in two coats, matte–glossy, solvent-based, acrylic resin-based, transparent, density 0.95 g/cm^3, touch dry 6–8 h, full hardening in at least 24 h, viscosity 24 seconds, solid content 27%, 200–250 g/m^2).

Sandpapers were purchased from a hardware store belonging to a local vendor. In the study, the test samples were sanded with 80, 120, and 180 grit sandpapers and cleaned using a compressor. Each coat was allowed to dry for 24 h between applications. All varnishes were applied to wooden surfaces using a brush, following industrial application standards. The application of varnishes on wood materials was performed following designated procedures. The varnishing process conformed to the standards outlined in ASTM-D 3023 [2017].

Color changes in the samples were evaluated using a CS-10 device (CHN Spec, China) with the CIE 10° standard observer and CIE D65 light source, utilizing an 8/d (8°/diffuse illumination) setup following the ASTM D 2244-3 [2007] standard. Analysis was performed using the CIELAB color system, and the quantification of total color variations was calculated using formulas detailed in Ayata et al. [2021a,b].

The criteria used for assessing overall color alterations were as follows [Barcík et al. 2015]: $\Delta E^* > 12$ (different color); $6 < \Delta E^* < 12$ (high color changes); $3 < \Delta E^* < 6$ (color change visible with medium-quality filter); $2 < \Delta E^* < 3$ (color change visible with high-quality filter); $0.2 < \Delta E^* < 2$ (small difference); $0.2 < \Delta E^*$ (invisible difference).

The results obtained after varnish application were based on the following values:

$$h^o = \arctan [b^*/a^*] \quad (1)$$

$$C^* = [(a^*)^2 + (b^*)^2]^{1/2} \quad (2)$$

$$\Delta C^* = [C^*_{\text{sample with varnish application}}] - [C^*_{\text{sample without varnish application}}] \quad (3)$$

$$\Delta L^* = [L^*_{\text{sample with varnish application}}] - [L^*_{\text{sample without varnish application}}] \quad (4)$$

$$\Delta a^* = [a^*_{\text{sample with varnish application}}] - [a^*_{\text{sample without varnish application}}] \quad (5)$$

$$\Delta b^* = [b^*_{\text{sample with varnish application}}] - [b^*_{\text{sample without varnish application}}] \quad (6)$$

$$\Delta H^* = [(\Delta E^*)^2 - (\Delta L^*)^2 - (\Delta C^*)^2]^{0.5} \quad (7)$$

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \quad (8)$$

where;
Δb^*: positive value indicates that the sample is more yellow than the reference, while a negative value indicates that the sample is more blue than the reference;
ΔL^*: positive value indicates that the sample is lighter than the reference, while a negative value indicates that the sample is darker than the reference;
ΔH^*: represents the hue difference or shade variation;
Δa^*: positive value indicates that the sample is redder than the reference, while a negative value indicates that the sample is greener than the reference;
ΔC^*: represents the chroma difference or saturation variation – a positive value indicates that the sample is more vivid and brighter than the reference, while a egative value indicates that the sample is duller and less clear than the reference [Lange 1999].

The data collected before and after varnish application were utilized to compute percentage (%) changes, standard deviations, homogeneity groups (denoted by letters), and minimum and maximum values. They were analyzed using one-way analysis of variance in SPSS software.

Results and discussion

Table 1 displays the results of the variance analysis for color parameters. These findings indicate that wood type (A), varnish type (B), and their interaction (AB) had a significant impact on chroma (C^*), lightness (L^*), hue (h^o), red (a^*), and yellow (b^*) color tone values (Table 1).

All measured results for the L^* parameter are provided in Table 2. According to these results, the application of all types of varnish on all types of wood resulted in decreases compared to the control samples. This means that the highest values are observed in the control samples for each wood species. The smallest percentage decreases were observed in lemon wood (0.81% for stone varnish, 0.69% for yacht varnish, and 3.66% for waxy varnish). The largest decreases were found in iatandza wood (27.56% for stone varnish, 26.90% for yacht varnish, and 27.30% for waxy varnish) (Table 2).

The results for different varnishes applied to iatandza wood were very close to each other. On black

Table 1. Results of analysis of variance for L^* parameter

Source	Test	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Sig.
Wood Type (A)	Lightness (L^*)	53067.820	8	6633.478	10781.335	0.000*
	Red (a^*) color	10519.143	8	1314.893	6593.240	0.000*
	Yellow (b^*) color	8616.066	8	1077.008	3867.405	0.000*
	Chroma (C^*)	7512.741	8	939.093	3221.321	0.000*
	Hue (h^o) tone	60129.326	8	7516.166	9070.677	0.000*
Varnish Type (B)	Lightness (L^*)	4500.058	3	1500.019	2437.969	0.000*
	Red (a^*) color	1120.551	3	373.517	1872.919	0.000*
	Yellow (b^*) color	686.120	3	228.707	821.258	0.000*
	Chroma (C^*)	1688.328	3	562.776	1930.461	0.000*
	Hue (h^o) tone	3164.252	3	1054.751	1272.897	0.000*
Interaction (AB)	Lightness (L^*)	1430.807	24	59.617	96.895	0.000*
	Red (a^*) color	354.434	24	14.768	74.051	0.000*
	Yellow (b^*) color	1477.960	24	61.582	221.132	0.000*
	Chroma (C^*)	1165.266	24	48.553	166.548	0.000*
	Hue (h^o) tone	2522.904	24	105.121	126.862	0.000*
Error	Lightness (L^*)	199.349	324	0.615		
	Red (a^*) color	64.615	324	0.199		
	Yellow (b^*) color	90.229	324	0.278		
	Chroma (C^*)	94.454	324	0.292		
	Hue (h^o) tone	268.474	324	0.829		
Total	Lightness (L^*)	1199707.744	360			
	Red (a^*) color	63749.332	360			
	Yellow (b^*) color	170042.241	360			
	Chroma (C^*)	233771.471	360			
	Hue (h^o) tone	1361408.245	360			
Corrected Total	Lightness (L^*)	59198.034	359			
	Red (a^*) color	12058.744	359			
	Yellow (b^*) color	10870.375	359			
	Chroma (C^*)	10460.788	359			
	Hue (h^o) tone	66084.956	359			

*: Significant

alder, hornbeam, and lemon wood, the greatest reductions were achieved with the application of waxy varnish (14.09%, 14.20%, and 3.66%, respectively). On plane wood, the same reduction rates were achieved with stone varnish and waxy varnish (13.36%). It is observed that the three different types of varnish produce varying results in terms of L^* values across the nine types of wood (Table 2).

In the study conducted by Ayata and Bal [2024], decreases in the L^* parameter were observed after applying solvent-based acrylic resin varnish, solvent-based yacht varnish, and solvent-based wood varnish (4.45%, 2.01%, and 6.13%, respectively) to lodgepole pine wood. In the study by Çamlıbel and Ayata [2024], it was reported that after applying solvent-based acrylic resin matte varnish to berangan, keranji, niové, rubber, and keruing woods, a decrease in L^* values was observed.

Table 3 contains all measured results for the a^* parameter. Increases in a^* values were observed for all

Table 2. Measurement results for *L** parameter

Wood Type	Varnish Type	N	Mean	Change (%)	*HG*	*SD*	Minimum	Maximum	COV
Black alder	Control	10	68.65	-	CD	0.69	67.72	70.08	1.00
	Stone	10	60.79	↓11.45	G	0.84	59.16	61.81	1.39
	Yacht	10	60.96	↓11.20	G	1.40	59.45	63.19	2.29
	Waxy	10	58.98	↓14.09	HI	1.18	57.86	61.05	1.99
Curupay	Control	10	51.08	-	M	0.90	48.96	51.98	1.77
	Stone	10	39.36	↓22.94	R	0.72	38.13	40.18	1.83
	Yacht	10	45.67	↓10.59	O	1.52	43.57	47.72	3.34
	Waxy	10	43.14	↓15.54	P	2.04	40.60	45.55	4.72
Hornbeam	Control	10	69.23	-	C	0.27	68.86	69.55	0.39
	Stone	10	63.49	↓8.29	F	0.37	62.55	63.90	0.59
	Yacht	10	63.23	↓8.67	F	0.51	62.42	63.89	0.80
	Waxy	10	59.40	↓14.20	H	0.24	58.97	59.79	0.40
Iatandza	Control	10	54.54	-	K	1.11	53.10	55.86	2.04
	Stone	10	39.51	↓27.56	R	1.32	37.50	41.81	3.34
	Yacht	10	39.87	↓26.90	R	0.99	38.00	41.14	2.49
	Waxy	10	39.65	↓27.30	R	0.27	39.22	40.10	0.68
Lemon	Control	10	76.87	-	A*	0.36	76.48	77.69	0.46
	Stone	10	76.25	↓0.81	A	0.32	75.91	76.70	0.42
	Yacht	10	76.34	↓0.69	A	0.29	75.75	76.66	0.38
	Waxy	10	74.06	↓3.66	B	0.44	73.51	74.68	0.59
Loquat	Control	10	57.41	-	J	0.29	56.86	57.66	0.51
	Stone	10	50.48	↓12.07	M	1.07	48.77	52.36	2.12
	Yacht	10	47.64	↓17.02	N	0.30	46.84	47.88	0.63
	Waxy	10	52.89	↓7.87	L	1.14	51.25	54.70	2.16
Magnolia	Control	10	64.51	-	E	0.41	63.74	64.87	0.64
	Stone	10	58.60	↓9.16	I	0.18	58.46	59.09	0.31
	Yacht	10	58.96	↓8.60	HI	0.45	58.58	60.10	0.77
	Waxy	10	59.38	↓7.95	H	0.86	57.69	60.11	1.46
Plane	Control	10	73.75	-	B	0.27	73.36	74.33	0.37
	Stone	10	63.90	↓13.36	EF	0.31	63.41	64.46	0.48
	Yacht	10	68.04	↓7.74	D	0.35	67.54	68.54	0.52
	Waxy	10	63.90	↓13.36	EF	0.25	63.59	64.27	0.40
Sucupira	Control	10	45.01	-	O	0.37	44.48	45.79	0.81
	Stone	10	31.62	↓29.75	U**	0.30	31.29	32.10	0.94
	Yacht	10	35.57	↓20.97	S	0.59	34.73	36.50	1.64
	Waxy	10	33.59	↓25.37	T	0.24	33.21	33.95	0.70

N: Number of Measurements, *SD*: Standard Deviation, *HG*: Homogeneity Group, COV: Coefficient of Variation, *: Lowest Value, **: Highest Value

Table 3. Measurement results for *a** parameter

Wood Type	Varnish Type	N	Mean	Change (%)	*HG*	*SD*	Minimum	Maximum	COV
Black alder	Control	10	9.14	-	O	0.36	8.39	9.68	3.94
	Stone	10	12.92	↑41.36	H	0.60	12.16	14.11	4.67
	Yacht	10	13.16	↑43.98	H	0.31	12.58	13.65	2.39
	Waxy	10	15.53	↑69.91	E	0.19	15.23	15.81	1.23
Curupay	Control	10	20.76	-	C	0.53	20.03	21.55	2.55
	Stone	10	27.54	↑32.66	A*	0.47	26.80	28.06	1.70
	Yacht	10	25.99	↑25.19	B	1.43	24.20	27.55	5.50
	Waxy	10	26.28	↑26.59	B	0.62	25.22	27.10	2.36
Hornbeam	Control	10	7.00	-	R	0.20	6.52	7.29	2.90
	Stone	10	10.61	↑51.57	M	0.22	10.37	11.16	2.11
	Yacht	10	9.01	↑28.71	O	0.29	8.62	9.50	3.16
	Waxy	10	10.61	↑51.57	M	0.14	10.39	10.84	1.27
Iatandza	Control	10	10.28	-	M	0.15	10.04	10.57	1.50
	Stone	10	16.44	↑59.92	D	0.70	15.49	17.41	4.23
	Yacht	10	15.51	↑50.88	E	0.33	15.18	16.05	2.13
	Waxy	10	16.59	↑61.38	D	0.78	14.87	17.29	4.69
Lemon	Control	10	5.29	-	U	0.25	4.79	5.76	4.71
	Stone	10	6.90	↑30.43	R	0.29	6.52	7.23	4.16
	Yacht	10	5.98	↑13.04	ST	0.11	5.82	6.12	1.79
	Waxy	10	8.38	↑58.41	P	0.36	7.95	8.84	4.30
Loquat	Control	10	7.75	-	Q	0.19	7.34	8.02	2.51
	Stone	10	12.78	↑64.90	HI	0.21	12.51	13.22	1.65
	Yacht	10	14.35	↑85.16	F	0.29	14.08	15.05	2.04
	Waxy	10	13.55	↑74.84	G	0.39	13.06	14.19	2.85
Magnolia	Control	10	4.61	-	V**	0.34	4.04	5.10	7.45
	Stone	10	5.64	↑22.34	TU	0.30	5.18	6.11	5.37
	Yacht	10	5.53	↑19.96	U	0.41	4.57	5.86	7.38
	Waxy	10	5.67	↑22.99	TU	0.33	5.12	6.12	5.77
Plane	Control	10	6.28	-	S	0.15	6.04	6.56	2.43
	Stone	10	12.01	↑91.24	J	0.21	11.54	12.35	1.77
	Yacht	10	11.64	↑85.35	JK	0.22	11.22	11.88	1.85
	Waxy	10	12.96	↑106.37	H	0.15	12.57	13.11	1.12
Sucupira	Control	10	9.63	-	N	0.41	8.68	10.14	4.31
	Stone	10	11.22	↑16.51	L	0.20	10.91	11.66	1.82
	Yacht	10	12.44	↑29.18	I	0.74	11.33	13.36	5.92
	Waxy	10	11.41	↑18.48	KL	0.48	10.46	12.16	4.22

N: Number of Measurements, *SD*: Standard Deviation, *HG*: Homogeneity Group,
COV: Coefficient of Variation, *: Lowest Value, **: Highest Value

types of varnishes on all types of wood. Hence, the lowest values were obtained for the control samples for each wood species (9.14 for black alder, 20.76 for curupay, 7.00 for hornbeam, 10.28 for iatandza, 5.29 for lemon, 7.75 for loquat, 4.61 for magnolia, 6.28 for plane, and 9.63 for sucupira). The greatest increase in the *a** parameter was achieved with plane wood (91.24% for stone varnish, 85.35% for yacht varnish, and 106.37% for waxy varnish).

In Ayata and Bal's [2024] research, it was noted that applying solvent-based acrylic resin varnish, solvent-based yacht varnish, and solvent-based wood varnish to lodgepole pine wood resulted in increases in the *a** parameter by 18.26%, 16.67%, and 47.39%, respectively. According to Çamlıbel and Ayata [2024], application of solvent-based acrylic resin matte varnish on keranji, niové, rubber, keruing, and berangan woods resulted in increases in *a** values.

The *b** parameter measurements for all samples are listed in Table 4. For this parameter, increases were observed with all three types of varnish used in the study on the wood species black alder, hornbeam, lemon, loquat, magnolia, and plane. Conversely, decreases were recorded on iatandza and sucupira wood. For curupay wood, a decrease was observed with stone varnish (2.43%), whereas increases were obtained for yacht varnish and waxy varnish (respectively 9.82% and 2.64%) (Table 4).

The lowest *b** values were found in the control samples for the wood species hornbeam (18.57), black alder (21.90), magnolia (22.10), lemon (22.77), loquat (16.21), and plane (14.58). Sucupira (13.93) and iatandza (20.62) wood species exhibited the opposite trend, with the highest *b** values found in the control samples. The highest *b** values for the wood species plane (24.62), loquat (20.31), lemon (30.96), and hornbeam (24.29) were obtained in the experimental samples coated with waxy varnish (Table 4).

In Ayata and Bal's [2024] study, it was observed that applying solvent-based acrylic resin varnish, solvent-based yacht varnish, and solvent-based wood varnish to lodgepole pine wood led to increases in the *b** parameter by 21.06%, 16.45%, and 28.29%, respectively, following the application of all varnish types to the wood.

Çamlıbel and Ayata [2024] noted that after applying solvent-based acrylic resin matte varnish, increases in *b** values were observed in niové, berangan, keruing, and keranji woods, while decreases were reported in rubber wood.

All measurements pertaining to the *C** parameter can be found in Table 5. The results reveal decreases in the *C** parameter for sucupira wood, and increases for all other wood types. Plane wood exhibited the highest percentage increases (51.83% with stone varnish, 64.04% with yacht varnish, and 75.19% with waxy varnish). The largest individual value recorded was 33.78 for waxy varnish applied to black alder wood. The outcomes for the three different varnishes applied to curupay wood were found to be very similar (Table 5).

The lowest value observed was 14.33 for stone varnish applied to sucupira wood. Except for sucupira, all unvarnished control samples had lower values than their varnished counterparts. This indicates that the application of varnish led to increased *C** values in all wood types except sucupira. The smallest increases were obtained in the case of iatandza wood (9.33% for stone varnish, 7.03% for yacht varnish, and 5.56% for waxy varnish) (Table 5).

Ayata and Bal [2024] observed increases in *C** values (20.77%, 16.24%, and 29.97%) after applying solvent-based acrylic resin varnish, yacht varnish, and solvent-based wood varnish to lodgepole pine wood. The study by Çamlıbel and Ayata [2024] indicated that after applying solvent-based acrylic resin matte varnish to niové, rubber, keranji, keruing, and berangan woods, increases in *C** values were obtained.

Table 6 lists the results obtained for the *h°* parameter. Values of *h°* decreased after application of the varnishes for all wood types except magnolia and lemon. The lowest *h°* value (33.94) was obtained for curupay wood treated with stone varnish, and the highest (78.27) for magnolia wood treated with yacht varnish. Lemon and magnolia woods showed slight increases of 0.05% and 0.06%, respectively, when yacht varnish was applied. The unvarnished samples of black alder, curupay, hornbeam, iatandza, loquat, plane, and sucupira woods had the highest *h°* values. Among the varnished samples, the greatest reductions were observed in sucupira wood (31.02% with stone varnish, 24.26% with yacht varnish, and 31.50% with waxy varnish) (Table 6).

In Ayata and Bal's [2024] study, the application of a solvent-based acrylic resin varnish to lodgepole pine wood led to a 0.52% increase in the *h°* value, while yacht varnish produced a decrease of 0.05%, and solvent-based wood varnish a decrease of 3.21%. According to Çamlıbel and Ayata [2024], decreases in *h°* values were observed after applying solvent-based acrylic resin matte varnish to rubber, niové, keruing, keranji, and berangan woods.

The results for total color differences are presented in Table 7. The ΔE^* values, ordered from smallest to largest, are as follows: 3.18 for yacht varnish on lemon, 6.00 for stone varnish on magnolia, 6.09 for waxy varnish on magnolia, 6.75 for stone varnish on lemon, 7.24 for yacht varnish on magnolia, 7.72 for yacht varnish on hornbeam, 7.75 for yacht varnish on curupay, 8.42 for waxy varnish on loquat, 8.57 for stone varnish on hornbeam, 8.58 for stone varnish on loquat, 9.20 for waxy varnish on lemon, 9.69 for waxy varnish on

Table 4. Measurement results for *b** parameter

Wood Type	Varnish Type	N	Mean	Change (%)	*HG*	*SD*	Mini-mum	Maxi-mum	COV
Black alder	Control	10	21.90	-	K	0.48	21.32	22.58	2.20
	Stone	10	28.07	↑28.17	D	0.78	26.90	29.34	2.80
	Yacht	10	30.44	↑39.00	B	0.22	30.15	30.73	0.71
	Waxy	10	30.00	↑36.99	B	0.51	29.31	30.65	1.70
Curupay	Control	10	18.95	-	NO	0.44	18.19	19.63	2.34
	Stone	10	18.49	↓2.43	OP	0.48	17.67	19.05	2.59
	Yacht	10	20.81	↑9.82	L	0.45	20.05	21.67	2.16
	Waxy	10	19.45	↑2.64	N	1.28	17.59	20.85	6.58
Hornbeam	Control	10	18.57	-	O	0.26	18.16	18.93	1.42
	Stone	10	23.81	↑28.22	I	0.21	23.39	24.13	0.87
	Yacht	10	23.00	↑23.86	J	0.23	22.69	23.45	0.99
	Waxy	10	24.29	↑30.80	H	0.15	24.10	24.58	0.60
Iatandza	Control	10	20.62	-	LM	0.25	20.30	21.00	1.23
	Stone	10	19.08	↓7.47	N	1.13	17.11	20.92	5.90
	Yacht	10	19.41	↓5.87	N	1.03	17.41	20.75	5.29
	Waxy	10	17.51	↓15.08	Q	0.35	17.06	18.01	2.00
Lemon	Control	10	22.77	-	J	0.51	21.78	23.63	2.23
	Stone	10	29.29	↑28.63	C	0.27	28.72	29.65	0.92
	Yacht	10	25.83	↑13.44	F	0.30	25.50	26.35	1.17
	Waxy	10	30.96	↑35.97	A*	0.53	30.13	31.55	1.72
Loquat	Control	10	16.21	-	S	0.19	15.96	16.46	1.15
	Stone	10	16.78	↑3.52	R	0.35	16.28	17.38	2.07
	Yacht	10	18.04	↑11.29	P	0.15	17.80	18.28	0.81
	Waxy	10	20.31	↑25.29	M	0.85	18.74	21.27	4.18
Magnolia	Control	10	22.10	-	K	0.55	21.22	22.70	2.49
	Stone	10	22.30	↑0.90	K	0.72	21.26	23.55	3.24
	Yacht	10	26.65	↑20.59	E	0.40	25.92	27.20	1.51
	Waxy	10	25.20	↑14.03	G	0.73	23.69	26.43	2.89
Plane	Control	10	14.58	-	T	0.21	14.19	14.88	1.43
	Stone	10	20.91	↑43.42	L	0.15	20.68	21.17	0.72
	Yacht	10	23.21	↑59.19	J	0.49	22.46	23.80	2.13
	Waxy	10	24.62	↑68.86	H	0.15	24.38	24.85	0.62
Sucupira	Control	10	13.93	-	U	0.21	13.68	14.31	1.53
	Stone	10	8.86	↓36.40	W**	0.35	8.59	9.62	3.91
	Yacht	10	11.16	↓19.89	V	0.43	10.40	11.72	3.86
	Waxy	10	8.88	↓36.25	W	0.33	8.29	9.25	3.66

N: Number of Measurements, *SD*: Standard Deviation, *HG*: Homogeneity Group, COV: Coefficient of Variation, *: Lowest Value, **: Highest Value

Table 5. Measurement results for *C** parameter

Wood Type	Varnish Type	N	Mean	Change (%)	*HG*	*SD*	Minimum	Maximum	COV
Black alder	Control	10	23.73	-	NO	0.50	23.01	24.42	2.11
	Stone	10	30.91	↑30.26	E	0.96	29.52	32.56	3.11
	Yacht	10	33.16	↑39.74	BC	0.29	32.81	33.57	0.87
	Waxy	10	33.78	↑42.35	A*	0.43	33.20	34.28	1.28
Curupay	Control	10	28.12	-	G	0.60	27.38	29.06	2.14
	Stone	10	33.20	↑18.07	BC	0.35	32.55	33.56	1.04
	Yacht	10	33.30	↑18.42	B	1.07	31.81	34.56	3.20
	Waxy	10	32.72	↑16.36	C	0.55	31.89	33.29	1.67
Hornbeam	Control	10	19.84	-	S	0.30	19.30	20.23	1.53
	Stone	10	26.07	↑31.40	IJ	0.15	25.81	26.30	0.56
	Yacht	10	24.70	↑24.50	L	0.19	24.37	25.06	0.76
	Waxy	10	26.50	↑33.57	I	0.15	26.30	26.80	0.57
Iatandza	Control	10	23.04	-	PQ	0.24	22.72	23.35	1.04
	Stone	10	25.19	↑9.33	K	0.98	23.68	26.29	3.87
	Yacht	10	24.66	↑7.03	L	1.00	23.14	26.09	4.05
	Waxy	10	24.32	↑5.56	LM	0.40	23.97	25.36	1.66
Lemon	Control	10	23.37	-	OP	0.54	22.31	24.33	2.32
	Stone	10	30.10	↑28.80	F	0.28	29.62	30.51	0.91
	Yacht	10	26.52	↑13.48	I	0.31	26.21	27.06	1.15
	Waxy	10	32.08	↑37.27	D	0.59	31.17	32.72	1.85
Loquat	Control	10	17.97	-	T	0.20	17.67	18.29	1.12
	Stone	10	21.09	↑17.36	R	0.37	20.71	21.84	1.75
	Yacht	10	23.06	↑28.32	PQ	0.24	22.90	23.68	1.04
	Waxy	10	24.42	↑35.89	LM	0.86	22.84	25.33	3.52
Magnolia	Control	10	22.58	-	Q	0.60	21.60	23.27	2.67
	Stone	10	23.00	↑1.86	PQ	0.77	21.94	24.33	3.33
	Yacht	10	27.22	↑20.55	H	0.46	26.32	27.82	1.70
	Waxy	10	25.65	↑13.60	JK	0.65	24.24	26.42	2.53
Plane	Control	10	15.88	-	V	0.21	15.48	16.18	1.30
	Stone	10	24.11	↑51.83	MN	0.18	23.75	24.33	0.76
	Yacht	10	26.05	↑64.04	IJ	0.51	25.34	26.94	1.94
	Waxy	10	27.82	↑75.19	G	0.17	27.44	28.03	0.61
Sucupira	Control	10	16.94	-	U	0.23	16.62	17.22	1.38
	Stone	10	14.33	↓15.41	W**	0.29	13.90	14.78	2.02
	Yacht	10	16.71	↓1.36	U	0.80	15.69	17.72	4.77
	Waxy	10	14.46	↓14.64	W	0.53	13.35	15.12	3.68

N: Number of Measurements, *SD*: Standard Deviation, *HG*: Homogeneity Group,
COV: Coefficient of Variation, *: Lowest Value, **: Highest Value

Table 6. Measurement results for h^o parameter

Wood Type	Varnish Type	N	Mean	Change (%)	*HG*	*SD*	Minimum	Maximum	COV
Black alder	Control	10	67.34	-	F	0.81	66.00	68.62	1.20
	Stone	10	65.29	↓3.04	H	0.43	64.31	65.67	0.67
	Yacht	10	66.63	↓1.05	FG	0.43	66.00	67.45	0.64
	Waxy	10	62.63	↓6.99	KL	0.56	61.92	63.51	0.90
Curupay	Control	10	42.40	-	T	0.70	40.67	43.25	1.64
	Stone	10	33.94	↓19.95	W*	1.11	32.45	35.82	3.27
	Yacht	10	38.75	↓8.61	U	1.88	36.04	40.88	4.86
	Waxy	10	36.48	↓13.96	V	2.31	33.23	39.35	6.33
Hornbeam	Control	10	69.34	-	E	0.39	68.69	70.24	0.56
	Stone	10	65.97	↓4.86	GH	0.59	64.48	66.57	0.90
	Yacht	10	68.60	↓1.07	E	0.73	67.52	69.67	1.06
	Waxy	10	66.40	↓4.24	G	0.29	65.96	66.90	0.43
Iatandza	Control	10	63.50	-	J	0.44	62.66	64.15	0.69
	Stone	10	49.17	↓22.57	R	1.95	46.26	52.25	3.96
	Yacht	10	51.33	↓19.17	Q	1.14	48.80	52.71	2.23
	Waxy	10	46.08	↓27.43	S	1.32	44.80	48.65	2.87
Lemon	Control	10	76.93	-	B	0.35	76.31	77.59	0.45
	Stone	10	76.74	↓0.25	B	0.53	75.88	77.41	0.69
	Yacht	10	76.97	↑0.05	B	0.19	76.58	77.20	0.24
	Waxy	10	74.86	↓2.69	D	0.43	74.32	75.36	0.57
Loquat	Control	10	64.44	-	I	0.57	63.98	65.90	0.89
	Stone	10	52.69	↓18.23	P	0.46	51.86	53.34	0.87
	Yacht	10	51.50	↓20.08	Q	0.54	50.54	52.28	1.05
	Waxy	10	56.27	↓12.68	N	0.86	55.12	58.05	1.53
Magnolia	Control	10	78.22	-	A	0.60	77.33	79.20	0.77
	Stone	10	75.82	↓3.07	C	0.40	75.07	76.40	0.52
	Yacht	10	78.27	↑0.06	A*	0.72	77.63	79.98	0.91
	Waxy	10	77.23	↓1.27	B	0.48	76.53	78.00	0.62
Plane	Control	10	66.71	-	FG	0.56	65.70	67.51	0.83
	Stone	10	60.11	↓9.89	M	0.44	59.44	60.92	0.74
	Yacht	10	63.21	↓5.25	JK	0.70	62.40	64.23	1.11
	Waxy	10	62.24	↓6.70	L	0.26	61.83	62.72	0.42
Sucupira	Control	10	55.36	-	O	1.38	53.79	58.51	2.48
	Stone	10	38.19	↓31.02	U	1.14	37.01	40.60	2.99
	Yacht	10	41.93	↓24.26	T	1.05	40.52	43.77	2.50
	Waxy	10	37.92	↓31.50	U	0.96	36.45	39.17	2.54

N: Number of Measurements, *SD*: Standard Deviation, *HG*: Homogeneity Group,
COV: Coefficient of Variation, *: Lowest Value, **: Highest Value

Table 7. Results for total color differences

Wood Type	**Varnish Type**	ΔL^*	Δa^*	Δb^*	ΔC^*	ΔH^*	ΔE^*	**Comparisons for ΔE^* [Barcík et al. 2015]**
Lemon	Yacht	-0.53	0.69	3.06	3.15	-	3.18	quality filter
Magnolia	Stone	-5.91	1.03	0.20	0.43	0.95	6.00	
Magnolia	**Waxy**	-5.13	1.06	3.10	3.08	1.13	6.09	
Lemon	Stone	-0.62	1.61	6.53	6.73	-	6.75	
Magnolia	Yacht	-5.55	0.92	4.56	4.65	-	7.24	
Hornbeam	Yacht	-6.00	2.01	4.43	4.86	0.22	7.72	
Curupay	Yacht	-5.42	5.23	1.86	4.18	3.65	7.75	
Loquat	**Waxy**	-4.52	5.80	4.10	6.46	2.97	8.42	
Hornbeam	Stone	-5.74	3.62	5.24	6.23	1.32	8.57	high color changes
Loquat	Stone	-6.93	5.03	0.57	3.12	3.99	8.58	
Lemon	**Waxy**	-2.82	3.09	8.19	8.71	0.90	9.20	
Curupay	**Waxy**	-7.95	5.52	0.49	4.60	3.09	9.69	
Sucupira	Yacht	-9.44	2.81	-2.77	-0.23	3.94	10.23	
Black alder	Stone	-7.86	3.78	6.17	7.17	0.97	10.69	
Plane	Yacht	-5.71	5.36	8.63	10.18	-	11.66	
Loquat	Yacht	-9.76	6.60	1.83	5.09	4.58	11.93	
Hornbeam	**Waxy**	-9.83	3.61	5.72	6.66	1.17	11.93	
Black alder	Yacht	-7.68	4.02	8.54	9.43	0.40	12.17	
Sucupira	**Waxy**	-11.43	1.78	-5.05	-2.48	4.74	12.62	
Plane	Stone	-9.85	5.74	6.32	8.24	2.24	13.04	
Curupay	Stone	-11.73	6.78	-0.47	5.08	4.51	13.55	
Black alder	**Waxy**	-9.67	6.39	8.10	10.05	2.33	14.13	different color
Sucupira	Stone	-13.40	1.59	-5.07	-2.61	4.63	14.41	
Plane	**Waxy**	-9.86	6.68	10.03	11.94	1.63	15.57	
Iatandza	Yacht	-14.67	5.24	-1.21	1.62	5.13	15.62	
Iatandza	Stone	-15.02	6.16	-1.54	2.15	5.98	16.31	
Iatandza	**Waxy**	-14.89	6.31	-3.11	1.28	6.92	16.47	

curupay, 10.23 for yacht varnish on sucupira, 10.69 for stone varnish on black alder, 11.66 for yacht varnish on plane, 11.93 for yacht varnish on loquat, 11.93 for waxy varnish on hornbeam, 12.17 for yacht varnish on black alder, 12.62 for waxy varnish on sucupira, 13.04 for stone varnish on plane, 13.55 for stone varnish on curupay, 14.13 for waxy varnish on black alder, 14.41 for stone varnish on sucupira, 15.57 for waxy varnish on plane, 15.62 for yacht varnish on iatandza, 16.31 for stone varnish on iatandza, and 16.47 for waxy varnish on iatandza (Table 7).

Among the experimental samples coated with waxy varnish, sucupira, black alder, plane, and iatandza were assigned to the "different color" category ($\Delta E^*>12.00$) [Barcík et al. 2015]. Similarly, in the case of samples coated with stone varnish, iatandza, sucupira, plane, and curupay woods were placed in that category, while for the samples coated with yacht varnish, iatandza wood was assigned to the same category. Lemon wood treated with yacht varnish satisfied the criteria for the category "change visible with high-quality filter" ($2<\Delta E^*<3$). The "high color changes" ($6.00<\Delta E^*<12.00$) category [Barcík et al. 2015] included magnolia, hornbeam, lemon, curupay, and loquat woods coated with waxy varnish; magnolia, hornbeam, curupay, sucupira, plane, and loquat woods coated with yacht varnish; and lemon, black alder, loquat, and hornbeam woods coated with stone varnish (Table 7).

In the study by Ayata and Bal [2024] on lodgepole pine wood, reported total color differences (ΔE^*) were 5.93 with solvent-based acrylic resin varnish, 4.16 with yacht varnish, and 8.49 with transparent semi-covering varnish. In the study by Çamlıbel and Ayata [2024] of the effects of solvent-based acrylic resin matte varnish, the ΔE^* values were found to be 10.63 for keranji, 10.17 for niové, 13.70 for keruing, 14.70 for rubber, and 15.28 for berangan.

The structural attributes of varnish layers vary due to the specific ingredients used in the production of the varnishes. Differences in the types and amounts of primary binders and additional layer-forming agents are key factors responsible for creating this diversity [Sönmez 1989].

The components of the varnish may chemically interact with the different wood species used in the study, which might lead to differences in color shades. This particularly concerns the binders and pigments.

Conclusions

This study has yielded the following conclusions:
- It was observed that the type of varnish and the species of wood were influential factors in the differentiation of color parameters.
- It is believed that the reasons for the differences in the results lie in the structural properties of the varnishes. Furthermore, it is notable that each type of wood naturally exhibits distinct traits – density, pore structure, natural color, and texture – leading to varying degrees of absorption of varnish and unique interactions with its chemical components.

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