

Color and Glossiness Properties of Wood Material Surfaces Coated with Aloe Vera Doped Varnish

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Surface properties of wood materials were determined before and after coating with cellulosic varnish doped with aloe vera gel. For this purpose, samples were prepared from Anatolian black pine (*Pinus nigra* subsp. *pallasiana*), fir (*Abies nordmanniana* subsp. *bornmulleriana* Mattf.), Ayous (*Triplochiton scleroxylon* K. Schum), and Scotch pine (*Pinus sylvestris* L.) woods in accordance with TS 53 (1981) and TS ISO 3129 (2021) principles and then coated with cellulosic varnishes doped with 0%, 5%, 10% and 15% aloe vera (L.) gel according to ASTM D3023-98 (2017) principles. Color changes according to ASTM D2244-21 (2021) and surface glosses according to TS EN ISO 2813 (2014) were determined on varnished surfaces. As the percentage of aloe vera gel in the varnish increased, the red color tone, yellow color tone, total color change, glossiness perpendicular and parallel to the fibers, and difference values decreased. Aloe vera gel can be preferred as an additive in cellulosic varnish in applications where the objective is no change or minimal change in the color and glossiness values, depending on type of wood and area of use.

DOI: 10.15376/biores.20.3.6577-6598

Keywords: Aloe vera gel; Cellulosic varnish; Color change; Glossiness; Wood materials

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INTRODUCTION

Wood material has been preferred in interior and exterior decoration for centuries, as it contains various colors and textures. Natural organic, hygroscopic, anisotropic, and heterogeneous wood material fades due to the sun's rays and cannot withstand external effects for a long time. For this reason, wooden material surfaces are covered with varnishes with protective layer properties. The layer protects the wood against external influences and also increases its aesthetic value. The color, fiber structure, and texture of the varnished wood material become more prominent (Sönmez and Budakcı 2004).

The color of wood includes all color differences from white to black. Color is not uniform, even on the same tree. Another reason for the color difference is the different reflection of the rays due to the different intensities. Brightness is the property of reflection of rays coming on the material surface. The brightest surface in wood material is the radial section, where the medullary rays are seen as sheets or bright mirrors. The wood is less shiny in the tangential direction to the annual rings, and it does not show any shine in cross-section. The desired color and brightness can be given by coating the processed wood surface with varnishes (Ors and Keskin 2001).

Natural resins with improved properties are used as the main binder or modifying element in varnishes (Sönmez and Budakcı 2004). The melt of the resin-modified

nitrocellulose in nitrous liquids is called cellulosic varnish. Nitrocellulose is the main binder in the cellulosic system. Resin is an off-white polymer that has completed its formation and has a low solid matter content (Budakcı 2003).

Aloe vera (*Aloe barbadensis*) is a plant belonging to the Liliaceae family and is the most important species of the *Aloe* genus (Vega-Galvez *et al.* 2011). The plant consists of succulent green leaves that converge on the stem in the form of a rosette. The leaf of the plant consists of two parts, the green tunic and the gel; it has more than 200 ingredients, such as water and fat-soluble vitamins, minerals, enzymes, polysaccharides, phenolic compounds, and organic acids (Basaran 2020).

The gel inside the plant leaf is a liquid extract that has been known as medicine among the people since ancient times. Most scientists have investigated the compounds in the gel. Thousands of poly-mono saccharides with different chemical properties and biological activities are found in the gel. The gel also contains lignin, salicylic acid, saponins, sterols, and triterpenoids. Non-starch polysaccharides and lignin make up 35% of the dry mass of the gel. Fresh aloe gel contains the proteolytic enzyme carboxypeptidase, glutathione peroxidase, and several isoenzymes of superoxide dismutase. Aloe gel contains vitamins, such as A, C, E, B12, thiamin, niacin, folic acid, and minerals, such as Na, K, Ca, Mg, Mn, Zn, Cr, and Fe. Aloe plants contain amino acids lysine, histidine, arginine, cysteine, alanine, methionine, leucine, and isoleucine. Today, the gel has commercial uses as a food and beverage additive, a moisturizer in cosmetics, and a wound healer in pharmaceuticals. These effects of the gel are attributed to the high molecular weight components in its content (Güler 2010).

In this study, various biofilms were created using AVG (The gel obtained by processing the leaf extract of aloe vera) and SCK (the fruit juice industry sour cherry kernel waste). Some properties of biofilms such as swelling, water holding capacity (WVP), mass loss, corrosion, and biodegradation, *etc.*, were investigated comparatively. As a result, two different variety additives (AVG and SCK) addition and four different weight percent have a significant effect on the biofilms' swelling percentage, mass loss in water, tensile strength, and tensile elongation (Soydal *et al.* 2024).

It was aimed to determine the effect of addition a polyvinyl alcohol (PVOH) polymer and lactic acid in the presence of aloe vera on the mechanical properties of the wood adhesive. Positive effects were observed on the mechanical properties, compatibility, of the resulting mixture by combining aloe vera, lactic acid with PVOH and wood adhesive (Sweah *et al.* 2021).

Recently, the increasing awareness of being sensitive to the environment and the responsibility it brings has accelerated the determination of natural preservatives with alternative and functional properties that will meet the needs of the wood surface finishing sector by making use of natural and renewable resources.

In this study, it was aimed to determine the effect of aloe vera gel on the surface appearance properties of wood when it was applied in increasing percentages to cellulosic sanding sealer and cellulosic glossy varnish. A further goal was to investigate the possibilities of use in the wood surface finishing industry. This study is original in this respect, as aloe vera gel was used for the first time in the field of wood surface finishing. It is thought that the study will make significant contributions to the emergence of new job opportunities.

EXPERIMENTAL

Woods

Experiment materials were prepared from Anatolian black pine (*Pinus nigra* subsp. *pallasiana*), fir (*Abies nordmanniana* subsp. *bornmulleriana* Mattf.), Ayous (*Triplochiton scleroxylon* K. Schum), and Scotch pine (*Pinus sylvestris* L.) woods by random selection method from the market.

Aloe vera

Aloe vera (*Aloe barbadensis*) samples used in the study were obtained from the producer company located in Konyaaltı district of Antalya Province, which is the only commercial grower of *Barbadensis* Miller genus seedlings in Turkey (Source: <https://www.aloeveraantalya.com/galeri-1.html>). The geographic coordinates of the district are shown in Fig. 1.

Aloe vera samples that were kept in the refrigerator in accordance with the manufacturer's recommendations were kept in a vertical position for 1 day to remove the yellow colored liquid from the place where the leaves were cut. Then the leaves were divided with a knife into two in the middle and the inner gel part was removed with a spoon. The gel part in solid form was passed through the blender and the foamy mixture was left to rest in the refrigerator for 1 day. The gel, which became liquid in the refrigerator, was filtered and made ready for the experiments. Steps for the preparation of aloe vera gel are shown in Fig. 2.



Fig. 1. Aloe vera samples used in the experiments and aloe vera the production facility (Source: <https://www.aloeveraantalya.com/galeri-1.html>) and the geographic coordinates of the district



Fig. 2. Steps for the preparation of aloe vera gel

Cellulosic Varnish

A recent trend has been to study the use of nanocellulose particles for the formation of wood finishes. Professionals prefer nitrocellulose varnish finishes and to achieve durable, hard, colorless coatings, especially on furniture (Hubbe and Laleicke 2025). Cellulosic varnishes harden with solvent evaporation and dry physically (Sönmez and Budakcı 2004, Hubbe and Laleicke 2025). Since there is no chemical reaction in the layer formation, it can be applied to any type of wood material surface, provided that it is flawless. The moisture content of the wood material should be at most 12%. Fillers (C_{ss}) and final coat (C_{gv}) varnishes are used in the preparation of a protective layer with cellulosic varnishes. In order for the layer to show sufficient resistance to external effects,

it is envisaged that 4 coats should be applied and the layer thickness should be at most 200 μm to avoid the risk of cracking (Sönmez and Budakçı 2004).

Alkyd resin-based, nitrocellulose modified, air-drying cellulosic sanding sealer and cellulosic glossy varnishes used for varnishing the experiment samples were purchased from the market. Technical information of varnishes is given in Table 1.

Table 1. Technical Information of Varnishes

Varnish	Viscosity (20C° s/DIN6)	Dry Film Thickness (μm)	Solids (% by Weight)	Number of Layers Proposed	Recommended Film Thickness (g/m^2)	Ctm Ratio (% by Weight)
Css	50 to 60	35 to 40	30 ± 2	2 to 3 cross coats	220 to 250	90 to 100
Cgv	40 to 55	35 to 40	32.5 ± 2	2 to 3 cross coats	160 to 180	90 to 100

Css: Cellulosic sanding sealer; Cgv: Cellulosic glossy varnishes; Ctm: Cellulosic thinner mixing (Source: <https://tdsapp.polisankansai.com/en/pdf/view/61320cab8db9030010d872f4/en/webpage>, <https://tdsapp.polisankansai.com/en/pdf/view/5a9e3e44b7e0d5e54020f073/en/webpage>)

Preparation of Test Samples

Samples were prepared from the sapwood part of randomly selected first class material that had uniform fiber, did not have knots or cracks, and had no color and density difference, and the annual rings were upright to the surface (TS 53 1981; TS ISO 3129 2021). Samples were cut to $11 \times 11 \times 1.2 \text{ cm}^3$, and they were kept according to TS ISO 13061-1 (2021) principle, under the conditions of $20 \pm 2 \text{ }^\circ\text{C}$ temperature and $50 \pm 5\%$ relative humidity until they reached constant weight. Average moisture of 12 randomly chosen samples was determined as $9 \pm 0.5\%$. After samples had been sawn into their final sizes ($10 \times 10 \times 1 \text{ cm}^3$) were sanded with No. 80 and No. 100 sandpapers following the first wetting, then they were sanded with No. 150 sandpaper following the final wetting. Sanded surfaces were cleaned from dust using a soft bristle brush and vacuum and made ready for varnishing before surface treatment. In the research, $(4 \times 4 \times 1 \times 1 \times 12) = 192$ samples in total were prepared for the surface experiments. The trial pattern for the surface experiments is shown in Table 2, and images samples experiments are given in Fig. 3.

Table 2. The Trial Pattern for the Surface Experiments

Wood species	Varnish type	Color measurement treatment	Gloss measurement treatment	The number of samples (for each)	Total
Anatolian black pine	V and 0% Av	1	1	12	48
Fir	V and 5% Av	1	1	12	48
Ayous	V and 10% Av	1	1	12	48
Scots pine	V and 15% Av	1	1	12	48
4	4	1	1	12	192

Varnishing Process

Varnishing of the samples was carried out to match the industrial application according to ASTM D3023-98 (2017) principles and proposals of producing companies. Varnishes were applied to experiment samples with a medium brush. The amount of varnish was determined by conforming to the proposals of producing companies for two

cross coats that are required to be applied, and by scaling with analytical and 0.01 g precision balance in a way that there are 220 g per m² in cellulosic sanding sealer and 160 g per m² in cellulosic glossy varnish. The amount of mixture applied to the experiment samples by adding 0%, 5%, 10%, and 15% aloe vera gel by weight into cellulosic sanding sealer and cellulosic glossy varnish are given in Table 3.

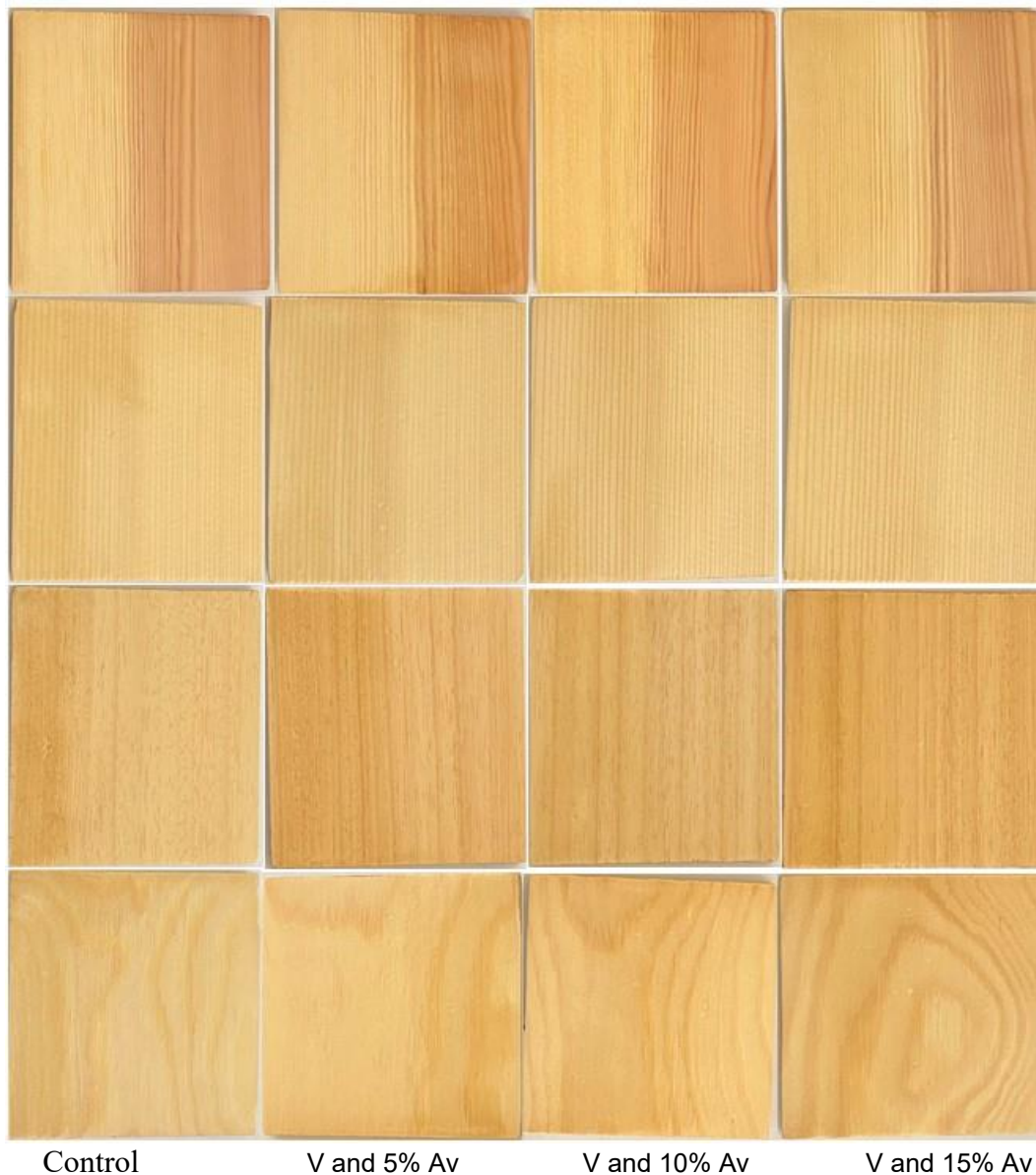


Fig. 3. Images samples experiments

Table 3. Amount of Mixture Applied to the Experiment Samples (g/m²)

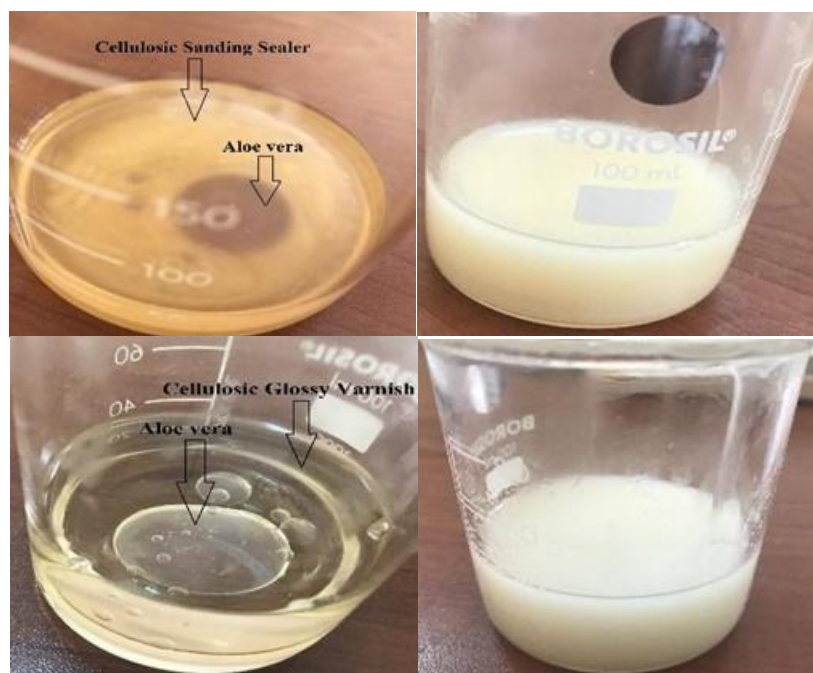
Varnish	0% Aloe vera	5% Aloe vera	10% Aloe vera	15% Aloe vera
Css	220	231	242	253
Cgv	160	168	176	184

Samples over which cellulosic sanding sealer was applied in two cross coats were kept drying for 24 h in a dust-free environment at room temperature in parallel with the ground plane. Dried samples were sanded with 220 and 400 water sandpaper equally, and varnish dusts were cleaned with a soft hairbrush and vacuum method. Cellulosic glossy varnish was applied in two cross coats to the surfaces of experiment samples and kept drying for 3 weeks. After drying, it was kept in an air-conditioning cabinet at 23 ± 2 °C and $50 \pm 5\%$ relative humidity for 16 h according to ASTM D3924-16 (2019) principles before the experiments.

The pH values of aloe vera and varnishes on universal indicator strips are shown in Table 4, and images before and after mixing are given in Fig. 4. It has been reported in the literature that the pH of aloe vera gel grown in the field is between 4.4 to 4.7 and the high acidity of aloe vera gel may be due to the accumulation of organic acids, such as malic acid, in the cells of the pulp (Boudreau and Beland 2006).

Table 4. pH Values of Aloe Vera and Varnishes

pH (Universal indicator strips)	
Aloe vera (Av)	4
Cellulosic sanding sealer (Css)	4
Cellulosic glossy varnish (Cgv)	4

**Fig. 4.** Aloe vera and varnishes before and after mixing

Color Measurement

The ColorStriker colorimeter measuring according to ASTM D2244-21 (2021) is shown in Fig. 5.

The $L^*a^*b^*$ color space (also referred to as CIELAB) is presently one of the most popular color spaces for measuring object color and is widely used in virtually all fields. It is one of the uniform color spaces defined by CIE in 1976. In this color space, L^* indicates lightness ($L^*=0$, black), ($L^*=100$, white) and a^* and b^* are the chromaticity coordinates and c^* is chroma, and h° is the hue angle. The value of chroma c^* is 0 at the center and increases according to the distance from the center. Hue angle h is defined as starting at the $+a^*$ axis and is expressed in ($^\circ$); 0° would be $+a^*$ (red), 90° would be $+b^*$ (yellow), 180° would be $-a^*$ (green), and 270° would be $-b^*$ (blue). CIE $L^*a^*b^*$ color space is shown in Fig. 6 (Konica Minolta 2007).



Fig. 5. ColorStriker colorimeter

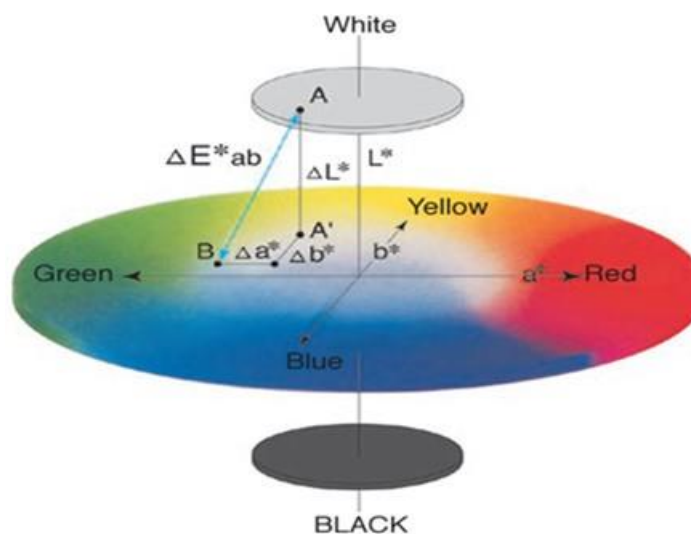


Fig. 6. CIE $L^*a^*b^*$ color space

To determine the change in yellow color tone (b^*), variable quality Δb^* was calculated as ($\Delta b^* = \text{Varnished value } b^* - \text{Unvarnished value } b^*$). When the Δb^* has a low value, it means that the yellow color tone did not change or changed little (Yalinkılıç 2021). To determine the change in red color tone (a^*), variable quality Δa^* was calculated as ($\Delta a^* = \text{Varnished value } a^* - \text{Unvarnished value } a^*$). A low Δa^* value means that the red color tone did not change or changed little (Yalinkılıç and Sönmez 2015). In the $L^*a^*b^*$ color space, color difference can be expressed as a single numerical value, ΔE^* , which indicates the size of the color difference but not in what way the colors are different. ΔE^* is defined by the following equation $\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$ (Konica Minolta 2007). The ΔE^* is in low value and means color tone did not change or changed little (Söğütü and Sönmez 2006).

Surface Glossiness Measurement

The glossiness was measured in accordance with the principles of TS EN ISO 2813 (2014) and ASTM D523-14 (2018), which determine the light-reflecting ability of wood material surfaces. For this purpose, measurements were made with a glossiness measuring instrument (micro-TRI-gloss μ) parallel and perpendicular to the fibers of the samples. Micro-TRI-gloss μ and the measuring principle are shown in Fig. 7.



Fig. 7. Surface glossiness measuring device (micro-TRI-gloss μ)

Data Analysis

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

RESULTS AND DISCUSSION

Red color tone (Δa^*) values, which were obtained by the differences between varnished and unvarnished measurements, were used to determine the interaction of aloe

vera with cellulosic varnish. Red color values were found different in terms of wood species and varnish and aloe vera mix type. A multi-factor analysis of variance was performed to determine the source of differences, and its results are shown in Table 5.

Table 5. Results of Variance Analysis on Change in Red (Δa^*) Color Tone

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	P $\leq$ 0.05
Wood Species (A)	3	138.936	46.312	415.5012	0.0000*
Varnish and Aloe vera mix type (B)	3	9.863	3.288	29.4952	0.0000*
AB	9	3.927	0.436	3.9148	0.0001*
Error	176	19.617	0.111		
Total	191	172.342			

*: Difference is meaningful according to 0.05

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

Table 6. Comparison Result of Duncan Test Made at the Level of Wood Species and Varnish and Aloe Vera Mix Type

Source		$\bar{x}$	HG
Wood species	Anatolian black pine	0.7052	C
	Fir	0.7846	C
	Ayous	2.822	A*
	Scots pine	1.583	B
Varnish and aloe vera mix type	Control	1.804	A
	Varnish and 5% Aloe vera (V and 5% Av)	1.559	B*
	Varnish and 10% Aloe vera (V and 10% Av)	1.303	C
	Varnish and 15% Aloe vera (V and 15% Av)	1.229	C
LSD: ± 0.1341			

*: The highest increase in red color tone; $\bar{x}$: Arithmetic mean; HG: Homogeneity group; Control: Varnish and 0% Aloe vera (V and 0% Av)

According to Table 6, the highest change in red color tone was found in ayous wood materials and (varnish and 5% aloe vera) mix type. The lowest change in red color tone was found in Anatolian black pine and (varnish and 15% aloe vera). Comparison results of Duncan test, which was made at the level of interaction between wood species and varnish and aloe vera mix type, are given in Table 7, and the corresponding graph is shown in Fig. 8.

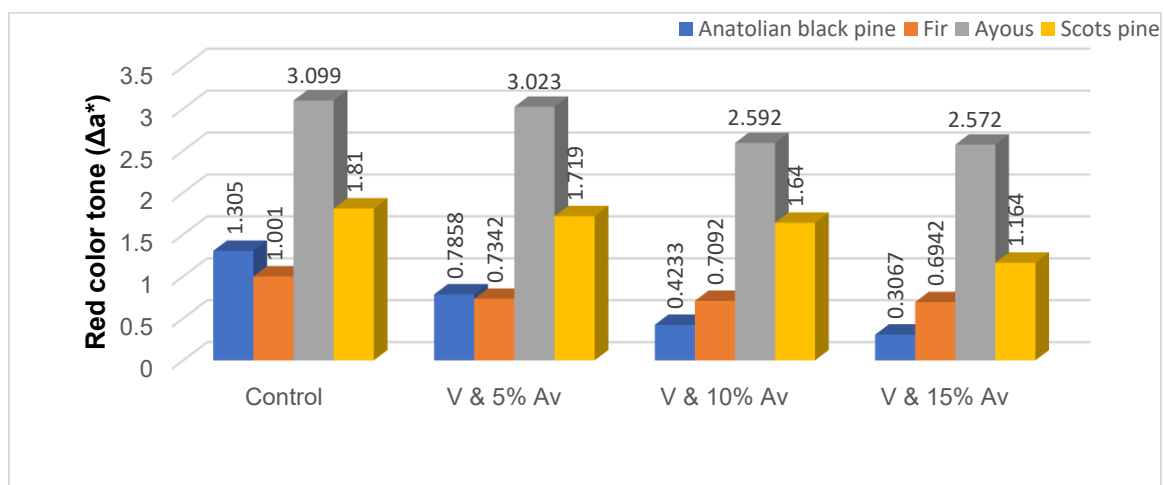
Table 7. Duncan Test Comparisons for Wood Species - Varnish and Aloe Vera Mix Type Interaction

Wood	Varnish	Means	HG
Anatolian black pine	Control	1.305	D
	Varnish and 5% Aloe vera	0.7858	FG
	Varnish and 10% Aloe vera	0.4233	H
	Varnish and 15% Aloe vera	0.3067	I**
Fir	Control	1.001	EF
	Varnish and 5% Aloe vera	0.7342	FG
	Varnish and 10% Aloe vera	0.7092	G
	Varnish and 15% Aloe vera	0.6942	G
Ayous	Control	3.099	A
	Varnish and 5% Aloe vera	3.023	A*
	Varnish and 10% Aloe vera	2.592	B
	Varnish and 15% Aloe vera	2.572	B
Scots pine	Control	1.810	C
	Varnish and 5% Aloe vera	1.719	C
	Varnish and 10% Aloe vera	1.640	C
	Varnish and 15% Aloe vera	1.164	DE

LSD: ± 0.2683 , *: The highest increase in red color tone

**: The lowest increase in red color tone

According to Table 7, the highest change in red color tone was seen in ayous over which varnish and 5% aloe vera was applied. The lowest change was obtained in Anatolian Black pine over which varnish and 15% aloe vera was applied. It was determined that the red color tone of four tree species decreased as the percentage of aloe vera in the cellulosic varnish increased. It may be recommended to use Anatolian black pine coated with 15% aloe vera added cellulosic varnish in applications where the red color tone does not change or changes little. Indeed, because the Δa^* is in low value means red color tone did not change or changed little, has been reported in the literature. This situation is compatible with the literature (Yalinkılıc and Sönmez 2015). If other wood materials are preferred according to the place of use, it may be recommended to use wood materials coated with 15% aloe vera added cellulosic varnish.

**Fig. 8.** Red color tone (Δa^*) variation for wood species - varnish and aloe vera mix type interaction

Yellow color tone (Δb^*) values, which were obtained by the differences between varnished and unvarnished measurements, were used to determine the interaction of aloe vera with cellulosic varnish. Yellow color values were found different in terms of wood species and varnish and aloe vera mix type. A multi-factor analysis of variance was performed to determine the source of differences, and its results are shown in Table 8.

Table 8. Results of Variance Analysis on Change in Yellow (Δb^*) Color Tone

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	P $\leq$ 0.05
Wood Species (A)	3	215.226	71.742	55.1388	0.0000*
Varnish and Aloe vera mix type (B)	3	191.410	63.803	49.0373	0.0000*
AB	9	43.238	4.804	3.6923	0.0003*
Error	176	228.996	1.301		
Total	191	678.869			

*: Difference is meaningful according to 0.05

According to the results of the variance analysis, wood species and varnish and aloe vera mix type and their mutual interactions were found statistically significant ($P \leq 0.05$). Comparison results of Duncan test that was made at the level of wood species and varnish and aloe vera mix type are given in Table 9.

Table 9. Comparison Result of Duncan Test Made at the Level of Wood Species and Varnish and Aloe Vera Mix Type

Source		$\bar{x}$	HG
Wood species	Anatolian black pine	9.160	B
	Fir	9.570	B
	Ayous	11.12	A*
	Scots pine	8.185	C
Varnish and aloe vera mix type	Control	11.01	A
	Varnish and 5% Aloe vera (V and 5% Av)	9.701	B*
	Varnish and 10% Aloe vera (V and 10% Av)	9.023	C
	Varnish and 15% Aloe vera (V and 15% Av)	8.301	D
LSD: ± 0.4592			

*: The highest increase in yellow color tone; $\bar{x}$: Arithmetic mean; HG: Homogeneity group; Control: Varnish and 0% Aloe vera (V and 0% Av)

According to Table 9, the highest change in yellow color tone was found in ayous wood materials and (varnish and 5% aloe vera) mix type. The lowest change in yellow color tone was found in Scots pine and (varnish and 15% aloe vera). Comparison results of Duncan test that was made at the level of interaction between wood species and varnish and aloe vera mix type are given in Table 10, and the corresponding graph is shown in Fig. 9.

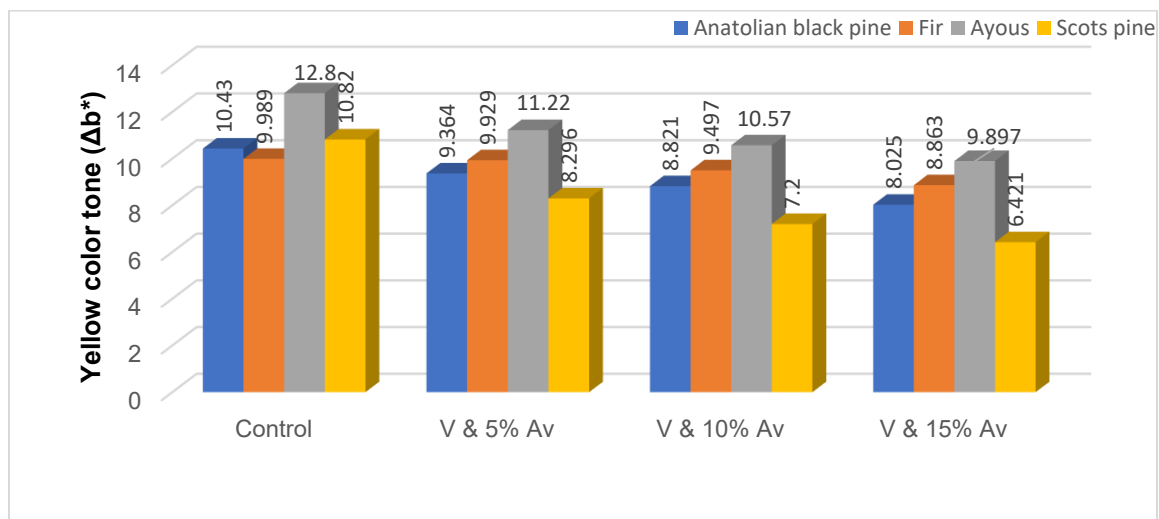
Table 10. Duncan Test Comparisons for Wood Species – Varnish and Aloe Vera Mix Type Interaction

Wood	Varnish	Means	HG
Anatolian black pine	Control	10.43	BCD
	Varnish and 5% Aloe vera	9.364	EF
	Varnish and 10% Aloe vera	8.821	FG
	Varnish and 15% Aloe vera	8.025	GH
Fir	Control	9.989	CDE
	Varnish and 5% Aloe vera	9.929	CDE
	Varnish and 10% Aloe vera	9.497	EF
	Varnish and 15% Aloe vera	8.863	FG
Ayous	Control	12.80	A
	Varnish and 5% Aloe vera	11.22	B*
	Varnish and 10% Aloe vera	10.57	BCD
	Varnish and 15% Aloe vera	9.897	DE
Scots pine	Control	10.82	BC
	Varnish and 5% Aloe vera	8.296	G
	Varnish and 10% Aloe vera	7.200	H
	Varnish and 15% Aloe vera	6.421	I**

LSD: ± 0.9185 , *: The highest increase in yellow color tone

**: The lowest increase in yellow color tone

According to Table 10, the highest change in yellow color tone was seen in ayous over which varnish and 5% aloe vera was applied, whereas the lowest change was obtained in Scots pine over which varnish and 15% aloe vera was applied. It was determined that the yellow color tone of four tree species decreased as the percentage of aloe vera in the cellulosic varnish increased. It may be recommended to use Scots pine coated with 15% aloe vera added cellulosic varnish in applications where the yellow color tone does not change or changes little. Indeed, it has been reported that because Δb^* is a low value the yellow color tone did not change or changed little. This situation is compatible with the literature (Yalinkilic 2021). If other wood materials are preferred according to the place of use, it may be recommended to use wood materials coated with 15% aloe vera added cellulosic varnish.

**Fig. 9.** Yellow color tone (Δb^*) variation for wood species - varnish and aloe vera mix type interaction

Using the differences of varnished and unvarnished measurements, were used to determine the interaction of aloe vera with cellulosic varnish.

Total color change values were found different in terms of wood species and varnish and aloe vera mix type. Multi-factor analysis of variance was performed to determine the source of differences, and its results are shown in Table 11.

Table 11. Variance Analysis for Changes in Total Color Tone (ΔE^*)

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	$P \leq 0.05$
Wood Species (A)	3	206.290	68.763	40.6313	0.0000*
Varnish and Aloe vera mix type (B)	3	349.436	116.479	68.8255	0.0000*
AB	9	80.373	8.930	5.2768	0.0000*
Error	176	297.858	1.692		
Total	191	933.958			

*: Difference is meaningful according to 0.05

According to the results of the variance analysis, wood species and varnish and aloe vera mix type and their mutual interactions were found statistically significant ($P \leq 0.05$). Comparison of the results of Duncan test made at the level of wood species and varnish and aloe vera mix type are given in Table 12.

Table 12. Comparison Result of Duncan Test Made at the Level of Wood Species and Varnish and Aloe Vera Mix Type

Source		$\bar{x}$	HG
Wood species	Anatolian black pine	11.02	BC
	Fir	11.05	B
	Ayous	13.21	A*
	Scots pine	10.52	C
	Control	13.28	A
Varnish and Aloe vera mix type	Varnish and 5% Aloe vera (V and 5% Av)	11.89	B*
	Varnish and 10% Aloe vera (V and 10% Av)	11.07	C
	Varnish and 15% Aloe vera (V and 15% Av)	9.560	D
LSD: ± 0.5237			

*: The highest increase in total color change; $\bar{x}$: Arithmetic mean; HG: Homogeneity group; Control: Varnish and 0% Aloe vera (V and 0% Av)

According to Table 12, the highest change in total color tone was found in ayous wood materials and (varnish and 5% aloe vera) mix type, the lowest change in total color tone was found in Scots pine and (varnish and 15% aloe vera). Comparison results of the Duncan test made at the level of interaction between wood species and varnish and aloe vera mix type are given in Table 13, and the corresponding graph is shown in Fig. 10.

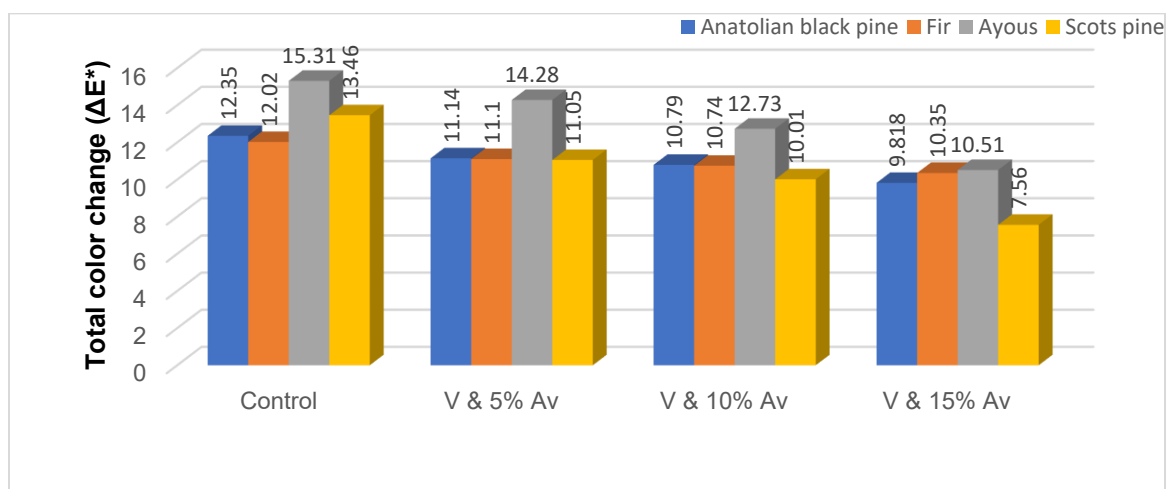
Table 13. Duncan Test Comparisons for Wood Species - Varnish and Aloe Vera Mix Type Interaction

Wood	Varnish	Means	HG
Anatolian black pine	Control	12.35	D
	Varnish and 5% Aloe vera	11.14	EF
	Varnish and 10% Aloe vera	10.79	FGH
	Varnish and 15% Aloe vera	9.818	H
Fir	Control	12.02	DE
	Varnish and 5% Aloe vera	11.10	EF
	Varnish and 10% Aloe vera	10.74	FGH
	Varnish and 15% Aloe vera	10.35	FGH
Ayous	Control	15.31	A
	Varnish and 5% Aloe vera	14.28	AB*
	Varnish and 10% Aloe vera	12.73	CD
	Varnish and 15% Aloe vera	10.51	FGH
Scots pine	Control	13.46	BC
	Varnish and 5% Aloe vera	11.05	EFG
	Varnish and 10% Aloe vera	10.01	GH
	Varnish and 15% Aloe vera	7.560	I**

LSD: ± 1.047 , *: The highest increase in total color change

**: The lowest increase in total color change

According to Table 13, the highest change in total color tone was seen in ayous over which varnish and 5% aloe vera was applied, whereas the lowest change was obtained in Scots pine over which varnish and 15% aloe vera was applied. It was determined that the total color change values of four tree species decreased as the percentage of aloe vera in the cellulosic varnish increased. It may be recommended to use Scots pine coated with 15% aloe vera added cellulosic varnish in applications where the total color tone does not change or changes little. It has been reported in literature that because ΔE^* is in low value means color tone did not change or changed little. This situation is compatible with the literature (Sögütlü and Sönmez 2006). If other wood materials are preferred according to the place of use, it may be recommended to use wood materials coated with 15% aloe vera added cellulosic varnish.

**Fig. 10.** Total color change (ΔE^*) variation for wood species - varnish and aloe vera mix type interaction

Glossiness perpendicular to fibers values obtained by the differences between varnished and unvarnished measurements were used to determine the interaction of aloe vera with cellulosic varnish. Glossiness perpendicular to fibers values were different in terms of wood species and varnish and aloe vera mix type. A multi-factor analysis of variance was done to determine the source of differences. Results are shown in Table 14.

Table 14. Variance Analysis for Change in Glossiness Perpendicular to Fibers

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	P ≤ 0.05
Wood Species (A)	3	5173.230	1724.410	46.7135	0.0000*
Varnish and Aloe vera mix type (B)	3	20776.568	6925.523	187.6092	0.0000*
AB	9	1744.588	193.843	5.2511	0.0000*
Error	176	6496.973	36.915		
Total	191	34191.359			

*: Difference is meaningful according to 0.05

According to the results of the variance analysis, wood species and varnish and aloe vera mix type and their mutual interactions were found statistically significant ($P \leq 0.05$). Comparison of the results of Duncan test made at the level of wood species and varnish and aloe vera mix type is given in Table 15.

Table 15. Comparison Result of Duncan Test Made at the Level of Wood Species and Varnish and Aloe Vera Mix Type

Source		$\bar{x}$	HG
Wood species	Anatolian black pine	72.869	A
	Fir	66.227	B
	Ayous	61.246	C
	Scots pine	74.063	A*
Varnish and Aloe vera mix type	Control	82.781	A
	Varnish and 5% Aloe vera (V and 5% Av)	72.879	B*
	Varnish and 10% Aloe vera (V and 10% Av)	64.015	C
	Varnish and 15% Aloe vera (V and 15% Av)	54.729	D
LSD: ± 2.446			

*: The highest increase in glossiness perpendicular to fibers;

$\bar{x}$: Arithmetic mean; HG: Homogeneity group; Control: Varnish and 0% Aloe vera (V and 0% Av)

According to Table 15, the highest change in glossiness perpendicular to fibers was found in Scots pine wood materials and (varnish and 5% aloe vera) mix type, the lowest change in glossiness perpendicular to fibers was found in ayous and (varnish and 15% aloe vera). A comparison of the results of the Duncan test made at the level of interaction between wood species and varnish and aloe vera mix type is given in Table 16, and the corresponding graph is shown in Fig. 11.

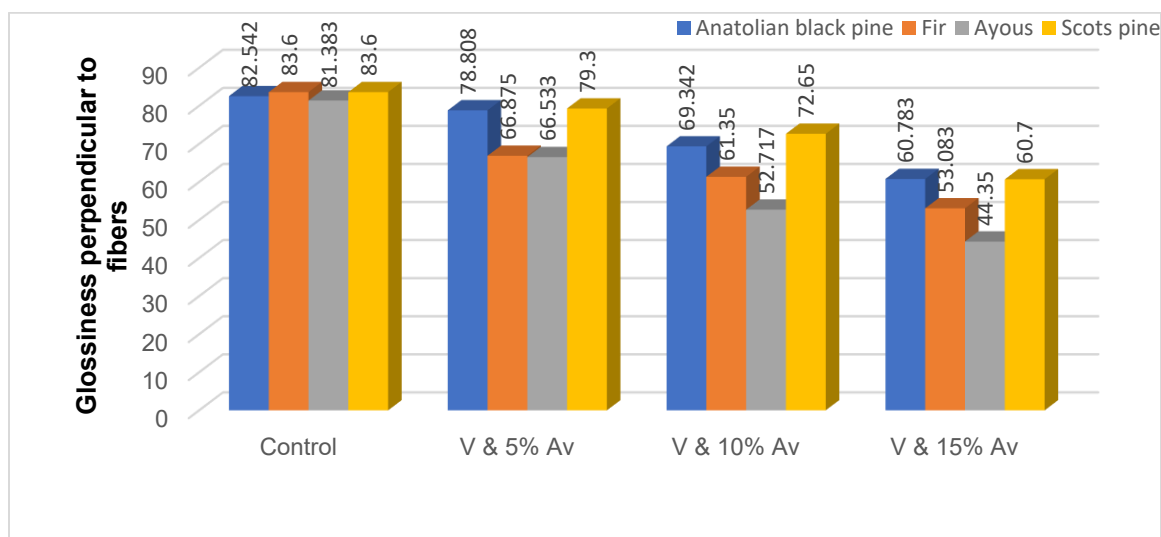
Table 16. Duncan Test Comparisons for Wood Species - Varnish and Aloe Vera Mix Type Interaction

Wood	Varnish	Means	HG
Anatolian black pine	Control	82.542	A
	Varnish and 5% Aloe vera	78.808	A
	Varnish and 10% Aloe vera	69.342	BC
	Varnish and 15% Aloe vera	60.783	D
Fir	Control	83.600	A
	Varnish and 5% Aloe vera	66.875	C
	Varnish and 10% Aloe vera	61.350	D
	Varnish and 15% Aloe vera	53.083	E
Ayous	Control	81.383	A
	Varnish and 5% Aloe vera	66.533	C
	Varnish and 10% Aloe vera	52.717	E
	Varnish and 15% Aloe vera	44.350	F**
Scots pine	Control	83.600	A
	Varnish and 5% Aloe vera	79.300	A*
	Varnish and 10% Aloe vera	72.650	B
	Varnish and 15% Aloe vera	60.700	D

LSD: ± 4.893 , *: The highest increase in glossiness perpendicular to fibers

**: The lowest increase in glossiness perpendicular to fibers

According to Table 16, the highest change in glossiness perpendicular to fibers was seen in Scots pine over which varnish and 5% aloe vera was applied, whereas the lowest change was obtained in ayous over which varnish and 15% aloe vera was applied. It was determined that the glossiness values perpendicular to the fibers of four tree species decreased as the percentage of aloe vera in the cellulosic varnish increased. It may be recommended to use ayous coated with 15% aloe vera added cellulosic varnish in applications where the glossiness values does not change or changes little. If other wood materials are preferred according to the place of use, it may be recommended to use wood materials coated with 15% aloe vera added cellulosic varnish.

**Fig. 11.** Glossiness perpendicular to fibers variation for wood species - varnish and aloe vera mix type interaction

Glossiness parallel to fibers values, which were obtained by the differences varnished and unvarnished measurements, were used to determine the interaction of aloe vera with cellulosic varnish. Glossiness parallel to fibers values were found different in terms of wood species and varnish and aloe vera mix type. A multi-factor analysis of variance was performed to determine the source of differences, and its results are shown in Table 17.

Table 17. Variance Analysis for Change in Glossiness Parallel to Fibers

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	P ≤ 0.05
Wood Species (A)	3	4960.280	1653.427	58.6978	0.0000*
Varnish and Aloe vera mix type (B)	3	14285.101	4761.700	169.0436	0.0000*
AB	9	1849.157	205.462	7.2940	0.0000*
Error	176	4957.652	28.168		
Total	191	26052.189			

*: Difference is meaningful according to 0.05

According to the results of the variance analysis, wood species and varnish and aloe vera mix type and their mutual interactions were found statistically significant ($P \leq 0.05$). A comparison of the Duncan test results made at the level of wood species and varnish and aloe vera mix type is given in Table 18.

Table 18. Duncan Test Made at the Level of Wood Species and Varnish and Aloe Vera Mix Type

Source		$\bar{x}$	HG
Wood species	Anatolian black pine	91.546	A*
	Fir	83.996	B
	Ayous	79.363	C
	Scots pine	91.046	A
Varnish and Aloe vera mix type	Control	98.773	A
	Varnish and %5 Aloe vera (V and 5% Av)	89.540	B*
	Varnish and 10% Aloe vera (V and 10% Av)	81.960	C
	Varnish and 15% Aloe vera (V and 15% Av)	75.677	D
LSD: ± 2.137			

*: The highest increase in glossiness parallel to fibers

$\bar{x}$: Arithmetic mean; HG: Homogeneity group; Control: Varnish and 0% Aloe vera (V and 0% Av)

According to Table 18, the highest change in glossiness parallel to fibers was found in Anatolian black pine wood materials and (varnish and 5% aloe vera) mix type, the lowest change in glossiness parallel to fibers was found in ayous and (varnish and 15% aloe vera). The comparison of Duncan test results made at the level of interaction between wood species and varnish and aloe vera mix type is given in Table 19, and the corresponding graph is shown in Fig. 12.

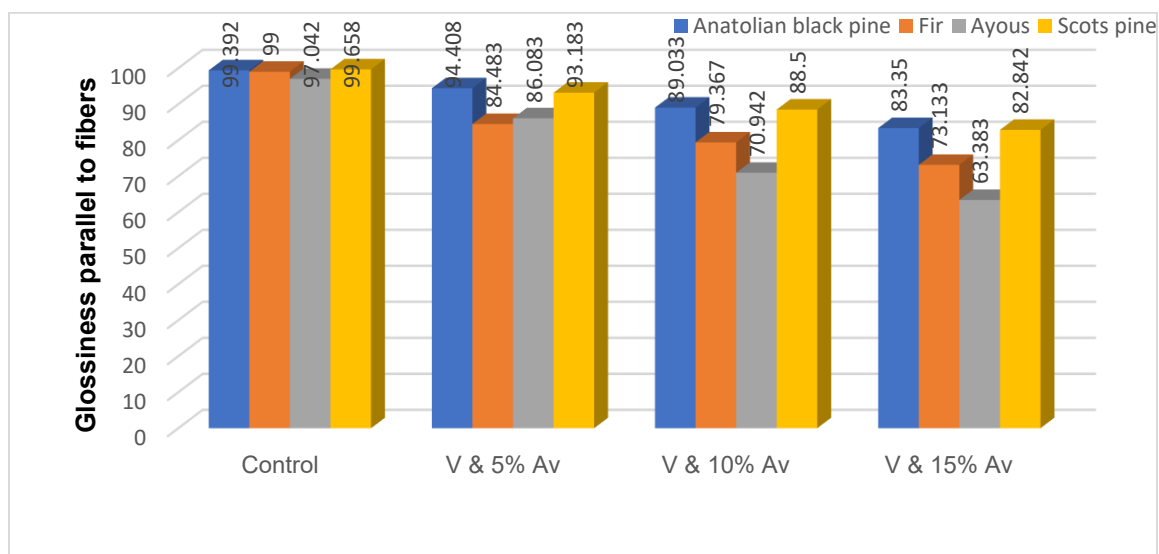
Table 19. Duncan Test Comparisons for Wood Species - Varnish and Aloe Vera Mix Type Interaction

Wood	Varnish	Means	HG
Anatolian black pine	Control	99.392	A
	Varnish and 5% Aloe vera	94.408	B*
	Varnish and 10% Aloe vera	89.033	CD
	Varnish and 15% Aloe vera	83.350	FG
Fir	Control	99.000	A
	Varnish and 5% Aloe vera	84.483	EF
	Varnish and 10% Aloe vera	79.367	G
	Varnish and 15% Aloe vera	73.133	H
Ayous	Control	97.042	AB
	Varnish and 5% Aloe vera	86.083	DEF
	Varnish and 10% Aloe vera	70.942	H
	Varnish and 15% Aloe vera	63.383	I**
Scots pine	Control	99.658	A
	Varnish and 5% Aloe vera	93.183	BC
	Varnish and 10% Aloe vera	88.500	DE
	Varnish and 15% Aloe vera	82.842	FG

LSD: ± 4.274 , *: The highest increase in glossiness parallel to fibers

**: The lowest increase in glossiness parallel to fibers

According to Table 19, the highest change in glossiness parallel to fibers was seen in Anatolian black pine over which varnish and 5% aloe vera was applied, whereas the lowest change was obtained in ayous over which varnish and 15% aloe vera was applied. It was determined that the glossiness values parallel to the fibers of four tree species decreased as the percentage of aloe vera in the cellulosic varnish increased. It may be recommended to use ayous coated with 15% aloe vera added cellulosic varnish in applications where the glossiness values does not change or changes little. If other wood materials are preferred according to the place of use, it may be recommended to use wood materials coated with 15% aloe vera added cellulosic varnish.

**Fig. 12.** Glossiness parallel to fibers variation for wood species- varnish and aloe vera mix type interaction

This study is original in that aloe vera is used for the first time in wood surface finishing. Further studies are needed to definitively determine the usability of aloe vera, which has a wide range of uses in other industries, also in the wood surface paint and varnish industry.

It is recommended to conduct experiments such as hardness, bonding strength, surface roughness, wet temperature (hot water spillage), dry temperature (layer contact with hot food pot, *etc.*), resistance to cigarette burn, resistance to weathering and combustion test, *etc.*

This study can be considered as a literature for future studies.

CONCLUSIONS

1. There was an increase in the red color tone, yellow color tone, total color change, glossiness perpendicular to the fibers, and glossiness parallel to the fibers difference values in all of the control samples (due to varnish and 0% aloe vera).
2. It was determined that these difference values in all four tree species decreased as the percentage of aloe vera in cellulosic varnish increased.
3. It may be recommended to use 15% aloe vera added cellulosic varnish in applications where the color and the glossiness values does not change or changes little.
4. Accordingly, it can be said that aloe vera affects red color tone, yellow color tone, total color change, glossiness perpendicular to the fibers, and glossiness parallel to the fibers.

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Article submitted: May 5, 2025; Peer review completed: May 30, 2025; Revised version received and accepted: June 10, 2025; Published: June 24, 2025.

DOI: 10.15376/biores.20.3.6577-6598