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COMPARISON OF COLOR PROPERTIES OF MAGNOLIA, TEAK, ALDER, AYOUS, AND LOTOFA WOOD TREATED WITH ARABIC GUM

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Abstract
The effect of gum arabic application on the color parameters of five different wood species - ayous, alder, lotofa, magnolia and teak - was investigated. The results were obtained differently. The most significant decrease in C value was found in ayousta (37.11%) and the least increase was found in teak (3.50%). The red-green color component (a*) increased in all samples, with the highest increase being obtained in ayousta (58.25%) and the lowest increase in magnolia (8.01%). It was noted that the lightness (L*) values decreased in all wood types, the most significant decrease was observed in lotofa (17.07%) and the least decrease was observed in magnolia (4.90%). A general increase was determined in the yellow-blue color component (b*) except for teak, where a slight decrease was recorded (0.29%). Differences were also observed in the color tone angle (h°) parameter; a slight increase (1.16%) was obtained in the experimental group samples of magnolia wood, while the most significant decrease (13.62%) was found in the experimental group samples of lotofa wood.*

Keywords: Alder, ayous, lotofa, teak, magnolia, color, gum Arabic

INTRODUCTION

The term "gum" refers to naturally occurring polysaccharides that can form viscous or gel-like solutions. These polysaccharides are often abundant raw materials derived from plants. Their biocompatibility, sustainability, and biodegradability have been reported as the subject of numerous studies. The molecular composition and chemical structure of this material are often influenced by the plant source and the methods used to extract and process it. Plant gums are also characterized as complex carbohydrate polymers, and their chemical structures are generally described as derived from sugar monomers (hyaluronates, cellulose, starch, and alginates) (Ahmad et al., 2019).

Gum arabic is a water-soluble natural product. It has various uses in the food and pharmaceutical industries, particularly in both oral and topical applications. It is also used as a stabilizing additive and binding agent for colloidal mixtures (Elzain and Mariod, 2018).

The color of wood can be considered an important factor in terms of functionality, aesthetics, and performance. Above all, the natural color of wood affects visual harmony and aesthetic perception in interior design, furniture making, and furniture decoration. There are several reasons for applying gum arabic to wood. First, it reduces moisture absorption by forming a thin protective film on wood surfaces. This is especially important for wood used outdoors. Gum arabic also acts as a natural adhesive, making it ideal for bonding thin materials to wood surfaces or as a primer for varnishes. Furthermore, when mixed with water, it forms a transparent film, giving the wood a subtle sheen and enhancing its aesthetic appeal while preserving its natural appearance.

The color parameters of wood samples taken from lotofa, ayous, magnolia, alder, and teak were compared using a colorimeter and a colorimetric standard after the chemical application of gum arabic. This study contributes to the literature by presenting a comparative analysis of the effects of gum arabic prepared in a laboratory environment on the color parameters of the wood of these tree species.

MATERIAL AND METHODS

Wood samples of ayous (*Triplochiton scleroxylon* K. Schum), lotofa (*Sterculia rhinopetala*), Magnolia (*Magnolia grandiflora* L.), teak (*Tectona grandis* L.), and alder (*Alnus glutinosa* L. *Gaertn*.) were prepared in dimensions of 100 mm × 100 mm × 20 mm and conditioned following the ISO 554 (1976) standard. Both the wood samples and gum Arabic were sourced from a commercial supplier. A solution was prepared by mixing 20 g of ground gum Arabic with 100 ml of distilled water in a glass container and boiling it for 20 min. After boiling, the mixture was strained through cheesecloth to obtain a pure solution. The wood surfaces were sanded using a vibrating sander with 80, 120, and 150 grit sandpapers. The prepared solution was then applied in a single coat to the wood surfaces using a brush. A total of 50 wood specimens were used in the study, with 5 samples prepared for each wood species. After application, 1 week was waited for it to dry. Color changes were assessed using a CS-10 device (CHN Spec, China) under a CIE D65 light source with a CIE 10° standard observer and an 8/d illumination system, following ASTM D2244-3 (2007). The chroma difference or color saturation variation was expressed as ΔC^*, while the hue difference or tonal variation was represented as ΔH^* (Lange, 1999). Table 1 provides definitions for the other parameters, while Table 2 shows the color change range based on Jirouš and Ljuljka (1999) (Lange, 1999).

Table 1

Descriptions for ΔL^*, Δa^*, Δb^*, and ΔC^* (Lange, 1999)

In negative case	Parameter	In positive case
Matte, more blurred than reference	ΔC^*	Clearer, brighter than reference
Bluer than reference	Δb^*	More yellow than reference
Darker than reference	ΔL^*	Lighter than reference
Greener than reference	Δa^*	Redder than reference

Table 2

Color change range according to Jirouš and Ljuljka (1999)

ΔE^* Range		Color Change Estimation	ΔE^* Range	Color Change Estimation
< 0.20		Unnoticeable	3.00 - 6.00	Very noticeable
0.20 - 0.50		Very slight	6.00 - 12.00	Intense
0.50 - 1.50		Light	> 12.00	Very intense
1.50 - 3.00		Noticeable		

The total color differences were calculated using the following formulas.

$$C^* = [(a^*)^2 + (b^*)^2]^{0.5} \quad (1)$$

$$h^o = \arctan (b^*/a^*) \quad (2)$$

$$\Delta C^* = (C^*_{\text{sample with prepared solution}} - C^*_{\text{control}}) \quad (3)$$

$$\Delta a^* = (a^*_{\text{sample with prepared solution}} - a^*_{\text{control}}) \quad (4)$$

$$\Delta L^* = (L^*_{\text{sample with prepared solution}} - L^*_{\text{control}}) \quad (5)$$

$$\Delta b^* = (b^*_{\text{sample with prepared solution}} - b^*_{\text{control)}}) \quad (6)$$

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

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0.5} \quad (8)$$

The data obtained from the color parameters of the wood samples (ayous, lotofa, magnolia, teak, and alder) were analyzed using software. Descriptive statistics, including means and standard deviations, were

calculated for each wood species, both before and after the application of gum Arabic. To determine if there were significant differences in the color changes between the different wood species after the application of gum Arabic, a One-Way Analysis of Variance (One-Way ANOVA) was performed. The analysis was conducted at a significance level of $p < 0.05$. The One-Way ANOVA allowed for the comparison of color parameters (L^*, a^*, b^*, C^*, and $h°$) across all wood species, both with and without gum Arabic application. Post-hoc tests were performed when significant differences were found to identify which groups (wood species) differed from each other. The results were also presented graphically using to illustrate the differences in the color changes for each wood species.

RESULTS AND DISCUSSION

After applying gum Arabic, the total color differences (ΔE^*) were calculated using color formulas, and the results are shown in Table 3. The ΔE^* values were found to be 10.34 for lotofa, 10.42 for ayous, 8.70 for alder, 5.15 for teak, and 4.30 for Magnolia. For lotofa, ayous, and alder wood species, the color change criterion (Jirouš and Ljuljka, 1999) was determined as “intense” (6.00 - 12.00), while for Teak and Magnolia wood species, it was classified as “very noticeable” (3.00 - 6.00). The ΔL^* (darker than reference) values were found to be negative for all wood species after the application, while the Δa^* (redder than reference) and ΔC^* (clearer, brighter than reference) values were found to be positive. The Δb^* values were found to be negative (bluer than reference) for Teak, while for the other wood species, they were positive (more yellow than reference) (Table 3). Figure 1 displays the visual comparison of total color differences (ΔE^*) recorded across the wood types.

Table 3

The results of the total color differences

Wood Type	ΔL^*	Δa^*	Δb^*	ΔC^*	ΔH^*	ΔE^*	Color change criterion (Jirouš and Ljuljka, 1999)
Lotofa	-9.29	4.55	0.30	2.79	3.60	10.34	Intense (6.00 - 12.00)
Ayous	-5.29	4.20	7.93	9.06	-	10.42	
Alder	-5.72	3.03	5.81	6.58	-	8.70	
Teak	-4.61	2.29	-0.06	0.90	2.11	5.15	Very noticeable (3.00 - 6.00)
Magnolia	-3.05	0.25	3.02	3.02	0.29	4.30	

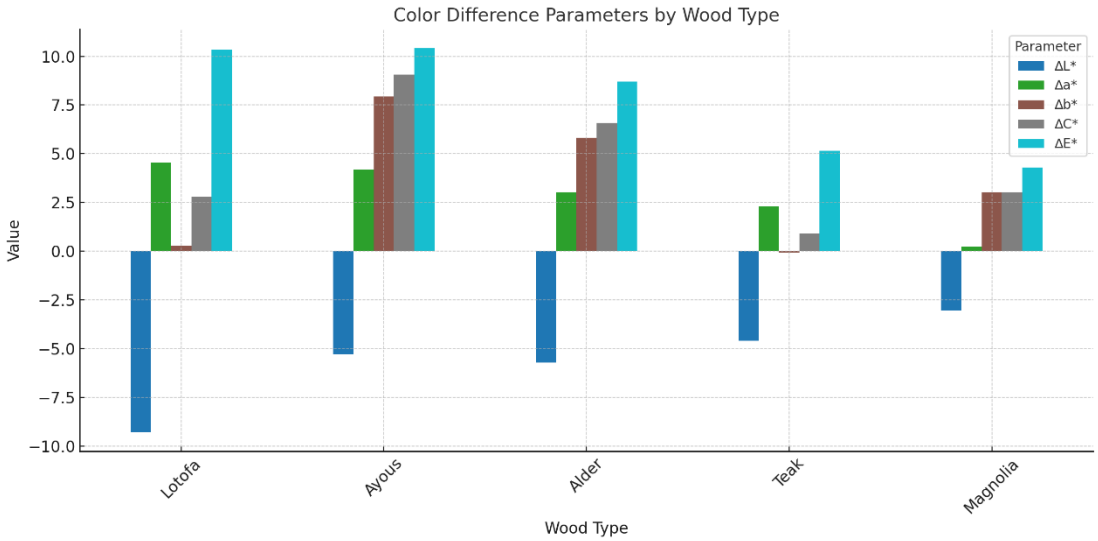

Figure 1. Visual comparison of ΔE^* values among wood species

Table 4 displays the variance analysis results for the L^* parameter. The findings indicate significant influences from all factors and their interaction (Table 4).

Table 4

The variance analysis results of L* parameter

Source	Sum of Squares	Degree of Freedom	Mean Square	F Value	Sig
Wood Type (A)	5340.918	4	1335.230	646.432	0.000*
Application (B)	781.706	1	781.706	378.451	0.000*
Interaction (AB)	105.870	4	26.468	12.814	0.000*
Error	185.898	90	2.066		
Total	352743.112	100			
Corrected Total	6414.392	99			
*: Significant					

Table 5 outlines the findings for the *L** parameter. In ayous wood, following the application of Arabic gum, the *L** value decreased from 68.52 to 63.22, representing a 7.73% reduction. The treated samples displayed lower consistency and higher variation. For alder wood, the *L** value declined from 69.95 to 64.23, corresponding to an 8.18% reduction, with homogeneity remaining stable, though variation increased. Lotofa wood exhibited a more substantial decline in *L** value, from 54.36 to 45.08, a decrease of 17.07%. Both homogeneity and variation decreased in the treated samples. Magnolia wood showed a slight reduction in *L** value from 62.19 to 59.14, a 4.90% drop, with decreased homogeneity and increased variation. Finally, teak wood saw its *L** value fall from 53.21 to 48.60, an 8.66% reduction, with treated samples showing an increase in variation (Table 5). The results associated with the *L** parameter are presented in the graphical format in Figure 2.

Table 5

The results of L* parameter (One-Way-ANOVA)

Wood Type	Appli-cation	Mean	Change (%)	Homogeneity Group	Mini-mum	Maxi-mum	Standard Deviation	Coefficient of Variation
Ayous	No	68.52	↓7.73	B	1.21	65.91	70.60	1.76
	Yes	63.22		CD	3.49	58.17	67.20	5.51
Alder	No	69.95	↓8.18	A*	0.14	69.77	70.14	0.20
	Yes	64.23		C	1.77	61.29	66.06	2.76
Lotofa	No	54.36	↓17.07	F	0.64	53.11	55.01	1.18
	Yes	45.08		H**	1.42	42.86	47.03	3.15
Magnolia	No	62.19	↓4.90	D	0.46	61.58	63.04	0.74
	Yes	59.14		E	0.94	58.12	60.43	1.58
Teak	No	53.21	↓8.66	F	0.29	52.72	53.61	0.55
	Yes	48.60		G	0.55	47.77	49.41	1.13
Number of Measurements: 10, *: Highest value, **: Lowest value								

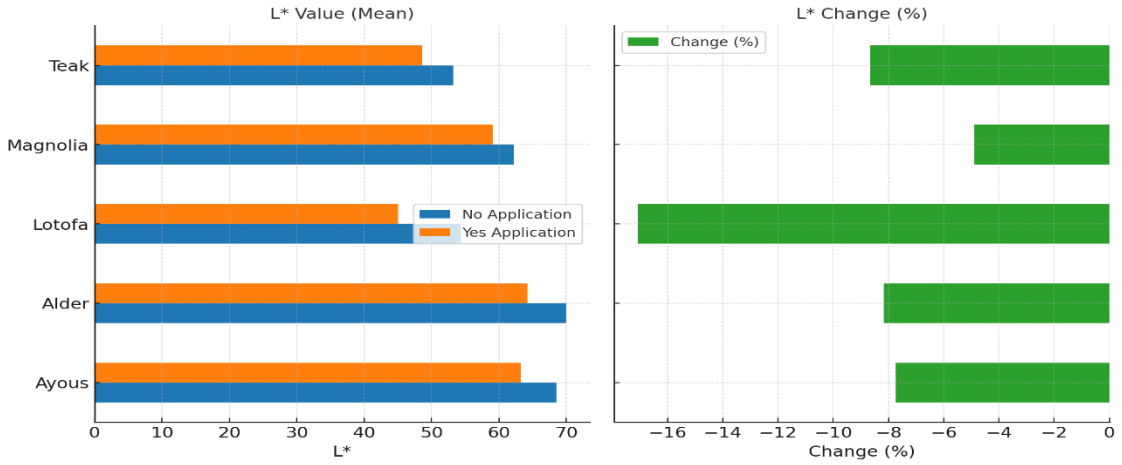

Figure 2. Chart illustrating the outcomes for the *L** parameter

Table 6 displays the variance analysis results for the *a** parameter. The analysis indicates that all factors and their interaction have significant effects (Table 6).

Table 6

The variance analysis results of a* parameter

Source	Sum of Squares	Degree of Freedom	Mean Square	F Value	Sig
Wood Type (A)	1256.827	4	314.207	2319.093	0.000*
Application (B)	205.234	1	205.234	1514.791	0.000*
Interaction (AB)	58.978	4	14.745	108.826	0.000*
Error	12.194	90	0.135		
Total	10712.023	100			
Corrected Total	1533.233	99			
*: Significant					

Table 7 displays the results for the *a** parameter. In ayous wood, after the application of Arabic gum, the *a** value rose from 7.21 to 11.41, marking an increase of 58.25%. The treated samples showed improved homogeneity and reduced variation. In alder wood, the *a** value increased from 8.83 to 11.86, a 34.31% increase, with homogeneity improving, although variation also increased. For lotofa wood, the *a** value went up from 11.80 to 16.35, reflecting a 38.56% rise, accompanied by an increase in both homogeneity and variation. In Magnolia wood, the *a** value rose slightly from 3.12 to 3.37, a modest 8.01% increase, but homogeneity remained low and variation increased. In teak wood, the *a** value showed a 23.39% increase, rising from 9.79 to 12.08 (Table 7). A graphical interpretation of the *a** parameter data is shown in Figure 3.

Table 7

The results of a* parameter (One-Way-ANOVA)

Wood Type	Appli-cation	Mean	Change (%)	Homogeneity Group	Mini-mum	Maxi-mum	Standard Deviation	Coefficient of Variation
Ayous	No	7.21	↑58.25	F	0.29	6.78	7.62	4.08
	Yes	11.41		C	0.31	11.09	11.91	2.68
Alder	No	8.83	↑34.31	E	0.17	8.62	9.11	1.96
	Yes	11.86		B	0.55	11.25	12.66	4.60
Lotofa	No	11.80	↑38.56	B	0.25	11.33	12.16	2.09
	Yes	16.35		A*	0.49	15.66	17.13	3.01
Magnolia	No	3.12	↑8.01	G**	0.22	2.86	3.43	6.92
	Yes	3.37		G	0.14	3.15	3.68	4.10
Teak	No	9.79	↑23.39	D	0.32	9.16	10.22	3.29
	Yes	12.08		B	0.61	11.07	12.73	5.08
Number of Measurements: 10, *: Highest value, **: Lowest value								

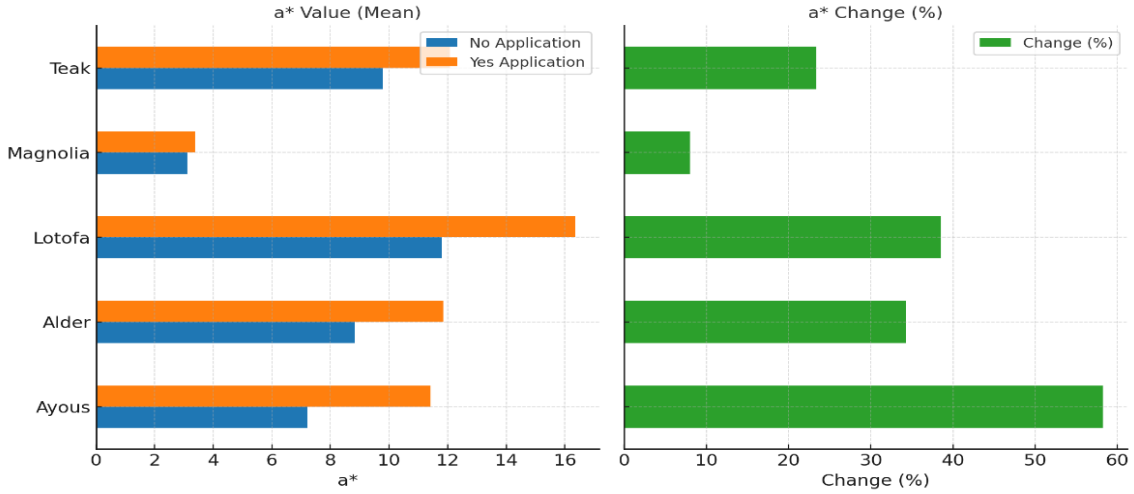

Figure 3. Visual depiction of *a** parameter measurements

Table 8 outlines the variance analysis results for the *b** parameter, indicating that all factors and their interactions have a statistically significant effect (Table 8).

Table 8

The variance analysis results of b* parameter

Source	Sum of Squares	Degree of Freedom	Mean Square	F Value	Sig
Wood Type (A)	1046.678	4	261.670	1254.293	0.000*
Application (B)	288.864	1	288.864	1384.648	0.000*
Interaction (AB)	240.280	4	60.070	287.941	0.000*
Error	18.776	90	0.209		
Total	53349.938	100			
Corrected Total	1594.598	99			
*: Significant					

Table 9 presents the results for the *b** parameter. In ayous, following the application of Arabic gum, the *b** value rose from 23.57 to 31.50, marking a 33.64% increase. The treated samples showed higher homogeneity and lower variation. For alder, the *b** value increased from 20.88 to 26.69, a 27.83% rise, with homogeneity improving, but variation also increasing. In lotofa, the *b** value went up slightly from 20.70 to 21.00, an increase of 1.45%, while homogeneity remained unchanged. Magnolia showed an 18.46% increase in the *b** value, from 16.36 to 19.38, but with a decrease in homogeneity and an increase in variation. Lastly, in teak, the *b** value slightly decreased from 23.75 to 23.68, a 0.29% decrease (Table 9). Figure 4 conveys the graphical evaluation of the *b** parameter results.

Table 9

The results of b* parameter (One-Way-ANOVA)

Wood Type	Appli-cation	Mean	Change (%)	Homogeneity Group	Mini-mum	Maxi-mum	Standard Deviation	Coefficient of Variation
Ayous	No	23.57	↑33.64	C	0.63	22.30	24.39	2.69
	Yes	31.50		A*	0.48	30.73	32.00	1.54
Alder	No	20.88	↑27.83	D	0.16	20.51	21.06	0.75
	Yes	26.69		B	0.50	25.92	27.31	1.88
Lotofa	No	20.70	↑1.45	D	0.49	19.88	21.27	2.38
	Yes	21.00		D	0.56	20.31	21.79	2.68
Magnolia	No	16.36	↑18.46	F**	0.15	16.16	16.62	0.90
	Yes	19.38		E	0.63	18.46	20.28	3.26
Teak	No	23.75	↓0.29	C	0.14	23.58	23.96	0.57
	Yes	23.68		C	0.42	22.87	24.25	1.77
Number of Measurements: 10, *: Highest value, **: Lowest value								

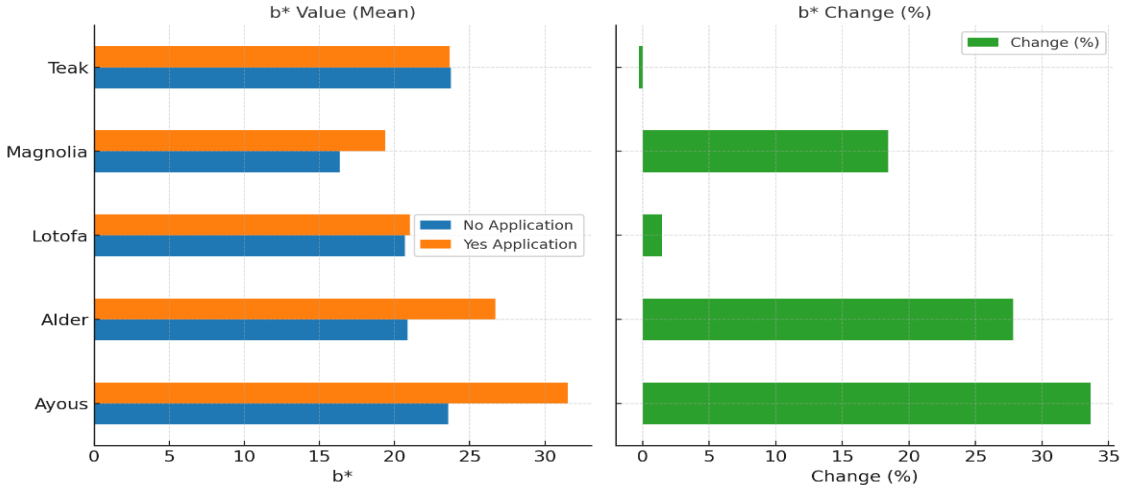

Figure 4. Graph-based overview of the *b** parameter data

Table 10 presents the results of the variance analysis for the *C** parameter. The analysis shows significant effects for all the factors and their interaction evaluated (Table 10).

Table 10

The variance analysis results of C* parameter

Source	Sum of Squares	Degree of Freedom	Mean Square	F Value	Sig
Wood Type (A)	1294.036	4	323.509	1426.982	0.000*
Application (B)	499.835	1	499.835	2204.749	0.000*
Interaction (AB)	215.972	4	53.993	238.161	0.000*
Error	20.404	90	0.227		
Total	63991.912	100			
Corrected Total	2030.247	99			
*: Significant					

The results for the *C** parameter are presented in Table 11. In the ayous species, after the application of Arabic gum, the *C** value increased from 24.44 to 33.51, showing a 37.11% increase. In this species, the samples with gum application exhibited higher homogeneity and lower variation. In the alder species, the *C** value increased from 22.67 to 29.25, resulting in a 29.03% increase. However, greater variation was observed in the samples with gum application. In the lotofa species, the *C** value rose from 23.83 to 26.62, indicating an 11.71% increase. Homogeneity improved and variation decreased in this species as well. In the Magnolia species, the *C** value increased from 16.66 to 19.68, showing an 18.13% increase. However, homogeneity decreased while variation increased. In the teak species, the *C** value increased from 25.69 to 26.59, which represents a 3.50% increase (Table 11). The representation of the *C** parameter findings is charted in Figure 5.

Table 11

The results of C* parameter (One-Way-ANOVA)

Wood Type	Appli-cation	Mean	Change (%)	Homogeneity Group	Mini-mum	Maxi-mum	Standard Deviation	Coefficient of Variation
Ayous	No	24.44	↑37.11	E	0.85	22.53	25.55	3.49
	Yes	33.51		A*	0.42	32.80	33.93	1.27
Alder	No	22.67	↑29.03	G	0.15	22.35	22.92	0.67
	Yes	29.25		B	0.58	28.51	30.10	1.97
Lotofa	No	23.83	↑11.71	F	0.48	23.21	24.50	2.03
	Yes	26.62		C	0.21	26.32	26.95	0.80
Magnolia	No	16.66	↑18.13	I**	0.14	16.43	16.86	0.86
	Yes	19.68		H	0.62	18.77	20.55	3.15
Teak	No	25.69	↑3.50	D	0.21	25.34	25.99	0.80
	Yes	26.59		C	0.52	25.66	27.30	1.97
Number of Measurements: 10, *: Highest value, **: Lowest value								

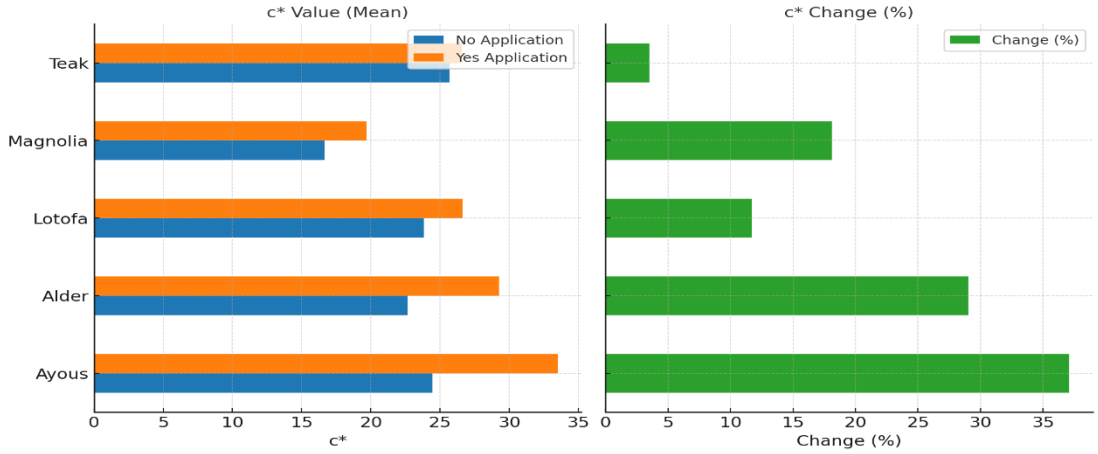

Figure 5. Display of *C** parameter values in graphical format

Table 12 presents the variance analysis results for the h^o parameter. The findings indicate that all factors and their interactions have significant effects (Table 12).

Table 12

The variance analysis results of h^o parameter

Source	Sum of Squares	Degree of Freedom	Mean Square	F Value	Sig
Wood Type (A)	5951.918	4	1487.979	2186.029	0.000*
Application (B)	258.824	1	258.824	380.245	0.000*
Interaction (AB)	240.659	4	60.165	88.390	0.000*
Error	61.261	90	0.681		
Total	466676.811	100			
Corrected Total	6512.662	99			
*: Significant					

The results for the h^o parameter are shown in Table 13. In the ayous species, the h^o value decreased from 73.05 to 70.08 after applying Arabic gum, indicating a 4.07% reduction. Additionally, the homogeneity decreased, and the variation increased in the gum-treated samples. In the alder species, the h^o value decreased from 67.07 to 65.87, resulting in a 1.79% decrease, and again, lower homogeneity was observed in the treated samples. For lotofa, the h^o value significantly dropped from 60.30 to 52.09, a reduction of 13.62%, with a notable decrease in homogeneity. In the Magnolia species, the h^o value slightly increased from 79.20 to 80.12, showing a 1.16% improvement, and homogeneity remained high. Finally, in teak, the h^o value decreased from 67.60 to 62.98, a 6.83% decrease, with a corresponding decrease in homogeneity (Table 13). Findings related to the $h°$ parameter are illustrated using visual tools in Figure 6.

Table 13

The results of h^o parameter (One-Way-ANOVA)

Wood Type	Appli-cation	Mean	Change (%)	Homogeneity Group	Mini-mum	Maxi-mum	Standard Deviation	Coefficient of Variation
Ayous	No	73.05	↓4.07	C	0.36	72.50	73.77	0.50
	Yes	70.08		D	0.66	69.11	70.84	0.94
Alder	No	67.07	↓1.79	E	0.45	66.56	67.63	0.67
	Yes	65.87		F	0.86	64.62	67.11	1.30
Lotofa	No	60.30	↓13.62	H	0.64	58.89	60.82	1.05
	Yes	52.09		I**	1.54	49.86	54.20	2.96
Magnolia	No	79.20	↑1.16	B	0.75	78.05	80.23	0.95
	Yes	80.12		A*	0.53	79.51	80.78	0.66
Teak	No	67.60	↓6.83	E	0.63	66.67	68.80	0.93
	Yes	62.98		G	1.14	61.74	65.46	1.80
Number of Measurements: 10, *: Highest value, **: Lowest value								

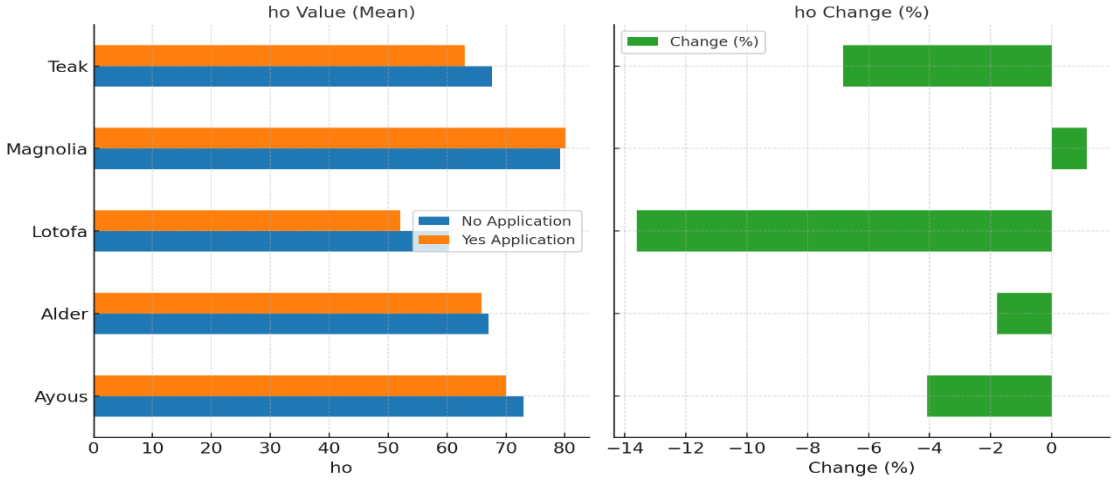

Figure 6. Graphical layout of $h°$ parameter results

In the study conducted by Ulay and Ayata (2025), it has been reported that the application of gum Arabic for color change on loquat, santos, sapele, and mahogany woods resulted in changes in their parameters.

The interaction of wood with natural resins such as gum Arabic varies depending on the structural properties and components of the wood. Wood is primarily composed of three main components: cellulose, hemicellulose, and lignin. Gum Arabic interacts with cellulose, which can smooth the wood surface and create a more homogeneous texture. Hemicellulose, which provides flexibility to the wood, can influence the balance of moisture on the surface when interacting with gum Arabic, potentially leading to changes in color or appearance over time. Lignin, a dark-colored compound responsible for the rigidity of the wood, can deepen the wood's color when interacting with gum Arabic. This interaction can also alter the surface's glossiness and matte properties. As a result, gum Arabic, through its interaction with the structural components of wood, can bring about both aesthetic and functional changes.

CONCLUSIONS

After application, all wood species experienced a darkening effect (decrease in L^*) and a reddening effect (increase in a^*), with the most significant changes observed in lotofa and the least in Magnolia. The b^* values generally increased, indicating a shift toward more yellow tones, except for teak, where it remained almost unchanged. The C^* increased for all species, with the most notable increase in ayous, while the $h°$ shifted toward warmer tones in most species, except Magnolia, which shifted slightly toward cooler tones.

To evaluate the stability of color changes over time, natural or artificial aging tests can be conducted. It is recommended to investigate the effects of outdoor environmental conditions, such as UV light and humidity.

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