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Determination of optical properties of ovangkol (Guibourtia ehie (a.chev.) j.léonard) wood treated with oxalic acid and hydrogen peroxide

Oksalik asit ve hidrojen peroksit ile işlem görmüş ovangkol (Guibourtia ehie (a.chev.) j.léonard) odununun optik özelliklerinin belirlenmesi

Ümit AYATA *[1] Osman ÇAMLIBEL[2]

[1] Bayburt University, Faculty of Art and Design, Department of Interior Architecture and Environmental Design, Bayburt
[2] Kırıkkale University, Kırıkkale Vocational School, Furniture and Decoration Program, Kırıkkale

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Abstract

Ovangkol wood, an exotic wood species, is becoming valuable in the woodworking industries, particularly in the furniture sector. Bleaching treatments alter the color of the wood. In this study, changes in certain surface properties [whiteness index (*WI**), glossiness, and color parameters (lightness (*L**), red color (*a**) tone, yellow color (*b**) tone, chroma (*C**), and hue angle (*h*°))] were investigated by applying two different bleaching chemicals [oxalic acid ($C_2H_2O_4$) and hydrogen peroxide (H_2O_2) + sodium hydroxide (NaOH)] on ovangkol (*Guibourtia ehie* (A.Chev.) J.Léonard) wood surfaces. According to the results, increases in *WI** in the parallel direction and all color parameters were observed with the $C_2H_2O_4$ chemical. Additionally, with the NaOH + H_2O_2 solution, increases in *L** and *h*° values were achieved, while decreases in *a**, *C**, and *b** parameters were observed. When using the $C_2H_2O_4$ chemical, the Δ*E** value was recorded as 4.25, whereas it was determined as 13.14 for treatments with solutions containing H_2O_2 + NaOH. Positive changes in Δ*L** values were observed with both chemicals. However, positive Δ*a**, Δ*b**, and Δ*C** values were observed with the $C_2H_2O_4$ chemical, while these values were negative with the NaOH + H_2O_2 solution. The glossiness values decreased at both 60° and 85° angles regardless of whether the bleaching agents were applied parallel or perpendicular to the wood fibers.

Özet

Bir egzotik ağaç türü olan ovangkol odunu başta mobilya sektörü olmak üzere ahşap işleyen endüstri alanlarında değerli bir tür olma yolundadır. Ağartma işlemleri ile ahşabın rengi değişmektedir. Bu araştırmada, ovangkol (*Guibourtia ehie* (A.Chev.) J.Léonard) odununun yüzeylerinde 2 farklı ağartma kimyasallarının [oksalik asit ($C_2H_2O_4$) ve hidrojen peroksit (H_2O_2) + sodyum hidroksit (NaOH)] uygulanması ile bazı yüzey özelliklerindeki [beyazlık indeksi (*WI**), parlaklık ve renk parametreleri (ışıklılık (*L**), kırmızı (*a**) renk tonu, sarı (*b**) renk tonu, kroma (*C**) değeri ve ton açısı (*h*°)] meydana gelen değişimler araştırılmıştır. Sonuçlara göre, $C_2H_2O_4$ kimyasalı ile *WI** ‖ yönde ve bütün renk parametrelerinde artışlar tespit edilmiştir. Buna ek olarak, NaOH + H_2O_2 çözeltisi ile *L** ve *h*° değerlerinde artışlar elde edilirken, *a**, *C** ve *b** parametrelerinde azalışlar görülmüştür. $C_2H_2O_4$ kimyasalı kullanıldığında Δ*E** değeri 4.25 olarak kaydedilirken, H_2O_2 + NaOH içeren çözeltilerle yapılan işlemler sonucunda Δ*E** değeri 13.14 olarak belirlenmiştir. Her iki kimyasalda da Δ*L** değerlerinde pozitif değişimler gözlemlenmiştir. Bununla birlikte, $C_2H_2O_4$ kimyasalıyla Δ*a**, Δ*b** ve Δ*C** değerlerinin pozitif olduğu görülürken, NaOH + H_2O_2 çözeltisi kullanıldığında bu değerlerin negatif olduğu gözlemlenmiştir. Her iki ağartma maddesinin ahşap yüzeylerine uygulanması ile parlaklık değerleri, liflere paralel veya dik yönde tespit edilmiş olmasına bağlı olmaksızın, hem 60° hem de 85 ° de azalmıştır.

INTRODUCTION

Bleaching refers to the elimination of natural color pigments from wood using various oxidizing and reducing agents. This method should be reserved for situations where it is absolutely essential, as it often diminishes the inherent beauty and vibrant look of veneered or solid wood. Recently, the importance of bleaching has increased, and it is commonly used on hardwoods such as walnut, oak, ash, and birch (Kurtoğlu 2000).

Bleaching is performed for various purposes, including the following: ensuring color uniformity across all parts that make up the furniture, enhancing the color, grain, and texture of the wood by removing the causes of color darkening, lightening wood that has been previously stained with dark tones to achieve the desired lighter shades, maintaining color consistency to prevent color variations in furniture produced at different times, enabling the production of desired colors, and indirectly increasing marketing opportunities, preventing unwanted discoloration resulting from the interaction between natural wood pigments and paint pigments, achieving color stability by reducing the likelihood of color changes over time due to wood by-products and extractives, and eliminating undesirable color changes caused by blue mold and fungi (Sönmez 2005).

Today, a range of chemicals is employed for wood bleaching, such as oxalic acid ($C_2H_2O_4$), hydrogen peroxide (H_2O_2), and sodium hydroxide (NaOH).

Wastewater from oxalic acid activation is considered more environmentally friendly than that from inorganic acids because it can break down through microbiological and photochemical processes (Taxiarchou and Douni 2014). Oxalic acid (HOOC-COOH) is a reducing agent and a carboxylic acid. Chemically, there are at least two possible bleaching mechanisms. One involves the acidic hydrolysis of ester groups, such as those found in lignin, which is catalyzed by the acidic oxalic acid. This reaction produces an alcohol and a carboxylic acid (Herstedt and Herstedt 2017).

Sodium hydroxide (NaOH) in solution is a white, odorless, and non-volatile liquid. While it does not catch fire, it is extremely reactive and can react explosively with water and other materials, generating sufficient heat to ignite adjacent flammable substances. A key benefit of NaOH is its ability to interact easily with water, enhancing its role as a compaction aid and achieving higher density with the same compactive effort. It is also notably effective when applied to soils containing high levels of aluminum (Alshaaer 2000, Olaniyan 2008, Olaniyan et al. 2011).

NaOH aqueous solutions interact with cellulose to form a Na^+/water and cellulose system, which develops stable hydrogen-bonded networks. These networks can break up the tightly packed cellulose chains and prevent their polymerization. The treatment with alkali reduces the length of molecular chains, leading to a minor decrease in the uniformity of cell structures, crystallinity, and crystal grains. This process allows chemical reagents to more easily penetrate the cellulose fibers while preserving their chemical makeup. Furthermore, the degree of cellulose swelling increases as the temperature drops (Jiao and Xiong 2014).

Hydrogen peroxide is extensively utilized as a bleaching agent, particularly in the textile industry, as well as in pulp and paper processing and domestic laundry. It reacts with various substances like carbonates, borates, pyrophosphates, and sulfates to create peroxyhydrates or peroxy compounds (Farr et al. 2003).

The bleaching pretreatment applied in wood veneer painting is thought to remove the color disparity between earlywood and latewood, produce a lighter substrate, create a more consistent stain color, and minimize variations within the same batch (Liu et al. 2015). In the literature, it was reported that bleaching processes were conducted on various wood species using oxalic acid ($C_2H_2O_4$) and sodium hydroxide (NaOH) + hydrogen peroxide (H_2O_2) + chemicals. Some of these studies are provided in Table 1.

In these studies, (Table 1), it was reported that the total color difference values were higher with the H_2O_2 + NaOH solution compared to the $C_2H_2O_4$ chemical. Sodium hydroxide, a potent alkaline chemical, is used for wood pulping and in certain paint removers (Williams 2010). In the literature, it is observed that no bleaching process has been carried out on ovangkol wood, a valuable wood species in the furniture industry.

Ovangkol (*Guibourtia ehie* (A. Chev.) J. Léonard (*Fabaceae*, *Detarioideae*)) is classified under the subfamily *Caesalpinioideae*. It is native to tropical Africa, with its range extending across Cameroon, Liberia, Ivory Coast, Ghana, Gabon, and Nigeria. This species thrives in closed rainforests and transitional forests (WCMC 1991). It is commonly found in evergreen and semi-deciduous moist forests stretching from Liberia to Gabon (Tosso et al. 2016). In Ghana, this species thrives successfully in the drier areas of moist mixed forests (Hawthorne 1995). Its official commercial names include *Guibourtia ehie*, *Copaifera ehie* A. Chev., and Kévazingo. Local names in Gabon include Ovengkol (Fang), Amazone; Hyedua ovengkol (Cameroon, Gabon); amazakou; Amazou, Whimawe (Ivory Coast); mongoy (Gambia); anokye, ehie, hyeduanini, hyedun (Ghana). The timber is employed in the creation of top-notch furniture, carpentry work, woodturning, ornamental veneers, and flooring (Raponda-Walker and Sillans 1961, White and Abernethy 1996).

In light of the information provided above, ovangkol wood emerges as a valuable timber species used in various woodworking industries. This study investigates some surface changes occurring after bleaching application on ovangkol (*Guibourtia ehie* (A.Chev.) J.Léonard) wood. The obtained results were aimed at creating a new potential for usage areas of the wood species.

Table 1. Studies on bleaching by using $C_2H_2O_4$ and H_2O_2 + NaOH.

Wood type	Bleaching chemical type	Change for color parameters *L**	*a**	*b**	*C**	*h°*	Reference
Cocobolo	$C_2H_2O_4$	↓	↓	↓	↓	↓	Çamlıbel and Ayata (2024b)
	H_2O_2 + NaOH	↑	↓	↑	↑	↑	
Basralocus	$C_2H_2O_4$	↑	↑	↑	↑	↑	Ayata and Bal (2024)
	H_2O_2 + NaOH	↑	↓	↑	↑	↑	
Okoumé	$C_2H_2O_4$	↑	↑	↑	↑	↓	Çamlıbel and Ayata (2024a)
	H_2O_2 + NaOH	↑	↓	↓	↓	↑	
Balau red	$C_2H_2O_4$	↓	↓	↓	↓	↑	Peker et al. (2024)
	H_2O_2 + NaOH	↑	↓	↑	↑	↑	
Amazon Rosewood	$C_2H_2O_4$	↓	↑	↑	↑	↑	Ayata et al. (2024a)
	H_2O_2 + NaOH	↑	↓	↑	↑	↑	
Ayous	$C_2H_2O_4$	↑	↓	↑	↓	↑	Ayata et al. (2024b)
	H_2O_2 + NaOH	↑	↓	↓	↓	↑	
Bulletwood	$C_2H_2O_4$	↑	↑	↑	↑	↓	Peker et al. (2023a)
	H_2O_2 + NaOH	↑	↓	↑	↑	↑	
Movingui	$C_2H_2O_4$	↑	↑	↑	↑	↑	Peker et al. (2023b)
	H_2O_2 + NaOH	↑	↓	↑	↑	↑	
Satinwood ceylon	$C_2H_2O_4$	↓	↓	↑	↓	↑	Ayata and Çamlıbel (2023)
	H_2O_2 + NaOH	↑	↓	↓	↓	↑	
Ilomba	$C_2H_2O_4$	↑	↑	↑	↑	↑	Ayata and Bal (2023)
	H_2O_2 + NaOH	↑	↓	↓	↓	↑	
Olon	$C_2H_2O_4$	↑	↑	↑	↑	↑	Peker and Ayata (2023)
	H_2O_2 + NaOH	↑	↓	↓	↓	↑	
Canelo	$C_2H_2O_4$	↑	↑	↑	↑	↑	Peker (2023a)
	H_2O_2 + NaOH	↑	↑	↑	↑	↑	
Lotofa	$C_2H_2O_4$	↑	↓	↑	↑	↑	Peker (2023b)
	H_2O_2 + NaOH	↑	↓	↓	↓	↑	
Black locust	$C_2H_2O_4$	↑	↓	↑	↓	↑	Peker and Ulusoy (2023)
	H_2O_2 + NaOH	↑	↓	↓	↓	↓	
Linden	$C_2H_2O_4$	↓	↑	↑	↑	↓	Çamlıbel and Ayata (2023a)
	H_2O_2 + NaOH	↑	↓	↓	↓	↑	
Ekop	$C_2H_2O_4$	↓	↑	↑	↑	↑	Çamlıbel and Ayata (2023b)
	H_2O_2 + NaOH	↑	↓	↑	↑	↑	
İzombé	$C_2H_2O_4$	↓	↑	↑	↑	↑	Peker et al. (2023c)
	H_2O_2 + NaOH	↑	↓	↑	↑	↑	

MATERIAL AND METHOD

Material

In this research, ovangkol (*Guibourtia ehie* (A.Chev.) J.Léonard) wood was utilized as the primary material. The wood samples were procured from a commercial supplier, ensuring top-notch quality, and measured 100 mm x 100 mm x 15 mm. Following this, the samples were prepared according to ISO 554 (1976) standard.

Prior to the bleaching process, the test samples underwent sanding with 80, 120, and 180 grits, and the surfaces were thoroughly cleaned using compressed air.

In this study, two distinct bleaching agents were employed: a water-based single-component bleaching agent [oxalic acid ($C_2H_2O_4$)] and a double-component bleaching agent [A: hydrogen peroxide (H_2O_2) and B: sodium hydroxide (NaOH), mixed in a ratio of 2:1]. The study procured the chemicals from a specialized company known for selling wood bleaching agents.

Method

Application of Bleaching Chemicals to Wood Material Surfaces

The bleaching chemicals were administered onto the surfaces of the wooden material using a brush sponge. After the bleaching process, a natural drying period of 2 weeks was allowed.

Determination of Optical Properties

Glossiness was measured using the ETB-0833 gloss meter according to ISO 2813 (1994), at angles of 20°, 60°, and 85°, in both perpendicular (⊥) and parallel (∥) orientations to the wood grain.

The whiteness index (*WI**) was assessed with the Whiteness Meter BDY-1, following ASTM E313-15e1 (2015).

Color changes were analyzed with the CS-10 colorimeter (CHN Spec, China), based on the CIELAB color system, adhering to ASTM D 2244-3 (2007) standards. The measurements were taken under CIE 10° standard observer conditions and CIE D65 light source, using an 8/d (8°/diffuse illumination) lighting setup.

In the CIELAB system, the *L** axis indicates lightness, ranging from 100 (white) to 0 (black), while the *a* and *b* axes represent chromaticity coordinates: +*a* for red, -*a* for green, +*b* for yellow, and -*b* for blue. The *a**, *L**, and *b** values are utilized to compute the total color difference, Δ*E**. Consequently, the color variation between two samples can be accurately assessed using the DIN 6174 (1979) equation (Hauptmann et al. 2012). The absolute values (Δ*E**) of color difference for visual assessment are outlined in comparison criteria (DIN 5033 1979) in Table 2.

Table 2. Comparison criteria for evaluating Δ*E** values.

Δ*E values**	**Visual color score difference**
<0.20	Imperceptible
0.20 - 0.50	Very weak
0.50 - 1.50	Weak
1.50 - 3.00	Noticeable
3.00 - 6.00	Very noticeable
6.00 - 12.00	Strong
> 12.00	Very strong

The total color differences were calculated using the formulas listed below (Çamlıbel and Ayata 2024a, b):

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

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

$$\Delta C^* = (C^*_{\text{bleached test sample}} - C^*_{\text{unbleached test sample}}) \quad (3)$$

$$\Delta a^* = (a^*_{\text{bleached test sample}} - a^*_{\text{unbleached test sample}}) \quad (4)$$

$$\Delta L^* = (L^*_{\text{bleached test sample}} - L^*_{\text{unbleached test sample}}) \quad (5)$$

$$\Delta b^* = (b^*_{\text{bleached test sample}} - b^*_{\text{unbleached test sample}}) \quad (6)$$

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

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

The definitions of Δ*a**, Δ*C**, Δ*H**, Δ*b**, and Δ*L** are provided below (Lange 1999).

Δ*L**: Negative sample is darker than the reference and positive sample is lighter than the reference,

Δ*a**: Negative sample is greener than the reference and positive sample is redder than the reference,

Δ*b**: Negative sample is more blue than the reference and positive sample is more yellow than the reference,

Δ*C**: Chroma or saturation difference, positive sample is clearer and brighter than the reference and negative sample is duller than the reference,

Δ*H**: Hue or shade difference.

Calculation of Test Data with Statistical Analysis

Upon analyzing the data obtained from the study using a statistical software, various parameters including maximum and minimum values, standard deviations, means, homogeneity groups, analysis of variances, and percentage (%) change rates were computed.

RESULT AND DISCUSSION

The results of the analysis of variance are shown in Table 3. These results indicate that there were significant differences in the whiteness index (*WI**) values for both the perpendicular (⊥) and parallel (∥) orientations, as detailed in Table 3.

The measurement results for the whiteness index (*WI**) values are presented in Table 4.

For the results obtained for *WI** values in the perpendicular direction (*WI** ⊥), the lowest value (14.42) was observed on samples bleached with $C_2H_2O_4$ chemical, while the highest value (28.36) was found on samples treated with NaOH + H_2O_2 chemical (Table 4).

Table 3. The outcomes of analysis of variance for whiteness index (*WI**) values

Source	Dependent variable	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
Bleaching chemical type	*WI** perpendicular to fibers	1207.635	2	603.817	10292.341	0.000*
	*WI** parallel to fibers	1061.139	2	530.569	4320.076	0.000*
Error	*WI** perpendicular to fibers	1.584	27	0.059		
	*WI** parallel to fibers	3.316	27	0.123		
Total	*WI** perpendicular to fibers	12507.780	30			
	*WI** parallel to fibers	6569.820	30			
Corrected total	*WI** perpendicular to fibers	1209.219	29			
	*WI** parallel to fibers	1064.455	29			

*: Significant

Table 4. The measurement results for whiteness index (*WI**) values

Test	Chemical type	N	Mean	Change (%)	*HG*	Standard deviation	Minimum	Maximum	COV
*WI** (⊥)	Control	10	15.44	-	B	0.27	15.00	15.70	1.76
	$C_2H_2O_4$	10	14.42	↓6.61	C**	0.17	14.20	14.60	1.17
	NaOH + H_2O_2	10	28.36	↑83.68	A*	0.27	28.10	28.80	0.96
*WI** (‖)	Control	10	8.88	-	C**	0.13	8.70	9.00	1.48
	$C_2H_2O_4$	10	9.82	↑10.59	B	0.41	9.20	10.30	4.15
	NaOH + H_2O_2	10	21.94	↑147.07	A*	0.43	21.20	22.40	1.96

HG: Homogeneity group, COV: Coefficient of variation, N: Number of measurements, *: Highest value, **: Lowest value

As for the results obtained for *WI** values in the parallel direction (*WI** ‖), the highest value (21.94) was seen on samples bleached with NaOH + H_2O_2 chemical, whereas the lowest value (8.88) was obtained on control experiment samples. Improvements in the *WI** ‖ values were observed with the utilization of both bleaching chemicals investigated in the study (10.59% with $C_2H_2O_4$ and 147.07% with NaOH + H_2O_2) (Table 4).

Table 5 presents the outcomes of the variance analyses conducted for glossiness values. When examining the bleaching method, it was noted that glossiness values obtained from measurements parallel to the fibers at 20 degrees were deemed nonsensical. However, significant glossiness values were obtained for measurements conducted at all other degrees and directions (Table 5).

Measurement results for glossiness values are provided in Table 6. Glossiness values decreased at 60 and 85 degrees, whether measured parallel or perpendicular to the fibers, following the application of both bleaching agents to the wooden surfaces. Notably, the control group, which did not undergo bleaching treatment, yielded the highest results in these tests. The lowest values at 60 degrees in both directions occurred when using the $C_2H_2O_4$ chemical on the wooden material. As for glossiness values measured at 20 degrees, decreases were noted in the perpendicular direction to the fibers with both bleaching chemicals, while increases were observed in the parallel direction (Table 6).

The variance analysis results calculated for the color parameters are provided in Table 7. Based on these results, noteworthy findings were derived for the lightness (*L**) value, chroma (*C**) value, yellow (*b**) color tone value, red (*a**) color tone value, and hue (*h*°) angle value (Table 7).

The measurement results for the color parameters are provided in Table 8. Samples treated with NaOH + H_2O_2 chemical exhibited highest *L** value (63.28), contrasting with the lowest observed on control samples (50.95). Increases in *L** parameter were observed with both chemicals used in the study (6.97% with $C_2H_2O_4$ and 24.20 % with NaOH + H_2O_2) (Table 8). In the literature, it was reported that bleaching applications using $C_2H_2O_4$ and H_2O_2 + NaOH chemicals resulted in increases in the *L** parameter [bulletwood (Peker et al. 2023a), ilomba (Ayata and Bal 2023), canelo (Peker 2023a), lotofa (Peker 2023b), movingui (Peker et al. 2023b), olon (Peker and Ayata 2023), basralocus (Ayata and Bal 2024), okoumé (Çamlıbel and Ayata 2024a), and ayous (Ayata et al. 2024b)].

The highest *a** value was recorded on samples subjected to bleaching with $C_2H_2O_4$ chemical (7.88), while the lowest was evident on samples treated with NaOH + H_2O_2 chemical (2.61). When $C_2H_2O_4$ chemical was applied to wood material, a 10.52% increase was observed in *a** value, whereas a decrease of 63.39% was found when NaOH + H_2O_2 solution was applied to the wood material (Table 8).

Table 5. The outcomes of analysis of variance for glossiness values

Source	Dependent variable	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
Bleaching chemical type	Glossiness at ⊥20°	0.006	2	0.003	3.857	0.034*
	Glossiness at ⊥60°	2.461	2	1.230	73.984	0.000*
	Glossiness at ⊥85°	80.046	2	40.023	329.759	0.000*
	Glossiness at ‖20°	0.008	2	0.004	2.700	0.085**
	Glossiness at ‖60°	3.926	2	1.963	292.823	0.000*
	Glossiness at ‖85°	140.616	2	70.308	947.263	0.000*
Error	Glossiness at ⊥20°	0.021	27	0.001		
	Glossiness at ⊥60°	0.449	27	0.017		
	Glossiness at ⊥85°	3.277	27	0.121		
	Glossiness at ‖20°	0.040	27	0.001		
	Glossiness at ‖60°	0.181	27	0.007		
	Glossiness at ‖85°	2.004	27	0.074		
Total	Glossiness at ⊥20°	1.110	30			
	Glossiness at ⊥60°	70.710	30			
	Glossiness at ⊥85°	131.710	30			
	Glossiness at ‖20°	1.020	30			
	Glossiness at ‖60°	102.390	30			
	Glossiness at ‖85°	262.620	30			
Corrected total	Glossiness at ⊥20°	0.027	29			
	Glossiness at ⊥60°	2.910	29			
	Glossiness at ⊥85°	83.323	29			
	Glossiness at ‖20°	0.048	29			
	Glossiness at ‖60°	4.107	29			
	Glossiness at ‖85°	142.620	29			

*: Significant, **: Insignificant

Table 6. Statistical analysis results for glossiness values

Test	Chemical Type	N	Mean	Change (%)	*HG*	Standard Deviation	Minimum	Maximum	COV
⊥20°	Control	10	0.20	-	A*	0.00	0.20	0.20	0.00
	$C_2H_2O_4$	10	0.17	↓15.00	B**	0.05	0.10	0.20	28.41
	NaOH + H_2O_2	10	0.20	↓0.00	A*	0.00	0.20	0.20	0.00
⊥60°	Control	10	1.84	-	A*	0.14	1.70	2.10	7.77
	$C_2H_2O_4$	10	1.14	↓38.04	C**	0.05	1.10	1.20	4.53
	NaOH + H_2O_2	10	1.53	↓16.85	B	0.16	1.30	1.70	10.70
⊥85°	Control	10	3.58	-	A*	0.60	2.80	4.40	16.80
	$C_2H_2O_4$	10	0.10	↓97.21	B**	0.00	0.10	0.10	0.00
	NaOH + H_2O_2	10	0.13	↓96.37	B	0.05	0.10	0.20	37.16
‖20°	Control	10	0.16	-	B**	0.05	0.10	0.20	32.27
	$C_2H_2O_4$	10	0.18	↑12.50	AB	0.04	0.10	0.20	23.42
	NaOH + H_2O_2	10	0.20	↑25.00	A*	0.00	0.20	0.20	0.00
‖60°	Control	10	2.22	-	A*	0.04	2.20	2.30	1.90
	$C_2H_2O_4$	10	1.34	↓39.64	C**	0.13	1.20	1.50	9.44
	NaOH + H_2O_2	10	1.87	↓15.77	B	0.05	1.80	1.90	2.58
‖85°	Control	10	5.06	-	A*	0.43	4.30	5.50	8.50
	$C_2H_2O_4$	10	0.56	↓88.93	B	0.14	0.40	0.70	25.53
	NaOH + H_2O_2	10	0.38	↓92.49	B**	0.13	0.20	0.50	34.65

HG: Homogeneity group, COV: Coefficient of variation, N: Number of measurements, *: Highest value, **: Lowest value

In the literature, it was reported that bleaching applications using the chemical $C_2H_2O_4$ resulted in increases in the *a** value, while bleaching applications using H_2O_2 + NaOH chemicals resulted in decreases [izombé (Peker et al. 2023c), ilomba (Ayata and Bal 2023), bulletwood (Peker et al. 2023a), olon (Peker and Ayata 2023), linden (Çamlıbel and Ayata 2023a), ekop (Çamlıbel and Ayata 2023b), movingui (Peker et al. 2023b), basralocus (Ayata and Bal 2024), okoumé (Çamlıbel and Ayata 2024a), and Amazon rosewood (Ayata et al. 2024a)].

Table 7. The outcomes of analysis of variance for color parameters

Source	Dependent variable	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
Bleaching chemical type	*L**	805.416	2	402.708	278.501	0.000*
	*a**	162.437	2	81.219	374.358	0.000*
	*b**	44.311	2	22.156	77.366	0.000*
	*C**	88.796	2	44.398	107.193	0.000*
	h°	1272.430	2	636.215	693.742	0.000*
Error	*L**	39.042	27	1.446		
	*a**	5.858	27	0.217		
	*b**	7.732	27	0.286		
	*C**	11.183	27	0.414		
	h°	24.761	27	0.917		
Total	*L**	95749.459	30			
	*a**	1203.764	30			
	*b**	8647.066	30			
	*C**	9854.930	30			
	h°	154190.298	30			
Corrected total	*L**	844.458	29			
	*a**	168.295	29			
	*b**	52.043	29			
	*C**	99.979	29			
	h°	1297.191	29			

*: Significant

Regarding *b** values, the highest value was attained on samples bleached using $C_2H_2O_4$ chemical (18.61), whereas the nadir was observed on samples treated with NaOH + H_2O_2 chemical (15.78). Upon investigation of *b** parameter, it was noted that application of $C_2H_2O_4$ chemical to wood material yielded a 13.54% augmentation, while application of NaOH + H_2O_2 solution induced a decline of 3.75% in wood material (Table 8). The literature indicates that bleaching with $C_2H_2O_4$ resulted in higher *b** values, while bleaching with H_2O_2 + NaOH led to lower *b** values [ilomba (Ayata and Bal 2023), satinwood ceylon (Ayata and Çamlıbel 2023), olon (Peker and Ayata 2023), black locust (Peker and Ulusoy 2023), lotofa (Peker 2023b), linden (Çamlıbel and Ayata 2023a), okoumé (Çamlıbel and Ayata 2024a), and ayous (Ayata et al. 2024b)].

Table 8. The measurement results for color parameters.

Test	Chemical type	N	Mean	Change (%)	*HG*	Standard deviation	Minimum	Maximum	COV
*L**	Control	10	50.95	-	C**	1.42	49.28	53.13	2.78
	$C_2H_2O_4$	10	54.50	↑6.97	B	0.36	53.95	55.06	0.66
	NaOH + H_2O_2	10	63.28	↑24.20	A*	1.49	60.72	64.90	2.35
*a**	Control	10	7.13	-	B	0.71	6.20	8.30	9.93
	$C_2H_2O_4$	10	7.88	↑10.52	A*	0.25	7.46	8.25	3.23
	NaOH + H_2O_2	10	2.61	↓63.39	C**	0.29	2.14	3.22	11.17
*b**	Control	10	16.39	-	B	0.85	15.28	17.38	5.19
	$C_2H_2O_4$	10	18.61	↑13.54	A*	0.17	18.38	18.86	0.92
	NaOH + H_2O_2	10	15.78	↓3.72	C**	0.32	15.16	16.23	2.06
*C**	Control	10	17.88	-	B	1.05	16.59	19.26	5.88
	$C_2H_2O_4$	10	20.21	↑13.03	A*	0.16	20.05	20.45	0.78
	NaOH + H_2O_2	10	16.01	↓10.46	C**	0.34	15.34	16.41	2.11
h°	Control	10	66.54	-	B**	1.10	64.47	68.29	1.66
	$C_2H_2O_4$	10	67.04	↑0.75	B	0.76	66.13	68.43	1.13
	NaOH + H_2O_2	10	80.60	↑21.13	A*	0.98	78.52	82.06	1.22

HG: Homogeneity group, COV: Coefficient of variation, N: Number of measurements, *: Highest value, **: Lowest value

The highest C^* value was discerned on samples treated with $C_2H_2O_4$ chemical (20.21), in contrast to the lowest observed on samples bleached with NaOH + H_2O_2 chemical (16.01). During the C^* test, it was found that the application of $C_2H_2O_4$ chemical to the wood material led to a 13.03% rise, whereas the utilization of NaOH + H_2O_2 solution resulted in a decline of 10.46% in wood material (Table 8). The literature shows that using $C_2H_2O_4$ for bleaching increased the b^* value, whereas using H_2O_2 + NaOH for bleaching decreased the b^* value [ilomba (Ayata and Bal 2023), lotofa (Peker 2023b), olon (Peker and Ayata 2023), linden (Çamlıbel and Ayata 2023a), and okoumé (Çamlıbel and Ayata 2024a)].

Furthermore, highest h^o value was witnessed on samples treated with NaOH + H_2O_2 chemical (80.60), whereas the lowest was registered on control samples (66.54). Enhancements in the h^o parameter were noted with application of both bleaching chemicals employed in the study (0.75% with $C_2H_2O_4$ and 21.13% with NaOH + H_2O_2) (Table 8). According to the literature, bleaching procedures employing $C_2H_2O_4$ and H_2O_2 + NaOH chemicals yielded higher h^o values [canelo (Peker 2023a), lotofa (Peker 2023b), satinwood ceylon (Ayata and Çamlıbel 2023), ilomba (Ayata and Bal 2023), olon (Peker and Ayata 2023), ekop (Çamlıbel and Ayata 2023b), movingui (Peker et al. 2023b), izombé (Peker et al. 2023c), basralocus (Ayata and Bal 2024), balau red (Peker et al. 2024), Amazon rosewood (Ayata et al. 2024a), and ayous (Ayata et al. 2024b)].

The results for color parameters are provided in Table 9. The ΔE^* value was found to be 4.25 when using the $C_2H_2O_4$ chemical, whereas treatments with solutions prepared using H_2O_2 + NaOH resulted in a ΔE^* value of 13.14. The ΔL^* values were found to be positive (lighter than reference) when both chemicals were used. On the other hand, the Δa^*, Δb^*, and ΔC^* values were positive (in sequence: redder than the reference, more yellow than reference, and clearer and brighter than reference) when using the $C_2H_2O_4$ chemical. Conversely, when using the NaOH + H_2O_2 solution, they were determined to be negative (in sequence: greener than reference, more blue than reference, and duller than reference). According to the color change criteria of DIN 5033 (1979), treatments with $C_2H_2O_4$ resulted in a color change classified as “very noticeable (3.00-6.00)”, while treatments with NaOH + H_2O_2 solution resulted in a color change classified as “very strong (> 12.00)” (Table 9).

In studies conducted in the literature using $C_2H_2O_4$ and H_2O_2 + NaOH, it has been reported that the NaOH + H_2O_2 solution yielded higher ΔE^* values compared to the $C_2H_2O_4$ chemical (Ayata and Çamlıbel 2023, Çamlıbel and Ayata 2023a, b, Peker and Ayata 2023, Peker and Ulusoy 2023, Peker 2023a,b, Peker et al. 2023a,b,c, Ayata and Bal 2023, 2024, Ayata et al. 2024a,b, Çamlıbel and Ayata 2024a,b, and Peker et al. 2024). According to Lu et al. (2023), bleaching treatments conducted on ayous, linden, and poplar woods using the NaOH/H_2O_2/Na_2SiO_3 chemical resulted in increases in brightness and darkness (L^* and h^o values), while the red and a^*, yellow and b^*, and C^* decreased.

Performing the bleaching process again can lead to achieving lighter hues. The timber species determines the susceptibility to color alteration post-bleaching (Anonymous 2017). The objective of chemically bleaching wood is to disturb the conjugated double bonds found in the compounds accountable for coloration. This process doesn't necessarily mandate the breaking of every double bond; rather, it involves halting the exchange of electrons among atoms. This interruption obstructs the absorption of visible light, consequently eradicating the color. Chemical wood bleaching may take place via oxidation (electron loss) or reduction (electron addition) (Kristiansson 2012).

During the bleaching process, quinones, which are part of the lignin groups contributing to color, are oxidized into colorless structures, and the coniferyl aldehyde groups and conjugated double bond structures in lignin are broken down (Lindholm et al. 2009). The color-producing groups, auxiliary color groups, and elements associated with coloring undergo elimination via oxidation, reduction, and degradation facilitated by the bleaching agent. As a result, the wood loses its coloration (Lu et al. 2023).

Table 9. Measurement results for ΔL^*, Δb^*, ΔH^*, Δa^*, ΔC^*, and ΔE^*.

Chemical type	ΔL^*	Δa^*	Δb^*	ΔC^*	ΔH^*	ΔE^*	The color criteria (DIN 5033 1979)
$C_2H_2O_4$	3.55	0.75	2.22	2.33	0.21	4.25	Very noticeable (3.00 - 6.00)
NaOH + H_2O_2	12.33	-4.52	-0.62	-1.88	4.15	13.14	Very strong (> 12.00)

CONCLUSION

- The Δ*E** value was obtained as 4.25 with the $C_2H_2O_4$ chemical and 13.14 with the H_2O_2 + NaOH solution. Positive Δ*L** values were found with both chemicals. Oxalic acid resulted in a low total color difference. Δ*a**, Δ*b**, and Δ*C** values were calculated positively with $C_2H_2O_4$ and negatively with the NaOH + H_2O_2 solution.

- Increases were noted in both the *WI** ‖ direction and all color parameters when employing the $C_2H_2O_4$ chemical. Additionally, application of the NaOH + H_2O_2 solution led to rises in the *h*° and *L** values, while decreases were observed in the *C**, *a**, and *b** parameters.

- Glossiness values exhibited a decline at both 60 and 85 degrees, regardless of whether measured parallel or perpendicular to the fibers, subsequent to the application of both bleaching agents onto the wooden surfaces.

- Oxalic acid used in the study was found to result in a lower total color difference.

REFERENCES

Alshaaer M (2000) Stabilization of kaolinitic soil from Jordan for construction purposes. Vrije Universiteit Brussels Master's Thesis, Belgium.

Anonymous (2017) Resene pro-select technical information, timber colour change, colour change in timber floors after installation. www.resene.com/proselect 11/2017.

ASTM D2244-3 (2007) Standard practice for calculation or color tolerances and color, differences from instrumentally measured color coordinates. ASTM International, West Conshohocken, PA.

ASTM E313-15e1 (2015) Standard practice for calculating yellowness and whiteness indices from instrumentally measured color coordinates. ASTM International, West Conshohocken, PA.

Ayata Ü, Bal BC (2023) Effect of application of various bleaching chemicals on some surface properties of ilomba (*Pycnanthus angolensis* Exell) wood. EU 2nd International Conference on Health, Engineering and Applied Sciences, August 4-6, 2023, Belgrade, pp: 95-105.

Ayata Ü, Bal BC (2024) Basralocus (*Dicorynia guianensis* Amshoff) wood bleaching applications. Avrasya 10th International Conference on Applied Sciences May 2-5, 2024 Tbilisi, pp: 133-142.

Ayata Ü, Çamlıbel O (2023) A study on the application of bleaching treatment on Satinwood ceylon (*Chloroxylon swietenia* DC) wood used indoors and outdoors. The Journal of Graduate School of Natural and Applied Sciences of Mehmet Akif Ersoy University, 14(2): 273-281.

Ayata Ü, Kaplan Ş, Çamlıbel O, Bilginer EH (2024a) Bleaching Applications on Amazon Rosewood (*Dalbergia spruceana* Benth.) Wood. Journal of Green Technology and Environment, 2(1): 21-28.

Ayata Ü, Çamlıbel O, Bilginer EH (2024b) Investigation of some surface changes occurring after bleaching treatment on ayous (*Triplochiton scleroxylon* K. Schum) wood. Wood Industry and Engineering, 6(1): 1-8.

Çamlıbel O, Ayata Ü (2023a) The bleaching application on linden wood (*Tilia tomentosa* - Moench.). Fareast 2nd International Conference on Applied Sciences, October 20-22, 2023, Manila, pp: 107-116.

Çamlıbel O, Ayata Ü (2023b) Application of wood bleaching chemicals on ekop wood (*Tetraberlinia bifoliolata* Haum.). Fareast 2nd International Conference on Applied Sciences, October 20-22, 2023, Manila, pp: 125-135.

Çamlıbel O, Ayata Ü (2024a) The effects of bleaching chemicals on some surface properties of okoumé (*Aucoumea klaineana* Pierre) wood. Latin America 8th International Conference on Scientific Researches, May 1-5, 2024, Havana, Cuba.

Çamlıbel O, Ayata Ü (2024b) Testing of bleaching on Cocobolo (*Dalbergia retusa* Hemsl.,) wood. ArtGRID - Journal of Architecture Engineering and Fine Arts, 6(1): 80-95.

DIN 5033 (1979) Deutsche Normen, Farbmessung. Normenausschuß Farbe (FNF) im DIN Deutsches Institut für Normung eV, Beuth, Berlin März.

DIN 6174 (1979) Colorimetric evaluation of colour differences of surface colours according to the CIELAB formula.

Farr JP, Smith WL, Steichen DS (2003) Bleaching agents. Kirk-Othmer Encyclopedia of Chemical Technology, 4: 43-81.

Hauptmann M, Pleschberger H, Mai C, Follrich J, Hansmann C (2012) The potential of color measurements with the CIEDE2000 equation in wood science. European Journal of Wood and Wood Products, 70: 415-420.

Hawthorne WD (1995) Ecological profiles of Ghanaian forest trees. Oxford Forestry Institute, Oxford, pp: 345.

Herstedt L, Herstedt M (2017) Chemical bleaching of wood: an investigation into the bleaching of mahogany, walnut, rosewood, padauk, and purpleheart. Studies in Conservation, 62(3): 162-172.

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

ISO 554 (1976) Standard Atmospheres for Conditioning and/or Testing - Specifications, International Organization for Standardization.

Jiao C, Xiong J (2014) Accessibility and morphology of cellulose fibres treated with sodium hydroxide. BioResources, 9(4): 6504-6513.

Kristiansson L (2012) Chemical bleaching of wood and its aging: An investigation of mahogany, walnut, rosewood, padauk and purpleheart. Bachelor thesis presented June 1, 2012 for bachelor degree in Furniture Conservation from Carl Malmsten – Furniture Studies, Linköping University.

Kurtoğlu A (2000) Ağaç malzeme yüzey işlemleri. İ.Ü. Orman Fakültesi, İstanbul.

Lange DR (1999) Fundamentals of colourimetry - application report no. 10e. DR Lange: New York, NY, USA.

Lindholm C, Jäkärä J, Mårtens H (2009) Bleaching of mechanical pulps. In Mechanical Pulping (pp. 360-398). Helsinki, Finland: Paper Engineers' Association.

Liu Y, Guo H, Gao J, Zhang F, Shao L, Via BK (2015) Effect of bleach pretreatment on surface discoloration of dyed wood veneer exposed to artificial light irradiation. BioResources, 10(3): 5607-5619.

Lu D, Xiong, X, Lu G, Gui C, Pang X (2023) Effects of NaOH/H_2O_2/Na_2SiO_3 bleaching pretreatment method on wood dyeing properties. Coatings, 13(2): 233.

Olaniyan OS (2008) Stabilization of kaolinitc soil from Nigeria for construction purposes. Unpublished Soil Stabilization Practical Exercise, Vrije Universiteit Brussels.

Olaniyan OS, Olaoye RA, Okeyinka OM, Olaniyan DB (2011) Soil stabilization techniques using sodium hydroxide additives. International Journal of Civil & Environmental Engineering, 11(6): 9-22.

Peker H (2023a) Canelo (*Drimys winteri* J.R. Forst. & G. Forst.) ahşabında ağartma uygulamaları. ICAFVP 3. Uluslararası Tarım, Gıda, Veteriner Ve Eczacılık Bilimleri Kongresi, 10-12 Kasım 2023, Beyrut, Lübnan, pp: 165-174.

Peker H (2023b) Lotofa (*Sterculia rhinopetala*) odununda tek ve çift bileşenli ağartıcılarının uygulanması. ICAFVP 3. Uluslararası Tarım, Gıda, Veteriner Ve Eczacılık Bilimleri Kongresi, 10-12 Kasım 2023, Beyrut, Lübnan, pp: 173-182.

Peker H, Ayata Ü (2023) Effects of bleaching chemicals on some surface characteristics of olon (*Zanthoxylum heitzii*) wood. Furniture and Wooden Material Research Journal, 6(2): 210-218.

Peker H, Bilginer EH, Ayata Ü, Çamlıbel O, Gürleyen L (2023a) The application of bleaching chemicals (oxalic acid and hydrogen peroxide + sodium hydroxide) on bulletwood (*Manilkara bidentata* (A.DC.) A. Chev.) wood. Sivas Cumhuriyet University Journal of Engineering Faculty, 1(2): 48-54.

Peker H, Bilginer EH, Ayata Ü, Çamlıbel O (2023b) A research on the application of single and double-component wood bleaching chemicals on movingui (*Distemonanthus benthamianus* Baillon) wood used in the furniture industry, Sivas Cumhuriyet University. Journal of Science and Technology, 2(2): 73-79.

Peker H, Bilginer EH, Ayata Ü, Gürleyen L, Çamlıbel O (2023c) The application of different wood bleaching chemicals on izombé wood (*Testulea gabonensis* Pellegr.) used in indoor and outdoor designs. 2nd International Culture, Art and Communication Symposium, Bayburt, Turkey, 15-17 December 2023, pp: 289-303.

Peker H, Bilginer EH, Ayata Ü, Çamlıbel O, Gürleyen L (2024) Identification of certain surface characteristics of balau red (*Shorea guiso*) wood treated with wood bleaching chemicals followed by wax treatment. Turkish Journal of Science and Engineering, 6(1): 14-21.

Peker H, Ulusoy H (2023) Ahşap ağartıcı kimyasalları uygulanmış yalancı akasya (*Robinia pseudoacacia* L.) odununda bazı yüzey özelliklerinin belirlenmesi. 8. Asya Pasifik Uluslararası Modern Bilimler Kongresi, 11-12 Eylül 2023, Delhi, India, pp: 464-465.

Raponda - Walker A, Sillans S (1961) Plantes utiles du Gabon. Edition Lechevalier, Sepia, 614 p.

Sönmez A (2005) Ağaç işlerinde üstyüzey işlemleri I. Hazırlık ve Renklendirme, 2. Baskı, Gazi Üniversitesi Teknik Eğitim Fakültesi, Ankara, Turkey (p. 132). ISBN: 975-97281-0-9.

Taxiarchou M, Douni I (2014) The effect of oxalic acid activation on the bleaching properties of a bentonite from Milos Island, Greece. Clay Minerals, 49(4): 541-549.

Tosso F, Doucet JL, Kaymak E, Daïnou K, Duminil J, Hardy OJ (2016) Microsatellite development for the genus Guibourtia (*Fabaceae, Caesalpinioideae*) reveals diploid and polyploid species. Applications in Plant Sciences, 4: 1600029.

WCMC (1991) Provision of data on rare and threatened tropical timber species, 58.

White LJT, Abernethy K (1996) Guide de la végétation de la réserve de la Lopé, Gabon, Ecofac-Gabon, Libreville, 224 p.

Williams RS (2010) Finishing of wood. Wood Handbook, 16-39.