Mobilya ve Ahşap Malzeme Araştırmaları Dergisi
Furniture and Wooden Material Research Journal
Research Article - Araştırma Makalesi 2023-6(2), 210-218

Effects of bleaching chemicals on some surface characteristics of olon (*Zanthoxylum heitzii*) wood

Hüseyin Peker[1], Ümit Ayata[2]*

Abstract

Olon wood is used internationally in plywood, furniture, interior carpentry, and mold making. In this study, the effects of wood bleaching chemicals (oxalic acid and H_2O_2+NaOH) on certain surface properties (color, glossiness, and whiteness index: *WI**) of olon wood (*Zanthoxylum heitzii*) were investigated. The results of the bleached samples were compared with those of a control group. Based on the results obtained, it was determined that the variance analyses conducted for all tests in the study yielded statistically significant results. Application of both bleaching chemicals led to an increase in the h^o and L^* values. The ΔE^* values were determined as 2.07 for the single-component and 10.30 for the double-component. In contrast, these parameters increased with the single-component bleach while the a^*, b^* and C^* values decreased with the double-component wood bleach. The WI^* values exhibited an increase in both directions when they were exposed to both bleaching chemicals. Both bleaching agents resulted in reductions in glossiness values at 85 degrees in both directions. Furthermore, there were declines with the single-component bleach and rises with the double-component bleach when measuring glossiness at 60 degrees in both directions.

Keywords: Bleach, olon, oxalic acid, H_2O_2, NaOH

Olon (*Zanthoxylum heitzii*) odununun bazı yüzey özellikleri üzerine ağartıcı kimyasalların etkileri

Öz

Olon odunu yurt dışında, kontrplakta, mobilyada, iç marangozlukta ve kalıpçılıkta kullanılmaktadır. Bu çalışmada, olon (*Zanthoxylum heitzii*) ahşabında bazı yüzey özellikleri (renk, parlaklık ve beyazlık indeksi: WI^*) üzerine ağartıcı kimyasalların (oksalik asit ve H_2O_2+NaOH) etkileri araştırılmıştır. Bir kontrol gurubu ile ağartılmış numunelere ait sonuçlar birbirleri ile kıyaslanmıştır. Elde edilen sonuçlara göre, çalışmada yapılan bütün testler için varyans analizleri anlamlı olarak tespit edilmiştir. ΔE^* değerleri tek komponentli için 2.07 ve çift komponentli için 10.30 olarak bulunmuştur. Her iki ağartma kimyasalı karşısında yapılan uygulamalar ile h^o ve L^* değerleri artmıştır. Buna karşılık çift komponentli ahşap ağartıcı ile a^*, b^* ve C^* değerleri azalırken, tek komponentli ağartıcıda bu parametreler artmıştır. Her iki ağartma kimyasalı karşısında WI^* değerleri her iki yön için artış değerleri sergilemiştir. Her iki yönde yapılan 85 derece parlaklık değerlerinde her iki ağartma ile azalmalar elde edilmiştir. Buna ek olarak, yine her iki yönde yapılan 60 derece parlaklıkta ise tek komponentlide azalışlar ve çift komponentlide artışlar görülmüştür.

Anahtar kelimeler: Ağartma, olon, oksalik asit, H_2O_2, NaOH

Article history, Received: 02.10.2023, Accepted: 25.11.2023, Published: 29.12.2023, *email:umitayata@yandex.com
[1]Artvin Çoruh University, Faculty of Forestry, Department of Forest Industrial Engineering, Artvin/Türkiye
[2]Bayburt University, Faculty of Arts and Design, Department of Interior Architecture and En. Design, Bayburt/Türkiye
To cite: 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, DOI:10.33725/mamad.1369843

1 Introduction

While a bleaching pretreatment is commonly employed for wood modification, there have been numerous studies conducted to assess how bleaching impacts the enhancement of wood colour (Liu et al., 2015).

Various chemicals are used in bleaching processes. One of these chemicals is peroxide. The primary benefit of the peroxide process lies in its swift breakdown, generating free radicals that interact with the hydroxyl group of the fiber and the matrix, fostering strong adhesion between the fiber and matrix at the composite interface (Pizzi and Kumar, 2019; Sreekala et al., 2000).

Table 1 presents the studies conducted in the literature on bleaching applications. When examining these studies, it can be observed that various bleaching chemicals applied have altered the colour parameters of different wood species.

Table 1. The studies conducted in the literature on bleaching applications

Wood Type	Chemical Type	The change after application					Reference
		L*	***a****	***b****	**C***	***h**°*	
Ilomba	Oxalic acid	↑	↑	↑	↑	↑	Ayata and Bal, (2023)
(*Pycnanthus angolensis* Exell)	H_2O_2 + NaOH	↑	↓	↓	↓	↑	
Linden	Oxalic acid	↓	↑	↑	↑	↓	Çamlıbel and Ayata, (2023a)
(*Tilia tomentosa* - Moench.)	H_2O_2 + NaOH	↑	↓	↓	↓	↑	
Ekop	Oxalic acid	↓	↑	↑	↑	↑	Çamlıbel and Ayata, (2023b)
(*Tetraberlinia bifoliolata* Haum.)	H_2O_2 + NaOH	↑	↓	↑	↑	↑	
Satinwood ceylon	Oxalic acid	↓	↓	↑	↓	↑	Ayata and Çamlıbel, (2023)
(*Chloroxylon swietenia* DC)	H_2O_2 + NaOH	↑	↓	↓	↓	↑	
Izombé	Oxalic acid	↓	↑	↑	↑	↑	Peker et al., (2023)
(*Testulea gabonensis*)	H_2O_2 + NaOH	↑	↓	↑	↑	↑	
Canelo	Oxalic acid	↑	↑	↑	↑	↑	Peker, (2023a)
(*Drimys winteri* J.R. Forst. & G. Forst.)	H_2O_2 + NaOH	↑	↑	↑	↑	↑	
Lotofa	Oxalic acid	↑	↓	↑	↑	↑	Peker, (2023b)
(*Sterculia rhinopetala*)	H_2O_2 + NaOH	↑	↓	↓	↓	↑	
Black locust	Oxalic acid	↑	↓	↑	↓	↑	Peker and Ulusoy, (2023)
(*Robinia pseudoacacia* L.)	H_2O_2 + NaOH	↑	↓	↓	↓	↓	

The olon tree (*Zanthoxylum heitzii* - syn. *Fagara heitzii* Aubr. et Pellegr.) is found in African forests (Tailfer, 1989; Matig et al., 2006). Commercially known as “olon” *Fagara heitzii* is a member of the *Rutaceae* tree family. This tree species is used for timber although it has low impact resistance. It is used in interior carpentry, furniture, plywood, molding and other applications (Vivien and Faure, 1985; Walker and Sillans, 1995).

When looking at these studies, it can be seen that no bleaching application has been performed on olon wood. The aim of this study is to investigate the changes (colour, glossiness, and whiteness index) caused by the application of different wood bleaching chemicals on olon wood surfaces.

2 Material and Method

2.1 Material

2.1.1 Wood material

In this study, olon (*Zanthoxylum heitzii*) wood was used as the experimental material. The test material was obtained in 1st-grade quality with dimensions of 85 x 150 x 20 mm from a commercial facility. Care was taken to ensure that the test samples were free from cracks, had smooth fibers and were free from knots, resin pockets and any significant variations in colour and density. Subsequently, the samples were prepared according to the TS ISO 13061-1 (2021) standard.

2.1.2 Wood bleaching chemicals

In the study, double different bleaching chemicals were used: a water-based single-component bleaching agent [oxalic acid ($C_2H_2O_4$): liquid, colourless, odorless, pH value 2.0±0.5] and a double-component bleaching agent [pH value 7, liquid, odorless, colorless, soluble, with water as the diluent, consisting of hydrogen peroxide (H_2O_2): component A and sodium hydroxide (NaOH): component B mixed in a 2:1 ratio].

2.2 Method

2.2.1 The application of bleaching treatment to wood material surfaces

In the study, wood surfaces were sanded with sandpapers of 80, 100, and 150 grit sizes. Subsequently, the surfaces were cleaned by using a compressor. Following that, bleaching chemicals were applied to the cleaned materials' surfaces using a sponge. The application was carried out parallel to the fibers.

2.2.2 Determination of color properties

The color change of the samples was measured using a CS-10 (CHN Spec, China) device based on the CIELAB colour system according to the ASTM D 2244-3 (2007) standard. Total color difference results were determined using the following formulas:

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

$$h^o = \arctan (b^*/a^*) \tag{2}$$

$$\Delta C^* = (C^*_{\text{a sample subjected to a bleaching process}} - C^*_{\text{a sample not subjected to a bleaching process}}) \tag{3}$$

$$\Delta a^* = (a^*_{\text{a sample subjected to a bleaching process}} - a^*_{\text{a sample not subjected to a bleaching process}}) \tag{4}$$

$$\Delta L^* = (L^*_{\text{a sample subjected to a bleaching process}} - L^*_{\text{a sample not subjected to a bleaching process}}) \tag{5}$$

$$\Delta b^* = (b^*_{\text{a sample subjected to a bleaching process}} - b^*_{\text{a sample not subjected to a bleaching process}}) \tag{6}$$

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

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

The comparison criteria for evaluating ΔE^* values are presented in Table 2 (Barański et al., 2017).

Table 2. Comparison criteria for ΔE^* value (Barański et al., 2017)

ΔE^* value	Colour change criteria
$\Delta E^* < 0.2$	Invisible colour change
$2 > \Delta E^* > 0.2$	Slight change of colour
$3 > \Delta E^* > 2$	Colour change visible in high filter
$6 > \Delta E^* > 3$	A colour change visible with the average quality of the filter
$12 > \Delta E^* > 6$	High colour change
$\Delta E^* > 12$	Different colour

The definitions of ΔC^*, ΔH^*, ΔC^*, Δa^*, Δb^* and ΔL^* are as follows: A positive value indicates that the sample is more vivid or brighter than the reference while a negative value suggests that the sample is more dull or less vivid than the reference. ΔL^* indicates the lightness difference. A positive value means that the sample is lighter than the reference while a negative value implies that the sample is darker than the reference. Δb^* as a positive value indicates that the sample is more yellow than the reference while a negative value suggests that the sample is more blue than the reference. Δ*a** as a positive value means that the sample is more red than the reference while a negative value indicates that the sample is more green than the reference. Δ*H** represents the hue difference or shade difference. Δ*H** is reported as the tonal difference between the sample and the reference (Lange, 1999).

2.2.3 Determination of glossiness properties

Glossiness tests were conducted by using an ETB-0833 model gloss meter device at three different angles (20°, 60°, and 85°) in both perpendicular and parallel directions to the fibers following the ISO 2813 (1994) standard.

2.2.4 Determination of whiteness index (*WI**) properties

In this study, whiteness index (*WI**) values were determined in both perpendicular and parallel directions to the fibers by using the Whiteness Meter BDY-1 device following the ASTM E313-15e1 (2015) standard.

2.3 Statistical Analysis

The obtained data were analyzed by using an SPSS program to determine the minimum and maximum values, standard deviations, percentage change rates, homogeneity groups, variance analysis and multiple comparisons. Measurements were taken in sets of 10. In total, 30 samples were prepared.

3 Results and Discussion

The results are presented for total color differences in Table 3. According to these results, Δ*E** values were found to be 2.07 for single-component and 10.30 for double-component bleaching agents. When compared to the colour change criteria (Barański et al., 2017), the single-component bleaching chemical meets the “Slight change of colour (1.5 to 3.0)” criterion while the double-component bleaching chemical meets the “High colour change (6.0 to 12.0)” criterion. Δ*L** and Δ*H** values were obtained in the positive direction for both bleaching chemicals. On the other hand, Δ*a**, Δ*b**, and Δ*C** values were observed to have a negative effect in the case of single-component and a positive effect in the case of double-component (Table 3).

In a study conducted by Möttönen et al. (2003), bleaching was applied using a 35% hydrogen peroxide solution according to the Wood-Brite method on wood species such as teak, oak, birch, Norway maple, and European spruce. The Δ*E** values for these wood species were found to be 4.63, 7.73, 3.06, 2.49, and 1.03, respectively.

Table 3. The results for total color differences

Treatment	Δ*L**	Δ*a**	Δ*b**	Δ*C**	Δ*H**	Δ*E**	Color change criteria (Barański et al., 2017)
Single Component	1.53 Lighter than the reference	0.09 Redder than the reference	1.39 Yellower than the reference	1.38 Clearer, brighter than the reference	0.22	2.07	Slight change of color ← Lange, (1999)
Double Component	9.15 Lighter than the reference	-2.93 Greener than the reference	-3.70 Bluer than the reference	-4.13 Hazier, duller than the reference	2.30	10.30	High color change ← Lange, (1999)

The results of the multivariate analysis of variance are presented in Table 4. Upon examining these results, it is evident that all tests have been found to be statistically significant for the type of bleaching chemical (Table 4).

Table 4. Multivariate analysis of variance results

Source	Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.
Bleaching Chemical	Lightness (L*)	480.995	2	240.498	1427.687	0.000*
	Red (a*) colour tone	59.224	2	29.612	452.738	0.000*
	Yellow (b*) colour tone	138.653	2	69.327	812.868	0.000*
	Chroma (C*)	164.010	2	82.005	1005.105	0.000*
	Hue (h°) angle	323.642	2	161.821	299.120	0.000*
	Glossiness value at ⊥20°	0.833	2	0.416	535.286	0.000*
	Glossiness value at ⊥60°	0.625	2	0.312	26.857	0.000*
	Glossiness value at ⊥85°	0.043	2	0.021	4.235	0.025*
	Glossiness value at ‖20°	1.014	2	0.507	82.464	0.000*
	Glossiness value at ‖60°	2.282	2	1.141	24.646	0.000*
	Glossiness value at ‖85°	2.565	2	1.282	159.553	0.000*
	Whiteness index in the perpendicular (⊥)	1477.625	2	738.812	991.202	0.000*
	Whiteness index in the parallel (‖)	1544.562	2	772.281	4489.039	0.000*
Error	Lightness (L*)	4.548	27	0.168		
	Red (a*) colour tone	1.766	27	0.065		
	Yellow (b*) colour tone	2.303	27	0.085		
	Chroma (C*)	2.203	27	0.082		
	Hue (h°) angle	14.607	27	0.541		
	Glossiness value at ⊥20°	0.021	27	0.001		
	Glossiness value at ⊥60°	0.314	27	0.012		
	Glossiness value at ⊥85°	0.136	27	0.005		
	Glossiness value at ‖20°	0.166	27	0.006		
	Glossiness value at ‖60°	1.250	27	0.046		
	Glossiness value at ‖85°	0.217	27	0.008		
	Whiteness index in the perpendicular (⊥)	20.125	27	0.745		
	Whiteness index in the parallel (‖)	4.645	27	0.172		
Total	Lightness (L*)	161159.552	30			
	Red (a*) colour tone	415.861	30			
	Yellow (b*) colour tone	12611.480	30			
	Chroma (C*)	13018.015	30			
	Hue (h°) angle	196373.632	30			
	Glossiness value at ⊥20°	14.590	30			
	Glossiness value at ⊥60°	145.260	30			
	Glossiness value at ⊥85°	0.660	30			
	Glossiness value at ‖20°	11.980	30			
	Glossiness value at ‖60°	182.140	30			
	Glossiness value at ‖85°	5.790	30			
	Whiteness index in the perpendicular (⊥)	35777.710	30			
	Whiteness index in the parallel (‖)	21348.490	30			
Corrected Total	Lightness (L*)	485.543	29			
	Red (a*) colour tone	60.990	29			
	Yellow (b*) colour tone	140.956	29			
	Chroma (C*)	166.213	29			
	Hue (h°) angle	338.248	29			
	Glossiness value at ⊥20°	0.854	29			
	Glossiness value at ⊥60°	0.939	29			
	Glossiness value at ⊥85°	0.179	29			
	Glossiness value at ‖20°	1.180	29			
	Glossiness value at ‖60°	3.532	29			
	Glossiness value at ‖85°	2.782	29			
	Whiteness index in the perpendicular (⊥)	1497.750	29			
	Whiteness index in the parallel (‖)	1549.207	29			

*: Significant

Table 5 contains images of experimental samples subjected to bleaching treatment and those that have not undergone bleaching.

Table 5. Images of bleached and unbleached (control) test samples

Unbleached (control)	**Single component [Oxalic acid ($C_2H_2O_4$)]**	**Double component [Hydrogen peroxide (H_2O_2) + sodium hydroxide (NaOH)]**
		

The measurement results for all tests are presented in Table 6. According to these results, changes were observed in *L** values with both chemicals. The lowest increase in *L** value was 2.20% in the single-component while the highest increase was 13.16% in the double-component. The highest *L** value was observed in the double-component (78.18) while the lowest was found in the control samples (69.62).

In the case of *b** values, there was a decline in the double-component and an upturn in the single-component. The single-component demonstrated a 6.57% rise in the *b** value while the double-component showed a decrease of 17.49%. The highest *b** value was recorded in the single-component (22.55) while the lowest was found in the double-component (17.46).

In *a** values, an increase was observed in the single-component and a decrease in the double-component. The highest result for *a** value was determined in the single-component (4.48) while the lowest result was in the double-component (1.45). An increase of 2.20% was obtained in the single-component for the *a** value while a decrease of 66.97% was observed in the double-component.

In terms of *C** values, there was an increase in the single-component and a decrease in the double-component. The single-component showed a 3.39% increase in *C** value while the double-component exhibited a 19.07% decrease. The highest *C** value was observed in the single-component (22.99) whereas the lowest *C** value was recorded in the double-component (19.07).

Changes were observed in h^o values with both chemicals. The lowest increase in ho value was 0.61% in the single-component while the highest increase was 9.18% in the double-component. The highest h^o value was obtained in the double-component (85.47) while the lowest result was seen in the control samples (78.28) (Table 6).

*WI** values showed increases in both directions (perpendicular and parallel to fibers) with both chemicals. The *WI** values in the double-component were higher than those in the single-component. After the single-component application, *WI** values were 2.49% for ⊥ direction and 12.49% for ‖ direction while *WI** values were 53.46% for ⊥ direction and 83.75% for ‖ direction after the double-component application. *WI** measurements for control samples remained at low values after both bleaching applications (Table 6).

The double-component bleaching chemical has increased the measurements on fibers conducted at 20 degrees both perpendicular and parallel by 80.00% and 82.98% respectively. Decreases in glossiness values were observed at 85 degrees in both types of bleaching for fibers oriented in both perpendicular and parallel directions. Decreases were obtained at 60 degrees for fibers oriented perpendicular in single-component (12.72% and 16.47% respectively) while increases were detected in double-component bleaching (1.32% and 10.44% respectively) for fibers oriented parallel (Table 6).

Surface modification is believed to eliminate chromophores responsible for colour that are linked to functional groups within lignin. It is a well-established fact that the application of H_2O_2 during the bleaching process in thermomechanical pulp production reduces the concentration of wood extracts in the pulp and increases the brightness of the pulp. Quinones, which are components of lignin groups contributing to colour, undergo oxidation during this procedure resulting in the formation of colorless structures. Additionally, the coniferyl aldehyde groups and conjugated double bond structures within lignin are broken down (Lindholm et al., 2009).

Table 6. Results for whiteness index (*WI**), colour, and glossiness values before and after bleaching

Test	Treatment	Number of Measurements	Mean	Change (%)	Homogeneity Group	Standard Deviation	Coefficient of Variation	Minimum Value	Maximum Value
L^*	Unbleached (control)	10	69.62	-	C**	0.23	0.33	69.35	69.97
	Single-Component	10	71.15	↑2.20	B	0.66	0.93	70.26	72.36
	Double-Component	10	78.78	↑13.16	A*	0.13	0.17	78.61	79.02
a^*	Unbleached (control)	10	4.39	-	A	0.23	5.14	3.99	4.70
	Single-Component	10	4.48	↑2.05	A*	0.17	3.78	4.18	4.67
	Double-Component	10	1.45	↓66.97	B**	0.34	23.51	1.13	2.17
b^*	Unbleached (control)	10	21.16	-	B	0.32	1.51	20.68	21.68
	Single-Component	10	22.55	↑6.57	A*	0.26	1.14	22.17	22.89
	Double-Component	10	17.46	↓17.49	C**	0.30	1.70	17.04	17.97
C^*	Unbleached (control)	10	21.61	-	B	0.31	1.46	21.15	22.08
	Single-Component	10	22.99	↑6.39	A*	0.23	1.01	22.62	23.30
	Double-Component	10	17.49	↓19.07	C**	0.30	1.74	17.09	18.03
h^o	Unbleached (control)	10	78.28	-	B**	0.61	0.79	77.44	79.23
	Single-Component	10	78.76	↑0.61	B	0.50	0.64	78.24	79.59
	Double-Component	10	85.47	↑9.18	A*	1.00	1.16	82.91	86.27
$\perp 20^o$	Unbleached (control)	10	0.50	-	C**	0.00	0.00	0.50	0.50
	Single-Component	10	0.63	↑26.00	B	0.05	7.67	0.60	0.70
	Double-Component	10	0.90	↑80.00	A*	0.00	0.00	0.90	0.90
$\perp 60^o$	Unbleached (control)	10	2.28	-	A	0.12	5.39	2.20	2.50
	Single-Component	10	1.99	↓12.72	B**	0.11	5.53	1.80	2.10
	Double-Component	10	2.31	↑1.32	A*	0.09	3.79	2.20	2.40
$\perp 85^o$	Unbleached (control)	10	0.18	-	A*	0.12	68.29	0.10	0.40
	Single-Component	10	0.10	↓44.44	B**	0.00	0.00	0.10	0.10
	Double-Component	10	0.10	↓44.44	B**	0.00	0.00	0.10	0.10
$\parallel 20^o$	Unbleached (control)	10	0.47	-	B**	0.05	10.28	0.40	0.50
	Single-Component	10	0.47	0.00	B**	0.05	10.28	0.40	0.50
	Double-Component	10	0.86	↑82.98	A*	0.12	13.65	0.70	1.00
$\parallel 60^o$	Unbleached (control)	10	2.49	-	B	0.23	9.36	2.20	2.80
	Single-Component	10	2.08	↓16.47	C**	0.20	9.83	1.80	2.30
	Double-Component	10	2.75	↑10.44	A*	0.21	7.52	2.50	3.00
$\parallel 85^o$	Unbleached (control)	10	0.73	-	A*	0.15	20.47	0.60	1.00
	Single-Component	10	0.12	↓83.56	B	0.04	35.14	0.10	0.20
	Double-Component	10	0.10	↓86.30	B**	0.00	0.00	0.10	0.10
WI^* ($\perp$)	Unbleached (control)	10	28.49	-	B**	1.19	4.16	27.30	29.90
	Single-Component	10	29.20	↑2.49	B	0.36	1.23	28.70	29.70
	Double-Component	10	43.72	↑53.46	A*	0.84	1.91	42.90	44.90
WI^* ($\parallel$)	Unbleached (control)	10	19.45	-	C**	0.18	0.91	19.00	19.60
	Single-Component	10	21.88	↑12.49	B	0.65	2.98	21.10	22.60
	Double-Component	10	35.74	↑83.75	A*	0.25	0.69	35.40	36.00

For the Homogeneity Group ► *: Highest value, **: Lowest Value

4 Conclusion

- All variance analyses were found to be significant for all tests conducted in the study.
- ΔE^* values were found to be 2.07 for single-component and 10.30 for double-component.
- The applications performed against both bleaching chemicals resulted in an increase in the h^o and L^* values.
- While the a^*, b^*, and C^* values increased with the single-component wood bleach, these parameters decreased with the double-component bleach.

Acknowledgment
None

Author Contributions
Hüseyin Peker: Data curation, formal analysis, research, methodology**, Ümit Ayata:** sources, supervision, validation, visualization, laboratory work, material procurement, writing, review and editing.

Funding statement
No financial support was received for the study.

Conflict of interest statement
The authors declare no conflict of interest

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