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Testing of Bleaching Application on Kingwood (*Dalbergia cearensis* Ducke) Wood

Analiza primjene izbjeljivanja na drvu *kingwooda* (*Dalbergia cearensis* Ducke)

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ABSTRACT • *In this study, surface changes (whiteness index: WI*, color parameters, and glossiness properties) occurring after bleaching with oxalic acid ($C_2H_2O_4$) and hydrogen peroxide (H_2O_2) + sodium hydroxide (NaOH) chemicals in kingwood (Dalbergia cearensis Ducke) wood, used for high-quality applications such as quality turning, marquetry, furniture, inlay work, musical instruments, and decorative items, were investigated. The ΔE* values were determined as 5.46 for the single component and 8.69 for the double component. Decreases in L* and h° parameters were obtained by the action of the $C_2H_2O_4$ chemical, while increases were observed in the a*, C*, and b* parameters. Additionally, the use of H_2O_2 + NaOH chemicals in the bleaching process resulted in increases in L*, b*, C*, and h° values, with a decrease noted in the a* parameter. Observations revealed reductions in glossiness values at 60 and 85 degrees when employing two distinct bleaching agents in both orientations. It can be said that the bleaching agents used in the study exert varying effects as modifiers on the surface of wooden materials.*

KEYWORDS: *kingwood; whiteness index; color; Dalbergia cearensis Ducke; bleaching; glossiness*

SAŽETAK • *U radu se istražuju površinske promjene (indeks bjeline WI*, parametri boje i sjaj) drva kingwooda (Dalbergia cearensis Ducke) nakon izbjeljivanja oksalnom kiselinom ($C_2H_2O_4$) i vodikovim peroksidom (H_2O_2) + natrijevim hidroksidom (NaOH). Drvo kingwooda upotrebljava se za izradu proizvoda visoke kvalitete kao što su tokareni elementi, intarzije, namještaj, glazbala i ukrasni predmeti. Nakon primjene jednokomponentnog sredstva za izbjeljivanje na površini drva dobivena je vrijednost ΔE* od 5,46, a nakon primjene dvokomponentnog sredstva vrijednost 8,69. Smanjenje parametara L* i h° postignuto je djelovanjem kemikalije $C_2H_2O_4$, a istodobno je uočeno povećanje parametara a*, C* i b*. Nadalje, primjena kemikalija H_2O_2 + NaOH u procesu izbjeljivanja rezultirala je povećanjem parametara L*, b*, C* i h° te smanjenjem parametra a*. Pri mjerenju paralelno i okomito na vlakanca drva nakon primjene obaju sredstava za izbjeljivanje rezultati su pokazali smanjenje vrijednosti sjaja pri kutu od 60 i 85°. Može se reći da sredstva za izbjeljivanje primijenjena u istraživanju imaju različite učinke kao sredstva za modifikaciju površine drva.*

KLJUČNE RIJEČI: *drvo kingwooda; indeks bjeline; boja; Dalbergia cearensis Ducke; izbjeljivanje; sjaj*

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1 INTRODUCTION
1. UVOD

Sodium hypochlorite bleach, often known by the brand name clorox, is widely available as a household bleach. It is considered a gentle bleaching agent and typically lightens the color of most woods by a few shades, though oak may experience a slight darkening. Nonetheless, it does not completely remove this coloration. When applied to colors stemming from water stains, sodium hypochlorite tends to be effective, yet it is less so on earthy tones and certain organic pigments (Zeilman, 1960).

Inadequate peroxide levels left in the bleaching process may cause a decrease in fiber brightness, while an excessive amount escalates the expenses associated with the bleaching agent, peroxide. Hence, closely monitoring the peroxide concentration is of utmost importance in wood fiber bleaching procedures (Chai *et al*., 2004).

In the literature, it is observed that bleaching applications are carried out on various tree species: bamboo (Nguyen *et al*., 2019), movingui (Peker *et al*., 2023b), lotofa (Peker, 2023b), canelo (Peker, 2023a), birch (Mononen *et al*., 2005), lime (Çamlıbel and Ayata, 2023a), maritime pine (Mehats *et al*., 2021), olon (Peker and Ayata, 2023), birch (Liu *et al*., 2015), bulletwood (Peker *et al*., 2023a), ayous, linden, poplar (Lu *et al*., 2023), izombé (Peker *et al*., 2023c), oak, birch, Norway maple, European larch (Möttönen *et al*., 2003), balau red (Shorea guiso) (Peker *et al*., 2024), satinwood ceylon (Ayata and Çamlıbel, 2023), ilomba (Ayata and Bal, 2023), black locust (Peker and Ulusoy, 2023), birch (Yamamoto *et al*., 2017), and ekop (Çamlıbel and Ayata, 2023b).

Information regarding color changes obtained using various bleaching chemicals has been provided in the above studies. While some surface changes resulting from bleaching applications have been identified, it has been noted that there are no records of bleaching applications being conducted on kingwood (*Dalbergia cearensis* Ducke) wood in the literature.

Here is further information about this tree species: kingwood (*Dalbergia cearensis* Ducke), also known as jacarandá-violet, miolo-de-negro, pau-violeta, or simply violet, is a distinctive species native to the caatinga region stretching from Ceará to the southern parts of Piauí and Bahia. It thrives in areas with dense tree cover, typically found in the foothills and hinterlands where deep soils and favorable microclimates support the growth of lush vegetation (Carvalho, 1997). Notably, kingwood is renowned for its epigeal germination of seeds, particularly in semi-arid regions where surface temperature fluctuations influence germination proximity to or on the soil surface (Gutierrez *et al*., 1988).

The distinctive samaras, characterized by flattened and undivided structures, disperse gradually throughout the year after detachment from compact axillary clusters. This distribution pattern is considered an evolutionary adaptation that reduces predation pressure, thereby enhancing the chances of successful germination and reproduction (Wheelwright, 1985).

As a deciduous species, kingwood can reach heights of 5-8 meters, featuring wood with a specific gravity of 1.01 g/cm^3. Lacking water storage structures in its trunk or roots, the tree sheds its leaves at the onset of the dry season. Leaves typically persist for four to six months, regenerating with new foliage and flowers at the onset of the rainy season, coinciding with fruit maturation (Lorenzi, 2009). With a high seed germination rate of 70 %, seeds of kingwood exhibit phanero-epigeal-storage germination, sprouting seedlings within three days after planting (Nogueira *et al*., 2010).

It dries quickly, and care must be taken to avoid excessive checking and splitting. The material is dried without deterioration (Lincoln, 1986). The wood has a slightly aromatic odor and, when fresh, has brown-light purple stripes at regular intervals (Didier, 1992). It works well with both hand and machine tools, with a moderate blunting effect on cutting edges. Maintaining sharp cutting edges can achieve a very smooth surface. Nails and screws hold well, and the wood can provide a thin, natural waxy surface. The timber is durable and highly resistant to protective treatments. Today, it is mainly used in veneer and marquetry as sliced veneer for plywood and in solid form for inlays, turning, and various decorative items (Lincoln, 1986).

Another source describes the wood as having "brown-purple and black or black-purple, alternating concentric layers. It is finely striped and has a pleasant smell. Fine-textured; irregular grain; heavy; hard; extremely durable; takes a high, waxy, natural polish. It is a highly valuable timber, available only in small sizes and used for high-quality applications such as fine furniture, marquetry, musical instruments, inlay work, turning, and fancy articles" (Uphof, 1959). The calorific value of kingwood wood is 4,327 kcal/kg, volatile matter is 87.86 %, ash is 0.26 %, and fixed carbon is 11.87 % (Oliveira *et al*., 2019).

This study investigates the surface changes occurring after bleaching applications on kingwood (*Dalbergia cearensis* Ducke) wood.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Material
2.1. Materijal

2.1.1 Wood material
2.1.1. Drvni materijal

Climate conditioning was applied to test samples of kingwood (*Dalbergia cearensis* Ducke) with dimensions of 100 mm × 100 mm × 18 mm at (20±2) °C and 65 % relative humidity (ISO 554, 1976).

2.1.2 Bleaching chemicals
2.1.2. Kemikalije za izbjeljivanje

Oxalic acid ($C_2H_2O_4$) and hydrogen peroxide (H_2O_2) + sodium hydroxide (NaOH) (in a ratio of 2:1) chemicals were used in the study.

2.2 Methods
2.2. Metode

2.2.1 Application of bleaching
2.2.1. Nanošenje sredstva za izbjeljivanje

The chemicals were applied to the wood material surfaces using the brushing technique.

2.2.2 Tests
2.2.2. Ispitivanja

The Shore D hardness value was determined according to ASTM D 2240, (2010) using a shore hardness testing device (Model Ld-J Loyka, Durometer: Shenzhen Yibai Network Technology Co., Ltd., China) with a 5 kg load applied. Ten measurements were taken. Glossiness tests were conducted at three different angles (20°, 60°, and 85°) perpendicular and parallel to the fibers (ISO 2813, 1994) using an ETB-0833 model gloss meter device, shore D hardness value was measured using a shore meter device (ASTM D 2240, 2010), whiteness index (WI^*) values were measured perpendicular and parallel to the fibers using a whiteness meter BDY-1 device (ASTM E313-15e1, 2015), and color properties were measured using a CS-10 device (ASTM D 2244-3, 2007).

In the literature, ΔC^* is defined as chroma difference or saturation difference and ΔH^* as hue difference or shade difference. Definitions for other parameters are provided in Table 1 (Lange, 1999), and comparison criteria for visual assessment of color difference (ΔE^*) are given in Table 2 (Barański *et al*., 2017).

Total color differences were determined using the following formulas:

$$\Delta a^* = [a^*_{bleached}] - [a^*_{control}] \quad (1)$$

$$\Delta C^* = [C^*_{bleached}] - [C^*_{control}] \quad (2)$$

$$\Delta L^* = [L^*_{bleached}] - [L^*_{control}] \quad (3)$$

$$\Delta b^* = [b^*_{bleached}] - [b^*_{control}] \quad (4)$$

$$\Delta H^* = [(\Delta E^*)^2 - (\Delta L^*)^2 - (\Delta C^*)^2]^{1/2} \quad (5)$$

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta b^*)^2 + (\Delta a^*)^2]^{1/2} \quad (6)$$

$$C^* = [(a^*)^2 + (b^*)^2]^{1/2} \quad (7)$$

$$h^o = \arctan [b^*/a^*] \quad (8)$$

Δa^*: positive values of Δa^* indicate a shift towards a more pronounced red tone compared to the reference, while negative values suggest a shift towards a greener hue. ΔH^*: reflects changes in the hue angle or tint. ΔC^*: positive values of ΔC^* signify an increase in chroma or saturation, resulting in a more vibrant and luminous appearance compared to the reference. Conversely, negative values indicate a decrease in chroma or saturation, leading to a reduction in vibrancy and distinctiveness relative to the reference. ΔL^*: when ΔL^* values are positive, they indicate a shift towards a lighter color compared to the reference, while negative values suggest a shift towards a darker color. Δb^*: positive values of Δb^* indicate an increase in yellowness compared to the reference, while negative values suggest an increase in blueness (Lange, 1999).

2.3 Statistical analysis
2.3. Statistička analiza

Maximum and minimum values, standard deviations, homogeneity groups, means, variance analyses, and percentage (%) change rates were determined using a statistical program.

Table 1 Color change criteria by Barański *et al*. (2017)
Tablica 1. Kriteriji promjene boje prema Barański *et al*. (2017.)

Color change criteria / *Kriteriji promjene boje*	**ΔE^* value** *ΔE^* vrijednost*
Invisible color change / *promjena boje koja nije vidljiva*	$\Delta E^* < 0.2$
Slight change of color / *blaga promjena boje*	$2 > \Delta E^* > 0.2$
Color change visible in high filter / *promjena boje vidljiva uz kvalitetan filtar*	$3 > \Delta E^* > 2$
Color change visible with average quality of filter / *promjena boje vidljiva uz filtar prosječne kvalitete*	$6 > \Delta E^* > 3$
High color change / *izrazita promjena boje*	$12 > \Delta E^* > 6$
Different color / *različita boja*	$\Delta E^* > 12$

Table 2 Results of shore D hardness value determined in kingwood wood
Tablica 2. Rezultati Shore D tvrdoće drva *kingwood*

Number of measurements *Broj mjerenja*	**Mean (HD)** *Srednja vrijednost (HD)*	**Standard deviation** *Standardna devijacija*	**Minimum**	**Maximum**	**Coefficient of variation** *Koeficijent varijacije*
10	78.70	2.16	75.00	81.00	2.75

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

The result for the shore D hardness value determined on the kingwood specimen is given in Table 3. According to the determined result, the shore D hardness value for kingwood wood is 78.70 HD, ranging between 75.00 and 81.00 HD (Table 2).

The results for total color differences are shown in Table 3. The Δ*E** values were found to be 5.46 for the single component and 8.69 for the double component. The Δ*L** values were determined to be negative (darker than the reference) in the single component and positive (lighter than the reference) in the double component. Δ*a** values were negative (greener than the reference) in the double component and positive (redder than the reference) in the single component (Table 3).

After the application of both bleaching chemicals, Δ*b** (more yellow than the reference) and Δ*C** (clearer, brighter than the reference) values were obtained in the positive direction. Comparing the values obtained in this study with the color change criteria (Barański *et al.* 2017), it was determined that the single-component bleaching agent falls into the "color change visible with average quality of filter (6>Δ*E**>3)" category, while the double-component chemical falls into the "high color change (12>Δ*E**> 6)" category (Table 3).

The color differences (Δ*E**) for various wood species after being bleached using the Wood-Brite method with a 35 % hydrogen peroxide solution were as follows: teak (*Tectona grandis*) had a Δ*E** of 4.63, oak (*Quercus robur*) had a Δ*E** of 7.73, birch (*Betula pendula*) had a Δ*E** of 3.06, Norway maple (*Acer platanoides*) had a Δ*E** of 2.49, and European larch (*Picea abies*) had a Δ*E** of 1.03 (Möttönen *et al.*, 2003).

All test results data are provided in Table 5. The double-component chemical yielded the highest *L** value (48.53), in contrast with the single-component chemical, which showed the lowest value (38.17). While the *L** parameter decreased by 10.31 % in the single-component chemical, it increased by 14.03 % in the double-component chemical (Table 5). In the literature, decreases with the application of $C_2H_2O_4$ and increases with H_2O_2 + NaOH were observed in Satinwood Ceylon (Ayata and Çamlıbel, 2023), balau red (Shorea guiso) (Peker *et al.*, 2024), ekop (Çamlıbel and Ayata, 2023b), lime (Çamlıbel and Ayata, 2023a), and Izombé (Peker *et al.*, 2023c) wood species.

The lowest *a** value (1.68) was recorded in the double-component chemical, whereas the highest value (8.39) was obtained in the single-component chemical. In the *a** test, there was a 28.68 % increase in the single-component chemical, whereas a notable decrease of 74.23 % was noted in the double-component chemical (Table 5). In the literature, increases in the *a** parameter due to $C_2H_2O_4$ application and decreases due to H_2O_2 + NaOH application have been reported in various wood types such as bulletwood (Peker *et al.*, 2023a), movingui (Peker *et al.*, 2023b), Satinwood ceylon (Ayata and Çamlıbel, 2023), ilomba (Ayata and Bal, 2023), olon (Peker and Ayata, 2023), canelo (Peker, 2023a), lotofa (Peker, 2023b), black locust (Peker and Ulusoy, 2023), lime (Çamlıbel and Ayata, 2023a), ekop (Çamlıbel and Ayata, 2023b), and izombé (Peker *et al.*, 2023c).

The double-component chemical exhibited the highest *b** parameter value (14.59), whereas the lowest value was observed in the control experimental group samples (10.52). The *b** value increased by 25.29 % with the single-component chemical and by 38.69 % with the double-component chemical (Table 5). Increases in the *b** parameter have been identified with oxalic acid application and H_2O_2 + NaOH treatments in wood types such as ekop (Çamlıbel and Ayata, 2023b), izombé (Peker *et al.*, 2023c), canelo (Peker, 2023a), bulletwood (Peker *et al.*, 2023a), and movingui (Peker *et al.*, 2023b).

In the *C** test, the single-component chemical yielded the highest result (15.3), while the control samples had the lowest (12.38). Both the single and double-component chemicals showed increases in the *C** value (26.25 % and 18.66 %, respectively), with an overall increase of 25.29 % (Table 6). Increases in the *C** parameter were observed with the application of $C_2H_2O_4$ and H_2O_2 + NaOH chemicals in wood types such as izombé (Peker *et al.*, 2023c), ekop (Çamlıbel and Ayata, 2023b), bulletwood (Peker *et al.*, 2023a), movingui (Peker *et al.*, 2023b), and canelo (Peker, 2023a).

The highest *h*° parameter value (83.42) was observed in the double-component chemical, whereas the lowest (57.48) was found in the single-component chemical. A decrease of 1.32 % was observed in the *h*°

Table 3 Results of total color differences
Tablica 3. Rezultati ukupne promjene boje

Treatment / *Tretman*	Δ*L**	Δ*a**	Δ*b**	Δ*C**	Δ*H**	Δ*E**	**Color change criteria** / *Kriteriji promjene boje* (Barański *et al.*, 2017)
Single-component chemical *jednokomponentna kemikalija*	-4.39	1.88	2.66	3.26	0.10	5.46	Color change visible with average quality of filter *promjena boje vidljiva uz filtar prosječne kvalitete* (6 > Δ*E** > 3)
Double-component chemical *dvokomponentna kemikalija*	5.97	-4.84	4.07	2.31	5.88	8.69	High color change / *izrazita promjena boje* (12 > Δ*E** > 6)

value with the single-component chemical, while the double-component chemical exhibited a significant increase of 43.21 % (Table 4). In the *h*° values, decreases with the use of oxalic acid for bleaching purposes and increases with the use of H_2O_2 + NaOH chemicals were achieved in wood types such as bulletwood (Peker *et al*., 2023a) and lime (Çamlıbel and Ayata, 2023a).

Decreases in the *WI** values measured in both directions were observed with the single component (⊥: 25.91 % and ||: 21.68 %) and increases were determined with the double component (⊥: 35.17 % and ||: 78.67 %). The highest results for *WI** values in both directions were found with the application of the double-component chemical (⊥: 12.26 and ||: 10.22), while the lowest results were obtained with the application of the single-component chemical to wooden surfaces (⊥: 6.72 and ||: 4.48) (Table 4).

It was observed that decreases in glossiness values were achieved at 60 and 85 degrees by using two different bleaching chemicals in both directions. When both chemicals were applied to wooden surfaces, no change in glossiness values perpendicular to the fibers was observed at 20 degrees. However, different outcomes were exhibited parallel to the fibers (an increase

Table 4 Measurement results for all tests
Tablica 4. Rezultati svih ispitivanja

Test	Treatment *Tretman*	*N*	Mean *Srednja vrijednost*	Change ratio, % *Stupanj promjene, %*	Homogeneity group *Homogenost grupe*	Standard Deviation *Standardna devijacija*	Min.	Max.	COV
*L**	Control	10	42.56	-	B	1.14	40.79	44.00	2.68
	Single Component	10	38.17	↓10.31	C**	1.12	35.74	39.31	2.95
	Double Component	10	48.53	↑14.03	A*	0.88	47.45	49.89	1.81
*a**	Control	10	6.52	-	B	0.49	5.72	7.07	7.48
	Single Component	10	8.39	↑28.68	A*	0.45	7.50	8.92	5.31
	Double Component	10	1.68	↓74.23	C**	0.37	1.15	2.28	21.78
*b**	Control	10	10.52	-	C**	0.50	9.58	11.15	4.75
	Single Component	10	13.18	↑25.29	B	0.90	11.18	14.02	6.84
	Double Component	10	14.59	↑38.69	A*	0.78	13.10	15.42	5.38
*C**	Control	10	12.38	-	C**	0.67	11.19	13.19	5.40
	Single Component	10	15.63	↑26.25	A*	0.99	13.47	16.46	6.34
	Double Component	10	14.69	↑18.66	B	0.80	13.15	15.56	5.46
h°	Control	10	58.25	-	B	0.92	56.83	59.50	1.58
	Single Component	10	57.48	↓1.32	B**	0.63	56.14	58.39	1.10
	Double Component	10	83.42	↑43.21	A*	1.28	81.30	85.15	1.53
⊥20°	Control	10	0.10	-	A	0.00	0.10	0.10	0.00
	Single Component	10	0.10	0.00	A	0.00	0.10	0.10	0.00
	Double Component	10	0.10	0.00	A	0.00	0.10	0.10	0.00
⊥60°	Control	10	0.76	-	A*	0.08	0.60	0.80	11.10
	Single-Component	10	0.25	↓67.11	C**	0.05	0.20	0.30	21.08
	Double Component	10	0.59	↓22.37	B	0.09	0.50	0.70	14.84
⊥85°	Control	10	0.20	-	A*	0.09	0.10	0.30	47.14
	Single Component	10	0.10	↓50.00	B**	0.00	0.10	0.10	0.00
	Double Component	10	0.10	↓50.00	B**	0.00	0.10	0.10	0.00
‖20°	Control	10	0.12	-	A	0.04	0.10	0.20	35.14
	Single Component	10	0.13	↑8.33	A*	0.05	0.10	0.20	37.16
	Double Component	10	0.10	↓16.67	A**	0.00	0.10	0.10	0.00
‖60°	Control	10	1.22	-	A*	0.08	1.10	1.30	6.47
	Single Component	10	0.97	↓20.49	B	0.32	0.60	1.40	32.62
	Double Component	10	0.83	↓31.97	B**	0.05	0.80	0.90	5.82
‖85°	Control	10	1.16	-	A*	0.25	0.80	1.50	21.96
	Single Component	10	0.10	↓91.38	B**	0.00	0.10	0.10	0.00
	Double Component	10	0.10	↓91.38	B**	0.00	0.10	0.10	0.00
*WI** (⊥)	Control	10	9.07	-	B	0.05	9.00	9.10	0.53
	Single Component	10	6.72	↓25.91	C**	0.12	6.60	6.90	1.83
	Double Component	10	12.26	↑35.17	A*	0.36	11.90	12.80	2.91
*WI** (‖)	Control	10	5.72	-	B	0.20	5.50	6.00	3.57
	Single Component	10	4.48	↓21.68	C**	0.18	4.20	4.70	4.05
	Double Component	10	10.22	↑78.67	A*	0.41	9.70	10.70	3.99

*Highest value, **Lowest value, *N* – Number of measurements, COV – Coefficient of variation / **najviša vrijednost, **najniža vrijednost, N – broj mjerenja, COV – koeficijent varijacije*

Table 5 Multivariate analysis of variance results
Tablica 5. Rezultati multivarijantne analize varijance

Test	**Sum of squares** *Zbroj kvadrata*		***df***	**Mean square** *Srednji kvadrat*	***F***	**Sig.**	**$\alpha \leq 0.05$**
Bleaching chemical type / *Vrsta sredstva za izbjeljivanje*	Lightness (L^*)	539.871	2	269.936	242.390	0.000*
	Red (a^*) color tone	239.780	2	119.890	630.287	0.000*
	Yellow (b^*) color tone	85.336	2	42.668	76.240	0.000*
	Chroma (C^*)	56.099	2	28.049	40.617	0.000*
	Hue (h^o) angle	4357.468	2	2178.734	2270.000	0.000*
	Glossiness at ⊥20°	0.000	2	0.000	.	.**
	Glossiness at ⊥60°	1.349	2	0.674	115.234	0.000*
	Glossiness at ⊥85°	0.067	2	0.033	11.250	0.000*
	Glossiness at ‖20°	0.005	2	0.002	1.703	0.201**
	Glossiness at ‖60°	0.781	2	0.390	10.776	0.000*
	Glossiness at ‖85°	7.491	2	3.745	173.158	0.000*
	*WI** perpendicular (⊥)	154.634	2	77.317	1604.580	0.000*
	*WI** parallel (‖)	182.451	2	91.225	1136.109	0.000*
Error / *Pogreška*	Lightness (L^*)	30.068	27	1.114		
	Red (a^*) color tone	5.136	27	0.190		
	Yellow (b^*) color tone	15.111	27	0.560		
	Chroma (C^*)	18.646	27	0.691		
	Hue (h^o) angle	25.914	27	0.960		
	Glossiness at ⊥20°	0.000	27	0.000		
	Glossiness at ⊥60°	0.158	27	0.006		
	Glossiness at ⊥85°	0.080	27	0.003		
	Glossiness at ‖20°	0.037	27	0.001		
	Glossiness at ‖60°	0.978	27	0.036		
	Glossiness at ‖85°	0.584	27	0.022		
	*WI** perpendicular (⊥)	1.301	27	0.048		
	*WI** parallel (|)	2.168	27	0.080		
Total / *Ukupno*	Lightness (L^*)	56262.903	30			
	Red (a^*) color tone	1162.896	30			
	Yellow (b^*) color tone	4986.506	30			
	Chroma (C^*)	6150.955	30			
	Hue (h^o) angle	136587.118	30			
	Glossiness at ⊥20°	0.300	30			
	Glossiness at ⊥60°	10.040	30			
	Glossiness at ⊥85°	0.680	30			
	Glossiness at ‖20°	0.450	30			
	Glossiness at ‖60°	32.160	30			
	Glossiness at ‖85°	14.240	30			
	*WI** perpendicular (⊥)	2778.610	30			
	*WI** parallel (‖)	1574.540	30			
Corrected total / *Ukupno nakon ispravka*	Lightness (L^*)	569.940	29			
	Red (a^*) color tone	244.916	29			
	Yellow (b^*) color tone	100.446	29			
	Chroma (C^*)	74.744	29			
	Hue (h^o) angle	4383.382	29			
	Glossiness at ⊥20°	0.000	29			
	Glossiness at ⊥60°	1.507	29			
	Glossiness at ⊥85°	0.147	29			
	Glossiness at ‖20°	0.042	29			
	Glossiness at ‖60°	1.759	29			
	Glossiness at ‖85°	8.075	29			
	*WI** perpendicular (⊥)	155.935	29			
	*WI** parallel (‖)	184.619	29			

*Significant, **Insignificant / **značajno, **nije značajno* of 8.33 % with the single component and a decrease of 16.67 % with the double component). At 60 and 85 degrees, the control experimental group samples exhibited the highest results in both directions (Table 4).

The results of the analysis of variance are presented in Table 5. When these results were examined, the type of bleaching chemical was found to be statistically significant across all tests (Table 5).

4 CONCLUSIONS
4. ZAKLJUČAK

A reduction in *WI** values was noted in both orientations with the single component, whereas an increase was observed with the double component. The application of the double-component chemical yielded the highest *WI** values in both orientations, while the lowest values were recorded when using the single-component chemical on wooden surfaces.

The ΔE^* values were calculated as 5.46 for the single component and 8.69 for the double component.

The $C_2H_2O_4$ chemical led to reductions in the L^* and h^o parameters, accompanied by increases in the a^*, C^*, and b^* parameters. Furthermore, the application of H_2O_2 + NaOH chemicals during bleaching resulted in increases in L^*, b^*, C^*, and h^o values, while a decrease was observed in the a^* parameter.

It was observed that employing two distinct bleaching agents in both orientations resulted in reductions in glossiness values at 60 and 85 degrees.

It is recommended to conduct experiments related to natural or artificial aging tests on the bleached materials obtained.

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