Application of Single and Double Component Wood Bleaching Chemicals on Surface Properties of Naga (*Brachystegia cynometroides*) Wood

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Abstract

In this study, some surface changes (color parameters, whiteness index (*WI**), and glossiness) occurring after the application of single [oxalic acid ($C_2H_2O_4$)] and double component [sodium hydroxide (NaOH) + hydrogen peroxide (H_2O_2)] wood bleaching chemicals on naga (*Brachystegia cynometroides*) wood were investigated. The bleached surfaces were compared with the unbleached surfaces. According to the obtained results, the ΔE^* values were determined as 2.99 for $C_2H_2O_4$ chemical and 16.95 for NaOH + H_2O_2 chemical. Significant results were found for all tests in the analysis of variance. Increases in *b** and *C** values were observed with $C_2H_2O_4$, while decreases were observed with NaOH + H_2O_2 chemical. With both wood bleaching chemicals, increases were found in *WI** values in parallel directions to the fibers, as well as in ho and *L** values, while decreases were obtained in glossiness values at 60 and 85 degrees in both parallel and perpendicular directions to the fibers, and in *a** values.

Keywords: Naga, bleaching, whiteness index, *Brachystegia cynometroides*, color, glossiness

Introduction

The color of wood is an important indicator in the assessment of surface characteristics and the value of items. Therefore, wood bleaching has become one of the advanced technologies for enhancing the visual features and decorative effects of wood, as well as for the effective use of man-made rapidly growing wood (Duan 2002).

Bleaching is a process of color removal or whitening that can occur in a solution or on a surface. Materials that produce color in the solution or on fibers typically consist of organic compounds with broad conjugated chains containing alternating single and double bonds and typically including heteroatoms, carbonyl, and phenyl rings in the conjugated system. The part of the molecule that absorbs a light photon is called a chromophore (color carrier). Bleaching agents are used not only in textile, paper, and pulp bleaching but also in home laundry (Farr *et al.* 2003).

There are two methods for bleaching wood. The first method involves commercial wood bleaches that are high-strength acidic bleaches. These come with various brand names and can be purchased from most paint and hardware stores. The second bleaching method is household chlorine bleach. Bleaching wood takes longer but is much safer to use and causes less damage to the wood (Broadnax 1977).

A moderate increase in brightness or decrease in color can be achieved in a single step. The higher the target color removal, the more stages are required, increasing the likelihood of damaging the product's properties. This is particularly true for delicate materials (Suess 2009).

Under mild operating conditions, hydrogen peroxide has little or no lime-removing effect, making it particularly attractive for bleaching highly efficient (mechanical and semi-chemical) pulps. However, under severe conditions, this reagent has delignifying properties that can be used to obtain chemically pulped paper with high brightness and stability with very little degradation. Hydrogen peroxide is easy to transport, store, and use. It is highly flexible and almost non-volatile. Additionally, its reaction products are relatively non-toxic (Ramos *et al.* 2008).

Bleaching is the most important step in the experiment. At this stage, the linkage of conjugated double bonds in the side chain of lignin has been broken, as well as the chromophoric groups, resulting in a whiter absorption spectrum moving from the visible region to the ultraviolet region. It is advantageous to put it into an alkaline solution at this stage, but in a strong alkaline solution, H_2O_2 decomposes and releases O_2, which increases the use of H_2O_2. If the pH drops below 9, the decomposition of H_2O_2 slows down significantly. It is very important to control the pH in a narrow range (Hemmasi 2017).

In the literature, there are studies on bleaching applications using different bleaching chemicals on various wood species (Ayata and Bal 2024; Ayata and Çamlıbel, 2024; Ayata *et al*. 2024a;b; Çamlıbel and Ayata 2024; Peker *et al.* 2023a;b;c; 2024; Yamamoto *et al.* 2017; Ayata and Çamlıbel 2023; 2024; Mononen *et al.* 2005; Ayata and Bal 2023; Nguyen *et al*. 2019; Peker and Ayata 2023; Mehats *et al.* 2021; Peker 2023a;b; Peker and Ulusoy 2023; Ayata 2024; Liu *et al*. 2015; Çamlıbel and Ayata 2023a;b). However, it has been observed that no bleaching application has been performed on naga wood.

Naga can sometimes reach heights of up to 40 meters, with a cylindrical trunk (Aubréville, 1936). The heartwood is light to dark brown, somewhat resembling low-quality mahogany. It may have alternating dark and light streaks. The sapwood is about 15 cm wide, white or pale in color, and distinct from the heartwood. The fibers are generally tightly interlocked, and quarter-sawn surfaces display a ribbon-like figure. The texture is medium (Anonymous, 1956).

Cutting this timber with machine tools is moderately difficult, while working with hand tools is challenging. Saw teeth dull quite quickly. Most other processes result in moderate blunting of cutting edges. Due to the interlocked grain, severe tearing can occur during planing and molding. Achieving smooth surfaces is difficult, making the wood suitable for surface treatments. There is a moderate tendency for splitting during nailing. The wood is not suitable for tool manufacturing or general construction requiring high durability, but it is technically suitable for plywood production (Anonymous, 1956; 1951).

In this study, some surface changes occurring after the application of single and dual-component wood bleaching chemicals on naga (*Brachystegia cynometroides*) wood were investigated.

Materials and Methods

Wood Material

Samples of Naga (*Brachystegia cynometroides*) wood were prepared in dimensions of 100 mm x 100 mm x 15 mm. Conditioning treatments were applied to the samples (20±2°C with 65% relative humidity) (ISO 554, 1976).

Wood Bleaching Chemicals

Single-component (oxalic acid: $C_2H_2O_4$) and dual-component (hydrogen peroxide (H_2O_2) and sodium hydroxide (NaOH), prepared in a 2:1 ratio) bleaching chemicals were used.

Application of Bleaching on Wood Surfaces

Before the bleaching application, the wooden material surfaces were sanded with 80, 100 and 150 grit sandpaper. These chemicals were applied to the wood surfaces using a sponge, in a single layer. After applying one coat, the treated wood was allowed to dry. Then measurements were taken.

Determination of Some Surface Properties

Whiteness index (*WI**) values (ASTM E313-15e1 2015) (Whiteness Meter BDY-1), glossiness tests (ISO 2813 1994) (ETB-0833 model gloss meter), shore D hardness values (ASTM D 2240 2010), and color changes (ASTM D 2244-3 2007) (CS-10) were measured. Total color differences were calculated using the following formulas.

$$\Delta L^* = (L^*_{\text{bleached sample}} - L^*_{\text{unbleached sample}}) \quad (1)$$

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

$$h^o = \arctan(b^*/a^*) \quad (3)$$

$$\Delta H^* = [(\Delta E^*)^2 - (\Delta L^*)^2 - (\Delta C^*)^2]^{0.5} \quad (4)$$

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

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

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0.5} \quad (7)$$

$$\Delta b^* = (b^*_{\text{bleached sample}} - b^*_{\text{unbleached sample}}) \quad (8)$$

ΔC^*: chroma difference or saturation difference, and ΔH^*: hue difference or shade difference are indicated. Table 1 provides important information on other parameters (Lange, 1999). ΔE^* comparison criteria (DIN 5033 1979) are given in Table 2.

Table 1. Information regarding Δa^*, ΔL^*, Δb^*, and ΔC^* values (Lange 1999)

Test	Positive Description	Negative Description
Δb^*	More yellow than the reference	More blue than the reference
ΔL^*	Lighter than the reference	Darker than the reference
Δa^*	More red than the reference	More green than the reference
ΔC^*	Clearer, brighter than the reference	More dull, matte than the reference

Table 2. Comparison criteria for ΔE^* assessment (DIN 5033 1979)

Visual	Total Colour Difference	Visual	Total Colour Difference
Undetectable	<0.20	Distinct	1.50 - 3.00
Very Weak	0.20 - 0.50	Very Distinct	3.00 - 6.00
Weak	0.50 - 1.50	Strong	6.00 - 12.00
		Very Strong	> 12.00

Statistical Analysis

Standard deviations, means, minimum and maximum values, homogeneity groups, variance analysis results, and percentages (%) of changes have been calculated using a statistical program.

Table 3. Results of shore D hardness values

Number of Measurements	Mean (HD)	Standard Deviation	Minimum	Maximum	Coefficient of Variation
10	49.30	2.58	47.00	54.00	5.24

Results and Discussion

The Shore D test result for wood is obtained as 49.30 HD (Table 3). The results of ΔE^* are presented in Table 4.

The ΔE^* values were calculated as 2.99 with $C_2H_2O_4$ chemical and 16.95 with NaOH + H_2O_2 chemical. For both bleaching agents, the Δa^* values were negative (greener than the reference) and the ΔL^* values were positive (lighter than the reference) as determined (Table 4).

With $C_2H_2O_4$ chemical, the ΔC^* and Δb^* values were positive (clearer, brighter, and more yellow than the reference), while with NaOH + H_2O_2 chemical, they were negative (duller, cloudier, and more blue than the reference) (Table 4).

"Distinct (1.5 to 3.0)" criteria were obtained with $C_2H_2O_4$ chemical and "very strong (> 12.0)" with NaOH + H_2O_2 chemical (Table 4).

Table 4. Results of total color differences

Chemical Type	ΔL^*	Δa^*	Δb^*	ΔC^*	ΔH^*	ΔE^*	The color change criteria (DIN 5033, 1979)
$C_2H_2O_4$	0.16	-0.11	2.98	2.40	1.77	2.99	Distinct (1.5 ila 3.0)
NaOH + H_2O_2	13.07	-9.89	-4.32	-8.55	6.58	16.95	Very Strong (> 12.0)

The test results are provided in Table 5. With the application of bleaching agents to wooden material surfaces, increases were observed in the direction parallel to the fibers for both bleaching agents in terms of *WI**, h^o, and L^* values, while decreases were noted in the glossiness values and a^* values in both perpendicular and parallel directions at 60 and 85 degrees. Additionally, increases were observed with single component in b^* and C^* values, while decreases were observed with NaOH + H_2O_2 chemical.

The highest results in brightness values and a^* values in both perpendicular and parallel directions at 60 and 85 degrees were found in the control experiment group. For *WI**, increases were obtained with NaOH + H_2O_2 chemical in glossiness values perpendicular to the fibers and at 20 degrees perpendicular and parallel to the fibers, while decreases were obtained with $C_2H_2O_4$ chemical (Table 5).

The lowest results for L^* (62.20), h^o (52.54), and *WI** ‖ (10.65) values were observed in the control test samples. The lowest results for a^* (6.20), b^* (16.69), and C^* (17.87) values were obtained with NaOH + H_2O_2, whereas the lowest *WI** ⊥ value (20.04) was determined with $C_2H_2O_4$ chemical (Table 5).

When considering the highest results, L^* (75.27), h^o (69.66), and *WI** (⊥: 37.32 and ‖ : 24.78) values were obtained with NaOH + H_2O_2 chemical, while the a^* (16.09) test was found with the control samples, and the b^* (23.98) and C^* (28.82) tests were found with $C_2H_2O_4$ chemical (Table 5).

Table 5. Changes in color parameters, glossiness values, and whiteness index values after the application of single and dual-component wood bleaching chemicals on naga (*Brachystegia cynometroides*)

Test	Chemical Type	Mean	Change (%)	*HG*	Standard Deviation	Minimum	Maximum	COV
L^*	Control	62.20	-	B**	0.31	61.72	62.57	0.50
	$C_2H_2O_4$	62.35	↑0.24	B	0.35	61.71	62.85	0.57
	NaOH + H_2O_2	75.27	↑21.01	A*	1.06	73.80	76.76	1.40
a^*	Control	16.09	-	A*	0.20	15.72	16.45	1.22
	$C_2H_2O_4$	15.98	↓0.68	A	0.37	15.48	16.66	2.29
	NaOH + H_2O_2	6.20	↓61.47	B**	0.68	5.56	7.18	11.02
b^*	Control	21.00	-	B	0.24	20.68	21.33	1.13
	$C_2H_2O_4$	23.98	↑14.19	A*	0.28	23.46	24.49	1.17
	NaOH + H_2O_2	16.69	↓20.52	C**	0.99	15.70	18.13	5.96

*C**	Control	26.42	-	B	0.27	25.99	26.80	1.01
	$C_2H_2O_4$	28.82	↑9.08	A*	0.39	28.11	29.27	1.37
	$NaOH + H_2O_2$	17.87	↓32.36	C**	1.13	16.74	19.50	6.32
h°	Control	52.54		C**	0.39	51.93	53.03	0.75
	$C_2H_2O_4$	56.32	↑7.19	B	0.48	55.27	56.80	0.85
	$NaOH + H_2O_2$	69.66	↑32.58	A*	1.05	68.28	71.45	1.51
⊥20°	Control	0.50	-	B	0.00	0.50	0.50	0.00
	$C_2H_2O_4$	0.48	↓4.00	B**	0.04	0.40	0.50	8.78
	$NaOH + H_2O_2$	0.66	↑32.00	A*	0.14	0.40	0.80	21.66
⊥60°	Control	2.66	-	A*	0.20	2.50	3.00	7.35
	$C_2H_2O_4$	1.96	↓26.32	C**	0.08	1.90	2.10	4.30
	$NaOH + H_2O_2$	2.22	↓16.54	B	0.08	2.10	2.30	3.55
⊥85°	Control	1.10	-	A*	0.30	0.80	1.60	27.10
	$C_2H_2O_4$	0.10	↓90.91	B**	0.00	0.10	0.10	0.00
	$NaOH + H_2O_2$	0.10	↓90.91	B**	0.00	0.10	0.10	0.00
‖ 20°	Control	0.50	-	B	0.00	0.50	0.50	0.00
	$C_2H_2O_4$	0.44	↓12.00	B**	0.11	0.30	0.60	24.43
	$NaOH + H_2O_2$	0.64	↑28.00	A*	0.05	0.60	0.70	8.07
‖ 60°	Control	3.38	-	A*	0.18	3.10	3.60	5.37
	$C_2H_2O_4$	2.20	↓34.91	C**	0.09	2.10	2.30	4.29
	$NaOH + H_2O_2$	2.70	↓20.12	B	0.13	2.60	2.90	4.94
‖ 85°	Control	2.72	-	A*	0.28	2.50	3.20	10.22
	$C_2H_2O_4$	0.58	↓78.68	B	0.21	0.30	0.80	37.07
	$NaOH + H_2O_2$	0.10	↓96.32	C**	0.00	0.10	0.10	0.00
*WI** (⊥)	Control	21.55	-	B	0.26	21.20	21.90	1.22
	$C_2H_2O_4$	20.04	↓7.01	C**	0.17	19.80	20.30	0.85
	$NaOH + H_2O_2$	37.32	↑73.18	A*	1.68	35.10	39.20	4.50
*WI** (‖)	Control	10.65	-	B**	0.14	10.50	10.80	1.27
	$C_2H_2O_4$	10.86	↑1.97	B	0.14	10.70	11.00	1.32
	$NaOH + H_2O_2$	24.78	↑132.68	A*	0.96	23.70	26.00	3.87

HG: Homogeneity Group, COV: Coefficient of Variation, Number of Measurements: 10, *: Highest value, **: Lowest value

Variance analysis results are provided in Table 6. Upon examination of the variance analysis results, the type of bleaching agent was found to be significant for all tests (Table 6).

Table 6. Analysis of variance results (*: Significant)

Test	Sum of Squares	df	Mean Square	F value	Sig.
*L**	1125.402	2	562.701	1261.386	0.000*
*a**	644.971	2	322.485	1514.875	0.000*
*b**	269.124	2	134.562	358.953	0.000*
*C**	663.118	2	331.559	662.482	0.000*
h°	1618.038	2	809.019	1619.687	0.000*
⊥20° glossiness	0.195	2	0.097	13.140	0.000*
⊥60° glossiness	2.504	2	1.252	72.853	0.000*
⊥85° glossiness	6.667	2	3.333	112.500	0.000*
‖ 20° glossiness	0.211	2	0.105	22.219	0.000*
‖ 60° glossiness	7.016	2	3.508	176.709	0.000*
‖ 85° glossiness	38.915	2	19.457	472.435	0.000*
*WI** (⊥)	1831.905	2	915.952	941.584	0.000*
*WI** (‖)	1311.558	2	655.779	2048.124	0.000*

Various chemicals used in bleaching studies have been reported to induce changes in color parameters (Peker *et al.* 2023a;b;c; 2024; Yamamoto *et al.* 2017; Ayata and Çamlıbel 2023; 2024; Mononen *et al.* 2005; Ayata and Bal 2023; Nguyen *et al*. 2019; Peker and Ayata 2023; Mehats *et al.* 2021; Peker 2023a;b; Peker and Ulusoy 2023; Liu *et al.* 2015; Çamlıbel and Ayata 2023a;b).

Conclusions

The application of bleaching agents has resulted in changes in color parameters, glossiness values, and whiteness index values. These results have been confirmed by the data obtained from SPSS. The $NaOH + H_2O_2$ chemical had a greater effect on wood surfaces in terms of total color difference results compared to the $C_2H_2O_4$ chemical. The obtained results are important in terms of the potential applications of this tree species. It is recommended to conduct various aging tests on these materials.

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