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The effects of carbonate and vinegar mixture on selected surface properties of iatandza (*Albizia ferruginea*) wood

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ABSTRACT: The color of wooden materials can be altered through various applications (thermal treatment, bleaching, impregnation, aging, etc.). This study aimed to investigate alterations in color, whiteness index (*WI**), and glossiness properties resulting from the application of two distinct solutions (two different types of vinegar and a mixture of carbonate) on the surfaces of iatandza (*Albizia ferruginea*) wood. A reference group was established, and the surfaces subjected to treatments were compared among themselves. According to the results of the analysis of variance conducted, the solution type prepared over all tests was determined to be statistically significant. The *L**, *C**, *b**, and *a** values in the color parameters decreased while the h^o value exhibited an increase after the application of solutions. The Δ*E** values were measured at 13.63 for the carbonate + vinegar (A) solution and 13.13 for the carbonate + vinegar (B) solution. Furthermore, the calculated differences Δ*b**, Δ*L**, Δ*a**, and Δ*C** using color formulas were observed to be negative for both solutions. Glossiness values exhibited reductions in both directions at 60 and 85 degrees, alongside decreases in *WI** values in both orientations. It was noted that the application of solutions resulted in alterations to the surface characteristics of the wooden material.

Keywords: Iatandza, Color, Carbonate, Glossiness, Vinegar

Iatandza (*Albizia ferruginea*) odununda seçilmiş bazı yüzey özellikleri üzerine karbonat ve sirke karışımının etkileri

ÖZ: Ahşap malzemenin rengi çeşitli uygulamalar ile değişmektedir (ısıl işlem, ağartma, emprenye işlemi, yaşlandırma, vb.). Bu çalışmada, iatandza (*Albizia ferruginea*) odunu yüzeylerinde hazırlanmış olan iki farklı çözeltilerin (iki farklı sirke türü ve karbonat karışımı) meydana getirdiği renk, beyazlık indeksi (*WI**) ve parlaklık özelliklerindeki değişimler araştırılmıştır. Bir kontrol gurubu oluşturularak çözeltiler ile muamele edilmiş yüzeyler birbirleriyle kıyaslanmıştır. Yapılan varyans analizi sonuçlarına göre bütün testleri üzerinde hazırlanan çözelti türü anlamlı olarak tespit edilmiştir. Uygulanan çözeltiler sonrasında renk parametrelerinden olan *L**, *C**, *b** ve *a** değerleri azalış gösterirken, h^o değeri artmıştır. Δ*E** değerleri karbonat + sirke (A) çözeltisi ile 13.63 ve karbonat + sirke (B) çözeltisi ile 13.13 olarak elde edilmiştir. Buna ek olarak, renk formüllerinin kullanılması ile hesaplanmış olan Δ*b**, Δ*L**, Δ*a** ve Δ*C** değerleri her iki çözelti ile negatif olarak bulunmuştur. Parlaklık değerlerinde ise her iki yönde yapılan 60 ve 85 derecelerde ve her iki yöndeki *WI** değerlerinde azalmalar tespit edilmiştir. Uygulanan çözeltiler ile ahşap malzemeye ait yüzey özeliklerinin değiştiği görülmüştür.

Anahtar kelimeler: Iatandza, Renk, Karbonat, Parlaklık, Sirke

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1 Introduction

Wood, being a natural, fibrous, and organic material, has been utilized across a diverse array of applications throughout history. Its attractive cost and ease of manipulation have ensured its continued prominence as a renewable resource in the furniture and cabinetry sectors. Each tree species possesses distinct characteristics and properties, highlighting the importance of considering specific attributes like mechanical and physical properties for optimal use in engineering applications (Miller, 2007).

Wood products are extensively utilized in both interior and exterior applications owing to their aesthetic appeal, low density, low thermal expansion, and robust mechanical strength. Nevertheless, wood is vulnerable to decay caused by a variety of organisms, notably fungi, leading to considerable economic and resource losses (Hsu et al., 2007).

Various types of vinegar encompass spirit vinegar, grain vinegar, fruit vinegar, wine vinegar, apple cider vinegar, and malt vinegar. Additionally, blends derived from the alcoholic fermentation of natural sugars are utilized as primary ingredients. The nomenclature of vinegar is based on the specific source material utilized (Sellmer-Wilsberg, 2009).

Vinegar is characterized as a condiment produced through the alcoholic fermentation followed by acetic fermentation of diverse sugary and starchy substances (Cruess, 1958).

Vinegar comes in various forms with classification usually revolving around the primary ingredient utilized during production. This encompasses a range of types such as malt vinegar, wine vinegar, balsamic vinegar, apple cider vinegar, fruit vinegar, and a plethora of others found in today's international market (Hailu et al., 2012).

Iatandza (*Albizia ferruginea*) is a perennial tree species that reaches approximately 45 meters in height and 3 meters in width. Its leaves are occasionally bifoliate with lobes sometimes exceeding seven pairs (Agyare et al., 2006). This species, under the threat of deforestation, is widespread in West and Central Africa (Kareru et al., 2007).

Locally in Ghana, it is known as Awiemfo semina. It bears thick, dark reddish-brown bark, which can be peeled off in small rough scales, exuding red sap. The branches are flattened (Irvine, 1961).

Boiling the bark of "Ongokea gore" and "*Piptadeniastrum africanum*," referred to as "Evouvous," is used as a traditional remedy to treat infertility among the Ewondo tribe in the central region of Cameroon (Noumi et al., 2011).

People often consume powdered root bark along with salts as a remedy for constipation in Nigeria. The trunk bark source has been medically utilized to treat dysentery and wounds along the Ivory Coast shores. Additionally, the root bark is used to treat sickle cell anemia and lumbar pain (Abbiw, 1990).

In the wood of Iatandza (*Albizia ferruginea*), cellulose content ranges from 44.10% to 46.50%, hemicellulose from 28.30% to 31.60%, lignin from 25.20% to 28.40%, and extractive material quantity from 8.30% to 9.00% (Quartey, 2009). Its modulus of elasticity is 13847 N/mm^2, and bending strength is 49.90 N/mm^2 (Appiah-Kubi et al., 2012).

In the literature, it is observed that a solution of vinegar and carbonate mixture is not used to change the color of wood material.

This research was conducted on the use of mixtures formed by adding vinegar (grape and hawthorn) and carbonate to induce color changes on iatandza wood surfaces (color, whiteness index (*WI**), and glossiness). The obtained results were discussed with tables.

2 Materials and Methods

2.1 Wood Material

Iatandza (*Albizia ferruginea*) wood was prepared in dimensions of 100 x 100 x 15 mm (by preparing 5 samples per group). Subsequently, these samples underwent conditioning at 20±2°C and 65% relative humidity (ISO 554, 1976).

2.2 Chemicals

Two different types of vinegar were used in this study: A: grape (with added sodium metabisulfite) and B: hawthorn (with carbohydrate %1.00, saturated sugar %0.17, salt %0.07, fat %0.05, saturated fat %0.02, and protein %0.30). Additionally, carbonate chemicals were utilized.

2.3 Method

2.3.1 Application of Prepared Carbonate and Vinegar Mixtures to Wood Surfaces

Solutions prepared in two different types [50 ml vinegar (A) + 5 g carbonate and 50 ml vinegar (B) + 5 g carbonate] were applied as a single layer onto the wood surfaces using a brush.

2.3.2 Determination of Color Properties

Color changes were measured using the CS-10 (CHN Spec, China) [CIE 10° standard observer; CIE D65 light source, illumination system: 8/d (8°/diffuse illumination)] device (ASTM D 2244-3, 2007) (Ayata, 2023; Peker and Ayata, 2023).

ΔC^* is defined as the chroma difference or saturation difference while ΔH^* is defined as the hue difference or shade difference in the literature. Additionally, some important information about other parameters is presented in Table 1 (Lange, 1999).

Table 1. The definitions of Δa^*, ΔC^*, Δb^*, and ΔL^* (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

The comparison criteria for visual assessment of color difference (ΔE^*) are provided in Table 2 (DIN 5033, 1979).

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

Visual	Total Color Difference
Undetectable	<0.2
Very Weak	0.2 - 0.5
Weak	0.5 - 1.5
Distinct	1.5 - 3.0
Very Distinct	3.0 - 6.0
Strong	6.0 - 12.0
Very Strong	> 12.0

The results for total color differences were determined using the following formulas.

$C^* = [(a^*)^2 + (b^*)^2]^{0.5}$ (1)
$h^o = \arctan(b^* / a^*)$ (2)
$\Delta C^* = (C^*_{\text{treated with solution}} - C^*_{\text{not treated with solution}})$ (3)
$\Delta a^* = (a^*_{\text{treated with solution}} - a^*_{\text{not treated with solution}})$ (4)
$\Delta L^* = (L^*_{\text{treated with solution}} - L^*_{\text{not treated with solution}})$ (5)
$\Delta b^* = (b^*_{\text{treated with solution}} - b^*_{\text{not treated with solution}})$ (6)
$\Delta H^* = [(\Delta E^*)^2 - (\Delta L^*)^2 - (\Delta C^*)^2]^{0.5}$ (7)
$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0.5}$ (8)

2.3.3 Determination of Whiteness Index (*WI**) Properties

In this study, the Whiteness Meter BDY-1 device was used to determine the whiteness index (*WI**) values in both parallel and perpendicular directions to the fibers (ASTM E313-15e1, 2015).

2.3.4 Determination of Glossiness Properties

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

2.4 Statistical Analysis

Standard deviations, maximum and minimum values, mean values, homogeneity groups, variance analyses, and percentage (%) change rates were calculated using a statistical program.

3 Results and Discussion

The results of the analysis of variance are presented in Table 3. According to these results, it is observed that the factor of solution type applied for all tests was obtained significantly (Table 3).

Table 3. The results of the analysis of variance

Source	Test	Sum of Squares	df	Mean Square	F value
L*	1068.249	2	534.125	880.222	0.000*
a*	62.431	2	31.216	192.874	0.000*
b*	66.703	2	33.352	235.080	0.000*
C*	115.744	2	57.872	375.348	0.000*
***h*º**	135.690	2	67.845	79.942	0.000*
⊥20º glossiness	0.252	2	0.126	33.516	0.000*
⊥60º glossiness	3.979	2	1.989	191.829	0.000*
⊥85º glossiness	0.384	2	0.192	36.000	0.000*
‖20º glossiness	0.051	2	0.025	14.250	0.000*
‖60º glossiness	1.976	2	0.988	48.326	0.000*
‖85º glossiness	2.579	2	1.289	28.818	0.000*
***WI** (⊥)*	356.216	2	178.108	2329.901	0.000*
***WI** (‖)*	20.305	2	10.152	468.569	0.000*

*: Significant

The measurement results for color parameters are provided in Table 4. In terms of the *L** parameter, the control samples exhibited the highest value at 54.91, whereas the lowest value was recorded in the experimental samples treated with the carbonate + vinegar (A) mixture solution at 41.88. The most significant reduction in *L** value was observed in the carbonate + vinegar (A) solution with a decrease rate of 23.73% while the lowest reduction rate was noted in the carbonate + vinegar (B) solution at 22.31% (Table 4).

For the *a** value, the highest result is observed in the control samples (9.70) while the lowest result is determined in the application of the solution consisting of carbonate + vinegar (B) mixture (6.50). The highest decrease rate in the *a** parameter is found in the carbonate + vinegar (B) solution with 32.99% while the lowest decrease rate is obtained with the prepared carbonate + vinegar (A) solution with 29.90% (Table 4).

Table 4. Results for color parameters

Test	Solution Type	N	Mean	Change (%)	*HG*	*SD*	Minimum	Maximum	COV
L*	**Control (not treated with solution)**	10	54.91	-	A*	1.15	53.18	56.32	2.10
	Carbonate + Vinegar (A)	10	41.88	↓23.73	C**	0.57	41.13	42.93	1.37
	Carbonate + Vinegar (B)	10	42.66	↓22.31	B	0.40	42.22	43.42	0.94
a*	**Control (not treated with solution)**	10	9.70	-	A*	0.32	9.36	10.39	3.27
	Carbonate + Vinegar (A)	10	6.80	↓29.90	B	0.54	6.26	8.03	7.90
	Carbonate + Vinegar (B)	10	6.50	↓32.99	B**	0.31	5.97	6.85	4.78
b*	**Control (not treated with solution)**	10	19.89	-	A*	0.48	18.90	20.63	2.42
	Carbonate + Vinegar (A)	10	17.15	↓13.78	B	0.35	16.62	17.62	2.02
	Carbonate + Vinegar (B)	10	16.43	↓17.40	C**	0.27	16.01	16.75	1.64
C*	**Control (not treated with solution)**	10	22.13	-	A*	0.50	21.19	22.91	2.25
	Carbonate + Vinegar (A)	10	18.34	↓17.13	B	0.41	17.78	18.98	2.22
	Carbonate + Vinegar (B)	10	17.67	↓20.15	C**	0.22	17.42	18.02	1.24
***h*°**	**Control (not treated with solution)**	10	64.00	-	B**	0.75	62.55	65.01	1.16
	Carbonate + Vinegar (A)	10	68.61	↑7.20	A*	0.84	67.41	69.87	1.23
	Carbonate + Vinegar (B)	10	68.39	↑6.86	A	1.13	66.83	70.29	1.66

Vinegar (A): Grape, Vinegar (B): Hawthorn, COV: Coefficient of Variation, *SD*: Standard Deviation, *HG*: Homogeneity Group, N: Number of Measurements, *: Highest Result, **: Lowest Result

In regard to the *b** parameter, the highest value was recorded in the control samples at 19.89 while the lowest value was observed in the experimental samples treated with the carbonate + vinegar (B) mixture solution registering at 16.43. Notably, the most pronounced decrease in the *b** parameter occurred with the application of the carbonate + vinegar (B) solution to wood surfaces resulting in a reduction rate of 17.40%. Conversely, the treatment process involving the carbonate + vinegar (A) solution exhibited the least decrease rate at 13.78% (Table 4).

Regarding the *C** parameter, the highest measurement was noted in the control samples at 22.13, whereas the lowest value was recorded in the experimental samples treated with the carbonate + vinegar (B) mixture solution showing a reading of 17.67. Interestingly, the most substantial reduction rate of 20.15% in the *C** parameter was observed with the carbonate + vinegar (B) solution while the carbonate + vinegar (A) solution exhibited a comparatively lower decrease rate of 17.13% (Table 4).

In h^o value, the lowest result is determined in the control samples (64.00) while the highest result is observed after the application of the carbonate + vinegar (A) mixture solution (68.61). The highest increase rate for h^o is 7.20% in the carbonate + vinegar (A) solution while the lowest increase rate is 6.86% in the carbonate + vinegar (B) solution (Table 4).

Table 5 presents the results for total color differences. Δ*E** values obtained using the color formulas provided in the materials and methods section are 13.63 for the carbonate + vinegar (A) solution and 13.13 for the carbonate + vinegar (B) solution, and the results are very close to each other. Δ*H** values are calculated as 1.23 for the carbonate + vinegar (A) solution and 1.53 for the carbonate + vinegar (B) solution (Table 5).

Δ*L**, Δ*a**, Δ*b**, and Δ*C** values are negative (respectively darker than the reference, greener than the reference, bluer and duller than the reference) for both solutions applied to the wooden material surfaces. When compared with the color change criteria, it is observed that both prepared solutions give "very strong (> 12.0)" results (Table 5).

Table 5. Results for total color differences

Solution Type	Δ*L**	Δ*b**	Δ*a**	Δ*C**	Δ*H**	Δ*E**	Criteria (DIN 5033, 1979)
Carbonate + Vinegar (A)	-13.03	-2.90	-2.74	-3.79	1.23	13.63	Very strong (> 12.0)
Carbonate + Vinegar (B)	-12.25	-3.20	-3.46	-4.46	1.53	13.13	

The measurement results for whiteness index (*WI**) values are presented in Table 6. Decreases are observed in *WI** values in both directions after the application of the prepared solutions to the wooden material surfaces. The highest results in *WI** values are determined in the control samples (⊥: 16.56 and ‖: 5.65). In addition, the decrease rates for *WI** values are determined as 45.89% and 42.15% for the ⊥ direction and 22.48% and 35.22% for the ‖ direction for carbonate + vinegar (A) and carbonate + vinegar (B) solutions, respectively (Table 6).

Table 6. Results for whiteness index (*WI**) values

Test	Solution Type	N	Mean	Change (%)	*HG*	*SD*	Mini-mum	Maxi-mum	COV
*WI** ⊥	**Control (not treated with solution)**	10	16.56	-	A*	0.38	16.20	17.20	2.30
	Carbonate + Vinegar (A)	10	8.96	↓45.89	C**	0.25	8.70	9.30	2.74
	Carbonate + Vinegar (B)	10	9.58	↓42.15	B	0.15	9.40	9.80	1.62
*WI** ‖	**Control (not treated with solution)**	10	5.65	-	A*	0.05	5.60	5.70	0.93
	Carbonate + Vinegar (A)	10	4.38	↓22.48	B	0.23	4.20	4.70	5.36
	Carbonate + Vinegar (B)	10	3.66	↓35.22	C**	0.08	3.60	3.80	2.30

Vinegar (A): Grape, Vinegar (B): Hawthorn, COV: Coefficient of Variation, *SD*: Standard Deviation, *HG*: Homogeneity Group, N: Number of Measurements, *: Highest Result, **: Lowest Result

The measurement results for glossiness values are listed in Table 7. When looking at the glossiness tests, measurements made perpendicular (⊥) to the fibers at 20, 60, and 85 degrees show decreases. Again, the highest glossiness results are found in the control test samples (⊥20^o: 0.34, ⊥60^o: 1.88, and ⊥85^o: 0.34) (Table 7).

Decreases in glossiness values parallel to the fibers at 60 and 85 degrees are observed with both solutions. At 20-degree parallel to the fibers, a decrease of 30.00% with the carbonate + vinegar (A) solution and an increase of 20.00% with the carbonate + vinegar (B) solution are observed (Table 7).

In the study conducted by Çamlıbel and Ayata (2024), it was reported that applying solutions prepared from mixtures of vinegar and baking soda to the surfaces of movingui

(*Distemonanthus benthamianus* Baillon) wood resulted in decreases in all glossiness values, *WI** values, and *L** and *a** values while increases were observed in *C**, *h*°, and *b** values.

Table 7. Results for glossiness values

Test	Solution Type	N	Mean	Change (%)	*HG*	*SD*	Mini-mum	Maxi-mum	COV
⊥20°	Control (not treated with solution)	10	0.34	-	A*	0.06	0.30	0.42	16.63
	Carbonate + Vinegar (A)	10	0.12	↓64.71	C**	0.04	0.10	0.20	35.14
	Carbonate + Vinegar (B)	10	0.22	↓35.29	B	0.08	0.10	0.30	35.86
⊥60°	Control (not treated with solution)	10	1.88	-	A*	0.10	1.70	2.00	5.49
	Carbonate + Vinegar (A)	10	1.04	↓44.68	C**	0.08	0.90	1.10	8.11
	Carbonate + Vinegar (B)	10	1.20	↓36.17	B	0.12	1.10	1.40	9.62
⊥85°	Control (not treated with solution)	10	0.34	-	A*	0.13	0.20	0.50	37.20
	Carbonate + Vinegar (A)	10	0.10	↓70.59	B**	0.00	0.10	0.10	0.00
	Carbonate + Vinegar (B)	10	0.10	↓70.59	B**	0.00	0.10	0.10	0.00
‖20°	Control (not treated with solution)	10	0.20	-	B	0.00	0.20	0.20	0.00
	Carbonate + Vinegar (A)	10	0.14	↓30.00	C**	0.05	0.10	0.20	36.89
	Carbonate + Vinegar (B)	10	0.24	↑20.00	A*	0.05	0.20	0.30	21.52
‖60°	Control (not treated with solution)	10	1.84	-	A*	0.14	1.60	2.00	7.77
	Carbonate + Vinegar (A)	10	1.26	↓31.52	B**	0.16	1.10	1.50	12.52
	Carbonate + Vinegar (B)	10	1.76	↓4.35	A	0.13	1.60	1.90	7.19
‖85°	Control (not treated with solution)	10	1.34	-	A*	0.20	1.00	1.50	14.59
	Carbonate + Vinegar (A)	10	0.66	↓50.75	B**	0.25	0.30	1.00	38.60
	Carbonate + Vinegar (B)	10	1.20	↓10.45	A	0.18	1.00	1.40	14.70

Vinegar (A): Grape, Vinegar (B): Hawthorn, COV: Coefficient of Variation, *SD*: Standard Deviation, *HG*: Homogeneity Group, N: Number of Measurements, *: Highest Result, **: Lowest Result

4 Conclusion

This study has yielded the following outcomes:

- The color parameter values of *L**, *C**, *b**, and *a** decreased whereas the *h*° value demonstrated an increase following the application of solutions.
- The Δ*E** values were recorded as 13.63 for the carbonate + vinegar (A) solution and 13.13 for the carbonate + vinegar (B) solution.
- Glossiness values showed decreases in both directions at 60 and 85 degrees accompanied by declines in *WI** values in both orientations.
- The changes (Δ*a**, Δ*b**, Δ*L**, and Δ*C**) calculated using color formulas were found to be negative for both solutions.
- The application of solutions led to changes in the surface properties of the wooden material.
- It is recommended to conduct natural or artificial aging tests after the application of interior or exterior varnishes on the samples treated with the obtained solution.

Author Contribution

Ümit Ayata: Review and Editing, Conducting Research, Drafting Manuscript, Resources, Validation, Visualization, Determination of Methodology, Supervision, Performing Analyses, Data Refinement, Manuscript Writing.

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