ONLINE ISSN 2069-7430
ISSN-L 1841-4737

PRO LIGNO
www.proligno.ro

Vol. 20 N° 3 2024
pp. 3-9

A STUDY ON THE COLOR-CHANGING EFFECT OF VINEGAR + BAKING SODA MIXTURE ON SCOTS PINE (*Pinus sylvestris* L.) WOOD

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Abstract:

In this study, changes in selected surface properties (glossiness, color, and whiteness index: WI) occurring after the application of two different solutions vinegar (A) + baking soda and vinegar (B) + baking soda) composed of vinegar (hawthorn and grape) and baking soda chemicals on Scots pine (Pinus sylvestris L.) wood surfaces were investigated. Results were compared with processed experimental samples, and a control group was formed. Based on the findings, the prepared solution type showed significance across all tests, except for measurements taken perpendicular to the fibers at 85 degrees, as indicated by the results of the variance analysis. Following the application of solutions, reductions were noted in the L* and a* values within the color parameters, whereas an increasing trend was observed in h^o, C*, and b* values. The ΔE* values were determined to be 8.11 for the carbonate + vinegar (A) solution and 6.69 for the carbonate + vinegar (B) solution. Furthermore, utilizing color formulas revealed negative Δb* and ΔL* values for both solutions, while Δa* and ΔC* values were computed as positive. Decreases were observed in glossiness values at 20 and 60 degrees in both directions, alongside reductions in WI* values in both orientations. It was noted that the application of solutions led to alterations in the surface characteristics of the wooden material.*

Key words: *vinegar, color, baking soda, Scots pine, glossiness, whiteness index.*

INTRODUCTION

Wood, considered one of the fundamental traditional materials, stands out as the sole renewable and eco-friendly option among them. Anticipated to see notable advancements, it owes this to its distinctive visual appeal, remarkable strength-to-weight ratio, inherent biodegradability, ability to enhance indoor spaces, and a host of other natural attributes. Additionally, its robust plasticity, versatility, efficient processing capabilities, low energy consumption during processing, and recyclability contribute to its prominence. Wood holds an essential place in various sectors including construction, furniture production, interior design, and transportation infrastructure (Cao et al. 2022).

Color is the interpretation of an object's outer surface by the human eye's retina, elicited by radiation reflecting within the visible range of the electromagnetic spectrum (400-700nm). It, alongside texture and shine, stands out as a crucial aesthetic characteristic of wood, exerting a substantial impact on its economic worth (Pandey 2005; Papp et al. 2012; Baar et al. 2019).

It has been observed that various studies have been conducted on color alteration in Scots pine wood in the literature [in color alteration, impregnation with melamine, silicone, water glass, and tall oil by Lahtela and Kärki (2014), treatment with epoxidized linseed oil and methyltriethoxysilane by Jebrane et al. (2017), treatment with sodium hypochlorite (NaClO) by Ulay and Ayata (2023), treament with $KMnO_4$ + $NaHSO_3$ + H_2O_2, NaOH + H_2O_2, H_2C_2O4 + $C_2H_4(OH)_2$, NaOH + $Ca(OH)_2$, $NaSiO_3$ + H_2O_2 by Karamanoğlu (2012), and heat-treatment with ThermoWood method by Ayata et al. (2017). These studies report on the stages at which color changes occur. However, there are no reports in the literature of using a solution of baking soda and vinegar for color change purposes specifically with Scots pine wood. In addition, there are very few studies in the literature that use a baking soda and vinegar solution for color change purposes. Reports indicate that the use of a vinegar and baking soda solution leads to changes in color, glossiness, and whiteness index properties in the wood species iatandza (Ayata 2024), Honduras rosewood (Ayata et al. 2024), ayous (Ayata and Ayata 2024a), and Movingui (Çamlibel and Ayata 2024). Scots pine wood is utilized for various purposes in different countries.

Scots pine wood finds extensive application in the field of furniture making and carpentry, notably in the crafting of windows, doors, and flooring materials. It proves to be beneficial for paneling and as underlying structures for ceilings. Moreover, it serves a purpose in the inner fittings of vessels and train compartments. Furthermore, it plays a role in the manufacture of resin and turpentine. The external appearance of this wood varies, ranging from a yellowish hue to whitish-pink tones, and tends to undergo darkening over time due to exposure to environmental factors. While applying varnish can be a challenging task, the wood itself boasts high durability. Following the cleaning of resin, it becomes suitable for painting (Şanıvar and Zorlu 1980).

In this study, selected surface changes that occurred after the application of two different solutions (utilizing vinegar and baking soda chemicals) on Scots pine (*Pinus sylvestris* L.) wood surfaces were examined.

OBJECTIVE

This study investigates the changes occurring between Scots pine (*Pinus sylvestris* L.) wood and solutions created from a mixture of carbonate and vinegar. The objective is to analyze how the obtained results interact with the wood materials during the process of color alteration, aiming to offer fresh insights for producers and consumers alike.

MATERIALS

Samples of Scots pine (*Pinus sylvestris* L.) wood were acquired in dimensions of 100 x 200 x 20mm. The samples were prepared following the TS ISO 13061-1 (2021) standard. In this study, carbonate and two different types of vinegar were used: grape vinegar (with sodium metabisulfite additive) and hawthorn vinegar (contains 0.17% saturated sugar, 1.00% carbohydrate, 0.05% fat, 0.07% salt, 0.02% saturated fat, and 0.30% protein).

METHODS

Two different solutions were prepared: one with 50ml of vinegar (A) and 5g of carbonate, and the other with 50ml of vinegar (B) and 5g of carbonate. These solutions were then applied to wooden surfaces using a brush. This method was used by antique furniture makers and woodworkers to achieve different tones in the wood. However, it is now rarely used in modern practices. This method allows for the achievement of different color tones.

Glossiness tests were conducted using the ETB-0833 model gloss meter, following the ISO 2813 (1994) standard. Whiteness index (*WI**) values were measured in parallel and perpendicular directions to the fibers. (ASTM E313-15e1 2015). Color changes were measured using a CS-10 (CHN Spec, China) device (ASTM D 2244-3 2007). The chroma value (*C**) begins at zero at the center and increases as you move away from the center. The hue angle (h^o) is measured from the +*a** axis; at 0°, the color is red, at 90° it is yellow, at 180° it is green, and at 270° it is blue (Cecchini 2014). In the literature, Δ*C** is defined as the chroma part or saturation difference, and Δ*H** as the hue part or shade difference (Lange 1999).

Table 1

The definitions of Δa*, ΔC*, Δb*, and ΔL* (Lange 1999)

Test	Positive Description	Negative Description
Δ***b****	More yellow than the reference	More blue than the reference
Δ***L****	Lighter than the reference	Darker than the reference
Δ***a****	More red than the reference	More green than the reference
Δ***C****	Clearer, brighter than the reference	More dull, matte than the reference

The comparison criteria for the visual evaluation of the calculated Δ*E** color difference are provided in Table 2 according to DIN 5033 (1979).

Table 2

Comparison criteria for ΔE* evaluation (DIN 5033 1979)

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

The total color differences were calculated using the formulas provided by Ayata and Ayata (2024a;b).

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

Minimum and maximum values, standard deviations, homogeneity groups, means, variance analyses, and percentage (%) change rates were determined using a statistical software.

RESULTS AND DISCUSSION

Table 3 presents the outcomes of the variance analysis. Based on these findings, it is evident that the chemical type factor exhibits significant effects across all tests, with the exception of the gloss values measured perpendicular to the fibers at 85 degrees (Table 3).

The measurement results for color parameters, whiteness index (*WI**) values, and glossiness values are given in Table 4.

The control samples yielded the highest L^* value at 72.93, whereas the application of the vinegar (A) + carbonate mixture resulted in the lowest L^* value among the test samples at 66.99. The most significant reduction in the L^* parameter was observed with the vinegar (A) + carbonate solution, decreasing by 8.14%, while the vinegar (B) + carbonate solution showed the lowest decrease rate at 7.95% (Table 4).

For the a^* parameter, the highest value is recorded in the control samples at 8.70, while the lowest value is found in the samples treated with the vinegar (B) + carbonate solution, which is 8.15. The greatest decrease in the a^* value, 6.32%, is observed with the vinegar (B) + carbonate solution, while the smallest decrease, 5.98%, is seen with the vinegar (A) + carbonate solution (Table 4).

In the control samples, the b^* value recorded the lowest result at 22.32, whereas the highest result was obtained following the application of the vinegar (A) + carbonate mixture, reaching 27.82. The most notable increase in the b^* parameter occurred with the vinegar (A) + carbonate solution, showing a rise of 24.64%, while the vinegar (B) + carbonate solution exhibited the lowest increase rate at 14.70% (Table 4).

The greatest increase in the C^* parameter is observed with the vinegar (A) + carbonate solution, showing a 20.99% rise, while the smallest increase is seen with the vinegar (B) + carbonate solution, which results in a 13.27% increase. For the C^* value, the control samples have the lowest reading at 23.96, whereas the highest value, 28.99, is recorded after applying the vinegar (A) + carbonate mixture (Table 4).

Regarding the h^o value, the control samples exhibited the lowest result at 68.70, while the highest result was attained post-application of the vinegar (A) + carbonate mixture to the test samples, reaching 73.61. The most substantial increase rate in the h^o parameter was observed with the treatment of vinegar (A) + carbonate solution on wooden surfaces, showing a rise of 7.15%, whereas the treatment of vinegar (B) + carbonate solution resulted in the lowest increase rate at 5.28% (Table 4).

Upon examining the glossiness tests, decreases are observed in all degrees and directions except for measurements perpendicular to the fibers at 85 degrees. The highest glossiness results are obtained in the control test samples (⊥20°: 1.06, ⊥60°: 4.28, ∥20°: 1.16, ∥60°: 5.84, and ∥85°: 4.10). The lowest glossiness results are found on samples treated with vinegar (B) + carbonate solution perpendicular to the fibers at 20 and 60 degrees (⊥20°: 0.52 and ⊥60°: 2.14), while on samples treated with vinegar (A) + carbonate solution parallel to the fibers at 60 and 85 degrees (∥60°: 3.18 and ∥85°: 1.02) (Table 4).

Decreases are determined in *WI** values after the application of solutions in both directions. The highest results in *WI** values are obtained in the control samples (⊥: 39.06 and ∥: 18.44). Additionally, the lowest results are found on samples treated with vinegar (A) + carbonate solution (⊥: 23.64 and ∥: 12.50). The decrease rates for *WI** values are determined as 39.48% to 36.76% in the perpendicular direction and 32.21% to 18.98% in the parallel direction for vinegar (A) + carbonate and vinegar (B) + carbonate solutions, respectively (Table 4).

The color changes in the wood species Honduras rosewood (Ayata et al. 2024), ayous (Ayata and Ayata 2024a), iatandza (Ayata 2024), and movingui (Çamlibel and Ayata 2024) treated with a vinegar + baking soda solution have been reported.

ONLINE ISSN 2069-7430
ISSN-L 1841-4737

PRO LIGNO
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Table 3

Results of the variance analysis for color parameters, whiteness index (WI*) values, and glossiness values

Chemical Type					
Test	**Sum of Squares**	**df**	**Mean Square**	**F value**	**Sig.**
L*	229.805	2	114.903	354.500	0.000*
a*	1.917	2	0.958	6.101	0.007*
b*	153.195	2	76.598	1090.479	0.000*
C*	129.774	2	64.887	186.468	0.000*
h^o	130.024	2	65.012	109.170	0.000*
⊥20^o glossiness	1.664	2	0.832	103.145	0.000*
⊥60^o glossiness	28.664	2	14.332	120.325	0.000*
⊥85^o glossiness	0.000	2	0.000	.	.**
∥20^o glossiness	1.952	2	0.976	299.455	0.000*
∥60^o glossiness	43.299	2	21.649	2283.328	0.000*
∥85^o glossiness	57.032	2	28.516	601.509	0.000*
WI* (⊥)	1483.699	2	741.849	3087.227	0.000*
WI* (∥)	178.291	2	89.145	908.959	0.000*
Error					
Test	**Sum of Squares**	**df**		**Mean Square**	
L*	8.751	27		0.324	
a*	4.241	27		0.157	
b*	1.897	27		0.070	
C*	9.395	27		0.348	
h^o	16.079	27		0.596	
⊥20^o glossiness	0.218	27		0.008	
⊥60^o glossiness	3.216	27		0.119	
⊥85^o glossiness	0.000	27		0.000	
∥20^o glossiness	0.088	27		0.003	
∥60^o glossiness	0.256	27		0.009	
∥85^o glossiness	1.280	27		0.047	
WI* (⊥)	6.488	27		0.240	
WI* (∥)	2.648	27		0.098	
Total			**Corrected Total**		
Test	**Sum of Squares**	**df**	**Test**	**Sum of Squares**	**df**
L*	143133.424	30	***L****	238.557	29
a*	2095.328	30	***a****	6.157	29
b*	19272.878	30	***b****	155.092	29
C*	21516.259	30	***C****	139.170	29
h^o	153708.144	30	h^o	146.103	29
⊥20^o glossiness	18.044	30	**⊥20^o glossiness**	1.882	29
⊥60^o glossiness	284.180	30	**⊥60^o glossiness**	31.880	29
⊥85^o glossiness	0.300	30	**⊥85^o glossiness**	0.000	29
∥20^o glossiness	21.240	30	**∥20^o glossiness**	2.040	29
∥60^o glossiness	559.400	30	**∥60^o glossiness**	43.555	29
∥85^o glossiness	198.280	30	**∥85^o glossiness**	58.312	29
WI* (⊥)	26952.720	30	**WI* (⊥)**	1490.187	29
WI* (∥)	7197.520	30	**WI* (∥)**	180.939	29
***: Significant**					

The results for total color differences are presented in Table 5. ΔH^* values are found as 2.27 with vinegar (A) + carbonate solution and 0.98 with vinegar (B) + carbonate solution. ΔE^* values are obtained as 8.11 with vinegar (A) + carbonate solution and 6.69 with vinegar (B) + carbonate solution. ΔL^* and Δb^* values are determined as negative (darker than the reference and more blue than the reference, respectively) with the application of both solutions on wooden surfaces, while Δa^* and ΔC^* values are found as positive (redder than the reference and clearer, brighter than the reference, respectively). Compared to the color change criteria, both solutions yield "strong (6.00 to 12.00)" results (see Table 5).

ONLINE ISSN 2069-7430
ISSN-L 1841-4737
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Table 4

Results obtained for color parameters, whiteness index (WI*) values, and glossiness values

Test	Chemical Type	Mean	Change Ratio (%)	Homogeneity Group	Standard Deviation	Minimum	Maximum	Coefficient of Variation
*L**	Control (no treatment)	72.93	-	A*	0.73	71.72	73.85	1.00
	Vinegar (A) + baking soda	66.99	↓8.14	B**	0.61	66.38	67.89	0.91
	Vinegar (B) + baking soda	67.13	↓7.95	B	0.27	66.81	67.68	0.40
*a**	Control (no treatment)	8.70	-	A*	0.31	8.20	9.31	3.59
	Vinegar (A) + baking soda	8.18	↓5.98	B	0.57	7.43	8.90	6.97
	Vinegar (B) + baking soda	8.15	↓6.32	B**	0.22	7.83	8.60	2.69
*b**	Control (no treatment)	22.32	-	C**	0.23	22.10	22.78	1.01
	Vinegar (A) + baking soda	27.82	↑24.64	A*	0.30	27.13	28.17	1.07
	Vinegar (B) + baking soda	25.60	↑14.70	B	0.27	25.24	26.07	1.05
*C**	Control (no treatment)	23.96	-	C**	0.29	23.71	24.50	1.21
	Vinegar (A) + baking soda	28.99	↑20.99	A*	0.35	28.27	29.39	1.21
	Vinegar (B) + baking soda	27.14	↑13.27	B	0.92	26.57	29.65	3.37
h°	Control (no treatment)	68.70	-	C**	0.61	67.65	69.86	0.89
	Vinegar (A) + baking soda	73.61	↑7.15	A*	1.06	72.37	75.05	1.44
	Vinegar (B) + baking soda	72.33	↑5.28	B	0.53	71.25	73.01	0.74
⊥20°	Control (no treatment)	1.06	-	A*	0.14	0.80	1.20	13.53
	Vinegar (A) + baking soda	0.62	↓41.51	B	0.04	0.60	0.70	6.80
	Vinegar (B) + baking soda	0.52	↓50.94	C**	0.04	0.50	0.60	8.11
⊥60°	Control (no treatment)	4.28	-	A*	0.51	3.50	5.00	12.00
	Vinegar (A) + baking soda	2.28	↓46.73	B	0.29	2.10	2.80	12.54
	Vinegar (B) + baking soda	2.14	↓50.00	B**	0.11	2.00	2.30	5.02
⊥85°	Control (no treatment)	0.10	-	A	0.00	0.10	0.10	0.00
	Vinegar (A) + baking soda	0.10	0.00	A	0.00	0.10	0.10	0.00
	Vinegar (B) + baking soda	0.10	0.00	A	0.00	0.10	0.10	0.00
∥20°	Control (no treatment)	1.16	-	A*	0.08	1.00	1.20	7.27
	Vinegar (A) + baking soda	0.64	↓44.83	B	0.05	0.60	0.70	8.07
	Vinegar (B) + baking soda	0.60	↓48.28	B**	0.00	0.60	0.60	0.00
∥60°	Control (no treatment)	5.84	-	A*	0.11	5.70	6.00	1.84
	Vinegar (A) + baking soda	3.18	↓45.55	C**	0.10	3.00	3.30	3.25
	Vinegar (B) + baking soda	3.42	↓41.44	B	0.08	3.30	3.50	2.31
∥85°	Control (no treatment)	4.10	-	A*	0.27	3.90	4.50	6.50
	Vinegar (A) + baking soda	1.02	↓75.12	C**	0.18	0.80	1.30	17.78
	Vinegar (B) + baking soda	1.36	↓66.83	B	0.20	1.10	1.60	14.38
*WI** ⊥	Control (no treatment)	39.06	-	A*	0.82	38.20	40.20	2.11
	Vinegar (A) + baking soda	23.64	↓39.48	C**	0.17	23.40	23.90	0.72
	Vinegar (B) + baking soda	24.70	↓36.76	B	0.12	24.60	24.90	0.47
*WI** ∥	Control (no treatment)	18.44	-	A*	0.29	18.10	18.80	1.56
	Vinegar (A) + baking soda	12.50	↓32.21	C**	0.31	12.10	13.00	2.50
	Vinegar (B) + baking soda	14.94	↓18.98	B	0.34	14.50	15.40	2.26
Vinegar (A): Grape, Vinegar (B): Hawthorn, Number of Measurements: 10, *: Highest Result, **: Lowest Result								

Table 5

Results for total color differences

Chemical Type	Δ*L**	Δ*b**	Δ*a**	Δ*C**	Δ*H**	Δ*E**	Color Change Criterion (DIN 5033, 1979)
Vinegar (A) + baking soda	-5.94	-0.52	5.50	5.04	2.27	8.11	Strong (6.00 to 12.00)
Vinegar (B) + baking soda	-5.80	-0.55	3.28	3.18	0.98	6.69	

CONCLUSION

Declines were observed in glossiness values at both 20 and 60 degrees in both directions, accompanied by decreases in *WI** values in both orientations. After the application of solutions, reductions were evident in the *L** and *a** values of the color parameters, while an upward trend was noted in h^o, *C**, and *b** values. Furthermore, the utilization of color formulas unveiled negative Δb^* and ΔL^* values for both solutions, with Δa^* and ΔC^* values being calculated as positive. The ΔE^* values were determined as 8.11 for the carbonate + vinegar (A) solution and 6.69 for the carbonate + vinegar (B) solution. It was clear that applying the solutions led to changes in the surface properties of the wood.

In this study, since the focus is on color darkening, it is recommended to use these chemicals if a change in the color of wood is desired in the furniture industry.

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