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ИСПОЛЬЗОВАНИЕ КРАСИТЕЛЕЙ, ПОЛУЧЕННЫХ ИЗ НЕКОТОРЫХ РАСТЕНИЙ, ДЛЯ ИЗМЕНЕНИЯ ЦВЕТА ДРЕВЕСИНЫ СОСНЫ ОБЫКНОВЕННОЙ (*PINUS SYLVESTRIS* L.)

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Аннотация. Красители, полученные из растений, используются в различных промышленных областях, таких как текстильная, кожевенная, пищевая промышленность, косметика и деревообработка. Это исследование фокусируется на использовании растворов, полученных из таких материалов, как корица, кукуруза, чернокочанная капуста, кукурузный краситель и куркума, для изменения цвета древесины сосны обыкновенной (*Pinus sylvestris* L.). Поверхности, обработанные растворами, были сравнены с необработанными поверхностями. Согласно результатам анализы дисперсии для всех полученных цветовых параметров показали статистически значимые различия. Значения Δ*E** составили 63,52 для корицы, 31,95 для кукурузы, 72,80 для чернокочанной капусты, 67,79 для кукурузного красителя и 50,91 для куркумы. Было отмечено уменьшение всех значений *L**, в то время как значения *b** и *C** увеличились. Было установлено, что растительные красители, использованные в исследовании, оказывают влияние на изменение цвета поверхности древесных материалов.

Ключевые слова: древесина, цвет, корица, кукуруза, чернокочанная капуста, кукурузный краситель, куркума

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Original article

USE OF DYES OBTAINED FROM SOME PLANTS IN SCOTS PINE (*PINUS SYLVESTRIS* L.) WOOD FOR COLOR CHANGING PURPOSES

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Abstract. Dyes obtained from plants are used in various industrial fields such as textiles, leather, food, cosmetics, and woodworking. This research focuses on the use of solutions obtained from materials such as cinnamon, corn, black cabbage, corn dye, and turmeric for color modification of Scots pine (*Pinus sylvestris* L.) wood. Surfaces treated with the solutions were compared with untreated surfaces. According to the results, dispersion analyses for all color parameters obtained were found to be statistically significant. The ΔE^* values obtained were 63,52 for cinnamon, 31,95 for corn, 72,80 for black cabbage, 67,79 for corn dye, and 50,91 for turmeric. A decrease was observed in all L^* values, while increases were noted in all b^* and C^* values. It was observed that the plant-based dyes used in the research had a color-changing effect on the surface of wood materials.

Keywords: wood, color, cinnamon, corn, black cabbage, corn dye, turmeric

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Introduction

There is a vast range of natural wood colors du e to the potential variations in wood color both between and within tree species. Nevertheless, the variety of natural and commercially available colors does not always align with customer demands (Application of natural…, 2009).

One useful characteristic for identifying tree species is their color. The color of some trees may fade under the influence of sunlight, while others may darken to some extent over time. However, each tree has its unique color. For example, walnut is brown, oak is dirty yellow, beech is pink, elm is reddish-brown, and ash is white (Shanyva, Zorlu, 1980).

Wood's natural appearance flaws, like uneven color variations and dull tones, can be remedied through treatments such as bleaching, staining, and surface finishing, which improve its overall aesthetic and decorative appeal. Additionally, the appearance of lower-grade wood can be enhanced by mimicking the color of more prized tree species (Hu et al., 2020).

Whether natural or dyed, items made from unvarnished wood materials have low resistance to external influences. This is because wood dyes used on wooden surfaces do not form a protective layer; they only alter the color and tone (Sonmez, 2005; Yalynkylych and Syonmez, 2009).

A broad spectrum of natural dyes and stains, providing colors like yellow, brown, blue, red, black, and their blends, has traditionally been obtained from plants. These dyes are extracted from almost all parts of plants, including bark, roots, wood, leaves, fruits, seeds, and flowers (Siva, 2007).

In addition to providing essential resources such as fiber, food, shelter, and fuel, plants are also valuable sources of natural dyes. These colors are produced by the interaction of various organic and inorganic compounds within the plants, which absorb light in the visible spectrum ranging from 400 to 800 nm (Aggarwal, 2021).

This research investigates the application of solutions derived from materials like black cabbage, cinnamon, maize dye, corn, and turmeric to alter the color of Scots pine (*Pinus sylvestris* L.) wood.

Materials and Methods

Scots pine (*Pinus sylvestris* L.) wood was chosen as the subject of this study. Test specimens were prepared in dimensions of 100 mm × 100 mm × 15 mm. Subsequently, the samples were conditioned under environmental conditions of 20 ± 2 °C and 65 % relative humidity, in accordance with ISO 554 (1976).

This study used the solid-liquid extraction method, and due to the evaporation of the solvent in the extraction process, the temperature was not increased above the boiling point of the solvent. About 1 g of dried plants (*Rubia tinctorium* L, barassica var. Acephala, zea mays, curcuma longa and cinnamomum) were weighed respectively, taken in the 250 ml beaker, and dissolved in 100 ml of solvent (H_2O). After heating the beaker at 70–80 °C for 1h, the extract was filtered, and stored and stored in liquid form after cooling at room temperature, and used for dyeing

Wood materials were dyed with natural dyes at a material-to-liquor ration of 1:100. The dye bath temperature was kept at 55–60 °C for 1h. The pH of the dye bath was set at different specified levels ranging from 4–8. Potassium aluminium sulphate ($KAl(SO_4)_2$ $12H_2O$), copper sulphate ($CuSO_{45}$ H_2O) Acestic acid and sodium carbonate were employed for adjustment of pH at such speciified levels. Finally, dyed materials were washed with cold water and dried in a shady, airy place.

Color changes were measured using the CS-10 (CHN Spec, China) device [CIE 10° standard observer; CIE D65 light source, illumination system: 8/d (8°/diffuse illumination)] (ASTM D 2244-3, 2007). The total color differences were determined using the formulas provided below.

The total color differences were calculated using the following formulas.

$$C^* = \left[(a^*)^2 + (b^*)^2\right]^{0.5}, \quad (1)$$

$$h° = \arctan(b^*/a^*), \quad (2)$$

$$\Delta C^* = (C^*_{sample\ with\ varnished} - C^*_{control}), \quad (3)$$

$$\Delta a^* = (a^*_{sample\ with\ varnished} - a^*_{control}), \quad (4)$$

$$\Delta L^* = (L^*_{sample\ with\ varnished} - L^*_{control}, \quad (5)$$

$$\Delta b^* = (b^*_{sample\ with\ varnished} - b^*_{control}), \quad (6)$$

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

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

Table 1 contains the definitions of the other parameters, while Table 2 (Lange, 1999) presents the color change range according to Jirouz and Ljuljka (1999).

Ten measurements were taken per test. Standard deviations, maximum and minimum values, mean values, homogeneity groups, variance analyses, and percentage (%) change rates have been calculated using a statistical program.

Table 1

Descriptions for Δa^*, ΔL^*, Δb^* and ΔC^* (Lange, 1999)

Parameter	In negative case	In positive case
ΔL^*	Darker than reference	Lighter than reference
Δb^*	Bluer than reference	More yellow than reference
ΔC^*	Matte, more blurred than reference	Clearer, brighter than reference
Δa^*	Greener than reference	Redder than reference

Table 2

Color change range according to Jirouš and Ljuljka (1999)

Δ*E** Range	Color Change Estimation	Δ*E** Range	Color Change Estimation
< 0,20	Unnoticeable	3,00–6,00	Very noticeable
0,20–0,50	Very slight	6,00–12,00	Intense
0,50–1,50	Light	> 12,00	Very intense
1,50–3,00	Noticeable		

Results and Discussion

The analysis of variance results for all color parameters are presented in Table 3. The plant material type was found to be statistically significant for all color parameters (Table 3).

Table 3

Analysis of variance results for color parameters

Test	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	F Value	α≤0,05
*L**	Herbal Ingredient Type	26389,441	5	5277,888	2164,472	0,000*
	Error	131,675	54	2,438	–	–
	Total	142182,692	60	–	–	–
	Corrected Total	26521,116	59	–	–	–
*a**	Herbal Ingredient Type	30370,254	5	6074,051	360,272	0,000*
	Error	910,420	54	16,860	–	–
	Total	38801,699	60	–	–	–
	Corrected Total	31280,674	59	–	–	–
*b**	Herbal Ingredient Type	17170,190	5	3434,038	242,720	0,000*
	Error	764,001	54	14,148	–	–
	Total	171441,456	60	–	–	–
	Corrected Total	17934,191	59	–	–	–
*C**	Herbal Ingredient Type	21145,170	5	4229,034	168,362	0,000*
	Error	1356,407	54	25,119	–	–
	Total	214918,991	60	–	–	–
	Corrected Total	22501,577	59	–	–	–
h°	Herbal Ingredient Type	27266,543	5	5453,309	618,986	0,000*
	Error	475,744	54	8,810	–	–
	Total	385891,833	60	–	–	–
	Corrected Total	27742,287	59	–	–	–

In a study conducted to change colors using different plant-based materials, the results of the measured color parameters are presented in Table 4. According to these results, decreases were observed in all *L** values (63,59 % for maize dye, 57,72 % for cinnamon, 40,35 % for corn, 79,74 % for black cabbage, and 20,65 % for turmeric).

Table 4

Measurement results of color parameters

Test	Herbal Ingredient Type	Mean	Change (%)	Homo-geneity Group	Standard Deviation	Mini-mum	Maxi-mum	Coefficient of Variation
*L**	Control	77,95	–	A*	1,09	76,29	79,90	1,39
	Cinnamon	32,96	↓57,72	D	1,39	30,52	34,27	4,21
	Corn	46,50	↓40,35	C	0,40	45,94	47,02	0,87
	Black Cabbage	15,79	↓79,74	F**	1,85	13,52	19,39	11,72
	Maize Dye	28,38	↓63,59	E	1,00	25,88	29,12	3,52
	Turmeric	61,85	↓20,65	B	2,63	57,14	64,66	4,26
*a**	Control	9,88	–	C	0,34	9,57	10,77	3,47
	Cinnamon	48,96	↑395,55	A*	4,47	41,09	54,95	9,12
	Corn	12,48	↑26,32	C	0,16	12,28	12,78	1,30
	Black Cabbage	–19,42	↓296,56	E**	4,11	–23,62	–12,00	–21,17
	Maize Dye	–10,32	↓204,45	D	5,96	–25,64	–3,90	–57,77
	Turmeric	25,59	↑159,01	B	5,35	20,46	36,17	20,91
*b**	Control	27,55	–	E**	0,91	26,92	29,97	3,30
	Cinnamon	49,52	↑79,75	C	3,64	45,72	57,16	7,35
	Corn	32,48	↑17,89	D	0,14	32,31	32,79	0,43
	Black Cabbage	51,56	↑87,15	C	5,76	41,59	57,93	11,17
	Maize Dye	69,15	↑151,00	B	5,92	62,80	84,27	8,56
	Turmeric	73,22	↑165,77	A*	1,60	71,50	76,90	2,19
*C**	Control	29,27	–	E**	0,97	28,59	31,85	3,31
	Cinnamon	69,78	↑138,40	B	3,33	65,26	73,37	4,77
	Corn	34,80	↑18,89	D	0,13	34,61	35,06	0,38
	Black Cabbage	55,16	↑88,45	C	6,58	44,23	62,53	11,93
	Maize Dye	73,06	↑149,61	B	9,53	66,04	92,92	13,05
	Turmeric	77,71	↑165,49	A*	2,11	75,24	80,56	2,71
h°	Control	70,27	–	C	0,13	70,13	70,59	0,19
	Cinnamon	45,36	↓35,45	D**	3,85	41,42	52,53	8,50
	Corn	68,48	↓2,55	C	1,65	63,86	69,29	2,40
	Black Cabbage	110,48	↑57,22	A*	2,80	105,12	113,68	2,54
	Maize Dye	98,18	↑39,72	B	3,61	93,56	106,92	3,67
	Turmeric	70,80	↑0,75	C	3,80	63,17	74,24	5,36

Number of Measurements: 10, *: Highest result, **: Lowest result.

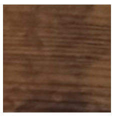
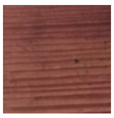
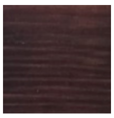
All b^* values showed increases (17,89 % for corn, 79,75 % for cinnamon, 87,15 % for black cabbage, 151,00 % for maize dye, and 165,77 % for turmeric). Increases were observed in all C^* values (138,40 % for cinnamon, 18,89 % for corn, 149,61 % for maize dye, 88,45 % for black cabbage, and 165,49 % for turmeric). The highest result for the L^* value was found in the control sample (77,95), while the lowest results for the b^* and C^* values were observed in the control group (27,55 and 29,27, respectively). For the ho parameter, a decrease of 2,55 % was observed with the corn solution, and a decrease of 35,45 % was noted for cinnamon. On the other hand, increases of 57,22 % for black cabbage, 39,72 % for maize dye, and 0,75 % for turmeric were observed. In the a^* parameters, an increase of 159,01 % for turmeric, 395,55 % for cinnamon, and 26,32 % for corn was observed, while a decrease of 296,56 % for black cabbage and 204,45 % for maize dye was found (Table 4).

The results of the total color differences are presented in Table 5. The ΔE^* values recorded were 63,52 for cinnamon, 31,95 for corn, 72,80 for black cabbage, 67,79 for maize dye, and 50,91 for turmeric, indicating the extent of color change for each herbal ingredient. The ΔH^* parameter was determined as 19,21 for cinnamon, 27,67 for black cabbage, 0,74 for corn, and 14,87 for maize dye (Table 5).

Table 5

Results of the total color differences

Herbal Ingredient Type	ΔL^*	Δa^*	Δb^*	ΔC^*	ΔH^*
Cinnamon	–44,99	39,08	21,97	40,51	19,21
Corn	–31,46	2,60	4,93	5,53	0,74
Black Cabbage	–62,16	–29,30	24,01	25,88	27,67
Maize Dye	–49,57	–20,20	41,59	43,78	14,87
Turmeric	–16,11	15,70	45,67	48,44	–

Herbal Ingredient Type		ΔE^*	Color Change (Jirouš and Ljuljka 1999)
Control		0	–
Cinnamon		63,52	Very intense (> 12,00)
Corn		31,95	Very intense (> 12,00)
Black Cabbage		72,80	Very intense (> 12,00)
Maize Dye		67,79	Very intense (> 12,00)
Turmeric		50,91	Very intense (> 12,00)

All ΔL^* values were determined to be negative (darker than the reference). The Δa^* values were negative (more green than the reference) for the Black cabbage and maize dye products, while they were positive (more red than the reference) for the cinnamon, corn, and turmeric products. The Δb^* and ΔC^* values were found to be positive (respectively, more yellow than the reference and clearer, brighter than the reference). It was determined that all plant-based products fell into the "very intense (>12,00)" category according to the color criteria (Jirouš and Ljuljka, 1999) (Table 5).

In a study conducted by Atılgan (2009), experimental samples from Scots pine, oriental beech, and pedunculate oak were used. Dye extracts [pine, acorn, Anatolian chestnut, and yellow dock] were applied to these wood samples. To ensure the adhesion of these extracts to the wood surface and to fix the color of the dye, mordants such as iron sulfate, aluminum sulfate, and vinegar were used. Following this, color measurements were taken, and surfaces of different colors were obtained, as reported in the study.

Conclusions

The plant-based ingredients used have significantly altered the color parameters of the wood. Cinnamon, maize dye, and turmeric caused substantial changes in the color parameters, while black cabbage and corn resulted in contrasting effects on certain color parameters. Each herbal ingredient induced unique color changes, influencing the wood's color in different ways and allowing for a wide range of decorative and aesthetic outcomes.

In the subsequent stages of this study, it is recommended to investigate the effects of variables such as application times, temperature, and concentration of plant-based ingredients on wood in more detail. Additionally, examining the impact of these plant dyes on the durability of wood and the long-term color changes would also be beneficial.

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