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IMPACT OF WASTE VEGETABLE OILS ON THE COLOR PARAMETERS, WHITENESS INDEX, AND GLOSSINESS OF SIBERIAN PINE (*PINUS SIBIRICA*) WOOD

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Abstract:

Waste vegetable oils can be effectively used in heat treatment processes involving an oily medium, influencing the properties of wood. However, the use of these oils for color modification of wood surfaces has not been widely explored in the existing literature. This study investigates the impact of waste vegetable oils-specifically olive, corn, and walnut oils-on the surface properties of Siberian pine (Pinus sibirica) wood. The results reveal significant changes in the wood's surface characteristics, as indicated by multivariate variance analysis. When the selected waste oils were applied to wood materials, it was determined that the L (lightness) and ho (color tone angle) values decreased, while the a* (red-green), b* (yellow-blue) and C* (color brightness) values increased. In addition, it was observed that the gloss and whiteness index values of all waste oils used decreased in both directions - parallel and transverse to the wood fibers. ΔE* (total color difference) values were obtained as 19.27 in samples using waste olive oil, 18.72 for waste walnut oil and 16.83 for waste corn oil. As a result of the results, the study showed that the application of waste vegetable oils affected the surface properties of Siberian pine wood, especially its gloss, color, and whiteness. In addition, it caused significant changes in the wood material.*

***Key words**: Glossiness; Waste oils; Color parameters; Siberian pine; Whiteness inde.*

INTRODUCTION

Wood has long been an integral part of human life. Wood stands out as a renewable material that fits within the framework of a green and circular economy (Štefko et al. 2014; Potkány et al. 2021).

Globally, food consumption leads to the generation of significant amounts of waste vegetable oils, also known as used or frying oils. In many parts of the world, a large portion of these waste oils is disposed of improperly (Tashtoush et al. 2003).

However, vegetable oils that contain minimal amounts of sulfur, nitrogen, and metals can serve as a renewable, usable, and environmentally friendly energy source. Because of these beneficial characteristics, waste vegetable oils are considered viable alternatives for various non-food applications (Valdés and Garcia 2006).

Due to their inherent unsaturated nature, vegetable oils are reportedly prone to oxidation when exposed to air, leading to their deterioration over time. Monounsaturated fats, on the other hand, have been reported to oxidize more slowly than polyunsaturated fats, which are more prone to rapid oxidation (Rafiq et al. 2015).

This study examines changes in color parameters, gloss values, and whiteness index resulting from the application of selected waste vegetable oils with different properties to the surfaces of test samples of Siberian pine (*Pinus sibirica*) wood. The results provide important information about the interactions between wood and various types of waste vegetable oils produced with various properties. These findings will provide insight into how waste vegetable oils affect both the wood and the different oil types used, highlighting their importance for the wood industry in terms of their potential impact on wood processing and preservation.

MATERIAL AND METHODS

In this study, the wood species used were Siberian pine (*Pinus sibirica*). The materials were procured by purchasing from a commercial timber vendor. The experimental material was obtained from a commercial establishment and selected as first-grade quality, with dimensions of 100 mm x 100 mm x 20 mm.

Randomly chosen samples were carefully inspected to ensure they were free from knots, defects, cracks, and exhibited uniform color and density. Following the TS ISO 13061-1 (2021) standards, the samples were then prepared. Climate conditioning processes were carried out on the wooden materials in accordance with the TS ISO 642 554 (1997) standard.

In this study, waste vegetable oils from walnut, corn, and olive varieties were utilized to treat the surfaces of wood materials. These oils were applied using the brushing technique, which allowed for a uniform distribution across the wood.

Table 1 provides a detailed overview of some key properties of the waste vegetable oils used in this experiment. This information is crucial for understanding the characteristics of each oil and how they may influence the treatment of the wood surfaces.

Table 1

Certain characteristics of the waste vegetable oils utilized in this study

Feature	Walnuts (per 100 g)	Corn (per 100 g)	Olives (per 100 g)
Polyunsaturated fatty acid	-	51.00	10.50
Monounsaturated fatty acid	-	28.00	74.00
Saturated fatty acid	9.10	12.00	15.15

In this study, color changes in oiled and unoiled wood samples were obtained using a CS-10 colorimeter (CHN Spec, China) based on the CIELAB color system. Measurements on the colorimeter were determined in accordance with ASTM D 2244-3 (2007). Total color differences (ΔE)* were calculated using formulas that evaluate color changes.

$$h^o = \arctan (b^*/a^*) \quad (1)$$
$$\Delta H^* = [(\Delta E^*)^2 - (\Delta L^*)^2 - (\Delta C^*)^2]^{0.5} \quad (2)$$
$$C^* = [(a^*)^2 + (b^*)^2]^{0.5} \quad (3)$$
$$\Delta b^* = (b^*_{\text{oil coated sample}}) - (b^*_{\text{reference}}) \quad (4)$$
$$\Delta C^* = (C^*_{\text{oil coated sample}}) - (C^*_{\text{reference}}) \quad (5)$$
$$\Delta a^* = (a^*_{\text{oil coated sample}}) - (a^*_{\text{reference}}) \quad (6)$$
$$\Delta L^* = (L^*_{\text{oil coated sample}}) - (L^*_{\text{reference}}) \quad (7)$$
$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0.5} \quad (8)$$

The definitions of the color difference parameters ΔH^*, Δa^*, ΔC^*, Δb^*, and ΔL^*, summarized by Lange (1999), are as follows:

Δb^*: A positive value indicates a more yellowish hue of the sample compared to the reference, and a negative value indicates a more blue hue.

ΔL^*: A positive value indicates a lighter hue of the sample than the reference, and a negative value indicates a darker hue.

ΔH^*: Measures the difference in hue or tone between the sample and the reference.

ΔC^*: This represents the change in color saturation. A positive result indicates that the sample is more vibrant and intense than the reference, while a negative result indicates that it is duller or less saturated.

Δa^*: A positive value indicates a more reddish hue of the sample compared to the reference, and a negative value indicates a more greenish hue.

Additionally, the criteria table of Cividini et al. (2007) for visual assessment of color differences $(\Delta E^*)^*$ is presented in Table 2.

Table 2

Comparison criteria for ΔE* evaluation (Cividini et al. 2007)

Rate of Color Difference	Range of Δ*E**
No visible difference	Δ*E** < 0.20
Small difference	2.00 > Δ*E** > 0.20
Color difference visible with high quality screen	3.00 > Δ*E** > 2.00
Color difference visible with medium quality screen	6.00 > Δ*E** > 3.00
High color difference	12.00 > Δ*E** > 6.00
Different colors	Δ*E** > 12.00

Gloss measurements were determined using an ETB-0833 model gloss meter at a 60° angle, taking measurements in both perpendicular (⊥) and parallel (‖) directions relative to the wood grain.

The ISO 2813 (1994) standard was used to determine the gloss level of oil-coated and uncoated surfaces.

In addition, whiteness index (*WI**) values were obtained using a Whiteness Meter BDY-1 and ASTM E313-15e1 (2015) standard, taking measurements in both perpendicular and parallel directions to the wood grain. Minimum and maximum measurement values, homogeneity groups, standard deviations, multivariate analyses of variance, percentage (%) change ratios, and means were determined using statistical software.

RESULTS AND DISCUSSION

Multivariate ANOVA results for color parameters, brightness values, and whiteness index are shown in Table 3. It was determined that the waste vegetable oil type had significant results on all tested properties (Table 3).

Table 3

The results of the multivariate analysis of variance

Sources	Test	Sum of Squares	Degree of Freedom	F Value	Mean Square	Sig
Waste Vegetable Oil Type	*a**	510.973	3	744.990	170.324	0.000*
	*L**	1363.875	3	1220.383	454.625	0.000*
	*b**	730.197	3	1499.303	243.399	0.000*
	*C**	1152.022	3	1904.801	384.007	0.000*
	h°	264.290	3	217.063	88.097	0.000*
	Glossiness ⊥60°	5.775	3	42.540	1.925	0.000*
	Glossiness ‖60°	6.664	3	79.020	2.221	0.000*
	WI* ⊥	505.091	3	438.955	168.364	0.000*
	WI*‖	544.491	3	7741.578	181.497	0.000*
*: Significant						

The results of total color differences (ΔE*) using color formulas with the application of waste vegetable oils are shown in Table 4.

Table 4

The results of the total color differences

Oil Type	Δ*a**	Δ*L**	Δ*b**	Δ*H**	Δ*C**	Δ*E**	Color change criterion (Cividini *et al.* 2007)
Walnut	8.45	-12.51	11.06	2.71	13.66	18.72	Different colors (Δ*E** > 12.00)
Corn	7.44	-11.68	9.57	2.48	11.86	16.83	
Olive	8.66	-15.23	8.01	3.99	11.10	19.27	

When the Δ*E** values were compared with the color change criterion according to Cividini et al. (2007), it was obtained that all three waste vegetable oils met the "different colors" criterion with Δ*E** values greater than 12.00 (Table 4).

The Δ*E** values were ranked in descending order as follows: waste olive oil (19.27), waste walnut oil (18.72), and waste corn oil (16.83). For all three oils, the Δ*L** values were negative, indicating that the treated wood surfaces became darker than the reference. The Δ*a** values were positive, suggesting that the surfaces became redder, while the Δ*b** values were also positive, indicating a more yellowish hue. Additionally, the Δ*C** values were positive, which means the surfaces appeared clearer and brighter than the reference (Table 4).

These findings highlight the significant color changes caused by the application of waste vegetable oils on the wood surfaces.

Ayata and Bal (2023) reported in their study on European black pine wood treated with waste olive, corn, and walnut oils, that the ΔE* values were 4.87 for waste olive oil, 4.86 for waste corn oil, and 3.88 for waste walnut oil.

The Δ*E** values after the application of waste vegetable oils to European spruce wood were determined by Peker et al. (2023b) as 5.24 for walnut oil, 5.42 for corn oil, and 5.39 for olive oil.

According to the research by Çamlıbel and Ayata (2024), when waste vegetable oils were applied to iroko wood surfaces, waste corn oil resulted in the lowest Δ*E** value (23.70), while waste olive oil produced the highest value (24.48).

Several studies in the literature have focused on determining the total color difference (Δ*E**) values resulting from the application of waste vegetable oils on wood surfaces.

The findings obtained from the use of waste vegetable oils are presented in Table 5.

Table 5

The results of measurements (One-Way-ANOVA)

Test	Oil Type	Mean	Homogeneity Group	Change (%)	Maxi-mum	Mini-mum	Standard Deviation	Coefficient of Variation
*L**	Control	68.05	A*	-	68.74	67.68	0.35	0.52
	Walnut	55.54	C	↓18.38	56.34	54.45	0.56	1.01
	Corn	56.37	B	↓17.16	57.54	55.34	0.73	1.30
	Olive	52.82	D**	↓22.38	53.82	51.94	0.72	1.36
*a**	Control	10.86	C**	-	11.06	10.46	0.19	1.71
	Walnut	19.32	A	↑77.90	19.82	18.75	0.38	1.98
	Corn	18.30	B	↑68.51	19.21	17.64	0.59	3.23
	Olive	19.53	A*	↑79.83	20.24	18.46	0.62	3.18
*b**	Control	24.88	D**	-	25.15	24.20	0.27	1.10
	Walnut	35.94	A*	↑44.45	36.22	35.30	0.26	0.74
	Corn	34.45	B	↑38.46	35.73	33.72	0.62	1.80
	Olive	32.88	C	↑32.15	33.24	32.09	0.35	1.05
*C**	Control	27.15	D**	-	27.48	26.37	0.32	1.18
	Walnut	40.81	A*	↑50.31	41.23	40.42	0.30	0.73
	Corn	39.01	B	↑43.68	40.16	38.32	0.60	1.54
	Olive	38.25	C	↑40.88	38.76	37.22	0.50	1.31
h°	Control	66.41	A*	-	66.71	66.25	0.17	0.26
	Walnut	61.74	B	↓7.03	62.36	60.68	0.51	0.82
	Corn	62.02	B	↓6.61	63.64	60.93	0.89	1.44
	Olive	59.27	C**	↓10.75	60.52	58.19	0.73	1.24
*WI** (⊥)	Control	18.80	A*	-	19.80	17.80	0.88	4.69
	Walnut	11.04	C	↓41.28	11.80	10.60	0.43	3.89
	Corn	12.74	B	↓32.23	13.40	12.10	0.53	4.17
	Olive	9.40	D**	↓50.00	10.10	8.70	0.54	5.72
*WI** (‖)	Control	11.10	A*	-	11.40	10.80	0.22	1.95
	Walnut	2.22	D**	↓80.00	2.30	2.10	0.08	3.55
	Corn	2.94	B	↓73.51	3.30	2.80	0.20	6.65
	Olive	2.64	C	↓76.22	2.70	2.60	0.05	1.96
⊥60°	Control	2.71	A*	-	3.30	2.30	0.38	14.07
	Walnut	2.58	A	↓4.80	2.70	2.40	0.10	4.00
	Corn	2.10	B	↓22.51	2.30	2.00	0.12	5.50
	Olive	1.76	C**	↓35.06	1.90	1.60	0.11	6.11
‖60°	Control	2.96	A*	-	3.30	2.70	0.19	6.41
	Walnut	2.94	A	↓0.68	3.20	2.60	0.23	7.72
	Corn	2.34	B	↓20.95	2.50	2.10	0.14	6.11
	Olive	2.00	C**	↓32.43	2.10	1.90	0.07	3.33
Number of Measurements: 10, *: Highest value, **: Lowest value								

In terms of *L** (lightness) values, the control group exhibited the highest value at 68.05, whereas the lowest value of 52.82 was observed in samples treated with waste olive oil. The application of all waste oils caused a reduction in *L** values, signifying a darkening effect on the wood surface. The percentages of reduction, from greatest to least, were 22.38% for waste olive oil, 18.38% for waste walnut oil, and 17.16% for waste corn oil (Table 5).

For the *a** (red-green) value, the control samples had the lowest value of 10.86, while the highest value of 19.53 was observed in the samples treated with waste olive oil. The application of all waste oils resulted in an increase in *a** values, indicating a shift toward a redder hue. The increase in *a** values, ranked from highest to lowest, was 79.83% for waste olive oil, 77.90% for waste walnut oil, and 68.51% for waste corn oil (Table 5).

These findings demonstrate how the application of different waste vegetable oils significantly altered both the lightness and color (red-green) properties of the wood, with waste olive oil causing the most pronounced changes in both directions.

Regarding the *b** (yellow-blue) parameter, the lowest value was recorded in the control samples at 24.88, whereas the highest value, 35.94, was measured in the samples treated with waste walnut oil. The application of all waste oils led to an increase in *b** values, indicating a shift towards a more yellow hue. When ranked from highest to lowest, the increase rates for the *b** values were 44.45% for waste walnut oil, 38.46% for waste corn oil, and 32.15% for waste olive oil (Table 5).

For the *C** (chroma) parameter, the control samples exhibited the lowest value of 27.15, while the highest value of 40.81 was found in the samples treated with waste walnut oil. Similar to the other color parameters, the *C** values increased with the application of all waste oils, indicating a clearer and brighter surface. The increase in *C** values, ranked from highest to lowest, was 50.31% for waste walnut oil, 43.68% for waste corn oil, and 40.88% for waste olive oil (Table 5).

With respect to the *h*° (hue angle) parameter, the highest value was observed in the control samples at 66.41, while the lowest value of 59.27 was recorded in samples treated with waste olive oil. The application of all waste vegetable oils resulted in a decline in *h*° values, suggesting a shift toward a less vivid hue. The percentage decreases in *h*° values were determined as 10.75% for waste olive oil, 7.03% for waste walnut oil, and 6.61% for waste corn oil (Table 5).

In terms of the whiteness index (*WI*)* and glossiness, all the waste vegetable oils caused reductions in both directions (across the fibers and parallel to the fibers). For the *WI** across the fibers (⊥), the highest values were 66.41 in the control and 18.80 in the parallel direction (‖). The reduction rates for *WI** across the fibers were 50.00% for waste olive oil, 41.28% for waste walnut oil, and 32.23% for waste corn oil. For *WI** parallel to the fibers, the reduction rates were higher, with 80.00% for waste walnut oil, 76.22% for waste olive oil, and 73.51% for waste corn oil (Table 5).

Similarly, for glossiness, the highest values recorded were 2.71 (across the fibers) and 2.96 (parallel to the fibers) in the control samples. The reduction rates for glossiness across the fibers (⊥) were 4.80% for waste walnut oil, 22.51% for waste corn oil, and 35.06% for waste olive oil. For glossiness parallel to the fibers (‖), the reduction rates were 0.68% for waste walnut oil, 20.95% for waste corn oil, and 32.43% for waste olive oil (Table 5).

Overall, these results demonstrate that the application of waste vegetable oils (olive, walnut, and corn oils) significantly influenced the wood's color parameters and surface features, with each oil contributing differently to the final appearance and gloss characteristics of the treated samples.

There are several reasons why the color of wood changes when vegetable waste oil is applied: Vegetable oils penetrate the pores of the wood, which can cause the wood's color to become darker or deeper.

As the wood's texture absorbs more of the oil, its color becomes more pronounced. When wood comes into contact with vegetable oils, it chemically reacts with substances like lignin and tannins inside the wood.

Ayata (2024) investigated the effects of waste vegetable oils on the surfaces of different tree species, including fukadi, ayous, guatambú, mahogany, and renga. They reported that waste oil application resulted in increases in *a** and *b** parameters and decreases in C* in ayous and guatambú trees. Additionally, decreases were found for both a* and b* parameters in mahogany and renga, while increases were found in *C**. Decreases in *h*° and *L** values were observed for all tree species with the applied waste oils.

Çamlıbel and Ayata (2023a) conducted a study on tiama wood treated with various waste vegetable oils (sunflower, corn, olive, and walnut oils) and reported decreases in *h*°, *a**, *L**, *b**, and *C** parameters for all oils, and in *WI** values in both directions. They also reported that *WI** values measured perpendicular to the fibers were higher than those measured parallel to the fibers.

A study by Çamlıbel and Ayata (2023a) reported that Δ*E** values for tiama wood treated with waste vegetable oils of varying properties were calculated as 17.33 for walnut oil, 16.84 for corn oil, 17.65 for sunflower oil, and 16.61 for olive oil.

Ayata and Bal (2023), in their study on European black pine wood treated with waste walnut, olive, and corn oils, reported that gloss levels increased at all angles and directions for all three types of waste vegetable oils. They also reported that *WI** values measured perpendicular to the fibers increased for all oils, while *L** and *h*° values also increased, and *b**, *a**, and *C** parameters decreased.

Peker et al. (2023b) reported that vegetable oils of different properties applied to the surfaces of European spruce wood caused increases in the *a**, *b**, h^o, *L**, and *C** parameters. Gloss values both increased and decreased depending on the processing direction. Furthermore, *WI** values increased in the direction perpendicular (⊥) to the wood grain, while decreases were observed in the direction parallel (║).

A study by Çamlıbel and Ayata (2024) reported that application of waste vegetable oil to the surfaces of test samples of iroko wood resulted in increases in the *a** and *C** parameters, while decreases were observed in the *b**, *L**, and h^o parameters.

Çamlıbel and Ayata (2023b), in their study on acacia wood treated with various waste vegetable oils (walnut, olive, and corn oil), reported that the *b**, *a**, and *C** parameters increased for all three oil types. On the other hand, they reported that decreases were detected in *L** and h^o values both in parallel and perpendicular directions to the grain, in *WI** values in perpendicular direction to the grain, and in brightness values at 60° angles in both grain directions.

CONCLUSIONS

Color changes: When all waste vegetable oils of varying properties were applied to wood surfaces, a decrease in the *L** and h^o parameters was observed, indicating that the wood used in the study darkened and its color tone became less saturated. Conversely, an increase in the *a**, *b**, and *C** parameters was observed, indicating a shift toward a redder, yellower, and more vibrant surface color.

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