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THE EFFECT OF VARIOUS BLEACHING SUBSTANCES ON SURFACE ROUGHNESS AND COLOR CHANGE IN BEECH WOOD

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Abstract

In this study, it was aimed to investigate the effect of bleaching chemicals on color change and surface roughness of Eastern Beech (*Fagus orientalis* Lipsky.) wood. Five bleaching agents were used in this study. This sodium hydroxide-hydrogen peroxide ($NaOH$-H_2O_2), oxalic acid ($H_2C_2O_4$), peracetic acid ($C_2H_4O_3$), peracetic acid diluted 1/3, peracetic acid diluted 1/6. According to the results, it was determined that all bleaching chemicals increased the surface roughness, and the highest value was found in the samples treated with peracetic acid (229,07) diluted at a ratio of 1/3. As for the color change, sodium hydroxide-hydrogen peroxide (23.25) chemicals gave the highest color change results. It can be said that the most effective bleaching agent for Eastern beech wood is sodium hydroxide-hydrogen peroxide.

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1. Introduction

Wood has many superior properties, so it has been used for a long time in some areas such as furniture, artifacts and construction. In this study, oriental beech (*Fagus orientalis* Lipsky.) is a species of beech family (Fagaceae) with a smooth trunk that can grow up to 40 m. It is possible to come across in Eastern Anatolia and Eastern Black Sea regions in our country. It belongs to the group of mature trees. It sticks well with glue. It stands out as a very successful tree in holding varnish and paint. If we need to talk about general usage areas; Beech wood is a good furniture wood. When it is used on bleach, it shows a color difference without excessive wear. The natural wood pattern gives us a kind of artistic pleasure, colors and patterns differ significantly from one wood type to another.

In fact, color differences often occur on a type of wood, or even on a wood plate for many reasons (Atar et al., 2004). The color of the wood is largely dependent on the absorption and reflection of light, which is determined by its chemical components. In most species, the heartwood has a darker color than the sapwood. The spontaneous transition of sapwood to heartwood is accompanied by a loss of physiological activity and the formation of various darker secondary metabolites. The color of the furniture is very important to its appearance. Some special colors in interior decoration need to be coordinated with the facilities.

However, the natural color of the wood cannot meet the requirements (Atar et al., 2004). Some methods were used because it could not meet the color requirement sufficiently. One of these techniques is bleaching. Bleaching is a ubiquitous process in many industrial processes, including healthcare, food and beverage manufacturing, consumer goods, home care, paper, textile manufacturing, and water treatment (Kitis, 2003; Sharma et al., 2020). There is great interest in developing more sustainable bleaches; however, significant difficulties remain in distinguishing them from different technologies (Anderson, 2001; Bajpai, 2013, 2015; Germer et al., 2011; Wang et al., 2020). These challenges are largely due to the lack of quantitative knowledge and robust methods to evaluate the technical and environmental performance of different bleaching technologies.

In order to obtain a homogeneous color in furniture, wood is either bleached or dyed. The only way to prevent discoloration in wood material is to bleach the wood or use bleach on the wood before waxing. Bleaching is the removal of the color pigments in the wood by using various bleaching chemicals and bleaching systems (Ozbay and Ozcifci, 2010). Today, traditional chloride oxidizing chemicals are still used in some factories that contain linen fabric in China. However, chloride oxidizing chemicals are highly toxic and can cause serious environmental problems. Thus, hydrogen peroxide has replaced most of the traditional chloride oxidizing chemicals due to its environmental benefits (Torrades, et al.,1996, Yetis, et al., 1996, Deshmukh, et al., 2009). In wood material, there are many bleaching agents, but the most commonly used chemicals are sodium hydroxide (NaOH), hydrogen peroxide (H_2O_2), oxalic acid ($H_2C_2O_4$) and peracetic acid ($C_2H_4O_3$) (Ozbay ve Ozcifci, 2010).

2. Materials and Methods

2.1. Test Material

In the study, one wood species, two section types (sapwood and heartwood), one varnish type and five bleaching agents were used as test material.

2.2. Wood Material

In this study, Eastern Beech (*Fagus orientalis* Lipsky.) wood, which is one of the leafy tree species of commercial importance in our country, was used. For this purpose, the Eastern Black Sea Region, where the tree species to be tested naturally spread, was chosen. Trabzon, Gümüşhane and Artvin regions, where the optimal growth of the species is found in this region, were determined as sample areas. Care was taken to ensure that the tree species were from a homogeneous stand in the sample areas and sample trees were selected according to the simple random sampling method. Age, aspect, diameter and altitude habitat characteristics were taken into consideration in the selection of trees. Habitat characteristics were taken into account. Care has been taken to ensure that the injured trees are those that can best represent the habitat, have a perfect trunk structure, and are straight and solid.

For this purpose, 60 trees were used in order to examine the number of tree species taken from their growing places, the core-sapwood status of the cross-section shape and the effect of sandpaper. The places where the sample trees used in the study were taken and the general characteristics of the tree species were determined according to the principles of TS 4176.

2.3. Varnish Type

In the research; a single type of varnish, cellulosic-based, which is widely used in the furniture and joinery industry, was chosen. The reason for choosing cellulosic varnish is that it dries quickly, provides good adhesion and does not spoil any process. Some important packaging features of the varnish purchased as a set from the manufacturer are given in Table 1 below.

Table 1: Packaging specifications

Varnish types	Density (g/cm^3)	Viscosity DIN/CUP4	Powder drying (min)	Touch dry (min)	Sandpaper drying (min)	Solids content (%)
Cellulosic filler varnish	0.95	300 second	3-5	10	2-4	30
Cellulosic topcoat matt varnish	0.95	301 second	3-5	10	2-4	33

2.4. Bleaching Agents

The materials to be used for bleaching should color the wood, do not penetrate deeply, do not damage the surface, can be easily and completely removed from the surface, and should be inexpensive. A large part of the wood of the materials to be used for bleaching partially creates vapours harmful to human health. It also partially leaves salt residues on the surface of the wood material. For this reason, the wood material surface must be washed later. Five different bleaching agents were used in this study and they were coded as in Table 2 below.

Table 2: Bleaching agents used

Control group	1
Sodium hydroxide - hydrogen peroxide	2
Oxalic acid	3
Peracetic acid	4
1/3 diluted peracetic acid	5
1/6 diluted peracetic acid	6

The sodium hydroxide - hydrogen peroxide preparation recipe is as follows. 35% hydrogen peroxide was used. Sodium hydroxide was dissolved in 1 litre of water and 50 g was mixed with hydrogen peroxide. It is a derivative of hydrogen peroxide. Oxalic acid preparation recipe 100 g of oxalic acid was dissolved in 1 litre of water. Wood tends to turn dark grey after exposure to external conditions, and its solutions are used to brighten and brighten dark (dull, dirty) wood. The peracetic acid preparation recipe is mixed with 40% H_2O_2 and 96% acetic acid at a ratio of 1/1. It is used for bleaching wood materials. It is a mixture of equal amounts of acetic acid (CH_3COOH), hydrogen peroxide and water. Peracetic acid is a clear liquid with a pungent odour.

2.5. Preparation of Experiment Samples, Application of Bleaching Processes and Application of Varnishes

The trees on which the test samples were prepared are approximately 2.5-5.5 m. logs of 1.20-1.50 m in length were taken from among the heights of Karadeniz Technical University. It was brought to the

Forestry Industrial Engineering laboratory of the Faculty of Forestry, and pieces of 3 cm thickness and 11 cm width with tolerance were obtained by sawing with a band saw machine, in tangential-radial sections with heartwood. Then, these pieces were stacked in a well-ventilated place and left to dry naturally. The parts with natural drying were kept in the air-conditioning room at 20 ± 2 C temperature and 65 ± 5% relative humidity until they reached a constant weight and their humidity was ensured to be approximately 12%. The parts whose air-conditioning processes were completed were processed in a planer, thickness and circular saw machines and were brought to the dimensions of 1300x100x20 mm. The pieces were processed in a circular saw machine and cut into 3 equal pieces in the transverse direction and 6 pieces of each piece, 400x100x20 mm in size, were obtained.

Each sample group was divided into 6 groups in order to investigate the effect of the bleaching agent, and one of these groups was left as a control, and the bleaching agents mentioned above were applied to the others with a brush, with 120-150 gr/m^2. After the application, they were kept for 1 day and then the sample surfaces were cleaned from the bleaching agent residues by wiping with a warm cloth with distilled water. Then varnish was applied. The application conditions and mixture amount of the varnish to be used in the experiments were made according to the manufacturer's recommendations. For this purpose; varnish type viscosity (according to DIN Cup/4mm/20 °C) 2 sec. and the amount of mixture was chosen as in Table 3.

Table 3: Varnish types and mixture amounts

Varnish Types	Varnish (part)	Thinner (part)
Cellulosic Filler Varnish	100	80
Cellulosic Topcoat Matte Varnish	100	80

In the application of varnish to the parts, a spray gun with a needle tip diameter of 1.8 mm was used and the air pressure in the application was 3 atm. was selected. In practice; care was taken to ensure that the varnish thicknesses were equal by moving the spray gun perpendicular to the part surfaces and parallel, with a distance of 25-30 cm. Varnishing of the sample parts was carried out as 2 layers of filler varnishing and 1 layer of final varnishing at 120 ±5 g/m^2 per unit area according to industrial applications. After both filling and varnishing applications, the sample pieces were dried and a vibratory hand sanding machine was used for sanding. For this purpose, aluminium oxide paper sanding bands no 220 were used after the first coat of varnish application and no 400 after the second coat of varnish was applied.

After varnish applications; the cellulosic varnished parts were left to dry for 12 hours at a temperature of 20 ±2 °C and a relative humidity of 65±5%. The applications were carried out in the workshop environment. For this purpose, attention was paid to ensure that the environment was dust-free and excessive airflow, temperature and relative humidity were avoided. Thus, test samples in standard sizes were obtained from these pieces of 430x100x20 mm, all of which were completed.

2.6. Test Methods

2.6.1. Surface Roughness

For this purpose, a total of 240 pieces of 400x100x20 mm size belonging to each tree species were used. Measurements were made with a needle scanning roughness tool (Mitutoyo SJ 301) in accordance with DIN 4768 and in the transverse direction of the samples. (Figure 1). The needle tip radius of the roughness tool is 0.5 mm, the needle tip angle is 90 degrees, the wavelength (λ) is 2.5 mm, and the measuring speed is 0.5 mm/sec.

Figure 1: Roughness Measuring Instrument

2.6.2. Determination of Optical Properties

Color measurements were made in accordance with the ASTM 2244 standard. The L*, a* and b* color model uses rectangular coordinates based on the vertical yellow-blue and green-red axes. The well-balanced structure of the L*, a*, and b* color space is based on the theory that color cannot be green and red or blue and yellow at the same time. As a result, simple values can be used to describe the adjectives red/green or yellow/blue. CIE L*, a*, and b* also indicate a color, L* indicates whiteness, a* indicates red/green, and b* indicates yellow/blue.

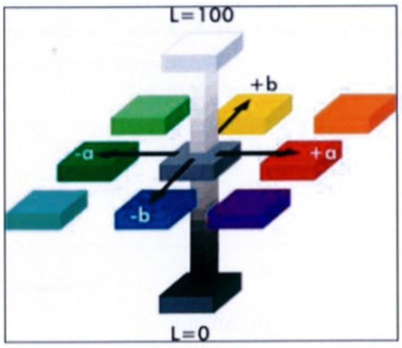


Figure 2: CIE L*a*b* color plane

According to the L* a* b* system, the color difference or distance between two colors; It is calculated according to the formula $\Delta E=[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$.

2.6.3. Statistical Methods

The arithmetic mean (X), standard deviation (S) and percent coefficient of variation (V) of the features were calculated. Analysis of variance was used to determine whether there were differences in the comparison of wood type, varnish type, section types shape and roughness characteristics. In cases where there was a difference, homogeneity groups were determined by the Duncan test. In the analysis of variance, F calc and F table values were determined, If the account values are greater than 5% (N.O.), between 5% and 1% (*), between 1% and 0.1% (**) and if it is less than 0.1% (***) signs.

3. Results

3.1. Color Changes of Samples as a Result of Bleaching Processes

3.1.1. Color Change in Beech Wood as a Result of Bleaching

The color changes obtained in the test samples as a result of bleaching processes in beech wood are given in Table 4.

Table 4: Color change in beech wood as a result of bleaching

		Sapwood				Heartwood			
		Radial Section	Radial Section*	Tangential Section	Tangential Section*	Radial Section	Radial Section*	Tangential Section	Tangential Section *
Sodium Hydroxide -Hydrogen Peroxide	***L****	70.78	88.59	70.82	84.68	71.43	88.49	63.89	78.36
	a*	10.16	0.09	10.63	1.67	10.69	0.66	11.84	3.50
	b*	25.59	14.54	24.32	14.86	26.25	13.60	24.80	18.91
	ΔE		**23.25**		**19.02**		**23.49**		**17.71**
Oxalic Acid	***L****	71.24	69.22	72.82	71.24	69.07	68.59	69.76	69.26
	a*	11.09	13.44	10.13	11.86	11.67	13.06	11.27	12.31
	b*	26.87	27.35	23.71	23.73	27.12	26.05	26.36	24.83
	ΔE		**3.14**		**2.34**		**1.82**		**1.92**
Peracetic Acid	***L****	71.79	76.99	73.74	77.02	72.54	77.40	69.62	76.34
	a*	10.59	7.71	9.03	6.97	10.15	7.35	11.53	8.05
	b*	25.60	25.37	22.60	23.12	25.47	23.81	26.39	24.69
	ΔE		**5.95**		**3.91**		**5.85**		**7.76**
1/3 Diluted Peracetic Acid	***L****	71.23	80.28	71.52	77.28	68.65	76.40	67.01	74.68
	a*	10.73	6.51	9.77	6.83	11.60	7.79	11.86	8.44
	b*	25.46	25.17	23.37	23.30	27.39	26.14	26.40	26.48
	ΔE		**9.99**		**6.47**		**8.73**		**8.4**
1/6 Diluted Peracetic Acid	***L****	72.08	81.50	75.53	82.21	68.39	77.09	67.95	78.09
	a*	9.94	5.87	7.76	4.93	11.55	7.21	11.16	7.08
	b*	24.30	24.29	20.47	22.01	27.05	25.41	24.79	25.15
	ΔE		**10.26**		**7.42**		**9.86**		**10.94**

(*: change relative to control)

Color change values are given in Table 5.

Table 5: Color change (ΔE) values in beech wood as a result of bleaching processes

	Sapwood	**Sapwood**	**Heartwood**	**Heartwood**	
	Radial Section	**Tangential Section**	**Radial Section**	**Tangential Section**	**Average Values**
Sodium Hydroxide-Hydrogen Peroxide	23.25	19.02	23.49	17.71	**20.87**
Oxalic Acid	3.14	2.34	1.82	1.92	**2.31**
Peracetic Acid	5.95	3.91	5.85	7.76	**5.87**
1/3 Diluted Peracetic Acid	9.99	6.47	8.73	8.4	**8.40**
1/6 Diluted Peracetic Acid	10.26	7.42	9.86	10.94	**9.62**
Average Values	**10.52**	**7.83**	**9.95**	**9.35**	

3.1.2. Effects of Bleaching Processes on Roughness in Beech Wood

The % roughness values formed as a result of bleaching processes in beech wood are given in Table 6.

Table 6: % roughness values of beech wood as a result of bleaching processes

Sap-Heart	Radial-Tangential	Sodium Hydroxide-Hydrogen Peroxide	Oxalic Acid	Peracetic Acid	1/3 Diluted Peracetic Acid	1/6 Diluted Peracetic Acid
Sapwood	**Radial**	173.9 (37.5)*	129 (8.429)*	184.2 (52)*	187.1 (48.5)*	149.8 (33.6)*
	Tangential	93.8 (19.7)*	154.6 (41.5)*	118.4 (18.3)*	66.3 (8.8)*	161 (32.6)*
Heartwood	**Radial**	172.7 (48.2)*	155.7 (30.5)*	171.7 (36.6)*	229 (40.9)*	155.6 (22.8)*
	Tangential	217.4 (38.8)*	148.8 (18.3)*	186.9 (44.2)*	193.8 (41.2)*	140.8 (36.6)*

(Average, standard deviation*)

The results of the analysis of variance to examine the effects of bleaching processes on the % roughness of beech wood, core and sapwood, radial and tangential sections are given in Table 7.

Table 7: The results of analysis of variance to investigate the effects of bleaching processes in beech wood

Source	Sum Of Squares	Degrees of Freedom	Mean Squares	F	Significance Level
Heartwood-Sapwood Effect (A)	37663.751	1	37663.751	30.224	***
Radial - Tangential Section Effect (B)	15442.697	1	15442.697	12.392	**
Effect of Bleach (C)	8764.277	4	2191.069	1.758	N.O
AXB	16283.129	1	16283.129	13.067	***
AXC	33493.528	4	8373.382	6.719	***
BXC	27331.933	4	6832.983	5.483	***
AXBXC	30513.752	4	7628.438	6.122	***
Error	124615.639	100	1246.156		
Total	3350011.249	120			

(5% (N.O.: not obvious), between 5% and 1% (*), between 1% and 0.1% (**) and if it is less than 0.1% (***) signs)

According to these results, as a result of bleaching processes in beech wood, it was found that the effect of heart and sapwood was effective at the level of 0.1% in roughness values, in the section type it was effective with a 1% probability of error, and the effect of bleaching agents was insignificant with a 5% probability of error. Duncan test was performed by selecting a 99% significance level. The reciprocal effects of the researched groups were found to be significant. Duncan test results of the groups whose effects were investigated are given in Table 8.

Table 8: Duncan test results of effective groups as a result of bleaching processes on % roughness in beech wood

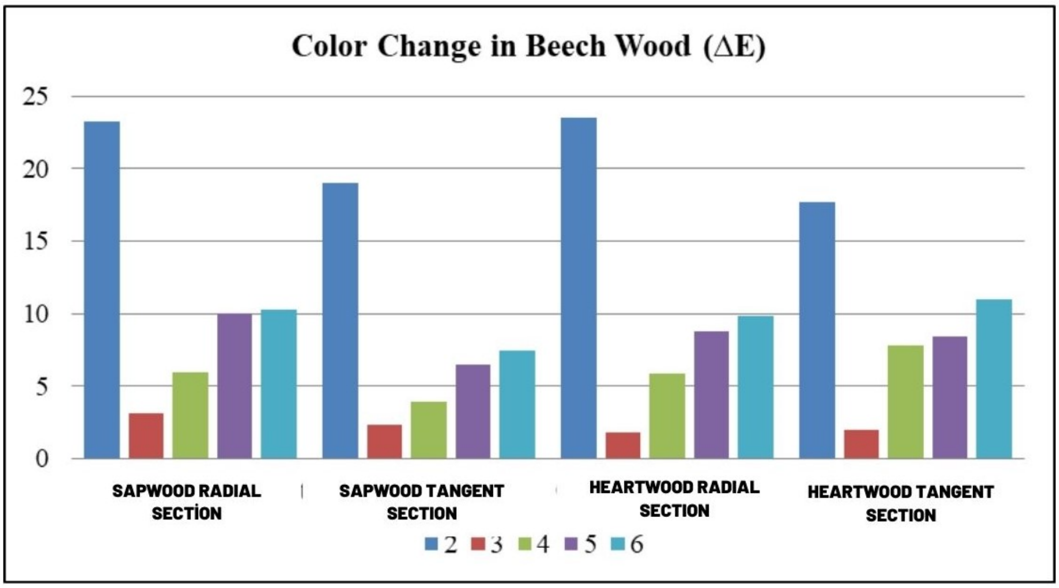
Variance Sources	Variance Sources	% Roughness Value	Homogeneity Groups
Heartwood - Sapwood	Heartwood	177.296	A
	Sapwood	141.864	B
Radial Section – Tangential Section	Radial Section	170.924	A
	Tangential Section	148.236	B
Effect of Bleach	Sodium Hydroxide-Hydrogen Peroxide	164.51	A
	Oxalic Acid	147.09	A
	Peracetic Acid	165.36	A
	1/3 Diluted Peracetic Acid	169.12	A
	1/6 Diluted Peracetic Acid	151.81	A

According to the Duncan test results, a greater roughness change occurred as a result of bleaching processes in the heartwood and bleaching processes in the radial section. All bleaching agents produced generally equal changes.

4. Discussion

4.1. Color Change in Beech Wood as a Result of Bleaching Processes

The color change values obtained as a result of the bleaching processes are given in Figure 3.



(Blue: sodium hydroxide-hydrogen peroxide, Burgundy: oxalic acid, Green: Peracetic acid, Purple: 1/3 diluted peracetic acid, light blue: 1/6 diluted peracetic acid)

Figure 3: Color change in beech wood (ΔE)

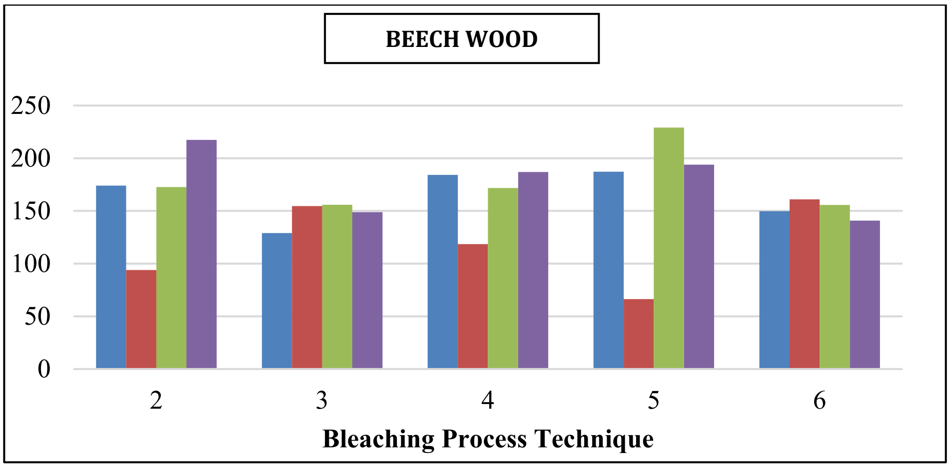
Accordingly, the highest color change in the radial section of the sapwood is obtained as a result of bleaching with sodium hydroxide - hydrogen peroxide (23.25), followed by bleaching with peracetic acid diluted 1/6, peracetic acid diluted 1/3 and peracetic acid, respectively. while the lowest one was obtained as a result of bleaching with oxalic acid (19.02). The highest color change in the tangential section of the sapwood is obtained as a result of bleaching with sodium hydroxide - hydrogen peroxide (19.02), while it was followed by bleaching with peracetic acid diluted 1/6, peracetic acid diluted 1/3 and peracetic acid, respectively. if it was low, it was obtained as a result of bleaching with oxalic acid (2.34). The highest color change in the heartwood radial section was obtained as a result of bleaching with sodium hydroxide - hydrogen peroxide (23.49), followed by bleaching with 1/6 diluted peracetic acid, 1/3 diluted peracetic acid and peracetic acid, respectively. if it was low, it was obtained as a result of bleaching with oxalic acid

(1.82). The highest color change in the tangential section of the heartwood was obtained as a result of the sodium hydroxide – hydrogen peroxide (17.71) bleaching process, followed by bleaching with peracetic acid diluted 1/6, peracetic acid diluted 1/3 and peracetic acid, respectively. if it was low, it was obtained as a result of bleaching with oxalic acid (1.92).

The reason why hydrogen peroxide is effective in color change is that it reacts with lignin protective and lignin carbonyl groups and conjugated double bonds (nucleophilic) in the wood material. Peracetic acid, on the other hand, changes the lignin structure (electrophilic) by reacting with the olefinic and aromatic parts of lignin. For this reason, very large lignin masses such as wood and mechanical pulp can cause darkening, let alone lightening. Peracetic acid also reacts with the hexauronic acid groups of hemicelluloses. This also explains the development of color values with the dilution of the peracetic acid ratio (Young and Akthar, 1997).

4.2.Surface Roughness as a result of Bleaching Processes in Beech Wood

The surface roughness values obtained as a result of bleaching processes are given in Figure 4.



(Blue: Sapwood Radial Section, Burgundy: Sapwood Tangential Section, Green: Heartwood Radial Section, Purple: Heartwood Tangential Section) (2: sodium hydroxide-hydrogen peroxide,3: oxalic acid,4: Peracetic acid,5: 1/3 diluted peracetic acid.6: 1/6 diluted peracetic acid)

Figure 4: Surface roughness values in beech wood

According to the results of the analyses carried out to examine the effects of bleaching processes on the % roughness of beech wood, heart and sapwood, radial and tangential sections, the highest surface roughness in beech wood when compared to heartwood and sapwood is peracetic acid diluted 1/3 in the radial section (229) obtained as a result of the bleaching process. The lowest surface roughness was obtained by treating the sapwood tangential section with peracetic acid (66.3) diluted 1/3 in a bleaching agent. According to the results of the analyses carried out to examine the effects of bleaching processes on % roughness in beech wood in radial and tangential sections, the radial section was effective in sapwood, while the tangential section was effective in the heartwood. If we examine Table 9 in detail, that is, in terms of bleaching processes, the highest bleaching process with peracetic acid (187.1) diluted 1/3 in the sapwood radial section of beech wood, and the lowest surface roughness with oxalic acid (129) was obtained. In the tangential section of the sapwood, the highest bleaching process with peracetic acid (161) diluted 1/6, and the lowest surface roughness was obtained with peracetic acid diluted 1/3 (66.3). In the heartwood radial section, the highest bleaching process with peracetic acid (229) diluted 1/3, and the lowest surface roughness in the bleaching process with peracetic acid diluted 1/6 (155.6) was obtained in beech wood. In the heartwood tangential section of the beech wood, the highest sodium hydroxide - hydrogen peroxide (217.4) bleaching process, and the lowest surface roughness in the bleaching process with 1/6 diluted peracetic acid (140,8) were obtained.

It should be taken into account that the application of peroxide in an alkaline environment and the application of peracetic acid in an acidic environment will also affect the surface roughness.

5. Conclusion

The bleaching agent was not very effective on beech wood. All bleaching agents produced generally equal changes. According to the results of the analyses carried out to examine the effects of bleaching processes on % roughness in beech wood in radial and tangential sections, the radial section was effective in sapwood, while the radial section was effective in the heartwood.

The heart and sapwood have no effect on the color change. There is no effect of cross-section type on color change in beech wood. Bleaching with sodium hydroxide-hydrogen peroxide performed well on color change in beech wood.

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Disclosure Statement

No potential conflict of interest was reported by the author(s).

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