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# Wood Industry & Engineering

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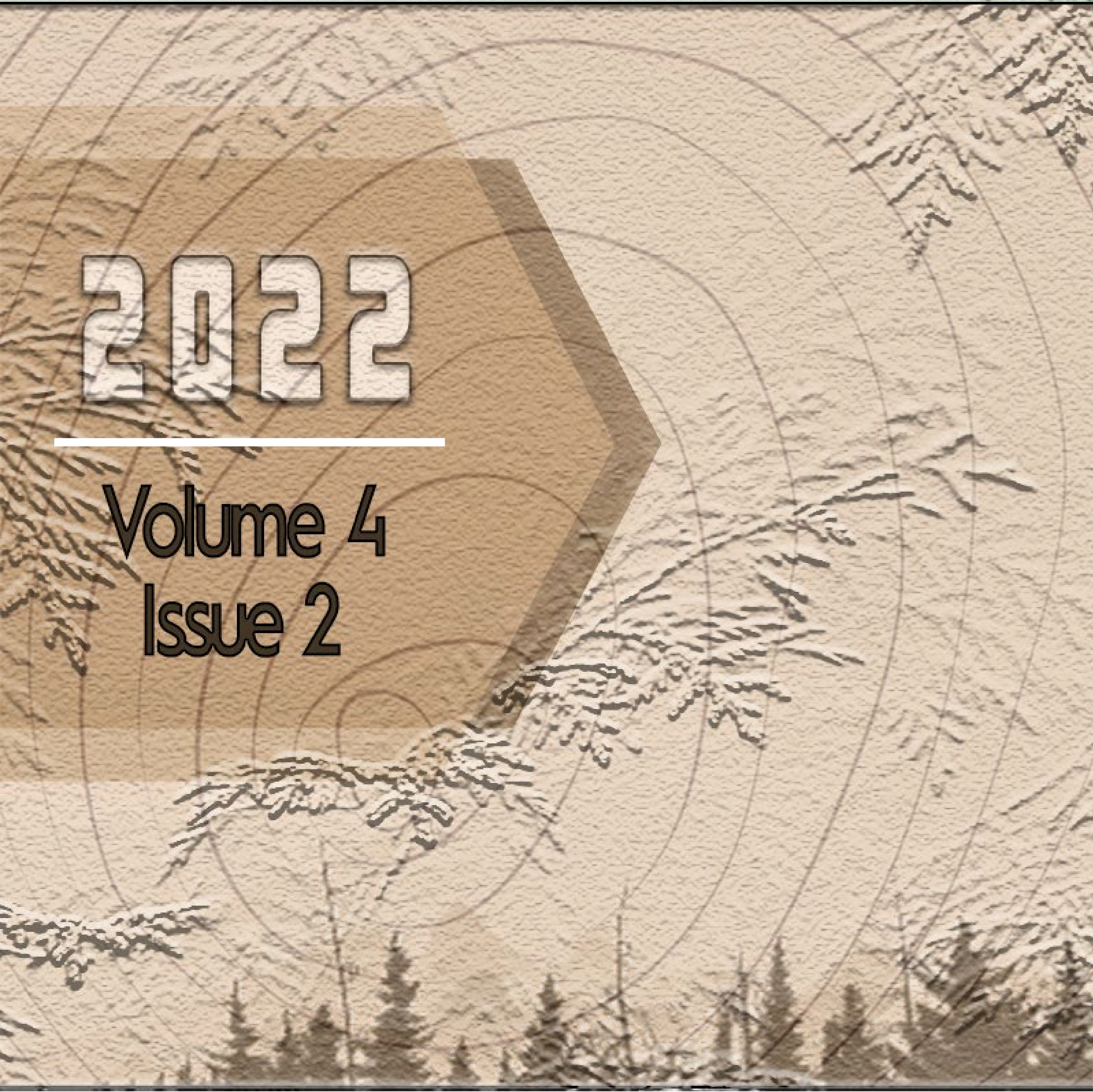

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# THE EFFECT OF VARIOUS BLEACHING SUBSTANCES ON SURFACE ROUGHNESS AND COLOR CHANGE IN BEECH WOOD

*Özlem Bozdoğan Balçık[1], Turgay Özdemir[1]*

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

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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 (ƛ) 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.

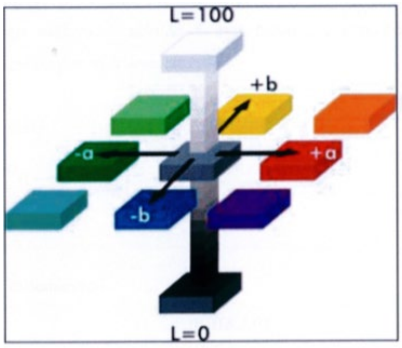


Figure 2: CIE L*a*b* color plane

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<br>(37.5)* | 129<br>(8.429)* | 184.2<br>(52)* | 187.1<br>(48.5)* | 149.8<br>(33.6)* |
| | **Tangential** | 93.8<br>(19.7)* | 154.6<br>(41.5)* | 118.4<br>(18.3)* | 66.3<br>(8.8)* | 161<br>(32.6)* |
| **Heartwood** | **Radial** | 172.7<br>(48.2)* | 155.7<br>(30.5)* | 171.7<br>(36.6)* | 229<br>(40.9)* | 155.6<br>(22.8)* |
| | **Tangential** | 217.4<br>(38.8)* | 148.8<br>(18.3)* | 186.9<br>(44.2)* | 193.8<br>(41.2)* | 140.8<br>(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

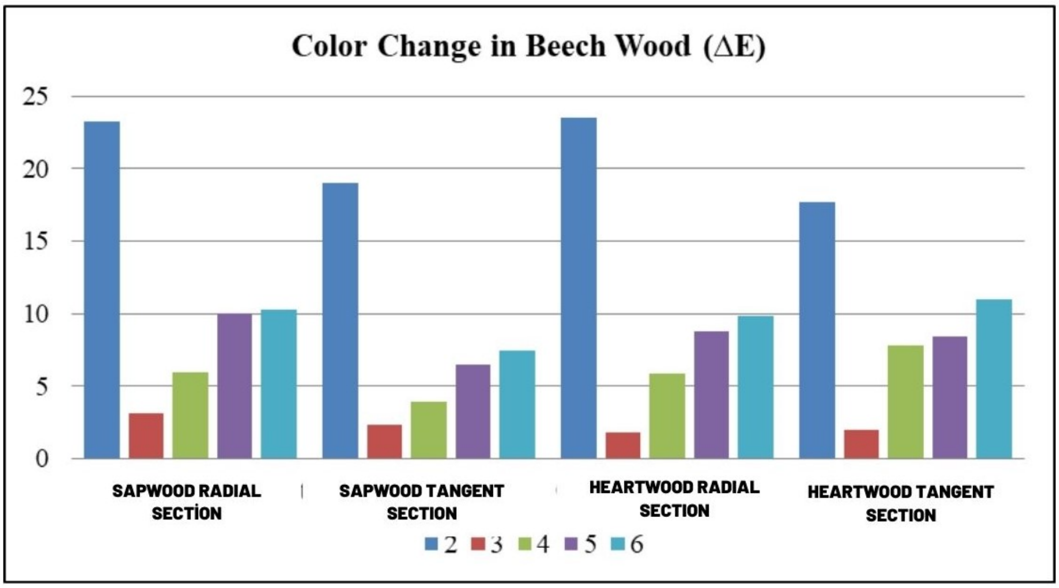
| Variance Sources | Variance Sources | % Roughness Value | Homogeneity Groups |
|---|---|---|---|
| **Heartwood - Sapwood** | Heartwood | 177.296 | A |
| | Sapwood | 141.864 | B |
| **Radial Section – Tangential Section** | Radial Section | 170.924 | A |
| | Tangential Section | 148.236 | B |
| **Effect 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)

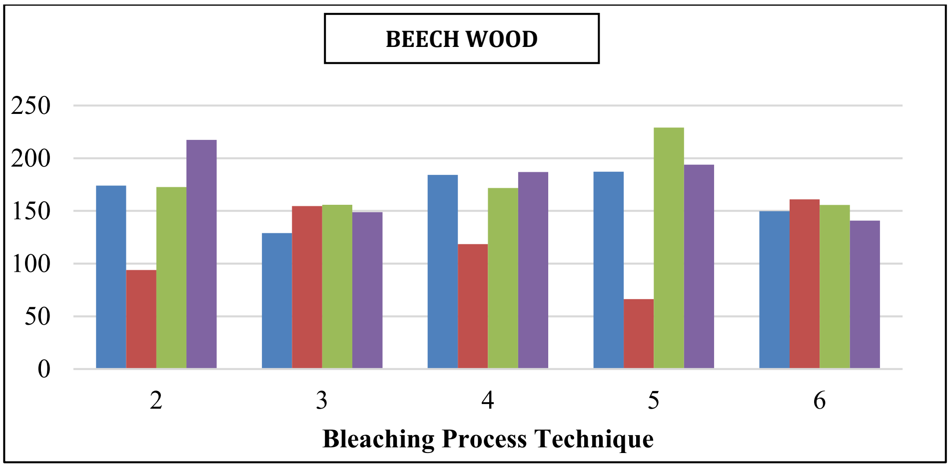
Accordingly, the highest color change in the radial section of the sapwood is obtained as a result of bleaching with sodium hydroxide - hydrogen peroxide (23.25), followed by bleaching with peracetic acid diluted 1/6, peracetic acid diluted 1/3 and peracetic acid, respectively. while the lowest one was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

## 6. Acknowledgments

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## Disclosure Statement

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

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# THE EFFECTS OF VARNISH AND WEATHERING PROCESSES ON HEATED WILD CHERRY WOOD (*Cerasus avium* (L.) Moench)

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## Abstract

The rapid deformation in the appearance features of heat-treated wooden (HT) materials used outdoors is a significant problem in terms of aesthetics and economics. It is seen that the various surface protection treatments applied have not provided a permanent solution to this problem, yet. There is a clear need for more detailed studies to contribute to the problem's solution. In this study, the heat-treated Wild Cherry (*Cerasus avium* (L.) Moench) wood samples were subjected to accelerated (QUV) and natural weathering (NW) in a way that the panels would be at an angle of 45° to the ground plane after varnishing. After that, the features like the thickness of the varnish layer (LT), total color change (ΔE), glossiness (G), and surface roughness average (Ra) were examined before and after the weathering process. The results of the examination showed that LT decreased in heat-treated samples compared to control samples (UT) depending on the lengthening of weathering time; both NW (120 days) and QUV (144 hours) increased first, then decreased (240 days and 288 hours). Glossiness increased by 18% over control samples at 144 hours at QUV, but remained almost the same at 120 days NW; on the other hand, it decreased with increasing duration in both aging. On the other hand, total color change results achieved at NW 120 days were approximately double the results obtained at 144 and 288 hours on QUV, while increased up to 3 times at NW 240 In addition, it was understood that there was no significant difference in Ra according to the current weathering conditions.

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# THE EFFECTS OF VARNISH AND WEATHERING PROCESSES ON HEATED WILD CHERRY WOOD (*Cerasus avium* (L.) Moench)

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## 1. Introduction

ThermoWood® is a modified product that can be used in places where dimensional stability and biological degradation are primarily important. At the same time, the color of the wooden material darkens, and the color homogeneity is provided in ThermoWood®. The color change is seen as a gain, especially in hardwood, and provides potential opportunities for new markets (Johansson, 2005).

An industrial-scale heat-treatment process for wood has been developed at VTT in cooperation with the Finnish wood product industry. The ThermoWood® process is licensed to the members of the Finnish Thermowood Association. The ThermoWood process can be divided into three main phases:

Phase 1: Temperature increase and high-temperature drying Using heat and steam, the kiln temperature is raised rapidly to a level of around 100°C. Thereafter, the temperature is increased steadily to 130°C, during which time the high-temperature drying takes place and the moisture content in the wood decreases to nearly zero.

Phase 2: Heat treatment Once high-temperature drying has taken place, the temperature inside the kiln is increased to between 185°C and 215°C. When the target level has been reached, the temperature remains constant for 2–3 hours depending on the end-use application.

Phase 3: Cooling and moisture conditioning, the final stage is to lower the temperature by using water spray systems; when the temperature has reached 80–90°C, re-moisturizing takes place to bring the wood moisture content to a useable level, 4–7% (Web-1).

ThermoWood® process graph main diagram is given in Figure 1.

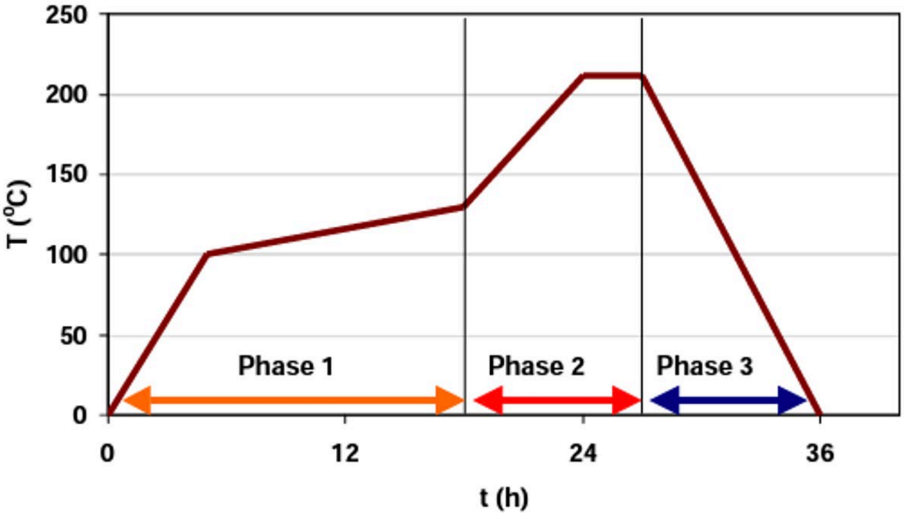

Figure 1: ThermoWood® process graph main diagram (Web-1)

Wooden materials exposed to heat lost their charm because the color of the material, especially in outdoor use, changes over time, and after a while, the dark appearance of the material exposed to direct sunlight is grayed out (Web-1). The color change issue which comes up as an esthetical problem brings about some question marks in the choice of the heat-treated wooden material. Therefore, to avoid the color change in heat-treated wooden material and protect the original color, the coating of the surfaces by applying some top surface treatments like paint/varnish, pigment, and UV protection is a must (Güler, 2010). However, it does not necessarily mean that the varnish layer of the wooden material surfaces that are used in furniture and decoration has a protective - effect. When the aim is to create a protective varnish layer, the possible effects that wood may come across in places where it is used must be taken into consideration and a type of varnish that can endure these effects must be chosen and applied. Besides, regular and timely maintenance and repair must do the varnish layer, and the varnish layer features and user manual to the consumers must be announced (Sönmez, 2000; Çakıcıer, 2007).

The effects of degradation caused by the weathering of the wooden material surface on the protective varnish layer can be determined periodically, by measuring the degradation of the varnish layer in external environmental conditions. However, when the degradation mechanism is left to time, the determination of the natural weathering effects takes many years, the production processes slow down and costs increase. This situation negatively affects the competition process for the varnish and paint manufacturers in the industry. Thanks to artificial weathering techniques, these difficulties in the natural weathering process are eliminated and it is now possible to get faster results (Çakıcıer, 2007). However, in both cases, it must be taken into consideration that the conditions of the usage and testing environments are never identical.

Today, increasing environmental awareness encourages the promotion of more environment-friendly material usage to benefit from wooden material. Choosing water-based varnish to coat the protective layers and wooden material surfaces is important in this regard. The compatible test results obtained from the polyurethane and synthetic varnish that are commonly used in the market and of the water-based varnish tests will bring a remarkable achievement to the field. From this point forth, the Wild Cherry (*Cerasus avium* (L.) Moench) samples were coated with various types of varnish including water-based ones. The color, glossiness, surface roughness, and layer thickness measurements were performed on varnished and heat-treated samples exposed to OUV and NW processes. Because of the fact that the incidence angle of external environmental conditions to the surface of the material can lead to different results, the study samples in NW were treated with a 45 ° contact angle.

## 2. Materials and Methods

### 2.1. Material

Wild cherry (*Cerasus avium* (L.) Moench) was used in the study. Trees were selected according to TS 2470 (1976) and were sawn into 60 mm thick timbers before heat treatment. The ThermoWood® (Web-1) was used in heat treatment (Table 1).

Table 1: Variations used in the study

| **Test samples** | | **Abbreviation** |
|---|---|---|
| Temperature (°) | Time (h) | |
| Control | - | UT |
| 190 | 1 | HT1 |
| 190 | 2 | HT2 |
| 212 | 1 | HT3 |
| 212 | 2 | HT4 |

A total of 200 test sample pieces, with 40 pieces for each of 5 different varnish types that were prepared at 10 mm x 78 mm x 150 mm (thickness, width, and length) sizes were waited in the conditioning chamber with 20 ± 2 °C temperature and %65±5 relative humidity until it reached the constant weight according to TS EN 15679 (2010).

### 2.2. Method

After the test samples were sanded with 80 grits first, then 120, and finally 180, they were varnished. The basic information about the varnish types is given in Table 2.

Table 2: The basic information about the varnish types (VT) used in the study

| **Company code** | **Type of varnish** | **Polymer family(PF)** | **Research code (RC)** |
|---|---|---|---|
| Aquacool FX 7680 | One-component water borne(bright) | Water-based acrylic polyurethane based | **WB$_1$** |
| Aquacool FX 0820 | Two-component waterborne(bright) | Water-based polyurethane based | **WB$_2$** |
| Aquacool FX 7560 | One-component water borne(bright) | Water-based acrylic polyurethane based | **WBM** |
| BV38Z011 | One-component (bright) | Alkyd resinous polyurethane based | **PU** |
| 938-9001 Yacht | Bright | Alkyd based | **SYN** |

The basic characteristics of varnish types obtained from the market and used in the varnishing process are given in Table 3.

Table 3: The basic characteristics of varnish-type applications

| **RC** | **Viscosity** | **Proper amount. (gr/cm$^{2)}$** | **Method** | **Solid content** | **Amount of varnish applied** |
|---|---|---|---|---|---|
| **WB$_1$** | DIN 4 plate, 20°C 11 seconds. →<br>DIN 6 plate 20°C, 45-55 seconds → | 65-125<br>80-150 | Dipping<br>1,8 Paint blaster | 19% ± 2<br>43%±2 | FX 6150 primer 2 coats,<br>FX 7680 top coat 2 coats |
| **WB$_2$** | DIN 4plate 20°C de 11 seconds →<br>DIN 4 plate 20°C de, 35-45 seconds→ | 65-125<br>60-100 | Dipping<br>1,8 Paint blaster | 19% ±<br>32%±2 | FX 6150 primer 2 coats<br>FX 0820 2 coats (%20 AX 115 hard and % 10 water supplement) |
| **WBM** | DIN 4 plate20°C, 26-33 seconds →<br>DIN 4 plate20°C de 45-55 seconds → | 60-80<br>70-110 | Dipping<br>1,8 Paint blaster | 33% ± 2<br>34%±2 | FX 7060-A primer 2 coats<br>FX 7560 top coat 2 coats |
| **PU** | DIN 4 plate20°C de 14-16 seconds → | 150-200 | 1,8 Paint blaster | 60%±2 | Thin single-coat application (hard and 1-1 % 10 Cellulosic thinner)<br>Completely two coats (hard and 1-1 % 10 Cellulosic thinner supplement ) |
| **SYN** | DIN4 plate 25 ˚C'de 95-100 seconds→ | 120-150 | 1,8 Paint blaster | 50%±1 | Thin single-coat application(% 10 Synthetic thinner supplement )<br>Two coats application (% 10 Synthetic thinner supplement) |

The test samples were then divided into four groups; the weathering process was not applied to one group with the purpose of control (UW), two groups were reserved for QUV weathering (144 h and 288 h) and one group was also reserved for natural weathering (120 days-NW120 and 240 days-NW240). The principles of the QUV and NW applications can be seen in Table 4.

Table 4: The principles of the QUV and NW applications

| **Group 2** | **Group 3** | **Group 4** | | | | | |
|---|---|---|---|---|---|---|---|
| QUV* | | NW | | | | | |
| 144 hours | 288 hours | 120 days (08.05-08.09.2014) | | | 240 days (18.09-18.01.2015) | | |
| 1. 8 hours UV (313EL UVB)<br>2. 15 minutes sprinkling<br>3. 3 hours 45 minutes conditioning | | Climate properties(Average values)** | | | | | |
| | | Temperature (°C) | Relative Humidity (%) | Rain (mm m$^{-3}$) | Temperature (°C) | Relative Humidity (%) | Rain (mm m$^{-3}$) |
| | | 23.74 | 68.61 | 3.00 | 10.27 | 87.03 | 4.22 |

*ASTM G 154 (ASTM 2006), **Location-Düzce weather station.

The weathering applications were conducted as two variations at QUV Accelerated Artificial Test (Accelerated Weathering Tester-Model QUV/Spray) device which was produced by Q-LAB company for 144 and 288 hours in line with ASTM G154 (ASTM 2006) standard and NW was applied in Düzce Weather

Station's Garden. Natural weathering was adjusted as two-time variations for 120 (NW120) and 240 days (NW240) and sample holder panels were also adjusted to an angle of 45 ° to the ground plane (Figure 2).

Figure 2: Natural weathering of test samples with an angle of 45°.

In natural weathering, the first measurements were completed within 10 days after 120 days, and then the samples were re-weathering for 240 days.

**Measuring the layer thickness (LT)**

It was performed with Defelsko Positector 200 B3 according to ASTM D 6132 (ASTM 2008) and ISO 2808 (ISO 2007) standards (Web-2). Defelsko Positector 200 measures the layer thickness of many different surfaces with the ultrasonic method without damaging the surface. The measuring range is between 50-3800 µ and can measure with ± (2 microns + 3% of reading) precision. For measuring, the ultrasonic gel is dropped on the clean-prepared layer surface, and the value on the indicator is read by fixing positector prob on the gel.

**Measuring the glossiness value (G)**

It was carried out with Erichsen brand Picogloss 562 Mc Gloss Meter according to BS EN ISO 2813 (2002)principles. The gloss meter device that measures at 60±2° was calibrated before each measurement. For daily calibration, the well-polished and smooth black glass with a refractive index of 1,567 whose glossiness was set to 100 for each geometry was used. The measurement was carried out parallel and perpendicular to the fibers from a total of twenty points and average glossiness was calculated by averaging the values that were parallel and vertical to the fibers.

**Measuring the color values (*ΔE**)**

Color measurement was carried out according to the CIELab color system and the color area where the measurement was carried out is given in Figure 3. In the CIELab system, the differences in colors and their places were determined by L*, a*, b* color coordinates. Here, L * is located on the black-and-white (black, L * = 0, white, L * = 100) axis, a * is located on red – green (positive value is red, negative value is green) axis, and b * is located on the yellow-blue (positive value is yellow; negative value is blue) axis. The "*" sign written with letters is used in order to distinguish the CIE formula from other formulas in different color systems which were developed before (Yeşil, 2010).

The color difference was examined with Konica-Minolta (CR-231) spectrometer which was calibrated as a=4,91; b=3,45; c=6,00, L=324,9 for white according to ISO 7724–2 (ISO 1984) standard. Ten measurements were carried out for each variation according to TS EN 15679 (TS 2010). The red color shade (a*), the yellow color shade (b*), and the color lightness (L*) were examined independently of one another in order to decide which color shade was affected by the change and the total color change (*ΔE**) of the designated color values was calculated by the formula below according to ISO 7724–3 (ISO 1984) (Equation 1);

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

In the equation; ΔL*: Li-Le, Δa*: ai-ae, Δb*: bi-be, i: initial measure, e: final measure

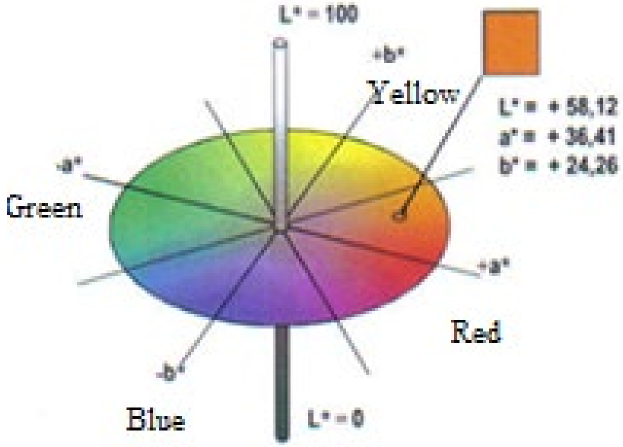

Figure 3: The determination of L*, a* ve b* values according to the CIELab system (Aytin, 2013).

### Measuring the surface roughness average (Ra)

It was carried out with a Mitutoyo surface test measuring device (Mitutoyo Surftest SJ-301). The profiles were measured with a device that has a recording stylus in Mitutoyo Surftest SJ-301. The device operates with a 4 (μm) stylus diameter, a vertical angle of 90º to the fiber, and a 10 mm/minute measuring speed.

In determining the surface roughness, a plane whose cutting blade speed was 4500 cycles/minute and 4 panels whose surfaces were smoothened by being grated in the thickness machine were prepared for each variation. The surface roughness of 5 pieces of each panel that were waited at 20±2 °C temperature and %65±5 relative humidity for 1 month was measured from 10 different points for each variation and the measurement was carried out as the determining measurement points would be vertical to the fiber direction. The surface roughness average (Ra) was determined according to ISO 4287 (ISO 1997) and DIN 4768 (DIN 1990).

For all parameters, all multiple comparisons were first subjected to an analysis of variance (Univariate), and significant differences between mean values of control and treated samples were determined using Duncan's multiple range test.

## 3. Results

### 3.1. Layer Thickness (LT)

According to the analysis of multi-variance results conducted for layer thickness (LT); it was seen that varnish(V), weathering(W), and wood types(WT) factors and their interactions with one another had significant effects on LT value at the level of $P<0.05$ and there were significant differences between subgroups. It was stated that the significance level of the effects of factors and interactions on LT value was highest (0.810) at VT and lowest (0.068) at WT. The results of the Duncan test were conducted in order to determine the effects of WT, VT, and W factors on LT value given with arithmetic mean (M) and standard error (SE) in Table 5.

Table 5: Average mean(M), standard error (SE), and Duncan test results for layer thickness.

| **WT** | **M** | **VT** | **M** | **W** | **M** |
|---|---|---|---|---|---|
| **UT** | 88.12 D* | **WB$_1$** | **110.84 D*** | **UW** | 90.64 C |
| **HT$_1$** | **82.84 AB** | **WB$_2$** | 101.13 C | **144** | **85.59 B** |
| **HT$_2$** | 80.96 A | **SBM** | 78.85 B | **288** | **81.80 A** |
| **HT$_3$** | **85.60 C** | **PU** | 65.01 A | **NW120** | 82.09 A |
| **HT$_4$** | 83.85 BC | **SYN** | **65.54 A** | **NW240** | 81.24 A |
| **SE** | 0.905 | **-** | 0.905 | **-** | 0.905 |

(*) Represents the highest G value among all the factors.

### 3.2. Glossiness (G)

According to multiple variance analysis (MVA) results for the average glossiness; it was seen that there were significant effects of VT, W, and WT factors and their interactions on G value at the level of $P<0.05$ and there were significant differences among subgroups. Besides, it was stated that the significance level of the effects of each factor and their interactions on G value was the highest at 0.722 in W and the lowest at 0.121 in WT. The results of the Duncan test conducted in order to determine the effects of WT, VT, and W factors on G value are given with M and SE in Table 6.

Tablo 6: Duncan test results, M and SE for average glossiness.

| **HT** | **M** | **VT** | **M** | **W** | **M** |
|---|---|---|---|---|---|
| **UT** | 76.16 ABC | **$WB_1$** | **81.83 C** | **UW** | 76.291 B |
| **$HT_1$** | **78.86 BC** | **$WB_2$** | 76.37 B | **144** | **90.068 C*** |
| **$HT_2$** | 79.70 C | **SBM** | 77.08 C | **288** | **69.570 A** |
| **$HT_3$** | **73.62 A** | **PU** | 80.31 BC | **NW120** | 77.856 B |
| **$HT_4$** | 74.99 AB | **SYN** | **67.75 A** | **NW240** | 69.575 A |
| **SE** | 1.386 | **-** | 1.386 | **-** | 1.386 |

### 3.3. Total Color Change (*ΔE**)

According to MVA results for the total color change, it was seen that there were significant differences among the subgroups where there were significant effects of VT, W, and WT factors and their interactions on *ΔE** at the level of $P<0.05$. It was stated that the effects of each factor and their interactions on *ΔE** were highest at 0.853 in W and lowest at 0.068 in VT. The results of the Duncan test conducted in order to determine the effects of tree type, VT, and W factors on *AE** value are given with M and SE in Table 7.

Table 7: Duncan test results, M and SE for ΔE*.

| **HT** | **M** | **VT** | **M** | **W** | **M** |
|---|---|---|---|---|---|
| **UT** | **11.967 A*** | **$WB_1$** | 14.426 B | **UW** | - |
| **$HT_1$** | 13.990 C | **$WB_2$** | 14.634 BC | **144QUV** | 8.325 A* |
| **$HT_2$** | 12.752 B | **SBM** | 15.202 CD | **288QUV** | **7.869 A*** |
| **$HT_3$** | 16.862 D | **PU** | **15.508 D** | **NW120** | 17.502 B |
| **$HT_4$** | **17.446 D** | **SYN** | **13.247 A*** | **NW240** | **24.717 B** |
| **SE** | 0.216 | **-** | 0.216 | **-** | 0.193 |

L*, a* ve b* values for heat-treated Wild Cherry (*Cerasus avium* (L.) Moench) wood UW test samples are given in Figures 4a, 4b, and 4c.

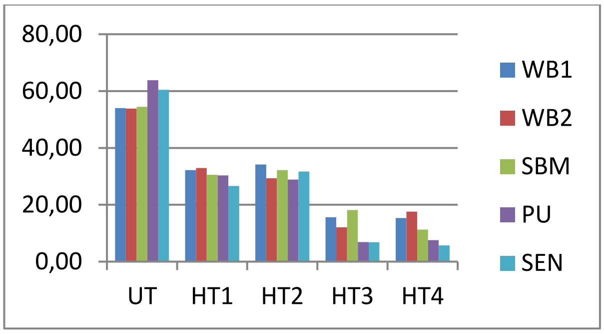

Figure 4a: L* values in UW samples.

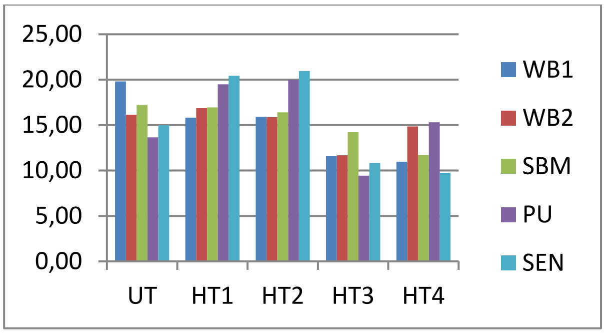

Figure 4b: a* values in UW samples

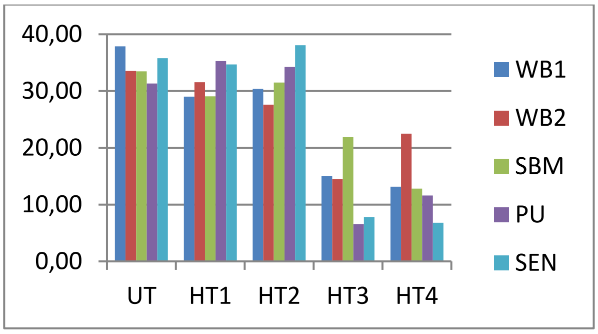

Figure 4c: b* values in UW samples

Figures 3b and 3c show that L* and b* substantially contributed to the change occurring in the color of heat-treated samples. It was understood that the increase in temperature had a significant role when the principles of heat treatment were considered.

According to the color values of test samples measured after QUV and NW weathering applications, it was observed that the color of test samples grayed out in NW while the appearance of samples stayed the same as before UW (Figures 5a and 5b, Figure 6a, 6b, 6c, and 6d).

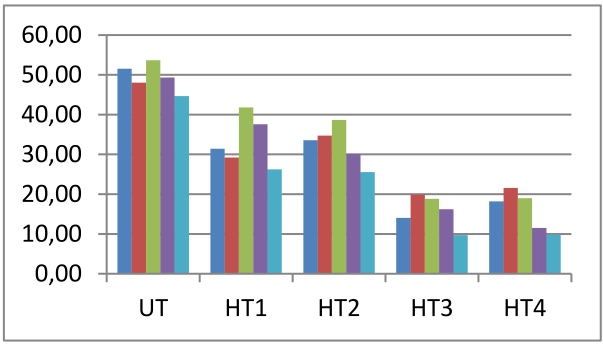

Figure 5a: 288QUV L* values

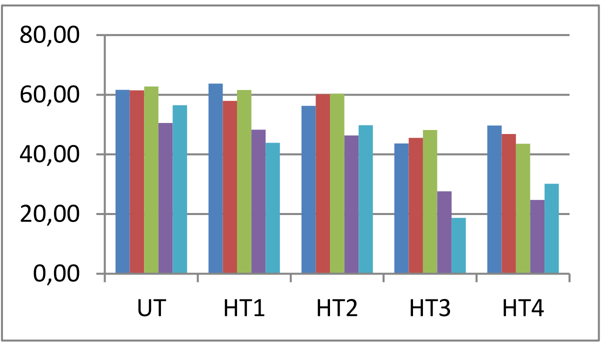

Figure 5b: NW240 L* values

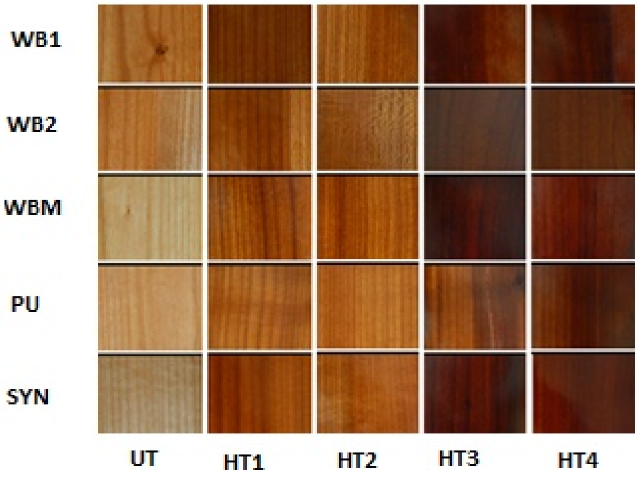

Figure 6a: The appearances in UW samples

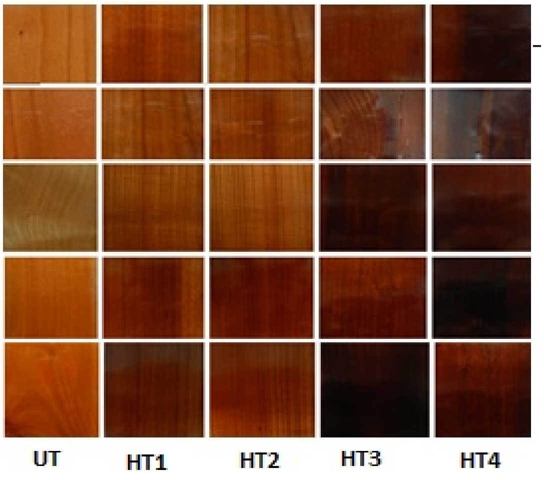

Figure 6b: The appearances after 144QUV

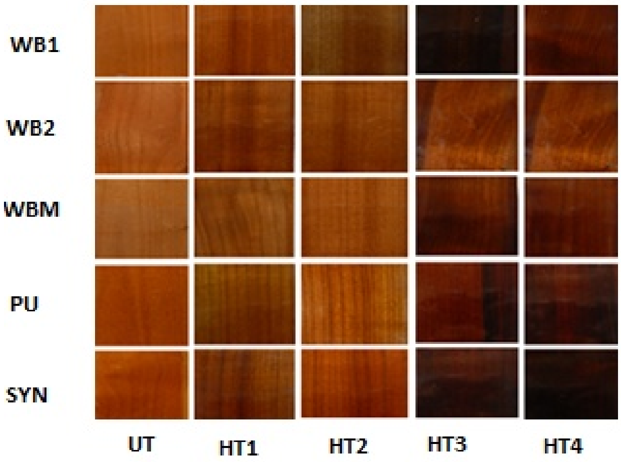

Figure 6c: The appearances after 288QUV

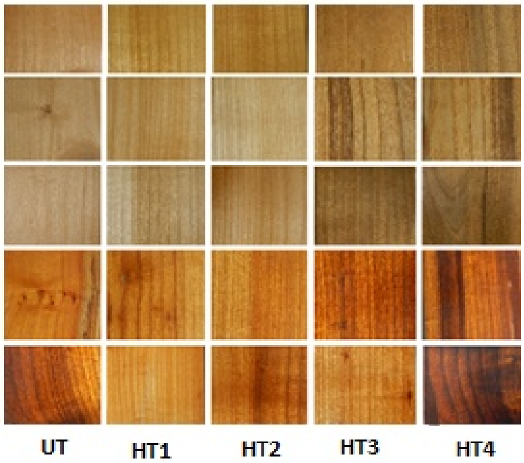

Figure 6d: The appearances after NW120

### 3.4. Surface roughness (Ra)

Roughness average MVA results showed that W, VT, and WT factors and their interactions had effects on Ra at the level of $P<0.05$ and there were significant differences among subgroups. According to the significance level of each factor and the effects of their interactions on Ra, the biggest effect was determined as (0.520) in W and the smallest effect was also determined as (0.017) in VT. The results of the Duncan test conducted in order to determine the effects of WT, VT, and W factors on Ra are given with M and SE in Table 8.

Tablo 8: Duncan test results, M and SE for average surface roughness.

| WT | M | VT | M | W | M |
|---|---|---|---|---|---|
| **UT** | **0.988 A** | **$WB_1$** | 0.729 A | **UW** | 0.917 A |
| **$HT_1$** | 0.702 A | **$WB_2$** | 0.387 A | **144** | 0.770 A |
| **$HT_2$** | 0.819 A | **SBM** | 0.975 AB | **288** | **1.242 A** |
| **$HT_3$** | 0.881 A | **PU** | **1.056 AB** | **NW120** | **0.884 A** |
| **$HT_4$** | **1.375 A** | **SYN** | **1.618 A** | **NW240** | **1.095** |
| **SE** | 0.261 | **-** | 0.261 | **-** | 0.233 |

### 4. Discussion

According to Table 5, LT was determined as the highest UT, the lowest $HT_2$ variations in WT; the highest WB1, the lowest PU and SYN in varnishes in VT; the highest 144 hours in QUV, and no difference between NW120 and NW240 in W. It is noted that among the varnish types, water-based varnishes have high LT values, and $WB_1$ with the highest value is 40% higher than SYN with the lowest value. Thus, it can be stated that water-based varnishes are more resistant to QUV and NW conditions.

According to Table 6; G was determined as the highest $HT_1$, the lowest $HT_3$ variations in WT; the highest $WB_1$ in VT, the lowest SEN in varnishes in VT; the highest 144 hours in QUV, the shortest 288 hours in QUV and NW240 variations in W. When the results are examined in terms of wood type and HT, it is seen that the HT temperature is effective in W and there is more gloss loss with W as the temperature increases. On the other hand, among the VT, the G values of the varnishes except SYN are higher and closer to each other. Considering the effect of weathering treatments on G, it can be said that the G values that increased rapidly at the beginning of QUV compared to the UW samples (G was found to be 17.95% more than UW at 144 hours QUV) decreased rapidly in the continuation of the weathering process (G was found to be 8.82% less than UW at 288 hours QUV). On the other hand, G was almost the same as the UW samples in NW120; however, it decreased by approximately 8.80% in NW240 compared to UW. Based on these results, it is noteworthy that the QUV effect on G created using 313EL UVB lamps is higher compared to the NW weathering, and 288 hours of QUV weathering values and NW240 values are close to each other.

Gorman and Feist (1989) stated that brightness and color changes can be easily observed in a short period of time in wood exposed to natural outdoor and artificial UV weathering. They also reported that Douglas fir (*Pseudotsuga menziesii*) and Mahogany (*Swietenia mahogani*) type woods regain the brightness they lost in the first months after the sixth month and a decrease in their brightness is observed in the next six-month period. Güler (2010) investigated the change in gloss values in heat-treated Ash (*Fraxinus excelsior* L.), Anatolian chestnut (*Castenea sativa* Mill.), Limba (*Terminalia superba*) and Iroko (*Chlorophora excelsa*) samples after the application of cellulosic, synthetic, polyurethane, water-based varnish. The study revealed that the gloss values of the samples increased at 150°C and 3 hours of heat treatment in all varnish types and decreased at 150°C and 6 hours of heat treatment and 180°C and 3 and 6 hours of heat treatment. Ayata and Çakıcıer (2017) reported that the gloss value decreased after 432 hours of QUV in some ThermoWood® wood species on which they applied single and double-component water-based varnish. Gündüz *et al*. (2019) investigated the G change over time on WBV-coated surfaces on which they applied 1000 hours of QUV. They found that brightness increased up to about 100% in up to 500 hours, then started to decrease again, and was about 8% higher than the initial value at the end of the QUV.

According to Duncan test results in Table 7; ΔE* was determined as the highest $HT_4$ in WT, the lowest UT variations, the highest PU and the lowest SYN in VT, the highest NW240, and the lowest 288 QUV in W. When the results are examined in terms of tree species and HT, it is seen that HT temperature has an effect on *ΔE**, and *ΔE** increases as the temperature increases. It is understood that *ΔE** is as high as 45% at $HT_4$ compared to UT. Considering the effect of weathering treatments on *ΔE**, it can be stated that the effect of natural weathering has a significantly higher effect.

*ΔE** in wooden material was caused because of the changes in color components (color lightness (L*), red color shade (a*), and yellow color shade (b*)) due to both heat treatment and usage. The results of various studies revealed that the color change mainly resulted from L*. Matsuo *et al*. (2010) stated that L* decreased dramatically with heat treatment and *ΔE** changed largely because of this reason. In another study, heat-treated Scotch pine (*Pinus sylvestris* L) and Eastern beech (*Fagus orientalis* L.) woods were varnished with polyurethane and cellulosic varnish, and they were exposed to 3 and 6 hours of natural weathering. As a result, more positive results were obtained in color values (Kart, 2017).

According to Duncan's test results in Table 8, Ra did not change between weathering and heat treatment except VT variations. Kart (2017) stated that after varnishing heat-treated Scotch pine (*Pinus sylvestris* L) and Eastern beech (*Fagus orientalis* L.) woods with polyurethane and cellulosic varnish, they achieved more positive results in the surface roughness values measured following 3 and 6 hours of natural weathering.

## 5. Conclusion

The heat-treated Wild Cherry (*Cerasus avium* (L.) Moench) wood samples were exposed to QUV and NW with an angle of 45° to the ground plane after varnishing. Based on the findings, significant changes were obtained in total color change while there was no remarkable deformation in glossiness, average surface roughness and layer thickness of test samples. Especially the angle of 45° used in weathering could be said to be effective on the height of total color change. However, in order to reach a final judgment, the results of natural weathering applied with the angle of 5° and 90° should be seen, as well. It was understood that the average glossiness values in both accelerated and natural weathering followed a similar pattern and there were no significant losses in both weatherings.

Accordingly, the fact that there were no significant losses in the properties of the protective film layer of varnish revealed that the development of the varnish content should be focused on in a way that can slow the rapid changes in the color differences. Another result of the study was that there were no significant differences between the varnish types with respect to the properties examined.

## 6. Acknowledgments

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## Disclosure Statement

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

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