# VARNISH LAYER HARDNESS, SCRATCH RESISTANCE, AND GLOSSINESS OF VARIOUS WOOD SPECIES AS AFFECTED BY HEAT TREATMENT

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The aim of the study was to determine the effects of different heat treatment and varnish application combinations on hardness, scratch resistance, and glossiness of wood materials sampled from limba (*Terminalia superba*), iroko (*Chlorophora excelsa*), ash (*Fraxinus excelsior* L.), and Anatolian chestnut (*Castenea sativa* Mill.) species. The heat treatment was applied at two levels (150 and 180 °C) for both 3 and 6 hour periods. After the heat treatment, four types of varnish (cellulose lacquer, synthetic varnish, polyurethane varnish, and water based varnish) were applied, and hardness, scratch resistance, and glossiness of varnish film layers of the treated woods were measured. The effects of heat treatment and varnish combination applications on above mentioned variables were analyzed according to the study design (factorial design with 4 (species) x 2 (heat) x 2(duration) x 4 (varnish) = 64 experimental units) with 10 samples for each combination of parameters. Glossiness increased on wood samples for all of the four wood species treated with cellulose lacquer and synthetic varnish and across all heating treatments. However, glossiness values were decreased for all the wood species depending on heating temperature and time. Values of hardness and scratch resistance were also decreased for all the four wood species across all the treatment combinations. The results were obtained from the upper surface of the application process and are thought to contribute to the national economy.

*Keywords: Heating treatment; Cellulose Lacquer varnish; Synthetic varnish; Polyurethane varnish; Water based varnish; Hardness; Scratch resistance; Glossiness*

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## INTRODUCTION

Wood is an essential element used for decoration and building materials, in both indoor and outdoor applications. Thus, durability capacity and natural looks of the used materials should be protected for the long-run under both indoor and outdoor conditions. For this reason there have been attempts to modify some of the wood properties by thermal processing techniques since the 1990's. However, results of the studies have indicated that heat treatment alone is not an adequate as a preventive action to protect the materials for varying conditions. On the other hand, application of a surface coating and/or protective lacquer coating on heat-treated materials can provide long-term protection of the woody materials against decay and deterioration of natural looks.

Wooden materials are organic matter, and they naturally cannot resist all of the external effects to which they are subjected, especially in the case of long-term exposure. Therefore, wooden materials should be protected by various preservatives (Sogutlu 2004). Wooden material should be preserved to improve its durability against outdoor effects. It has been reported that the most popular method is to coat outer surfaces of wooden materials with various lacquer layers to preserve them against weathering effects (Highley and Kirk 1979).

Nitrocellulose lacquers produce a very hard yet flexible, durable finish that can be polished to a high sheen. Drawbacks of these lacquers include the hazardous nature of the solvent, which is flammable, volatile, and toxic. Also there are hazards associated with the use of nitrocellulose in the lacquer manufacturing process. Polyurethane varnishes are typically hard, abrasion-resistant, and durable coatings. They are popular for hardwood floors but are considered by some to be difficult or unsuitable for finishing furniture or other detailed pieces. Synthetic resins are tougher and more resistant to wear. Synthetic varnishes are very highly resistant to scratches, temperature, and sweat, but they give serious problems in repairing. Water-based finishes are actually made up of droplets of solvent-based finish, usually acrylic or polyurethane, and a solvent, usually glycol ether, with water functioning as a thinner. Water-based finishes cure by coalescing: the droplets of finish move closer together and interlock as the water evaporates. Water-based finishes offer minimal solvent fumes, easy cleanup, and good scuff resistance, but they may raise the wood grain and offer only moderate resistance to water, heat, and solvents (Kurtoğlu 2000; Sonmez and Budakçı 2004).

Heat treatment is often applied to improve the dimensional stability of woods. The aim of heat treatment is to decrease swelling and shrinkage of wood, and thereby to increase its dimensional stability and biological resistance, permeability, the quality of surface treatments, and additionally to decrease the equilibrium moisture content. The heat treatment process involves exposing wood to elevated temperatures ranging from 120 to 240 $^{o}$C. Heat-treated wood has been considered as an ecological alternative to impregnated wood materials, and it can also be used for several purposes, e.g. for garden, kitchen furniture, outdoor furniture, sauna elements, building elements, furniture to be used under dry conditions, flooring materials, ceilings, inner and outer bricks, door-window joinery, sun blinds, and noise barriers (Korkut and Kocaefe 2009).

Most kitchen cabinets, some office furniture, and many interior fittings are manufactured using melamine-coated surfaces or wood-based panels (e.g., particleboard and MDF). For this reason, properties such as hardness and scratch resistance are very important for end-use applications. Gloss is a measure of the ability of the coated surface to reflect light in a mirror-like fashion, and it is an important coating property when the purpose is for the surface to have an aesthetic or decorative appearance.

Uysal et al. (1999) indicated that in the natural varnishing process the effects of the wood species on the layer hardness of varnish are unimportant, but the effects of varnish types are important. In the varnishing process, after bleaching the different wood types, bleaching chemicals and their concentration and varnish kinds affected the hardness of the varnish layer.

Ors and Atar (2001) reported that the hardness of varnish layers was not affected by impregnation and bleaching materials, but the hardness of wooden materials was increased by impregnation materials. Solvent groups however, decreased the hardness. It was concluded that synthetic varnishes were found suitable for use after bleaching and impregnation processes.

Kaygin and Akgun (2008) determined that there are significant differences among varnish systems. Accordingly, nanolacke UV gave the highest hardness value, followed by polyurethane, cellulosic, and then synthetic varnish. According to their adhesion resistances, nanolacke, polyurethane, and cellulosic varnish gave the best results (5A). These were followed by synthetic varnish (3A). Polyester varnish, on the other hand, showed the lowest adhesion resistance (2B). Nanolacke UV varnish has better resistance properties compared to conventional varnishes in terms of dry film resistance properties like surface hardness and adhesion. As a result, using nanolacke varnishes instead of conventional varnishes can be recommended for furniture and parquet areas for which varnish layer hardness and bonding strength are important.

The aim of this study is to examine the effect of heat treatment on some types of wood varnish layers in ash, Anatolian chestnut, limba, and iroko woods, each of them having high industrial potential in Turkey.

## EXPERIMENTAL

### Materials

The four tree species considered in the present work are highly preferred by the furniture and the other woodworking industries. Two of them, ash (*Fraxinus excelsior* L.) and chestnut (*Castenea sativa* Mill.), are commonly distributed in the western Black Sea region of Turkey. The other two species, limba (*Terminalia superba*) and iroko (*Chlorophora excelsa*) are exotic to Turkey.

Test samples were prepared from ash, chestnut, limba, and iroko woods that met ASTM D 358 (1983) requirements and were coated according to ASTM D 3023 (1998) standards with cellulose lacquer, synthetic varnish, polyurethane varnish, and water-based varnishes. The sample surfaces were sanded with abrasive paper to remove fiber swellings and dust before varnishing. The producer’s directions were considered for the solvent composition and hardener ratio. The varnishes were obtained from firms in Istanbul, Turkey. The amount of varnish used was calculated based on solid content and the manufacturer’s directions. Some of the properties of the varnishes used in the tests are given in Table 1.

*Water-based varnish*

The density of the synthetic varnish used in the experiments was 0.95 g/cm$^3$, and its viscosity was 18 s/DIN CUP 4 mm/20°. The varnish was applied to the wooden panels with a brush.

*Synthetic varnish*

The density of the synthetic varnish used in the experiment was 0.94 g/cm$^3$, and its viscosity was 18 s/DIN CUP 4 mm/20°. The varnish was applied to the wooden panels with a brush.

**Table 1.** Properties of Varnishes Used in Tests

| Type of Varnish | pH | Solid content (%) | Amount applied (g m$^{-2}$) | Number of varnish layer applied | Viscosity (DINCup/4mm) |
|---|---|---|---|---|---|
| Water-based (filler) | 6.95 | 26 | 83 | 3 | 18 |
| Water-based (finishing) | 8.83 | 39 | 75 | 2 | 18 |
| Synthetic | 8.87 | 54 | 83 | 3 | 18 |
| Cellulose lacquer (filler) | 4.08 | 29 | 83 | 3 | 18 |
| Cellulose lacquer (finishing) | 4.2 | 26 | 100 | 2 | 18 |
| Polyurethane (filler) | 6.55 | 55 | 83 | 2 | 18 |
| Polyurethane (finishing) | 6.25 | 42 | 75 | 1 | 18 |

*Cellulose lacquer*

The density of the cellulosic varnish used in the experiment was 0.95 g/cm$^3$, and its viscosity was 18 s/DIN CUP 4 mm/20°. The application of the varnish to the wooden panels was performed with a brush.

*Polyurethane varnish*

The density of the polyurethane varnish used in the experiment was 0.95 g/cm$^3$, and its viscosity was 18 s/DIN CUP 4 mm/20°. The varnish was applied to the wooden panels with a brush.

## Heat Treatment, Finishing, and Conditioning

The heat treatment was applied at two levels (150 and 180 $^{o}$C) for both 3 and 6 hours periods. Once the heat treatment was completed, four types of varnish (cellulose lacquer, synthetic varnish, polyurethane varnish, and water based varnish) were applied to the materials.

After heat treatment applications had been made in two different temperatures (150 to 180 $^{o}$C) and two durations (3 to 6 h) in a small heating unit controlled with ±1$^{o}$C sensitively under atmospheric pressure, treated and untreated samples were conditioned to 12% moisture contents (MC) in a conditioning room at 20±2 $^{o}$C and 65% (±5) relative humidity (RH).

## Mechanical Testing

Conditioned samples were subsequently subjected to the König pendulum hardness test to detect the hardness of the varnish coating according to ASTM D 4366-95 (1984). Test panels were placed on the panel table and a pendulum was gently placed on the panel surface. The pendulum was then deflected through 6° and released, while simultaneously starting the oscillation counter. The number of oscillations for the amplitude to decrease from 6° to 3° was determined to be the König hardness. Ten replications were conducted on separate specimens for each treatment group.

The rough drafts for the preparation of test and control samples were cut from the sapwood parts of massif woods with dimensions of 500 mm × 100 mm × 15 mm. Samples with dimensions of 100 mm × 100 mm × 10 mm were cut from the drafts, and a 6.5-mm diameter hole was drilled in the middle for the scratch resistance test.

The scratch resistance of the samples after the varnishing process was determined based on TS 4757. The scratch tester created a scratch on the sample surface that could be seen with the naked eye using a diamond bit (radius, 0.090±0.003 mm). The diamond bit was placed parallel to the horizontal plain using a spirit level, and the experimental sample was connected to a supporting disc with a pressure screw that works at a speed of 5±1 rotation/min. When the supporting handle with the diamond bit touched the sample, it was brought to a horizontal position, and the experiment was started after making adjustments with a sensitivity of ±0.01 N. The experiment started with a 5-N applied force, and if no trace resulted on the sample surface, the applied force was decreased in 0.5-N steps until a continuous scratch was formed. If a continuous scratch was formed with 5N, then the force was decreased to 2N by 0.5-N steps, to 1N by 0.25-N steps, and to 1N by 0.1-N steps. The experiment was concluded when a dotted scratch was formed. After cleaning the sample surface with a soft cloth and alcohol, the surface was checked by eye under 100-lx lamps. The value of the continuous scratch mark before the appearance of dotted scratches was accepted as the sample scratch resistance.

After the treatments applications, using light reflections, sample glossiness were measured with the aid of a Picogloss 562 MC glossmeter according to TS 4318 EN ISO 2813 (2002) standards. Ten panels for each varnish type and tree species were used in the experiments, and two measurements, that is, parallel and vertical to the fiber, were made on each sample.

Gloss is a measurement of the specular light reflectance of a varnished surface. In gloss measurement tests, a beam of light is directed toward the test varnish surface at a certain angle from the perpendicular. The percentage of the beam that is reflected at the same angle is measured by a photocell. Two standard angles are used: 60° for general gloss readings and 85° for sheen readings. Completely specular light reflection (perfect gloss) would be 100%; completely diffuse light reflection (mat or dead flat) would be 0%. The classification of varnishes according to gloss ratings depends on the ability of the surface to bounce back varying amount of light beamed on it, and these readings show the relative reflectability of the coated surface as compared with a smooth, flat mirror.

For all parameters related to hardness and scratch resistance, multiple compare-sons were first subjected to an analysis of variance (ANOVA), and significant differences between average values of control and treated samples were determined using Duncan's multiple range test at P value of 0.05 (Kalipsiz 1994).

## RESULTS AND DISCUSSION

Values of hardness decreased upon heating for all the four wood species across all the treatment combinations (Table 2). These results were in accrodance with the findings of earlier experiments conducted by Atar et al. (2004).

**Table 2.** Mean Values of Hardness (Number of Oscillations)

| | | Ash | Anatolian chestnut | Limba | Iroko |
|---|---|---|---|---|---|
| | | Means (standard deviation) | | | |
| cellulose lacquer | Control | 73.9 (5.28) a | 70.6 (5.60) a | 79.1 (2.60) a | 71.5 (3.50) ab |
| | 150/3 | 72.1 (6.30) a | 67.4 (9.94) a | 61.3 (9.62) b | 71.1 (6.71) a |
| | 150/6 | 72.9 (10.39) a | 68.5 (8.76) a | 62.3 (8.79) c | 70.5 (3.34) a |
| | 180/3 | 71.3 (7.23) a | 68.6 (6.88) a | 60.01 (6.87) d | 74.3 (6.00) a |
| | 180/6 | 67.9 (12.11) a | 72.5 (5.91) a | 57.9 (6.44) e | 66.8 (11.02) b |
| synthetic varnish | Control | 46.5 (2.17) a | 49.6 (1.78) ab | 50.4 (2.59) a | 45.9 (3.03) a |
| | 150/3 | 45.2 (2.62) bd | 41.0 (1.94) b | 36.1 (4.25) be | 39.5 (2.27) b |
| | 150/6 | 45.4 (3.20) cd | 47.9 (5.02) ab | 37 (3.59) ce | 37.9 (3.41) c |
| | 180/3 | 48.9 (3.57) d | 47.3 (4.57) cb | 37.4 (2.59) de | 39.1 (2.88) d |
| | 180/6 | 41.4 (2.50) ed | 50.4 (5.56) a | 30.5 (3.69) e | 40.7 (5.44) ec |
| polyurethane varnish | Control | 62.2 (4.64) a | 56.0 (7.39) a | 66.3 (10.18) a | 61.3 (7.51) a |
| | 150/3 | 38.2 (2.53) bde | 46.9 (7.03) bcd | 42.2 (3.58) bce | 39.1 (5.59) b |
| | 150/6 | 39.2 (7.50) ce | 37.3 (6.00) c | 36.7 (4.90) c | 41.4 (6.00) c |
| | 180/3 | 41.9 (4.53) de | 38.6 (7.07) d | 40.0 (4.50) de | 49.6 (6.09) dbce |
| | 180/6 | 45.4 (7.62) e | 51.9 (6.52) abcd | 35.3 (5.74) e | 43.0 (6.16) e |
| water-based varnish | Control | 28.8 (3.85) a | 31.8 (3.61) a | 34.8 (5.14) a | 34.9 (6.90) a |
| | 150/3 | 41.2 (5.39) ba | 35.4 (8.19) b | 33.1 (4.53) abcd | 35.2 (4.26) b |
| | 150/6 | 37.2 (3.94) cb | 38.4 (8.18) b | 28 (2.16) b d | 35.6 (4.14) c |
| | 180/3 | 38.3 (3.09) db | 35.7 (4.00) b | 28.4 (5.78) cd | 37.6 (4.74) d |
| | 180/6 | 42.8 (5.59) b | 37.7 (7.06) ba | 20.0 (2.31) d | 45.3 (6.16) e |

Homogenous groups: letters in each column indicate groups that are statistically different according to Duncan's multiple range test at $P < 0.05$.
Comparisons were between each control and its test.

The mean scratch resistance values according to wood species and varnish type are shown in Table 3. Values of scratch resistance decreased for all the four wood species across all the treatment combinations (Table 3). These results were in accordance with earlier experiments conducted by Keskin et al. (2010).

Results of the data indicated glossiness increased on wood samples for all of the four wood species treated with cellulose lacquer and synthetic varnish and across all heating treatments. However, glossiness were decreased for all the wood species treated with polyurethane varnish and water based varnish depending on heating temperature and time (Table 4).

Values of glossiness were also increased for all the four wood species across all the treatment combinations (Table 4).

The long-term durability of varnishes applied to wooden surfaces with respect to mechanical effects, such as friction, abrasion and impact, and to chemical effects, such as the effects of acids, alkalis, alcohols and detergents, depends on the resistance of the varnish layers to these effects. Varnished wooden surfaces are exposed to various effects, depending on the environments in which they are used. Therefore, in order to prevent economic losses, the use of varnish types that supply optimum efficiency according to the usage area is required (Kaygin and Akgun 2009).

**Table 3.** Means of Scratch Resistance (N)

| | | Ash | Anatolian chestnut | Limba | Iroko |
|---|---|---|---|---|---|
| | | Means (standard deviation) | | | |
| cellulose lacquer | Control | 3.5 (0.10) a | 2.5 (0.05) acd | 2.5 (0.15) a | 3 (0.25) a |
| | 150/3 | 3.4 (0.22) abcd | 2.7 (0.27) b | 1.75 (0.29) be | 2.3 (0.27) bde |
| | 150/6 | 2.6 (0.22) bcd | 2.5 (0.10) acd | 1.8 (0.27) cde | 2.3 (0.27) cde |
| | 180/3 | 2.3 (0.57) cd | 2.2 (0.27) cd | 1.6 (0.22) de | 1.7 (0.27) de |
| | 180/6 | 1.4 (0.22) d | 1.9 (0.22) d | 1.4 (0.42) e | 1.2 (0.27) e |
| synthetic varnish | Control | 3.5 (0.15) a | 4.0 (0.05) a | 2.3 (0.05) a | 4 (0.20) abcd |
| | 150/3 | 3.4 (0.22) abcd | 4.1 (0.22) a | 1.88 (0.25) bcde | 3.5 (0.10) be |
| | 150/6 | 3.1 (0.22) bcd | 3.0 (0.05) b | 1.5 (0.15) ce | 3.6 (0.22) ce |
| | 180/3 | 2.9 (0.22) cd | 3.0 (0.10) b | 1.7 (0.27) dce | 4.7 (0.27) d |
| | 180/6 | 2.4 (0.22) d | 3.0 (0.35) b | 1.2 (0.27) e | 3.1 (0.22) e |
| polyurethane varnish | Control | 3.0 (0.10) a | 3.0 (0.15) a | 2.5 (0.10) ae | 4 (0.20) a |
| | 150/3 | 6.7 (0.57) bae | 7.7 (0.45) b | 3.8 (0.27) b | 5.7 (0.45) bac |
| | 150/6 | 7.1 (0.22) c | 7.4 (0.42) cade | 2.9 (0.22) cae | 6.3 (0.27) ca |
| | 180/3 | 6.6 (0.82) dae | 7.2 (0.57) da | 3.5 (1.0) dace | 6.2 (0.27) cabd |
| | 180/6 | 5.2 (0.57) ea | 8.0 (0.61) ea | 1.4 (0.22) e | 5.5 (0.35) da |
| water-based varnish | Control | 3.0 (0.10) ae | 3.5 (0.10) acde | 1.5 (0.10) ace | 2.5 (0.10) a |
| | 150/3 | 3.9 (0.22) b | 3.7 (0.27) b | 2.6 (0.22) b | 2.4 (0.22) bd |
| | 150/6 | 3.0 (0.35) ce | 3.2 (0.27) cde | 1.1 (0.22) c | 2.3 (0.27) cad |
| | 180/3 | 3.1 (0.22) de | 2.9 (0.22) de | 2.2 (0.76) dace | 2 (0.27) da |
| | 180/6 | 1.8 (0.27) e | 2.6 (0.22) e | 1.1 (0.22) e | 3.1 (0.22) e |

Homogenous groups: letters in each column indicate groups that are statistically different according to Duncan's multiple range test at $P < 0.05$.
Comparisons were between each control and its test.

However, some of the properties of varnishes applied as a means of protection are either partially known or misunderstood. As a result of the mistakes made in choosing the type of varnish to use, the protective material may lose its protective properties because it does not have the desired strength and durability, and large economic losses may be incurred. The provision of a long lifespan for the furniture and maximum profit are highly dependent on the proper use and quality of the protective material (dye or varnish). Various varnishes and varnish systems for use on wood surfaces have been developed over time as a result of quality demands and environmental protection consciousness (Kaygin and Akgun 2008).

Ozalp et al. (2009) found that while the hardness, brightness, and sticking resistance were improved for both wooden types which were kept for 2 h at temperatures of 100, 150, and 200 °C, they deteriorated for both wooden types kept for 4 and 6 h at the same temperatures. Regarding brightness values, this decreased as temperature and time of the heating process increased for both types of wood. If hardness and sticking resistance are important in water-based varnish applications, the heating process applied to the wooden material at 100 °C and 2 h yielded optimum result. If brightness criterion is important in the processes, heating process should not be applied to the wood.

**Table 4.** Means of Glossiness

| | | Ash | Anatolian chestnut | Limba | Iroko |
|---|---|---|---|---|---|
| | | Means (//-⊥) (standard deviation) | | | |
| | Control | 21.8 (2.19) - | 21.8 (2.19) - | 28.7 (3.08)- | 24.9 (1.90)- |
| cellulose | | 20.7 (2.17) | 20.7 (2.17) | 28.5 (8.51) | 23.5 (1.30) |
| lacquer | 150/3 | 51.3 (7.72) - | 52.5 (12.65) - | 48.3 (16.73)- | 49.4 (7.72)- |
| | | 37.2 (4.97) | 36.8 (8.48) | 29.6 (13.87) | 37.1 (6.49) |
| | 150/6 | 56.9 (6.94) - | 53.9 (5.62) - | 51.1 (8.45)- | 60.5 (9.27)- |
| | | 40.8 (6.07) | 37.9 (3.16) | 33.0 (9.57) | 43.2 (9.54) |
| | 180/3 | 45.8 (9.25) - | 46.8 (12.90) - | 53.3 (7.03)- | 51.6 (8.24)- |
| | | 32.9 (7.45) | 31.6 (10.56) | 40.8 (6.43) | 35.3 (6.02) |
| | 180/6 | 48.4 (5.54) - | 34.1 (5.98) - | 51.9 (9.17)- | 40.5 (8.13)- |
| | | 35.4 (6.03) | 23.5 (6.39) | 32.7 (7.57) | 26.0 (7.33) |
| | Control | 69.9 (6.61) - | 69.9 (6.60) - | 74.0 (5.98)- | 78.6 (2.57)- |
| synthetic | | 62.4 (3.62) | 62.4 (3.62) | 62.9 (7.97) | 70.6 (6.53) |
| varnish | 150/3 | 78.7 (11.07) - | 82.4 (4.14) - | 76.9 (5.44)- | 81.1 (2.67)- |
| | | 70.0 (8.28) | 69.0 (7.33) | 55.6 (6.09) | 71.5 (3.05) |
| | 150/6 | 78.8 (3.23) - | 77.6 (3.99) - | 76.9 (5.36)- | 81.3 (5.79)- |
| | | 70.7 (4.62) | 63.2 (5.99) | 60.0 (7.79) | 71.1 (9.28) |
| | 180/3 | 75.7 (4.87) - | 75.5 (2.83) - | 76.7 (6.91)- | 76.7 (3.91)- |
| | | 66.5 (4.88) | 59.3 (3.10) | 63.1 (5.86) | 56.7 (5.58) |
| | 180/6 | 73.8 (5.96) - | 71.5 (8.93) - | 70.9 (13.36)- | 72.9 (8.47)- |
| | | 62.3 (8.08) | 49.4 (13.37) | 47.8 (14.28) | 51.4 (12.70) |
| | Control | 28.3 (2.29) a-d | 28.3 (2.29) - | 21.1 (3.26)- | 24.5 (3.81)- |
| polyurethane | | 24.2 (2.10) | 24.2 (2.10) | 21.4 (1.99) | 19.0 (2.26) |
| varnish | 150/3 | 25.2 (4.19) c | 28.1 (2.45) - | 27.2 (5.44)- | 28.9 (6.16)- |
| | | 22.2 (3.32) | 23.7 (1.48) | 23.6 (6.32) | 24.9 (3.97) |
| | 150/6 | 30.4 (2.15) a | 28.5 (3.88) - | 28.8 (5.05)- | 28.4 (6.28)- |
| | | 24.6 (2.94) | 24.3 (3.04) | 25.6 (5.39) | 24.1 (4.49) |
| | 180/3 | 26.8 (6.10) b | 27.9 83.62) - | 26.6 (5.01)- | 25.6 (4.48)- |
| | | 22.1 (4.41) | 22.5 (2.31) | 20.6 (4.72) | 20.7 (2.80) |
| | 180/6 | 25.1 (4.46) d | 26.9 (3.64) - | 24.2 (5.11)- | 28.8 (2.89)- |
| | | 21.1 (3.59) | 19.8 (1.99) | 21.1 (4.75) | 24.7 (2.58) |
| | Control | 19.8 (3.07) - | 19.8 (3.07) - | 23.7 (2.30)- | 26.1 (1.02)- |
| water-based | | 11.6 (0.42) | 11.6 (0.42) | 15.3 (1.90) | 17.3 (0.84) |
| varnish | 150/3 | 26.8 (2.96) - | 23.7 81.59) - | 28.7 (0.75)- | 26.8 (0.67)- |
| | | 17.8 (0.88) | 17.0 (0.87) | 21.9 (1.42) | 18.2 (0.80) |
| | 150/6 | 26.1 (1.87) - | 26.2 (2.08) - | 26.7 (1.59)- | 27.0 (1.42)- |
| | | 19.0 (3.69) | 19.1(0.69) | 18.3 (2.43) | 17.4 (1.51) |
| | 180/3 | 24.4 (3.36) - | 24.7 (1.38) - | 20.7 (4.19)- | 26.2 (3.02)- |
| | | 16.0 (2.11) | 17.3 (1.02) | 14.1 (2.61) | 17.3 (2.34) |
| | 180/6 | 24.1 (1.63) - | 26.7 (4.26) - | 23.5 (1.00)- | 25.1 (2.47)- |
| | | 16.0 (2.01) | 22.5 (3.95) | 18.5 (0.57) | 16.8 (0.88) |

Ozalp and Korkut (2009) found that the brilliance and sticking resistance were improved for both wooden types that were kept for 2 hours at temperatures of 100 °C. Hardness values of all samples which were processed for 2, 4, and 6 hours in 100 °C, 125 °C, and 150 °C were high. Brightness values for beech wood and Scotch pine samples after water-based double component varnish applications, highest values were obtained at 100 °C and 2 hours, while the lowest values were seen at 150 °C and 6 hours, depending on the heating process, temperature, and time.

The fact that the differences between the tools and production techniques used when making varnishes may have effects on the properties of the varnish layers and on their resistance performance against external agents cannot be ignored. The solidity of a varnish layer depends on its ability to resist the various physical, mechanical, and chemical effects that it encounters. However, wood surfaces that are coated with varnishes may be subjected to many other effects that relate to the locations where the products are used. For example, the effects that may be encountered are different between an office setting and a bathroom setting. Another example is the different effects encountered by parquet boards used on the floor of a house and the same boards used in a gym. In all of the various settings, it is expected that the varnish layer will last a long time due to its resistance to the effects stated above. Thus, determining which of the different varnishes can endure and determining the extent to which they can resist the various effects that will be encountered are extremely important. Consequently, in terms of the selection of the varnish to be applied on specific wood surfaces, future financial losses can be avoided at the very beginning by considering the features of the space where the product is going to be used and by selecting the varnish that has the best resistance to the anticipated effects (Kaygin and Akgun 2009).

## CONCLUSIONS

The surface hardness of the varnished samples after heat treatment was observed to be lower than that of varnished untreated samples. Surface hardness generally exhibited a decrease with increasing exposure temperature and duration compared to the control groups for all wood species.

Scratch resistance of heat-treated samples was found to be lower than that of un-treated samples. According to wood species, the greatest scratch resistance was obtained for Anatolian chestnut (8.0 N), whereas limba had the least scratch resistance (1.1 N). Anatolian chestnut had the highest resistance, followed in order by ash, iroko, and limba. Consequently, it can be stated for wooden parquets that scratch resistance against mechanical effects, such as friction, scratching, and impact is significant, especially in tight places such as an office, classroom, or corridor.

The glossiness of the varnished samples after heat treatment was observed to be higher than that of varnished untreated samples.

For future studies, water based and solvent varnishes should be evaluated with varying temperature, pressure, and periods for different wood species for both indoor and outdoor usage.

Resistance of woods against fungal attack can be compared under different heating and varnish treatments for both outdoor environment and accelerated aging conditions (UV, xenon-ark and thermal aging, salt spray etc.).

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## REFERENCES CITED

ASTM D 358 (1983). "Wood to be used as panels in weathering test of coating," American Society for Testing and Materials, West Conshohocken, PA, USA.

ASTM D 3023 (1998). "Standard practice for determination of resistance of factory applied coatings on wood products of stain and reagents," American Society for Testing and Materials, USA.

ASTM D 4366-95 (1984). "Standard test methods for hardness of organic coatings by pendulum test," ASTM, Philadelphia, PA.

Atar, M., Keskin, H., and Yavuzcan, H. G. (2004). "Varnish layer hardness of oriental beech (*Fagus orientalist* L.) wood as affected by impregnation and bleaching," *JCT Research* 1(3), 219-224.

Highley, T. L., and Kirk, T. K. (1979). "Mechanisms of wood decay and the unique features of heartrots," *Phytopsthology* 69(10), 1151-1157.

Kalipsiz, A. (1994). *Statistical Methods*, Istanbul University Publication No. 3835. Faculty of Forestry Publication No. 427. Istanbul University. Istanbul. Turkey. ISBN 975-404-368-X.

Kaygin, B., and Akgun, E. (2008). "Comparison of conventional varnishes with Nanolacke UV varnish with respect to hardness and adhesion durability," *International Journal of Molecular Sciences* 9(4), 476-485.

Kaygin, B., and Akgun, E. (2009). A nano-technological product: An innovative varnish type for wooden surfaces," *Scientific Research and Essays* 4 (1), 1-7.

Keskin, H., Atar, M., Korkut, S., and Tekin, A. (2010). "Scratch resistance of cellulosic, synthetic, polyurethane, waterborne, and acid-hardening varnishes used on woods," *Industrial Crops and Products* 31(2), 219-224.

Korkut, S., and Kocaefe, D. (2009). "Effect of heat treatment on wood properties," *Duzce University Journal of Forestry* 5(2), 11-34.

Kurtoğlu, A. (2000). *Wood Material Surface Treatments General Information*, Volume 1, Istanbul University Publication No: 4262, Faculty of Forestry Publication No: 463, ISBN 975-404-590-9.

Ors, Y., and Atar, M. (2001). "Effects of bleaching and ımpregnation processes on the hardness of the varnish layer in beech wood," *Turkish Journal of Agriculture and Forestry* 25, 443-450.

Ozalp, M., Gezer, I., and Korkut, S. (2009). "The investigation of heat treatment with water-based varnish double components in varnish applications of wood material," *African Journal of Biotechnology (AJB)* 8(8), 1689-1694, ISSN: 1684-5315.
Ozalp, M., and Korkut, S. (2009). "The effects of heat treatment on varnished wood by double component water-based varnish," Proceedings of the 6$^{th}$ Asia-Pacific Drying Conference (ADC2009), October 19-21 2009 Bangkok-Thailand, pp:720-723, ISBN: 978-974-456-705-5.
Sogutlu, C. (2004). "The using of some native wood species in Kundekari construction," Ph.D. Thesis, Gazi University, Graduate School of Natural and Applied Sciences, pp. 101-102 (1504), Ankara, Turkey.
Sonmez, A., and Budakçı, M. (2004). *Ağaçişlerinde Üst Yüzey İşlemleri -II- Koruyucu Katman ve Boya/Vernik Sistemleri*, Sevgi Ofset, ISBN: 975-97281-0-9 (TK), Ankara.
TS 4757 (1986). "Furniture surfaces—Determination of scratch resistance," Turkish Standards Institution, Ankara-Turkey.
TS 4318 EN ISO 2813 (2002). "Paints and varnishes - Determination of specular gloss of non-metallic paint films at 20, 60 and 85," Turkish Standards Institution, Ankara, Turkey.
Uysal, B., Atar, M., and Ciftci, A. (1999). "The effects of chemicals for using the bleaching of the wood surfaces on the layer hardness of varnish," *Turkish Journal of Agriculture and Forestry* 23, 443-450.

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