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The Effect of Hot and Cold Check Tests on Surface Roughness and Glossiness in Varnished Wood Material

Utjecaj testa vruće i hladne provjere na hrapavost i sjaj površine lakiranog drva

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ABSTRACT • *In this study, specimens from Scots pine (Pinus sylvestris L.), Anatolian chestnut (Castanea sativa Mill.) and Eastern beech (Fagus orientalis Lipsky) tree species, prepared according to ISO 3129, were conditioned according to TS ISO 13061-1. Cellulosic varnish, water-based varnish, and glass polish varnish were applied to their surfaces in accordance with ASTM-D 3023 principles. In the study, roughness (TS 2495 EN ISO 3274 and TS EN ISO 21920-3) and gloss (according to TS EN ISO 2813) values of the samples were calculated after hot and cold check test. Varnished test specimens prepared in 100 mm × 100 mm ×10 mm dimensions were first kept in drying oven at (50±5) °C for 1 hour, then were kept in conditioning room for 1 hour, and then at (-20±2) °C for 1 hour, according to ASTM D1211-97. These processes were accepted as one cycle, and tests were continued until 15 cycles. Afterward, glossiness was measured as perpendicular and parallel to fibers at 60° with a gloss measurement device, and surface roughness values of Ra and Rz were determined with a surface roughness measuring device. According to the results obtained, Scots pine (Pinus sylvestris L.), Eastern beech (Fagus Orientalis Lipsky), and Anatolian chestnut (Castanea sativa Mill.) varnish-coated wood material surfaces all showed a decrease in gloss values after hot-cold shock effect. While an increase occurred in Rz values of roughness for all wooden surfaces, Ra values roughness increased for Scots pine and chestnut and decreased for eastern beech. Gloss and roughness values of surface-treated wood materials against changing weather conditions can determine usefulness of the surface material used. The findings obtained in this study can be useful to manufacturers who use wooden products in the design of marine vehicles and those who export furniture to countries in different climatic conditions.*

KEYWORDS: *wood material; varnish; surface roughness; glossiness; hot and cold-check test*

SAŽETAK • *U ovom su istraživanju uzorci drva bora (Pinus sylvestris L.), anatolskog kestena (Castanea sativa Mill.) i bukve (Fagus orientalis Lipsky) pripremljeni prema ISO 3129 i kondicionirani prema TS ISO 13061-1, a na njihovu su površinu, prema ASTM D 3023, naneseni nitrocelulozni lak, vodeni lak i lak visokog sjaja. U istraživanju su izračunane vrijednosti hrapavosti (TS 2495 EN ISO 3274 i TS EN ISO 21920-3) i sjaja (TS EN ISO 2813) uzoraka nakon testa vruće i hladne provjere. Lakirani uzorci dimenzija 100 mm × 100 mm ×10 mm najprije su jedan sat sušeni pri (50±5) °C, zatim su jedan sat kondicionirani pri sobnim uvjetima i jedan sat pri (-20±2) °C, prema ASTM D1211-97. Ti procesi sušenja i kondicioniranja čine jedan ciklus, a ispitivanje se sastojalo od*

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15 ciklusa. Nakon toga izmjeren je sjaj okomito i paralelno s vlakancima drva pod kutom od 60º u odnosu prema mjernom uređaju te su određeni parametri hrapavosti površine Ra i Rz. Prema dobivenim rezultatima, svi su lakirani uzorci drva bora (Pinus sylvestris L.), bukve (Fagus orientalis Lipsky) i anatolskog kestena (Castanea sativa Mill.) nakon testa hladne provjere pokazali smanjenje vrijednosti sjaja. Međutim, na svim površinama uzoraka drva zabilježeno je povećanje Rz vrijednosti hrapavosti, dok su se Ra vrijednosti hrapavosti povećale na borovini i kestenovini, a smanjile na bukovini. Vrijednosti sjaja i hrapavosti površinski obrađenih drvnih materijala mogu odrediti njihovu uporabljivost u promjenjivim okolišnim uvjetima. Rezultati dobiveni u ovom istraživanju bit će korisni proizvođačima koji upotrebljavaju drvo u proizvodnji brodova ili izvoze namještaj u zemlje s drugačijim klimatskim uvjetima.

KLJUČNE RIJEČI: *drvni materijal; lak; hrapavost površine; sjaj; test vruće i hladne provjere*

1 INTRODUCTION
1. UVOD

Wood is a renewable material very important for human beings, who have used it in art and architecture from the past to the present. Today, protecting the properties of wood from external factors and providing hygienic conditions has become one of the most critical problems (Atilgan, 2022). In the use of wood material after it is finished, top surface materials such as paint, varnish and impregnation applied to wood surfaces are required to maintain its strength and aesthetic properties (Goktas *et al*., 2006).

Wood material might be easily deformed by some external factors. Polymer structures such as lignin and cellulose, which make up the wood material, are affected by ultraviolet rays like other organic polymer structures. Negative changes occur in almost all physical and mechanical properties of wood material due to exposure to outdoor conditions without any protective treatment (Pelit and Korkmaz, 2019). Protective treatment is necessary for the long-term and efficient use of wood and wood-based materials for protection. In wooden materials, these processes include impregnation, varnishing and painting (Vardanyan *et al*., 2015). In the protection process, a protective layer is created, using materials with the feature of layering to protect furniture and decoration elements against physical, mechanical, and chemical effects, outdoor conditions, and biological pests. It is applied in the form of covering wood material surfaces (Sonmez, 2000). In order to extend the aesthetic and economic life of the surfaces, paints and varnishes are the most used materials in creating a protective layer with liquid surface treatments (Kurtoglu, 2000). The most inconvenient factors for wood material in outdoor conditions are temperature, humidity, different wavelengths of sunlight, and UV radiation, and changing of these conditions at certain times of the day according to the season cause negative effects on the wood material (Feist and Hon, 1984). Varnish types and varnishing techniques should be chosen appropriately. The tests applied to determine the resistance of paint and varnish layers against external effects were applied to determine the performance of varnish systems or to develop products. Today, many surface treatment materials and many application methods have been developed for surface treatments (Ozdemir, 2003). Surface treatment and selection of a protective layer are very important for a long-term use of wood material (Ulay ve Budakci, 2015). There are many studies in the literature about varnish, which is one of the wood finishing materials used in the woodworking and furniture industry. The highest hardness value on varnished surfaces was obtained with polyester varnish. The glossiest surfaces were obtained with polyurethane varnish (Sonmez, 2000; Cakicier, 1994). When Scots pine and chestnut tree species were used in outdoor conditions after impregnation and varnishing, higher hardness values were obtained with polyurethane varnish than with synthetic varnish in both tree species (Peker, 1997). When examining the effect of layer thickness on wood varnishes, it was seen that the third layer varnish applications caused an increase in glossiness (Budakci, 1997). It was observed that the glossiness of water-based varnishes was lower than that of solvent-based varnishes (Yakin, 2001). Wood species were found to be insignificant for the glossiness of different varnish layers, while the varnish effect was significant (Budakci, 2003). The layer increase in varnish applications negatively affects the flexibility properties of the varnish layer. The layer increases the surface tension and causes exfoliation (Cakicier, 2007). Gurleyen *et al*. (2017) analyzed glossiness values on parquets with UV varnish applied according to different varnish layers produced from limba, sapele, chestnut, and iroko woods (Gurleyen *et al*., 2017). Dongel *et al*. (2008) investigated the glossiness effect of dry heat on solid wood and wood-based flooring materials. Eastern beech solid parquet covered with polyurethane parquet varnish, laminated parquet covered with UV-curable polyurethane varnish, and laminate parquet with high-density fiberboard (HDF) in the middle layer were used as test samples (Dongel *et al*., 2008). In addition, Gurleyen *et al*. (2017) determined the glossiness values in single and double UV system parquet varnish layers applied to rowan (*Sorbus* L.) wood (Gurleyen *et al*., 2017).

In the work of Sonmez and Kesik (1999), test samples were prepared by using beech (*Fagus orientalis* L.), pine (*Pinus sylvestris* L.) and oak (*Quercus petreae* L.) wood, and cellulosic, polyurethane, and acrylic varnishes were applied to the surface of sample panels. Samples were first kept at -18 °C for one hour and then removed and kept at 50 °C for one hour. These processes were accepted for one cycle and tests continued for 20 cycles. Tests were carried out according to ASTM D-1211. There was no visible failure on the sample panels. However, all the sample panels lost some hardness. On the other hand, in the case of glossiness measurement, the glossiness of oak panels coated with cellulosic varnish was increased, but the glossiness of other panels was decreased. (Sonmez and Kesik, 1999). It was also reported that, when Gubas solid wood material was subjected to the hot-cold check test applied to its surface varnish (acidic hardener and cellulosic), the surface with cellulosic varnish exhibited fracture, cracking, and color change (Yolanda, 1998).

In his study, Altiparmak (2017) observed the deformation of the surfaces after the hot-cold shock effect of yacht varnish, polyurethane varnish, and epoxy varnish applied on limba, chestnut, and sapele woods. No cracking or surface deformation was observed on the panel surfaces in the 20-cycle cold-check test (Altiparmak, 2017). In the study of Budakci *et al*. (2010), cellulosic, polyurethane and acrylic varnishes were applied on oriental beech, yellow pine and sessile oak, and color changes were determined after the effects of hot and cold shocks after accelerated aging effects (Budakci *et al*., 2010). It was stated that, in the hot-cold aging tests of the varnish layers, the samples should be kept at temperatures of -20 and 50 °C for 1 h each, and this process should be considered as 1 period; the performance of the layers with no degradation in 10 periods should be considered as sufficiently good, while layers with no degradation in 25 periods should be considered as high-performance (Payne, 1965).

In some areas where wood materials with wood finishing are used, sudden temperature changes occur, which can cause the painted and varnished surface to lose its properties. It is important to determine the effect of these changes on the wood species and varnishes used in places with sudden climate changes. However, when the literature is examined, few studies can be found.

Based on the data obtained from the surface roughness and glossiness change on varnished surfaces that may be exposed to the effects of sudden climatic changes (hot and cold), it will be possible to select the appropriate wood type and varnish for the place of use.

Wood species of Scots pine (*Pinus sylvestris* L.), Anatolian chestnut (*Castanea sativa* Mill.), and Eastern beech (*Fagus orientalis* L.) and Cellulosic, water-based, and glass polish varnishes, which are used in the woodworking industry and manufacture of various marine vehicles, were used in the present study. These tree species and varnishes, which are frequently used, can be deformed in environments where they are exposed to sudden temperature changes (especially marine vehicles, yachts, etc.). The aim of this study was to determine the effect of the Hot and Cold-Check Test on the roughness and gloss changes on the surfaces and to specify the most suitable wood type and varnish.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

In this study, Scots pine (*Pinus sylvestris* L.), Anatolian chestnut (*Castanea sativa* Mill.), and Eastern beech (*Fagus orientalis* L.) tree species, which are widely used in the woodworking industry and yacht decoration applications, were preferred.

Cellulosic varnish, water-based varnish and glass polish varnish were used in the experiments. The varnishes used in the experiments were obtained from Çaglayan Wood Products and Hardware Industry Afyonkarahisar/Turkey (Table 1).

Timber used in the preparation of the samples were obtained by random selection from companies in Afyonkarahisar/Turkey. Experiment samples were prepared from sapwood not damaged by insects and fungi, free of knots, cracks, and inclusions, with no discoloration and a smooth fiber structure, according to ISO 3129 (ISO 3129, 2019).

According to ISO 3129, 3 wood species, three varnish types, and five replications for each parameter, i.e. 45 test samples were prepared. Measurements were made from 3 different points on each test sample, and 135 data were obtained for each type of test. The test samples were prepared in the dimensions of 100 mm × 100 mm × 10 mm (longitudinal direction × radial direction × tangential direction) in Afyon Kocatepe Uni-

Table 1 Characteristics of varnishes used
Tablica 1. Svojstva primijenjenih lakova

Type of varnish *Vrsta laka*	**Solid ratio, %** *Udio suhe tvari, %*	**Density at 20 °C, g/cm³** *Gustoća pri* 20 °C, g/cm³	**Viscosity at 20 °C, s** *Viskoznost pri* 20 °C, s
Cellulosic / *nitrocelulozni lak*	34-40	0.92-0.99	100-110 (DIN6 mm)
Water-based / *vodeni lak*	32-38	1.02-1.04	30-40 (DIN4 mm)
Glass polish varnish / *lak visokog sjaja*	47-51	0.92-0.94	90-140 (DIN6 mm)

Table 2 Assignment of levels to factors (parameters used)
Tablica 2. Dodjeljivanje razina faktorima (korišteni parametri)

Parameter / *Parametar*	**Coded levels** / *Odabrane razine*		
	Level 1	**Level 2**	**Level 3**
Wood species *vrsta drva*	Scots pine *borovina*	Eastern beech *bukovina*	Anatolian chestnut *drvo anatolskog kestena*
Type of varnish *vrsta laka*	Cellulosic *nitrocelulozni lak*	Water-based *vodeni lak*	Glass polish varnish *lak visokog sjaja*
Hot and cold shock test *test vruće i hladne provjere*	Before *prije*	After *poslije*	

versity Afyon Vocational School Furniture and Decoration Workshop. They were conditioned at temperatures of (20±2) °C and (65±5) °C, with a moisture content (*MC*) of about 12 %. (TS ISO 13061-1, 2021). The surfaces of the samples were sanded with 80 and 120 grit sandpapers, respectively. The varnishing process of the test samples was carried out by the principles specified in ASTM-D 3023 (ASTM-D3023, 2017). The dust on the surface was cleaned with compressed air. The varnishes were applied in two layers at 2 (27.5 bar) atm pressure (DYO, 1990) with an air gun with a tip opening of 1.8 mm, perpendicular and parallel to the fibers, at 125 g/m^2. After 1 coat of application, the samples were sanded with 400-grit sandpaper. After sanding, the varnish was applied again. Table 2 gives the parameters and levels used in the application.

The experimental process of the study is given in Figure 1.

This test is applied to wood material that has been painted and varnished according to ASTM-D 1211 by exposing it to shock, heat and cold. Its purpose is to determine the varnish layer performance in sudden temperature changes that occur in natural climatic conditions. Hot-cold tests indicate the flexibility of transparent varnish layers on wooden surfaces or their resistance to sudden temperature changes (Sonmez and Kesik,1999). In this context, surface-treated test specimens prepared in dimensions of 100 mm × 100 mm ×10 mm were exposed to cold check test for periods of 1 h (50±5) °C, 1 h laboratory conditions, and 1 h (-20±2) °C, for 15 cycles according to ASTM D 1211-97 (2001) standard.

Surface Roughness Tester Time TR220 (Time Group Inc., China) type surface roughness measurement equipment was used for the determination of surface roughness values via a contact stylus trace method. The sampling length was taken as 0.8 mm. The stylus probe speed was chosen as 10 mm/min, the diameter of the measurement needle was 5 µm, and the needle tip was 90°. Care was taken to have a measurement environment around (18–22) °C and without vibrations. Perpendicular and parallel glossiness measurement of the fibers was made. The tool was calibrated before measurement, and calibration was checked at established intervals. The roughness of the wood material after the effect of hot-cold shock was determined according to TS 2495 EN ISO 3274 and TS 6212 EN ISO 4288.

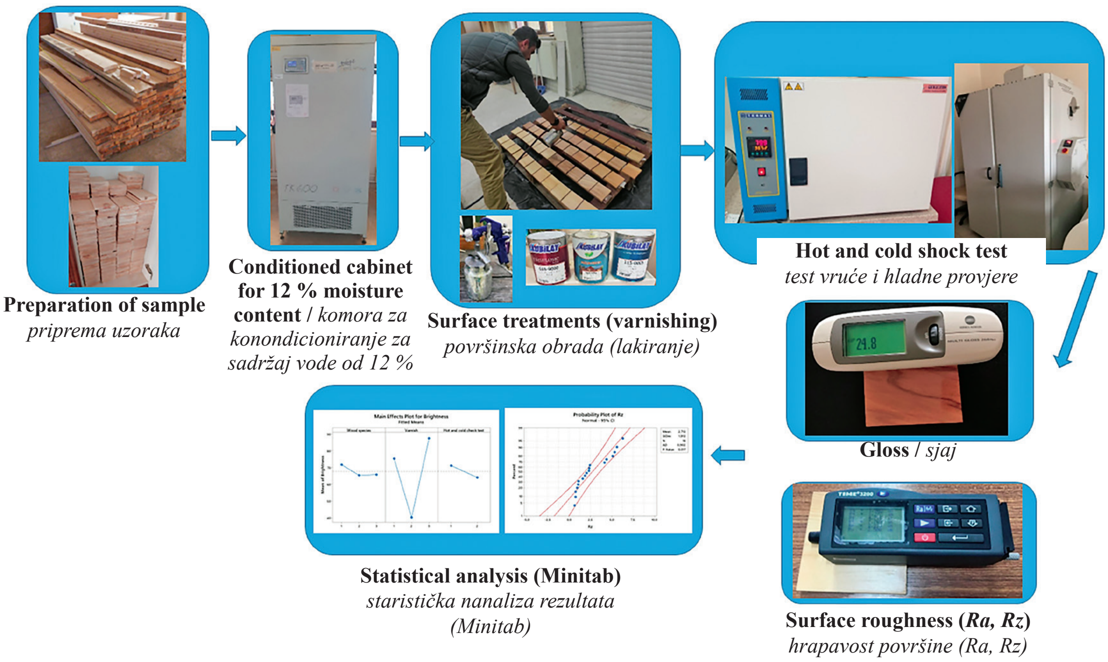

Figure 1 Schematic representation of experimental design
Slika 1. Shematski prikaz eksperimenta

In the study, glossiness measurements were carried out using a Glossmeter at 60°. Not many errors were observed when measuring at 60° on matte and glossy surfaces (Ozen and Sonmez, 1990; Ordu and Sofuoglu, 2016). Glossiness measurements were carried out using Konica Minolta Multi Gloss 268 Plus (Glossmeter) gloss meter according to the principles specified in TS 4318 EN ISO 2813.

For the evaluation of the data, the Minitab 19 statistical software program was used. The values of the factor effects of wood species, varnish types, and hot-cold shock test were determined using the analysis of one-way variance (ANOVA) and the Tukey procedure. The differences in the means were accepted at a significance of $P<0.05$.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

Experiments were carried out to determine the effect of wood species, varnish types, and hot-cold shock test on roughness parameters (*Ra*, *Rz*) and surface glossiness of the samples. Roughness parameters and glossiness values measured on surfaces are given in Table 3.

Since the *P* value is greater than 0.05 (P=0.102) according to Figure 2, it is seen that the values of the *Ra* measurement show a normal distribution at the 95 % confidence level. Analysis of variance results for *Ra* is given in Table 4.

According to the results of a one-way analysis of variance for *Ra* (at 95% confidence level, Table 4),

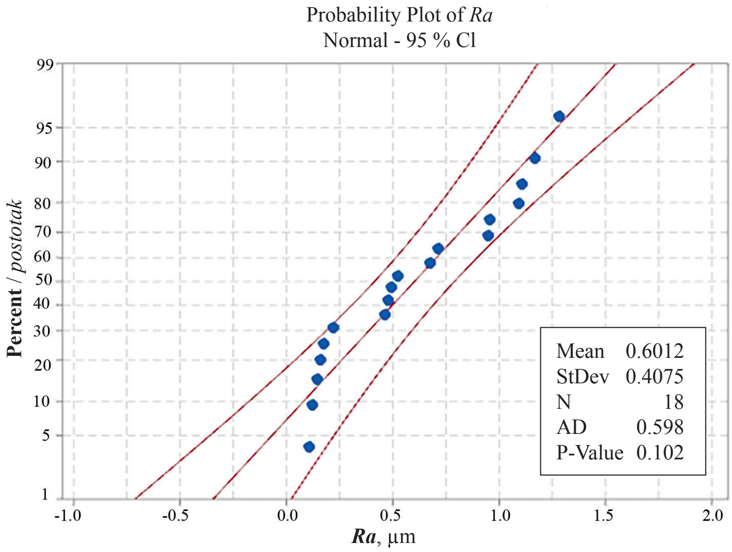

Figure 2 Normality graphs for *Ra*
Slika 2. Grafovi normalne distribucije za *Ra*

Table 3 Roughness parameters (*Ra* and *Rz*) and gloss values measured on surfaces
Tablica 3. Parametri hrapavosti (*Ra* i *Rz*) i vrijednosti sjaja izmjerene na površinama

Wood species *Vrsta drva*	**Varnish** / *Lak*	**Hot and cold shock test** *Test vruće i hladne provjere*	***Ra*, µm**	***Rz*, µm**	**Glossiness** *Sjaj*
Scots pine *borovina*	Cellulosic *nitrocelulozni lak*	Before / *prije*	0.475	1.595	87.753
		After / *poslije*	0.489	1.854	77.007
	Water-based *vodeni lak*	Before / *prije*	0.959	4.147	44.827
		After / *poslije*	1.169	4.408	43.507
	Glass polish varnish *lak visokog sjaja*	Before / *prije*	0.118	0.742	91.520
		After / *poslije*	0.175	0.771	85.927
Eastern beech *bukovina*	Cellulosic *nitrocelulozni lak*	Before / *prije*	0.526	2.047	81.513
		After / *poslije*	0.465	2.337	63.593
	Water-based *vodeni lak*	Before / *prije*	1.092	5.347	36.713
		After / *poslije*	0.948	5.600	36.447
	Glass polish varnish *lak visokog sjaja*	Before / *prije*	0.217	1.049	89.953
		After / *poslije*	0.159	1.090	84.233
Anatolian chestnut *drvo anatolskog kestena*	Cellulosic *nitrocelulozni lak*	Before / *prije*	0.676	2.337	72.053
		After / *poslije*	0.716	2.433	70.40
	Water-based *vodeni lak*	Before / *prije*	1.105	5.131	45.047
		After / *poslije*	1.287	6.309	34.540
	Glass polish varnish *lak visokog sjaja*	Before / *prije*	0.106	0.626	92.160
		After / *poslije*	0.140	0.962	81.253

Table 4 Results of one-way analysis of variance for *Ra*
Tablica 4. Rezultati jednosmjerne analize varijance za *Ra*

Source / *Izvor*	***DF***	***Adj SS***	***Adj MS***	***F* Value**	***P* Value**
Wood species / *vrsta drva*	2	0.04470	0.02235	0.12	0.887
Error	15	2.77871	0.18525		
Total	17	2.82341			
Varnish / *lak*	2	0.6724	1.33622	132.77	0.000
Error	15	0.1510	0.01006		
Total	17	2.8234			
Hot and cold check test *test vruće i hladne provjere*	1	0.00417	0.004171	0.02	0.880
Error	16	2.81924	0.176203		
Total	17	2.82341			

there is a significant difference since P=0.000 for the varnish type. It is seen that tree species (P=0.887>0.05) and hot-cold test (P=0.880>0.05) did not make any significant difference. Tukey test was applied for the varnish type, and it was seen that each varnish type formed a separate group (Table 5).

Table 5 Results of Tukey test for *Ra*
Tablica 5. Rezultati Tukey testa za *Ra*

Varnish *Lak*	*N*	**Mean** *Srednja vrijednost*	**Grouping** *Grupiranje*
2	6	1.0933	A
1	6	0.5578	B
3	6	0.1525	C

Figure 3 presents the main effects plot in terms of *Ra* of wood species, varnish types and hot-cold check test.

According to the main effect plot created for *Ra*, it was observed that the highest roughness value occurred in Anatolian chestnut tree species, while lower and close values were obtained in other tree species. In terms of varnish type, the *Ra* roughness value from the lowest is listed as glass polish, cellulosic and water-based. Although the values were close to each other before and after the test in terms of hot and cold-check test, there was a slight increase in the roughness value after the test.

When the interaction graph is examined in terms of R_a (Figure 4), it is seen that all three tree species have similar results in terms of applied varnish. The lowest roughness value was obtained in glass polish, followed by cellulosic and synthetic varnish, respectively. When the wood type and hot-cold test interaction were examined, a slight increase was observed in the roughness value after the test in Scots pine and Anatolian chestnut tree species, while a decrease occurred in Eastern beech tree species. When the interaction between the varnish type and the hot-cold test was examined, no change was observed in the post-test R_a value in cellulosic and glass lacquer varnish types, while an increase occurred in the water-based varnish type after the cold-hot test.

Since the P value is less than 0.05 (P=0.017) according to Figure 5, it is seen that the values in the *Rz*

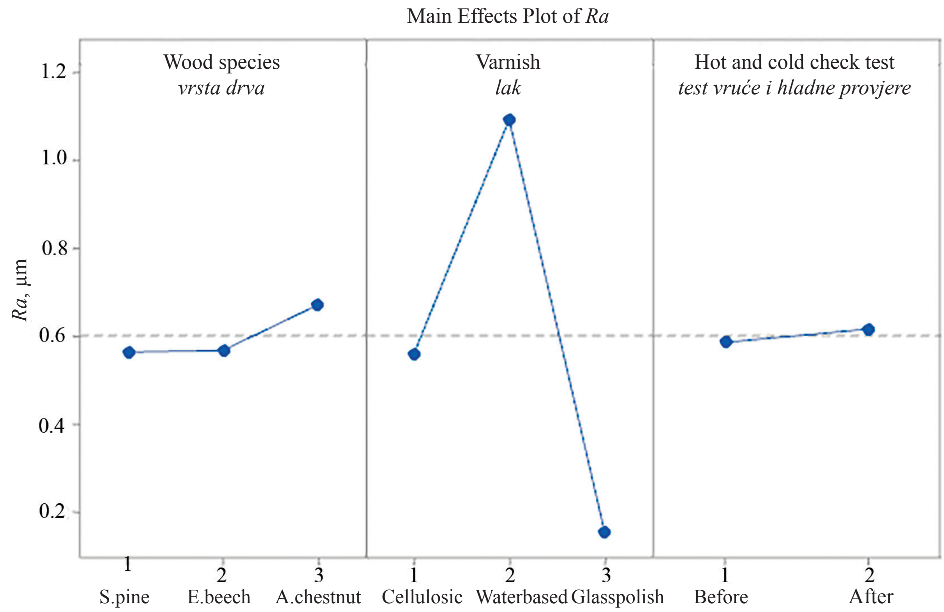

Figure 3 Main effects plot in terms of *Ra* of wood species, varnish types, and hot-cold check test
Slika 3. Dijagram glavnih učinaka na *Ra* s obzirom na vrstu drva, vrstu laka i test vruće i hladne provjere

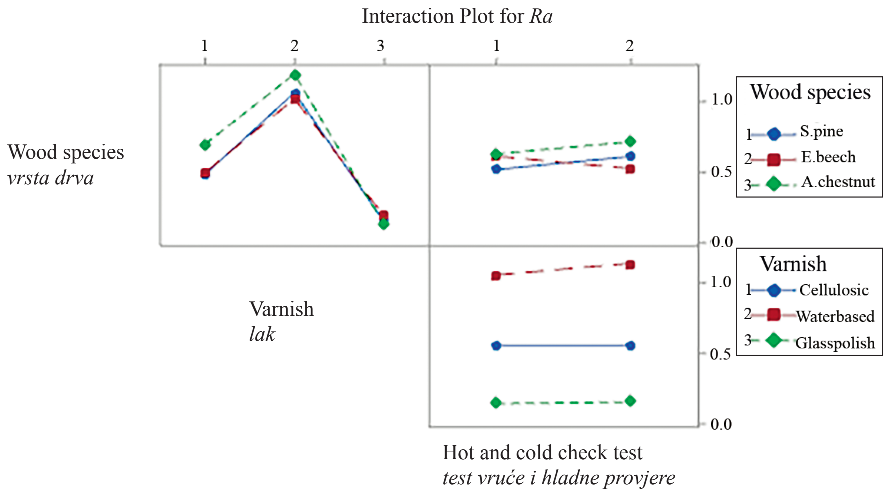

Figure 4 Interactions of wood species, varnish, and hot-cold check test of *Ra*
Slika 4. Interakcije vrsta drva, laka i testa vruće i hladne provjere za *Ra*

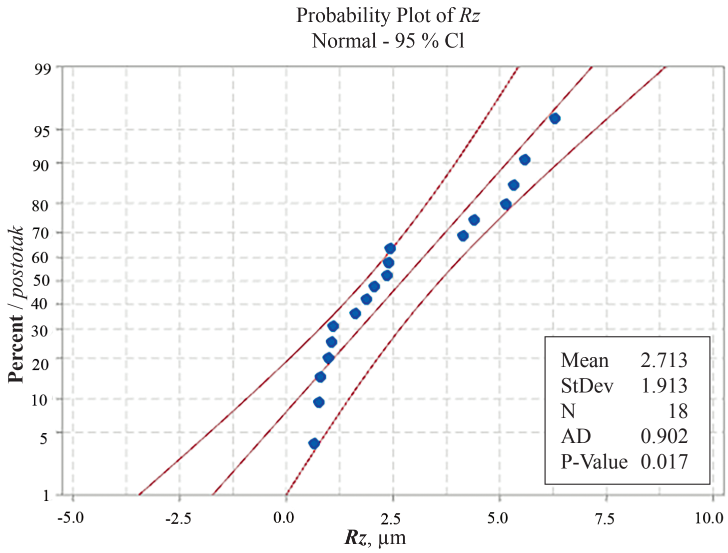

Figure 5 Normality graphs for *Rz*
Slika 5. Grafovi normalne distribucije za *Rz*

measurement did not show normal distribution at the 95 % confidence level. The analysis of variance results for *Rz* is given in Table 6.

According to Table 6, there is a significant difference for *Rz* as *P*=0.000 for the varnish type according to the results of a one-way analysis of variance at a 95% confidence level. It is seen that tree species (*P*=0.792>0.05) and hot-cold test (*P*=0.743>0.05) did not make any significant difference. Tukey test was applied for the varnish type in terms of *Rz*, and it was seen that each varnish type formed a separate group (Table 7).

According to the main effect plot created for *Rz*, it was observed that the lowest roughness value occurred in Scots pine tree species, while higher and

Table 6 Results of one-way analysis of variance for *Rz*
Tablica 6. Rezultati jednosmjerne analize varijance za *Rz*

Source / *Izvor*	*DF*	*Adj SS*	*Adj MS*	*F* Value	*P* Value
Wood species / *vrsta drva*	2	1.909	0.9543	0.24	0.792
Error	15	60.316	4.0211		
Total	17	62.225			
Varnish / *lak*	2	58.347	29.1736	112.85	0.000
Error	15	3.878	0.2585		
Total	17	62.225			
Hot and cold check test *test vruće i hladne provjere*	1	0.4303	0.4303	0.11	0.743
Error	16	61.7946	3.8622		
Total	17	62.2249			

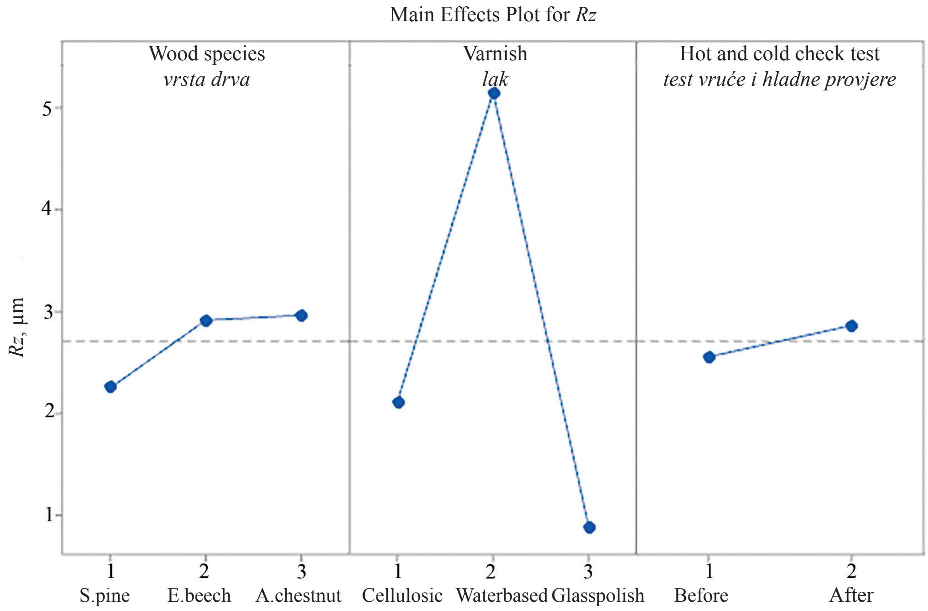

Figure 6 Main effects plot in terms of *Rz* of wood species, varnish types, and hot-cold check test
Slika 6. Dijagram glavnih učinaka na *Rz* s obzirom na vrstu drva, vrstu laka i test vruće i hladne provjere

close values were obtained in other tree species. In terms of varnish type, the *Ra* roughness value from the lowest is listed as glass polish, cellulosic and water-based. Although the values were close to each other before and after the test in terms of the hot and cold-check test, there was a slight increase in the *Ra* roughness value after the test.

When the interaction graph is examined in terms of *Rz*, it is seen that all three tree species have similar results in terms of the applied varnish, as in the *Ra* value. The lowest roughness value was obtained in glass polish, followed by cellulosic and synthetic varnish, respectively. When the interaction between the tree species and the hot-cold test was examined, there was a slight increase in the roughness value after the test in all three tree species. When the interaction between the varnish type and the hot-cold test was examined, it was observed that the *Ra* value of cellulosic and glass varnish, varnish types, increased slightly after the test, while an increase was observed in the water-based varnish type after the cold-hot test. As a result of sudden temperature changes, roughness parameters (*Ra* and *Rz*) increased in Scots pine and Anatolian chestnut tree species for all three varnish types. The literature states that the molecular sizes of water-based varnishes are smaller than those of solvent-based systems; therefore, they penetrate more into the cavities of the wood material, thus giving thin layers (Sonmez *et al.*, 2004).

Table 7 Results of Tukey test for *Rz*
Tablica 7. Rezultati Tukey testa za *Rz*

Varnish *Lak*	***N***	**Mean** *Srednja vrijednost*	**Grouping** *Grupiranje*		
2	6	5.157	A		
1	6	2.107		B	
3	6	0.8733			C

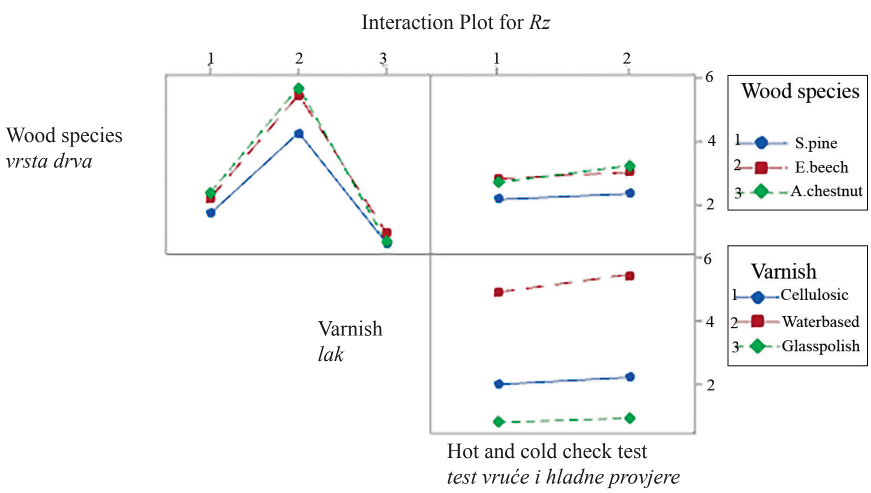

Figure 7 Interactions of wood species, varnish, and hot-cold check test of *Rz*
Slika 7. Interakcije vrste drva, laka i testa vruće i hladne provjere za *Rz*

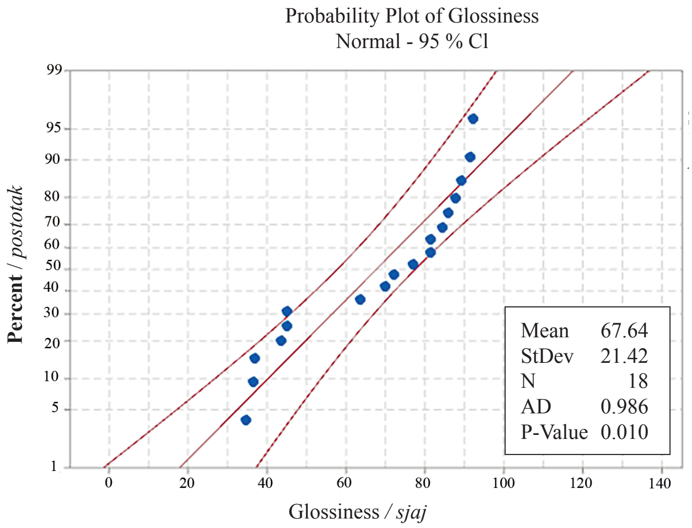

Figure 8 Normality graphs for glossiness
Slika 8. Grafovi normalne distribucije za sjaj

Table 8 Results of one-way analysis of variance for glossiness
Tablica 8. Rezultati jednosmjerne analize varijance za sjaj

Source / *Izvor*	***DF***	***Adj SS***	***Adj MS***	***F* Value**	***P* Value**
Wood species / *vrsta drva*	2	153.6	76.78	0.15	0.862
Error	15	7649.2	509.94		
Total	17	7802.7			
Varnish / *lak*	2	7223.3	3611.66	93.50	0.000
Error	15	579.4	38.63		
Total	17	7802.7			
Hot and cold check test *test vruće i hladne provjere*	1	230.4	230.4	0.49	0.495
Error	16	75.72.4	473.3		
Total	17	7802.7			

The low layer thickness reveals the effect of the texture of the wood material and may cause higher roughness (Table 3).

The normality graph for glossiness is given in Figure 8.

Since the *P* value is less than 0.05 (*P*=0.010) according to Figure 8, it is seen that the values in the glossiness measurement did not show normal distribution at the 95 % confidence level. Variance analysis results for glossiness are given in Table 8.

Based on Table 8 (according to the results of a one-way analysis of variance at a 95 % confidence level), there is a significant difference in terms of varnish type for glossiness as *P*=0.000. It is seen that tree species (*P*=0.862>0.05) and hot-cold test (*P*=0.495>0.05) did not make any significant difference. Tukey test was applied for the varnish type in terms of glossiness, and it was seen that each varnish type formed a separate group (Table 9).

According to the main effect plot created for glossiness (Figure 9), the highest glossiness value occurred in Scots pine tree species, while lower and close values were obtained in other tree species. Glossiness value in terms of varnish type is listed from the lowest to the highest as water-based, cellulosic, and glass polishes. Although the values were close to each other before and after the test in terms of hot and cold-check test, there was a decrease in the glossiness value after the test.

When the interaction graph is examined in terms of glossiness, it is seen that all three tree species have similar results according to the varnish applied. The lowest glossiness value was obtained in water-based varnish in every tree species, followed by cellulosic and glass varnish, respectively. Considering the wood type and the interaction of the hot-cold test, a slight decrease in the post-test glossiness value occurred in each tree species. When the interaction between the varnish type and the hot-cold test was examined, a decrease in the glossiness value after the test occurred in each type of varnish applied. Glossiness values were listed from the highest to the lowest according to the varnish type applied as glass polish, cellulosic and water-based. This sequence did not change before and after the hot-cold test.

Table 9 Results of Tukey test for glossiness
Tablica 9. Rezultati Tukey testa za sjaj

Varnish *Lak*	N	**Mean** *Srednja vrijednost*	**Grouping** *Grupiranje*
3	6	87.41	A
1	6	75.33	B
2	6	40.18	C

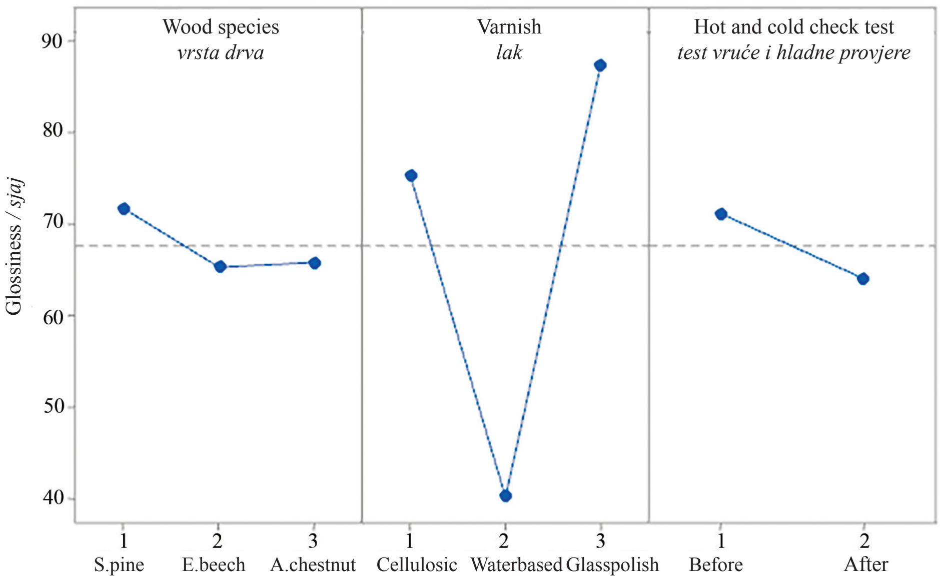

Figure 9 Main effects plot in terms of glossiness of wood species, varnish types, and hot-cold check test
Slika 9. Dijagram glavnih učinaka na sjaj s obzirom na vrstu drva, vrstu laka i test vruće i hladne provjere

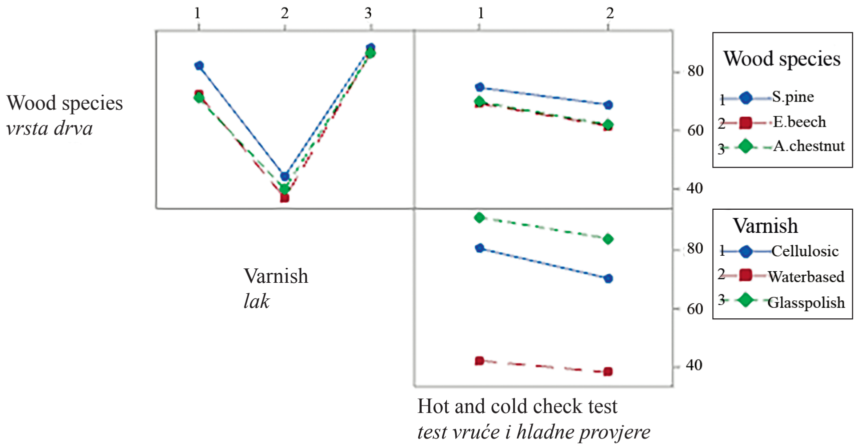

Figure 10 Interactions of wood species, varnish, and hot-cold check test of glossiness
Slika 10. Interakcije vrsta drva, laka i testa vruće i hladne provjere za sjaj

Kesik (1999) determined the effect of the hot-cold shock test on hardness and glossiness in Scots pine (*Pinus sylvestris* L.), Eastern beech (*Fagus orientalis* L.) and oak (*Quercus petreae* L.) tree species with cellulosic, polyurethane and acrylic varnish. According to the results of the experiment, it was determined that after the process, the hardness and glossiness values of all varnish types decreased. Ozalp *et al*. (2009), stated that hardness and glossiness values decreased in solid wood material kept at 100, 150 and 200 °C for 4 and 6 hours. The comparison, made in terms of the aging factor, showed that the highest total color change value was obtained in the samples without the hot-cold test, and the lowest in the samples with the hot-cold test. Similarly, the highest glossiness value was found in the samples without the hot-cold test and the lowest in the samples with the hot-cold test. It was reported in the literature that the varnish layers prepared for wooden surfaces lose their glossiness in outdoor weather conditions (Akpinar, 2012). Glossiness values also differ according to varnish types (Saygin, 2016). It was observed and found in the literature that a decrease in glossiness values occurs when wood is exposed to hot or cold external effects. As a result of sudden temperature changes, the glossiness decreased for each tree species and each varnish type. It was stated that the reasons for the decrease in the value of wood could lie in the formation of hemicelluloses and extractives, decomposition of products resulting from the effect of high heat or lignin polymerization reactions formed as a result of heat (Kamperidou *et al*., 2013; Barcík *et al*., 2015). In their study, they reported that the natural glossiness value of some trees was affected negatively after the increase in temperature and that the decrease in the glossiness value of the wood material depending on the temperature occurred as a result of chemical changes in glucose, hemicellulose and lignin

(Esteves *et al.,* 2008). The glossiness values differed according to the varnish type, and this result was also supported by the literature (Sonmez, 1989). The highest glossiness value was determined in the samples without the hot-cold test and the lowest in the samples with the hot-cold test (source). The literature states that the molecular sizes of water-based varnishes are smaller than those of solvent-based systems. Therefore, they penetrate more into the cavities of the wood material, thus creating thin layers (Sonmez *et al*., 2004). The low layer thickness reveals the effect of the texture of the wood material and the lowest glossiness value is obtained in water-based varnish. Water-based varnishes give the closest glossiness values to unvarnished samples (Sofuoglu and Aykac, 2020).

4 CONCLUSIONS
4. ZAKLJUČAK

Cellulosic varnish, water-based varnish and glass polish parquet varnish were applied to the surfaces of Scots pine, Eastern beech and Anatolian chestnut. Glossiness and roughness measurements were performed to detect the deformation on the surface during the hot-cold test process applied to the surfaces. The results show as follows:

The highest glossiness value was observed in Scots pine trees, while lower and close values were obtained in other tree species.

In terms of varnish type, the glossiness value was listed from the lowest as water-based (40.18 gloss), cellulosic (75.33 gloss) and glass polish (87.41 gloss).

Although the values were close to each other before and after the test in terms of hot and cold-check test, there was a decrease in the glossiness value after the test.

It was observed that the highest average roughness value (*Ra*) occurred in Anatolian chestnut trees, while lower and close values were obtained in other tree species.

In terms of varnish type, *Ra* roughness value was listed from the lowest as glass polish (0.1525 µm), cellulosic (0.5578 µm) and water-based (1.0933 µm).

Although the pre-test and post-test values were close to each other in terms of hot and cold-check test, there was a slight increase in the roughness value after the test.

It can be said that the changes in glossiness and roughness that occur on the surface of the varnished wood material after the hot-cold shock test do not affect the useful functions and surface properties of the products but are only affected in terms of aesthetics.

It can be predicted that such surface changes may occur in the three types of varnish applied to all three tree species, the furniture exported to countries with different climatic conditions, and the surface treatment material used on sea vehicles such as yachts/boats.

5 REFERENCES
5. LITERATURA

1. Akpinar, E., 2012: The effect of stem height on the physical and mechanical properties of European larch (*Larix decidua* Mill.) wood grown in Trabzon-Macka region. MSc Thesis, Karadeniz Technical University, Graduate School of Natural and Applied Sciences Trabzon, Turkey.
2. Altiparmak, M., 2017: Comparison of the performance of various varnishes used in wooden yachts on different wood species. MSc Thesis, Mugla Sitki Kocman University, Graduate School of Natural and Applied Sciences, Mugla, Turkey.
3. Aykac, S.; Sofuoglu, S. D., 2020: Investigation of the effect of varnish types on surface properties used in bamboo wooden material. Journal of Polytechnic, 24 (4): 1353-1363.
4. Atilgan, A., 2022: The use of resin laque as a top surface material on wood material and investigation of its antimicrobial effect. PhD Thesis, Gazi University Graduate School of Natural and Applied Sciences, Ankara, Turkey.
5. Barcík, Š.; Gašparík, M.; Razumov, E. Y., 2015: Effect of temperature on the color changes of wood during thermal modification. Cellulose Chemistry and Technology, 49 (9-10): 789-798.
6. Budakci, M., 1997: Effects of the resistance to adhesion surface of layer thickness glossy and hardness at the wood's varnishes. MSc Thesis, Gazi University Graduate School of Natural and Applied Sciences, Ankara, Turkey.
7. Budakci, M., 2003: Design and production of a new adhesion testing device and its utilization with testing of wood varnishes. PhD Thesis, Gazi University Graduate School of Natural and Applied Sciences, Ankara, Turkey.
8. Budakci, M.; Sevim Korkut, D.; Esen, R., 2010: The color changes on varnish layers after accelerated aging through the hot and cold-check test. African Journal of Biotechnology, 9 (24): 3595-3602.
9. Çakicier, N., 1994: The effects of varnishes treated on wood surfaces in the colour of wood stains. MSc Thesis, Gazi University Graduate School of Natural and Applied Sciences, Ankara, Turkey.
10. Cakicier, N., 2007: Changes due to weathering of surface finishing layers of wood. PhD Thesis, Istanbul University Graduate School of Natural and Applied Sciences, Istanbul, Turkey.
11. Dongel, N.; Kureli, I.; Sogutlu, C., 2008: The effect of dry heat for the colour and gloss changes on the wood and wood based floor covering materials. Journal of Polytechnic, 11 (3): 255-263.
12. Esteves, B.; Velez Marques, A.; Domingos, I.; Pereira, H., 2008: Heat-induced colour changes of pine (*Pinus pinaster*) and eucalypt (*Eucalyptus globulus*) wood. Wood Science and Technology, 42: 369-384.
13. Feist, W. C.; Hon, D. N. S., 1984: Chemistry of weathering and protection, The Chemistry of Solid Wood. American Chemical Society, Chapter 11, pp. 401-451.
14. Goktaş, O.; Mammadov, R.; Duru, M. E.; Baysal, E.; Çolak, A. M.; Ozen, E., 2006: Development of new environment friendly natural-colored preservatives for wood surface dying derived from different tree and herbaceous plant extracts and determination of their color parameters. Ekoloji, 15 (60): 16-23 (in Turkish).
15. Gurleyen, T.; Ayata, U.; Gurleyen, L.; Esteves, B.; Sivrikaya, H.; Can A., 2017: The determination of colour and

glossiness values on the parquets that underwent single and double layered UV varnishing system treatment. In: Proceedings of 2nd International Conference on Material Science and Technology in Cappadocia (IMSTEC'17), Nevsehir, Turkey, pp. 408-412.
16. Gurleyen, T.; Ayata, U.; Gurleyen, L.; Esteves, B.; Çakicier, N., 2017: Determination of color, glossiness and hardness values on single and double layer uv system parquet varnish layers applied to rowanberry (*Sorbus* L.) Wood. In: Proceedings of 5th International Symposium on Innovative Technologies in Engineering and Science (ISITES2017), Baku – Azerbaijan, pp. 1327-1336.
17. Kesik, H. I., 1999: The Tests with accelerating aging effects on varnish layers. MSc Thesis, Gazi University, Graduate School of Natural and Applied Sciences, Ankara, Turkey.
18. Kurtoglu, A., 2000: Agaç malzeme yuzey islemleri, Genel bilgiler, Cilt I, İstanbul University Publications, Istanbul University Publication no: 4262 (in Turkish).
19. Kamperidou, V.; Barboutis, I.; Vasileiou, V., 2013: Response of colour and hygroscopic properties of Scots pine wood to thermal treatment. Journal of Forestry Research, 24: 571-575. https://doi.org/10.1007/s11676-013-0389-y
20. Ordu, M.; Sofuoglu, S. D., 2016: Comparison of natural color and brightness value for the various types of wood. Ejovoc, 6 (4): 43-51.
21. Ozalp, M., 2008: The investigation of borax pentahydrate influences with double components in varnish applications of wood materials. Wood Research, 53 (4): 121-128.
22. Ozdemir, T., 2003: The Investigations of varnishes' features at some tree species grown in Turkey. PhD Thesis, Karadeniz Technical University Graduate School of Natural and Applied Sciences, Turkey.
23. Ozen, R.; Sonmez, A., 1990: Ahşap yüzeyler için hazırlanan verniklerin fiziksel, kimyasal ve mekanik etkilere karşı dayanaklıkları, Doğa Türk Tarım ve Ormancılık Dergisi, 1428-1436 (in Turkish).
24. Payne, H. F., 1965: Organic Coating Technology, Library of Congress Catalog, 1: 390.
25. Peker, H., 1997: Efficiency of treatment chemicals materials to varnishes used on surfaces of furniture. PhD Thesis, Karadeniz Technical University Graduate School of Natural and Applied Sciences, Trabzon, Turkey.
26. Pelit, H.; Korkmaz, M., 2019: Effect of water-based varnishes added nanographene on the surface properties of beech (*Fagus orientalis* Lipsky) wood, Journal of Politechnic, 22 (1): 203-212. https://doi.org/10.2339/politeknik.385436
27. Saygin, E., 2016: The effects of resin cleaning process on the layer performance of water-based varnishes. MSc Thesis, Duzce University, Institute of Science and Technology, Duzce, Turkey.
28. Sönmez, A., 1989: Durability of varnishes used on surfaces of wooden furniture against important physical mechanical and chemical effects. PhD Thesis, Gazi University, Institute of Science and Technology, Ankara, Turkey.
29. Sonmez, A.; Kesik, H. I., 1999: The aging tests for varnish coating with cold-check. Journal of Polytechnic, 2 (4): 27-32.
30. Sonmez, A., 2000: Ağaçişlerinde üstyüzey işlemleri: Hazırlık ve renklendirme, Gazi Üniversitesi Publication, Technical Education Faculty, Ankara (in Turkish).
31. Sonmez, A.; Budakci, M.; Yakın, M., 2004: Effect of application methods on the hardness gloss and adhesion strength of waterborne varnish coating on the wooden surface. Journal of Polytechnic, 7 (3): 229-235.
32. Ulay, G.; Budakci, M., 2015: Studies carried out in Turkey regarding water-based varnishes used on wood surfaces. Duzce University Journal of Science and Technology, 3 (2): 470-480.
33. Yakin, M., 2001: Effects of the resistance to adhesion, glossy and hardness at the waterborne varnishes. Master's thesis, Gazi University Graduate School of Natural and Applied Sciences, Ankara, Turkey.
34. Vardanyan, V.; Galstian, T.; Riedl, B., 2015: Effect of addition of cellulose nanocrystals to wood coatings on color changes and surface roughness due to accelerated weathering, Journal of Coatings Technology and Research, 12 (2): 247-258. https://doi.org/10.1007/s11998-014-9634-3
35. Yolanda, L. T., 1998: Evaluation of finishing properties and coating systems for gubas, Forest Products Research and Development Institute, 24 (1): 33-41.
36. ***ASTM-D 1211:1997 Standard test method for temperature-change resistance of clear nitrocellulose lacquer films applied to wood. ASTM International, West Conshıhocken, PA, USA.
37. ***ASTM D2244-21:1998 Standard practice for calculation of color tolerances and color differences from instrumentally measured color coordinates. ASTM Standards, ASTM International, W. Conshohocken, PA.
38. ***ASTM D 3023:1998 Standard practice for determination of resistance of factory applied coatings on wood products to stains and reagents, pp. 1-3. ASTM Standards, ASTM International, W. Conshohocken, PA.
39. ***ASTM D3023-98R17:1998 Standard practice for determination of resistance of factory-applied coatings on wood products to stains and reagents, ASTM Standards, ASTM International, W. Conshohocken, PA.
40. ***DYO, 1996: Spray gun motion study. Technical Bulletin, Dewilux Factories Co., Izmir.
41. ***ISO 3129:2019 Wood – Sampling methods and general requirements for physical and mechanical testing of small clear wood specimen. Switzerland: International Organization for Standardization.
42. ***TS 2495 EN ISO 3274:2005 Geometrical Product Specifications (GPS) – Surface texture: Profile method – Nominal characteristics of contact (stylus) instruments. Turkish Standard Institution, Ankara, Turkey.
43. ***TS EN ISO 2813:2014 Paints and varnishes – Determination of gloss value at 20 degrees, 60 degrees and 85 degrees, Turkish Standard Institution, Ankara, Turkey.
44. ***TS EN ISO 21920-3:2022 Geometrical Product Specifications (GPS) – Surface texture: Profile – Part 3: Specification operators, Turkish Standard Institution, Ankara, Turkey.
45. ***TS EN ISO 13061-1:2021 Physical and mechanical properties of wood – Test methods for small clear wood specimens. Part 1: Determination of moisture content for physical and mechanical tests, Turkish Standard Institution, Ankara, Turkey.

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