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Original Article

Surface glossiness properties of wood impregnated with some plant extracts

Bazı bitkisel ekstraktlar ile emprenye edilen ağaç malzemelerin yüzey parlaklık özellikleri

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ABSTRACT

This study investigated the changes in surface glossiness after 100 and 300 h of accelerated weathering of beech wood (*Fagus orientalis* L.) that was coated with polyurethane and cellulosic and water-based varnishes after impregnation with 5% and 10% concentrations of mimosa (*Acacia mollissima*) and quebracho (*Schinopsis lorentzii*) extracts and 4.5% Tanalith-E. The highest glossiness values were observed in the untreated control samples before and after accelerated weathering. Moreover, except for the samples coated with polyurethane varnish, the surface glossiness values of other samples decreased after accelerated weathering. Among the varnish types, the polyurethane varnish showed the best result in terms of surface glossiness, with higher values being observed after the 100-h weathering period than those before weathering. Increasing the tannin concentrations from 5% to 10% resulted in a decrease in the glossiness values. Wood impregnated with mimosa and quebracho extracts and varnished with polyurethane was able to maintain both durability and surface glossiness for a longer time.

Keywords: Tannin, varnish, accelerated weathering, glossiness

ÖZ

Bu çalışmada, %5 ve %10 konsantrasyonlarda mimoza (*Acacia mollissima*) ve kebrako (*Shinopsis lorentzii*) ekstraktları ve %4,5'lik Tanalith-E ile emprenye edilen kayın (*Fagus orientalis* L.) odunundan hazırlanan deney örnekleri poliüretan, selülozik ve su bazlı vernikler ile üst yüzey işlemine tabi tutulmuştur. 100 ve 300 saatlik hızlandırılmış yaşlandırma sonrasında yüzey parlaklığında meydana gelen değişimler araştırılmıştır. Elde edilen sonuçlara göre, yaşlandırma öncesi ve yaşlandırma sorası en yüksek parlaklık değerleri emprenye edilmemiş kontrol örneklerinde elde edilmiştir. Ayrıca poliüretan verniği haricinde genel olarak yaşlandırma işlemi ile birlikte vernik yüzeylerindeki parlaklık değerlerinde azalma meydana gelmiştir. Vernik çeşitleri içerisinde en iyi parlaklık değerleri poliüretan verniğinde elde edilmiştir. 100 saat yaşlandırma işlemine tabi tutulan poliüretan vernikli deney örnekleri kontrol örneklerine göre daha yüksek parlaklık değeri vermiştir. Tanenler ile emprenye edilen örneklerde konsantrasyon seviyesi %5'ten %10'a arttırıldığında parlaklık değerlerinde belli oranlarda azalma görülmüştür. Bu sonuçlara göre, mimoza ve kebrako ekstraktları ile emprenye edilen ağaç malzemeler poliüretan verniği uygulanarak hem dayanıklılıkları hem de yüzey parlaklıkları uzun süre korunabilir.

Anahtar Kelimeler: Tanen, vernik, hızlandırılmış yaşlandırma, parlaklık

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INTRODUCTION

Wood materials can be used for more than 10,000 applications. Their renewability; anatomical structure; physical, mechanical, and chemical properties; and easy machinability provide several advantages. In contrast, their hygroscopic nature is responsible for some negative aspects such as the lack of dimensional stabilization. Moreover, wood being an organic material is susceptible to destruction by biotic factors such as insects and fungi (Budakci, 2003). Numerous problems have also been recognized to be encountered in outdoor applications of wood materials, which include color change, glossiness deterioration, and the formation of surface roughness and cracks due to the effects of ambient conditions (humidity, UV, etc.) (Feist, 1982; Kartal, 1992; Williams, 2005). These negative features of wood materials can be reduced or minimized using various impregnation processes and surface treatments. In addition, the esthetic aspect of the wood can be enhanced or maintained (Kurtoğlu, 1984; Evans et al., 2005; Soylamış, 2007; Temiz et al., 2007).

From the past till today, various impregnation materials for wood have been developed to improve both indoor and outdoor long-term uses. With the application of these impregnation materials, the resulting increase in the service life of wood products provides both technical and economic benefits for the users. In addition, the long-term use of wood materials indirectly contributes to the sustainability of forests, despite the fact that several impregnants used in the past few years have been restricted or totally prohibited in several European countries due to adverse environmental effects (Kartal et al., 2006; Cao et al., 2011). Therefore, efforts have been recently increasing for the development of impregnation materials that would be both environmentally friendly and not hazardous to human health. Several studies have been conducted on the possibility of utilizing plant extracts, especially for the impregnation of indoor wood materials. These studies have determined that plant extracts are effective against the insects that cause the destruction of wood (Şen, 2002; Clausen and Yang, 2007; Tascioglu et al., 2012; Tascioglu et al., 2013). In this study, two commercial herbal extracts, namely, mimosa and quebracho, were used as impregnation materials. Mimosa extract is obtained by hot water extraction from the bark of *Acacia mollisima* tree and contains 33% of condensed tannins. Quebracho extract is obtained by hot water extraction from the wood of *Schinopsis lorentzii* tree and contains about 20% of condensed tannins (Huş, 1965). Chemical analyses of both extracts have revealed the presence of phenolic compounds such as catechol, epicatechin, and several fatty acids (Yalcin, 2012), which indicates the antifungal properties of these extracts (Ichihara and Yamaji, 2009; Pohl et al., 2011).

Wood contains hydroxyl functional groups such as hydroxyl, carbonyl, and carboxyl groups and aromatic and phenolic groups (Zhang et al., 2009). Under outdoor weather conditions, first, the color of the wood surfaces changes and the brightness decreases and then the roughness increases and various cracks appear. These modifications occur in the chromophore groups of the wood (Temiz et al., 2007; Zhang et al., 2009). Surface glossiness, which is the mirror-like reflection of light, is a very important feature for the esthetic and decorative appearance of wood surfaces (Çakıcıer et al., 2011). This is why it is essential to preserve the quality of the surface treatment so that the glossiness can be maintained for a long time on the wood surface where the treatment was applied.

Several factors are known to influence the glossiness of varnished surfaces, including climatic factors (Çakıcıer, 2007), tree type, varnish layer thickness, varnish application method (Sönmez et al., 2004), surface smoothness, and light reflection (Şanıvar, 1978). The chemicals used for the impregnation of wood materials have also been reported to be effective factors (Yalinkilic et al., 1999; Soylamış, 2007; Kesik, 2009; Baysal et al., 2013). After the impregnation process, structural wood materials require a surface treatment before use. Varnishing has been a preferred method of surface treatment in terms of reflecting the natural structure of the wood. That is why it is essential to determine the effects of impregnants on the surface treatments.

The primary purpose of this study was to examine the effects of treatment with environmentally friendly herbal extracts such as mimosa and quebracho on the surface glossiness values of oriental beech (*Fagus orientalis* L.) wood. In addition, different varnish applications and the changes in glossiness of the impregnated wood were evaluated under different accelerated weathering periods. This made it possible to determine the type of varnish application that best preserved the esthetic properties of the wood impregnated with the extracts.

MATERIALS AND METHODS

Materials

Within the scope of this study, samples of beech wood (*F. orientalis* L.) were prepared according to TS 4176 (1984) standard. Since beech sapwood has a *diffuse porous* structure that can be easily impregnated, it can provide suitable results for both impregnation and surface treatments (Bozkurt et al., 1993). The samples were cut with dimensions of 32 × 8 × 2 cm (length × radial tangent). The surfaces of the test specimens were sanded using 80-, 120-, and 150-grit sandpaper, respectively, until they reached a constant weight at 20°C±2°C and 65%±5% relative humidity (TS 642 ISO 554, 1997).

Mimosa (*A. mollissima*) bark extract and quebracho (*S. lorentzii*) wood extract prepared at concentrations of 5% and 10% were used for the impregnation of the experimental samples. Tanalith-E (4.5%) was used for comparison.

Within the scope of the study, the following three different varnish types were used: polyurethane and cellulosic and water-based varnishes. Each varnish type exhibited different behaviors when applied to the surfaces. Therefore, the effects of the different varnish applications on post-impregnation glossiness values were examined and compared.

Method

Impregnation process

The beech wood samples were first impregnated with mimosa and quebracho extracts to assess the effect of the varnish on the surface glossiness. Prior to impregnation, the oven-dry weight of the test samples was determined by drying them at 60°C for 48 h (m_0). The impregnation process was carried out in a vacuum-pressurized impregnation cylinder. An initial vacuum of 600 mmHg was applied for 20 min, and then a pressure of 12 bar was applied for 30 min. After the impregnation process, the wet weights (m_1) of the samples were measured and the retention amounts were calculated according to the following formula (TS 5723, 1988).

$$\text{Retention} = \frac{GxC}{V} x10 kg/m^3 \quad (1)$$

In the formula:
$G = (m_1 - m_0)$ (g),
C = Solution concentration, and
V = Volume of the wood sample (cm^3).

Varnish application

Varnish application was conducted in accordance with the manufacturer's recommendation. After the preparation of the varnishes for application, a finishing coat was applied using a spray gun. All the samples were dried under room temperature conditions after varnishing. The application viscosities of the varnishes were determined to be 15 snDIN/4 mm for polyurethane and 17 and 32 snDIN/4 mm for the cellulosic and water-based varnishes, respectively.

Accelerated weathering process

The tannins and surface varnishes used in this study were subjected to accelerated weathering to investigate the changes in the varnished surface glossiness, especially under the influence of abiotic (UV, temperature, etc.) factors under outdoor conditions. The weathering process was carried out in accordance with ISO 4892-3 (2005) using a UV-A 340 lamp in a calibrated QUV instrument (Figure 1a). For the weathering process, the conditioning program consisted of 0.76 UV W/m^2 for 8 h at 60°C and for 4 h at 50°C. The differences in the unweathered and weathered specimens are shown in Figure 1b.

Glossiness measurements

The measurements of surface glossiness of the wood parallel to the grain were conducted on all the samples after impregnation, varnishing, and weathering. Measurements were performed using a glossiness measuring device (a glossmeter) at an angle of 60° and using a calibrated surface according to the principles specified in ISO 2813 (1994) (Figure 1b). The glossiness values were measured both before weathering and after 100 and 300 h of accelerated weathering. A total of 810 measurements were performed, comprising 15 replications for each group.

Statistical Analyses

The effects of the impregnation material, the varnish type, and the weathering process on the glossiness of the varnished surfaces were statistically determined using the SPSS package program. All the variables were analyzed using Analysis of variance (ANOVA). Duncan's test with 95% confidence level was used to compare the mean values of the groups. The glossiness values according to the levels of impregnation, the varnish type, and the weathering period were compared.

RESULTS AND DISCUSSION

The retention amounts obtained with the impregnation process are shown in Table 1. The results show that there was no statistical difference in the retention amounts between the tannin species. In addition, the amounts of varnish applied per square meter for the polyurethane and cellulosic and water-based varnishes were determined to be 150, 130, and 130 g/m^2, respectively.

The average glossiness values of the varnished surfaces in terms of impregnation application are shown in Table 1. The highest glossiness values were detected in the unimpregnated control samples, whereas the lowest values were observed in the samples impregnated with mimosa and quebracho tannins at 5% concentration. These results indicate that when the samples were impregnated with Tanalith-E and tannins, there was a statistically significant decrease in the average glossiness values. In addition, when the concentration of each tannin was increased from 5% to 10%, there was again a statis-

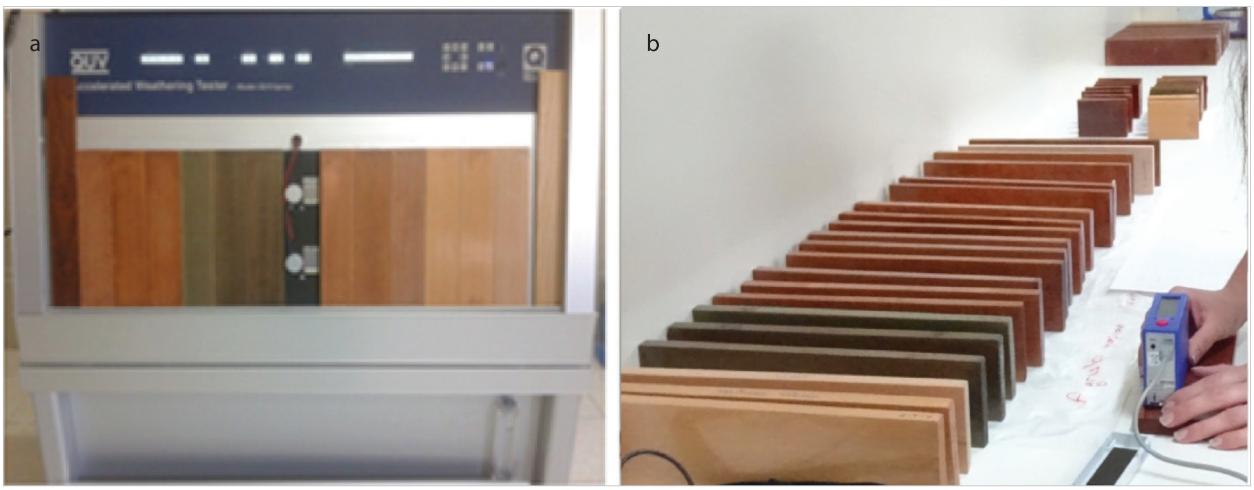

Figure 1. a, b. (a) Accelerated weathering, (b) Glossiness measurement

Table 1. Effects of impregnation on the glossiness of varnished surfaces

		Retention (kg/m³)		Mean glossiness parallel to grain	
Impregnation	Number of samples	Average	HG**	Average	HG**
Control	135	-	-	50.6	a*
4.5% Tanalith-E	135	55.68	b*	36.3	c
5% Mimosa	135	37.52	c	43.1	b
10% Mimosa	135	76.17	a	37.2	c
5% Quebracho	135	38.44	c	38.3	bc
10% Quebracho	135	76.42	a	33.8	d
P value (Significance)*		0.000		0.000	

*Values followed by the same letter are not significantly different ($p<0.05$), HG: Homogeneity group, *$p<0.05$.

Table 2. Effects of varnish application on surface glossiness (average of impregnation and weathering)

Varnish type	n	Mean glossiness parallel to grain	
Polyurethane	270	58.5	a*
Cellulosic	270	23.0	c
Water-based	270	38.1	b
P value (Significance)*		0.000	

*Values followed by the same letter are not significantly different, N: Number of sample, *$p<0.05$.

Table 3. Effects of weathering application on surface glossiness (average of impregnation and varnishing)

Accelerated weathering	n	Mean glossiness parallel to grain	
Before weathering	270	42.9	a
100 h	270	40.3	a
300 h	270	36.6	b
p value (Significance)*		0.000	

*Values followed by the same letter are not significantly different, N: Number of sample, *$p<0.05$.

tically significant reduction in the glossiness values. The lowest mean glossiness value was obtained with the 10% quebracho extract. The glossiness values were decreased in the wood samples treated with water-based impregnation materials (Özdemir et al., 2015).

The average glossiness values in terms of the varnish type are shown in Table 2. The results indicate that the highest average glossiness was observed in the polyurethane-varnished samples (58.5), while the glossiness values of the samples coated with water-based and cellulosic varnishes were 38.1 and 23.0, respectively. The difference in the glossiness values according to the varnish types may have been caused due to factors such as the drying systems and the chemical composition of the varnishes. It is believed that polyurethane varnish imparts a high glossiness value compared to that with other varnish types because of the chemical solidification between the varnish molecules together with the intermolecular cohesion (Soylamış, 2007).

The samples impregnated with tannins and Tanalith-E showed decreased glossiness values because of the water-based properties of these chemicals. Water-based impregnation materials have been reported to cause the fibers to swell and the surfaces to become rough (Yakın, 2001). Some studies have reported higher glossiness values with solvent-based impregnants, which have been shown to result in better filling of the wood surface and light reflection (Özdemir et al., 2015). It has also been reported that the low glossiness values in impregnated samples could be caused due to the impregnation materials adding their own chemical structures to the wood material surface (Soylamış, 2007).

Table 4. Effects of the interaction of weathering and impregnation on the surface glossiness of samples treated with polyurethane and cellulosic and water-based varnishes

Accelerated weathering	Impregnation	Number of samples	Polyurethane		Cellulosic		Water-based	
Control	Unimpregnated	15	76.2	a*	40.8	b*	45.2	bcd*
	4.5% Tanalith-E	15	45.9	ef	14.2	hl	38.3	ef
	5% Mimosa	15	53.4	e	33.0	gh	53.9	a
	10% Mimosa	15	52.2	de	18.0	c	47.6	bc
	5% Quebracho	15	57.1	g	26.5	de	50.2	ab
	10% Quebracho	15	45.4	de	28.9	d	47.0	bcd
100 h	Unimpregnated	15	81.7	a	45.7	a	32.3	g
	4.5% Tanalith-E	15	56.8	c	13.8	hl	46.7	bcd
	5% Mimosa	15	61.4	de	23.8	ef	35.2	fg
	10% Mimosa	15	57.7	bc	22.8	ef	33.3	fg
	5% Quebracho	15	55.8	g	20.8	fg	33.4	fg
	10% Kebrako	15	53.9	c	16.2	hl	29.3	gh
300 h	Unimpregnated	15	75.8	ab	24.4	ef	33.3	fg
	4.5% Tanalith-E	15	52.9	e	14.6	hl	43.1	cde
	5% Mimosa	15	63	cd	22.7	ef	41.4	de
	10% Mimosa	15	55.3	e	22.2	efg	25.6	g
	5% Quebracho	15	54.4	e	13.3	l	33.0	fg
	10% Quebraco	15	53.3	e	12.6	hl	17.8	l
	p value (Significance)*		0.000					

*Values followed by the same letter are not significantly different, *$p<0.05$.

The average glossiness values according to the weathering time periods are shown in Table 3. According to the statistical results, the highest average glossiness value (42.9) was obtained in the unweathered samples. However, there was no statistically significant difference among the samples weathered for 100 h. The lowest average glossiness value (36.6) was found in the samples after 300 h of weathering. Previous studies have shown that the effect of UV light on the surface glossiness was limited by weathering (Scrinzi et al., 2011; Baysal et al., 2013). Accelerated weathering causes erosion and roughness on the surfaces, thereby decreasing the surface glossiness values. Moreover, together with the weathering process, breakages in the varnish layer may also cause a decrease in the glossiness values (Çakıcıer, 2007).

Table 4 shows the differences in glossiness values with accelerated weathering of the impregnated and varnished samples.

Compared with the glossiness of the polyurethane-varnished samples, high glossiness values were obtained in the unimpregnated control samples, with the values being 76.2 before weathering, 81.7 after 100 h of weathering, and 75.8 h after 300 h of weathering. Baysal et al. (2005) also reported an increase in the glossiness values with weathering, depending on the varnish type. This increase could be attributed to the complete curing of the varnishes during the weathering process, and this process has been believed to be the basis for the increase in glossiness (Çakıcıer, 2007).

When the concentration of the impregnation materials was increased from 5% to 10%, it was observed that the glossiness values of the samples impregnated with tannins were reduced by a certain percentage. The highest glossiness value was obtained in the samples impregnated with quebracho extract (57.1) before weathering. After weathering, the highest glossiness value was obtained in the samples impregnated with 5% mimosa extract. Compared with the glossiness values before weathering, it was observed that the glossiness values of the polyurethane-varnished samples increased by 20% after the 100-h weathering process. Although there was a decrease in the glossiness value of the samples impregnated with 5% quebracho extract, it was not statistically significant (Figure 2).

When the glossiness values of the samples coated with cellulosic varnish were examined, in general, the highest glossiness values were obtained in the unimpregnated control samples. Statistical analysis of the results of the control samples showed

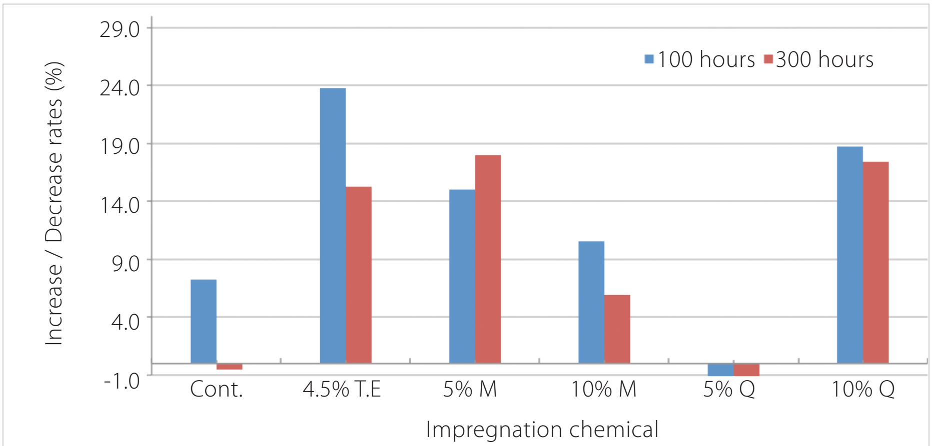

Figure 2. The rate of change in the glossiness values of polyurethane-varnished samples compared with those before weathering

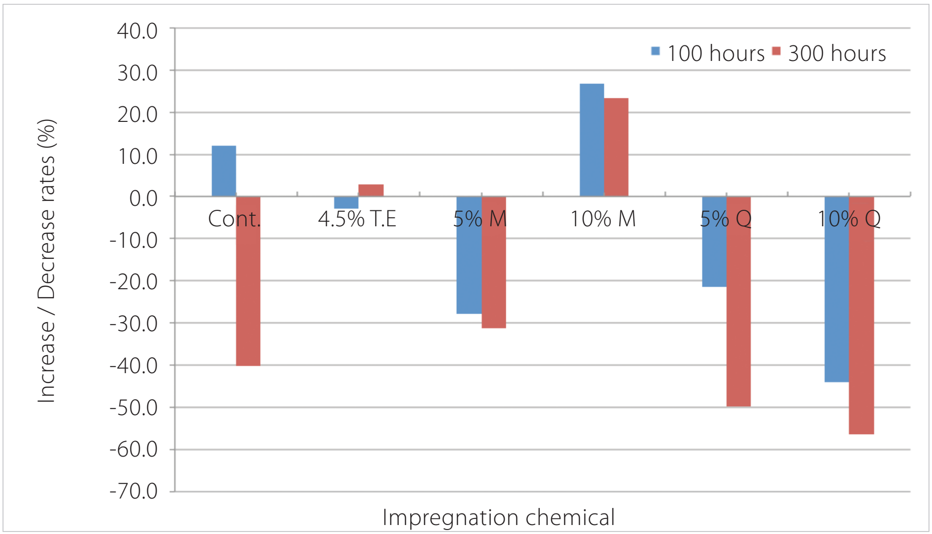

Figure 3. The rate of change in the glossiness values of samples treated with cellulosic varnish compared with those before weathering

the highest glossiness value of 45.7 at the end of the 100-h weathering period. In general, the highest glossiness values of the impregnated specimens were found in those impregnated with 5% mimosa extract. The glossiness values of the specimens impregnated with 5%-10% quebracho extract were significantly decreased, but there was no statistically significant change in the glossiness values of the Tanalith-E-impregnated specimens after weathering. In general, the weathering process had a decreasing effect (by 50%) on the glossiness of the samples treated with cellulosic varnish after 300 h of weathering compared to that of quebracho extract-impregnated specimens (Figure 3). Baysal et al. (2005) reported that the changes in the glossiness values were dependent on the impregnation chemicals and that after the weathering process, the glossiness values of the test specimens were decreased, whereas they showed an increase in some experimental specimens due to impregnation and the varnish type.

Regarding the samples coated with the water-based varnish, in general, the highest glossiness values were obtained in the unweathered samples. However, the highest glossiness value was found in those impregnated with Tanalith-E after 100 h of weathering. Moreover, it was observed that when the concentration levels of the chemicals in the impregnated samples were increased from 5% to 10%, there was a decrease in the glossiness values before and after weathering. The lowest glossiness value was observed in the samples impregnated with 10% quebracho extract (17.8). When compared with the glossiness values of unweathered specimens, besides those impregnated with Tanalith-E, a 60% decrease was observed in the glossiness values with weathering (Figure 4).

Based on the findings of this study, the impregnation process appears to have had a negative effect on the glossiness of the varnished surface. Similar results as well as those that differed

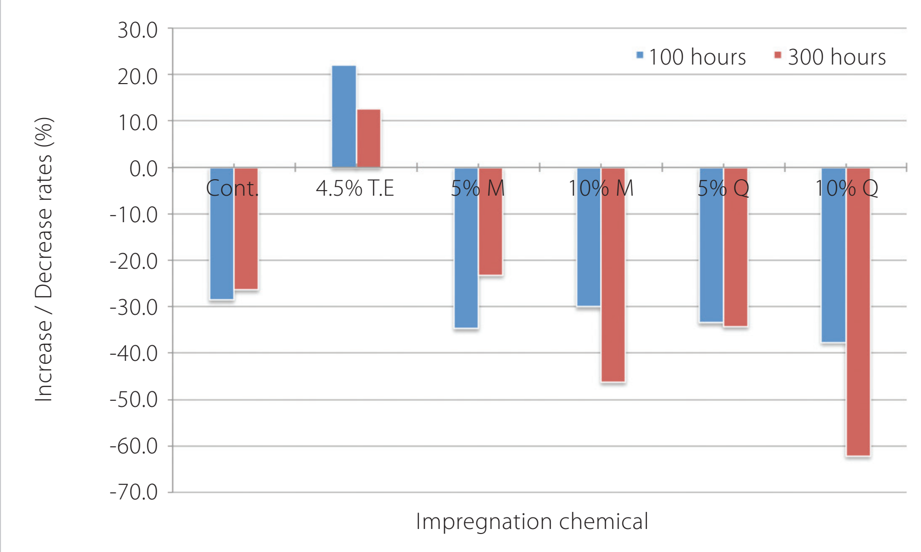

Figure 4. The rate of change in the glossiness values of samples coated with water-based varnish compared with those before weathering

could be found in the literature. Baysal et al. (2013) showed that CCB and Tanalith-E impregnants had a decreasing effect on the surface glossiness values of specimens coated with both cellulosic and polyurethane varnishes. Similarly, Topgül et al. (2009) stated that some boron compounds caused a reduction in surface glossiness with weathering. However, Özdemir et al. (2015) found that, at the end of their study, the glossiness values of Scots pine, beech, and chestnut samples without impregnation were higher than the glossiness values of samples impregnated with CCA, Tanalith-E, and boric acid and lower than those of samples impregnated with solvent-based immersol aqua.

In particular, it was noted that the control samples coated with cellulosic and water-based varnishes showed a significant decrease in their glossiness values when the weathering time reached 300 h. This result indicated that the decrease in the glossiness with weathering of the samples impregnated with tannins was caused not only due to the effect of the tannins but also due to the natural structure of the wood material. In addition to accelerated weathering, the effects of UV rays, heat, and rain can cause photochemical reactions, by which the surface glossiness changes due to the formation of free radicals from these reactions (Zahri et al., 2007; Rosu et al., 2010).

CONCLUSION

The glossiness of a varnished surface can be significantly affected by factors such as impregnation with tannins, the varnish type, and the accelerated weathering process ($p < 0.05$, Tables 1–3). When the effects of tannins on the glossiness of the varnished surface were examined, the highest glossiness values were observed in the control samples without impregnation. When the average values of all three varnish treatment types were taken into consideration, it was observed that the impregnation application and varnished surface glossiness values were reduced at different rates. In addition, with the increase in the tannin concentration ratio, there was again a decrease in the glossiness values. However, in the samples subjected to surface treatment with polyurethane varnish, the glossiness decreased after a certain weathering period (100 h) and after that (300 h), the glossiness values increased. In the samples coated with cellulosic varnish, the control samples without impregnation showed the highest glossiness values under all weathering conditions. The impregnation process was found to decrease the glossiness values, and the lowest glossiness values in the samples coated with cellulosic varnish were obtained in the quebracho tannin-impregnated samples after the 300-h weathering period. For the water-based varnishes, it was observed that with the weathering process, there was a decrease in the surface glossiness values of both the impregnated and the unimpregnated samples.

These results indicate that both mimosa and quebracho extracts can be considered as natural and environmentally friendly impregnation chemicals for wood materials, which could maintain the durability and esthetic features of wood for a long time along with the application of polyurethane varnish.

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