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Araştırma Makalesi

The effects of continuously wetting-drying cycles on pre-weathered and oil-coated rowan (*Sorbus torminalis*) wood

Sürekli ıslatma-kurutma döngülerinin ön yaşlandırılmış ve yağla kaplanmış üvez (*Sorbus torminalis*) odunu üzerindeki etkileri

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Abstract

The naturally weathered and then oil-coated (Teak oil) Rowan wood (*Sorbus torminalis*) was subjected to distilled (A) and swimming pool water (B) aging treatments with continuous wetting-drying up to the third cycle. Treatment conditions and water aging types seem to influence color variables somewhat. The highest lightness (ΔL*), redness (Δa*), and yellowness (Δb*) changes were measured in samples that were continuously aged at the third cycle procedure in swimming pool water, respectively. Similar results have also been observed for total color changes, such that pool water had higher discoloration effects on color values compared to distilled water at similar conditions, while increasing the cycle usually further lowered discoloration. The highest color change value of ΔEB_3: 10.49 (metric) was found in the third cycle in pool water treatment, followed by a value of ΔEB_2: 9.42 (metric) in the second cycle and a value of ΔEB_1: 1.71 (metric) in the first cycle, respectively. Color changes could be employed as a sensitive physical indicator of coating aging, which can be correlated to the associated chemical changes. All aging processes have lower gloss values than control in all aging procedures, regardless of water type**.** The lowest gloss value of 1.2 GU was noticed at the third cycle in swimming pool treatments. It is also notable that the most dramatic effect on surface hardness (Shore D) was found after the first cycle, while the lowest hardness values of 38 (metric) and 33 (metric) were found in swimming pools and distilled pure water-treated samples, respectively.

Keywords: Weathered Rowan wood, teak oil, color changes, glossiness, surface hardness.

Özet

Atmosferik dış şartlarda yaşlandırma işlemine tabii tutulmuş Üvez odunları (*Sorbus torminalis*), yağ esaslı yüzey işlem maddesi (Tik yağı) ile işleme tabi tutulmuştur. Daha sonra damıtılmış saf su (A) ve yüzme havuz suyu (B) ile sürekli ıslatma-kurutmaya tabii tutularak yaşlandırma işlemleri üç döngü olacak şekilde uygulanmıştır. İşlem koşullarının ve suda yaşlandırma türlerinin renk değişkenlerini bir dereceye kadar etkilediği görülmektedir. En yüksek parlaklık (ΔL*), kırmızılık (Δa*) ve sarılık (Δb*) değerlerinde meydana gelen farklıklar, yüzme havuz suyu ile muamele edilmiş üçüncü döngü prosedüründe yaşlandırılmış numunelerde ölçülmüştür. Toplam renk değişimleri için de benzer sonuçlar gözlemlenmiş, havuz yüzme suyunun renk değerleri üzerinde, benzer koşullarda damıtılmış suya göre daha yüksek oranda renk değiştirme etkisine sahip olduğu, kurutma-ıslatma döngüsünün arttırılmasının ise genellikle renk bozulmasını daha da artırdığı anlaşılmıştır. En yüksek renk değişimi değeri ΔEB_3: 10,49 (metrik) ile havuz suyu ile üçüncü döngüde elde edilirken, bunu ikinci döngüde ΔEB_2: 9,42 (metrik) değeri ve ilk döngüde ise ΔEB_1: 1,71 (metrik) değeri ile takip etmiştir. Örneklerin renklerinde meydana gelen değişiklikler, uygulanan yüzey işlem maddesinin yaşlanması sonucu oluşan kimyasal reaksiyonlarla ilişkili olduğu değerlendirilmiştir. Bu çalışmada, tüm yaşlandırma işlemine tabi tutulan numunelerin parlaklık değerleri, su türünden bağımsız olarak kontrol örneğinden daha düşük olarak belirlenmiştir. Yüzme havuzu yaşlandırmalarında numunelerin en düşük parlaklık değeri 1,2 GU ile üçüncü döngüde belirlenmiştir. Ayrıca yüzey sertliği (Shore D) üzerindeki en çarpıcı etkinin ilk döngüden sonra bulunması dikkat çekicidir ki en düşük sertlik değerleri ise 38 (metrik) ve 33 (metrik) olarak sırası ile yüzme havuzunda ve damıtılmış saf su ile işlem görmüş numunelerde bulunmuştur.

Anahtar kelimeler: Yaşlandırılmış üvez ağacı, tik yağı, renk değişimi, parlaklık, yüzey sertliği.

1. Introductions

Since wood is a light absorber, most components in wood are capable of absorbing visible and UV light to undergo photochemical complex reactions that ultimately lead to discoloration and degradation, commonly called weathering (Feist and Hon, 1984; Feist, 1990). Those wood surfaces become rough as the grain raises, creating checks that grow into large cracks. Generally, these impact discoloration, gather dirt and mildew, and become unsightly (Kubler, 1980; Gindl et al., 2004; Oberhofnerová et al., 2017). However, the weathering process can be significantly reduced by appropriate surface and/or bulk treatments, for which natural color and aesthetic appearance are important (Feist and Hon, 1984; Palashev, 1994; Williams and Knaebe, 2000).

Painting, coating, and surface finishing are commonly used to protect wood to varying degrees in outdoor conditions (Sahin, 2021). Several researchers have attempted to summarize the current knowledge on the weathering phenomena as well as the techniques of protecting wood (Feist and Hon, 1984; Sell and Fesit, 1986; Feist, 1990; Pánek and Reinprecht, 2014; Kržišnik et al., 2018). Hydrophobic extractives migrate to the surface and decrease surface energy during weathering (Feist and Hon, 1984). As a result, wetting of surface coating agents is adversely affected, and bonding is potentiated when substrates deteriorate (Williams et al., 1987; Williams et al., 1999; Williams et al., 2002).

In recent works, it was obviously hypothesized that coating was one of the most effective methods for remediating a weathered wood surface (Kubler, 1980; Williams et al., 2002; Gindl et al., 2004). Many types of natural and synthetic agents could be used to protect and nourish wood while they penetrate deep into the grain of the wood to create a long-lasting, hard-wearing finish that protects the wood and enhances its beauty (Singh and Singh, 2012; Broda, 2020; Sahin, 2021). However, recent trends in the use of wood for exterior applications have emphasized natural-type finishes that enhance the texture, grain, and inherent beauty of the wood (Singh and Singh, 2012; Broda, 2020; Timar et al., 2020). While several approaches have been used for developing an acceptable natural finish, surface treatments have been extensively studied to improve the service life of clear exterior finishes.

Šimunková et al. (2018) compared a high-gloss polyurethane lacquer with traditional shellac varnish (applied to oak) and the effect of artificial UV aging on some selected properties of the finished surfaces. They concluded that UV aging affected surface properties differently, highlighting a marked decrease in the water resistance of shellac finishes. However, teak oil is not extracted from teak trees; namely, it is often used to varnish teak wood surfaces, so it was named as teak oil. It typically consists of a blend of ingredients; namely, linseed oil, tung oil, and mineral spirits (Petroleum naphtha) (Tesarova and Cech, 2015; Panek and Reinprecht, 2016). However, teak oil is a finishing oil product for wooden materials (e.g., furniture). Although it was initially formulated for teak wood, it can be used in any indoor or outdoor application of wood items. It can be used on most softwood, hardwood, and tropical species, but it gives better application on hardwoods (Reinprecht et al., 2018). It has become popular for general outdoor situations, including decks, garden furniture, windows, doors, and fencing, because it beautifies the wood grain, protecting it against UV rays and water. Many advantageous results have been proposed for using teak oil as a wood surface coating agent (Tesarova and Cech, 2015; Panek and Reinprecht, 2016; Reinprecht et al., 2018). Some of them are (i) easy to use and fast drying (4–6 hours), (ii) giving the wood a stable surface, (iii) good water and dirt resistance, and (iv) providing UV protection to slow the graying process for all other exterior wood products.

The study of aging of wood surfaces and preservation is one of the significant topics for wood scientists (Feist and Hon, 1984; Sell and Fesit, 1986; Williams et al., 1987; Feist, 1990; Williams et al., 1999; Pánek and Reinprecht, 2014; Kržišnik et al., 2018). However, it is challenging to compare wood-finished surfaces due to the significant variability in testing (e.g., tested materials, aging factors, procedures, investigated parameters). Therefore, the aging of finishing materials, mainly applied on wood surfaces, needs to be examined using dedicated approaches, so the gap in the literature related to aging on the properties of the coating on weathered wood could be filled.

This study aims to evaluate the efficiency of teak oil applied to naturally five-year-weathered Rowan wood subjected to distilled and swimming pool water aging. The experimental findings presented in this study aim to contribute to the aging-induced changes in the quality of finished wood surfaces.

2. Material and Method

In this study, Rowan (*Sorbus aucuparia*) sapwood, from the forestlands region of Bolu Provinence-Turkiye, was used. A leading brand of commercially available teak oil was supplied from a retail store (a Turkish brand with a carried label). Three experimental wood samples were prepared in 5.0×5.0x1.5 cm (length parallel to tree axis x width in radial direction x thickness in radial direction). Average number of annual rings per centimeter were seven to ten for specimens, exposed outdoors for five years in Sobu height-Isparta-Turkiye (37°50'05.9"N 30°31'27.6"E). All the samples were defect-free but severely weathered with some profound color changes. The control and weathered wood samples were exposed to teak oil treatment by soaking for one minute. Afterwards, the samples were air-dried at the room temperatures for 72 hours.

The properties of the cured coatings on wood were assessed by the CIE L * a * b * C* h* (1976) color standard; differences (Δ values) were calculated as surface color changes. An X-Rite SP-68 spectrophotometer measured the color characteristics. The gloss of samples was determined according to ASTM D523 with a 60^{0}-measuring device (Glosgard II, Pacific Scientific, Lansing, MI). A Shore Hardness (Scale D) instrument was used according to the test method of ASTM D2240.

The aging effects of two different types of distilled pure water (A) and swimming pool water (B) were utilized to progress continuously through wetting-drying cycles for evaluating surface color, gloss, and hardness properties. Therefore, three wetting-drying stages were carried out continuously to evaluate properties. The pre-weathered and coated samples were soaked in the waters at atmospheric conditions for 16 hours. After each soaking and drying phase in the room temperatures, samples were separated and numbered. The remaining samples were continued for wetting-drying progress. At the end of each soaking stage, the sheets were dried in an atmospheric condition at 25 ^{o}C for five days.

Some code numbers and abbreviations were established throughout the study, as shown in Figures and Tables. These are samples subjected to distilled water treatments (A) and samples subjected to swimming pool water treatments (B); once (1), twice (2), and third-times (3) wetted-dried (cycle number) wood samples.

3. Results and Discussions

The color coordinate differences (ΔL, Δa, and Δb) of the teak oil-coated wood samples after up to three wetting-drying cycles are comparatively summarized in Table 1. Water types and aging intensity appear to greatlysignificantly impact color properties. The maximum lightness-darkness (ΔL), red-green (Δa), and blue-yellow (Δb) color coordinate changes were found with swimming water treated in the third cycled (aged) samples. However, the total intensity range of lightness is 0–100 units, where 0 represents the total darkness, followed by gray up to bright white (100 units). The highest changes of ΔLA_3:-7.95 (metric), ΔaB_3:-1.46 (metric), and ΔbB_3:-6.68 (metric) were measured in a sample that was continuously aged at the third cycle procedure in swimming pool water, respectively. It is vital to note that swimming pool water typically contains chlorine (1.0–3.0 ppm) and higher total dissolved solids (500–5000 ppm) than distilled water, which could affect further aging on surface coatings, as realized in this study.

The wood samples immersed in swimming pool water exhibited higher chroma changes (ΔCB) than those immersed in distilled water (ΔCA) under all conditions. Increasing the cycle is more effective for higher chroma properties (Figure 1). The highest chroma value of ΔCB_3: -6.83 (metric) was found, followed by ΔCB_2: -5.80 (metric) and ΔCB_1: -1.59 (metric), respectively. Notably, distilled water aging has only marginal effects on the chroma properties of samples (ΔCA_1: 0.1, ΔCA_2: 0.05, ΔCA_3: 0.21).

Although it is an easy and valuable method to determine the basic color coordinate values of the samples, the explanation of each color parameter (CIE L *, a *, b *) is quite complicated. However, examination of the total color difference (ΔE) value is essential in providing information about the way of change. The total color change of the samples is comparatively illustrated in Figure 2. It is obvious that considerably different discolorations were measured at similar aging procedures for two different water sources. The plots confirm that distilled water effects are only in a narrow range (ΔEA_1: 1.37, ΔEA_2: 1.65, ΔEA_3: 2.16) but increase as aging continues to the third cycle. The swimming pool treatments highly affect color changes in all conditions more than distilled water treatment conditions. A positive relationship between increasing aging levels (cycle) and color changes is also observed. The highest value of ΔEB_3: 10.49 (metric) was found in the third cycle procedure in swimming water treatment, followed by a value of ΔEB_2: 9.42 (metric) and a value of ΔEB_1: 1.71 (metric), respectively. Color changes could be employed as a sensitive physical indicator of coating aging, which can be correlated to the associated chemical changes.

The hue angle for most of the natural woods in the CIE L*; h*; C* color sphere is between 45˚ and 90˚, which human eyes perceive between yellow and brown. However, the hue (h) has slightly varied for both aging treatments. The hue changes for distilled water-treated samples were found to be ΔHA_1: -0.13˚, ΔHA_2: -0.47˚ and ΔHA_3: 0.01˚. The swimming water-treated samples show hue changes of ΔHB_1: 0.54˚, ΔHB_2: -0.7˚ and ΔHB_3: -0.43˚, respectively. Although a linear correlation between lightness (L*) and hue angle (h* = arc tan b*/a*) was reported for steamed wood (Tolvaj and Németh, 2008) and light irritated wood (Tolvaj et al., 2011). In this study, there is no correlation between lightness and hue values.

The gloss measurements revealed lower values than the control in all aging procedures, regardless of water type (Figure 3). However, there is no clear correlation between gloss values and the type of water treatment. The control samples have a gloss value of 2.6 GU. The lowest gloss value of 1.2 GU was observed at the third cycle in swimming pool treatments.

Table 1. Surface color properties (CIE L*, a*, b*) of woods.

Cycles	ΔLA	ΔLB	ΔaA	ΔaB	ΔbA	ΔbB
First	1.36	-0.33	0.1	-0.9	0.07	-1.41
Second	1.58	-7.39	0.45	-1	-0.12	-5.75
Third	2.15	-7.95	0.12	-1.46	0.18	-6.68

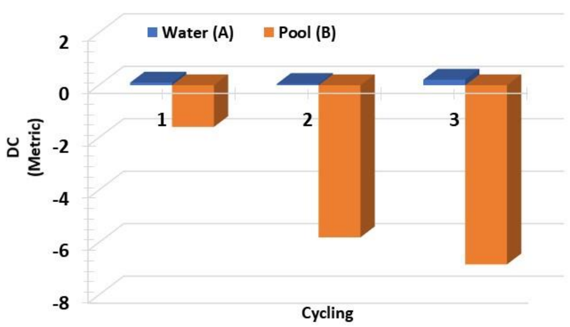

Figure 1. Chromacity (ΔC) properties of samples.

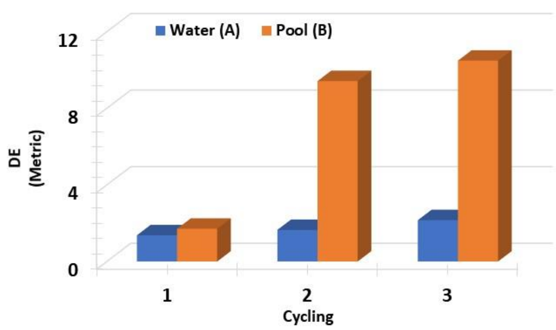

Figure 2. Color changes (ΔE) properties of samples.

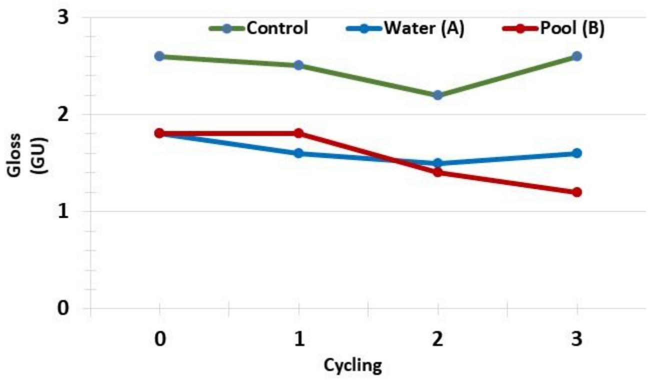

Figure 3. Gloss change properties of samples.

Weathering typically causes surface roughness, open cracks, and defects in treated surfaces. It is challenging to eliminate roughness and cracks with surface treatments. Even a high-quality coating often loses its protective ability because it cannot tolerate the stresses and strains of wood shrinkage and swelling. In this regard, any further analysis of these surface optical changes is beyond the scope of this study, which focuses mainly on the influence of aging on the adherence and resistance of coating films to a selection of two different water aging processes. However, these color changes are visible evidence of aging and an indication that other water sources should be involved in the aging procedures, as a function of the surface optical property factor involved.

It can be seen that the first aging cycle had the most dramatic effects for both types of samples concerning the changes in surface hardness, in Figure 4. The lowest Shore D value of 38 (metric) was obtained in the swimming pool-treated sample (B_1), while it was 33 (metric) for sample A_1. Throughout the second and third aging procedures, the hardness changes were much lower than those of the initial control value (A0&B0: 47 metric).

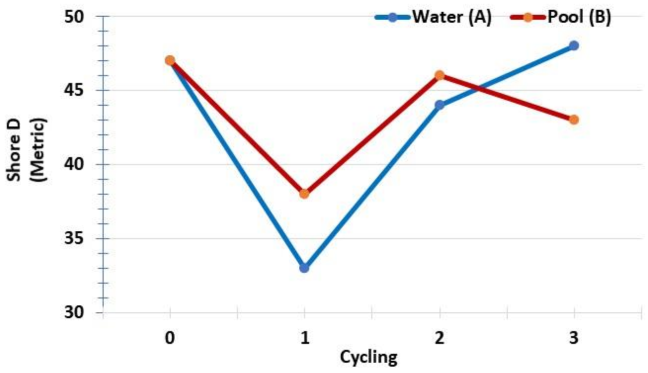

Figure 4. Hardness (shore D) changes the properties of samples.

4. Conclusions

The results presented in this study are based on conducted research on the five-year pre-weathered wood substrates and aging phenomena for transparent finishes using a comparative approach for distilled pure and swimming water conditions. Both water types could affect surface optical changes. It is expected to result in discoloration occurring on wood surfaces with water contact. However, swimming pool water appears to have further modification effects on surface physical properties than distilled water.

Surface finishing or coating on wooden materials is sensitive to wetting as well as the ingredients of the agent. It could be hypothesized that chlorine and other pool agents, typically found in swimming pool water (1-3 ppm), may have detrimental effects on further discolorations. Teak oil is one of the well-known and suitable mainly for the exterior of all types of wood materials. However, Teak oil has some distinctive advantages over other coating agents. Some of those are easy to apply, provide a rich appearance with a warm matt finish, and are great resistant to water and staining. In this case, Teak oil could be used for outdoor furniture and wooden elements, which are used in harsh weather conditions.

Author contributions

Concept: H.T.Ş.; Design: U.Ö.; Supervision: H.T.Ş., U.Ö.; Data Collection: H.T.Ş.; Analysis: H.T.Ş., U.Ö.; Literature Search: H.T.Ş.; U.Ö.; Writing Manuscript: H.T.Ş.; Critical Review: U.Ö

References

Broda, M., 2020. Natural compounds for wood protection against fungi-a review. *Molecules*, 25(15), 3538.

Feist, W.C., 1990. Outdoor wood weathering and protection. Archaeological wood, properties, chemistry, and preservation. *Advanced in Chemistry Series*, (225), 263-298.

Feist, W.C., Hon, D.N.S., 1984. Chemistry of weathering and protection. *The chemistry of solid wood*, 207, 401-451.

Gindl, M., Reiterer, A., Sinn, G., Stanzl-Tschegg, S.E., 2004. Effects of surface ageing on wettability, surface chemistry, and adhesion of wood. *Holz als Roh-und Werkstoff*, 62(4), 273-280.

Kržišnik, D., Lesar, B., Thaler, N., Humar, M., 2018. Influence of natural and artificial weathering on the colour change of different wood and wood-based materials. *Forests*, 9(8), 488.

Kubler, H., 1980. Wood as building and hobby material, John Wiley & Sons, NY

Oberhofnerová, E., Pánek, M., García-Cimarras, A., 2017. The effect of natural weathering on untreated wood surface. Maderas. *Ciencia y tecnología*, 19(2), 173-184.

Palashev, Y., 1994. Change in the wood colour under the influence of climatic factors. Naukaza Gorata, 31(2), 65-71.

Pánek, M., Reinprecht, L., 2014. Colour stability and surface defects of naturally aged wood treated with transparent paints for exterior constructions. *Wood Research*, 59(3), 421-430.

Pánek, M., Reinprecht, L., 2016. Effect of vegetable oils on the colour stability of four tropical woods during natural and artificial weathering. *J Wood Sci*, 62, 74–84.

Reinprecht, L., Nosál, E., Jaš, F., 2018. The impact of accelerated weathering on the mold resistance and color stability of the Morway spruce wood treated with naturalis oils. *Acta Facultatis Xylologiae Zvolen res Publica Slovaca*, 60(2), 95-106.

Sahin, H., 2021. Evaluation of Natural Oil Adducts in Alkyd-Based Varnish Emulsion and Effect on Rowan (Sorbus torminalis)

Wood. *Asian Journal of Biotechnology and Bioresource Technology*, 7(3), 56-63.

Sell, J. and Fesit W.C., 1986. U.S. and European finishes for weather exposed wood-a comparison. *Forest Prod. J*., 36(4), 37-41.

Šimunková K., Pánek M., Zeidler A., 2018. Comparison of selected properties of shellac varnish for restoration and polyurethane varnish for reconstruction of historical artefacts. *Coatings*, 8(4), 12.

Singh T., Singh AP., 2012. A review on natural products as wood protectant. Wood Sci. Technol., 46, 851-870.

Tesařová, D., Cech, P., 2015. Influence of classic finished surfaces of massive wood on indoor environment. *Pro Ligno*, 11(4), 294-300.

Timar, M. C., Varodi, A. M., Liu, X. Y., 2020. The influence of artificial ageing on selected properties of wood surfaces finished with traditional materials-an assessment for conservation purposes. Bulletin of the Transilvania University of Brasov. Series II: Forestry• Wood Industry• Agricultural Food Engineering, 81-94.

Tolvaj, L., Mitsui, K., Varga, D., 2011. Validity limits of Kubelka–Munk theory for DRIFT spectra of photodegraded solid wood. *Wood Science and Technology*, 45, 135-146.

Tolvaj, L., Németh, K., 2008. Correlation between hue-angle and colour lightness of steamed black locust wood. *Acta Silvatica et Lignaria Hungarica*, 2008(4), 55-59.

Williams, R.S., Knaebe, M., 2000. Restoration of severely weathered wood. *Journal of Coatings Technology*, 72(902), 43-51.

Williams, R.S., Sotos, P., Feist, W.C., 1999. Evaluation of several finishes on severely weathered wood. *Journal of Coatings Technology*, 71(895), 97-102.

Williams, R.S., Winandy, J.E., Feist, W.C., 1987. Paint adhesion to weathered wood. *Journal of Coatings Technology*, 59(749), 43.

Williams, R.S., Winandy, J.E., Feist, W.C., 2002. Correlation of adhesive strength with service life of paint applied to weathered wood. In Proceedings of the 9'th Durability of Building Materials and Components Conference held 17-20, March 2002, in Brisbane, Australia. Sl: sn, 2002: 11 p.