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Borax and Calcite Modified Water-Based Acrylic Varnish: A Comprehensive Characterization Study

Vodeni akrilni lak modificiran boraksom i kalcitom: sveobuhvatna karakterizacija

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ABSTRACT • Wood surfaces should be coated in order to protect wooden materials from adverse environmental conditions. In this study, calcite (CaCO_3) and borax ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$) were added to the varnish to increase the protection effectiveness of the water-based acrylic varnish used for protection on fir tree (*Abies alba* L.) timber. The varnish mixture was applied on the samples with a brush. Rapid aging was applied to the samples with the QUV accelerated weathering tester to determine the surface durability of the samples. After rapid aging, color analysis and Taber abrasion test were performed on the sample surfaces for surface characterization. Then, the test results were compared with the pre-aging test results. The results were statistically analyzed. The results showed that the addition of filler did not significantly affect color stability after UV exposure ($p > 0.05$). Abrasion resistance was affected by both the type of filler and the UV treatment. 4 % calcite provided the highest resistance before aging. High filler content reduced UV resistance in some cases. Overall, lower filler ratios (≤ 2 %) resulted in a more balanced performance.

KEYWORDS: acrylic varnish; calcite; borax; UV aging; abrasion resistance; PCA

SAŽETAK • Drvene je površine potrebno zaštititi premazom kako okolišni uvjeti ne bi nepovoljno utjecali na njih. U ovom su istraživanju radi povećanja učinkovitosti zaštite vodenom akrilnom laku, koji se upotrebljavao za zaštitu je-lovine (*Abies alba* L.), dodani kalcit (CaCO_3) i boraks ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$). Lak je na uzorke nanosen kistom. Za određivanje trajnosti površine uzoraka provedeno je ubrzano starenje u QUV uređaju za ubrzano izlaganje vremenskim utjecajima. Nakon ubrzanog starenja na površinama uzoraka provedene su analiza boje i otpornosti na habanje radi karakterizacije površine. Potom su rezultati ispitivanja uspoređeni s rezultatima izmjerenim prije starenja. Rezultati su statistički obrađeni i prikazani u radu. Oni su pokazali da dodatak punila nije značajno utjecao na stabilnost boje nakon izlaganja UV zračenju ($p > 0,05$). No, na otpornost na habanje utjecali su i vrsta punila i izlaganje UV zračenju. Najveću otpornost prije starenja osigurao je dodatak 4 % kalcita. Visok udio punila u pojedinim je slučajevima smanjio otpornost na UV zračenje. Općenito, niži udjeli punila (≤ 2 %) rezultirali su uravnoteženijim svojstvima.

KLJUČNE RIJEČI: akrilni lak; kalcit; boraks; UV starenje; otpornost na habanje; PCA

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1 INTRODUCTION

1. UVOD

Wood is one of the oldest materials in human history. Wood productivity has also increased with human history (Mezentsev and Gavrikov, 2015) and today, there are over 5 thousand wooden products (Aboulnaga and Elsharkawy, 2022). It has an indispensable place in human life (Al-Kubaisy, 2022). It is an organic product, obtained from forest resources and has an important role in terms of ecology (Said, 2018). For this reason, wood must be protected carefully against adverse biotic and abiotic factors.

In the first centuries, simple protective methods were used such as burning the outer surface and applying pitch or tar (Žigon and Pavlič, 2023). These techniques aimed to protect wood from mechanical and chemical harm, is a common goal of protective coatings (Alam *et al.*, 2023). Nowadays, many techniques have been developed for the protection of wood surfaces that involve the protection of wood by forming a film on the surface. This technique emerged with the advancement of polymer chemistry about 150 years ago (Prieto and Kiene, 2018).

In addition to the protective function of surface coating materials used to protect wood materials, their aesthetic appearance is also important. For this reason, paints and varnishes are often preferred in the protection of wood surfaces (Feist and Abdullahi, 2016). Coatings such as varnishes and paints not only provide protection against environmental factors like UV radiation and moisture but also enhance the visual appeal of the wood (Teacă and Bodîrlău, 2016). For instance, varnishes can improve the surface durability and resistance to weathering, while also highlighting the natural beauty of the wood (Pánek *et al.*, 2017). Thus, the use of aesthetic coatings is integral to both preserving and enhancing wood materials (Jirouš-Rajković and Miklečić, 2021).

The paint and varnish sector is very dynamic. The formulation in their compositions is constantly renewed, and efforts are made to improve their superior features. For this reason, a wide variety of fillers are added to paints and varnishes. The added fillers reach up to 50 %. This amount is higher in water-based paints and varnishes. Some of the fillers used are titanium dioxide (rutile and anatase), calcite, mica, clay minerals (thickeners), quartz, feldspar, barite and color pigments (McGonigle and Ciullo, 1996).

Calcite (CaCO_3) in paint recipes is cheaper than many fillers. The production process of calcite is also simple. Therefore, the use of calcite in paint recipes provides not only financial but also environmental advantages. Calcite reduces paint and varnish cost and changes some physical properties. It is not as good as some fillers such as titanium dioxide (TiO_2) in terms of refractive index and particle size, but calcite improves

this filler distribution in the matrix through interaction with TiO_2 particles (Karakaş and Çelik, 2012).

In fact, neither the particle size nor the refractive index of calcite samples are at the desired level to obtain good opacity. Calcite is positively charged in the paint environment (Barhoum *et al.*, 2014). Some fillers can be negatively charged. Due to this feature, calcite helps negatively charged fillers to create a homogeneous distribution in the matrix (Machida *et al.*, 2023). Thus, it helps paints and varnishes to be opaquer (Altiner *et al.*, 2021).

Borax has several properties that make it suitable for paints, including high dispersion ability, optimum corrosion inhibition effect, and the ability to increase the density of paint films (Jianfeng *et al.*, 2012).

Borax's high affinity for electronegative atoms such as oxygen and its ability to form strong covalent bonds have made it suitable for use in impregnating, painting and varnish industries (Wu, 1955; Bhat *et al.*, 2005; Baysal, 2008; Atar *et al.*, 2009; Wei *et al.*, 2016).

Borax minerals have natural antiseptic properties and prevent microbial growth. Borax-added varnishes protect wooden surfaces against fungi, mold and bacteria. Thus, the life of varnishes is extended, especially on wooden surfaces used in humid and outdoor areas (Borges *et al.*, 2018; Estevez-Fregoso *et al.*, 2021).

In the presented study, borax and calcite were added to water-based acrylic varnish in certain proportions to improve its mechanical and physical properties. Prepared varnish mixtures were painted on the fir wood and their characterization was performed. The results were compared with neat waterborne acrylic varnish.

2 MATERIALS AND METHODS

2. MATERIJALI I METODE

The experiments conducted in this study encompassed all steps from material selection and varnish preparation to coating application to samples, conditioning, accelerated UV aging, and subsequent color change (ΔE^*) and abrasion resistance measurements. A summary of the entire experimental flow is presented in Figure 1 (Workflow).

2.1 Materials

2.1. Materijali

In the study, water-based acrylic varnish, which is harmless to the environment and human health, was preferred and calcite and borax (Tincal) were used as filler particles in the varnish.

Calcite was obtained from the "Somgroup Company" of Türkiye. Some technical properties of calcite are given in Table 1.

Tincal ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$) was purchased from online market. Its other commercial name is borax. In fact, borax is a boron mineral, which is a natural com-

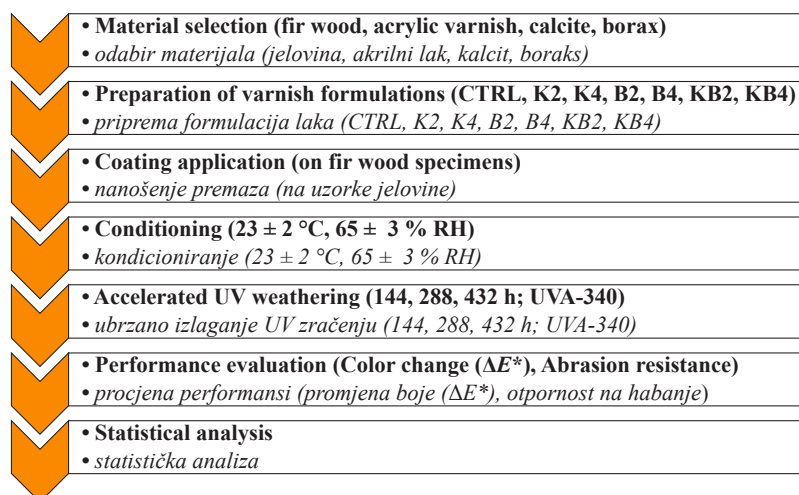


Figure 1 Schematic representation of the experimental workflow of the study. The varnish formulation codes (CTRL, K2, K4, B2, B4, KB2, KB4) are detailed in Table 2.

Slika 1. Shematski prikaz eksperimentalnog tijeka istraživanja. Oznake formulacija laka detaljno su objašnjene u tablici 2.

pound containing varying amounts of boron oxide in its structure. There are more than 230 different boron minerals in nature. The most important boron minerals in commercial terms are Tincal, Colemanite, Kernite, Ulexite, Pandermite, Boracite, Szaybelite and Hydroboracite. We preferred Tincal borax in this study due to its prevalent usage. Some technical properties are given in Table 1.

2.2 Preparation of samples

2.2. Priprema uzoraka

In this study, three different varnish groups (borax, calcite, and borax/calcite-supplemented varnishes) were prepared based on a conventional method reported in the literature (Azani and Hassanpour, 2024; Goktas *et al.*, 2024a; Goktaş *et al.*, 2024b), with minor modifications introduced to improve particle (borax and calcite) dispersion. First, 10 % aqueous solutions of borax, calcite and mixtures of these two materials were mixed with a mechanical mixer for 5 minutes, followed by ultrasonic mixing for 10 minutes to achieve homogeneous distribution. These solutions were then added to the water-based acrylic varnish, en-

suring the solid content ratio of 2 % and 4 %. The varnish and particle mixtures were initially mixed in a mechanical mixer at 1500 rpm and for 10 minutes (Aksu *et al.*, 2022). To ensure homogeneous distribution, the mixtures were further processed in a water bath containing ethylene glycol using a high-speed ultrasonic mixer for 20 minutes (Vardanyan *et al.*, 2014). The cooling provided by the water bath during mixing was intended to prevent the degradation of the polymeric structure, which could result from the increase in solution temperature due to molecular agitation caused by ultrasonic mixing (Azani and Hassanpour, 2024). Before application, the prepared particle-added varnish was mixed with a mechanical mixer at 2000 rpm for 5 minutes to ensure it was ready for use (Aksu *et al.*, 2022).

All varnish mixtures belonging to the three groups are given in Table 2. Wood sample surfaces were initially sanded with 180 grid sandpaper. Varnishes were applied with a brush (180 gr/m²) on 100 mm × 100 mm × 8 mm samples. The samples were kept at 23 ± 2 °C for 3 days to ensure that the varnish solidified on the surface.

Table 1 Typical properties of calcite (Karakaş and Çelik, 2012) and borax

Tablica 1. Tipična svojstva kalcita (Karakaş i Çelik, 2012.) i boraksa

Property / Svojstvo	Calcite/ Kalcit	Borax / Boraks
Chemical formula / kemijska formula	CaCO ₃	Na ₂ B ₄ O ₇ ·10H ₂ O
Density, g/cm ³ / gustoća, g/cm ³	2.7	1.73
Crystal system / kristalni sustav	Trigonal (3 2/m)	—
Refractive index / indeks loma	n _e = 1.486, n _o = 1.658	—
Hardness, Mohs / tvrdoća, prema Mohsu	3	—
Oil absorption, mL/100 g / upojnost ulja, mL/100 g	17	—
Appearance / izgled	—	White granules
Purity, % / čistoća, %	—	99.9
B ₂ O ₃ content, % / udio B ₂ O ₃ , %	—	36 – 38
Na ₂ O content, % / udio Na ₂ O, %	—	17

Table 2 Prepared varnish samples
Tablica 2. Pripremljeni uzorci laka

Sample code <i>Oznaka uzorka</i>	Samples / <i>Uzorci</i>	Varnish, g <i>Lak, g</i>	Calcite, g <i>Kalcit, g</i>	Borax, g <i>Boraks, g</i>
CTRL	Neat acrylic varnish / <i>čisti akrilni lak</i>	100	—	—
K2	2 % calcite supplemented / <i>dodatak 2 % kalcita</i>	98	2	—
K4	4 % calcite supplemented / <i>dodatak 4 % kalcita</i>	96	4	—
B2	2 % borax supplemented / <i>dodatak 2 % boraksa</i>	98	—	2
B4	4 % borax supplemented / <i>dodatak 4 % boraksa</i>	96	—	4
KB2	2 % calcite/borax supplemented / <i>dodatak 2 % kalcita/boraksa</i>	98	1	1
KB4	4 % calcite/borax supplemented / <i>dodatak 4 % kalcita/boraksa</i>	96	2	2

2.3 Methods

2.3. Metode

2.3.1 Color analysis

2.3.1. Analiza boje

Samples colors were analyzed before and after the UV treatment with CS-10 colorimeter (CHN Spec, China). Measurement conditions were CIE 10° standard observer; CIE D65 light source, illumination system: 8/d (8°/diffused illumination). To minimize the effect of surface heterogeneity, color measurements were performed at predefined and marked points on each sample. Furthermore, multiple measurements were taken and averaged to ensure repeatability. Therefore, the observed differences between measurements taken before and after UV irradiation were primarily attributed to UV-induced color changes. After color measurement, color differences (ΔE^*) were evaluated according to DIN 5033 (2017) (Table 3), and ΔE^* was calculated according to equations below. The percentage of reflection of light is expressed in the CIELAB color system, which is the visible light spectrum at a wavelength of 10 nm. L^* represents the darkness value, a^* and b^* represent the axes from green to red and from blue to yellow, respectively.

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

$$\Delta a^* = (a^* \text{ before UV} - a^* \text{ after UV}) \quad (2)$$

$$\Delta L^* = (L^* \text{ before UV} - L^* \text{ after UV}) \quad (3)$$

$$\Delta b^* = (b^* \text{ before UV} - b^* \text{ after UV}) \quad (4)$$

Table 3 Comparison criteria for ΔE^* evaluation (DIN 5033, 2017)**Tablica 3.** Kriteriji usporedbe za procjenu ΔE^* (DIN 5033, 2017.)

Total color difference (ΔE^*) <i>Ukupna promjena boje (ΔE^*)</i>	Visual color score difference <i>Vizualna razlika u ocjeni boje</i>
< 0.2	Imperceptible / <i>neprimjetna</i>
0.2 – 0.5	Very weak / <i>vrlo slaba</i>
0.5 – 1.5	Weak / <i>slaba</i>
1.5 – 3.0	Noticeable / <i>primjetna</i>
3.0 – 6.0	Very noticeable / <i>vrlo primjetna</i>
6.0 – 12.0	Strong / <i>izražena</i>
> 12.0	Very strong / <i>vrlo izražena</i>

2.3.2 Abrasion analysis

2.3.2. Analiza otpornosti na habanje

The test was carried out in accordance with the German Industrial Standard, European Norm (DIN EN) 13329 (also DIN 53799) (2021) using the Taber Abrasive. The test specimen was first divided into four marked quadrants and then fixed to the measuring device. Calibrated sandpaper was attached to two abrasive wheels with a defined weight (5.4 ± 0.2 N each). The wheels were placed on the test specimen. After pressing the start button, the sample holder rotated at a constant speed. The sandpaper was renewed after 200 revolutions (or earlier if necessary). The first wear point (IP) was determined when visible wear spots of at least 0.60 mm^2 each were present in two quadrants and a spot of equal size in a third quadrant. Abrasion resistances were evaluated according to the average abrasion point of the initial abrasion point (IP) and the final abrasion point (FP) and results were compared statistically ($P < 0.05$).

2.3.3 UV weathering

2.3.3. Ubrzano izlaganje UV zračenju

After the varnish mixtures prepared were applied to the fir samples ($100 \text{ mm} \times 100 \text{ mm} \times 8 \text{ mm}$), they were left to dry for three weeks in the climate laboratory at 20 ± 2 °C temperature and 65 ± 3 % relative humidity, corresponding to an equilibrium moisture content (EMC) of approximately 12 %. Then, the varnished materials were prepared by modifying the aging environment conditions of the ASTM G 154-06 (2006) standard (15 minutes water spray, 8 hours UV) (0.67 light intensity, 18 minutes water spray, 2 hours UV and 50 °C ambient temperature). The samples were exposed to UV aging effects for 144, 288 and 432 hours in the QUV accelerated weathering tester with UV-A 340 fluorescent lamps (Q-Lab, 2026).

2.3.4 Statistical analysis

2.3.4. Statistička analiza

For the evaluation of the analysis data, one-way analysis of variance (ANOVA) and Duncan's multiple range test were used. One-way ANOVA was applied to

determine whether there were statistically significant differences among the group means. In cases where significant differences were detected, Duncan's multiple range test was performed to identify which groups differed from each other. The significance level was set at $P < 0.05$.

3 RESULTS AND DISCUSSION

3. REZULTATI I RASPRAVA

3.1 Optical properties

3.1. Optička svojstva

Color changes in varnished samples after UV irradiation are presented in Table 4. The ΔE^* values of the samples ranged from 28.8 to 32.5. Significant color changes occurred in all varnish formulations after UV aging. Among the samples, formulation B2 showed the highest color change ($\Delta E^* = 32.5$), while formulation KB4 showed the lowest value ($\Delta E^* = 28.8$). The control sample showed a ΔE^* value of 30.4, which is within the observed range for modified varnish systems.

Although small differences were observed between the varnish mixtures, the one-way ANOVA test showed that the differences in total color change (ΔE^*) were not statistically significant ($F(6,35) = 1.149$, $p = 0.355$). This indicates that the addition of calcite, borax or a combination thereof does not significantly affect the color stability of acrylic varnish under UV exposure. A graphical representation of the total color difference (ΔE^*) values is presented in Figure 2.

The direction of color change in the $CIEL^*a^*b^*$ color space is shown in Figure 3. The trajectories generally show a shift towards positive a^* and b^* coordinates. This confirms that the coatings tend to develop reddish and yellowish tones after exposure to UV light.

Principal Component Analysis (PCA) was performed using the $CIEL^*a^*b^*$ color coordinate changes (ΔL^* , Δa^* , and Δb^*) in order to evaluate the multivariate behavior of the varnish formulations after UV exposure. The PCA score plot based on the first two principal components is presented in Figure 4.

The first principal component (PC1) explained the majority of the variance in the dataset, while the second principal component (PC2) accounted for a smaller proportion of the remaining variability. Together, the first two components explained a substantial portion of the total variance, indicating that the PCA model effectively represented the main variation patterns in the color change data.

Examination of PCA score distributions revealed that sample groups largely clustered in a similar region of the multivariate space. This overlap meant that the addition of calcite, borax, or their co-addition to the acrylic varnish system did not lead to a clearly separated multivariate color response under the conditions studied.

Loading vectors showed that the overall variation in the dataset was primarily related to the contributions of CIELAB color coordinates. Positive contributions of Δa^* and Δb^* indicate that the dominant color shift

Table 4 Color difference of samples

Tablica 4. Promjena boje uzoraka

Samples	K2	K4	B2	B4	KB2	KB4	Control
ΔE^* (Mean $\pm$ SD) (Sig. 0.355*)	30.7 ($\pm 2.29^{***}$) AB**	31.44 (± 3.55) AB	32.5 (± 1.73) B	29.8 (± 2.74) AB	30.2 (± 2.53) AB	28.8 (± 2.86) A	30.4 (± 2.73) AB

*Significance ($P < 0.05$), **Duncan groups groups, ***Standard deviation / *Značajnost ($P < 0,05$), **Duncanove skupine, ***standardna devijacija

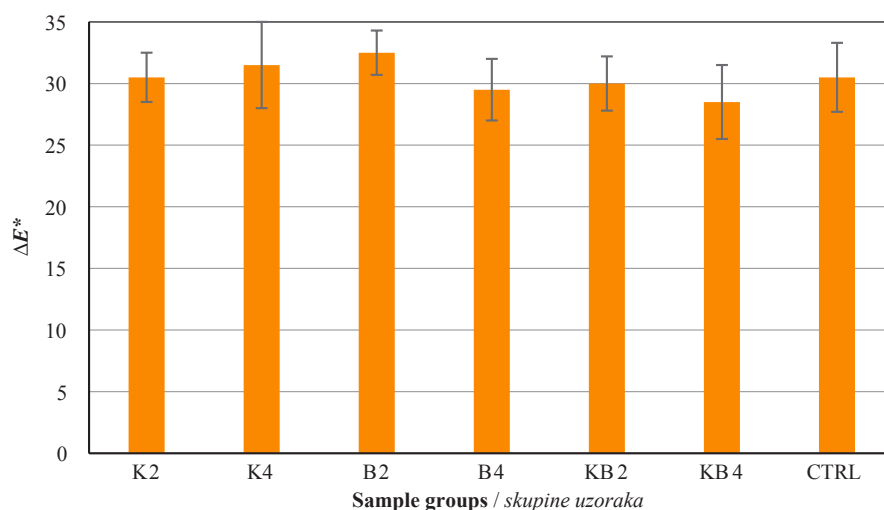


Figure 2 Total color difference (ΔE^*) after UV aging

Slika 2. Ukupna promjena boje (ΔE^*) nakon UV starenja

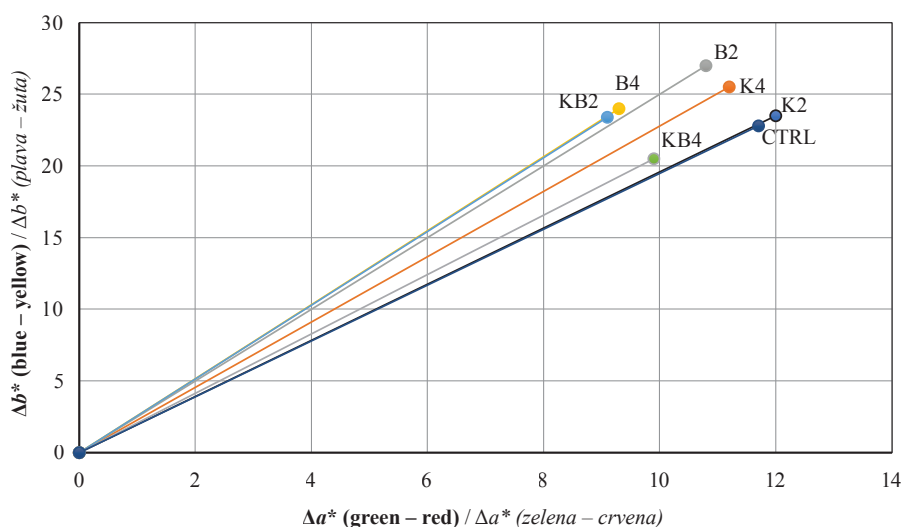


Figure 3 CIEL*a*b* color shift vector diagram (mean Δa^* and mean Δb^*) of varnish formulations after UV exposure

Slika 3. Vektorski dijagram promjene boje u CIEL*a*b* sustavu (srednja vrijednost Δa^* i srednja vrijednost Δb^*) formulacija laka nakon izlaganja UV zračenju

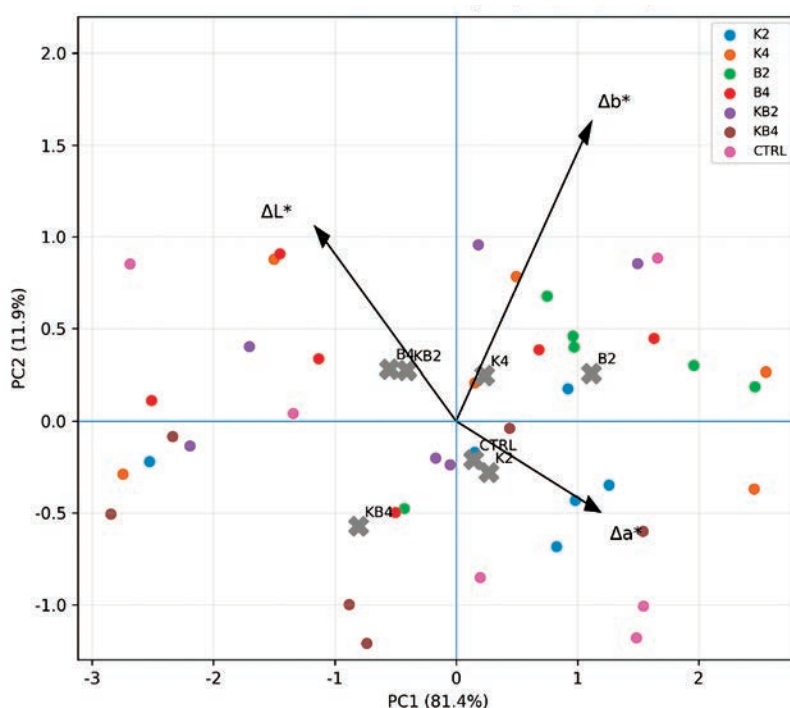


Figure 4 PCA score plot (PC1 – PC2) based on CIELAB color changes (ΔL^* , Δa^* , Δb^*) after UV exposure

Slika 4. Grafički prikaz rezultata PCA analize (PC1 – PC2) na temelju promjena CIELAB koordinata boje (ΔL^* , Δa^* , Δb^*) nakon izlaganja UV zračenju

after UV exposure occurs towards the red and yellow regions. This trend is consistent with the typical photo-degradation behavior of polymeric coating systems where UV radiation causes chromophore formation and yellowing in the polymer matrix.

The principal component analysis (PCA) graph obtained with 95 % confidence interval ellipses and PCA score ellipses is presented in Figure 5.

In this graph, CIELAB color coordinate changes (ΔL^* , Δa^* , and Δb^*) were used to examine the multi-

variate relationships between varnish formulations after exposure to UV light.

The varnish formulations showed a significant overlap in the PCA score graph with 95 % confidence interval ellipses (Figure 5), as well as in the PCA score graph based on CIELAB color changes (ΔL^* , Δa^* , Δb^*) after exposure to UV light (PC1–PC2) (Figure 4), revealing a similar multivariate color change response after UV exposure. This visual pattern is consistent with the one-way ANOVA result for ΔE , which showed

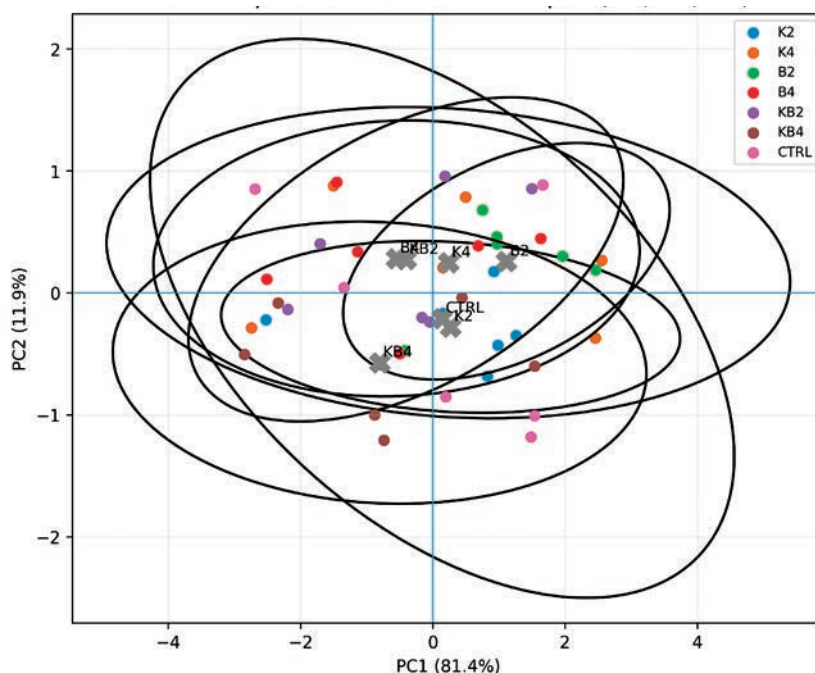


Figure 5 PCA score plot with 95 % confidence ellipses based on $CIEL^*a^*b^*$ color-coordinate changes (ΔL^* , Δa^* , Δb^*) after UV exposure

Slika 5. Grafički prikaz rezultata PCA analize s 95-postotnim elipsama pouzdanosti na temelju promjena $CIEL^*a^*b^*$ koordinata boje (ΔL^* , Δa^* , Δb^*) nakon izlaganja UV zračenju

no significant differences between groups ($F(6,35) = 1.149$, $p = 0.355$).

3.2 Abrasion properties

3.2. Svojstva otpornosti na habanje

The abrasion resistance and weight loss values of the varnish formulations before and after UV exposure are presented in Table 5, while the interaction between varnish formulation and UV exposure is illustrated in Figure 6.

The percentage change values represent the relative difference in abrasion resistance after UV expo-

sure compared to before UV exposure and were calculated using the following equation:

$$\text{Change (\%)} = \frac{[(\text{after UV} - \text{before UV}) / \text{before UV}] \times 100}{\quad} \quad (5)$$

Before exposure to UV weathering, K4 was the sample with the highest abrasion resistance. After UV treatment, this value decreased by 52.4 %. In contrast, the KB4 group, which had the lowest resistance at 41.67 cycles, showed a 116.0 % increase in abrasion resistance after exposure to UV weathering (reached 90.00 cycles). This may have been caused by UV rays creating cross-links in the varnish mixture. The forma-

Table 5 Abrasion resistance and weight loss values of varnish formulations after abrasion testing

Tablica 5. Otpornost na habanje i gubitak mase formulacija laka nakon ispitivanja

Samples Uzorci	Abrasion resistance before UV (Mean $\pm$ SD) Otpornost na habanje prije UV zračenja (srednja vrijednost $\pm$ standardna devijacija)	Duncan group Duncanove skupine	Abrasion resistance after UV (Mean $\pm$ SD) Otpornost na habanje nakon UV zračenja (srednja vrijednost $\pm$ standardna devijacija)	Duncan group Duncanove skupine	Weight loss before UV, g Gubitak mase prije UV zračenja, g	Weight loss after UV, g Gubitak mase nakon UV zračenja, g	Change in abrasion resistance, % Promjena otpornosti na habanje, %	p-value (UV effect) p-vrijednost (utjecaj UV zračenja)
Control	76.67 $\pm$ 15.06	BC	115.00 $\pm$ 8.37	a	0.0350	0.0617	+50.0	0.005
K2	71.67 $\pm$ 7.53	BC	96.67 $\pm$ 8.16	a	0.0567	0.0483	+34.9	0.002
K4	136.67 $\pm$ 66.23	A	65.00 $\pm$ 12.25	b	0.0467	0.0583	-52.4	0.041
B2	68.33 $\pm$ 4.08	BC	111.67 $\pm$ 25.63	a	0.0750	0.0717	+63.4	0.012
B4	76.67 $\pm$ 5.16	BC	90.00 $\pm$ 8.94	ab	0.0567	0.0300	+17.4	0.043
KB2	103.33 $\pm$ 21.60	AB	65.00 $\pm$ 15.17	b	0.0550	0.0733	-37.1	0.001
KB4	41.67 $\pm$ 4.08	C	90.00 $\pm$ 15.49	ab	0.0517	0.0567	+116.0	0.001

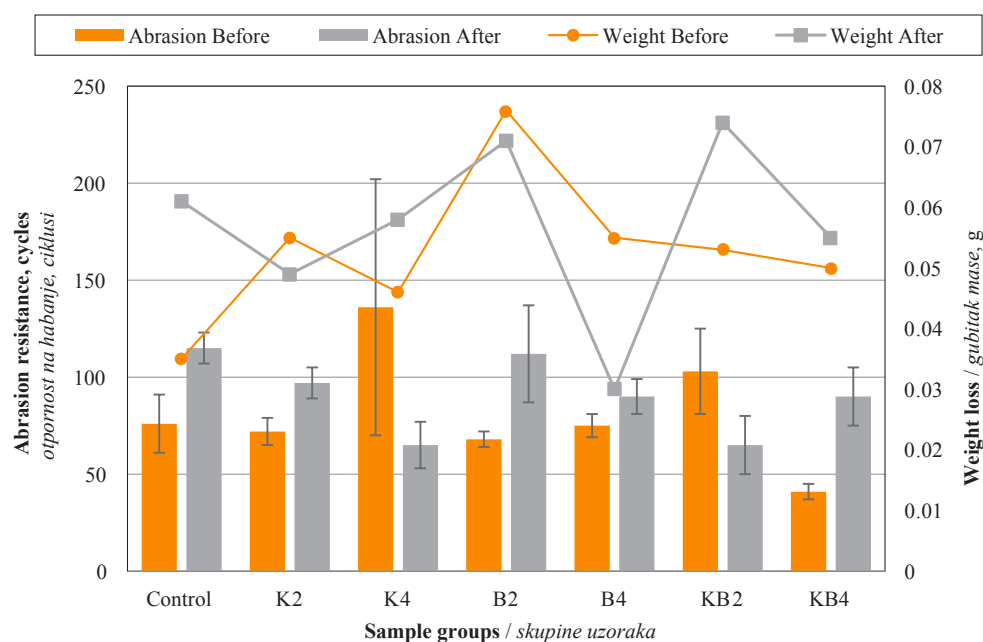


Figure 6 Interaction plot showing the effect of varnish formulation and UV exposure on abrasion resistance
Slika 6. Grafikon interakcije koji prikazuje utjecaj formulacije laka i izlaganja UV zračenju na otpornost na habanje

tion of a tighter bond structure in the matrix has increased abrasion resistance. Calcite is a material that is also used as a filling material in epoxy resins (Chindapasirt *et al.*, 2023). The matrix is known to improve durability. In this study, the addition of 4 % calcite/borax improved the abrasion resistance of the sample.

A clear inverse relationship between abrasion resistance and weight loss was observed in K4 and KB2 samples. The decrease in abrasion resistance was at the same rate as the increase in mass loss. The addition of 4 % calcite (K4) initially provided high resistance. However, after UV weathering, the abrasion resistance decreased by approximately 60 %. In this case, it can be concluded that the filling rate reduces UV resistance by more than 2 %. In contrast, balanced hybrid fillers (KB4) can improve wear resistance under environmental stress better than other samples.

4 CONCLUSIONS

4. ZAKLJUČAK

In this study, the effects of calcite and borax filler on the optical stability and wear resistance of water-based acrylic varnish were investigated. The samples were weathered (by UV radiation) and their surface characterization was investigated.

The addition of calcite and borax did not cause significant change in the total color difference (ΔE^*) after the weathering process. In all specimens, color shift towards reddish and yellowish tones occurred. It was determined that the sample with the highest abrasion resistance before UV treatment was the varnish sample (K4) with the addition of 4 % calcite. After UV

treatment, a significant difference occurred in the abrasion resistance of the samples. Abrasion resistance increased after UV treatment in B2 and control samples to which borax was added. However, weathering results and outdoor weathering results may differ. As a result of rapid aging, the acrylic particles may have physically moved closer together. This may have caused the UV treatment to make the varnish film layer more resistant to wear.

As a result, the addition of 4 % calcite demonstrated the highest resistance to abrasion prior to UV treatment. After UV treatment, the control sample showed the highest abrasion resistance. The varnish sample with 2 % borax added showed the closest abrasion resistance to the control sample. As the filling rate increased, UV durability decreased. It can be said that it is not appropriate to use a filling rate above 2 % in acrylic varnishes. UV treatment has unexpectedly changed the abrasion resistance of the specimens. For example, K4 and KB2 samples had the highest abrasion value before UV, but their abrasion resistance decreased after UV irradiation. On the contrary, samples that had low abrasion resistance before UV (K2, B2, B4, KB4, CTRL) showed increased abrasion resistance after UV treatment. In order to confirm the results obtained, it is necessary to perform an aging test in real conditions.

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