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Coloration of Lacquered Coatings for Furniture Production with Herbal Dyes and Determining Weathering Resistance

Obojenje lakova za namještaj s biljnim bojilima i određivanje njihove otpornosti na vremenske utjecaje

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ABSTRACT • *The main goal of the study is to produce eco-friendly furniture dyes by using bio-colorants and to determine the color stability of these dyes in outdoor conditions. In this regard, dye extracts obtained from red beet (Beta vulgaris), safflower (Carthamus tinctorius L.), and purple cabbage (Brassica oleracea), as a bio-colorant source, were applied to MDF test panels by mixing with water-based synthetic lacquer coatings. Also, three different synthetic dyes were applied to MDF test panels in order to compare the results with eco-friendly natural dyes. Natural dyes were mixed with metal and natural mordants such as iron sulfate, aluminum sulfate and vinegar. Lacquer coated test panels, coated with natural and synthetic dyes, were exposed to outdoor conditions for 50 days in Denizli/Turkey in order to assess the change in color. As a result, the maximum color stability occurred in the test panels lacquer coated with synthetic black dye, while the minimum color stability occurred in the test panels lacquer coated with synthetic light blue dye. It was determined that the thickness of the color coating layer applied to test panels increases color stability. It was also observed that the color stability performance of natural dyes is as good as that of synthetic dyes.*

KEYWORDS: *furniture industry, lacquer coating, natural dyes, weathering, color changes*

SAŽETAK • *Glavni cilj istraživanja bio je proizvesti ekološki prihvatljiva bojila za namještaj upotrebom prirodnih bojila te utvrditi postojanost boje tih bojila u vanjskim uvjetima. Kao izvor bojila upotrijebljeni su ekstrakti dobiveni iz cikle (Beta vulgaris), šafranike (Carthamus tinctorius L.) i crvenog kupusa (Brassica oleracea), koji su se nakon miješanja s vodenim lakovima nanosili na MDF ploče. Osim toga, na MDF ploče nanesena su i tri različita sintetička bojila radi usporedbe s rezultatima ekološki prihvatljivih prirodnih bojila. Prirodna su se bojila miješala s metalnim i prirodnim fiksatorima kao što su željezov sulfat, aluminijev sulfat i ocat. Ploče lakirane prirodnim i sintetskim bojilima 50 dana su izložene vanjskim vremenskim uvjetima u Denziliju, u Turskoj, kako bi se utvrdila promjena boje. Rezultati su pokazali da je najveća stabilnost boje postignuta na ispitnim pločama lakiranima sintetskim crnim bojilom, a najmanju stabilnost boje pokazale su ispitne ploče lakirane sintetskim svjetloplavim*

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bojilom. Utvrđeno je da debljina filma premaza nanesenoga na ispitne ploče povećava stabilnost boje. Također je uočeno da je stabilnost boje prirodnih bojila jednako dobra kao i stabilnost sintetskih bojila.

KLJUČNE RIJEČI: *proizvodnja namještaja, lak, prirodna bojila, izlaganje vremenskim uvjetima, promjene boje*

1 INTRODUCTION
1. UVOD

People are exposed to numerous types of pollutants such as volatile organic compounds (VOCs) in modern environment. VOCs are generally composed of typical solvents such as ethylbenzene, glycol ethers, methanol, methyl ketone, methyl isobutyl ketone, toluene and xylene and are counted among the most important chemicals lowering the indoor and outdoor air quality. Solvents dissolve dyes (Singh *et al*., 2016). However, they can lead to nausea, headache, irritation of eyes, nose and throat, allergy, mucosa membrane irritation, malaise, drowsiness, asthma, dermatitis, allergic rhinitis, pneumonia, allergy, fertility and development problems, kidney, lung and cardio damages, and even cause cancer on humans (Dalsan, 2021). According to Salthammer (1998), about 150 distinct VOCs are utilized in the wood treatment and coating business. Lacquer coated furniture and other colored wood-based products are among the important sources of VOCs (WHO, 1987; Uçgun,1998; Tong *et al*., 2019). These solvents have been proven to even induce miscarriages in expectant mothers, birth deformities, and learning problems to children (Wolfe, 2021). Additionally, children are particularly undefended to the effects of VOCs due to their relatively high respiratory rates, immature immune systems, close proximity to the ground, and their preference for mouth breathing over nasal breathing.

Eco-friendly bio-colorants obtained from biological sources do not contain VOCs. Bio-colorants are mainly made of pigments such as anthocyanidin, carotenoids, etc. In the past few years, based on the consumer preference as well as legislative action, the availability and use of bio-colorants has greatly increased (Zhu *et al*., 2021), which has continued the delisting of approved artificial dyes (Grüll *et al*., 2014). The current consumers prefer bio-colorants because they are healthier and are products of higher quality.

As a result of rising VOC emissions and their negative effects on air quality, Tong *et al*. (2019) offered to use cleaner dyes such as waterborne dyes and green coatings that can avoid the evaporation of a large amount of solvents discharged to the atmosphere. Green Peace efforts do not only affect private behavior but also the behavior of the major cities and businesses. So, the importance of using natural sources and aesthetic products increases day by day (Salthammer *et al*., 2002; Bechtold *et al*., 2007). Recently, there has been an increased interest in natural dyes on a global scale due to public awareness of their therapeutic and medical capabilities and the benefits they provide, as well as the widely acknowledged extreme toxicity of synthetic colors. Natural dyes are those that exist in nature, like plants, insects, animals, and minerals. Of all natural colors, most people favor plant-based colorants due to their medicinal properties (Chaitanya, 2014). The first technological advances have been made recently to bring natural dyes, pigments, and colorants to a more industrial scale, both in Europe and elsewhere in the world (Cardon, 2010).

In the recent years, efforts have been made to reduce and control indoor air pollution caused by furniture and wood-based product painting. The use of natural dyes is one of the alternative approaches to this problem. These dyes are made from plants and animals that have non-toxic, non-carcinogenic and biodegradable features. There are some studies about developing environmentally friendly wood stains obtained from natural dye plants. In this regard, plant colorants such as laurel (*Laurus nobilis* L.), oleander (*Nerium Oleander* L.) (Goktas *et al*., 2009b), walnut shell (*Juglans regia*) (Goktas *et al*. 2008), madder root (*Rubia tinctorium* L.) (Goktas *et al*., 2009a), have been investigated for their eligibility in wooden products and color stability of wood samples. Peker *et al*. (2013) studied the "Usage opportunities of natural dye extracted from acorn (*Quercus ithaburensis* Decaisne) in furniture industry upper surface treatment". Ozen *et al*. (2014) used *Punica granatum* and *Morus nigra* extracts as natural dyes for wood material and investigated their ability to color the materials. Goktas *et al*. (2015) investigated walnut husk on wood materials and determined the leaching performance of bio-based natural dyes. Yeniocak *et al*. (2015) studied the use of red beetroot (*Beta vulgaris*) on a natural color wood and determined its color stability under UV exposure. Yeniocak *et al*. (2017) also determined the impact of liquid glass (SiO_2) on natural dye-stained wood capacity to maintain its color. Velho *et al*. (2017) studied natural dyes and investigated their structure and use in polymers. Zhu *et al*. (2021) studied "staining of wood veneers with anti-UV property using the natural dye extracted from *Dalbergia cohinchinensis*".

In this study, the main goal is to use bio-colorants as an alternative to lacquer coating, which is used to manufacture babies and children's furniture. Currently, there is limited information about the natural weathering color resistance of plant-based dyes applied on MDF panels. Natural weathering is the most precise way for examining coating durability and properties as they would be expected to be used in the actual building (Grüll *et al*. 2014). The aim of this study is to determine the usability of natural dyes obtained from red beetroot (*Beta vulgaris* L.), safflower (*Carthamus tinctorius* L.), and purple cabbage (*Brassica oleracea*), which are VOCs free extracts used as eco-friendly colorants in painting of MDF panels, and evaluate their resistance to outdoor conditions.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 MDF boards
2.1. MDF ploče

MDF material is used as a substrate in the production of most children's room lacquered furniture. The easy processing of MDF material, its dimensional change stability and its compatibility with lacquer coating were the main reasons for its selection for tests samples. In this study, E1 quality MDF (Çamsan / Turkey) samples for all tests were prepared in dimensions of 100 mm × 100 mm × 10 mm. For each treatment group, five test samples were prepared.

2.2 Natural Colorants
2.2. Prirodna bojila

2.2.1 Red beetroot
2.2.1. Cikla

The Amaranthaceae family of plants, which includes red beets (*Beta vulgaris* L.), is one of the ten foods with the highest antioxidant properties. The phenolic elements, especially the betalains, named red beets, have antioxidant properties. Red beets are water-soluble and have nitrogen-containing color pigments known as betalains. Betalains are divided into two groups - betacyanins and betaxanthins. While betaxanthins have yellow-orange color pigments, betacyanins have red-purple cabbage color pigments. This diversity results from the various chemical structures and methods of synthesis. They are very good at retaining free radicals and preventing disorders linked to oxidative stress because of their significant antioxidant action. Additionally, due to their eligibility for use over a wide pH range (3-7) and their ability to naturally produce the correct hue, betalains can also be used as food coloring. Red beetroots, as natural colorants, were procured from the local market in Mugla, Turkey.

2.2.2 Safflower
2.2.2. Šafranika

Safflower (*Carthamus tinctorius* L.) is an annual oil plant also known as false saffron, parrot food, or painter's safflower. It is an herbaceous plant belonging to the genus Carthamus. Safflower, which can be 60 to 70 centimeters tall, blooms yellow, red and orange flowers in July and September, depending on the variety (Karadağ, 2007). It contains a dyestuff called carthamin, which is used as herbal medicine, and in food, paint, varnish, and cosmetics industries. Safflower, as a natural colorant, was procured from the local market in Mugla, Turkey.

2.2.3 Purple cabbage
2.2.3. Crveni kupus

Purple cabbage (*Brassica oleracea*) is a cabbage variety of the cruciferous family with large and thick layers of red and purple leaves, grown as an autumn vegetable. It usually turns blue when cooked. In order to preserve its red color, vinegar or an acidic fruit is added to it. Purple cabbage is a suitable food colorant. Purple cabbage exhibits a wide range of colors, from red to blue. depending on the pH of the medium (Ahmadiani *et al*., 2014). Purple cabbage, as a natural colorant, was procured from the local market in Mugla, Turkey.

2.2.4 Synthetic colorants
2.2.4. Sintetska bojila

In this study, three different synthetic dyes were also used to compare their behavior with bio colorants. They were, namely: black acrylic dye (Cassati Co.), blue synthetic dye and light blue synthetic dye (İzosan Co.). Bio-colorants were used for the coloration of a synthetic white water-based lacquer dye (Hydrolack-Dewilux DYO Co./ Turkey) for top surface coating.

2.3 Mordant agents
2.3. Fiksatori

Mordants agents were used to get efficient chemical bonding of dye on wood material and to provide colorization. Mordant agents were iron (III) sulfate ($Fe_2(SO_4)_3.7H_2O$ (technical grade 96 percent purity (Merck)), Aluminum Sulfate, Octadecahydrate ($Al_2(SO_4)_3.18H_2O$ (puriss. p.a. Fluka / Kimetsan Co.) and grape vinegar (Fersan Co).

2.4 Preparation of dyestuff
2.4. Priprema sredstva za bojenje

The preparation of the dyestuff was carried out by the authors according to the optimum conditions during the experimental process. Distilled water was used to extract the dry plant materials. A pot was used to exact the plant materials with the 1:10 g mass ratio of plant material to liquid water volume. The extraction process was completed in 60 minutes at the water boiling temperature of approximately 100 °C and the mixtures were stirred manually. Manual stirring during the extraction period was sufficient to distribute the plant material throughout the liquid due to the high liquor ratio. Make up water was added at the end of the extraction process to restore the beginning water volume.

Application conditions of colorants and mordant ratios are given in Table 1. Aqueous solutions were mordaned with 3 % iron (III) sulfate, 5 % aluminum sulfate and 10 % grape vinegar to ensure that the extracted dyes adhered to the applied substrate (to increase retention amount), stabilize their color, and produce color alternatives.

2.5 Dyeing test samples
2.5. Bojenje uzoraka

Natural dye solutions (20 g) were mixed with water-based lacquer dye (100 g) to get top coating coloration. Then mordants were added to the mixtures for the final application of MDF test samples. In order to measure the efficiency of mordants, some coated MDF samples were prepared without adding mordant. Natural dyes and mordants mixtures were added to water-based lacquer dye and then applied to MDF test samples by air pressure spray gun. The ratios of mixture are given in Table 1. In the study, two opaque paint coating layers were applied to the test samples. One of them was the base coat and the other was the top coat. The average thickness of the base coat was 0.20 mm and the average thickness of the top coat was 0.08 mm. Between the base and the top layer coating, 220 grit sandpaper was used for surface levelling. After the primer and top coat painting application process, the samples were kept at room temperature for 24 hours to dry. For each test group, five pieces were used.

2.6 Natural Weathering
2.6. Izlaganje prirodnim vremenskim uvjetima

Outdoor weathering tests were carried out in Denizli / Turkey (28° 30’ – 29° 30’ E”;37° 12’ – 38°12’ N”, at 354 m above sea level) for 50 days from July 8, 2018 to August 26, 2018. Denizli weather condition data was provided from the meteorology department in Denizli. Table 2 displays the meteorological conditions during the weathering processes. In accordance with EN 927-3 (2012), the samples were put roughly 1 m above the ground, exposed to external circumstances, at 45° inclinations and facing south. Prior to the measurements, the samples were stabilized at a temperature

Table 1 Application ratios of dyes and mordants
Tablica 1. Omjeri bojila i fiksatora pri nanošenju

<table>
<tr><th>Colorants / Bojila</th><th>Mordants
Fiksatori</th><th>Ratios, %
Omjeri, %</th><th>Lacquer dye, g
Lak, g</th><th>Natural colorant ratio, %
Omjer prirodnog bojila, %</th><th>Synthetic colorant ratio, %
Omjer sintetskog bojila, %</th><th>Repetition
Ponavljanje</th></tr>
<tr><td rowspan="4">Red beetroot
cikla (<u>Beta vulgaris</u>)</td><td>Control
kontrolni uzorak</td><td>0</td><td rowspan="15">100</td><td rowspan="12">20</td><td></td><td rowspan="15">5</td></tr>
<tr><td>iron (III) sulfate
željezov (III) sulfat</td><td>3</td><td></td></tr>
<tr><td>Aluminum sulfate
aluminijev sulfat</td><td>5</td><td></td></tr>
<tr><td>Vinegar / ocat</td><td>10</td><td></td></tr>
<tr><td rowspan="4">Safflower
šafranika (<u>Carthamus tinctorius</u> L.)</td><td>Control
kontrolni uzorak</td><td>0</td><td></td></tr>
<tr><td>iron (III) sulfate
željezov (III) sulfat</td><td>3</td><td></td></tr>
<tr><td>Aluminum sulfate
aluminijev sulfat</td><td>5</td><td></td></tr>
<tr><td>Vinegar / ocat</td><td>10</td><td></td></tr>
<tr><td rowspan="4">Purple cabbage
crveni kupus
(<u>Brassica oleracea</u>)</td><td>Control
kontrolni uzorak</td><td>0</td><td></td></tr>
<tr><td>iron (III) sulfate
željezov (III) sulfat</td><td>3</td><td></td></tr>
<tr><td>Aluminum sulfate
aluminijev sulfat</td><td>5</td><td></td></tr>
<tr><td>Vinegar / ocat</td><td>10</td><td></td></tr>
<tr><td>Synthetic colorant (black)
sintetsko bojilo (crno)</td><td>-</td><td>-</td><td rowspan="3"></td><td rowspan="3">20</td></tr>
<tr><td>Synthetic colorant (light blue)
sintetsko bojilo (svjetloplavo)</td><td>-</td><td>-</td></tr>
<tr><td>Synthetic colorant (blue)
sintetsko bojilo (plavo)</td><td>-</td><td>-</td></tr>
</table>

Table 2 An overview of on-site weather conditions during exposure
Tablica 2. Pregled mjesnih vremenskih uvjeta tijekom izlaganja

Denizli / Turkey 2018	**July** / *Srpanj*	**August** / Kolovoz
Average temperature, °C / *prosječna temperatura*, °C	27.6	27
Highest temperature, °C / *najviša temperatura*, °C	43.9	44.4
Lowest temperature, °C / *najniža temperatura*, °C	12.6	11.6
Average rainy days / *prosječan broj kišnih dana*	2.5	2
Average monthly total rainfall, mm *prosječna mjesečna količina oborina*, mm	13.0	8.4

of (20±2) °C and a relative humidity of 65 %. Table 2 provides an overview of the weather patterns for 50 days of weather conditions.

Following the process of natural weathering, the color variables *L**, *a**, and *b** were identified. A colorimeter was used to gauge the specimen hues both before and after weathering. According to CIELab (1986), color and gloss characteristics of the test panels were assessed using a spectrophotometer 600d (Konica Minolta, Japan). The apparatus was set up with a D65 light source and a 10° observation angle (ISO 2470, CIELab-76). The *CIEL*a*b** method was used to determine these factors, where the *L** axis denotes lightness, while the *a** and *b** axes denote chromaticity coordinates. In this method, the +*a** factors indicate red color, the -a* factors represent green color, the +*b** factors represent yellow color, and the -*b** factors represent blue color. The *L** value ranges from 0 (black) to 100 (white). Each specimen had its parameters *L**, *a**, and *b** as well as gloss measured at the start of the experiment and 50 days afterwards. For each treatment group, five duplicates were produced. Before and after natural weathering, color measurements of the test samples were made from a single point.

The following equation was used to determine the total color changes in accordance with *CIElab* (1986):

$$\Delta a^* = a_f^* - a_i^* \quad (2)$$

$$\Delta b^* = b_f^* - b_i^* \quad (3)$$

$$\Delta L^* = L_f^* - L_i^* \quad (4)$$

$$\Delta E^* = \quad (5)$$

Where Δ*a**, Δ*b**, and Δ*L** represent the changes between the initial and final interval values. Δ*E** represents the total surface color change of the tested panels.

2.7 Statistical analysis
2.7. Statistička analiza

Based on the measurements obtained, the results were examined using the statistical software SPSS. The variance analysis was carried out once the test data were uploaded to the computer. The Duncan test was performed at a 95 % statistical confidence level. The homogeneity groups (HG) of experimental data were used for the statistical analysis. The difference that can be deemed statistically significant is denoted by a different letter in HG.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Color changes
3.1. Promjene boje

The descriptive statistical values of the weathering performances of MDF test panels that were coated with natural dye stuffs and synthetic paints are given in Table 3.

According to Table 3, the highest total color change (Δ*E**=29.912) was observed on the MDF test panels colored by synthetic light blue paint. The lowest (Δ*E**0.388) color change was observed on the test panels colored with synthetic black paint. In terms of the layer thicknesses of the synthetic dyes applied to the test piece surfaces, the black, blue and light blue synthetic dyes thicknesses were measured as 0.10 mm, 0.09 mm and 0.06 mm, respectively. These results showed that there is a positive relationship between the layer thickness of the dye and its color stability. It has been estimated that the reason for the greater color change in synthetic light blue paint than in natural dyes is due to the diluted and reduced thin layers. The synthetic black dye has the lowest color change value as expected, because synthetic dyes contain more chemical substances that increase color resistance. The same observations were made by other researchers. Grüll *et al*. (2011, 2014) reported that, for the same coating materials, in all cases darker pigmentation and higher film thickness led to higher durability during artificial and natural weathering. When comparing the bio and synthetic colorants in general, it is seen that the color change values of the synthetic colorants are small, except for the light blue paint. It is believed that the low color change values in synthetic dyes is the consequence of protective substances already present in them.

When the color change values of the plants are compared with each other, it is seen that samples dyed with safflower, red beetroot and purple cabbage pigment have ΔE*=15.58, 3.71 and 3.08, respectively. Exposure to the harsh conditions of the external environment has also been a major reason for the color change observed in the case of natural colorants in this study. The high color changes obtained from these plant-based bio-colorants compared to synthetic colorants can be seen as a

Table 3 Color changes of MDF panels exposed to a 50-day outdoor weathering
Tablica 3. Promjene boje MDF ploča izloženih 50 dana vanjskim vremenskim uvjetima

Colorants *Bojila*	**Mor-dants** *Fiksa-tori*	**Before weathering test** *Prije izlaganja vremenskim uvjetima*			**After 50 days of natural weathering test** *Nakon 50 dana izlaganja prirodnim vremenskim uvjetima*					
		L^*	a^*	b^*	ΔL^*	Δa^*	Δb^*	ΔE^*	*SD*	*P* (p<0.05)
Safflower[c] *šafranika*[c]	C[c]	89.8	-2.4	20	4.0	2.8	-16.7	17.402[j]	0.55	
	IS[a]	84.7	-0.6	14	7.54	0.7	-8.5	11.406[h]	0.53	
	AS[b]	90.8	-2.6	19.3	3.46	1.7	-16.3	16.792[ij]	0.25	
	V[b]	90.9	-2.9	19	304	1.9	-16.4	16.754[ij]	0.41	
Purple cabbage[b] *cikla*[b]	C[a]	91.9	-1.0	3.1	1.7	0.4	-0.8	1.886[b]	0.24	
	IS[d]	88.0	-1.5	2.1	4.4	1.8	2.6	5.388[g]	0.17	
	AS[c]	91.3	-1.0	2.5	2.8	0.2	-0.1	2.800[cd]	0.20	
	V[b]	91.2	-0.9	2.9	2.0	0.1	-1.0	2.268[c]	0.12	
Red beetroot[b] *crveni kupus*[b]	C[b]	92.0	-0.3	5.9	1.36	-0.6	-3.2	3.700[e]	0.24	*
	IS[a]	87.8	0.3	7.1	1.84	0.9	1.6	2.690[cd]	0.14	
	AS[c]	91.5	-0.3	6.7	1.6	-0.5	-.36	3.954[e]	0.21	
	V[d]	91.9	-0.6	6.8	1.86	-0.2	-4.0	4.502[f]	0.66	
SP (black)[a] *SP (crno)*[a]	-	23.7	-0.8	0	0	0.2	0.3	0.388[a]	0.14	
SP (light blue)[d] *SP (svjetloplavo)*[d]	-	53.5	0.8	-17.4	26.4	-2.1	13.9	29.912[k]	0.62	
SP (blue)[a] *SP (plavo)*[a]	-	84.0	-1.5	0.7	0.1	0.5	-0.4	0.724[a]	0.33	

C – Control (without mordant), IS – Iron (III) sulfate, As – Aluminum sulfate, V – Vinegar, SP – Synthetic Paint; [a,b,c,d, e] values having the same letter are not significantly different and vice versa (for Tukey test); *SD* – Standard deviation; *Significance level of 0.05 (for ANOVA)
C – kontrolni uzorak (bez fiksatora), IS – željezov (III) sulfat, As – aluminijev sulfat, V – ocat, SP – sintetsko bojilo; [a,b,c,d, e] *vrijednosti koje imaju isto slovo nisu značajno različite, i obrnuto (Tukey test); SD – standardna devijacija; * razina značajnosti od 0,05 (ANOVA)*

negative phenomenon. However, a lower color change can be expected if these bio-colorants are primarily used in interior furniture and wood-based products.

The highest color change observed for safflower dyes is in line with literature data. This feature is linked to the chromophore Carthamin's weak light fastness and great susceptibility to pH and oxygen (Obara and Onodera, 1979), which causes complete deterioration of historical fabrics.

Beetroot is reported to be a source of natural colorants but its color stability can be an obstacle for industry use. Betacyanins, like other naturally occurring plant pigments, have low stability, low tinctorial, and are prone to color fading during processing and storage, which restricts their development and use (Nistor *et al.*, 2017). The presence of betalains, one of the natural color pigments, and anthocyanins in beetroot can be used to explain the discoloration (Saenz *et al.*, 2012). It was also underlined that there are several sorts of processes in which betalains might degrade. Isomerization, deglycosylation, hydrolysis, decarboxylation, and dehydrogenation reactions are some of these processes. Different chromatic and structural alterations in betalains result from each reaction (Herbach *et al.*, 2006). It has been noted that light, oxygen, water activity, pH, and temperature have a significant impact on the stability of betalains. Betalains degraded more rapidly than anticipated when temperature and time increased (Güneser, 2016). According to Delgado *et al.* (2000), the concentration of pigments, pH and water activity, oxygen, light, metallic ions, enzymes, temperature, and the duration and circumstances of processing and storage are the main variables determining the durability of natural colorants in foods. Using the beetroot plant as a natural colorant in outdoor furniture and wood-based products can bring disadvantages in terms of color change. However, it is expected that this colorant can be used with less color change for interior products.

Considering the color change of mordants, the color changes are developed from the highest to the lowest in aluminum sulfate, vinegar, control (without mordant) and iron sulfate, respectively. However, except for iron (III) sulfate, the other three mordant options were in the same homogeneity group. This result shows that mordants are not necessary to provide color stability, except for color options, which is an advantage. There are studies in the literature about coloring wood material with natural dyes that were mixed with metal mordants (Goktas *et al.*, 2009a, Goktas *et al.*, 2009b, Yeniocak *et al.*, 2017). They used iron (III) sulfate and aluminum sulfate as metal and vinegar as natural mordant. No negative effects of metal mordants on color change were observed in the above studies. The fact that the negative effects of metal mordants on color change were not observed in those studies are in line with this study. The fact that mordants do not have negative effects on color change is an advantage as this provides more color combinations.

4 CONCLUSIONS
4. ZAKLJUČAK

This paper investigated the usability of natural plants as colorants that are eco-friendly products for furniture industry in the lacquer coating of MDF and their color stability resistance in outdoor weather conditions. The weathering performance of MDF test panels coated with natural dye stuffs and synthetic dyes was examined so that the panels were exposed to a 50-day outdoor weathering and then the color factors, L^*, a^*, b^* and ΔE^* were determined.

The highest color change (ΔE^*=29.91) was observed on the MDF test panels colored by synthetic light blue paint. The lowest color change (ΔE^*=0.38) was observed on the test panels colored with synthetic black paint. In this case, there is a positive relationship between the layer thickness of the paint and its color stability. In other words, the increase in the layer thickness also contributes to the increase in the color change resistance.

The color change in mordants is arranged from the highest to the lowest as aluminum sulfate, vinegar, control (without mordant) and iron sulfate, respectively. However, except for iron (III) sulfate, the other three mordant options were in the same homogeneity group. This result showed mordants are not necessary in terms of color stability, except for color options, which is quite an advantage.

To conclude, this paper suggests that the use of sustainable and environmentally friendly products in the furniture industry may decrease the load in one of the major pollution discharge issues. The main problem here is that synthetic dyes contain compounds that are harmful to the environment and human health. The aim of this study was to use natural colorants instead of synthetic colorants, which are harmful to both human beings and the environment. VOCs cannot be completely avoided because the basic coating material used is still a synthetic material. However, only substances harmful to the environment and human health, brought into living environments by means of synthetic colorants, have been eliminated. In other words, by using natural dyes as an alternative in the coloring process in furniture industry, only the hazardous chemicals that originate from synthetic colorants can be eliminated. In this sense, the development of colorants and coatings that are completely free of harmful chemicals should be the target of future studies for the furniture industry.

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