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Colour Change of Steamed Alder Wood Caused by UV Radiation

Promjena boje parenog drva johe uzrokovana UV zračenjem

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ABSTRACT • *Alder wood (Alnus glutinosa L.) was steamed with a saturated steam-air mixture at a temperature of t = 95 °C, or saturated steam at t = 115 °C and t = 135 °C to obtain a pale brown colour, a light red-brown colour and a dark brown-grey colour. Subsequently, samples of unsteamed and steamed alder wood were irradiated with a UV lamp in a Xenotest Q-SUN Xe-3-HS after drying in order to test the colour stability of steamed alder wood. The colour change of the wood surface was evaluated by means of measured values on the coordinates of the colour space CIE L*a*b*. The results show that the surface of unsteamed alder wood as well as steamed alder wood with a steam-air mixture at t = 95 °C and saturated steam at t = 115 °C darkened and browned due to photochemical reactions caused by UV radiation. The opposite tendency was recorded at the surface of alder wood steamed with saturated steam with a temperature of t = 135 °C, where the deep dark-brown-grey colour lightened to a brown-reddish colour shade under the influence of UV radiation. The analysis of the changes in the coordinates of the colour space CIE L*a*b* shows that the greater the darkening and browning of the alder wood by steaming, the smaller the changes in the values of ΔL*, Δa*, Δb* of the steamed alder wood caused by UV radiation. The positive effect of steaming on UV resistance is evidenced by the decrease in the overall colour difference ΔE*. While the value of the total colour difference of unsteamed alder wood caused by UV radiation is ΔE* = 10.9, it decreased to ΔE* = 8.7 for alder wood steamed with steam-air mixture at t = 95 °C, which is a decrease of 20.2 %; for alder wood steamed at t = 115 °C it decreased to ΔE* = 6.5, which is a decrease of 40.3 %; and for alder wood steamed with saturated water steam with the temperature t = 135 °C it decreased to ΔE* = 5.7, which is a decrease of 47.7 %.*

KEYWORDS: *alder wood; colour difference; steaming; saturated water steam; UV radiation*

SAŽETAK • *Za potrebe ispitivanja drvo johe (Alnus glutinosa L.) pareno je smjesom zasićene pare i zraka na 95 °C odnosno zasićenom parom na 115 i 135 °C kako bi se dobila blijedosmeđa, svijetla crvenosmeđa i tamna smeđosiva boja. Nepareni i pareni uzorci drva johe nakon sušenja su ozračeni UV lampom u uređaju Xenotest Q-SUN Xe-3-HS kako bi se ispitala stabilnost boje parenog drva. Promjena boje površine drva procijenjena je uz pomoć vrijednosti izmjerenih u koordinatnom sustavu boja CIE L*a*b*. Rezultati su pokazali da je površina neparenog drva johe i drva johe parenog smjesom pare i zraka na 95 °C te drva parenog zasićenom parom na 115 °C zbog fotokemijskih reakcija uzrokovanih UV zračenjem potamnjela i posmeđila. Suprotna je promjena zabilježena na površini drva johe parenoga zasićenom parom na 135 °C, na kojemu je tamna smeđosiva boja pod utjecajem UV zračenja posvijetlila i poprimila smeđocrvenkasti ton. Analiza promjena u koordinatnom sustavu boja CIE L*a*b**

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pokazuje da UV zračenje uzrokuje niže vrijednosti ΔL, Δa*, Δb* parenog drva johe što je tamnjenje i smeđenje drva johe zbog parenja jače. Pozitivan učinak parenja na otpornost prema UV zračenju vidljiv je po smanjenju ukupne promjene boje ΔE*. Tako je vrijednost ukupne promjene boje neparenog drva johe nakon UV zračenja parenjem smjesom pare i zraka na 95 °C smanjena s ΔE* = 10,9 na ΔE* = 8,7 (smanjenje od 20,2 %), parenjem zasićenom parom na 115 °C smanjena je na ΔE* = 6,5 (smanjenje od 40,3 %), a parenjem zasićenom parom na 135 °C zabilježeno je smanjenje od ΔE* = 5,7 (smanjenje je iznosilo 47,7 %).*

KLJUČNE RIJEČI: *drvo johe; promjena boje; parenje; zasićena vodena para; UV zračenje*

1 INTRODUCTION
1. UVOD

The colour of wood is a basic physical-optical property, which belongs to the group of macroscopic features on the basis of which the wood of individual woody plants differs visually. The colour of the wood is formed by chromophores, i.e., functional groups of the type: >C=O, -CH=CH-CH=CH-, -CH=CH-, aromatic nuclei found in the chemical components of wood (lignin and extractives such as dyes, tannins, resins, and others), which absorb some components of the electromagnetic radiation of daylight and thus create the colour of the wood surface perceived by human eye.

The colour of wood changes in thermal processes such as: wood drying, wood steaming, thermo-wood production technologies. The wood darkens and depending on the wood, acquires new shades of colour. Depending on the steaming conditions, beech wood acquires a pale pink to red-brown colour shade (Deliiski, 1991; Bekhta and Niemz, 2003; Molnar and Tolvaj, 2004; Cividini *et al.,* 2007; González *et al.,* 2009; Todaro *et al.,* 2012; Dzurenda, 2014; Milić *et al.,* 2015; Barcík *et al.,* 2015; Baranski *et al.,* 2017; Dzurenda and Dudiak, 2021; Dzurenda, 2022). Oak wood, as reported by Tolvaj and Molnar (2006), Todaro *et al.* (2012), Dzurenda (2018a), acquires colour shades from a pale brown-yellow colour to a dark brown-grey colour. The light white-yellow colour of maple wood in the process of steaming wood with saturated water steam acquires shades of pale pink-brown to brown-red colour (Dzurenda, 2018b; Dudiak, 2021).

Alder wood in the process of steaming with saturated steam-air mixture or saturated water steam is heated and changes its physical, mechanical and chemical properties. The action of heat initiates chemical reactions in wet wood, such as: extraction of water-soluble substances, degradation of polysaccharides, cleavage of free radicals and phenolic hydroxyl groups in lignin, resulting in the formation of new chromophoric groups that cause a change in the colour of the wood. These facts are used for full-volume modification of wood colour into non-traditional colour shades of alder wood. Depending on the length of the steaming time and the temperature of the steaming medium, the alder wood acquires a pale brown colour, through shades of a soft red-brown colour to a dark brown-grey colour (Dudiak and Dzurenda, 2021).

The colour on the surface of native wood, as well as thermally modified wood, changes due to long-term exposure to sunlight. The surface of the wood darkens and mostly yellows and browns. This fact is also referred to in the professional literature as natural aging (Hon, 2001; Reinprecht, 2008; Baar and Gryc, 2012).

Solar radiation falling on the wood surface is partly absorbed by and partly reflected from the surface. The absorbed spectrum of infrared electromagnetic radiation is converted into heat and the photon flux of ultraviolet and part of visible radiation of wavelengths λ = 200 – 400 nm is the source of initiation of photolytic and photooxidation reactions with lignin, polysaccharides and accessory substances of wood. Of the chemical components of wood, lignin is the most subject to photodegradation, which captures 80 – 85 % of UV radiation, while carbohydrates absorb 5 – 20 % and 2 % of the accessory substance (Gandelová, 2009). These reactions cleave the lignin macromolecule with the simultaneous formation of phenolic hydroperoxides, free radicals, carbonyl and carboxyl groups and to a lesser extent depolymerize polysaccharides to polysaccharides with a lower degree of polymerization to form carbonyl, carboxyl groups and gaseous products (CO, CO_2, H_2). Although photodegradation of natural wood is a phenomenon that has been widely studied by Hon (2001), Müller *et al.* (2003), Pandey (2005), Persze and Tolvaj (2012), Baar and Gryc (2012), Denes and Lang (2013), Zivkovic *et al.* (2013), Geffert *et al.* 2017; Geffertová *et al.* (2018), less attention has been paid to the issue of photodegradation and colour stability of steamed wood.

The aim of the work is to investigate the stability of the pale brown colour of alder wood obtained by the process of steaming with a saturated steam-air mixture with a temperature of t = 95 °C, or gentle red-brown and deep dark-brown-grey colour of alder wood steamed with saturated steam at temperatures t = 115 °C and t = 135 °C through a simulated aging process - UV radiation in Xenotest Q-SUN Xe-3-HS. The colour fastness of the wood is evaluated through changes in the coordinates L^*, a^*, b^* of the colour space CIE $L^*a^*b^*$ and the total colour difference ΔE^*.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

Wet wood of alder blanks with dimensions 40 mm × 100 mm × 800 mm and moisture content w = (58.3±3.2) % was thermally treated with a saturated steam-air mixture at a temperature of t = 95 °C, or saturated water steam at t = 115 °C and t = 135 °C for τ = 9 h in order to obtain a pale brown colour, a light red-brown colour and a dark-brown-grey colour in a pressure autoclave: APDZ 240 in Sundermann s.r.o. Banská **Štiavnica** (Slovakia). The alder wood steaming mode is shown in Figure 1. The temperatures of the saturated steam-air mixture and saturated water steam in individual steaming modes are given in Table 1. The values of temperatures t_{max} and t_{min} are the temperatures for controlling the regulation of the supply of saturated water steam to the pressure autoclave for the implementation of the technological process. The temperature t_4 is a parameter of the saturated water steam pressure in the autoclave to which the pressure in the autoclave must be reduced before the pressure device can be opened safely.

Steamed and unsteamed alder wood blanks were dried with a low temperature drying mode of Dzurenda (2021) to moisture content of w = 10 ± 0.5 %. Samples measuring 100 mm × 50 mm × 15 mm (L × R × T) were made to test the colour fastness of the wood. Colour measurement was performed on a radial surface machined by planing.

The colour coordinates of alder wood samples in the colour space CIE $L^*a^*b^*$, before irradiation are given in Table 2.

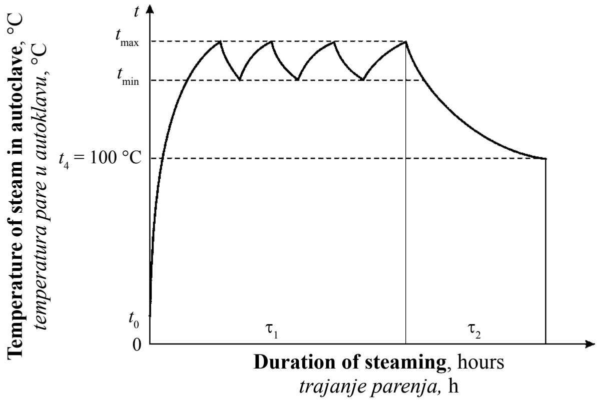

Figure 1 Mode of colour modification of alder wood with a saturated steam-air mixture or saturated water steam
Slika 1. Način promjene boje drva johe smjesom zasićene pare i zraka ili zasićenom vodenom parom

In the Q-SUN Xe-3-HS xenon test chamber (Q-Lab Corporation, USA), alder wood samples were irradiated for τ = 298 h. During the exposure, the colour of the irradiated surface was measured regularly at τ = 24 h intervals. The mode for simulating outdoor conditions was used, i.e., the wood was exposed to radiation outdoors but was protected from rain (Table 3). The samples placed in the Xenotest chamber were regularly and systematically relocated according to the recommended scheme to ensure the same irradiation intensity and temperature (Kúdela and Kubovský, 2016).

According to ASTM G 155, the radiation intensity was set to 0.35 W/m^2 at a radiation wavelength λ = 340 nm. This is the average annual radiation intensity

Table 1 Mode of colour modification of alder wood with a saturated steam-air mixture or saturated water steam
Tablica 1. Način promjene boje drva johe smjesom zasićene pare i zraka ili zasićenom vodenom parom

Mode / *Način*	**Temperature in autoclave, °C** *Temperatura u autoklavu,* °C			**Time of operation, h** *Trajanje postupka,* h		
	t_{min}	t_{max}	t_4	τ_1 – phase I	τ_2 – phase II	Total time *Ukupno vrijeme*
t_I = 95 ± 2.5 °C	92.5	97.5	-	8.0	1.0	9.0
t_{II} = 115 ± 2.5 °C	112.5	117.5	100	7.5	1.5	9.0
t_{III} = 135 ± 2.5 °C	132.5	137.5	100	7.5	1.5	9.0

Table 2 Coordinate values of colour space CIE L*a*b* of unsteamed and steamed alder wood
Tablica 2. Vrijednosti koordinata u CIE *L*a*b** sustavu boje neparenoga i parenog drva johe

Labeling of samples *Označivanje uzoraka*	**Colour coordinates in colour space CIE *L*a*b**** *Koordinate boje u CIE L*a*b*sustavu boje*		
	*L**	*a**	*b**
unsteamed alder wood *nepareno drvo johe*	79.0 ± 2.3	9.6 ± 1.6	22.5 ± 1.2
steamed at t = 95 ± 2.5 °C *pareno na t = 95 ± 2,5 °C*	70.4 ± 1.8	11.8 ± 1.4	21.5 ± 1.1
steamed at t = 115 ± 2.5 °C *pareno na t = 115 ± 2,5 °C*	62.9 ± 1.3	12.1 ± 0.9	19.1 ± 1.1
steamed at t = 135 ± 2.5 °C *pareno na t = 135 ± 2,5 °C*	51.9 ± 1.4	12.3 ± 0.8	16.5 ± 0.9

Table 3 Aging parameters set according to ASTM G 155
Tablica 3. Parametri starenja postavljeni prema ASTM G 155

Step *Korak*	**Mode** *Način rada*	**Radiation intensity, W/m²** *Intenzitet zračenja, W/m²*	**Black panel temperature, °C** *Temperatura crne ploče, °C*	**Air temperature, °C** *Temperatura zraka, °C*	**Relative humidity, %** *Relativna vlažnost zraka, %*	**Time, min** *Vrijeme, min*
1	Radiation *zračenje*	0.35	63	48	30	102
2	No radiation *bez zračenja*	–	–	38	–	18

in the temperate zone. The temperature, checked on the black panel, signals the maximum surface temperature. The specified air temperature is intended to accelerate changes in the wood surface. The colour was measured on each body in ten places, which means that 30 measurements were always made for one set of bodies.

The colour of the irradiated unsteamed and steamed alder wood surface samples, in the colour space CIE $L^*a^*b^*$, was measured with a Colour Reader CR-10 colorimeter (Konica Minolta, Japan). A D65 light source was used and the diameter of the optical scanning aperture was 8 mm. The total colour difference ΔE^* of the colour change of the surface of alder wood samples due to UV radiation is determined according to the following equation (ISO 11 664-4):

$$\Delta E^* = \sqrt{\left(L^*_{298} - L^*_0\right)^2 + \left(a^*_{298} - a^*_0\right)^2 + \left(b^*_{298} - b^*_0\right)^2} \quad (1)$$

Where: L_0^*, a_0^*, b_0^* - values at the surface colour coordinates of the dried milled unsteamed and steamed alder wood prior to exposure,

L_{298}^*, a_{298}^*, b_{298}^* - values on the surface colour coordinates of the dried milled unsteamed and steamed alder wood during UV exposure.

The measured values on the brightness coordinate L^* and the chromatic coordinates red colour a^* and yellow colour b^*, as well as the calculated values of the total colour differences ΔE^* during the observed exposure periods were statistically and graphically evaluated using EXCEL and STATISTICA 12 programmes (V12.0 SP2, USA).

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

The colour of unsteamed and steamed alder wood before and after UV irradiation in the Q-SUN Xe-3-HS test chamber is shown in Figure 2. According to the visual evaluation of the colour of alder wood before and after UV radiation, it can be stated that while the light white-grey colour with a touch of yellow colour of unsteamed alder wood darkens under UV radiation and acquires a brown-reddish colour, the light red-brown colour of alder wood steamed with the steam-air mixture at the temperature t = 95 °C slightly darkened under the influence of UV radiation and took on a pale yellow-brown colour. The dark brown-grey colour of alder wood steamed with saturated water steam with a temperature of t = 135 °C under the influence of UV radiation brightened to a paler brown-grey shade.

The course of colour changes of unsteamed and steamed alder wood in the colour space CIE $L^*a^*b^*$ under the influence of UV radiation in Xenotest Q-SUN Xe-3-HS for 298 h at the individual coordinates L^*, a^*, b^* is shown in Figure 3 to 5.

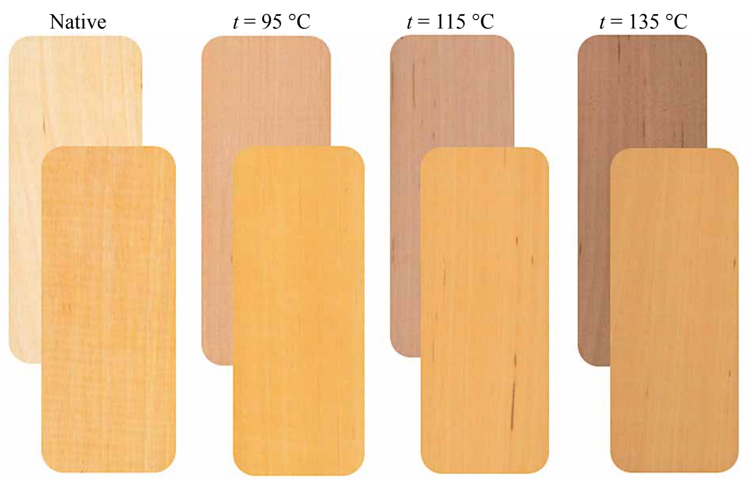

Figure 2 View of alder wood before and after UV irradiation: native; steamed at t = 95 °C; steamed at t = 115 °C and steamed at t = 135 °C
Slika 2. Izgled drva johe prije i nakon UV zračenja: prirodno drvo, pareno na 95 °C, pareno na 115 °C i pareno na 135 °C

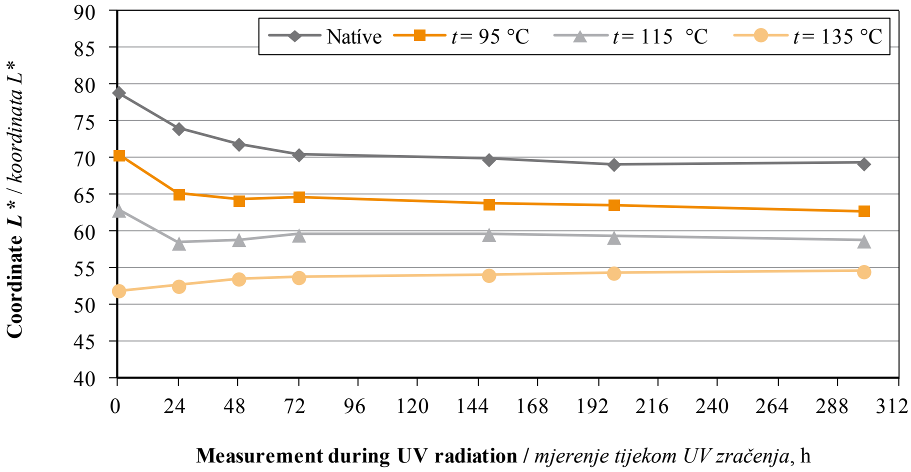

Figure 3 The course of changes of values on brightness coordinate *L** in the process of UV irradiation of samples of unsteamed and steamed alder wood
Slika 3. Promjena vrijednosti koordinate svjetline *L** tijekom UV zračenja uzoraka neparenoga i parenog drva johe

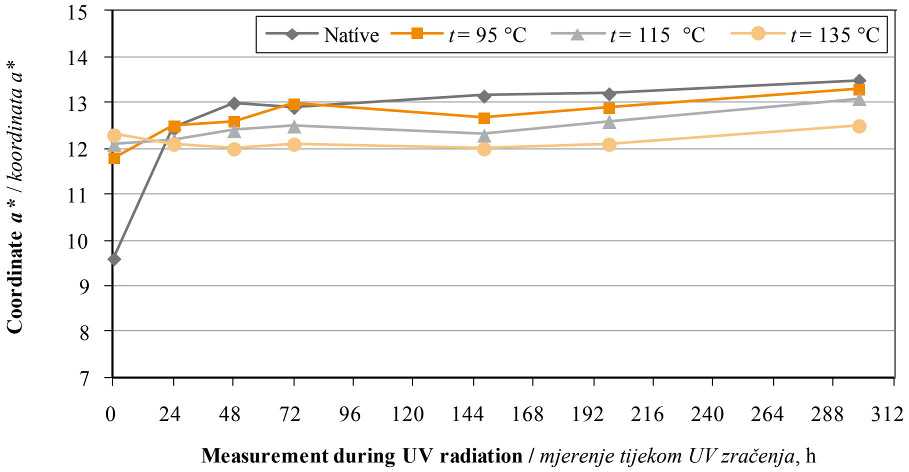

Figure 4 The course of changes of values on the coordinate of red colour *a** in the process of UV irradiation of samples of unsteamed and steamed alder wood
Slika 4. Promjena vrijednosti koordinate crvenog tona *a** tijekom UV zračenja uzoraka neparenoga i parenog drva johe

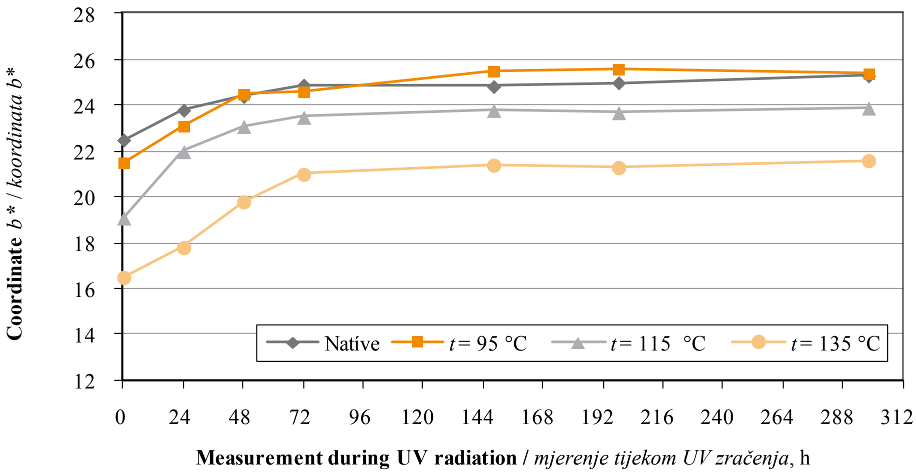

Figure 5 The course of changes of values on the coordinate of yellow colour *b** in the process of UV irradiation of samples of unsteamed and steamed alder wood
Slika 5. Promjena vrijednosti koordinate žutog tona *b** tijekom UV zračenja uzoraka neparenoga i parenog drva johe

From the course of changes in individual colour spaces CIE *L*a*b** during the action of UV radiation on the wood surface in Xenotest Q-SUN Xe-3-HS, it follows that the colour change of the surface of irradiated wood is not uniform. Significant changes in the colour of the wood occur in the first 72 h of UV radiation. Similar findings were recorded when testing the resistance of maple wood to UV radiation present in the oven (Dzurenda *et al.* 2022).

The degree of darkening and browning of unsteamed and steamed alder wood induced by UV radiation during 298 h of irradiation in the colour space CIE *L*a*b** is shown by the shifts on the individual coordinates.

Unsteamed alder wood darkened due to photochemical reactions induced by UV radiation and a decrease in the brightness coordinate was recorded from $L_0* = 79.0$ to $L_{298}* = 69.2$ i.e. by the value $\Delta L* = -9.7$; it turned brown by the increase of points on the chromatic coordinate of red colour from $a_0* = 9.6$ to $a_{298}* = 13.5$, i.e. $\Delta a* = +3.9$; and on the yellow coordinate from $b_0* = 22.5$ to $b_{298}* = 25.3$, i.e. the value of $\Delta b* = +3.8$. The above findings on the darkening of native - thermally untreated alder wood are in accordance with the opinions of experts dealing with changes in the properties of native wood of individual trees due to solar radiation, or UV radiation (Hon, 2001; Müller *et al.,* 2003; Pandey, 2005; Chang *et al.,* 2010; Baar and Gryc, 2011; Kúdela and Kubovský, 2016; Geffertová *et al.,* 2018; Dzurenda *et al.,* 2020).

Compared to unsteamed alder wood, steamed alder wood shows smaller changes on the coordinates of brightness *L** and red *a*,* except for changes on the chromatic coordinate of yellow *b*.* Numerically, this is documented by changes in the individual coordinates of the colour space CIE *L*a*b*.* While the darkness of thermally treated alder wood increased with steam-air mixture at the temperature $t = 95$ °C due to UV radiation, the values decreased from $L_0* = 70.4$ to $L_{298}* = 62.8$ i.e. $\Delta L* = -7.6$ and the darkness of alder wood treated with saturated water steam at $t = 115$ °C decreased due to UV radiation by decreasing values by $\Delta L* = -4.2$, so the brightness of steamed alder wood with saturated water steam at the temperature $t = 135$ °C increased from $L_0* = 51.2$ to $L_{298}* = 54.3$, i.e. the value of $\Delta L* = +2.6$.

At the chromatic coordinates of the colour space CIE *L*a*b*,* the colour changes of alder wood steamed with a steam-air mixture with the temperature $t = 95$ °C increased on the coordinate red colour *a** from the value $a_0* = 11.8$ to $a_{298}* = 13.1$ i.e., $\Delta a* = +1.5$, and on the yellow coordinate *b** from the value $b_0* = 21.5$ on $b_{298}* = 25.4$ i.e., $\Delta b* = +3.9$. The soft red-brown colour of steamed alder wood formed by steaming with saturated water steam with the temperature $t = 115$ °C due to UV radiation changed to a pale yellow-brown colour with an increase in values on the coordinate red colour by values $\Delta a* = +1.0$ and on the coordinate yellow by values $\Delta b* = +4.8$. Changes in the values of alder wood steamed with saturated water steam with the temperature $t = 135$ °C under the influence of UV radiation recorded an increase in the values on the red coordinate from $a_0* = 12.3$ to $a_{298}* = 12.5$, i.e., $\Delta a* = +0.2$ and on the yellow coordinate from the value $L_0* = 16.5$ to $L_{298}* = 21.6$, i.e. by the value $\Delta b* = +5.1$.

Figure 6 shows, in the form of a bar graph, the magnitudes of changes $\Delta L*$, $\Delta a*$, $\Delta b*$ on the coordinates of the colour space CIE *L*a*b** of the analysed alder wood samples induced by UV radiation during 298 h in Xenotest Q-SUN Xe-3-HS.

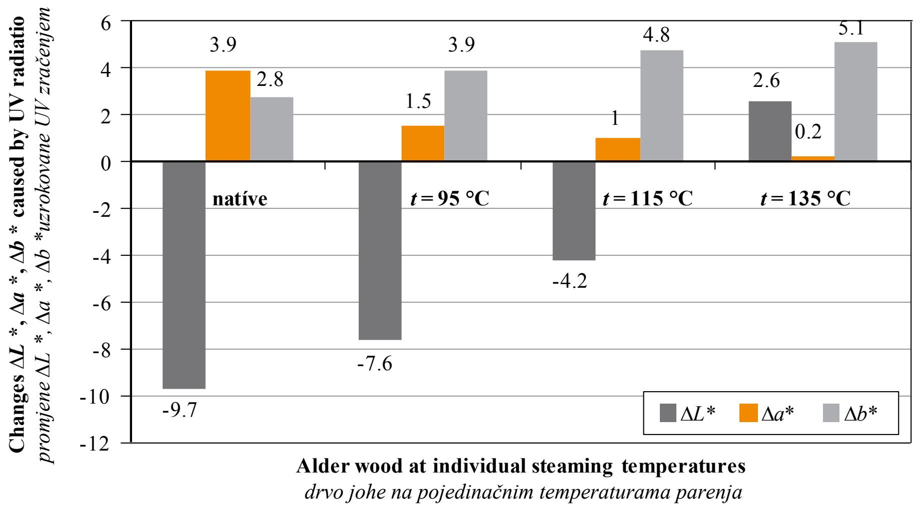

Figure 6 Values of total changes $\Delta L*$, $\Delta a*$, $\Delta b*$ generated by the action of UV radiation on the surface of alder wood in Xenotest Q-SUN Xe-3-HS during 298 h irradiation
Slika 6. Vrijednosti ukupnih promjena $\Delta L*$, $\Delta a*$, $\Delta b*$ nastalih djelovanjem UV zračenja na površinu drva johe u Xenotest Q-SUN Xe-3-HS tijekom 298 sati zračenja

From the presented values of changes ΔL^*, Δa^*, Δb^* caused by UV radiation, it follows that the values on the brightness coordinates L^* and red a^* in the colour space CIE $L^*a^*b^*$ of unsteamed wood are higher than those of steamed alder. The values of ΔL^*, Δa^*, decrease with increasing darkness acquired by the steaming process at higher steaming temperatures. Changes in the chromaticity coordinate of the yellow colour b^* have the opposite tendency, and they increase due to UV radiation.

The darker surface of steamed alder wood due to the decomposition of functional groups of alder wood chromophores performed in the steaming process absorbs to a lesser extent electromagnetic radiation spectra with a wavelength of red 630 – 750 nm and yellow 570 – 590 nm (Dudiak and Dzurenda, 2021), but is also more resistant to photochemical reactions of functional groups of chromophores in alder wood under UV radiation causing a change in the colour of the wood surface.

The fact that steamed wood, unlike unsteamed wood, is more resistant to UV radiation is also pointed out in the works of Dzurenda (2020), Varga *et al.* (2021) and Dzurenda *et al.* (2022).

In the work of Dzurenda (2019) "*The effect of UV radiation in Xenotest 450 on the color of steamed beech wood during the process of simulated aging"*, presented in the journal Annals of Warsaw University of Life Sciences - SGGW, it is stated that the lightening of the surface colour of steamed beech wood occurs after its irradiation with xenon lamp emitting UV radiation with a wavelength of 340 nm and intensity (42±2) W/m^2 for 7 days. The lightening of the red-brown colour of steamed beech wood is shown by the increase of the values on the brightness coordinate from L_0^* = 62.6 to the value of L_{168}^* = 69.3, i.e. ΔL^* = + 6.7; the increase of the value on the chromatic coordinate of the yellow colour from b_0^* = 17.1 to the value of b_{168}^* = 29.4, i.e. Δb^* = +12.3, and with a slight change in the value from a_0^* = 10.9 to a_{168}^* = 10.8, i.e. Δa^* = - 0.1.

The influence of UV radiation on steamed agate wood is discussed in Varga *et al.* (2021) who state that while the surface of steamed agate wood darkened slightly at a steaming temperature t = 100 °C, the surface of agate wood brightened at a steaming temperature t = 120 °C.

The positive effect of the steaming process on the decomposition of functional groups of maple wood chromophores manifested by darkening and browning of maple wood on the elimination of photochemical reactions caused by UV radiation is also described by Dzurenda *et al.* (2022). They point to the fact that the greater the darkening of the maple wood in the steaming process, the smaller the colour changes on the surface of the irradiated steamed maple wood by UV radiation. This is shown by the decrease of the total colour difference from the value ΔE^* = 18.5 for unsteamed maple wood to ΔE^* = 7.2 for steamed maple wood with saturated water steam at the temperature t = 135 °C, and with the results of FTIR analyses.

A complex view of the colour change of unsteamed and steamed alder wood induced by UV radiation in the form of the total colour difference ΔE^* is shown in Figure 7.

The lower values of the total colour difference ΔE^* of steamed alder wood caused by UV radiation are a quantitative expression of the degree of resistance of steamed wood to the absorption of UV wavelengths, which cause photochemical reactions causing changes in the colour of the wood. While the colour change of unsteamed alder wood irradiated during 298 h reaches the value ΔE^* = 10.9, alder wood steamed with a steam-air mixture at a temperature of t = 95 °C reaches the value ΔE^* = 8.7, which is a decrease of 20.2 %; for

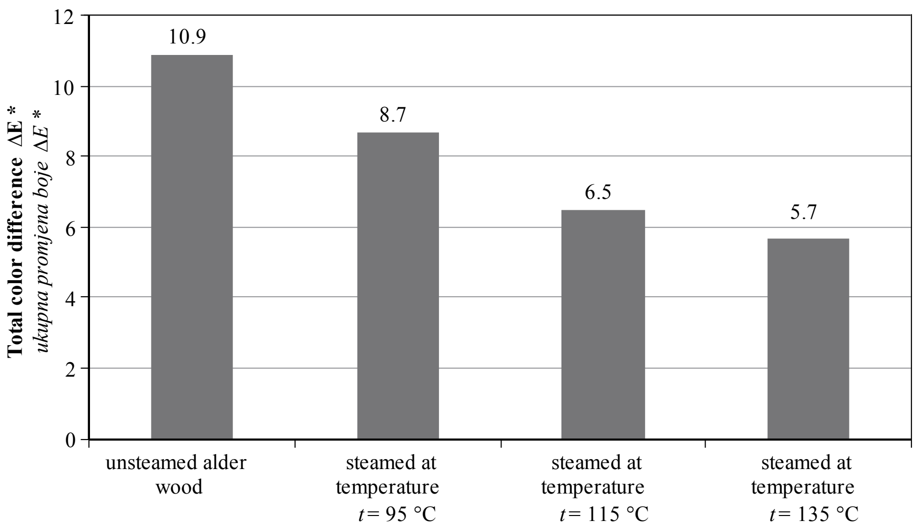

Figure 7 Influence of UV radiation on values of total colour difference ΔE^* of unsteamed and steamed alder wood
Slika 7. Utjecaj UV zračenja na vrijednosti ukupne promjene boje ΔE^* neparenoga i parenog drva johe

alder wood steamed with saturated water steam at the temperature t = 115 °C it reaches the value ΔE^* = 6.5, which is a decrease of 40.3 %; and for alder wood steamed with saturated steam at the temperature t = 135 °C the value of the total colour difference is ΔE^* = 5.7, which is a decrease of 47.7 %.

4 CONCLUSIONS
4. ZAKLJUČAK

The paper presents the results of surface colour changes of unsteamed and steamed alder wood due to UV radiation in Xenotest Q-SUN Xe-3-HS during 298 h irradiation of the surface of alder wood samples.

The surface colour of unsteamed alder wood changes colour under the influence of UV radiation more than the surface of steamed alder wood.

The measured changes in the values at the coordinates of the colour space CIE $L^*a^*b^*$ caused by UV radiation on unsteamed alder wood are: ΔL^* = - 9.7; Δa^* = + 3.9; Δb^* = + 2.8.

Changes in the values of the colour space CIE $L^*a^*b^*$ coordinates caused by UV radiation in steamed alder wood at a steaming temperature t = 95 °C are: ΔL^* = - 7.6; Δa^* = + 1.5; Δb^* = + 3.9; at steam temperature t = 115 °C: ΔL^* = - 4.2; Δa^* = + 1.0; Δb^* = + 4.8; and at a steam temperature t = 135 °C: ΔL^* = + 2.6; Δa^* = + 0.2; Δb^* = + 5.1.

The rate of colour change of alder wood induced by UV radiation expressed in terms of the total colour difference ΔE^* shows that while the value of the total colour difference of unsteamed alder wood ΔE^* = 10.9, for alder wood steamed at a temperature t = 95 °C ΔE^* = 8.7, for alder wood steamed with saturated water steam with a temperature of t = 115 °C ΔE^* = 6.5 and for alder wood steamed with saturated water steam with a temperature of t = 135 °C ΔE^* = 5.7, which is a decrease of 47.7 % compared to unsteamed alder wood

The decrease in changes in values ΔL^*, Δa^*, Δb^* and the overall colour difference ΔE^* of steamed alder wood caused by UV radiation indicate a positive effect of alder wood steaming - decomposition of functional groups of chromophores shown by darkening and browning of wood and increasing resistance of steamed alder wood to photochemical reactions of functional groups of alder wood chromophores with UV radiation shown by colour changes.

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