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Mode for hot air drying of alder blanks that retain the colour acquired during the steaming process

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Abstract: *Mode for hot air drying of alder blanks that retain the colour acquired during the steaming process*. The paper presents a hot-air mode for drying steamed alder in the form of blanks with dimensions: 38x100x800 mm from the initial moisture content $W_1 \approx 50$ % to the final moisture content $W_2 = 10\%$, while maintaining the colour of wood obtained in the process of steaming with saturated water steam. The drying process is divided into two parts: (I) evaporation of free water from wet wood at drying medium temperatures $t_d = 35$ - 40 °C and relative air humidity $\varphi = 70 – 60\%$, when there are no chemical changes in the lignin-saccharide complex of alder wood manifested by a change in colour; (II) evaporation of bound water from alder wood below the hygroscopicity limit is performed at temperatures $t_d = 60$ - 80 °C. The color coordinates of steamed alder wood after drying by a given mode in the CIE L* a* b* colour space are: L* = 62.5 ± 1.7; a* = 13.1 ± 0.8; b* = 18.5 ± 0.9. Total colour difference $\Delta E = 1.6$. According to the categorization of wood color changes in thermal processes of wood , this change belongs to small (insignificant) color changes.

***Key words*:** *wood, alder, friezes, steam,* drying, *colour*.

INTRODUCTION

The colour of alder wood according to Perelygin (1965) and Makoviny (2010) is light white-gray with a yellowish tinge. In the colour space model CIE L*a*b* Babiak et al. (2004) describe the colour of alder wood with the values of coordinates: L* = 75.02; a* = 8.06; b* = 20.90. Meints et al. (2017) for the color of alder wood give values: L* = 75.6; a* = 10.5; b* = 26.2. Technological processes of heat treatment of wet wood change its color. The wood is darker and, depending on the steaming mode, acquires a pale pink-brown, red-brown to dark brown-red colour (Tolvaj et al. 2009; Dzurenda 2014, 2018; Barcík et al. 2015; Baranski et al. 2017).

Wood drying is a hydrothermal process in which water is removed from wood. Drying of alder wood is normally carried out at drying medium temperatures t = 50 - 80 °C. The realization of the drying process at these temperatures creates conditions not only for the removal of water from the wood, but also for the course of chemical reactions causing changes in the lignin-carbohydrate complex of the wood, manifested by a change in the colour wood (Cividini et al. 2007; Dzurenda and Deliiski 2012; Geffert et al. 2020).

The aim of this work is to assess the proposed mode for drying steamed alder in the form of blanks with dimensions: 38x100x800 mm from moisture content $W_1 \approx 50\%$ to moisture content $W_2 = 10\%$ in hot air chamber drying kilns, from the aspect of change of color wood and dried timber quality.

MATERIALS AND METHODS

Hydrothermal treatment of alder wood blanks by steaming

Alder wood in the form of blanks were made from trees of the wood tree *Alnus glutinosa*, growing in the locality Krupinská planina.The age of the trees was 50 to 60 years. The dimensions of the radial and semi-radial friezes were 38x100x800 mm. Alder blanks were steamed before drying - thermally treated with saturated steam with temperature t = 125 ± 2.5 °C for $\tau = 7.5$ hours in order to obtain a brown-red-gray colour of wood.

Drying of steamed alder blanks while preserving the colour of the wood obtained by steaming

Drying of steamed alder in an air-conditioned space

Of the steamed alder blanks, 20 pieces were dried in an air-conditioned room at an air temperature of t = 20 °C and a relative humidity of φ = 60%. The colour of such dried steamed alder blanks was marked as reference value.

Mode for steamed alder wood in a hot air dryer

Steamed alder wood in the form of blanks with dimensions: 38x100x800 mm were dried in a hot air oven chamber KC 1/50 manufactured by SUSAR s.r.o. Nové Mesto nad Váhom (Slovakia). The conditions for drying of the steaming alder wood from moisture content of $W_1 \approx 50\%$ to moisture content $W_2 = 10\%$ shown in Table 1.

Table. 1 Drying mode for steamed alder wood

Phase of drying	Air temperature	Psychrometric difference	Time
	t_d [°C]	Δt [°C]	τ [h]
Wood heating	35	2	4
50 - 35	35	5	34
35 - 25	40	8	21
Conditioning wood	50	3	6
25 - 20	60	8	11
20 - 15	70	13	14
15 - 10	80	19	18
Treatment wood	80	7	7
Cooling wood	30	7	4

To prevent the colour of the wet alder wood from changing during the drying, the drying process is divided into two parts. Part (I) Drying of wood during adiabatic evaporation of free water from wet wood is proposed at humid air temperatures t = 35 - 40 ° C and relative air humidity φ = 70 - 60%. At these temperatures, conditions for chemical reactions of lignin in the lignin-saccharide complex manifested by a change in the chromophore system causing a change in colour of steamed alder wood are not created. At the end of this phase, conditioning is included in order to partially eliminate the moisture gradient formed in the lumber during the evaporation of water from the cell lumens. Conditioning is carried out by increasing the relative air humidity to φ = 84% and the air temperature to t = 50 °C. Part (II) Drying of alder wood below the limit of hygroscopicity is carried out at humid air temperatures t = 60 - 80°C.

Quality control of dried steamed alder blanks

After drying, the following were measured:

- color of steamed alder wood,
- the quality of the dried wood by determining: the deviation of the final moisture from the desired moisture w_0, the variation of the final moisture w_{k0} and the moisture content gradient Δw.

The colour of the wood on the planed surface, after drying the alder wood, was measured with a Colour Reader CR-10 colorimeter. The effect of the drying regime on the colour change of alder wood was evaluated by:

- determination of L*, a*, b* values on 36 samples steamed alder wood of dried in the chamber drying kilns and 20 samples of dried steamed alder wood in an air-conditioned room,
- comparing the values at L*, a*, b* of the dried blanks by the hot air drying mode with the values of the coordinates L*, a*, b* of alder wood dried in an air-conditioned space,

- determining the total colour difference ΔE quantified by the relation:

$$\Delta E = \sqrt{(L_1^* - L^*)^2 + (a_1^* - a^*)^2 + (b_1^* - b^*)^2} \quad (1)$$

where: L^*, a^*, b^* values on the coordinates of the color space of alder wood dried in the air-conditioned space,
L^*_1, a^*_1, b^*_1 values on the color space coordinates of alder wood dried by the proposed hot air drying mode in the KC 1/50 chamber drying kilns.

The deviation of the final moisture content from the required moisture is described by the equation:

$$w_0 = \frac{\sum_{i=1}^{n} w_{ik}}{n} - w_k \, [\%], \quad (2)$$

where: n – number of control samples [-],
w_{ik} – final sample moisture [%],
w_k – required final wood moisture [%].

The variation in final moisture content is evaluated by the difference between the maximum and minimum moisture values of the samples according to the relation:

$$w_{k0} = w_{max} - w_{min} \, [\%], \quad (3)$$

where: w_{max} – maximum moisture content in drying samples [%],
w_{min} – minimum moisture content in drying samples [%].

The moisture gradient in the timber was determined from the difference in moisture of the middle layer and the diameter of the two surface layers:

$$\Delta w = w_s - w_{pov} \, [\%], \quad (4)$$

where: w_s – center layer moisture content [%],
w_{pov} – moisture content of surface layers [%].

RESULTS AND DISCUSSION

The colour of steamed alder wood dried in an air-conditioned room at an air temperature of t = 20 °C and a relative humidity of φ = 60 % is described by the coordinates:

L* = 62.5 ± 1.7; a* = 13.1 ± 0.8; b* = 18.5 ± 0.9

The colour of steamed alder wood dried in an the chamber drying kilns is described by the coordinates:

L* = 61.6 ± 2.3; a* = 13.6 ± 1.3; b* = 17,7 ± 1,5

The differences between the colour of dried alder wood in chamber drying kiln and the colour of alder wood dried in the air-conditioned space are shown in Table 2.

Table 2. Coordinate values: L*, a*, b* and total colour difference ΔE

Items	Colour parameters	ΔE

	L*	a*	b*	
Wood dried in the chamber drying kilns	62.9	13.1	18.5	---
Wood dried in an air-conditioned room	61.6	13.6	17.7	---
Differences in ΔL*, Δa*, Δb* and ΔE*	- 1.3	0.5	- 0.8	1.6

The values on the color coordinates of the dried of the steaming alder blanks in the chamber drying kilns compared to the reference values - of the steaming alder wood dried in the air-conditioned space differs slightly. The whiteness of alder wood decreased by ΔL* = - 1.3, the value at the red coordinate increased by Δa* = + 0.5 and the value at the yellow coordinate decreased by Δb* = - 0.8. The value of the total color difference ΔE = 1.03, according to the categorization of wood colour changes in the thermal processes reported by Cividini et al.(2007) classifies the colour change of alder wood into the category ΔE = 0.2 - 2, i.e. the category of small colour changes.

The results of analyzes evaluating the quality of dried wood alder blanks are shown in Tab. 3.

Table. 3 Quality evaluation of dried wood

Quality features		Value [%]
Deviation of the final moisture content of the desired wood moisture content	w_0	1.1 ± 0.4
Fluctuation of final moisture of the samples	w_{k0}	1.7 ± 0.2
Moisture gradient of the samples	Δw	1.3 ± 0.2

On the basis of comparison of the measured quality values of dried wood with the values of dried timber of high quality Trebula and Klement (2002) shows that the wood dried blanks belongs to the quality class:

- II. quality class, deviation of final moisture from required moisture (w_0 = 0.6 – 1.5%)
- I. quality class, final moisture content variation ($w_{k0} \leq 2.0\%$)
- I. quality class, moisture gradient ($\Delta w \leq 1.5$ %).

The negative aspect of the regime of drying steamed alder wood is approx. 25% extension of the drying time of wood in comparison with the modes of drying of alder wood at temperatures t = 50 - 80 °C. This is due to the implementation of the drying process at lower temperatures.

CONCLUSION

The paper presents a mode for drying steamed alder in the form of blanks with dimensions: 38x100x800 mm from moisture content $W_1 \approx 50\%$ to final moisture content W_2 = 10%, while preserving the original color of the wood acquired during the steaming process.

The colour coordinates of the dried of the steaming alder wood in the CIE L*a*b* are: L* = 62.5 ± 1.7, a* = 13.1 ± 0.8, b* = 18.5 ± 0.9. The change in colour of alder wood due to the drying process, expressed as the total colour difference ΔE compared to the colour of alder wood dried in an air-conditioned space, is ΔE = 1.6. This colour change, according to the categorization of wood colour changes in the thermal processes reported by the authors Cividini et al.(2007), classifies the colour change of alder wood due to drying into the category ΔE = 0.2 – 2.0, i.e. small colour changes.

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Streszczenie: *Proces suszenia gorącym powietrzem półfabrykatów olchowych pozwalający na zachowanie barwy uzyskanej podczas procesu parowania.* W pracy przedstawiono tryb suszenia gorącym powietrzem parzonych półfabrykatów olchowych o wymiarach 38x100x800 mm od wilgotności początkowej $W_1 \approx 50\%$ do wilgotności końcowej $W_2 = 10\%$. Proces suszenia był prowadzony w sposób mający na celu zachowanie barwy drewna uzyskanego w procesie obróbki hydrotermicznej w środowisku nasyconej pary wodnej. Proces suszenia składał się z dwóch etapów. Etap pierwszy obejmował odparowanie wolnej wody z mokrego drewna przy temperaturach

schnącego medium t_d = 35 - 40°C i wilgotności względnej powietrza φ = 70 - 60%. Przy tych parametrach w kompleksie ligninowo-sacharydowym drewna olchowego nie zachodzą zmiany chemiczne objawiające się zmianą barwy. Etap drugi obejmował odparowanie wody związanej z drewna olchowego poniżej granicy higroskopijności, w temperaturach t_d = 60 - 80°C. Współrzędne barwy drewna olchowego parzonego po wysuszeniu przedstawioną metodą, w przestrzeni barw CIE L * a * b * wynoszą: L* = 62,5 ± 1,7; a* = 13,1 ± 0,8; b* = 18,5 ± 0,9. Całkowita zmiana barwy ΔE = 1,6. Zgodnie z kategoryzacją zmian barwy drewna w procesach termicznych, zmiana ta jest niewielka (nieznaczna).

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