Jerzy Majka[1], Maciej Sydor[2], Jakub Prentki[3], Magdalena Zborowska[4]

Initial Desorption of Reaction Beech Wood

Inicijalna desorpcija reakcijskog drva bukovine

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ABSTRACT • *The research aimed to obtain empirical data for modeling the initial desorption in reaction wood from the cross-section of the green beech (Fagus sylvatica L.) log. Firstly, we analyzed the chemical composition, macro and microscopic structure of tension and opposite wood tissue. Then, the Equilibrium Moisture Content (EMC) was measured by the Dynamic Vapor Sorption method during the initial desorption. The used air parameters were specific for the mild drying schedule of green beech timber (t = 20, 35, and 50 °C, Relative Humidity (RH) ranging from 95 to 0 %). Relationships between the EMC of reaction wood and drying parameters were modeled using the Response Surface Method (RSM). The tests revealed: different hygroscopic properties of tension and opposite wood, the dependence of EMC value on temperature, and differences between EMC values for initial (first) and second desorption. Moreover, it was confirmed that, during initial desorption, the EMCs of reaction wood are significantly higher than reference EMC data. The differences in the EMC value are up to 0.14 kg/kg (for air with RH above 90 %). The presented polynomial model of the initial desorption of reaction beech wood can improve drying schedules for beech sawn timber with a high amount of reaction tissue.*

KEYWORDS*: equilibrium moisture content; kiln-drying; response surface methodology; Fagus sylvatica L.; sorption isotherms; reaction wood; tension wood; opposite wood*

SAŽETAK • *Cilj je ovog istraživanja modeliranje inicijalne desorpcije poprečnog presjeka reakcijskog drva bukve (Fagus sylvatica L.) na temelju empirijskih podatka. Najprije je istražen kemijski sastav drva te je analizirana makroskopska i mikroskopska struktura reakcijskoga i opozitnog drva. Zatim je metodom dinamičke sorpcije pare izmjeren ravnotežni sadržaj vode tijekom inicijalne desorpcije. Drvo je podvrgnuto blagom režimu sušenja (t = 20, 35 i 50 °C, te relativnoj vlažnosti zraka u rasponu od 95 do 0 %). Odnosi između ravnotežnog sadržaja vode reakcijskog drva i parametara sušenja modelirani su metodom odzivne površine. Ispitivanjem su dobivena različita higroskopska svojstva reakcijskoga i normalnog drva, ovisnost ravnotežnog sadržaja vode o temperaturi sušenja te razlike između vrijednosti ravnotežnog sadržaja vode pri inicijalnoj (prvoj) i drugoj desorpciji. Također je potvrđeno da je ravnotežni sadržaj vode reakcijskog drva tijekom inicijalne desorpcije znatno veći od referentnih vrijednosti ravnotežnog sadržaja vode normalnog drva. Razlike u vrijednostima ravnotežnog sadržaja vode kreću se do 0,14 kg/kg (pri relativnoj vlažnosti zraka većoj od 90 %). Prikazani poli-*

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[1] Author is researcher at Poznań University of Life Sciences, Faculty of Forestry and Wood Technology, Department of Wood Science and Thermal Techniques, Poznań, Poland. https://orcid.org/0000-0002-6713-8077

[2] Author is researcher at Poznań University of Life Sciences, Faculty of Forestry and Wood Technology, Department of Woodworking and Fundamentals of Machine Design, Poznań, Poland. https://orcid.org/000-0003-0076-3190

[3] Author is researcher at Poznań University of Life Sciences, Faculty of Forestry and Wood Technology, Department of Wood Science and Thermal Techniques, Poznań, Poland.

[4] Author is researcher at Poznań University of Life Sciences, Faculty of Forestry and Wood Technology, Department of Chemical Wood Technology, Poznań, Poland. https://orcid.org/0000-0003-3028-5134

nomski model inicijalne desorpcije reakcijskog drva bukve može poslužiti za poboljšanje režima sušenja bukove piljene građe s velikim udjelom reakcijskog drva.

KLJUČNE RIJEČI: *ravnotežni sadržaj vode; sušenje u sušioniku; metoda odzivne površine; Fagus sylvatica* L.*; sorpcijske izoterme; reakcijsko drvo; tenzijsko drvo; opozitno drvo*

1 INTRODUCTION
1. UVOD

The equilibrium moisture content (EMC) depends on the wood species and the variation of its structure (Kollmann, 1936; Skaar, 1988). The most frequently used method of measuring the EMC is the procedure based on the Hailwood-Horrobin sorption model (1946). Simpson fitted this model to empirical EMC data provided by the "Forest Products Laboratory" (Simpson, 1973). These data are averaged values for desorption and adsorption and, by this simplification, have limited suitability for modeling a wood water relation in kiln-drying of timber (Wengert, 1976; Langrish and Walker, 1993; Salin, 2011; Glass *et al*., 2014; Redman *et al*., 2016). The EMC data is most often applied to relate air parameters and expected drying intensity during kiln-drying of timber. The relation is given by drying schedules for different wood species, usually using a Drying Gradient (DG) concept, which is defined as a ratio of the actual moisture content of timber and EMC values appropriate for drying parameters (Brunner, 1987). The EMC based on the initial desorption isotherms can significantly improve the accuracy of the drying gradient determination (Majka and Olek, 2013). Most published data on the hygroscopic properties of wood are the result of research on the phenomenon of the second desorption, occurring after drying the wood (Spalt, 1958; Weichert, 1963; Böhner, 1996; Ahmet *et al*., 1999; Jannot *et al*., 2006; Popper *et al*., 2009; Popper and Niemz, 2009; Jankowska, 2018). However, the second desorption process differs from the initial (first) desorption. The second desorption of beech wood gives lower EMC than the initial desorption, especially in higher air relative humidity (RH) (Barkas, 1936; Skaar, 1988).

The beech can form up to 25 % of the reaction tissue (Kúdela and Čunderlík, 2012). Reaction wood is a structure of wood tissue that takes the form of compression wood and tension wood. This type of reaction wood induces the desired displacement of the stem towards a more favorable position by tensile force (Côté, 1964; Scurfield G., 1973; Tulik and Jura-Morawiec, 2011; Felten and Sundberg, 2013; Groover, 2016). An indicator of reaction wood in a log is a pith eccentricity. The eccentricity is caused by wider annual increases on the tension side. On a microscopic scale, the reaction wood of beech is characterized by lower content of vessels with smaller diameter and length and significantly elongated tracheids with thickened walls. Changes in the S_2 and S_3 cell layers are a typical feature of the microscopic structure of reaction wood in beech (Côté *et al*., 1969; Wardrop and Davies, 1964). However, the essential factor influencing wood drying may be a non-lignified gelatinous layer (G-layer). Bound water diffusion in the G-layer causes an almost always higher in tension wood than in normal wood, despite similar density values. The fibers of reaction wood have a greater longitudinal shrinkage than normal wood (Scurfield and Wardrop, 1962; Tarmian *et al*., 2012). The reaction tissue of beech wood dries more slowly and has a higher final moisture content after drying than the opposite and normal tissue (Klement *et al*., 2019, 2020). The typical drying behavior of beech reaction wood is more evident during drying above Fiber Saturation Point (FSP) when liquid-free water is removed (Tarmian *et al*., 2009). Beech timber produced from logs with a high content of tension tissue shows a greater risk of developing defects during kiln-drying (Tarmian and Perré, 2009). As far as the authors are aware, there are no published data describing the relationship between the EMC of reaction wood and air parameters in the range corresponding to the kiln-drying schedules of sawn beech timber. Therefore, the aim of the research was to provide empirical EMC data and use them to develop a model of the initial desorption in the reaction beech wood.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Material
2.1. Materijal

The research material was primarily sawn in February 2020 from a green 105-year-old beech (*Fagus sylvatica* L.) log with a distinctly eccentric pith. The test tree was selected from a fresh mixed deciduous forest located in the Forest District Rzepedź (in the Subcarpathian province of south-east Poland, close to the border with Slovakia). The 100 mm disc (at breast height) was cut and uncontrolled changes in moisture content were prevented. Two sections of the research material were selected for laboratory tests, located on the cross-section of the trunk on opposite sides of the eccentric pith. The strip axis ran along the line marked

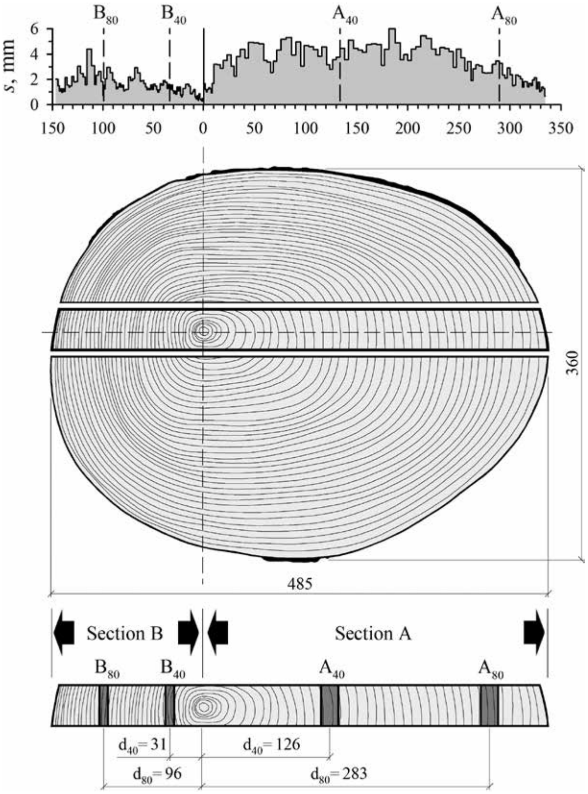

Figure 1 Disc cross-section with location of test samples and measurement results of width of annual rings (s) along trunk diameter (A – tension wood, B – opposite wood, d – distance from pith; all dimensions in millimeters)

Slika 1. Poprečni presjek diska s položajem ispitnih uzoraka i rezultatima mjerenja širine goda (*s*) duž promjera debla (A – reakcijsko drvo, B – opozitno drvo, d – udaljenost od srčike; sve su dimenzije iskazane u milimetrima)

by the highest difference in the width of annual increments (Figure 1). The test samples were prepared from two sections of the strip: A – tension wood and B – opposite wood. Both sections included 40 ± 1 and 80 ± 1 annual rings (the sections inner and outer cross-section zones).

2.2 Macro and microstructure

2.2. Makroskopska i mikroskopska struktura drva

The annual tree ring widths (*s*) were measured with an optical device with a computer image analyzer (BEPD-19, BIOtronik, Warsaw, Poland) with a measuring range of 470 mm and measurement uncertainty of 0.01 mm. According to the measurement results, the difference of about three times was found in the average width of annual rings between sections A and B. The average values of the annual ring widths in Section A (tension wood) are 1.40 ± 0.71 mm, and in Section B (opposite wood) 3.19 ± 1.30 mm. The width measurements of all annual rings are presented in Figure 1.

The microtome samples were photographed using a biological microscope with a computer image analyzer (B3 Professional, Motic, Hong-Kong, China).

2.3 Chemical composition of wood

2.3. Kemijski sastav drva

Firstly, each prepared wood sample was ground (0.5-1.0 mm fraction, mass ca. 50 g) in a Fritsch Pulverisette 15 laboratory mill (Fritsch GmbH, Germany). The cellulose content was measured according to Seifert's method using a mixture of acetylacetone, 1.4-dioxane, and hydrochloric acid to isolate cellulose (Browning, 1966). According to the chlorite method, the holocellulose content was measured using $NaClO_2$ as a reagent (Browning, 1966). The pentosane content was measured using hydrochloric acid and phloroglucinol according to the TAPPI standard method T 223 cm-01. Acid-insoluble lignin was assessed according to T 222 om-06 standard TAPPI method. The content of extractives soluble in alcohol was measured according to TAPPI standard method T 204 cm-97. All tests were carried out with three replicates for each option of samples.

2.4 Sorption experiments

2.4. Eksperimenti sorpcije

Sorption experiments were carried out using a dynamic vapor sorption (DVS) apparatus (DVS Advantage 2 from Surface Measurement Systems, London, UK). The appropriate air RH levels were achieved by mixing dry and saturated air streams. The EMC values for air humidity (RH) in the range of 95 to 0 % were measured. It was assumed that the hygroscopic equilibrium was obtained at a given RH value when the mass change was less than 0.0005 % min^{-1} for at least 60 min. The procedure was repeated for each RH step and the EMC values were calculated. Samples for measuring the EMC variability of the tension and opposition wood were produced in two stages. In the first stage, four fragments were separated from Section A (tension wood) and B (opposite wood), each containing three annual rings, i.e., 39-41 and 79-81. Then, the prepared fragments with dimensions of 20 mm in the tangential (T) and longitudinal (L) direction were divided in the radial plane into final samples with a thickness of ca. 1 mm. The initial mass of each investigated sample was 12 ± 0.5 mg.

The sorption experiments consisted of air parameters, specific for mild kiln-drying beech sawn wood schledue, which saves the natural color. Three air temperature values were used, i.e. 20, 35, and 50 °C and five relative air humidity (RH) values, i.e. 95, 80, 65, 50 and 35 %. After the parameters were measured during the initial desorption, an additional sorption experiment was performed, consisting of water adsorption and second desorption. An additional experiment compared the EMC values with the available literature data. The list of all variants of air parameters in the sorption experiments is presented in Table 1.

Table 1 Summary of air parameters in sorption experiments
Tablica 1. Pregled parametara zraka pri istraživanju sorpcije

Sorption phase *Faza sorpcije*	*t*, °C		
	20	35	50
Initial desorption / *inicijalna desorpcija*	**95, 80, 65, 50, 35**, *20, 5, 0*	**95, 80, 65, 50, 35**	**95, 80, 65, 50, 35**
Adsorption / *adsorpcija*	*0, 5, 20, 35, 50, 65, 80, 95*	–	–
Second desorption / *druga desorpcija*	*95, 80, 65, 50, 35, 20, 5, 0*	–	–

bold – RH values (%) included during experiments for initial desorption, italic – RH values (%) included during additional experiments / *podebljana slova – vrijednosti relativne vlažnosti zraka (%) tijekom istraživanja početne desorpcije, kurziv – vrijednosti relativne vlažnosti zraka (%) tijekom dodatnih istraživanja*

2.5 Sorption modeling
2.5. Modeliranje sorpcije

The Response Surface Methodology (RMS) was used to generalize the relationship between the EMC for initial desorption and the characteristic air parameters of the kiln-drying schedule (Box and Draper, 2007). The levels of independent variables used for the sorption experiments are presented in Table 2.

According to the following formulas, the independent variables were coded: $x_1 = (t - 35)/15$, and $x_2 = (\mathrm{RH} - 65)/15$. The third-order polynomial equation approximated the results:

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_1^2 + b_4x_2^2 + b_5x_1x_2 + \\ + b_6x_1^3 + b_7x_2^3 + b_8x_1^2x_2 + b_9x_1x_2^2 \qquad (1)$$

Where y is the predicted response (i.e. equilibrium moisture content for initial desorption), b_0-b_9 are estimated coefficients. The fitting algorithm (Levenberg-Marquardt approach) was used to estimate the coefficients of the response models of the initial desorption. Due to the possible linear dependence of the variables, backward stepwise regression was applied to exclude statistically insignificant model parameters (Chatterjee and Hadi, 2013). The experimental input data for RSM modeling are presented in Table 3. The results are supplemented by EMC values calculated from the Hailwood-Horrobin equation as applied by Simpson (1973) to the data from the Forest Products Laboratory (Wood Handbook, 2010).

2.6 Statistical analysis
2.6. Statistička analiza

The experimental data were analyzed using STATISTICA 13.3 software (TIBCO Software Inc., Palo Alto, CA, USA). A one-factor analysis of variance (ANOVA) was performed to determine significant differences between the components of the average content

Table 2 Levels of independent variables used for sorption experiments
Tablica 2. Razine neovisnih varijabli primijenjenih u istraživanju sorpcije

Independent variables *Nezavisne varijable*	**Actual levels** *Stvarne vrijednosti*
Dry-bulb temperature *t* (x_1), °C / *temperatura suhog termometra t* (x_1), °C	20 (-1); 35 (0); 50 (1)
Relative humidity RH (x_2), % / *relativna vlažnost zraka RVZ* (x_2), %	95 (-2); 80 (-1); 65 (0); 50 (1); 35 (2)

Table 3 Experimental (input) data for modeling initial desorption
Tablica 3. Eksperimentalni (ulazni) podatci za modeliranje početne desorpcije

***t*, °C**	**RH, %**	**EMC, kg/kg**				
(x_1)	**(x_2)**	**A_{40}**	**A_{80}**	**B_{40}**	**B_{80}**	**FPL data**
20 (–1)	95 (–2)	0.377	0.401	0.379	0.301	0.260
20 (–1)	80 (–1)	0.208	0.219	0.212	0.219	0.184
20 (–1)	65 (–0)	0.152	0.158	0.154	0.155	0.148
20 (–1)	50 (–1)	0.114	0.118	0.116	0.117	0.127
20 (–1)	35 (–2)	0.082	0.085	0.084	0.084	0.112
35 (–0)	95 (–2)	0.373	0.388	0.365	0.280	0.248
35 (–0)	80 (–1)	0.188	0.199	0.193	0.197	0.173
35 (–0)	65 (–0)	0.136	0.143	0.138	0.140	0.138
35 (–0)	50 (–1)	0.102	0.107	0.103	0.105	0.118
35 (–0)	35 (–2)	0.073	0.078	0.074	0.077	0.104
50 (–1)	95 (–2)	0.249	0.251	0.228	0.204	0.235
50 (–1)	80 (–1)	0.157	0.156	0.154	0.155	0.161
50 (–1)	65 (–0)	0.123	0.123	0.122	0.123	0.128
50 (–1)	50 (–1)	0.097	0.097	0.094	0.096	0.109
50 (–1)	35 (–2)	0.073	0.072	0.072	0.072	0.096

A, B – tension and opposite wood, respectively; 40, 80 – number of annual rings / *A – reakcijsko drvo, B – opozitno drvo; 40, 80 – broj godova* of the chemical composition of the examined wood samples. The post-hoc HSD Tukey's test was used to test the significance of differences between the average values of the mean. Significance was established at $p<0.05$.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Microscopic structure
3.1. Mikroskopska struktura drva

The microstructure of the investigated samples is shown in Figure 2. Microscopic images presented the features typical of tension and opposite wood. Gelatin fibers are mainly seen in the tension wood section (signed A_{40} and A_{80}). The lower content of gelatin fibers in the near pith zone (A_{40}) of the tension wood than the content of gelatin fibers in the outer zone (A_{80}) confirms previous information that asymmetric growth is not always accompanied by the formation of reactive tissue across the width of the tree trunk (Kojs *et al*., 2012). The microscopic images of the test samples taken from the pith area and peripheral parts of section B (marked B_{40} and B_{80}) are characteristic of the structure of the opposite wood. The anatomical elements have smaller lumen with a thicker wall than normal wood.

3.2 Chemical composition
3.2. Kemijski sastav drva

Table 4 summarizes the experimentally measured chemical composition of the tension wood (Section A) and opposition wood (Section B). These data were compared with the literature data for normal wood. The cellulose content is similar, but substances soluble in alcohol content in the tension wood samples (Section A) and opposition wood are ca. twice as

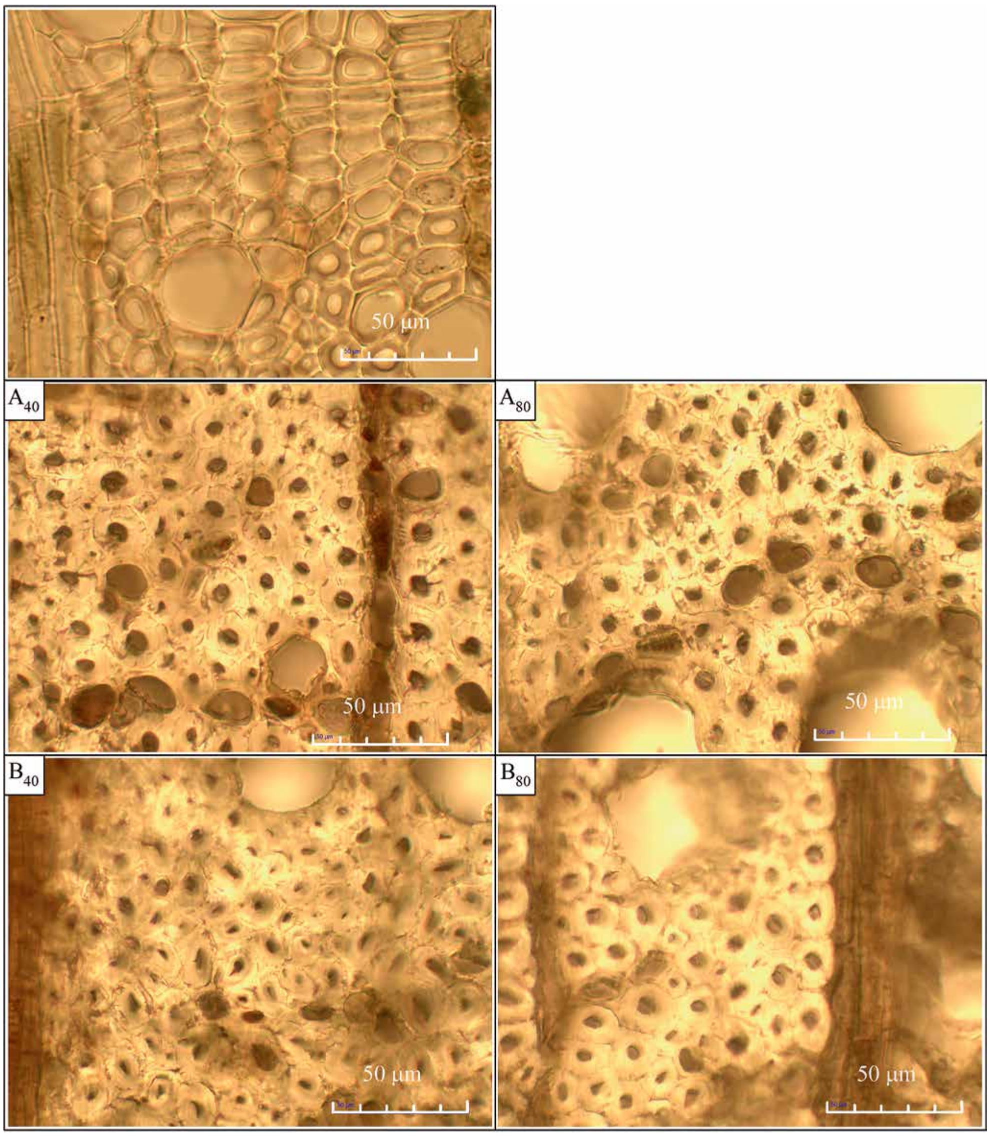

Figure 2 Microstructure of normal (above) and reaction (bottom) green beech (*Fagus sylvatica* L.) at a 40-fold magnification: A, B – tension and opposite wood, respectively, 40, 80 – number of annual rings
Slika 2. Mikrostruktura normalne (gore) i reakcijske (dolje) bukovine (*Fagus sylvatica* L.) pri povećanju 40 puta: A – reakcijsko drvo, B – opozitno drvo, 40, 80 – broj godova

Table 4 Chemical composition of beech reaction and normal wood (*Fagus sylvatica* L.)
Tablica 4. Kemijski sastav reakcijskoga i normalnog drva bukve (*Fagus sylvatica* L.)

Wood samples *Uzorak drva*	**Annual ring** *God*	**Symbol** *Oznaka*	**Holocellulose** *Holoceluloza*	**Cellulose** *Celuloza*	**Pentosans** *Pentozani*	**Lignin** *Lignin*	**Substances soluble in alcohol**[1] *Tvari topljive u alkoholu*[1]
Section A (Tension wood) *sekcija A (reakcijsko drvo)*	40±1	A_{40}	78.9 ^{b}± 1.4	40.0 ^{a}± 0.1	29.3 ^{b}± 1.4	22.8 ^{a}± 0.3	1.56^{a}± 0.21
	80±1	A_{80}	68.7 ^{a}± 1.7	40.2 ^{a}± 0.4	28.6 ^{ab}± 0.6	22.8 ^{a}± 0.3	1.54^{a}± 0.09
Section B (Opposite wood) *sekcija B (opozitno drvo)*	40±1	B_{40}	76.7 ^{b}± 4.2	42.6 ^{b}± 0.4	27.2 ^{a}± 0.1	21.2 ^{a}± 1.4	1.87 ^{ab}± 0.07
	80±1	B_{80}	70.0^{a}± 0.6	39.7 ^{a}± 0.3	28.8 ^{ab}± 0.2	22.9 ^{a}± 0.8	1.93^{b}± 0.12
Literature data for normal wood[2] *vrijednosti iz literature*[2]			–	49.1	22.0	23.8	0.8

[1] substances soluble in alcohol – benzene 1:1, [2]according to (Fengel and Wegener, 1983), mean value (n = 3) ± standard deviation; identical superscripts (a, b, c) denote no significant difference ($p < 0.05$) between mean values according to post-hoc Tukey's HSD test

[1] tvari topljive u otopini alkohola i benzena u omjeru 1:1, [2]prema: Fengel i Wegener, 1983., srednja vrijednost (n = 3) ± standardna devijacija; identični superskripti (a, b, c) označavaju da prema post-hoc Tukeyjevu HSD testu nema značajne razlike (p < 0,05) među srednjim vrijednostima

high as in normal wood. Moreover, a higher hemicellulose content (in Sections A and B) was found than in normal beech wood.

3.3 Sorption isotherms
3.3. Sorpcijske izoterme

The sorption isotherms of the reaction beech wood for the successive phases: initial (first) desorption, adsorption, and second desorption at a temperature of 20 °C are shown in Figure 3.

For all tension and opposite wood samples, it was confirmed as follows: the sorption hysteresis occurrence (desorption differs from the subsequent adsorption), differences between the first (initial) and second water desorption, the EMC value in the initial desorption was higher than the EMC value in the second desorption in the range of RH air above 70 %. The usefulness of the FPL data, which is presented as an additional isotherm (dot line, Figure 3), was confirmed only for adsorption. For this reason, the FPL data have limited suitability for determining the technological parameters of drying beech lumber with a high amount of "reaction wood". In our research, significantly lower EMC values were observed in the first desorption of

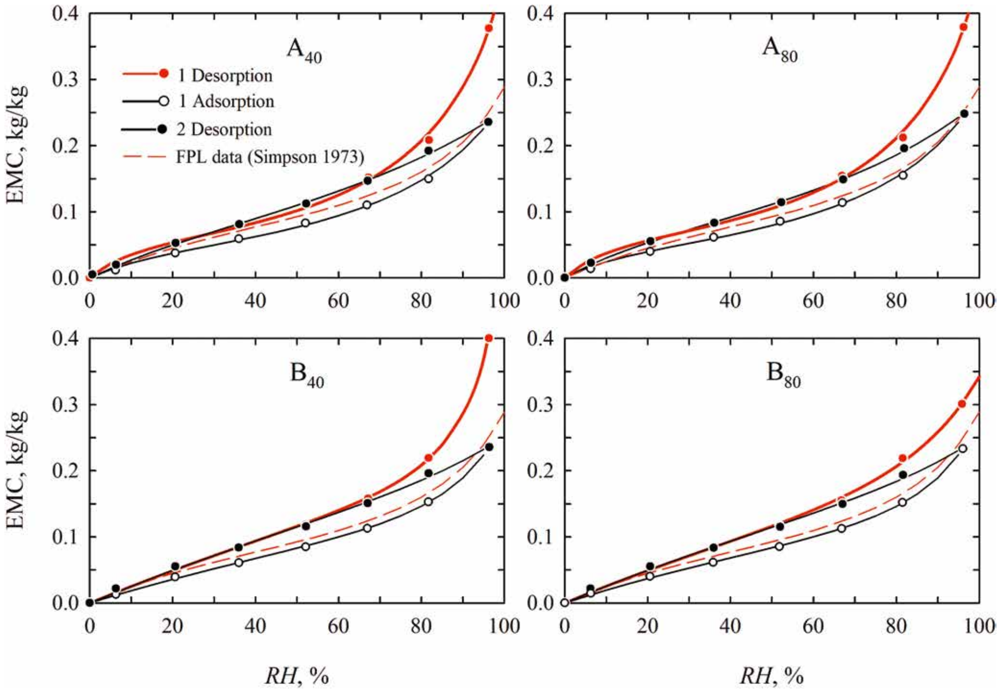

Figure 3 Sorption isotherms of green beech wood (*Fagus sylvatica* L.) at a temperature of 20 °C (A, B – samples of tension and opposite wood, respectively, 40, 80 – samples from inner and outer zone of trunk cross-section, respectively, FPL data – literature data for normal wood)

Slika 3. Sorpcijske izoterme drva bukve (*Fagus sylvatica* L.) pri temperaturi od 20 °C (A – reakcijsko drvo, B – opozitno drvo, 40, 80 – uzorci od srčike prema kori na poprečnom presjeku debla, FPL podatci – podatci iz literature za normalno drvo)

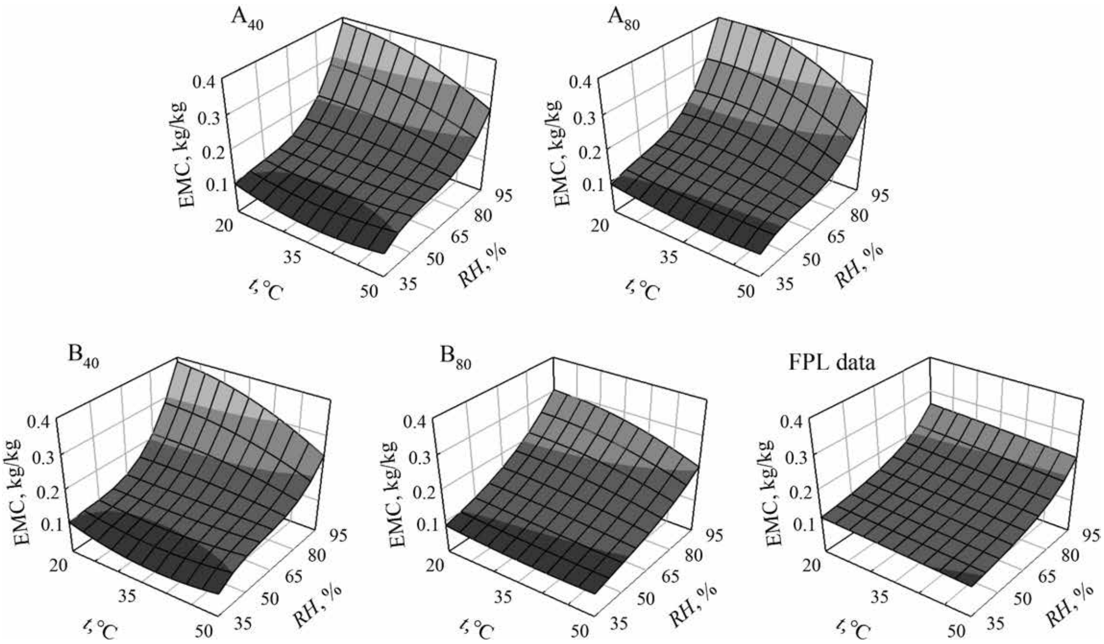

Figure 4 Effect of air parameters on equilibrium moisture content (EMC) of green beech wood during initial desorption: A, B – samples of tension and oposition wood, respectively, 40, 80 – samples from inner and outer zone of trunk cross-section, respectively, FPL data –reference

Slika 4. Utjecaj parametara zraka na ravnotežni sadržaj vode (RSV) u bukovini tijekom inicijalne desorpcije: A – reakcijsko drvo, B – normalno drvo, 40, 80 – uzorci od srčike prema kori na poprečnom presjeku debla, FPL podatci – podatci iz literature

the reaction wood sample with the highest extractive substance content, i.e. 1.93 % (sample B_{80}). The results of sorption experiments and chemical composition analysis confirmed a significant influence of the substances soluble in alcohol on the sorption phenomena. The influence of extractives on the sorption phenomenon was described previously, and it was pointed out that their higher content causes a decrease in EMC (Simón *et al.*, 2015; Jankowska *et al.*, 2016). The results of sorption experiments confirm earlier literature reports that wood containing more substances soluble in alcohol achieved lower EMC, especially when air RH is above 50 % (Hernández, 2007).

3.4 Initial desorption modeling
3.4. Modeliranje inicijalne desorpcije

Figure 4 presents a comparison of the EMC response surfaces for initial desorption as observed for reaction green beech wood and the FPL reference EMC data. The maximum difference between the estimated EMC of the reaction beech wood and the reference FPL data for the highest RH values included in the experiments is up to 0.14 kg/kg (for air RH above 90 %).

The responses models (Figure 4) present the differences in the hygroscopic properties of the tension and opposite wood tissues. The most significant differences in the EMC value occur in the air RH range above 70 %. The EMC of the tension wood (Section A) was significantly higher than that of the opposite wood (Section B). Moreover, responses models for the reaction tissue show that the EMC values are much more temperature-dependent for the initial desorption than can be calculated using the Simpson procedure, taking into account the FPL data (Simpson, 1973). In extreme cases, an increase in temperature from 20 to 50 °C, for RH near saturation reduces the EMC of the reaction beech wood by even 0.010 to 0.15 kg/kg. The EMC reduction for the same conditions calculated from the FPL data is only 0.025 kg/kg.

Table 5 shows the estimated coefficients of response models developed in this study.

Table 5 Estimated coefficients of response models
Tablica 5. Procijenjeni koeficijenti modela odziva

Coefficients *Koeficijenti*	**Response** *Odziv*			
	A_{40}	A_{80}	B_{40}	B_{80}
b_0	0.130	0.145	0.132	0.145
b_1	–	-0.0161	–	-0.0176
b_2	0.0411	0.0425	0.0435	0.0456
b_3	–	-0.015	–	-0.00729
b_4	0.0182	0.0192	0.0168	0.00741
b_5	-0.0137	-0.0158	-0.0156	-0.0105
b_6	–	–	–	–
b_7	0.00809	0.00843	0.00697	0.00129
b_8	-0.0137	-0.0137	-0.0142	-0.007
b_9	-0.00909	-0.00609	-0.0108	-0.00249
R^2	0.984	0.993	0.980	0.999
Adj R^2	0.971	–	0.966	–
Standard error	0.0167	0.0132	0.0179	0.00408

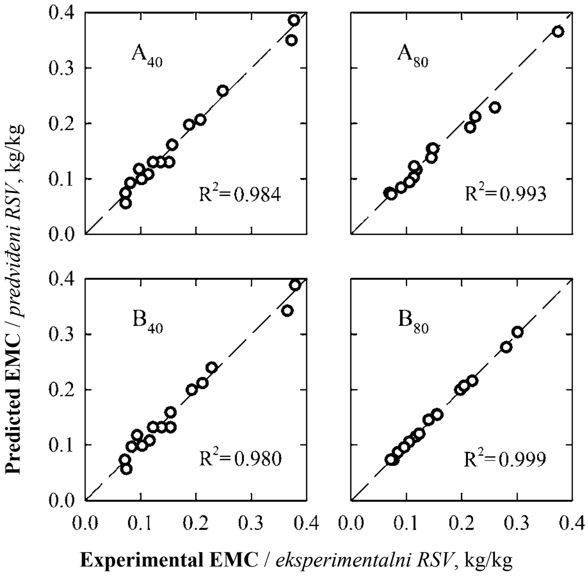

Figure 5 Experimental versus predicted equilibrium moisture content (EMC) using response models

Slika 5. Usporedba eksperimentalnoga i predviđenoga ravnotežnog sadržaja vode (RSV) primjenom modela odziva

Figure 5 compares the predicted EMC to the experimental EMC.

Figure 6 shows calculated absolute differences between reaction wood EMC for initial desorption and normal wood EMC according to FPL data (Simpson, 1973).

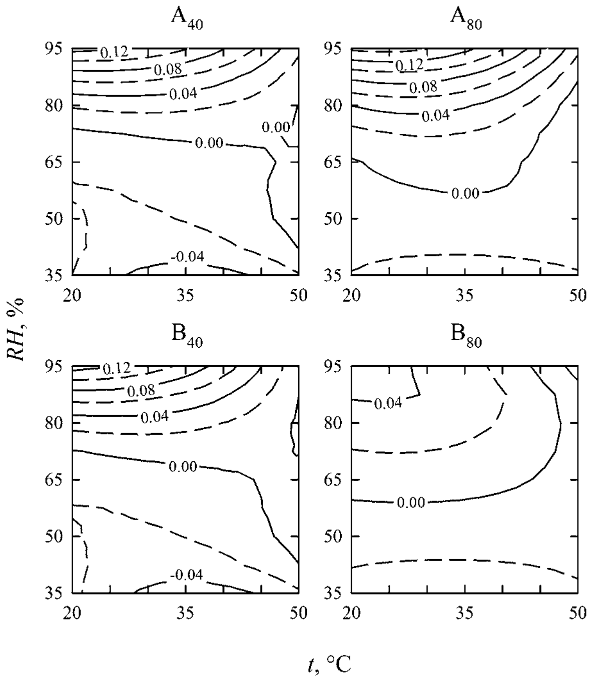

Figure 6 Calculated absolute differences between values of reaction wood EMC for initial desorption and FPL data for normal wood (Simpson, 1973)

Slika 6. Izračunane apsolutne razlike između vrijednosti RSV reakcijskog drva za početnu desorpciju i FPL podataka za normalno drvo (Simpson, 1973.)

4 CONCLUSIONS
4. ZAKLJUČAK

Taken together, these findings demonstrate that:

1. The research results show the possible range of variability of the hygroscopic properties of the raw beech wood containing pathological tissue. The dependence of the hygroscopic properties of the examined wood on the type of pathological tissue (tension wood, opposite wood) and chemical composition was confirmed. The experimental results show lower EMC values of tension beech wood in higher air RH values. The higher extractives content in reaction wood than in normal tissue is the most likely cause of the lower EMC.
2. It was confirmed that the EMC value for the initial desorption is higher than for the second desorption (in the range of RH above 70 %).
3. The EMC values for the initial desorption for investigated tissues are much more dependent on the temperature than in the Wood Handbook data, which does not consider the anomalous properties of the reaction wood.
4. The calculated EMC value corresponding to the initial desorption can verify kiln-drying schedules for beech sawn timber with a high content of reaction tissue. Applying the developed initial desorption models can significantly improve the accuracy of the drying gradient determination. It can be concluded that there is a potential to improve the efficiency and drying quality of beech kiln-drying.

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Corresponding address:

MACIEJ SYDOR
Poznań University of Life Sciences, Faculty of Forestry and Wood Technology, Department of Woodworking and Fundamentals of Machine Design, ul. Wojska Polskiego 28, Poznań, POLAND,
e-mail: maciej.sydor@up.poznan.pl