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Radovan Despot, Marin Hasan, Matija Jug, Bogoslav Šefc[1]

Biological durability of wood modified by citric acid

Biološka otpornost drva modificiranoga limunskom kiselinom

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ABSTRACT • *This paper presents the results of measurement of durability of beech wood (Fagus sylvatica) modified by Citric Acid (CA) against brown rot fungus Poria placenta according to EN 113. Modification was performed by impregnation with 7.0% CA and 6.5% sodium-hypophosphite (SHP) water solution and 10-hour curing at 140 °C. The influence of thermal treatment on durability was also researched. Weight percentage gain (WPG) caused by modification, moisture content (MC) and mass loss of wood (dm) after fungal nutrition were measured. WPG of modified beech wood was 6.1% and that of thermally treated wood was -0.3%. The results showed increased durability of modified wood to be 8.3 times greater than non-modified, while thermal treatment did not give significant durability improvement. These results indicate modification by CA as a promising alternative, but further research on optimisation of modification parameters is needed to achieve improvement of wood properties.*

Key words: *chemical modification of wood, esterification, citric acid, biological durability, Poria placenta, beech wood*

SAŽETAK • *U radu su prezentirani rezultati biološke otpornosti limunskom kiselinom modificiranog drva obične bukve (Fagus sylvatica) protiv gljive Poria placenta, a prema EN 113. Modifikacija je izvedena termokondenziranjem drvenih uzoraka impregniranih vodenom otopinom 7-postotne limunske kiseline (CA) i 6,5-postotnog natrij-hipofosfita (SHP) pri 140 °C. Tijekom prvih pet minuta impregnacije uzorci su vakuumirani, a potom je u operacijski cilindar puštena otopina. Za cijelo vrijeme impregnacije primijenjen je apsolutni tlak od 2 kPa pri temperaturi od 20 °C. Navedeni uvjeti održavani su tri sata, nakon čega je slijedilo potapanje uzoraka u trajanju 18 sati pri atmosferskom tlaku. Uzorci su potom prosušeni u standardnoj klimi tijekom 48 sati, a zatim zagrijavani (termokondenzirani) u sušioniku na temperaturi 140 °C deset sati. Dodatno je kontroliran i sam utjecaj temperature na biološku otpornost. Mjereno je povećanje mase (WPG) zbog modifikacije, sadržaj vode (MC) i gubitak mase (dm) nakon djelovanja gljive. WPG bukovine modificirane limunskom kiselinom iznosio je 6,1%, a samo zagrijanih uzoraka -0,3%. Rezultati su pokazali čak 8,3 puta veću biološku otpornost bukovine modificirane limunskom kiselinom dok samo zagrijavanje nije imalo statistički značajan utjecaj na biološku otpornost. Nakon djelovanja gljiva uzorci modificirani limunskom kiselinom imali su najveći, a kontrolni uzorci najmanji sadržaj vode. Rezultati pokazuju da je modifikacija limunskom kiselinom obećavajuća alternativna metoda u zaštiti drva, no potrebna su daljnja istraživanja optimiranja koncentracija CA i SHP-a u vodenoj otopini, vremena i temperature termokondenzacije radi poboljšavanja željenih svojstava drva.*

Ključne riječi: *kemijska modifikacija drva, esterifikacija, limunska kiselina, biološka otpornost, Poria placenta, obična bukva*

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1 INTRODUCTION
1. UVOD

Research on wood modification mostly deals with the improvement of wood properties i.e. elimination or reduction of limitations of wood as a raw material. Modified wood is expected to be more dimensionally stable, more durable against bluestain and rot fungi, and more resistant to UV radiation in comparison to unmodified wood. Mechanical properties should be unchanged. Ecological and economic feasibility of modification processes and chemicals must also be provided.

Thermal modification is a process where the wood cell wall polymers (especially hemicellulose, less lignin) are destructed to the radicals that repolymerise with OH groups of wood cell wall compounds only by heating. It is mostly conducted in operating cylinder at the temperature between 150 and 260 °C without the presence of oxygen (Rapp and Sailer, 2001; Rep and Pohleven, 2001; Yildiz *et al.*, 2003). Type of heating medium, period of heating, final temperature and wood species are the most important parameters of modification processes (Mitchell, 1988). Dimensional stability and durability against rot-fungi are improved with this type of modification, but some mechanical properties are degraded (Bengtsson *et al.*, 2002; Ladner and Halmschlager, 2002; Hasan and Despot, 2003; Britschke and Rapp, 2004). Thermal modification in vegetable oil has shown to be much better than modification in air atmosphere. In-air-atmosphere thermally-modified wood did not increase biological durability in comparison to non-modified wood. Increased retention of oil in modified wood increases its durability. Durability against moulds and bluestain increases at enhancing modification degree. Paucity of bluestain and mould's mycelium on the surface of modified wood ensures reduced discoloration. The amount of simple carbohydrates decreases and chemical structure of parenchyma cells contents changes during modification so fungal enzymes cannot recognise new structure and became less effective (Feist and Sell, 1987).

Chemical modification implies etherification, esterification or acetylation between some chemical and OH groups of wood. The 1.3 dimetilol 4.5 dihidroksietilen urea (DMDHEU) combined with an adequate catalyst reacts with OH groups of cellulose forming cross-linking between cellulose chains. Important parameters for successful modification by these chemical are temperature, processing time, type of catalyst and wood species. Dimensional stability of wood modified by DMDHEU is increased by 50 to 60% (Militz, 1993; Yusuf *et al.*, 1995). Increased durability is recorded in Pine wood, Asian cedar and Beech wood modified by DMDHEU against *Coniophora puteana*, *Tyromyces palustis* i *Coriolus versicolor* and some other rot fungi. Increased durability is also retained after one circle of leaching (Yusuf *et al.*, 1995). Militz (1993) reported that DMDHEU modification does not comply with other modern preservatives.

Modification by DMDHEU has a problem with releasing formaldehyde from N-methylol bonds by hydrolytic destruction at higher modification temperatures. Because of this problem, scientists are introducing new non-formaldehyde chemicals.

One group of such chemicals is polycarboxylic acids (PCA). The possibility of bonding PCA anhydride with OH groups of lignocelluloses ensures cross-link reaction, good bond stability and durability (Fang *et al.*, 1999). Esterification is a cross-linking reaction between cellulose and PCA. Citric Acid (CA) is widely spread in the nature and it completely satisfies strict ecological and economic requirements.

Šefc *et al.* (2006) have modified fir wood and beech wood by CA. Wood modified by CA and cured by temperature or by microwaves showed improved dimensional stability. Improved dimensional stability significantly decreased after leaching. Beech wood modified by DMDHEU showed similar improvement of dimensional stability as the one modified by CA. Fir and beech wood modified by CA had unchanged compression strength parallel to the grain while micro-tensile strength decreased by 30%. Wood modification by DMDHEU resulted in a 50 to 70% decrease of micro-tensile strength (Šefc, 2006; Xiel *et al.*, 2007). Hasan *et al.* (2006, 2007) reported multiple increasing of biological durability of pine sapwood modified by CA against some rot fungi.

Both of these chemical modifications have the same goal – to improve dimensional stability and biological durability with unchanged mechanical properties. Some studies on the influence of CA modification on physical and mechanical properties of wood have been already done. This paper presents some preliminary results on the weight percentage gain (*WPG*) and improvement of biological durability in lab conditions of beech wood modified by CA.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

Beech wood (*Fagus sylvatica* L.) was used for this research. Beech is commercially the most important wood species in Croatia and due to its very low-durability it is used as a reference wood species in European norms.

Lattices were sawn from wood close to bark of one air-dried and afterwards kiln-dried beech board. All specimens were cut, selected and marked axially and successively according to EN 113 (1996) (R×T×L = 25×15×50 [±0.2 mm]) (Tab. 1).

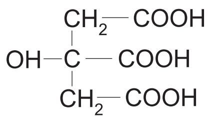
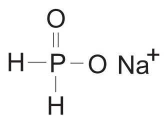
2.1 Chemicals, solutions and modification parameters
2.1. Sredstva, otopine i parametri modifikacije

7.0% water solution of CA with 6.5% sodium-hypophosphite monohydrate (SHP) as a catalyst was prepared for modification. Structural formulas of chemicals used in modification are presented in Table 2. Concentration of CA and SHP were optimised for cellulose modification in textile (Katović *et al.*, 2000)

Table 1 Type of modification, fungus species and number of specimens
Tablica 1. Vrsta modifikacije, vrsta gljive i broj uzoraka

Fungus species *Vrsta gljive*	**Modification type** *Vrsta modifikacije*	**No. of specimens** *Broj uzoraka*
Poria placenta (Fries) Coke sensu J. Erikson	modification by CA (MCA)	7
	Control 1	7
	Air Heat Treatment (AHT)	7
	Control 2	7

Table 2 Structural formulas of chemicals used for modification
Tablica 2. Strukturne formule sredstava upotrijebljenih za modifikaciju

Citric Acid (CA) *Limunska kiselina*	**Sodyum HypoPhosphite monohydrate (SHP)** *Natrij-hipofosfit monohidrat*
	

and applied in this research. Group of specimens was only air heat treated at the thermo-condensation temperature (ATM) and used as the control of possible influence of temperature on biological durability.

2.2 Wood impregnation and modification procedures
2.2. Postupak impregnacije i modifikacije drva

Oven-dried samples (103 ± 2 °C, up to constant mass) were weighed on lab balance (0.1 mg), conditioned at standard climate (20 °C and 65% relative humidity) up to moisture content of 12%. The impregnation cycle consisted of a 5-min initial vacuum of 2 kPa. The vacuum vessel was then filled with the CA+SHP solution and a vacuum of 2 kPa was maintained for 3 h, followed by 18 hours soaking at atmospheric pressure.

MCA and AHT specimens were air-dried at standard climate for 48 hours and afterwards cured at 140 °C for 10 hours in an oven.

2.3 WPG, MC and durability determination
2.3. Određivanje *WPG*, MC i biološke otpornosti drva

WPG of modified specimens was calculated as a ratio of difference of oven-dried mass after modification (m_2) and oven-dried mass before modification (m_1) and m_1 (1).

$$WPG = \frac{m_2 - m_1}{m_1} \cdot 100\ [\%] \tag{1}$$

Determination of biological durability of CA modified wood was done according to EN 113 (1996). Brown rot fungus *Poria placenta* (Fries) Coke sensu J. Erikson was chosen. “Potato dextroze agar (PDA)” by OXOID was used as a nutrient medium.

Moisture content (MC) of wood after fungal degradation was calculated as a ratio of difference of wet mass after exposure to fungi (m_3) and oven-dried mass after exposure to fungi (m_4) and m_4 (2).

$$MC = \frac{m_3 - m_4}{m_4} \cdot 100\ [\%] \tag{2}$$

Mass loss of samples caused by fungal nutrition (dm) was calculated by dividing the difference of oven-dried mass of specimens after fungal nutrition (m_4) and starting mass (m_2) with starting mass (3).

$$\mathrm{d}m = \frac{m_2 - m_4}{m_2} \cdot 100\ [\%] \tag{3}$$

This mass loss percentage dm [%] is the unit that shows the durability – as the dm decreases with the increase of wood durability.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

It is interesting to observe *WPG* of different wood species after the same modification procedures with CA. After the same modification procedure, fir-wood had the highest *WPG*, while the beech-wood had the lowest *WPG*. These data suggest that *WPG* depends on wood density. Air heat treatment (AHT) resulted in almost the same average mass loss of pine and beech wood (Tab. 3).

On one hand, according to Rapp and Sailer (2001), the increase of wood mass loss caused by oil heat treatment (OHT) results in the increase of biological durability of OHT wood. On the other hand, (Rapp and Sailer (2001) and Hasan *et al.* (2006) reported no difference in biological durability between the AHT wood and non-modified controls.

Results of this study confirm no significant difference in biological durability between AHT and control specimens. These results indicate that statistically high significant difference in biological durability of MCA specimens is exclusively the result of cross linking of CA on OH groups of pine sapwood components (Fig. 1).

Table 3 *WPG* of different wood species after modification
Tablica 3. *WPG* različitih vrsta drva nakon modifikacije

Modification type *Vrsta modifikacije*	**Mean value of *WPG*** *Srednja vrijednost WPG-a, %*	**Source** *Izvor*
MCA* Fir	17.9	Šefc (2006)
MCA* Pine	12.43	Hasan *et al.* (2006, 2007)
AHT** Pine	-0.30	
MCA* Beech	6.11	
AHT** Beech	-0.33	

* MCA = 7% CA + 6.5% SHP, 140 °C, 10 hours
** AHT = 140 °C, 10 hours

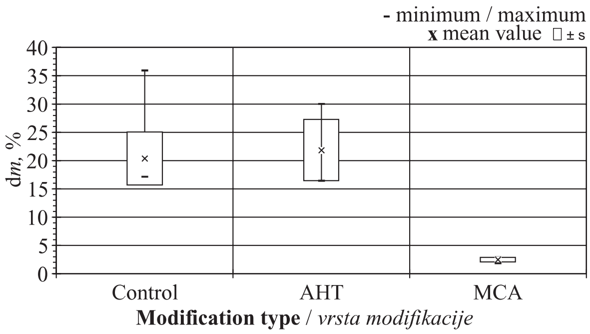


Figure 1 Mass loss (d*m*) of differently modified specimens after 16 weeks of exposure to *Poria placenta* (*n* = 14 for controls, *n* = 7 for AHT and MCA).
Slika 1. Gubitak mase (d*m*) različito modificiranih i kontrolnih uzoraka nakon 16 tjedana izlaganja gljivi *Poria placenta* (*n* = 14 za kontrolne, *n* = 7 za AHT i MCA)

Significant difference in MC between control, AHT and MCA specimens was determined. MC of MCA specimens was the highest. MC of AHT specimens was higher than controls but lower than MCA specimens. Due to influence of thermo-condensation temperature of 140°C thermo unstable hemicelluloses depolymerised. The concentration of simpler sugars increased and the fungus needed more water to attenuate incurred simpler sugars (Fig. 2).

While CA modification of pine sapwood resulted in *WPG* of 12.4% and 5.3 times greater biological durability against some rot fungus (Hasan *et al.*, 2006), MCA beech wood had 8.3 times greater biological durability regardless of the fact that *WPG* of beech wood was twice smaller than *WPG* of pine wood.

Durability against brown rot fungi of beech wood modified with CA and cured at only 140 °C seemed to be better than the OHT pine heated at the temperatures between 180 and 200 °C (Fig. 3).

At increasing *WPG* during chemical modification, biological durability also increases. It is to be expected that *WPG* will increase by optimising parameters of wood modification by CA. In this way biological durability of wood modified by CA could be even more improved.

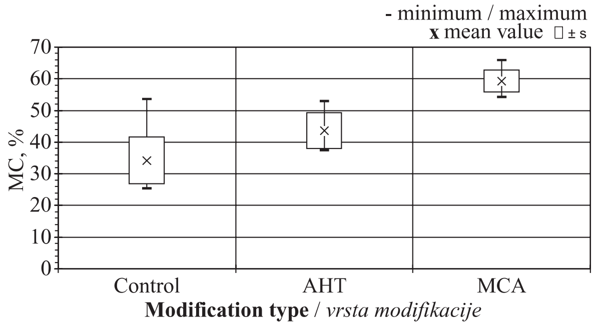


Figure 2 Moisture content (MC) of differently modified and control specimens after 16 weeks of exposure to *Poria placenta* (*n* = 14 for controls, *n* = 7 for AHT and MCA).
Slika 2. Sadržaj vode u drvu (MC) različito modificiranih i kontrolnih uzoraka nakon 16 tjedana izlaganja gljivi *Poria placenta* (*n* = 14 za kontrolne, *n* = 7 za AHT i MCA)

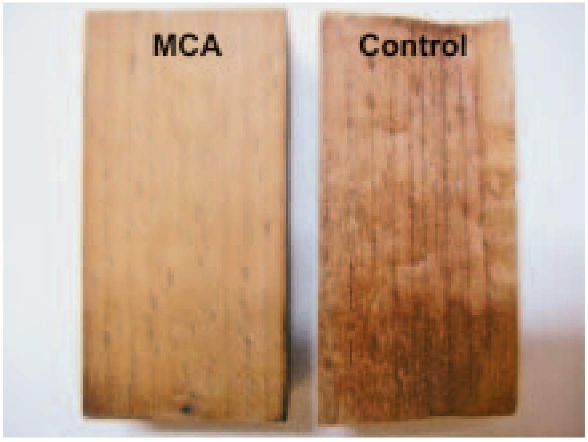


Figure 3 Appearance of specimens after 16 weeks of exposure to fungus *Poria placenta* (MCA = beech wood modified by CA, Control = unmodified beech wood).
Slika 3. Izgled uzoraka nakon 16 tjedana izlaganja gljivi *Poria placenta* (MCA - bukovina modificirana limunskom kiselinom, Control - nemodificirana kontrola)

4 CONCLUSION
4. ZAKLJUČAK

Biological durability of beech wood modified by citric acid (CA) is significantly increased. Weight percentage gain (*WPG*) of 6.1% resulted in an eight time increase of biological durability against brown rot fungus *Poria placenta* in comparison to unmodified controls.

Combining the concentrations of citric acid and catalyst in water solution and by optimisation of impregnation procedure, temperature and time of thermo-condensation it would be possible to optimise the desired wood properties.

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Effect of thermal post-treatment on some surface-related properties of oriented strandboards*

Utjecaj toplinske obrade na neka svojstva površine iverice s orijentiranim iverjem

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ABSTRACT • *A very promising method for improving the dimensional stability of oriented strandboard (OSB) has been studied in Brazil since 2001. According to this method, the OSB is thermally treated under mild conditions using a hot-press, where it is reheated without high level of compression stress. The properties of the treated OSB panels are different from and enhanced compared to those untreated ones. It means that the treated OSB can be used in more severe uses, like concrete formwork. This paper aims to evaluate the effect of the proposed thermal treatment on nail-holding capability and on surface hardness of OSB. Samples from 42 commercials OSB were thermally treated according to two levels of temperature (190°C and 220°C) and three heating times (12, 16 and 20 min) using a single opening hot-press. For comparison, control panels were kept untreated. The following surface-related properties were evaluated: Janka hardness, nail-holding capability in a plane normal to the surface, in the edge of the panel, water absorption and thickness swelling (TS) of edge sealed samples, and four surface roughness parameters. According to the Dunnett test, there were significant differences between treated and untreated panels for nail-holding, dimensional stability and surface roughness. The factorial ANOVA identified that the temperature was the main factor governing these properties while the duration of the treatment had lesser effect. It was concluded that the proposed thermal treatment improved significantly dimensional stability and did not affect adversely the nail-holding capability and surface roughness of the treated OSB.*

Keywords: *oriented strandboard, surface properties, thermal treatment.*

SAŽETAK • *Vrlo obećavajuća metoda za poboljšanje dimenzijske stabilnosti ploča iverica s orijentiranim iverjem (OSB ploča) proučava se u Brazilu od 2001. godine. Prema toj metodi, OSB ploča se obrađuje toplinom u umjerenim uvjetima, uporabom vruće preše, pri čemu se ponovo zagrijava bez velikog pritiska. Svojstva toplinski obrađenih OSB ploča poboljšana su u odnosu prema neobrađenim pločama. To znači da se termički obrađene OSB ploče mogu rabiti i u zahtjevnijim uvjetima, npr. kao betonske oplate. Cilj ovog rada bio je procijeniti utjecaj metode toplinske obrade OSB ploča na čvrstoću držanja čavala te površinsku tvrdoću tretiranih ploča. Uzorci izrađeni od komercijalne OSB ploče toplinski su obrađeni u vrućoj preši na dvije razine temperature (190 °C i 220 °C) i tri vremena zagrijavanja (12, 16 i 20 min). Za usporedbu su uzeti kontrolni uzorci koji nisu obrađivani. Istraživana su*

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ova svojstva površine OSB ploča: tvrdoća prema Janki, čvrstoća držanja čavala u ravnini okomitoj na površinu i na rub ploče, upijanje vode i debljinsko bubrenje uzoraka izoliranih rubova te četiri parametra hrapavosti površine. Prema Dunnett testu, između toplinski obrađenih i neobrađenih ploča postoje signifikantne razlike u čvrstoći držanja čavala, dimenzijskoj stabilnosti i hrapavosti površine. Faktorskom ANOVA analizom ustanovljeno je da je temperatura glavni činitelj koji utječe na poboljšanje svojstava, a da vrijeme zagrijavanja ima manji utjecaj. Može se zaključiti da opisana metoda toplinske obrade znatno utječe na poboljšanje dimenzijske stabilnosti OSB ploča, a ne utječe negativno na čvrstoću držanja čavala i hrapavost površine tako obrađenih ploča.

Ključne riječi: *iverice s orijentiranim iverjem, svojstva površine ploče, toplinska obrada*

1 INTRODUCTION
1. UVOD

The oriented strandboard (OSB) is a wood based panel used mainly for structural purposes. It has very good mechanical, physical and technological properties when compared with other composite panels made of wood particles. In comparison with plywood, OSB has lower mechanical properties, but it has been replacing plywood mainly due to the possibility of using low quality species and logs and low availability of veneer logs.

The OSB dimensional stability is worst than that of plywood: its thickness swelling is 7 to 10 times higher than that of plywood. Consequently it is necessary to improve the OSB dimensional stability to raise its market share. Many researches on treatments for the improvement of dimensional stability have been made and they can be divided in three types according to the stage when they are applied: before panel consolidation (furnish pre-treatment); during hot-pressing (steam injection press, not exactly a treatment); or after pressing (panel post-treatment).

Pre-treatments were evaluated by Paul *et al*. (2006), Pétrissans *et al*. (2003) and Goroyias and Hale (2002) and very good results have been obtained, but some adverse effects are common like decreasing of wood bonding, wood wettability and flexural properties. On the other hand, it is possible to use a post-treatment, as made by Suchsland and Xu (1991), where the board is treated after its consolidation.

A very promising post-treatment to improve the dimensional stability of the oriented strandboard (OSB) has been studied in Brazil since 2001. According to this method, the OSB is thermally treated under mild conditions using a hot-press, where the pressure is applied just to provide contact between press plates and surfaces of the board. The main difference from the well known thermal processes is in using lower temperature, but fast heating by conduction, and shorter time. Consequently, the results obtained so far show an improvement of the dimensional stability by reducing thickness swelling, equilibrium moisture content and permanent thickness swelling, as observed by Del Menezzi and Tomaselli (2006).

It has been observed that the treated OSB has longer service life than the untreated one because it has both higher resistance against fungi and better weathering behaviour as related by Del Menezzi (2006). These improvements could be obtained without any severe effect on mechanical properties, which always happens when wood and wood products are thermally treated for a longer time. Although the post-treatment is recommended to boards produced with thermal-resistant resins (phenol-formaldehyde, isocyanate), recently Okino *et al*. (2007) treated thermally urea-formaldehyde-bonded OSB and encouraging results have been obtained.

Consequently, the properties of the treated boards are enhanced and different from untreated ones. It means that the treated OSB can be used in more severe uses, such as concrete formwork. In this end-use two properties play an important role: nail-holding capability and surface hardness. These properties are not usually determined for wood based panels, but some studies dealing with these properties have been made (Falk *et al*. 2001, Viswanathan and Gothandapani 1999, Lee *et al.* 1996). The lack of that information is especially evident for wood and wood products that have been heat-treated. However, some works have related that thermal treatments can increase the corrosion of fasteners (Jermer and Anderson 2005) and decrease the surface hardness of wood (Brischke *et al*. 2005) or even improve it, depending on how intensive the applied treatment was, as argued by Syrjänen and Kangas (2000).

In this context, the present work aims to raise the technological information about this kind of treated material by evaluating the effect of the proposed thermal treatment on some surface-related proporties, which are important properties mainly when OSB is used in more severe uses.

2 MATERIALS AND METHODS
2. MATERIJAL I METODE

2.1 Wood material
2.1. Uzorci

Samples (50x50x1.25 cm^3) were cut from 42 commercials OSB panels and they had the following characteristics: made from *Pinus* sp, nominal density of 0.64 g/cm^3, three layers, 19 kg/m^3 solid resin (40% di-isocyanate resin on the core layer and 60% on the surface layer). The samples (boards) were kept in a conditioning room (65%; 20°C) until constant mass was reached.

2.2 Thermal treatment
2.2. Toplinska obrada

The thermal treatment was applied using a laboratory single-opening press. The boards were put into the press and repressed and re-heated, but without high level of compression stresses. The pressure was only enough to provide contact between the press plates and both surfaces of the boards. A preliminary study was carried out to evaluate the time needed for heating the boards above 170°C, which was set as the minimum temperature where the compression stresses could be released and some chemical degradation could occur. It is known as viscoelasticity transition temperature (T_g) and the wood matrix above this temperature losses its stiffness. In an OSB industrial plant, the pressing temperature varies from 190°C to 210°C, which is the range needed to promote the resin polymerization. Hence, two temperature levels were chosen: 190°C, industrial minimum; and 220°C slightly above the maximum. The results showed that the boards required at least 590s to reach the set T_g at 190°C and at least 400s at 220°C (Figure 1). It meant that the minimum treatment should be 8 minutes, provided that the board's temperature was kept for a certain time to release the compression stresses. The interval of at least 4 minutes was chosen, which was added to the required minimum.

Consequently, the boards were treated according to the following schedule: two temperature levels, 190°C and 220°C, during 12, 16 and 20 minutes. For

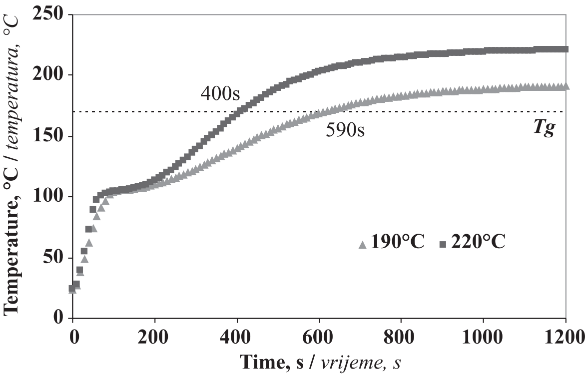

Figure 1 Temperature increase in the board when it is treated at 190 °C and 220 °C
Slika 1. Porast temperature u ploči kada se zagrijava na 190 °C i 220 °C

each temperature-time combinations, six boards were thermally treated and additional six boards were kept untreated (control samples), totalling 42 boards (Table 1). After the thermal treatment, the boards were returned to the conditioning room to cool down and to reach constant mass.

Table 1 Experimental design
Tablica 1. Podaci o eksperimentu

Treatment *Obrada*	**Temperature, °C** *Temperatura, °C*	**Time, min** *Vrijeme, min*	**Number of boards** *Broj ploča*
Control	-	-	6
T1	190	12	6
T2	190	16	6
T3	190	20	6
T4	220	12	6
T5	220	16	6
T6	220	20	6

2.3 Mechanical and dimensional stability properties
2.3. Mehanička svojstva i dimenzijska stabilnost

The following mechanical and dimensional stability properties were evaluated according to the ASTM D1037 (1999): nail-holding capability in a plane normal to the face (F⊥) and in the edge of the panel (E//), Janka hardness (JH), water absorption (WA) and thickness swelling (TS) after 2 and 24 hours. Both nail-holding tests were carried out on the same sample. To achieve the minimum thickness for the JH test, two pieces had to be glued so as to produce one sample. For each property, two samples were tested from each board, totalling 84 samples. For WA and TS, the four sample edges were sealed with wax, so that liquid water could only penetrate through the surface of the samples.

2.4 Surface roughness measurement
2.4. Mjerenja hrapavosti površine

The measurement of the surface roughness was carried out using the Surftest SJ-301 (Mitutoyo). It is a stylus type instrument which traces the minute irregularities of the board. The surface roughness is determined from vertical stylus displacement produced during the detector traversing over the surface irregularities (Mitutoyo, 1999). The device was set to measure surface roughness according to JIS (2001) and the evaluation length was 12.5 mm. The following surface roughness parameters were determined: R_a, the arithmetic mean of the absolute values of the profile deviations from the mean line; R_q, the square root of the arithmetic mean of the square of profile deviations from the mean line; R_z, sum of the mean height of the five highest profile peaks and the depth of the five deepest profile valleys measured from a line parallel to the mean line; R_t, the sum of the maximum profile peak height and the maximum profile valley depth over the evaluation length.

2.5 Statistical analysis
2.5. Statistička analiza

Initially the comparison between the treated and control board was evaluated for each mechanical property by running Dunnett test at 5% probability level. This test compares the means of the control and treated board, pair to pair, instead of comparing the whole treatments. To evaluate the effect of temperature (T_p), time (T_m) and its interaction (T_p x T_m), a factorial (3 x 2 levels) analysis of variance (ANOVA) was run without control values.

3 RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

3.1 Comparison between control and heat treated boards
3.1. Usporedba kontrolnih i toplinski obrađenih ploča

Figure 2 presents the results of the properties of both control and treated boards. As shown in this figure, JH of the treated boards had slightly lower values than those observed for control boards, but the Dunnett test failed to identify these differences as statistically significant. The board moisture content was about 9.2%. It is well known that thermal treatment makes wood more brittle and degrades wood polymers of the cellular wall causing mass loss. These effects increase proportionally to the treatment temperature and length and if carried out in the presence of oxygen, as argued by Militz (2002). Brischke *et al*. (2005) observed decreasing of the Brinell hardness of thermally treated silver fir and beech wood. The higher the mass loss, the lower the Brinell hardness.

The thermal treatment was applied under comparatively mild conditions in comparison with to the well known thermal wood processes, such as: opened system, atmosphere pressure, low moisture content and fast heating. Recently, Okino *et al*. (2007) applied the same thermal treatment on UF-bonded OSB and JH values were also slightly lower, although not statistically. According to Del Menezzi (2004) the permanent mass loss for this process is less than 5%, and it is much lower than those observed in others processes, which can explain the results observed here.

On the other hand, according to Figure 2 the treatment seems to be suitable for OSB because of the improvement of both F⊥ and E//. However, these improvements were statistically significant only for the boards treated at 220°C, while at 190°C the values observed were similar to those of control boards. Some explanation of these results can be given.

It is well known that wood based particle/fibre products like OSB, PB and MDF have unequal distribution of density through the thickness: higher density on the surface, while on the core it is lower. This characteristic is called vertical density profile (VDP) and is generated during hot-pressing. As the surface layers are hotter than the core layer during the early stages of hot-pressing, it is compressed more intensively because of the stiffness loss of the wood matrix, while on the core it remains still stiffer and is compressed in this way later.

It can be said that the thermal treatment used here acted as a re-pressing stage and it could improve the density of the surface layers. The F⊥ test was carried out on nail driven through the sample from surface to surface, and in this way those higher density regions probably helped to retain the nail, improving their values. It can also be supposed that some core densification took place because of the improvement of E// values. Nevertheless, these suppositions cannot be used to explain the observed JH values as well.

Figure 3 presents the results of the dimensional stability properties. The results of the physical properties indicated that the method provided an improvement of the dimensional stability of the treated panel. It can be observed that WA and TS were positively affected by the thermal treatment and that the dimensional stability of the treated board could be achieved. However, the improvement of the dimensional stability was more evident in longer contact with water (24h). It seems that for shorter water exposure (2h) the thermal treatment was not effective in reducing WA. For longer water exposure (24h), WA could be reduced only when higher treatment temperature was used. On the other hand, for both 2h and 24h of water exposure the TS values were reduced even when a lower temperature was applied. The values of TS2h were reduced up to 51%, and for TS24h to 55%

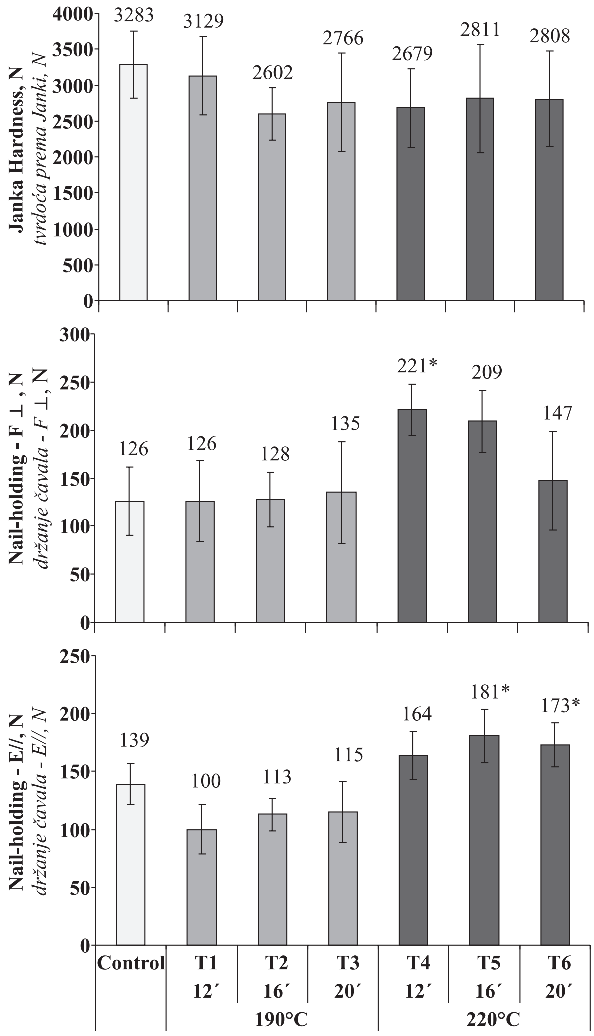

Figure 2 Janka hardness and nail-holding capability of control and thermally treated OSB (* statistically significant according to Dunnett at 5% probability)
Slika 2. Tvrdoća prema Janki i čvrstoća držanja čavala kontrolnih i toplinski obrađenih OSB ploča (* statistički signifikantno prema Dunnett testu na razini signifikantnosti 5%)

The results of surface roughness parameters are presented in Figure 4. The effect of the proposed thermal treatment was not as clear as for dimensional stability properties. Consequently, according to the Dunnett test only the treatments T2 and T4 were positively affected by the thermal treatment. For these groups the parameters R_a, R_q and R_z were reduced, which means an improvement of the surface quality. R_t was not affected by the thermal treatment.

3.2 Effect of temperature and time
3.2. Utjecaj temperature i vremena zagrijavanja

The results of factorial ANOVA are presented in Table 2. As expected, JH and WA-2h were not affected by the treatment, while F⊥, E//, WA-24h, TS-2h and TS-24h were. For the fastening properties, it can be said that only temperature affected the results and the higher it was, the higher were both nail-holding capacities.

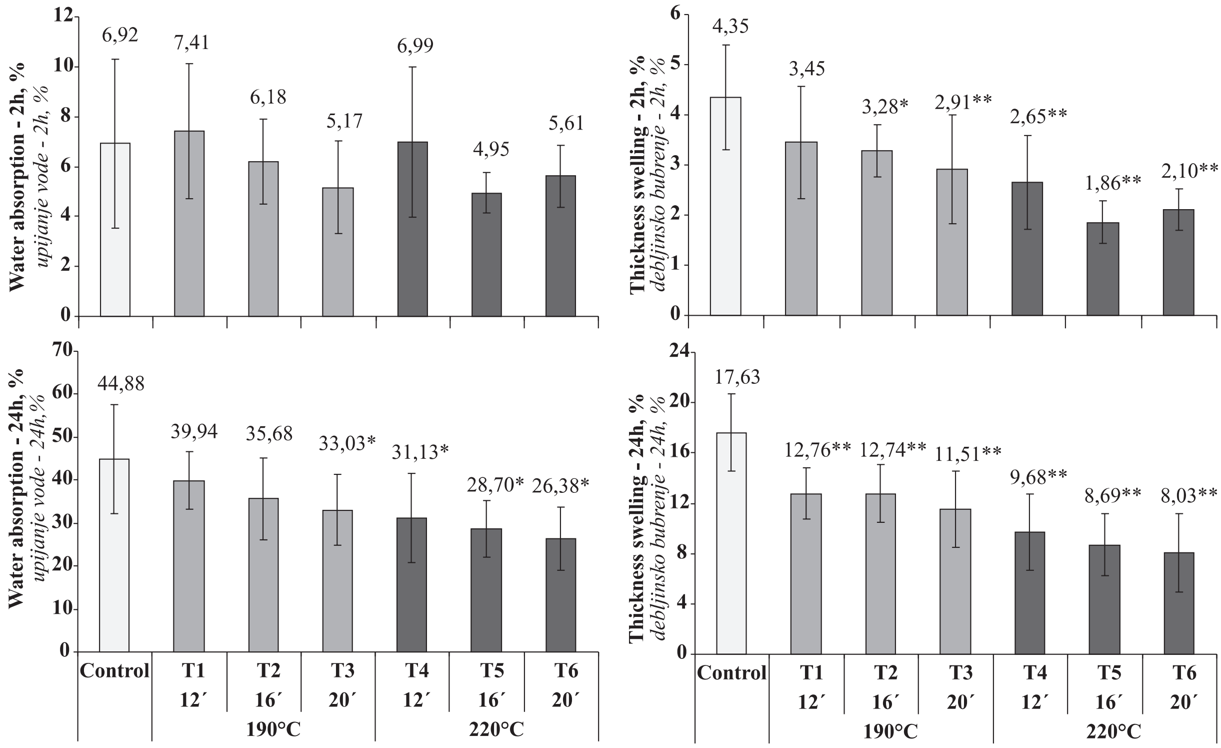

Figure 3 Dimensional stability of control and thermally treated OSB (**,* statistically significant according to Dunnett at 1% and 5% probability)
Slika 3. Dimenzijska stabilnost kontrolnih i toplinski obrađenih OSB ploča (**, * statistički signifikantno prema Dunnett testu na razini signifikantnosti 1 i 5%)

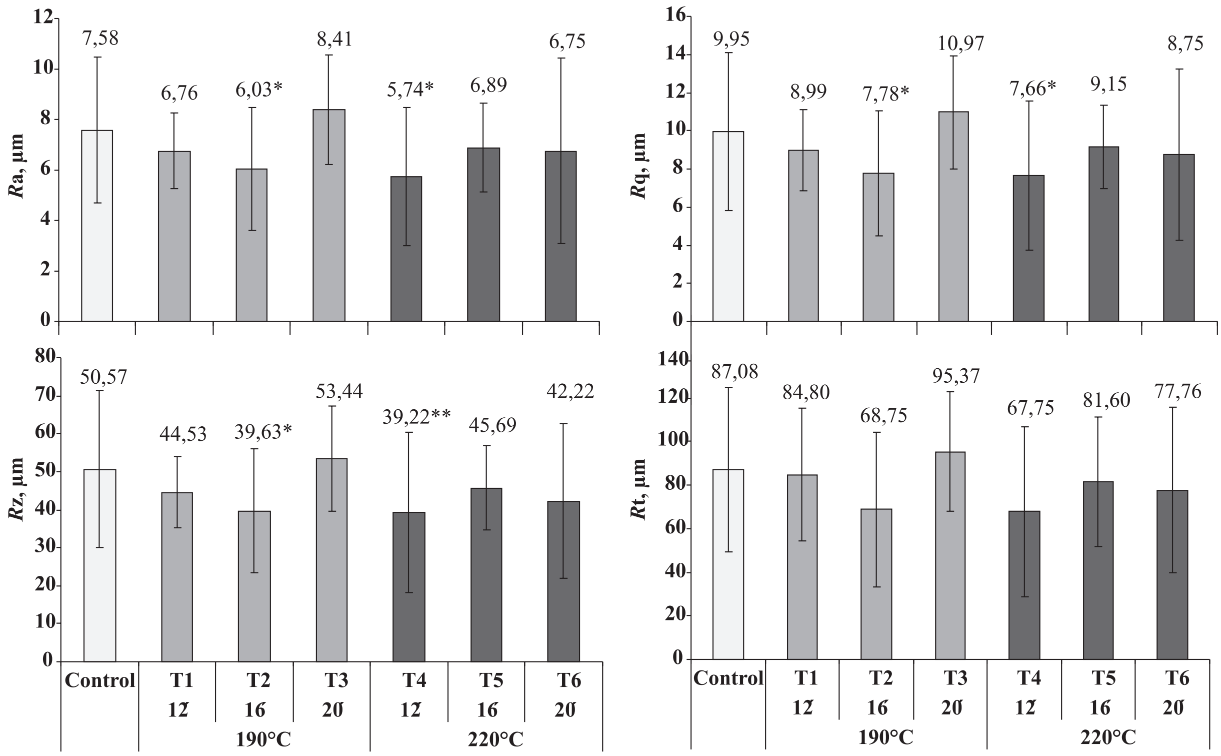

Figure 4 Surface roughness parameters of control and thermally treated OSB (**,* statistically significant according to Dunnett at 1% and 5% probability)
Slika 4. Parametri hrapavosti površine kontrolnih i toplinski obrađenih OSB ploča (**, * statistički signifikantno prema Dunnett testu na razini signifikantnosti 1 i 5%)

The dimensional stability properties were affected by treatment temperature, while TS-2h was also affected by treatment time.

Consequently, utilization of the higher temperature improved the dimensional stability of the OSB. For TS-2h the longer the treatment the lower the observed

Table 2. Summary of the factorial ANOVA analysis of variance for properties affected by thermal treatmen
Tablica 2. Sažeti podaci faktorske analize ANOVA varijanci za svojstva na koja utječe termička obrada

	Temperature – T_p *Temperatura*		**Time – T_m** *Vrijeme*		**T_p x T_m**	
Property *Svojstvo*	***F***	**Significant** *Signifikantno*	***F***	**Significant** *Signifikantno*	***F***	**Significant** *Signifikantno*
Janka hardness *Tvrdoća prema Janki*	0.054	0.817	0.742	0.480	2.169	0.123
Nail-holding - Face ⊥ *Držanje čavala – površina ploče ⊥*	5.091	0.028*	0.525	0.594	0.865	0.426
Nail-holding - Edge // *Držanje čavala – rub ploče //*	16.604	0.000**	0.353	0.704	0.042	0.959
Water absorption – 24h *Upijanje vode – 24h*	13.444	0.001**	3.295	0.043	0.183	0.834
Thickness swelling – 2h *Debljinsko bubrenje – 2h*	30.483	0.000**	5.728	0.005**	2.725	0.073
Thickness swelling – 24h *Debljinsko bubrenje – 24h*	28.188	0.000**	2.478	0.092	0.242	0.786
*R*a	11.958	0.007**	3.726	0.030*	3.077	0.053
*R*t	1.593	0.212	1.847	0.166	3.373	0.041*
*R*q	1.596	0.211	2.972	0.059	3.576	0.034*

***, * significant at the level α=0.01 and α=0.05*
***, * Signifikantno na razini signifikantnosti α=0,01 i α=0,05.*

value. In fact, for thermal treatments the temperature has been identified as a very important factor affecting the extent of changes in thermally treated wood (Del Menezzi 2004, Militz 2002, Syrjänen and Kangas 2000).

It is well-know that utilization of high temperature has a positive effect on dimensional stability and an adverse effect on mechanical strength. None of the evaluated mechanical properties were affected by time and this agrees with the study previously done by Del Menezzi (2004) who evaluated several mechanical properties of thermally treated OSB. It means that if even a shorter treatment were applied (12 min.) it would be already possible to improve these properties.

Within surface roughness properties only *R*a was affected by temperature and time of the treatment separately. In general, severe treatment (higher temperature) contributed to the improvement of the surface quality by reducing roughness. On the other hand, *R*t and *R*q were affected by the interaction between temperature and time of the thermal treatment. It means that the temperature effect depends on the time of the treatment. Figure 5 presents this behaviour. For *R*q parameter, at 190°C the longest treatment improved the quality of the surface, whereas at 220°C an opposite pattern was identified. However, the behaviour was not so clear for *R*t, but it might be concluded that at both temperatures the prolongation of the treatment had an adverse effect on the surface quality.

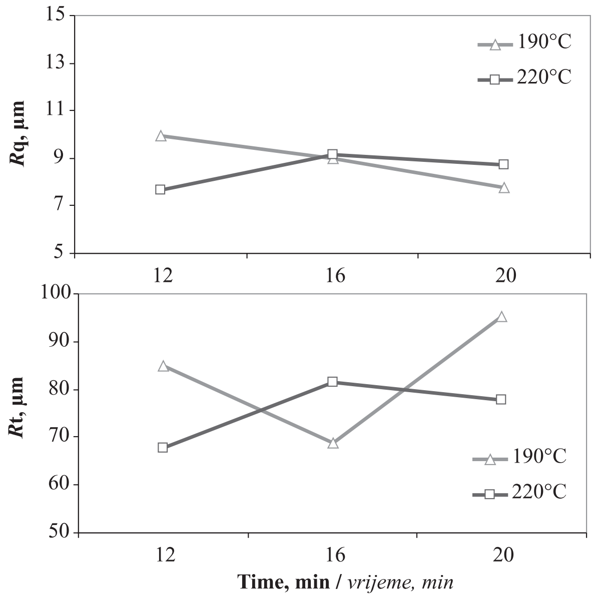

Figure 5 Combined effect of temperature and time of thermal treatment on *R*q and *R*t surface roughness parameters of OSB
Slika 5. Kombinirani učinak temperature i vremena zagrijavanja na parametre *R*q i *R*t hrapavosti površine OSB ploča

4 CONCLUSIONS
4. ZAKLJUČAK

Significant differences between treated and untreated boards for nail-holding, dimensional stability and surface roughness were identified. The temperature was the main factor governing these properties modifications while the duration of the treatment had less effect. It was concluded that the proposed thermal treatment improved significantly dimensional stability and did not affect adversely the nail-holding capability and surface roughness of the treated OSB, and could even improve it. The results for the nail-holding and surface hardness confirm those obtained for other previously investigated mechanical properties. Additional tests will be made to evaluate the effect of this thermal treatment on joints made with others fastenings.

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Dimensional stability of heat treated wood floorings

Dimenzijska stabilnost podnih obloga od pregrijanog drva

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ABSTRACT • *Heat treated wood (HTW) is successfully applied for floorings due to its better moisture resistance, increased dimensional stability, and uniform colour change to darker, brownish colours.*
The aim of this work was to define the hygroscopic range and equilibrium moisture content at ambient conditions of heat treated wood of two wood species – ash and beech. Material was treated at two temperature levels, 190 and 210 °C, and the properties were compared with native wood. The reduction in dimensional changes is expressed by volumetric shrinking and Anti Shrink Efficiency (ASE). Additionally, parquet elements were made out of such HTW, oil-impregnated and waxed, and subsequently tested for water vapour and liquid water permeability.
Shrinking gradients of HTW were not reduced in comparison with native beech wood, but the absolute reduction in water uptake resulted in cca 50 % lower EMC values and up to cca 60 % improved ASE values. Surface treatment further improved the hygroscopic properties of HTW.

Key words: *heat treated wood, parquet elements, dimensional stability, beech, ash*

SAŽETAK • *Pregrijano se drvo uspješno primjenjuje za podne obloge zahvaljujući smanjenoj higroskopnosti, boljoj dimenzijskoj stabilnosti te ravnomjernoj promjeni boje u tamnije smeđe tonove.*
Cilj je ovog rada utvrditi higroskopski raspon i ravnotežni sadržaj vode pri sobnim uvjetima za dvije vrste pregrijanog drva za parket – za jasenovinu i bukovinu. Uzorci su tretirani pri dvije temperaturne razine – 190 i 210 °C, a svojstva uspoređena s nativnim drvom. Smanjenje dimenzijskih promjena izraženo je kao poboljšanje dimenzijske stabilnosti (engl. Anti Shrink Efficiency – ASE). Nadalje, od proba pregrijanog drva načinjene su parketne daščice, tretirane parketnim uljem i voskom, te testirane na vodoupojnost i paropropusnost.
Koeficijenti utezanja pregrijanog drva nisu smanjeni u usporedbi s nativnim, ali je apsolutno smanjenje vodoupojnosti za 50% rezultiralo povećanjem dimenzijske stabilnosti za 60%. Površinska je obrada dodatno poboljšala higroskopna svojstva pregrijanog drva.

Ključne riječi: *pregrijano drvo, parketni elementi, dimenzijska stabilnost, bukovina, jasenovina*

1 INTRODUCTION
1. UVOD

Heat treated wood is a material with changed chemical composition, cell wall structure and physical properties. The process is generally conducted under the influences of heat and pressure. Temperature during thermal treatment usually ranges from 120 °C to 280 °C, treatment time spans between 15 minutes and 24 hours, depending on the type of the process, wood species, stock

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dimensions, initial moisture content, and the desired level of alteration of mechanical properties, resistance against biological deterioration, and dimensional stability of the product (Emmler and Scheiding, 2007). The presence of air or other oxidative medium can accelerate the degradation process of wood components during heat treatment and this is why the process is usually carried out in a protective gaseous medium (nitrogen, steam, CO_2) or immersed in various oils (Rep and Pohleven, 2001). Changes in cell wall chemistry cause the reduction of water uptake (Metsä-Kortelainen *et al.*, 2006) and, consequently, improvement in dimensional stability. Heat treatment of wood increases its moisture resistance, improves dimensional stability, enhances resistance against biological deterioration, and contributes to uniform colour change from original to dark brownish tones (Kollmann *et al.* 1975; Hill, 2006). This material also exhibits some shortcomings, such as reduced tensile and bending strength (which are not so relevant for flooring applications), unstable colour in exterior exposure (unless the surface is coated), appearance of surface checking and increased brittleness. From technological point of view, embrittlement results in appearance of fine irritating dust and rough, splintery edges during machining. Besides, after thermal treatment some wood species have a burnt smell for months. Heat treatment process was developed with the intention to use cheep softwoods for cladding and decking in outdoor use. At the beginning of the application of this method, the colour change was considered as a disadvantage. Nowadays, on the contrary, it is regarded as one of the main arguments for the application of this technology, because species with natural irregularities, like coloured heartwood of beech and ash, turn to aesthetically and technically valuable products when heat treated (exclusive parquet). It is especially attractive to use heat treated wood for parquet since it is possible to obtain different dark brownish colours by varying the process parameters. Furthermore, heat treated wood can be used as a substitute for tropical species (Sundquist, 2004). Better dimensional stability in variable climatic (room) conditions is an additional reason for the use of this material for parquet production.

Equilibrium moisture content of heat treated specimens after 3 years of natural exposure was 40 – 60 % lower compared to untreated wood, regardless of surface protection system, which indicates permanent improvement in dimensional stability (Jämsä and Viitaniemi, 2001). However, Arnold (2007) showed that the improvement in dimensional stability does not correlate well with the form stability of HTW elements. In other words, although HTW parquet will shrink and swell considerably less, it will still cup and twist due to the same ratios of radial to tangential properties as would native wood do. Heat treated wood is an excellent substrate for finishing as it is dry and free of resin which run out during heating. At temperatures above 180 °C oils and waxes are extracted from sapwood and later they cause no problems with adhesion (Jämsä and Viitaniemi, 2004).

The aim of this work was to define the hygroscopic range (determine the fibre saturation point, FSP) and equilibrium moisture content of heat treated wood prepared for parquet elements out of two wood species – ash and beech, heated at two temperature levels, 190 and 210 °C. The reduction in dimensional changes of heat treated wood compared to untreated wood was expressed by volumetric shrinking. Additionally, parquet elements were made out of such HTW, oil-impregnated and waxed, and subsequently tested for water vapour and liquid water permeability.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Specimen preparation
2.1. Priprema uzoraka

For the experimental purposes 10 replicates were prepared to form a sample of each of the following variables: wood species, ring orientation (structure), and treatment level, according to Table 1. Material for testing was commercially heat treated wood for two local parquet manufacturers at two temperature levels – *mild* at 190°C, and *intensive* at 210°C in water vapour atmosphere.

Laboratory tests implied weight measurements, along with length and width measurements in three pre-defined positions on every sample, using electronic

Table 1 Specimen preparation scheme
Tablica 1. Shema pripreme uzoraka

		Mark *oznaka*	**Texture** *tekstura*
Ash *jasenovina*	Native *prirodna*	A.N	radial *radijalna*
			tangential *tangentna*
	Heat treated - mild / *blago pregrijana*	A.HM	radial *radijalna*
			tangential *tangentna*
	Heat treated - intensive *jako pregrijana*	A.HI	radial *radijalna*
			tangential *tangentna*
Beech *bukovina*	Native *prirodna*	B.N	radial *radijalna*
			tangential *tangentna*
	Heat treated - mild *blago pregrijana*	B.HM	radial *radijalna*
			tangential *tangentna*
	Heat treated - intensive *jako pregrijana*	B.HI	radial *radijalna*
			tangential *tangentna*

calliper with the resolution of 1/100 mm. Separate panels of tangential and radial structure were used for measurements of dimensional changes over their width.

Since water uptake properties of HTW were unknown (no indication as to the time needed for specimen to achieve the fibre saturation point), the preliminary test with vertically immersed specimens was conducted during several days. Initially the specimens were vertically immersed (their end grain facing down) up to cca 1/3 of their height, the next day up to 2/3, and third day completely covered with water. The purpose of such procedure was to enable efficient capillary draw and a uniform, complete saturation. To avoid their floating, the specimens were loaded with weights. After seven days the HTW blocks still exhibited tendency to float, but since their dimensions stopped changing, it was concluded that the cell walls were fully saturated at that point. All the panels in the main test were subsequently water-saturated following such procedure. After complete water-logging, the specimens were taken out from the water and stored in a climate chamber (50 ± 5 % r.h. / 23 ± 2 °C) to dry. Their dimensions and weight were measured after 2, 4 and 7 days. Finally, the panels were oven-dried at 103 ± 2 °C to constant mass (48 hrs) and ultimately measured in dry condition. The values in absolute dry condition were used as references for determination of equilibrium MC levels during conditioning.

Water – vapour and liquid water permeability were determined on native and heat treated ash specimens. The samples were prepared as uncoated panels and panels treated with commercial flooring oil and wax. All surfaces of the panels but the faces were coated with two coats of extremely impermeable 2K epoxy paint. Faces of the specimens were amply treated with flooring oil (Lobasol HS Akzent 100 Oil) for 30 minutes, when the excess liquid was removed with a soft cloth. After 24 hours' drying, the samples were treated with flooring wax (Lobasol HS Akzent 100 Wax). Thin wax was gently applied and rubbed in the wood until the surface remained dry and polished. After further 24 hours, the tests were performed according to EN 927-4 and EN 927-5. They generally consist of weighing the panels before and after exposure to liquid water (for 72 hrs) or high air humidity (for two weeks) to establish the amount of absorbed water through the panel face.

2.2 Calculation
2.2. Izračun

Fibre saturation point (FSP) was estimated in such specimen condition when their dimensions reached their maximum after soaking. After complete saturation and through gradual drying period, to final oven-drying, the relation was determined between the moisture content and corresponding dimensions in various stages of the hygroscopic range. In this way five points were obtained on a straight line of the MC-dimension diagram. A point where the straight MC - dimension line intercepts the value of maximal dimensions (D_{max}, MC_{max} parallel with abscissa in Figure 1) defines the estimated fibre saturation point (FSP).

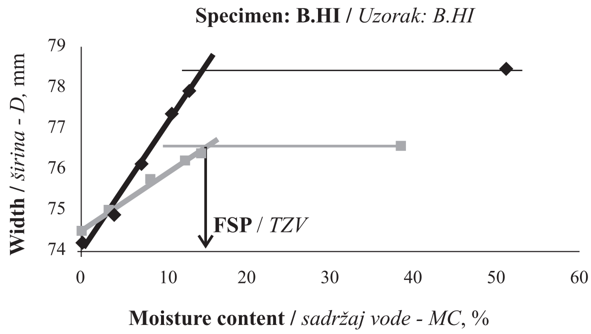

Figure 1 Estimation of fibre saturation point
Slika 1. Određivanje procijenjene tokče zasiećnosti vlakanaca

The value of shrinking β represents the ratio of the difference between the dimensions of fully saturated wood (D_v) and those of absolutely dried wood (D_0) compared to fully saturated D_v wood, and it was calculated according to equation

$$\beta(\%) = \frac{D_v - D_0}{D_v} \cdot 100 \qquad (1)$$

Volume shrinking (β_v) was calculated as a product of linear dimensional changes on separate radial and tangential texture samples, since it allowed to get more precise dimension measurements over the width of the specimens. It was calculated according to the equation

$$\beta_v = \beta_r + \beta_t + \beta_l - \beta_t \cdot \beta_r \qquad (2)$$

Anti-Shrink Efficiency (ASE) (Rowell, 2005) was calculated on the basis of shrinkage of native (β_o) and heat treated wood (β_p).

$$ASE(\%) = \left(1 - \frac{\beta_p}{\beta_0}\right) \cdot 100 \qquad (3)$$

Linear shrinking gradients (shrinking in radial or tangential direction per 1 % moisture decrease) were calculated according to the formula (Kollmann and Cote, 1968):

$$\beta_c(\%/\%) = \frac{\Delta\beta}{\Delta MC}$$

Where β_c – linear shrinking gradients
$\Delta\beta$ – difference of shrinking
ΔMC – difference of moisture content

3 RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

Figure 2 shows that the estimated fibre saturation point (FSP) values are somewhat higher than those quoted in the reference literature for samples of native wood. These values are higher for ca 10% MC and 4% MC for beech and ash, respectively). FSP of mild heat treated beech samples is about 50% lower compared to native wood, and intensive heat treated wood shows about 70% lower FSP value. Mild heat treated ash exhibits for about 35% lower FSP, and intensively treated about 40%. This

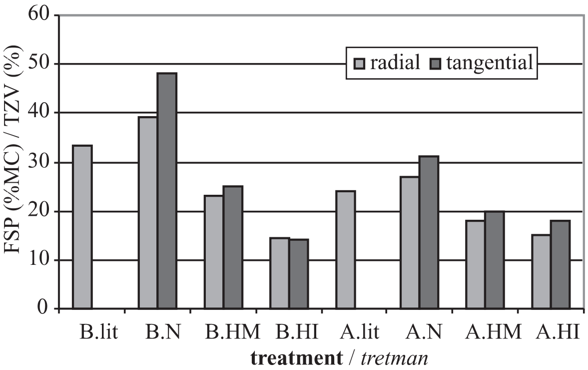

Figure 2. Fibre saturation point (FSP) for beech and ash for two treatment intensities (Marks on abscissa listed in Table 1, *lit* mark refers to literature values (Horvat and Krpan 1967))
Slika 2. Točka zasićenosti vlakanaca (TZV) bukovine i jasenovine za dva stupnja pregrijavanja (oznake na apscisi objašnjene su u tablici 1, osim oznake lit, koja predočuje vrijednost iz literature (Horvat i Krpan, 1967)

means that the intensity of the treatment (level of temperature, duration and other parameters) influences the intensity of changes, but that different species do not react equally to the regime parameters.

Measured equilibrium moisture content (EMC) (Figure 3) at room conditions (23±2 °C and 50±5% relative humidity, RH) amounts to 8% for native beech, and 10% for ash, while the reference literature value is 9% (Kollmann and Côté, 1968). Mild treated beech exhibits 15% lower EMC, mild treated ash 35%, while both intensive treated species attain nearly 50% lower EMC than native wood (EMC value for beech is reduced to 3.5%, and for ash to 5%). This means that in the same ambient conditions the heat treated wood absorbs almost 50% less water which, of course, affects the reduction in dimensional changes, but also aggravates the reliable measurements with electrical moisture meter. It is interesting to see that the EMC, established on tangential panels, exhibits a fraction higher values than those determined on radial samples, although both sets of panels were conditioned to constant mass. This behaviour and its delicate measurement will form an additional experimental work.

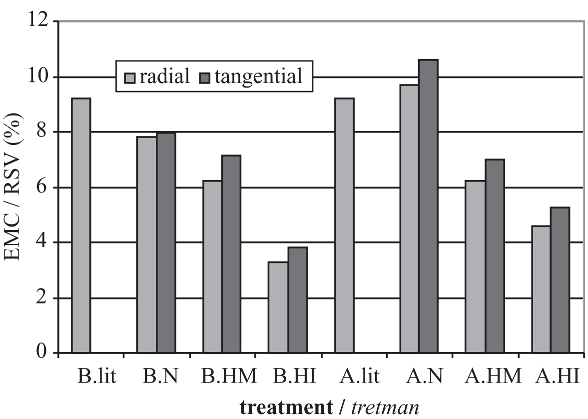

Figure 3 Equilibrium moisture content (EMC) at ambient conditions for beech and ash, for two levels of treatment intensities
Slika 3. Ravnotežni sadržaj vode (RSV) pri sobnim uvjetima za bukovinu i jasenovinu uz dva stupnja pregrijavanja

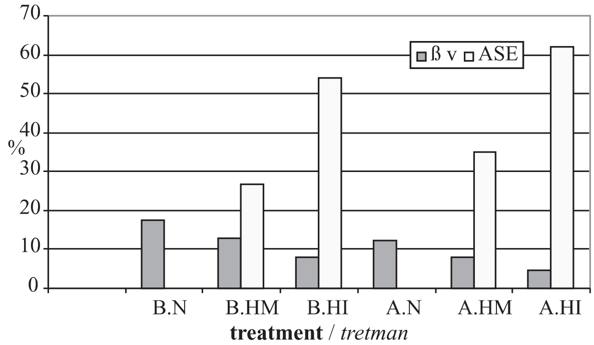

Figure 4 Volume swelling (β_v) and anti-shrink efficiency (ASE)
Slika 4. Volumno bubrenje (β_v) i poboljšanje dimenzijske stabilnosti (ASE)

Reduction in shrinking (Figure 4) results in better dimensional stability of heat treated wood, expressed as Anti-Shrink Efficiency (ASE). Heat treating at lower temperature (190 °C) resulted in improvement of dimensional stability of 27% for beech and of 35% for ash, while treatment on higher temperature (210 °C) resulted in better dimensional stability of 54% for beech and even 62% for ash samples.

Both sets of beech radial samples (mild and intensive treated) exhibit about 10% greater radial shrinking gradients than the native wood (Figure 5). In tangential direction the difference is greater, and heat treated wood exhibit significantly (up to 50 %) greater gradients. This means that shrinking at one percent change in moisture content is even greater with HTW than with genuine beech wood. On the other side, mild treated ash samples exhibit ca 40% reduction, and intensive treated about 60% reduction of partial shrinking gradients compared to untreated wood. Therefore, the shrinking gradient proves to be an irregular and not realistic parameter for the expression of dimensional properties and stability of HTW. Apparently, shrinking gradients were not much altered by heating treatment, but since the absolute values of water uptake and dimensional changes are much smaller than with native wood, overall dimensional stability of HTW is improved.

An additional aspect of dimensional changes, noted previously by Arnold (2007), about the ratio of radial to tangential properties being nearly the same as with the native wood, has been noticed here as well (Figure 5). It has some importance for the use of HTW for

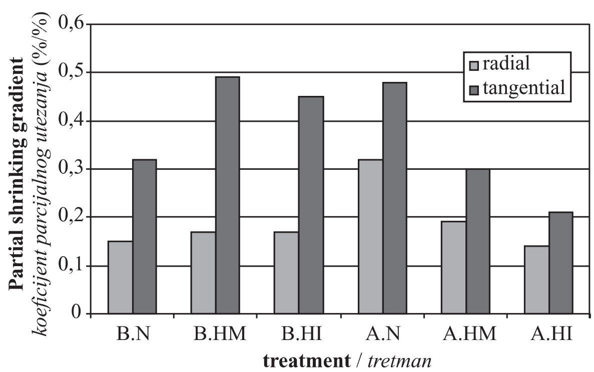

Figure 5 Partial shrinking gradient
Slika 5. Koeficijent parcijalnog utezanja

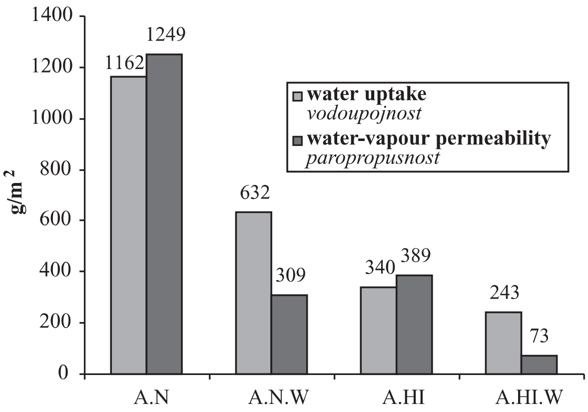

Figure 6. Liquid water and water-vapour permeability of ash wood according to EN 927-5 and EN 927-4 (W means waxed)
Slika 6. Vodoupojnost i paropropusnost javorovine prema EN 927-5 i EN 927-4 (W znači voštano)

flooring, indicating that although the dimensional changes of HTW may be much smaller, the distortions of elements due to the R/T ratio will be similar as with the native wood. Therefore the flooring elements of HTW may exhibit better dimensional stability than native wood elements, but not better shape stability in conditions of changing humidity.

Oiling and waxing significantly affects the hygroscopic properties of parquet elements, reducing the vapour uptake to approximately 25% of that of genuine wood (Figure 6). The effect is even better pronounced with HTW than with native wood, where the vapour uptake during 14 days in humid (>98% r.h.) conditions amounted to only about 70 g/m^2 or 20% of the value of genuine wood. Liquid water uptake was not affected to that level by heat treatment, but the comparison of Figures 3 and 6 shows that the reduction of absolute water uptake is substantially greater than could be concluded by the reduction of EMC values when surfacing is applied on HTW.

4 CONCLUSION
4. ZAKLJUČAK

The results of laboratory test show that the heat treated wood, when compared to genuine wood, exhibits a significant reduction of fibre saturation point (up to 15% in average), lower equilibrium moisture content in room conditions (3.5 to 5%), and improvements in dimensional stability (up to 60%) expressed as ASE. This applies to both wood species, but it should be mentioned that better effects were achieved with ash than with beech samples. Higher level of treatment temperatures yielded proportionally greater stabilization effects. Water vapour and liquid water uptake can be reduced by 70%, and simple oiling and waxing of parquet surfaces further contributes to better performance of HTW in humid conditions. Although the flooring elements of HTW may exhibit better dimensional stability than native wood elements, the ratio of radial to tangential properties remains nearly the same. Therefore, the distortions of HTW elements due to the R/T ratio will be similar as with the native wood, exhibiting similar shape stability as native flooring elements in conditions of changing humidity.

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LABORATORIJ ZA ISPITIVANJE NAMJEŠTAJA I DIJELOVA ZA NAMJEŠTAJ

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Properties of blue-stained wood

Svojstva drva zaraženoga gljivama plavila

Preliminary paper · Prethodno priopćenje
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ABSTRACT • *Discoloration of wood is frequently caused by blue-stain fungi. Among them Aureobasidium pullulans and Sclerophoma pithyophila are reported as the most important staining organism. In previous researches, it was generally considered that blue-stain fungi do not influence mechanical properties. However, there were some opposite results published as well. In order to elucidate this issue, specimens made of Scots pine (Pinus sylvestris) sapwood were exposed to two blue stain fungi A. pullulans and S. pithyophila for periods between two and eight weeks. FTIR, weight, colour and non-destructive modulus of elasticity measurements were performed before and after exposure. The results showed that blue stain fungi, besides considerable discoloration, do not cause any significant damage to wood. Surprisingly the non-destructive MoE analysis showed that modulus of elasticity even slightly increase after fungal exposure.*

Keywords: *Aureobasidium pullulans, colour, FTIR, modulus of elasticity, Pinus sylvestris, sap-stain, Sclerophoma pithyophila*

SAŽETAK • *Promjeni boje drva često uzrokuju gljive plavila. Među tim gljivama najpoznatije su Aureobasidium pullulans i Sclerophome pithyophila. U dosadašnjim radovima prevladavalo je mišljenje da gljive plavila ne mijenjaju mehanička svojstva zaraženog drva, iako su se pojavili i neki kontradiktorni rezultati. Radi razjašnjenja tih suprotnosti, 70 uzoraka bjeljike bijeloga bora (Pinus sylvestris) (veličine 0,5 × 1,0 × 20,0 cm^3) bilo je izloženo djelovanju gljiva Aureobasidium pullulans i Sclerophoma pithyophila u trajanju od dva do osam tjedana, a prema europskoj normi EN 152-1 (1990). Prije i nakon izlaganja gljivama, na istim je uzorcima obavljeno mjerenje mase, boje, FTIR te nedestruktivno mjerenje modula elastičnosti (MoE). Rezultati su pokazali da, osim značajne promjene boje, gljive plavila ne uzrokuju znatnije razaranje drvne tvari. Nedestruktivna metoda mjerenja modula elastičnosti pokazala je slabo povećanje MoE uzoraka nakon izlaganja gljivama.*

Ključne riječi: *Aureobasidium pullulans, boja, FTIR, modul elastičnosti, bijeli bor (Pinus sylvestris), gljive plavila, Sclerophoma pithyophila*

1 INTRODUCTION
1. UVOD

Discoloration of wood is long known phenomenon, which is based on different biotic and abiotic causes. The most important reasons for discoloration are bacteria and fungi, as a result of micro-organism-own pigments (e.g., melanin of blue stain fungi) (Zink and Fengel, 1989). Blue stain is a blue, grey or black striped wood discoloration on sapwood. Fungi causing blue-stain are called blue-stain or sap-stain fungi. Conifers and hardwood, round wood, lumber, finished wood and wood products can be colonized by these organisms (Schmid, 2006). They live on nutrients in the parenchyma cells of sapwood. However, in certain cases, mannanase, pectinase and amylase have been detected

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(Schirp *et al.,* 2003). Blue staining of wood is caused by about 100 to 250 fungi belonging to *ascomycetes* and *deuteromycetes* (Kaarik, 1980). *Aureobasidium pullulans* is the main organism causing disfigurement of wood coatings and surface of exposed timber (Sharpe and Dickinson, 1992). This disfigurement of timber in-service is referred to as "bluestain in-service". *A. pullulans* is also associated with the sap-staining of dead wood in the forest and in-service (Ray *et al.,* 2004). Another important blue stain fungus discolouring wood in service is *Sclerophoma pithyophila.* Both species are used in combination in the European standard laboratory test method for determining the effectiveness of preservatives against blue stain fungi (European Standard EN 152-1 & 2, 1990).

Although, blue stain fungi belongs to the same group of fungi as soft rot fungi (Troya *et al.,* 1990), it is generally assumed that blue stain fungi do not cause any or only little cell wall attack, and therefore strength properties are hardly affected (Schmid 2006). Thus the damage of wood is mainly cosmetic. It is supposed, that fungal hyphae are growing on the internal face of the cell walls without any enzymatical alteration on the surface. On the other hand, some hyphen of blue stain fungi have been seen in inside the parenchyma cell walls (Liese, 1964), or even between cell walls in middle lamella region (Rose *et al.,* 1999), which can affect mechanical properties. Furthermore, it is known for some time that blue stain fungi produce intra and extra-cellular enzymes, some of which can degrade polysaccharides and pectins. The, presence of lignin splitting enzymes was also reported (Troya *et al.,* 1990; Sharpe and Dickinson, 1992). The aim of our research was to evaluate whether blue stain fungi could anyhow influence mechanical properties of blue-stained wood. Such researches are nowadays much easier, as non-destructive techniques for determination of mechanical properties are widely available. These methods enable us to compare the modulus of elasticity before and after fungal exposure at the same specimen, avoiding wood heterogeneity.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

2.1 Sample preparation
2.1. Priprema uzoraka

Samples ($0.5 \times 1.0 \times 20.0$ cm^3) were made of Scots pine sapwood (*Pinus sylvestris*). Orientation and quality of wood meet the requirements of the standard EN 113 (1996). Afterwards, the samples were exposed to blue stain fungi for the period ranging between 2 and 8 weeks, according to the standard EN 152-1 (1990). *Aureobasidium pullulans* (de Barry) Arnaud (ZIM L060) and *Sclerophoma pithyophila* (Corda) Hohn (ZIM L070) (Raspor *et al.,* 1995) were used in this experiment. In total, 70 specimens were exposed to blue stain fungi.

2.2 Evaluation of modulus of elasticity
2.2. Određivanje modula elastičnosti

Modulus of elasticity (MoE) was determined before and after fungal exposure. Specimens were oven dried prior to MoE measurements. Because of difficulties encountered in measuring the axial vibrations, flexural vibration modes were used to characterize elastic parameters. Considering the hypothesis of the homogeneity of geometrical and mechanical properties along the sample, basic dynamics theorems can be applied to obtain the motion equation of first vibrations. Analysis was performed on specimen with clamped–free end conditions. During the test, the lateral displacement was measured of vibrating sample in damped vibration with known vibration mode. As an inductive proximity sensor was used, a small piece of metal foil of neglecting mass was glued on the surface of each sample. The damped frequency was obtained by FFT analysis of the exponentially decayed displacement signals detected in time domain. For determination of Young modulus of samples, we used the frequency equation deducted from Bernoulli model, which was assumed as acceptable because of the relatively high length-to-depth sample ratio, (E - Young modulus, N/m^2, ν - natural frequency, s^{-1}, $C = 3.51563$ – constant derived from Bernoulli equation, ρ – density, kg m^{-3}, l – free sample length, m, h – sample height, m) (Timoshenko *et al.,* 1974). Measurements were performed on seven replicates.

$$E = \frac{48 \cdot \pi^2 \cdot l^2 \cdot \rho \cdot \nu^2}{C^2 \cdot h^2} \tag{1}$$

2.3 Chemical analysis (CNS) of wood
2.3. Kemijska (CNS) analiza drva

Prior to nitrogen and carbon analysis, wood blocks that were used for MoE measurements, were milled into particles (MESH 80) and homogenized. Approximately, 0.2 g of an oven dry sample was combusted in the oxygen atmosphere at 1350°C in LECO 2000-CNS analyzer to determine carbon and nitrogen content.

2.4 FTIR and colour measurements
2.4. FTIR i mjerenje boje drva

FTIR spectra were recorded with the Perkin Elmer FTIR Spectrum One Spectrometer, using Abrasive Pad 600 Grit-Coated, PK/100 (Perkin Elmer) paper. DRIFT spectra of wood samples were recorded between 4000 cm^{-1} and 450 cm^{-1}. Colour of the specimens was recorded with HP Scanjet 4800 scanner. Scanner was chosen, as specimens were to narrow for measurements with colorimeter. Colour obtained with scanner and colorimeter gives comparable results (Noč, 2006). The reported values are the average value of seven replicate measurements. The colour was expressed in Cie L*a*b* format.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

As expected, the exposure of Scots pine wood specimens to blue stain fungi resulted in considerable

Table 1 Colour changes of Scots pine sapwood exposed to blue stain fungi
Tablica 1. Promjena boje bjeljike bijelog bora nakon izlaganja gljivama plavila

Incubation time (weeks) *Vrijeme izlaganja gljivama (tjedni)*	*Sclerophoma pithyophila*				*Aureobasidium pullulans*			
	*L**	*a**	*b**	Δ*E*	*L**	*a**	*b**	Δ*E*
0	85.1	3.8	13.7	0.0	85.1	3.8	13.7	0.0
2	66.7	3.1	10.7	18.7	82.6	3.8	14.6	2.6
4	63.8	2.6	9.0	21.8	79.7	2.8	12.8	5.6
6	57.5	2.5	7.5	28.3	71.9	3.1	11.3	13.4
8	58.4	2.5	7.7	27.4	70.1	3.0	10.1	15.4

Table 2 Modulus of Elasticity, mass changes, carbon and nitrogen content of Scots pine sapwood after exposure to blue stain fungi
Tablica 2. Modul elastičnosti, promjene mase, sadržaj ugljika i dušika bjeljike bijelog bora nakon izlaganja gljivama plavila

Incubation time (weeks) *Vrijeme izlaganja gljivama (tjedni)*	*Sclerophoma pithyophila*				*Aureobasidium pullulans*			
	Δ *m* %	Δ *MoE* %	*C* %	*N* %	Δ *m* %	Δ *MoE* %	*C* %	*N* %
0	0.8	1.2	47.63	0.0352	0.8	1.2	47.63	0.0352
2	0.6	2.8	46.33	0.0205	0.2	1.7	47.00	0.0160
4	0.3	3.6	46.55	0.0181	0.0	1.5	47.02	0.0163
6	0.2	2.5	46.48	0.0175	0.1	2.9	45.60	0.0164
8	0.8	2.7	46.27	0.0181	0.8	1.7	45.97	0.0162

colour changes. The first signs were visible after the second week of exposure. However, colour changes of specimens exposed to *S. pithyophila* (Δ*E* = 18.7) for two weeks, were more prominent than the ones exposed to *A. pullulans* (Δ*E* = 2.6). *S. pithyophila* remained more active all the time of exposure. Within the exposure time, the specimens became darker, less reddish and yellowish and more bluish and greenish (Table 1). Maximum colour change was observed after the sixth week at *S. pithyophila* and after eight week at *A. pullulans.* The most important reason for observed changes is melanin excreted by those two staining fungi (Schmid, 2006).

Mass changes of wood specimens exposed to blue stain fungi were insignificant. No mass losses were observed in any of the cases. Quite the contrary, all specimens gain some weight; firstly because specimens were immersed to malt agar suspension prior to fungal exposure, as proposed by EN 152-1 standard (1990), and secondly, as fungi contributes to the mass of the specimens with their biomass and excreted compounds like melamine. However, changes of mass are relatively small and are always smaller than 1 % (Table 2). These measurements are in line with the data presented by Higley (1999).

Nitrogen content in uninfected pine sapwood was 0.0352%. Immediately after exposure, nitrogen content dropped significantly, to 0.0205% at *S. pithyophila* and to 0.0160% at *A. pullulans*, and remained almost constant within time of exposure (Table 2). This indicates that blue stain fungi rapidly consumed nitrogen within the first two weeks of exposure. The remained nitrogen is either in biologically unavailable form, or it was used for chitin and protein synthesis and is present in wood as a constituent of fungal hyphae. Similar as nitrogen content, carbon content also decreased from initial 47.63%, to final 46.27 at *S. pithyophila* and to 45.97% at *A. pullulans.*

Unexpectedly, modulus of elasticity (MoE) of blue stained specimens did not decrease but even slightly increased (Table 2). The first increase of MoE was observed immediately after sterilization, even with specimens that were not exposed to wood decay fungi at all. Similar phenomenon is reported for heat treated wood, where MoE firstly increases within temperature of treatment and when temperatures overreach 150°C, MoE starts decreasing (Finnish Thermowood Association, 2003). This increase of MoE is assigned to the fact that after water evaporation, cellulose hydroxyl groups form hydrogen bonds between neighbouring micro-fibrils, which results in improved MoE of steam-sterilised wood. Another possible explanation for increased MoE values of blue-stained wood is the presumption that melanin could interact with wood functional groups, and additionally crosslink wood components. However, this is only a presumption, which is very difficult to be proved.

Infra red spectra confirm the above results. There were no differences in IR peaks between control unexposed pine wood and blue-stained wood even after eight weeks of exposure (Figure 1). This confirms that blue stain fungi did not change lignin, cellulose and hemicelluloses structure. Additionally, it seems that the amount of melanin in wood is too low to be observed from FTIR spectra. Secondly, as functional groups of

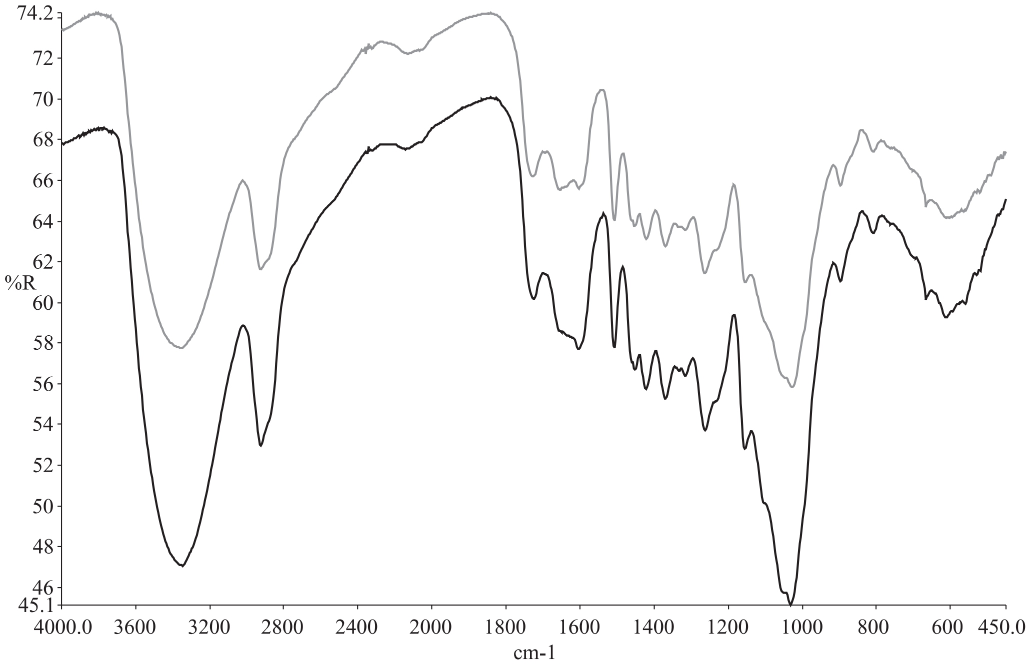

Figure 1 FTIR spectra of *Pinus* sylvestris sapwood before (lower line) and after eight-week exposure to *Sclerophoma pithyophila* (upper line)
Slika 1. FTIR spektri bjeljike bijelog bora prije (donja linija) i nakon osam tjedana izlaganja gljivi *Sclerophoma pithyophila* (gornja linija)

melanin are relatively similar to lignin functional groups, melanin cannot be resolved from FTIR spectra (Butler and Day, 1998).

This data are important from application point of view. Blue stained wood can, therefore, be used for various construction applications. And secondly if albino blue stain fungi are utilised for biocontrol applications (Farrell *et al.,* 1993), it could be presumed that those fungi do not significantly influence mechanical properties of colonised wood.

4 CONCLUSIONS
4. ZAKLJUČCI

Aureobasidium pullulans and *Sclerophoma pithyophila* affect significantly blue-stained pine wood specimens. However, the results of the experiments showed that this change is only aesthetic and does not influence weight or mechanical properties of blue-stained wood.

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TEMATSKI PRILOZI

DRVO & NAMJEŠTAJ

STRUČNI ČASOPIS

Darko Motik[1], Maja Moro[1], Renata Ojurović[2], Andreja Pirc[1], Herman Sušnik[2]

Istraživanje strukture obrazovanja na području prerade drva i proizvodnje namještaja

Research of educational structure in wood processing and furniture production sector

Stručni rad · Professional paper
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SAŽETAK • *Sve se više sužava vremenski obzor u kojemu se pojedinac sa svojim obrazovanjem može osjećati „sigurnim“ na tržištu rada, a globalizacija, multikulturalno zajedništvo te brz ekonomski rast i tehnološki razvoj postaju veliki izazovi, pri čemu znanje i ljudska kreativnost postaju osnovni resursi razvoja i opstanka na svjetskom tržištu. Cilj rada je utvrditi obrazovnu strukturu zaposlenih na području prerade drva i proizvodnje namještaja, pri čemu je naglasak stavljen na zastupljenost visokoobrazovanih stručnjaka. Analiza obrazovne strukture obuhvatila je, prema Nacionalnoj klasifikaciji djelatnosti (NKD), područje DD 20 – Prerada drva i proizvodnja proizvoda od drva i pluta te područje DN 36 – Proizvodnja namještaja i ostala prerađivačka industrija. Istraživanje pokazuje da s 50% ispitanih poslovnih subjekata upravlja visokoobrazovani kadar, dok je među ukupno zaposlenima u preradi drva i proizvodnji namještaja samo 3,77% visokoobrazovanih.*

Ključne riječi: *drvni sektor, obrazovna struktura, visoko obrazovanje (VSS)*

ABSTRACT • *The labour market is becoming less and less safe for individuals with their education, while globalisation, multicultural unification, and fast economic growth/technological development present great challenges – with knowledge and creativity being basic resources of development and survival on the world market. The aim of this study is to establish the educational structure of the employed in the field of wood processing and furniture manufacture. The emphasis is upon the proportion of high professional qualification. The analysis of educational structure includes – according to the National classification of activities - the DD 20 area of Wood processing and production of wood and cork, and the DN36 area of Furniture manufacture and other processing industries. The research has revealed that 50% of the surveyed companies are managed by highly qualified staff, while only 3.77% of the employed in wood processing and furniture manufacture have high qualifications.*

Key words: *wood sector, educational structure, high education (HPQ)*

1. UVOD
1 INTRODUCTION

Obrazovanje, oblik ljudskog kapitala, neposredno se odražava na proces gospodarskog razvoja zemlje povećanjem globalne produktivnosti rada, kao i na glavne nositelje razvoja, proizvodno-poslovne subjekte, i to povećanjem globalne konkurentnosti njihovih proizvoda i usluga. *Izvještaj Europske komisije o investicijama poduzeća u kontinuirano obrazovanje zapo-*

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Tablica 1. Razvrstavanje poslovnih subjekata prema kategorijama
Table 1 Classification of companies according to categories

	Obrt *Trade*	**Trgovačko poduzeće** *Trade company*			**Dioničko društvo** *Joint stock company*		Σ
		malo *Small*	**srednje** *Medium*	**veliko** *Big*	**srednje** *Medium*	**veliko** *Big*	
DD 20	15	33	7	0	2	1	58
DN 36	9	15	3	3	0	2	32
Σ	24	48	10	3	2	3	90

slenih za 2006. godinu sadržava važan podatak da 62% poduzeća u zemljama članicama Europske unije ulaže u obrazovanje jer se tako lakše prilagođavaju promjenama i potrebama na tržištu rada. Skoro priključenje Hrvatske EU i globalizacija nameću hrvatskim poduzećima, uključujući poduzeća hrvatskoga drvnog sektora, potrebu prepoznavanja važnosti obrazovanja i zapošljavanje visokoobrazovanih stručnjaka.

Obrazovna struktura zaposlenih u poslovnim subjektima hrvatskoga drvnog sektora nije na zadovoljavajućoj razini. Naime, mnogi imaju velik broj priučenih ili prekvalificiranih radnika i nemaju zaposlenih diplomiranih inženjera drvne tehnologije, poglavito poduzeća s manjim brojem zaposlenih i s nižim stupnjem obrade ili prerade drva. Na to upućuju i rezultati rada, a preporuka autora je povećanje ulaganja u intelektualni kapital koji ima sposobnost stvaranja novih ekonomskih vrijednosti.

2. METODE RADA
2 METHODS

Istraživanje za potrebe rada provedeno je metodom uzorka, koji je podijeljen na područja po djelatnosti i veličini poslovnog subjekta. Prema djelatnosti, poslovni su subjekti razvrstani na temelju Nacionalne klasifikacije djelatnosti (Pravilnik o razvrstavanju poslovnih subjekata prema Nacionalnoj klasifikaciji djelatnosti NKD 2002, NN broj 52/2003), odnosno DD 20 - *Prerada drva i proizvodnja proizvoda od drva i pluta* i DN 36 - *Proizvodnja namještaja i ostala prerađivačka industrija*. Prema veličini, poslovni su subjekti razvrstani na mala, srednja i velika, sukladno Zakonu o poticanju razvoja maloga gospodarstva, NN br. 29/2002, uz stupanje na snagu Zakona o izmjenama i dopunama Zakona o poticanju razvoja malog gospodarstva, NN br. 63/2007. Kriteriji za određivanje veličine jesu: ukupni godišnji prihod i prosječna godišnja zaposlenost za 2006. godinu.

Jedinice promatranja su trgovačka društva (društva s ograničenom odgovornošću i dionička društva) i obrti.

Veličina uzorka je 90 poslovnih subjekata, a tablica 1. prikazuje njihovo razvrstavanje i obuhvat prema kategorijama.

Okvir za podatke i izbor uzorka bili su razvojni projekti poslovnih subjekata unutar prve državne potpore Vlade RH za poboljšanje i unaprjeđenje industrijske prerade drva u 2007. godini, putem Ministarstva poljoprivrede, šumarstva i vodnoga gospodarstva.

Cilj rada je utvrditi obrazovnu strukturu zaposlenih na području prerade drva i proizvodnje namještaja, pri čemu je naglasak na zastupljenosti visokoobrazovanih stručnjaka.

3. REZULTATI
3 RESULTS

Ukupan broj zaposlenih u 90 promatranih poslovnih subjekata iznosio je 8 453. Od navedenog broja 4 114 osoba zaposleno je u preradi drva i proizvodnji proizvoda od drva i pluta (DD 20), dok je 4 339 osoba zaposleno u proizvodnji namještaja (DN 36), pri čemu najviše zaposlenih imaju srednja i velika trgovačka poduzeća te velika dionička društva. U srednjim trgovačkim poduzećima zaposlena je 2 451 osoba, u velikim trgovačkim poduzećima 2 133 osobe te u velikim dioničkim društavima 2 219 osoba. Promatrajući broj zaposlenih u trgovačkim poduzećima, u malim i srednjim trgovačkim poduzećima na području DD 20 zaposleno je 740, odnosno 1 620 osoba, što je više u usporedbi s područjem DN 36, na kojem je zaposleno 126 osoba, odnosno 831 osoba, dok je cjelokupan broj zaposlenih u velikim trgovačkim poduzećima na području DN 36 2 133. Na području DD 20 u 90 promatranih poslovnih subjekata ni jedan ne pripada kategoriji velikih trgovačkih poduzeća.

Od navedenih područja najmanje je zaposlenih u obrtu, pri čemu je usporedbom područja DD 20 i DN 36 više osoba zaposleno u obrtima na području DD 20.

Od ukupnog broja zaposlenih u 90 promatranih poslovnih subjekata 3,77% čine osobe s visokom stručnom spremom (VSS). Promatrajući pojedina područja, najveći postotak visokoobrazovanih osoba u odnosu prema broju zaposlenih imaju mala trgovačka poduzeća u kojima je od 866 zaposlenih osoba njih 59 ili 6,81% visokoobrazovanih. Najmanje osoba s visokom stručnom spremom u odnosu prema broju zaposlenih radi u velikim trgovačkim poduzećima - 2,77%. Usporedbom kategorija u tablici 2. vidljivo je da obrti, s obzirom na ukupan broj zaposlenih, zapošljavaju veći broj visokoobrazovanih ljudi nego srednja i velika trgovačka poduzeća te dionička društva. Uspoređujući visookoobrazovani kadar na području DD 20 i DN 36, na području DN 36 u odnosu prema broju zaposlenih, ustanovljeno je 0,63% više zaposlenika s visokom stručnom spremom nego na području DD 20.

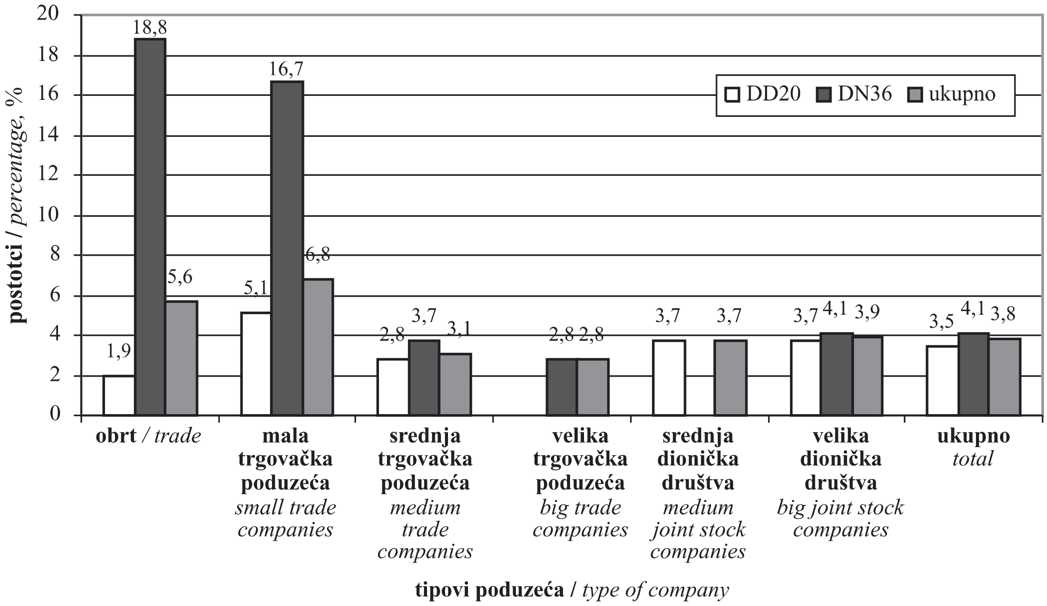
Tablica 2. Ukupan broj zaposlenih na području DD 20 i DN 36 u 90 promatranih poslovnih subjekata
Table 2 Total number of the employed in areas DD 20 and DN 36 in 90 surveyed business companies

		DD 20			**DN 36**			**Ukupno** *Total*		
		Broj zaposlenih *empolyed*	**VSS među zaposlenima** *HPQ among the employed*	**Postotak VSS-a među zaposlenima** *HPQ, %*	**Broj zaposlenih** *employed*	**VSS među zaposlenima** *HPQ among the employed*	**Postotak VSS-a među zaposlenima** *HPQ, %*	**Broj zaposlenih** *employed*	**VSS među zaposlenima** *HPQ among the employed*	**Postotak VSS-a među zaposlenima** *HPQ, %*
Obrt *trade*		360	7	1,94	101	19	18,81	461	26	5,64
Trgovačka poduzeća *trade companies*	mala *small*	740	38	5,14	126	21	16,67	866	59	6,81
	srednja *medium*	1 620	45	2,78	831	31	3,73	2 451	76	3,10
	velika *big*				2 133	59	2,77	2 133	59	2,77
Dionička društva *yoint stock companies*	srednja *medium*	323	12	3,72				323	12	3,72
	velika *big*	1 071	40	3,73	1 148	47	4,09	2 219	87	3,92
Ukupno *total*		4 114	142	3,45	4 339	177	4,08	8 453	319	3,77

Uspređujući pojedine kategorije na području DD 20 s pojedinim kategorijama s područja DN 36, vidljivo je sljedeće:

– u obrtima na području DN 36 od 101 zaposlene osobe njih 19 ili 18,81% ima visoku stručnu spremu, dok u obrtima u području DD 20 od 360 zaposlenika samo njih 7 ili 1,94% ima visokoškolsko obrazovanje
– u trgovačkim poduzećima (malim, srednjim i velikim) na području DD 20 od 2 360 zaposlenika njih 83 ili 3,52 % ima visoku stručnu spremu, što je približno postotku visokoobrazovanih na području DN 36, gdje je od 3 090 zaposlenih osoba njih 111 ili 3,59% visokoobrazovano
– u dioničkim društvima (srednjim i velikim) na području DD 20 zaposleno je 3,73% visokoobrazovanih osoba od 1 394 osobe, dok na području DN 36 radi 4,09% ili 47 visokoobrazovanih osoba od 1 148 zaposlenih osoba.

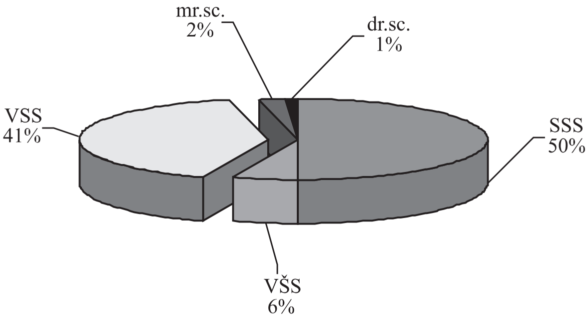
Slika 1. prikazuje postotni odnos zaposlenika i visoke stručne spreme u odnosu prema broju zaposlenih u pojedinim poslovnim subjektima. Najviše visokoobrazovanih osoba zaposleno je u obrtima i malim trgovačkom poduzećima koja pripadaju području DN 36, njih 18,8%, odnosno 16,7%. U ostalim poslovnim subjektima zaposleno je oko 4% s VSS-om, pri čemu je postotak zaposlenih na području DD 20 i DN 36 približno jednak.



Slika 1. Udio visoke stručne spreme (VSS-a) među zaposlenima prema vrsti poslovnog subjekta
Figure 1 Ratio of high professional qualification among the employed according to the type of company

Tablica 3. Stručna sprema ovlaštene osobe na području DD 20 i DN 36 (detaljni prikaz)
Table 3 Professional qualification of authorised person in DD20 and DN36 (detailed presentation)

		DD 20							DN 36							
		Obrt *trade*	**Trgovačko poduzeće** *trade company*			**Dioničko društvo** *joint stock company*		Σ	**Obrt** *trade*	**Trgovačko poduzeće** *trade company*			**Dioničko društvo** *joint stock company*		Σ	
			malo ***small***	**srednje** *medium*	**veliko** *big*	**srednje** *medium*	**veliko** *big*			**malo** *small*	**srednje** *medium*	**veliko** *big*	**srednje** *medium*	**veliko** *big*		**Ukupno** *Total*
SSS		13	22	2				37	3	5					8	45
VŠS		1	2				1	4	1						1	5
VSS *HPQ*	dipl. ing. drv .tehnologije *University graduated engineer of wood technology*	1	2	1		1		5	4	5		3			12	17
	dipl. oecc. *University grad. economist*		3	2				5		2	1			1	4	9
	dipl. ing. strojarstva *University graduated mechanical engineer*		1					1		1	1				2	3
	dipl. ing. arhitekture *University graduated architect*							0		2					2	2
	dipl. ing. šumarstva *University graduated silvicultural engineer*		1	1				2							0	2
	dipl. ing. elektrotehnike *University graduated electrotechnical engineer*							0			1				1	1
	dipl. ing. graditeljstva *University graduated civil engineer*							0	1						1	1
	dipl. ing. prometa *University graduated traffic engineer*		1					1							0	1
	završen kineziološki fakultet *Faculty of kinesiology*		1					1							0	1
mr. sc. *M. Sc.*	dipl. oecc. *University graduated economist*			1				1	0						0	1
	dipl. ing. strojarstva *University graduated mechanical eng*							0						1	1	1
dr. sc. *Ph.D.*						1		1							0	1
Ukupno / *Total*		15	33	7	0	2	1	58	9	15	3	3	0	2	32	90



Slika 2. Stručna sprema ovlaštene osobe na području DD 20 i DN 36
Figure 2 Professional qualification of authorised persons in DD 20 and DN 36

Prema slici 2. i tablici 3, najveći dio poslovnih subjekata zastupaju ovlaštene osobe (osoba koja zastupa društvo prema trećim osobama, pojedinačno i samostalno u svim poslovima u zemlji i inozemstvu) sa srednjom stručnom spremom, u njih 45 (50%), te ovlaštene osobe s visokom stručnom spremom, u njih 37 (41%). Vrlo je mali broj poslovnih subjekata koje zastupaju osobe s višom stručnom spremom, njih 5 (6%), dok magistri znanosti i doktori znanosti čine ovlaštene osobe u 2%, odnosno u 1% poslovnih subjekata.

U tablici 3. naveden je detaljan prikaz stručne spreme ovlaštenih osoba poslovnih subjekata na područjima DD 20 i DN 36. Od ukupnog broja poslovnih subjekata na području DD 20 u njih 15 ovlaštena osoba ima visoku stručnu spremu, unutar kojih je u 5 poslovnih subjekata ovlaštena osoba diplomirani inženjer drvne tehnologije. Na području DN 36 u 23 poslovna subjekta ovlaštena osoba ima visoku stručnu spremu, od toga je u 12 poslovnih subjekata ovlaštena osoba diplomirani inženjer drvne tehnologije. Također su zastupljeni diplomirani ekonomisti, diplomirani inženjeri strojarstva, arhitekture, šumarstva itd.
Od ukupnog broja poslovnih subjekata na području DD 20 u njih 4 ovlaštena osoba ima višu, a 37 srednju stručnu spremu, dok je na području DN 36 takvih 1, odnosno 8 osoba.

4. ZAKLJUČAK
4 CONCLUSION

Od ukupnog broja zaposlenih, u 90 promatranih poslovnih subjekata broj zaposlenih u preradi drva i proizvodnji proizvoda od drva i pluta (DD 20) približno je jednak broju zaposlenih u proizvodnji namještaja (DN 36), iako veći broj poslovnih subjekata pripada području DD 20.

Poslovne subjekte u gotovo podjednakom broju zastupaju osobe s visokom stručnom spremom te osobe sa srednjom stručnom spremom, dok tri poslovna subjekta zastupaju magistri znanosti i doktori znanosti. Visokoobrazovane osobe najvećim su dijelom diplomirani inženjeri drvne tehnologije, što je pozitivno za struku, te diplomirani ekonomisti.

Kako za prethodna razdoblja nije provođena analiza obrazovne strukture ovlaštenih osoba poslovnih subjekata na području prerade drva i proizvodnje namještaja, nije moguće utvrditi trend visokoobrazovanih ovlaštenih osoba poslovnih subjekata. Međutim, jaka konkurencija, globalizacija tržišta te brz ekonomski rast i tehnološki razvoj postavljaju velike izazove za poslovne subjekte i za osobe koje ih zastupaju. Stoga se može pretpostaviti da će se u budućim razdobljima broj visokoobrazovanih osoba u drvnom sektoru povećavati jer je to jedini način opstanka na velikome, razvijenome i konkurentnome svjetskom tržištu.

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Groove - elegancija koja nadahnjuje

Masivni namještaj oduvijek je sinonim za stil i postojanost. Pola stoljeća oblikovanja namještaja u Novoselcu čini DIN jednim od najboljih domaćih proizvođača. Kvalitetna sirovina, ekološki premazi te visokokvalitetan i funkcionalan okov daju tom namještaju pouzdanost, a njegov dizajn i način izrade svrstavaju ga u red vrlo poželjnih proizvoda na europskom tržištu. U vrijeme snažne konkurencije, globalno nepovoljnih gospodarskih prilika te opće tržišne neizvjesnosti mogu se održati tvrtke koje imaju izgrađen imidž pouzdanoga poslovnog partnera te koje svoj proizvod modificiraju prema željama kupca, zadržavajući uvijek istu razinu kvalitete.

Prilagođujući se impulsu s tržišta, DIN svake godine predstavlja novu liniju namještaja na najvećem sajmu namještaja IMM u Kölnu. Početkom godine prvi je put predstavljena kolekcija Groove. Riječ je o modernoj inačici DIN-ove klasične biblioteke, a za razliku od nje, koja je u osnovi replika američke odvjetničke biblioteke iz 19.st., ovaj je put to kreacija domaće dizajnerice Romine Radović. Riječ je o liniji jednostavnoga, ali atraktivnog dizajna koja, u kombinaciji s dojmom čvrstine i prirodne ljepote punoga hrastova drva, djeluje postojano i elegantno. Poput klasične biblioteke, i kolekcija Groove izrađena je modularno, što omogućuje prilagodbu gotovo svakom prostoru te nudi brojne mogućnosti slaganja. Moduli mogu imati masivna ili staklena vrata, a kupci mogu birati izgled fronti te boju. Biblioteka je zbog svoje funkcionalnosti pogodna za dnevne i radne sobe

te za urede. Iako se čak više od 90% masivnog namještaja DIN-a plasira na tržište Zapadne i Sjeverne Europe, moglo se očekivati da će ovaj proizvod postići uspjeh i na domaćem tržištu, koje je ekološki i estetski sve više osvješćenije. Time je ponovno potvrđena teza da je prirodni materijal uvijek u modi i premda dizajn kreira oblik, materijal je ono što krajnjem proizvodu daje stil i duh.

Tamara Svetina

FSC CERTIFIKACIJA ŠUMA I DRVNIH PROIZVODA

Općenito je prihvaćeno stajalište da se bogatstvom šuma i šumskim zemljištem treba upravljati na način da se poštuju sociološke, ekonomske, ekološke, kulturne i duhovne potrebe sadašnjih i budućih naraštaja. Štoviše, povećana društvena svijest o uništavanju i degradaciji šuma dovela je do toga da se potrošači žele osigurati da kupnjom drveta i drugih proizvoda šume neće pridonijeti tom uništavanju, već pomoći očuvanju šumskog bogatstva za budućnost. Odgovarajući na takve zahtjeve, pojavile su se međunarodne organizacije koje su izradile standarde što ih je potrebno zadovoljiti kako bi se steklo pravo na zaštićenu markicu koja će diferencirati proizvode nastale odgovornim gospodarenjem šumama u usporedbi s onima koji to nisu. Najstarija i najprihvaćenija takva organizacija je Vijeće za nadzor šuma (The Forest Stewardship Council - FSC). To je međunarodno tijelo koje pojedinim organizacijama daje dozvolu za izdavanje certifikata i time jamči autentičnost njihovih nalaza. Cilj je programa FSC da se promovira ekološki odgovorno, društveno korisno i ekonomski održivo gospodarenje šumama u svijetu tako da se ustanovi općepoznati standard koji će se priznati i poštovati u skladu s načelom odgovornog šumarstva.

FSC je osnovan 1993. uz potporu glavnih ekoloških nevladinih udruga kao što su World Wildlife Fund, Friends of the Earth i Greenpeace. To je nevladina udruga sa sjedištem u Oaxaci, Meksiko, a certifikate izdaje putem ovlaštenih tvrtki. Dosada je izdano oko 775 certifikata u 66 zemalja svijeta.

U novije vrijeme sve je više zahtjeva upućeno hrvatskoj drvnoj industriji da svoje proizvode koje izvozi na zapadno tržište poprati certifikatom. To je rezultat nastojanja velikih maloprodajnih lanaca drvnih proizvoda da svojim kupcima ponude etički prihvatljive proizvode. Kao veliki promotori FSC znaka ističu se britanski B&Q, američki Home Depot i švedska Ikea. Oni su svojim inzistiranjem da njihovi dobavljači posjeduju FSC certifikat znatno profilirali tržište, jer je ispitivanjima javnog mišljenja ustanovljeno da bi više od 80 % kupaca dalo prednost certificiranim proizvodima.

Bitna komponenta FSC certificiranja jest neprekinut nadzorni lanac u prometu drvnim proizvodima (Chain of Custody) koji jamči da drvo upotrijebljeno za izradu konačnog proizvoda potječe iz šuma kojima se gospodarilo, te da je jasan put što ga je ono prošlo u različitim fazama prerade. Na taj se način za svaki certificirani proizvod može ustanoviti njegovo podrijetlo. To, naravno, zahtijeva da svi sudionici u lancu budu certificirani, odnosno da se pridržavaju određenih standarda. Prvo, certifikat mora biti izdan organizaciji koja gospodari šumama i time postaje izvor certificirane sirovine za drvnu industriju, da bi zatim certifikat trebala dobiti primarna prerada drva, finalisti i, konačno, trgovci drvnim proizvodima.

U Hrvatskoj je proces certifikacije počeo 1999, kada su izdani prvi certifikati, i to Hrvatskim šumama, Upravi šuma Vinkovci i DI Spačvi. Nakon opsežnih radova, od listopada 2002, certificirana je cjelokupna površina kojom gospodare Hrvatske šume (2 milijuna hektara). Time je otvorena velika mogućnost hrvatskoj drvnoj industriji da iskoristi tu komparativnu prednost jer joj se omogućuje nabava većine svoga drva iz certificiranih izvora.

U svijetu je prema FSC sustavu certificirano oko 68 milijuna hektara šuma, te su spomenuta dva milijuna hektara hrvatskih šuma iznimno mnogo, osobito ako se uzme u obzir veličina naše zemlje. Ako se pak gleda relativno, površina državnih šuma Hrvatske najveći je svjetski certifikat. Certifikat može izdati samo organizacija koju ovlasti FSC centrala (za HŠ to je britanska tvrtka Soil Association Woodmark) koja obavlja inspekciju organizacije te uvidom u dokumentaciju i stanje na terenu utvrđuje stupanj usklađenosti sa standardom. FSC certifikat izdaje se na pet godina, a podložan je godišnjim monitoring posjetima.

Osim Hrvatskih šuma, u Hrvatskoj ima 42 certifikata za drvnu industriju (tzv. COC certifikata). Činjenica da je većina hrvatske drvne sirovine certificirana znatno olakšava i stjecanje COC certifikata za drvnu industriju. To je pogodnost koju naša drvna industrija treba prepoznati i iskoristiti s obzirom na konkurenciju na zapadnoeuropskom tržištu. Hrvatske šume osnovale su tvrtku-kćer Hrvatske šume consult d.o.o. koja svojim iskustvom može znatno pomoći drvnoj industriji da se poveže s tvrtkom ovlaštenom za izdavanje certifikata. Svi zainteresirani mogu se obratiti Ratku Matoševiću (tel. 098/44 11 77) ili na ratko.matosevic@hrsume.hr, koji će ih upoznati s potrebnim procedurama za stjecanje certifikata.

Ratko Matošević,
Hrvatske šume consult d.o.o.

HRVATSKO ŠUMARSKO DRUŠTVO (HŠD)

Hrvatsko šumarsko društvo ima izvor u Hrvatsko-slavonskome gospodarskom društvu, koje je na poticaj šumara osnovano u Zagrebu 1841. godine. Unutar njega, zaslugom šumara Dragutina Kosa, 1846. godine osnovano je šest sekcija. Šumarska je sekcija utemeljena 26. prosinca 1846. u Prečecu pokraj Zagreba. Taj se dan smatra početkom rada Hrvatskoga šumarskoga društva, iako su šumari bili većina već pri osnivanju Hrvatsko-slavonskoga gospodarskog društva.

Šumari doista mogu reći da su oduvijek u Europi jer je prvo šumarsko društvo osnovano u njemačkoj pokrajini Baden-Württenberg 1839, u Mađarskoj 1851, u Austriji 1852. itd.

Društvo je osnivač i pokretač svih znatnijih postignuća šumarske prakse, obrazovanja i znanosti. Ako bismo nabrajali samo najvažnije, onda su to iniciranje donošenja Zakona šumskog već 1852. te njegova stroga primjena od 1858; početak rada Gospodarskošumarskog učilišta u Križevcima 1860; priprema (tijekom 1876) i tiskanje znanstveno-stručnoga i staleškoga glasila "Šumarski list" 1877, koji izlaskom iz tiska broja 11-12/2001 bilježi 125. godište neprekidnog tiskanja; priprema i sudjelovanje na Milenijskoj izložbi u Budimpešti 1896. godine, gdje su Kraljevine Hrvatska i Slavonija imale svoj izložbeni prostor, a šumarstvo i prerada drva svoj posebni paviljon; gradnja Hrvatskoga šumarskog doma (ugao Trga Mažuranića, Vukotinovićeve i Perkovčeve) 1898. i u njemu početak rada Šumarske akademije (20. listopada 1898) kao četvrte visokoškolske ustanove Sveučilišta u Zagrebu (tada još "prislonjene" uz Mudroslovni fakultet); postav Šumarskog muzeja u istoj zgradi (čiji su izlošci kasnije, nažalost, razdijeljeni); vraćanje nacionaliziranog dijela zgrade Hrvatskoga šumarskog doma ponovno u vlasništvo HŠD-a 1977/78; osnivanje Akademije šumarskih znanosti 1996. godine. Tijekom proteklih godina mnoge su ekskurzije, predavanja i stručne rasprave u sklopu HŠD-a bile temeljem radova, odluka, zakona, propisa i naputaka za rad u šumarstvu i preradi drva, iako je bilo vremena "kada se struka slabo slušala". Zahvaljujući praksi, obrazovanju i znanosti spojenima i isprepletenima baš u svojoj udruzi HŠD-u, posrednim ili neposrednim utjecajem udruge, ali i članova pojedinaca, donošene su prave odluke, a onemogućivane ili barem ublaživane one koje bi bile pogubne za šume i šumarstvo Hrvatske. Tako su zbog 95 %-tne površine prirodnih šuma šume Hrvatske ostale među najprirodnijima i najočuvanijima u Europi.

Nepovoljne utjecaje raznih onečišćivača i posljedice civilizacijskih tekovina (tvornica, autocesta, naftovoda, dalekovoda, kanala i sl.) na šume šumarski stručnjaci nastoje ublažiti načinom gospodarenja koji odgovara današnjim ekološkim uvjetima.

Godine 1996. Hrvatsko šumarsko društvo svečano je obilježilo 150. obljetnicu svog utemeljenja. U toj prigodi tiskano je šest knjiga, od kojih ona Hrvatsko šumarsko društvo 1846-1996. na 450 stranica iscrpno prikazuje rad HŠD-a.

Tijekom svog postojanja HŠD je "što milom, što silom" mijenjao organizacijske oblike i nazive (Šumarski klub, Društvo inženjera i tehničara šumarstva i drvne industrije i sl.). Prema Zakonu o udrugama donesenom 1997. godine, nakon najšire demokratske rasprave članstvo (više od 2 800 članova) izabralo je organizacijski oblik nevladine jedinstvene udruge na razini države, s 19 ogranaka koji su glede aktivnosti i financiranja samostalni. Osim zajedničkog Statuta, kojega su se dužni držati članovi i svi ogranci, svaki ogranak može imati i posebna pravila koja definiraju određene specifičnosti. U članku 2. Statuta HŠD-a stoji: "Hrvatsko šumarsko društvo je jedinstvena udruga inženjera i tehničara šumarstva, drvne tehnologije, kemijske prerade drva i prometa drvnim proizvodima, te drugih stručnjaka s odgovarajućom stručnom spremom (najmanje srednjom), koji rade na poslovima iz navedenih oblasti", a članak 12. kao cilj HŠD-a navodi okupljanje stručnjaka iz djelatnosti navedenih u članku 2. "radi promicanja i zaštite interesa struke i članstva, unapređenja struke, promicanja inženjerskog i tehničarskog poziva, tehničkog razvoja i istraživanja, obrazovanja (srednjeg i visokog) i stalnog usavršavanja za postizanje optimalnog tehnološkog i gospodarskog razvoja, blagostanja, zdravlja, očuvanja okoliša i kvalitete društva". Navedeni cilj ostvaruje se različitim djelatnostima, koje su navedene u daljnjem tekstu članka 12. Statuta. Članke 2. i 12. ističemo da bismo zainteresirane podsjetili tko sve može biti članom HŠD-a i što je njegov cilj, jer je u svim ograncima osim u Osijeku, Sl. Brodu, Požegi, Virovitici i djelomice Zagrebu, osim šumara, bezrazložno malen broj članova ostalih struka.

Vodeći brigu o 43,5 % površine Hrvatske, šumarska struka, osim brige za šumu kao izvor sirovine za daljnju preradu, ima posebno naglašenu odgovornost za očuvanje općekorisne funkcije šume: socijalne (turističke, estetske, rekreacijske, zdravstvene) i ekološke (hidrološke, protuerozijske, klimatske, protuimisijske, vjetrobranske i dr.), kao i očuvanje biodiverziteta hrvatskih šuma.

Stoga se HŠD zalaže da šumarska struka bude zastupljena pri izradi svih zakona i projekata koji se odnose na hrvatski prostor.

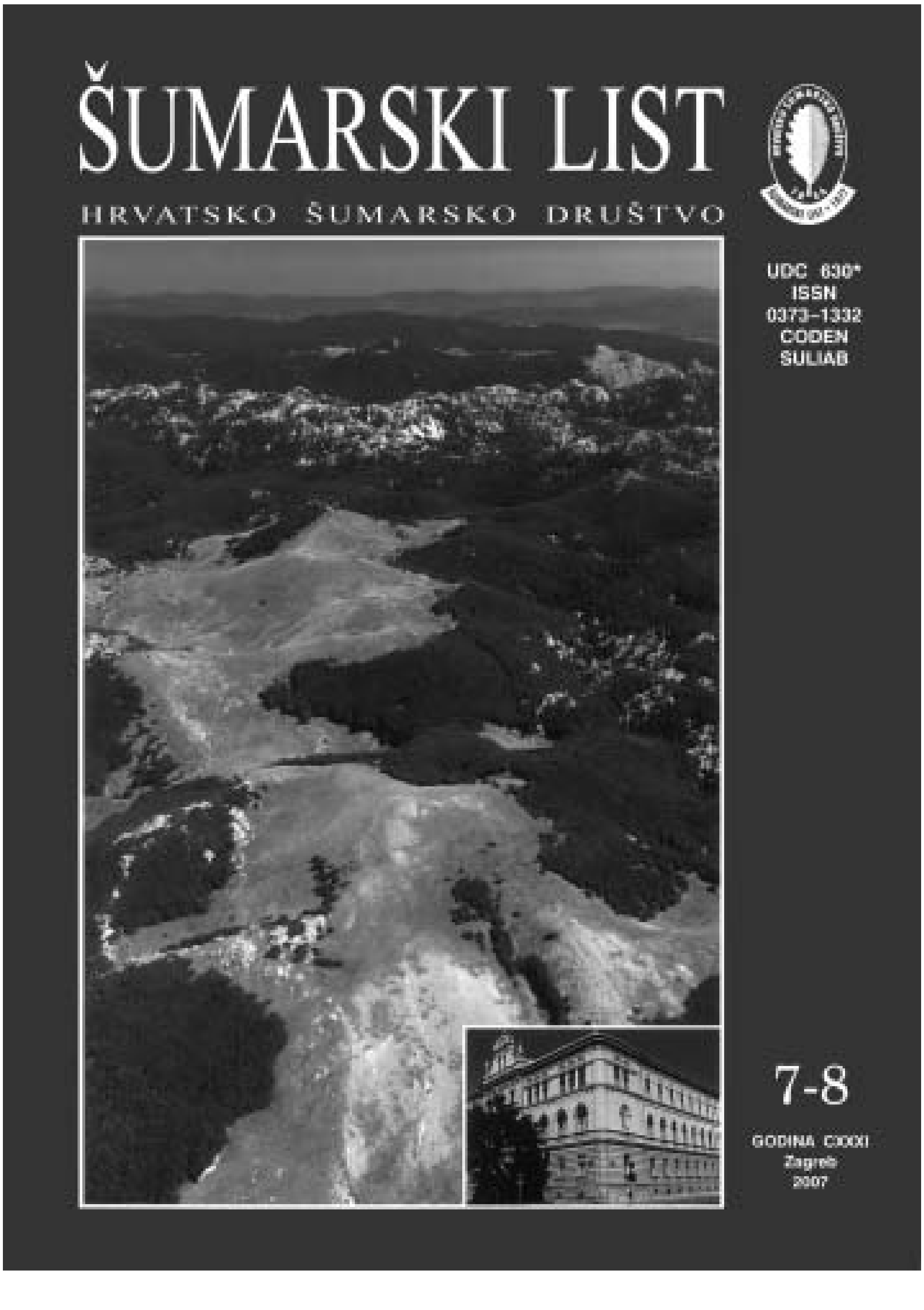
ŠUMARSKI LIST

Potreba za tiskanjem stručnog časopisa osjećala se netom nakon osnivanja Šumarske sekcije Hrvatsko-slavonskoga gospodarskog društva, pa prvi šumarski godišnjak izlazi 1847, zatim 1851. i 1852. godine. No pisana domoljubna i šumarska riječ na hrvatskom jeziku smetala je tuđinu, pa taj rad zamire u vrijeme Bachova apsolutizma. Ponovno je, pojačanim radom HŠD-a, tijekom 1876. godine pripremljen, a 1. siječnja 1877. tiskan prvi broj "Šumarskog lista". Taj prvi broj uredio je Vladoj Köröskenji, tadašnji tajnik HŠDa.

Od tada do danas njegovih 130 godišta na više od 61 500 stranica svjedokom su stručne i domoljubne riječi.

Urednici su mu bili ljudi od struke i pera kao što su Fran Kesterčanek, Josip Kozarac, Andrija Petračić, Ivo Čeović, Antun Levaković, Josip Balen, Milan Anić, Roko Benić, Milan Androić, Zvonimir Potočić. Danas je glavni urednik Branimir Prpić. Časopis objavljuje znanstvene i stručne članke s područja šumarstva, prerade drva, zaštite prirode, lovstva, ekologije, prikaze stručnih predavanja, savjetovanja, kongresa, proslava i sl, prikaze iz domaće i strane stručne literature te važnije spoznaje s drugih područja, bitne za razvoj i unapređenje šumarstva i prerade drva. Časopis također objavljuje sve što se odnosi na stručna zbivanja u nas i u svijetu, podatke i crtice iz prošlosti šumarstva, prerade i uporabe drva te aktivnosti Hrvatskoga šumarskog društva.

Časopis je referiran u Forestry abstracts, CAB abstracts, Agricola, Pascal, Geobase (IM) i dr.



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Flindersia australis R.Br.

NAZIVI I NALAZIŠTE

Flindersia australis vrsta je drva koja pripada porodici *Rutaceae* poznata pod lokalnim nazivima Australian maple, Crows ash (Velika Britanija i SAD), Flindersia, Flindosy (Francuska, Njemačka, Italija, Španjolska, Nizozemska), New guinea silkwood, Queensland maple, Silkwood, Silkwood maple. Raste na području Oceanije i jugoistočne Azije.

STABLO

Stablo doseže visinu od 30 metara, promjera je 75 do najviše 150 cm.

Kora mu je ljuskasta, nepravilno se ljušti, ostavljajući užljebljenja koja stablu daju grub izgled. Crvenkastosmeđe lenticele na površini kore često stvaraju okomite nizove.

DRVO

Makroskopska obilježja

Srž je ružičastosmeđasta, no sa starenjem (stajanjem) postaje smeđa, izraženog sjaja. Bjeljika je sivkasta. Žica drva često je usukana i valovita. Tekstura drva je fina i jednolična. Drvo je rastresito porozno. U ranom drvu pore su vidljive običnim okom, dok su u kasnom drvu vidljive samo uz pomoć povećala. Pore su srednje brojne, 4 do 12 na 1 mm^2. Drvni traci uži su od pora. Vrpce aksijalnog parenhima katkad su brojne i vidljive, rjeđe su aliformne. U drvu su zamjetni bijeli ili žuti sadržaji. Na poprečnom presjeku vidljivi su kristali.

Mikroskopska obilježja

Drvo je rastresito porozno. Članci traheja radijalno su raspoređeni (po 4 ili više u nizu), promjera 90 do 180 μm. Ploča perforacije je jednostavna. Drvni su traci homogeni, viši od 1 mm, širine 4 do 10 stanica. Aksijalni parenhim je paratrahealan do paratrahealno vazicentričan. U stanicama drvnih trakova često postoje kristali.

Fizikalna i mehanička svojstva

Gustoća prosušenog drva je oko 560 kg/m^3. Tangentno utezanje iznosi oko 5,0 %, a radijalno oko 3,5 %.

TEHNOLOŠKA SVOJSTVA

Obradivost

Drvo se lako ručno i strojno obrađuje.

Dobro se pili, ljušti, lako se čavla, lijepi, brusi, pjeskari i politira standardnim postupcima.

Sušenje

Drvo se lako i brzo suši. Materijal debljine do 75 mm lako se suši od faze sirovog drva, bez posebnog mijenjanja režima sušenja, premda postoji mogućnost kolapsa i vitoperenja, posebno u materijalu veće gustoće.

Trajnost i zaštita

Drvo *Flindersia australis* prirodno je slabo trajno i stoga nije pogodno za uporabu na otvorenome, ako nije prije impregnirano zaštitnim sredstvom.

Uporaba

Uporaba drva *Flindersia australis* vrlo je velika. U Australiji se uvelike upotrebljava za izradu namještaja, građevne stolarije i uređenje interijera, kao masivno drvo ili furnir.

Također se primjenjuje u proizvodnji drvenih željezničkih vagona, u brodogradnji i za izradu kundaka.

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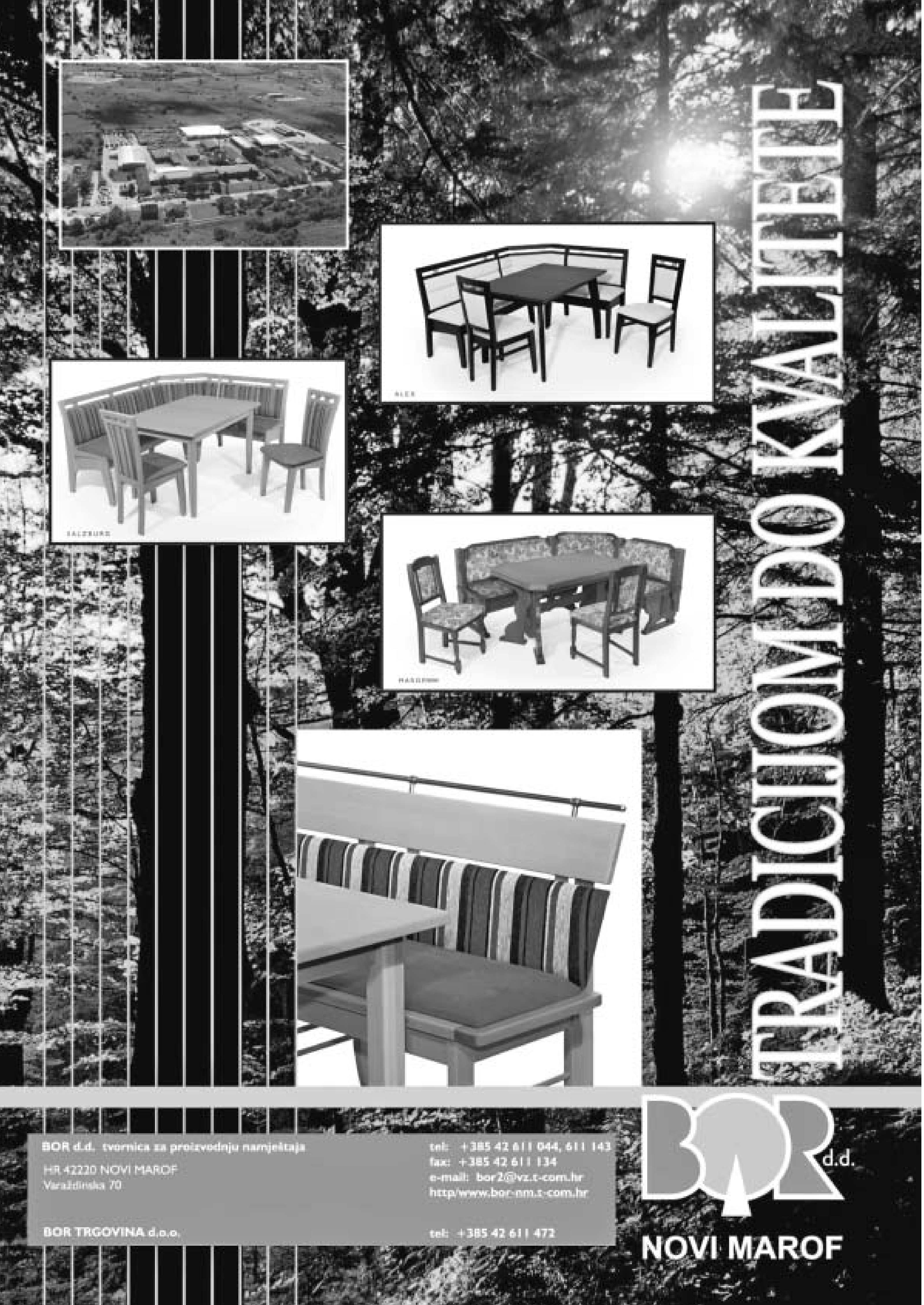
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Latinska imena pisana kosim slovima trebaju biti podcrtana.

U uvodu treba definirati problem i, koliko je moguće, predočiti granice postojećih spoznaja, tako da se čitateljima koji se ne bave područjem o kojemu je riječ omogući razumijevanje namjera autora.

Materijal i metode trebaju biti što preciznije opisane da omoguće drugim znanstvenicima obnavljanje pokusa. Glavni eksperimentalni podaci trebaju biti dvojezično navedeni.

Rezultati trebaju obuhvatiti samo materijal koji se izravno odnosi na predmet. Obvezatna je primjena metričkog sustava. Preporučuju se SI jedinice. Rjeđe rabljene fizikalne vrijednosti, simboli i jedinice trebaju biti objašnjeni pri prvom spominjanju u tekstu. Za pisanje formula koristiti Equation Editor (program za pisanje formula unutar MS Worda). Jedinice se pišu normalnim (uspravnim) slovima, a fizikalni simboli i faktori kosim slovima. Formule se susljedno obrojčavaju arapskim brojkama u zagradama, npr. (1) na kraju retka.

Broj slika mora biti ograničen na samo one koje su prijeko potrebne za pojašnjenje teksta. Isti podaci ne smiju biti navedeni u tablici i na slici. Slike i tablice trebaju biti zasebno obrojčene arapskim brojkama, a u tekstu se na njih upućuje jasnim naznakama ("tablica 1" ili "slika 1"). Naznaka željenog položaja tablice ili slike u tekstu treba biti navedena na margini. Svaka tablica i slika treba biti prikazana na zasebnom listu, a njihovi naslovi moraju biti tiskani na posebnim listovima, i to redoslijedom. Naslovi, zaglavlja, legende i sav ostali tekst u slikama i tablicama treba biti pisan hrvatskim i engleskim ili hrvatskim i njemačkim jezikom.

Slike i tablice trebaju biti potpune i jasno razumljive bez pozivanja na tekst priloga. Naslove slika i crteža ne pisati velikim tiskanim slovima. Uputno je da crteži odgovaraju stilu časopisa i da budu tiskani na laserskom printeru. Tekstu treba priložiti izvorne crteže ili fotografske kopije. Slova i brojke moraju biti dovoljno veliki da budu lako čitljivi nakon smanjenja širine slike ili tablice na 160 ili 75 mm. Fotografije trebaju biti crno-bijele; one u boji tiskaju se samo na poseban zahtjev, a trošak tiskanja u boji podmiruje autor. Fotografije i fotomikrografije moraju biti izvedene na sjajnom papiru s jakim kontrastom. Fotomikrografije trebaju imati naznaku uvećanja, poželjno u mikrometrima. Uvećanje može biti dodatno naznačeno na kraju naslova slike, npr. "uvećanje 7500 : l".

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Knjige: Prezime autora, inicijal(i) osobnog imena, godina: naslov. (ev. izdavačeditor): izdanje (ev. tom). Mjesto izdavanja, izdavač, (ev. stranice od - do).

Primjeri:

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